CGER-REPORT

ISSN 2434-5679
CGER-I164-2023

National Greenhouse Gas Inventory Report of JAPAN

2023

Ministry of the Environment, Japan
Greenhouse Gas Inventory Office of Japan (GIO), CGER, NIES

Center for Global Environmental Research

National Institute for Environmental Studies, Japan

CGER-REPORT

ISSN 2434-5679
CGER-I164-2023

National Greenhouse Gas Inventory Report of JAPAN

2023

Ministry of the Environment, Japan
Greenhouse Gas Inventory Office of Japan (GIO), CGER, NIES

Center for Global Environmental Research

National Institute for Environmental Studies, Japan

National Greenhouse Gas Inventory Report of JAPAN (2023)

Content reviewed by

Decarbonized Society Promotion Office, Global Environment Bureau, Ministry of the Environment, Japan

Primary Authors

Greenhouse Gas Inventory Office of Japan (GIO), Center for Global Environmental Research (CGER), Earth System Division (ESD), National Institute for Environmental Studies (NIES)

Elsa HATANAKA, Takefumi ODA, Hiroshi ITO, Naofumi KOSAKA, Atsuko HAYASHI, Eriko HIRATA, Wakana TAKI

With the cooperation of:

Greenhouse Gas Inventory Office of Japan (GIO)

Midori YANAGAWA, Naoko IKEDA

Mitsubishi UFJ Research and Consulting Co., Ltd.

Tatsuo ABE, Maya FUKUDA, Kiwamu KATAGIRI, Satoshi KAWANISHI, Kazumasa KAWASHIMA,Takashi MORIMOTO, Masaaki NAKAMURA, Seiya OYAMA, Atsushi SATO, Takuji TERAKAWA, Hiroyuki UEDA

Suuri Keikaku Co., Ltd.

Sho FUKUCHI, Tamon MARUYAMA, Ryuta NITTA, Masakazu OKADA, Atsushi SATO

Copies available from:

Center for Global Environmental Research (CGER)
Earth System Division (ESD)
National Institute for Environmental Studies (NIES)
16-2 Onogawa, Tsukuba, Ibaraki 305-8506 Japan
Phone: +81-29-850-2777 Fax: +81-29-850-2219
E-mail: www-cger@nies.go.jp
https://www.cger.nies.go.jp/en/activities/supporting/publications/report/index.html

Please cite this document as follows:
Greenhouse Gas Inventory Office of Japan and Ministry of the Environment, Japan (eds.), *National Greenhouse Gas Inventory Report of JAPAN 2023*, Center for Global Environmental Research, Earth System Division, National Institute for Environmental Studies, Japan, 2023.

This publication is printed on paper manufactured entirely from recycled material (Rank A), in accordance with the Act on Promotion of Procurement of Eco-Friendly Goods and Services by the State and Other Entities.

Foreword

On the basis of Article 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC), all Parties to the Convention are required to submit national inventories of greenhouse gas emissions and removals. Therefore, the inventories on emissions and removals of greenhouse gases and precursors are reported in the Common Reporting Format (CRF) and in this National Inventory Report, in accordance with the *UNFCCC Inventory Reporting Guidelines* (Decision 24/CP.19 Annex I).

This Report presents Japan's national inventory arrangements, the estimation methods of greenhouse gas emissions and removals from sources and sinks, and the trends in emissions and removals for greenhouse gases (carbon dioxide [CO_2], methane [CH_4], nitrous oxide [N_2O], hydrofluorocarbons [HFCs], perfluorocarbons [PFCs], sulfur hexafluoride [SF_6], nitrogen trifluoride [NF_3], and indirect CO_2), precursors (nitrogen oxides [NO_x], carbon monoxide [CO], and non-methane volatile organic compounds [NMVOC]), and sulfur oxides [SO_x]. Methodological details of the LULUCF sector accounting in the Nationally Determined Contribution (NDC) is presented as well, as other additional information.

The structure of this report is prepared in line with the structure specified in the Appendix of the *UNFCCC Inventory Reporting Guidelines*.

The Executive Summary focuses on the latest trends in emissions and removals of greenhouse gases in Japan. Chapter 1 deals with background information on greenhouse gas inventories, national inventory arrangements, the inventory preparation process, methodologies and data sources used, key category analysis, QA/QC plan, and results of uncertainty assessment. Chapter 2 describes the latest information on trends in emissions and removals of greenhouse gases in Japan. Chapters 3 to 7 provide the details of estimation methods for the sources and sinks described in the *2006 IPCC Guidelines*. Chapter 8 comprises current status of reporting of the emissions from sources not covered by these guidelines. Chapter 9 provides the current status of reporting of indirect emissions of CO_2 and N_2O. Chapter 10 provides the explanations on improvements and recalculations (data revision, addition of new categories, etc.) made since the previous submission. Annexes offer information to assist further understanding of Japan's inventory and other additional information.

For the latest updates or changes in data, refer to the website (https://www.nies.go.jp/gio/en/index.html) of the Greenhouse Gas Inventory Office of Japan (GIO).

April, 2023
Decarbonized Society Promotion Office
Global Environment Bureau
Ministry of the Environment

Preface

The GHG inventory of Japan including this report represents the combined knowledge of over 60 experts in a range of fields from universities, industrial bodies, regional governments, relevant government departments and agencies, and relevant research institutes, who are members of the Committee for the Greenhouse Gas Emissions Estimation Methods established by the Environment Agency (the current Ministry of the Environment) in November 1999 and held every year since.

In compiling the GHG inventory, the Greenhouse Gas Inventory Office of Japan (GIO) would like to acknowledge the contribution not only of the Committee members in seeking to develop the methodology, but of other experts who provided the latest scientific knowledge, the industrial bodies and government departments and agencies that provided the data necessary for compiling the inventory, and the secretariat members of the above-mentioned Committee. We would like to express our gratitude to the Decarbonized Society Promotion Office of the Global Environment Bureau of the Ministry of the Environment, for their support to GIO.

Upon preparation of this report, we have made efforts to improve it through receiving feedback from many internal and external experts. We hope this report will help fulfill our international obligations such as that under the Paris Agreement and is used widely as an index that shows the extent of Japan's measures implemented against global warming.

My appreciation also extends to Mr. Akira Osako, together with Ms. Akiko Higuchi, Ms. Masae Aoki, and Ms. Sachiyo Harigae, our assistants, who supported us with the smooth operation of GIO.

April, 2023

Elsa Hatanaka
Manager
Greenhouse Gas Inventory Office of Japan (GIO)
Center for Global Environmental Research (CGER)
Earth System Division (ESD)
National Institute for Environmental Studies (NIES)

Table of Contents

Executive Summary of the National GHG Inventory Report of Japan

E.S.1. Background Information on the GHG Inventory

Japan hereby reports its Greenhouse Gas (GHG) Inventory, which contains the information on emissions and removals of GHGs, including indirect GHGs and SO_x in Japan for FY1990 to FY2021[1], on the basis of Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC).

Estimation methodologies of GHGs inventories are required to be in line with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter *2006 IPCC Guidelines*) which was developed by the Intergovernmental Panel on Climate Change (IPCC), and Japan's estimation methodologies are basically in line with these guidelines. In order to enhance transparency, consistency, comparability, completeness and accuracy of the inventory, Japan also applies the *2013 Supplement to the 2006 IPCC Guidelines: Wetlands* (hereafter *Wetlands Guidelines*) and *the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (hereafter *KP Supplement*), and the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter *2019 Refinement*).

Japan's national inventory is reported in accordance with the *UNFCCC Reporting Guidelines on Annual Greenhouse Gas Inventories* (Decision 24/CP.19 Annex I, hereinafter referred to as the *UNFCCC Inventory Reporting Guidelines*) decided by the Conference of the Parties.

[1] "FY" (fiscal year), from April of the reporting year through March of the next year, is used because CO_2 is the primary GHGs emissions and estimated on a fiscal year basis. "CY" stands for "calendar year".

E.S.2. Summary of National Emission and Removal Related Trends

E.S.2.1. GHG Inventory

Total GHGs emissions[2] in FY2021 (excluding LULUCF[3], including indirect CO_2[4], hereafter, definition omitted) were 1,170 million tonnes (in CO_2 eq.). They decreased by 8.2% compared to the emissions in FY1990.

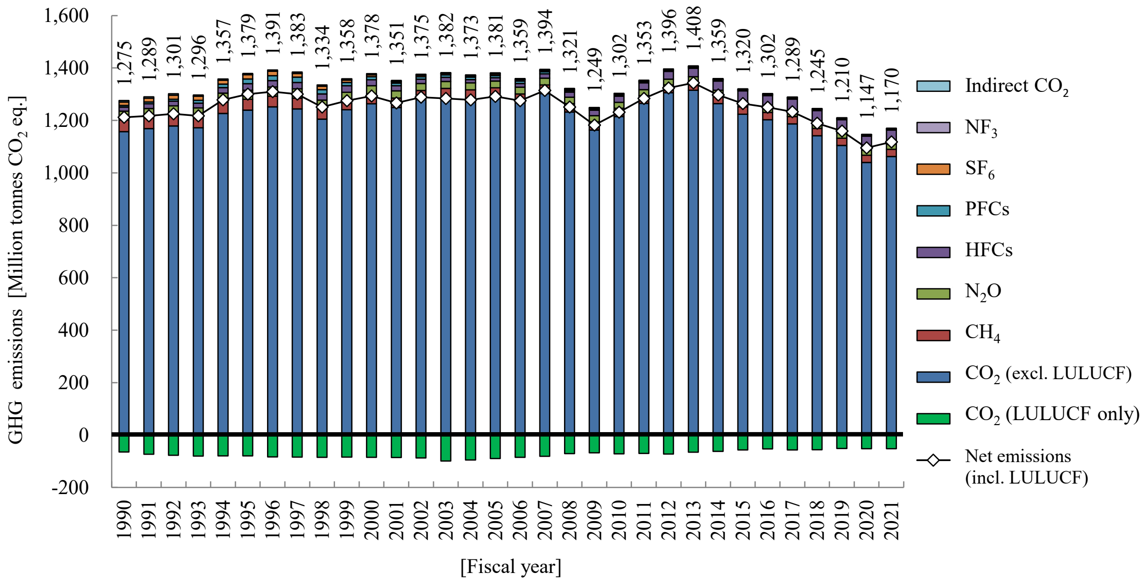


Figure 1 Trends in GHG emissions and removals in Japan

2 The sum of CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3 emissions converted to CO_2 equivalents multiplied by their respective global warming potential (GWP). The GWP is a coefficient by means of which greenhouse gas effects of a given gas are made relative to those of an equivalent amount of CO_2. The coefficients (100-year time horizon) are drawn from the *Fourth Assessment Report* (2007) issued by the IPCC.

3 Abbreviation of "Land Use, Land-Use Change and Forestry"

4 Carbon monoxide (CO), methane (CH_4) and non-methane volatile organic compounds (NMVOC) are oxidized in the atmosphere in the long term and converted to CO_2. Indirect CO_2 means value in CO_2 equivalent of these emissions. However, emissions of CO, CH_4 and NMVOC derived from combustion origin and biomass origin are excluded to avoid double counting.

Table 1 Trends in GHGs emissions and removals in Japan

[Million tonnes CO_2 eq.]	GWP	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2 (excl. LULUCF) *1	1	1,157.2	1,168.9	1,178.7	1,171.7	1,226.7	1,239.0	1,251.5	1,244.3	1,204.4	1,241.0	1,263.8	1,249.2	1,278.8	1,287.3	1,282.7	1,290.1	1,267.1	1,302.8	1,232.0	1,163.1
CO_2 (incl. LULUCF) *1	1	1,092.9	1,095.8	1,101.9	1,091.6	1,146.9	1,159.6	1,168.3	1,160.0	1,119.8	1,157.2	1,178.8	1,163.6	1,191.4	1,188.4	1,187.3	1,200.5	1,182.4	1,222.2	1,161.2	1,095.4
CO_2 (LULUCF only)	1	-64.3	-73.1	-76.8	-80.0	-79.8	-79.5	-83.2	-84.2	-84.6	-83.9	-84.9	-85.6	-87.3	-98.8	-95.4	-89.6	-84.7	-80.6	-70.8	-67.7
CH_4 (excl. LULUCF)	25	44.5	43.9	43.8	42.9	42.9	41.8	40.5	40.0	38.3	37.9	37.3	36.1	35.3	34.4	34.1	34.1	33.5	32.9	32.1	31.5
CH_4 (incl. LULUCF)	25	44.6	44.0	43.9	43.0	43.1	41.9	40.6	40.1	38.4	38.0	37.4	36.2	35.4	34.5	34.2	34.1	33.6	32.9	32.2	31.6
N_2O (excl. LULUCF)	298	32.2	31.9	32.1	32.0	33.2	33.5	34.6	35.4	33.8	27.7	30.2	26.6	26.0	25.8	25.7	25.3	25.2	24.7	23.8	23.2
N_2O (incl. LULUCF)	298	33.2	32.8	33.0	32.8	34.0	34.3	35.4	36.2	34.6	28.4	31.0	27.3	26.7	26.6	26.4	26.0	25.9	25.3	24.4	23.8
HFCs	HFC-134a: 1,430 etc.	15.9	17.4	17.8	18.1	21.1	25.2	24.6	24.4	23.7	24.4	22.9	19.5	16.2	16.2	12.4	12.8	14.6	16.7	19.3	20.9
PFCs	PFC-14: 7,390 etc.	6.6	7.5	7.6	11.0	13.5	17.7	18.3	20.1	16.6	13.2	11.9	9.9	9.2	8.9	9.2	8.6	9.0	7.9	5.8	4.1
SF_6	22,800	12.9	14.2	15.6	15.7	15.0	16.4	17.0	14.5	13.2	9.2	7.0	6.1	5.7	5.4	5.3	5.0	5.2	4.7	4.2	2.4
NF_3	17,200	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	1.5	1.4	1.6	1.5	1.4
Indirect CO_2	1	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.5	4.2	4.2	4.2	3.8	3.6	3.4	3.3	3.2	3.2	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,269.3	1,283.8	1,295.6	1,291.4	1,352.4	1,373.8	1,386.7	1,378.8	1,330.3	1,353.7	1,373.3	1,347.6	1,371.6	1,378.5	1,369.8	1,377.5	1,356.1	1,391.3	1,318.5	1,246.5
Net Total (including LULUCF, excluding indirect CO_2)		1,206.1	1,211.7	1,219.8	1,212.4	1,273.6	1,295.3	1,304.5	1,295.5	1,246.6	1,270.7	1,289.2	1,262.8	1,285.1	1,280.4	1,275.2	1,288.6	1,272.1	1,311.4	1,248.4	1,179.5
Gross Total (excluding LULUCF, including indirect CO_2)		1,274.8	1,289.1	1,300.6	1,296.2	1,357.2	1,378.5	1,391.5	1,383.4	1,334.5	1,357.8	1,377.5	1,351.4	1,375.2	1,381.9	1,373.2	1,380.7	1,359.2	1,394.3	1,321.2	1,249.1
Net Total (including LULUCF, including indirect CO_2)		1,211.5	1,217.0	1,224.9	1,217.1	1,278.4	1,299.9	1,309.2	1,300.1	1,250.7	1,274.8	1,293.5	1,266.6	1,288.7	1,283.8	1,278.5	1,291.9	1,275.3	1,314.4	1,251.1	1,182.0

[Million tonnes CO_2 eq.]	GWP	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Changes in emissions/removals (2021)	
														1990	Previous year
CO_2 (excl. LULUCF) *1	1	1,214.7	1,264.6	1,305.9	1,315.2	1,264.1	1,223.2	1,202.5	1,186.8	1,141.7	1,104.5	1,039.8	1,062.1	-8.2%	2.1%
CO_2 (incl. LULUCF) *1	1	1,143.2	1,194.9	1,233.4	1,250.0	1,201.8	1,166.5	1,149.7	1,130.0	1,085.4	1,053.4	987.7	1,010.0	-7.6%	2.3%
CO_2 (LULUCF only)	1	-71.5	-69.7	-72.5	-65.2	-62.3	-56.6	-52.8	-56.8	-56.3	-51.2	-52.1	-52.2	-18.9%	0.2%
CH_4 (excl. LULUCF)	25	31.1	29.9	29.2	29.1	28.6	28.3	28.2	28.0	27.7	27.5	27.4	27.4	-38.6%	-0.1%
CH_4 (incl. LULUCF)	25	31.2	29.9	29.3	29.2	28.7	28.3	28.3	28.1	27.7	27.6	27.4	27.4	-38.5%	0.0%
N_2O (excl. LULUCF)	298	22.7	22.3	22.0	21.9	21.5	21.2	20.6	20.9	20.4	20.0	19.7	19.5	-39.6%	-1.1%
N_2O (incl. LULUCF)	298	23.3	22.9	22.5	22.4	21.9	21.6	21.1	21.3	20.8	20.4	20.1	19.9	-40.1%	-1.1%
HFCs	HFC-134a: 1,430 etc.	23.3	26.1	29.4	32.1	35.8	39.3	42.6	45.0	47.1	50.0	52.2	53.6	236.0%	2.6%
PFCs	PFC-14: 7,390 etc.	4.3	3.8	3.5	3.3	3.4	3.3	3.4	3.5	3.5	3.4	3.5	3.2	-51.9%	-9.9%
SF_6	22,800	2.4	2.2	2.2	2.1	2.0	2.1	2.2	2.1	2.1	2.0	2.0	2.0	-84.1%	0.9%
NF_3	17,200	1.5	1.8	1.5	1.6	1.1	0.6	0.6	0.4	0.3	0.3	0.3	0.4	1065.6%	12.8%
Indirect CO_2	1	2.4	2.3	2.3	2.3	2.2	2.2	2.1	2.1	2.1	2.0	1.9	1.9	-65.9%	0.3%
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,300.0	1,350.7	1,393.6	1,405.4	1,356.5	1,317.8	1,300.1	1,286.7	1,242.7	1,207.7	1,144.9	1,168.1	-8.0%	2.0%
Net Total (including LULUCF, excluding indirect CO_2)		1,229.2	1,281.6	1,321.7	1,340.7	1,294.8	1,261.7	1,247.9	1,230.5	1,186.9	1,157.0	1,093.3	1,116.4	-7.4%	2.1%
Gross Total (excluding LULUCF, including indirect CO_2)		1,302.5	1,353.1	1,395.9	1,407.6	1,358.7	1,320.0	1,302.3	1,288.8	1,244.8	1,209.7	1,146.8	1,170.0	-8.2%	2.0%
Net Total (including LULUCF, including indirect CO_2)		1,231.6	1,284.0	1,324.0	1,343.0	1,297.0	1,263.9	1,250.0	1,232.6	1,189.0	1,159.0	1,095.2	1,118.3	-7.7%	2.1%

*1 Excluding indirect CO_2
*2 LULUCF: Land Use, Land-Use Change and Forestry

E.S.3. Overview of Source and Sink Category Emission Estimates and Trends

E.S.3.1. GHG Inventory

The breakdown of GHGs emissions and removals in FY2021 by sector[5] shows that the energy (excluding indirect CO_2) accounts for 86.8% of total GHGs emissions. It is followed by the industrial processes and product use sector (excluding indirect CO_2) (8.8%), the agriculture sector (2.8%), the waste sector (1.5%), and indirect CO_2 emissions (0.2%).

Removals by the LULUCF in FY2021 were equivalent to 4.5% of total GHGs emissions.

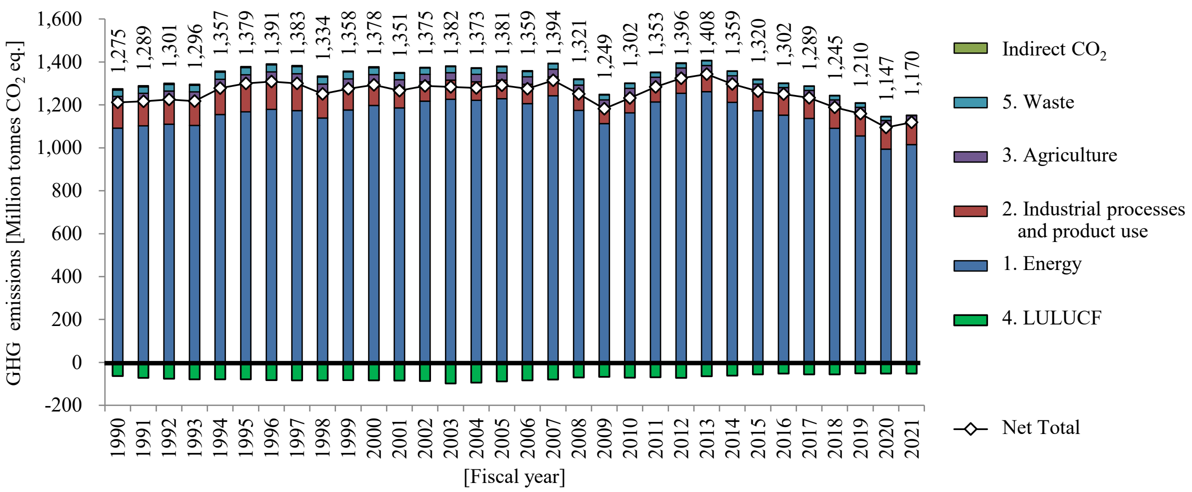


Figure 2 Trends in GHGs emissions and removals in each sector

[5] As indicated in the *2006 IPCC Guidelines* and the CRF.

Table 2 Trends in GHGs emissions and removals in each sector

[Million tonnes CO_2 eq.]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy*1	1,091.9	1,102.3	1,110.4	1,104.4	1,155.4	1,167.4	1,178.9	1,173.5	1,139.3	1,175.9	1,197.8	1,185.6	1,217.2	1,226.1	1,221.9	1,228.8	1,206.1	1,242.3	1,174.4	1,113.0
2. Industrial processes and product use*1	109.9	114.5	116.4	118.6	126.1	136.3	138.4	135.5	122.8	110.2	108.3	97.3	90.6	89.4	86.0	87.1	89.9	89.0	84.6	77.4
3. Agriculture	37.5	37.1	37.9	37.9	38.0	37.1	36.3	36.4	35.2	35.3	35.2	34.5	34.7	34.3	34.1	34.5	34.4	34.7	33.6	33.4
4. LULUCF*2	-63.3	-72.1	-75.8	-79.0	-78.8	-78.6	-82.3	-83.3	-83.7	-83.0	-84.1	-84.7	-86.5	-98.0	-94.6	-88.8	-84.0	-79.9	-70.1	-67.0
5. Waste	30.0	29.9	31.0	30.5	32.9	33.0	33.1	33.5	33.0	32.3	32.0	30.2	29.1	28.7	27.8	27.0	25.7	25.3	25.9	22.8
Indirect CO_2	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.5	4.2	4.2	4.2	3.8	3.6	3.4	3.3	3.2	3.2	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,269.3	1,283.8	1,295.6	1,291.4	1,352.4	1,373.8	1,386.7	1,378.8	1,330.3	1,353.7	1,373.3	1,347.6	1,371.6	1,378.5	1,369.8	1,377.5	1,356.1	1,391.3	1,318.5	1,246.5
Net Total (including LULUCF, excluding indirect CO_2)	1,206.1	1,211.7	1,219.8	1,212.4	1,273.6	1,295.3	1,304.5	1,295.5	1,246.6	1,270.7	1,289.2	1,262.8	1,285.1	1,280.4	1,275.2	1,288.6	1,272.1	1,311.4	1,248.4	1,179.5
Gross Total (excluding LULUCF, including indirect CO_2)	1,274.8	1,289.1	1,300.6	1,296.2	1,357.2	1,378.5	1,391.5	1,383.4	1,334.5	1,357.8	1,377.5	1,351.4	1,375.2	1,381.9	1,373.2	1,380.7	1,359.2	1,394.3	1,321.2	1,249.1
Net Total (including LULUCF, including indirect CO_2)	1,211.5	1,217.0	1,224.9	1,217.1	1,278.4	1,299.9	1,309.2	1,300.1	1,250.7	1,274.8	1,293.5	1,266.6	1,288.7	1,283.8	1,278.5	1,291.9	1,275.3	1,314.4	1,251.1	1,182.0

[Million tonnes CO_2 eq.]	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1. Energy*1	1,163.1	1,213.8	1,254.1	1,261.7	1,211.5	1,172.3	1,152.5	1,136.6	1,091.1	1,055.5	994.1	1,015.0
2. Industrial processes and product use*1	80.6	82.5	85.1	89.4	92.0	93.0	96.1	98.9	99.9	101.1	100.7	103.3
3. Agriculture	33.7	32.9	32.6	32.8	32.4	32.1	32.1	32.3	32.0	32.0	32.1	32.2
4. LULUCF*2	-70.9	-69.1	-71.9	-64.7	-61.7	-56.1	-52.3	-56.2	-55.8	-50.7	-51.6	-51.7
5. Waste	22.6	21.6	21.8	21.5	20.7	20.5	19.5	19.0	19.7	19.2	18.0	17.7
Indirect CO_2	2.4	2.3	2.3	2.3	2.2	2.2	2.1	2.1	2.1	2.0	1.9	1.9
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,300.0	1,350.7	1,393.6	1,405.4	1,356.5	1,317.8	1,300.1	1,286.7	1,242.7	1,207.7	1,144.9	1,168.1
Net Total (including LULUCF, excluding indirect CO_2)	1,229.2	1,281.6	1,321.7	1,340.7	1,294.8	1,261.7	1,247.9	1,230.5	1,186.9	1,157.0	1,093.3	1,116.4
Gross Total (excluding LULUCF, including indirect CO_2)	1,302.5	1,353.1	1,395.9	1,407.6	1,358.7	1,320.0	1,302.3	1,288.8	1,244.8	1,209.7	1,146.8	1,170.0
Net Total (including LULUCF, including indirect CO_2)	1,231.6	1,284.0	1,324.0	1,343.0	1,297.0	1,263.9	1,250.0	1,232.6	1,189.0	1,159.0	1,095.2	1,118.3

*1 Excluding indirect CO_2

*2 LULUCF: Land Use, Land-Use Change and Forestry

Chapter 1. Introduction

1.1. Background Information on Japan's Greenhouse Gas Inventory and Climate Change

Japan hereby reports its greenhouse gas (GHG) inventory, which contains information on emissions and removals of GHGs, including precursors (nitrogen oxides [NO_x], carbon monoxide [CO], non-methane volatile organic compounds [NMVOC]), and sulfur oxides (SO_x) in Japan from FY1990 to FY2021[1], on the basis of Article 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC).

Estimation methodologies for the GHG inventories are required to be in line with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 IPCC Guidelines*), prepared by the Intergovernmental Panel on Climate Change (IPCC), and Japan's estimation methodologies are basically in line with these guidelines. In order to enhance transparency, consistency, comparability, completeness, and accuracy of the inventory, Japan also applies the *2013 Supplement to the 2006 IPCC Guidelines: Wetlands* (*Wetlands Guidelines*), the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (*KP Supplement (2013)*), and the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2019 Refinement*).

Japan's national inventory is reported in accordance with the *UNFCCC Reporting Guidelines on Annual Greenhouse Gas Inventories* (Decision 24/CP.19 Annex I, hereinafter referred to as the *UNFCCC Inventory Reporting Guidelines*) decided by the Conference of the Parties.

1.2. Description of Japan's National Inventory Arrangements

1.2.1. Institutional, Legal and Procedural Arrangements

1.2.1.1. Institutional and legal Arrangement for the Inventory Preparation

The Government of Japan is to calculate the emissions and removals of GHGs for Japan and disclose the results every year, in accordance with Article 7, the Act on Promotion of Global Warming Countermeasures,[2] which determines the domestic measures for the UNFCCC, etc. The Ministry of the Environment (MOE), with the cooperation of relevant ministries, agencies and organizations, annually prepares Japan's national inventory in accordance with the UNFCCC and compiles other additional information.

The MOE assumes overall responsibilities for the national inventory and organizes the Committee for the Greenhouse Gas Emission Estimation Methods (Committee) in order to integrate the latest scientific knowledge into the inventory and to modify it to meet international requirements. The estimation of GHG emissions and removals are then carried out by taking the decisions of the Committee into consideration. Substantial activities, such as the estimation of emissions and removals and the preparation of the Common Reporting Format (CRF) tables and National Inventory Report (NIR), are done by the Greenhouse Gas Inventory Office of Japan (GIO), which belongs to the Center for Global Environmental Research in the Earth System Division of the National Institute for Environmental

[1] "FY (fiscal year)" is used because CO_2, which constitutes the largest part of the emission estimate, is on the fiscal year basis (April to March).
[2] Enacted in October 1998. The enforcement of the latest amendment was made on April 1, 2023.

Studies. The relevant ministries, agencies and organizations provide the GIO with the appropriate data (e.g., activity data, emission factors, and GHG emissions and removals) through compiling various statistics and providing other additional information, etc. The relevant ministries and agencies check the inventories (i.e., CRF, NIR), including the spreadsheets that are actually utilized for the estimation (Japan National Greenhouse gas Inventory files, hereinafter referred to as "JNGI files"), as a part of the Quality Control (QC) activities.

The checked inventories are determined as Japan's official GHG emission/removal values. The inventories are then published and submitted to the UNFCCC Secretariat.

Figure 1-1 shows the overall institutional arrangement for Japan's inventory preparation. More detailed information on the roles and responsibilities of relevant ministries, agencies and organizations in the inventory preparation process is described below.

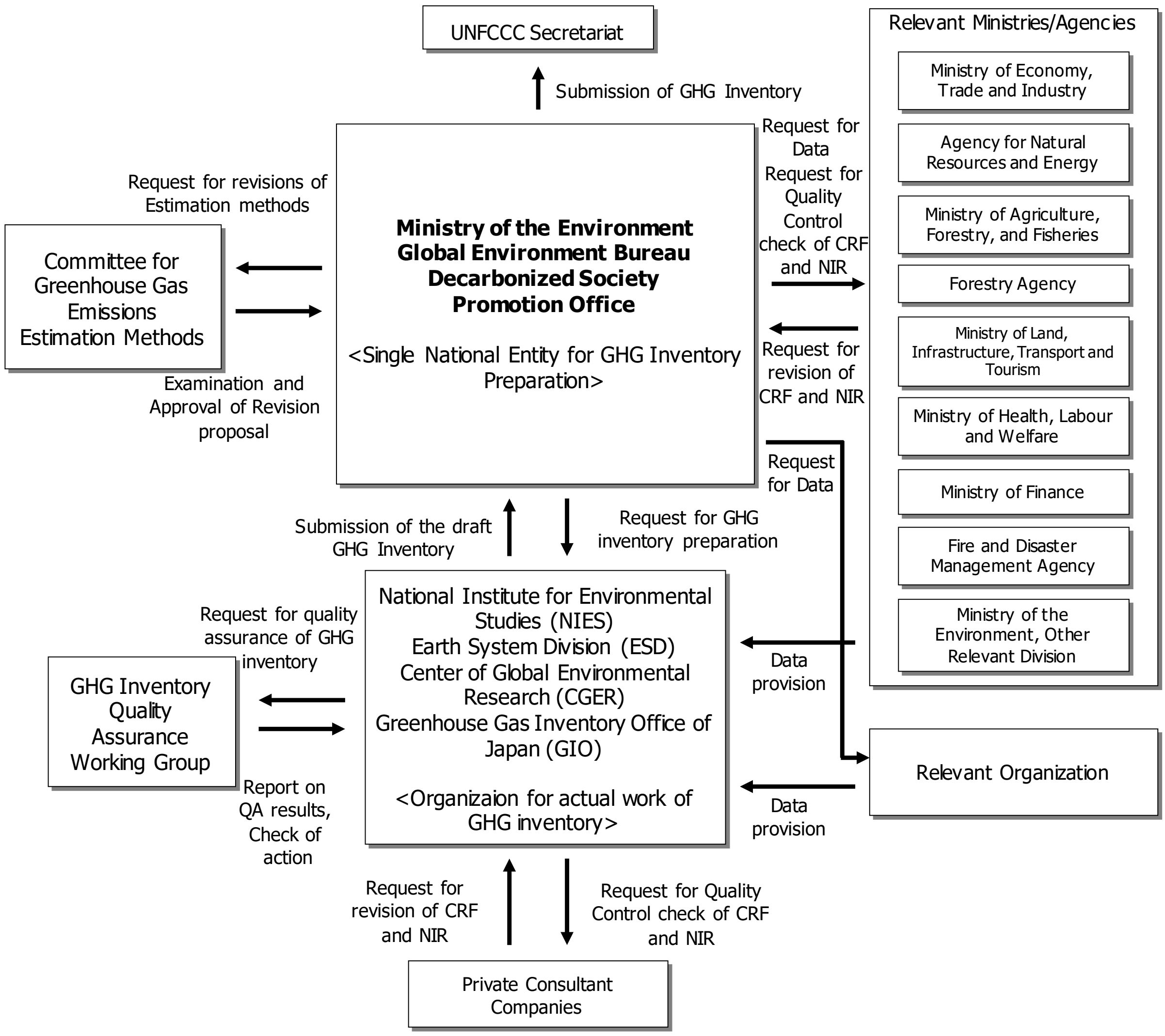


Figure 1-1 Japan's institutional arrangement for the national inventory preparation

1.2.1.2. Roles and responsibilities of each entity involved in the inventory preparation process

The following are the agencies involved in the inventory compilation process, and the roles of those agencies.

1) Ministry of the Environment (Decarbonized Society Promotion Office, Global Environment Bureau)

- The single national agency responsible for preparing Japan's inventory, which was designated pursuant to the *UNFCCC Inventory Reporting Guidelines*.
- It is responsible for editing and submitting the inventory.
- It coordinates the Quality Assurance and Quality Control (QA/QC) activities for the inventory.
- It checks and approves the QA/QC plan.
- It checks and approves the inventory improvement plan.

2) Greenhouse Gas Inventory Office of Japan (GIO), Center for Global Environmental Research, Earth System Division, National Institute for Environmental Studies

- Performs the actual work of inventory compilation. Responsible for inventory calculations, editing, preparation of part of the activity data necessary to prepare the inventory, and the archiving and management of all data.
- Prepares the revised draft of the QA/QC plan.
- Prepares the draft of the inventory improvement plan.

3) Relevant Ministries/Agencies

The relevant ministries and agencies have the following roles and responsibilities regarding inventory compilation.

- Preparation and provision of data such as activity data and emission factors required for the preparation of the inventory.
- Confirmation of data provided for the preparation of the inventory.
- Confirmation of the inventory (CRF, NIR, JNGI files, and other information) prepared by the GIO (Category-specific QC).
- (When necessary), responding to questions from expert review teams (ERTs) about the statistics controlled by relevant ministries and agencies, or about certain data they have prepared, and preparing comments on draft reviews.
- (When necessary), responding to in-country review by ERTs.

4) Relevant Organizations

Relevant organizations have the following roles and responsibilities regarding inventory compilation.

- Preparation and provision of data such as activity data and emission factors required for the preparation of the inventory.
- Confirmation of data provided for the preparation of the inventory.

- (When necessary), responding to questions from ERTs about the statistics controlled by relevant organizations, or about certain data they have prepared, and preparing comments on draft review reports.

5) Committee for the Greenhouse Gas Emissions Estimation Methods

The Committee for the Greenhouse Gas Emissions Estimation Methods (the Committee) is a committee created and run by the MOE. Its role is to consider the methods for calculating inventory emissions and removals, and the selection of parameters such as activity data (AD) and emission factors (EFs). Under the Committee, the inventory working group (WG) that examines cross-cutting issues, and breakout groups that consider sector-specific issues (Breakout group on Energy and Industrial Processes, Breakout group on Transport, Breakout group on F-gases [HFCs, PFCs, SF_6, and NF_3], Breakout group on Agriculture, Breakout group on Waste, Breakout group on LULUCF, and Breakout group on NMVOC), as well as the Sub-breakout group on Carbon Capture and Utilization (CCU) are set up. The inventory WG and the breakout groups/sub-breakout group comprise experts in various fields and consider suggestions for inventory improvements.

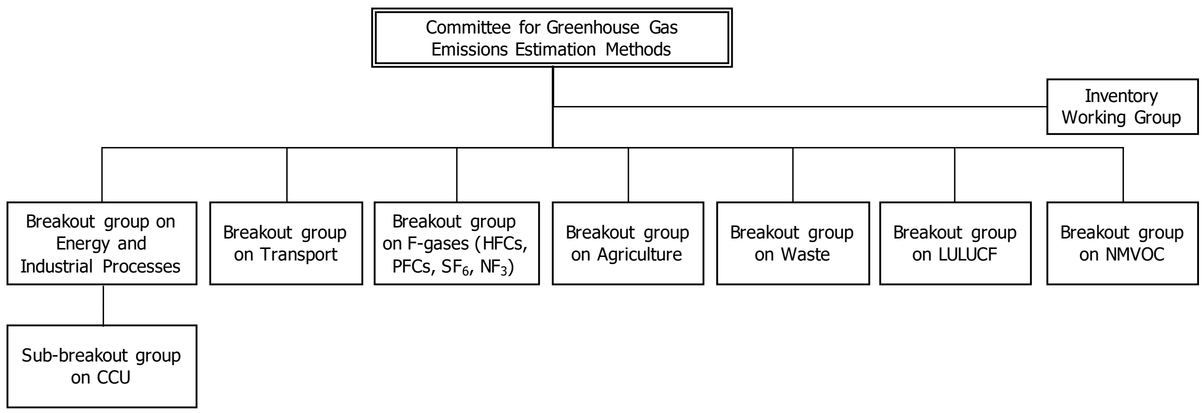


Figure 1-2 Structure of the Committee for the Greenhouse Gas Emissions Estimation Methods

6) Private Consulting Companies

Private consultant companies that are contracted by the MOE to perform tasks related to inventory compilation play the following roles in inventory compilation based on their contracts.

- Quality Control (QC) of the inventory (CRF, NIR, JNGI files) compiled by the MOE and the GIO.
- (When necessary), providing support for responding to questions from ERTs and for preparing comments on draft reviews.
- (When necessary), providing support for responding to in-country review by ERTs.

7) GHG Inventory Quality Assurance Working Group (QAWG)

The GHG Inventory Quality Assurance Working Group (the QAWG) is an organization for QA activities and comprises experts who are not directly involved in inventory compilation. Its role is to assure inventory quality and to identify places that need improvement by conducting detailed reviews of each emission source and sink in the inventory.

1.2.1.3. Response for UNFCCC inventory review

The inventory that Japan submits each year is to be reviewed by ERTs pursuant to *UNFCCC inventory review guidelines* (Decision 13/CP.20 Annex). Specifically, rigorous checks are performed from perspectives including: whether emissions and removals are accurately and completely estimated and reported, or whether transparent explanations are provided for estimation methods, or whether QA/QC activities and uncertainty assessments are performed appropriately in accordance with the designated guidelines[3].

In view of the fact that ensuring the transparency of Japan's inventory is a matter of importance, the system shown in Figure 1-3 is used for responding to reviews.

[Basic structure]

The MOE (Decarbonized Society Promotion Office, Global Environment Bureau), which in Japan is responsible for editing and submitting the inventory, is assigned to be the agency with overall control (responsibility) for review response, while the GIO performs the actual work, such as preparing source materials and communicating with the UNFCCC Secretariat. The relevant ministries and agencies, relevant organizations, and private consultant companies[4] that are involved in inventory compilation cooperate with review response through activities including providing relevant information, support for source material preparation, and QC implementation.

[3] The UNFCCC Inventory Reporting Guidelines and the *2006 IPCC Guidelines*.
[4] Private consultant companies cooperate in responding to reviews based on the operating agreement with MOE.

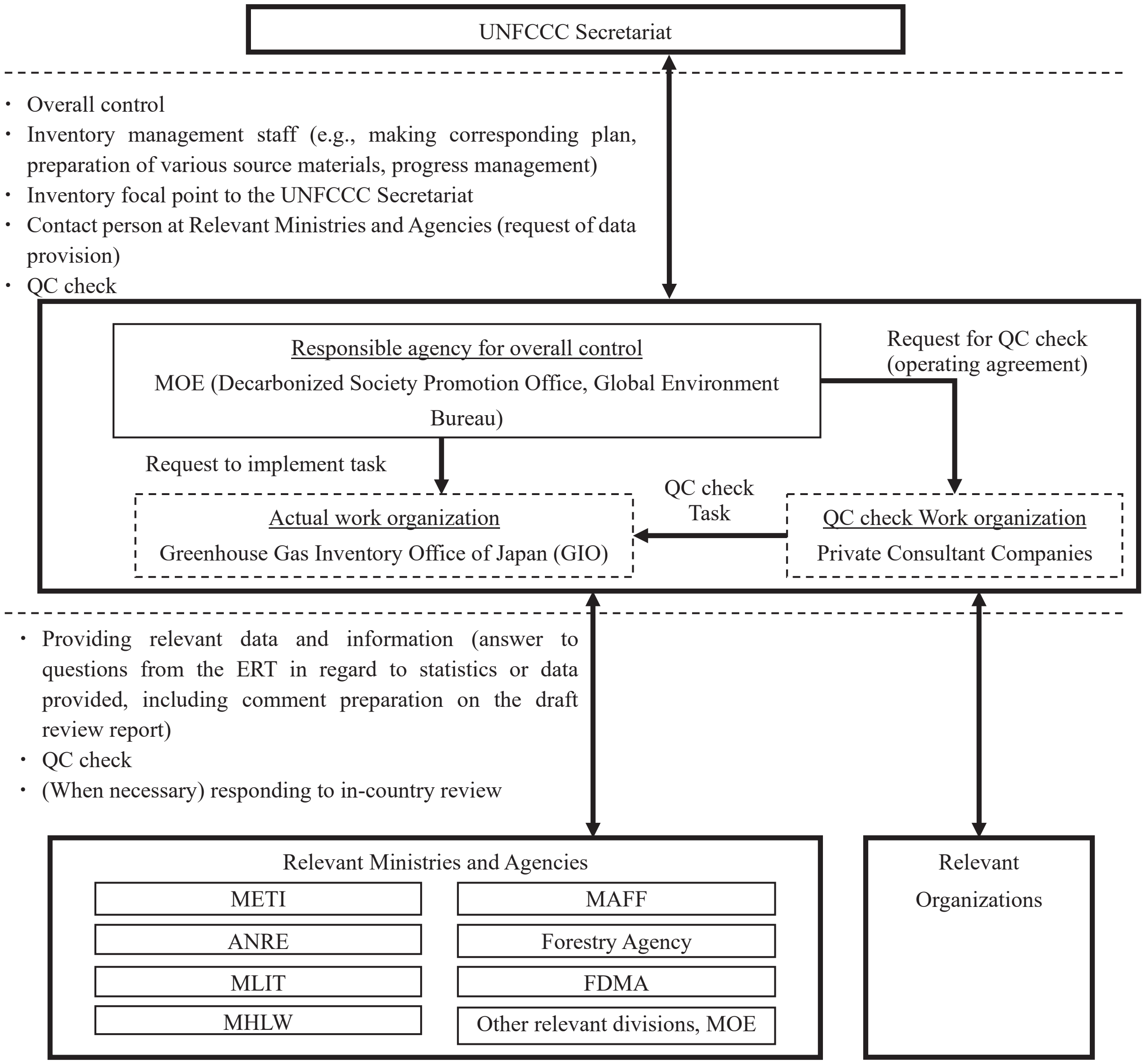


Figure 1-3 Basic structure of Japan's national system to respond to inventory review

1.2.2. Overview of Inventory Planning, Preparation and Management

MOE (Decarbonized Society Promotion Office, Global Environment Bureau) is the single national agency responsible for preparing Japan's inventory, and the GIO performs the actual work of inventory compilation. Relevant ministries and organizations are also involved in the preparation of the inventory, mainly by preparing AD, EFs, and other data needed for inventory compilation. Private consulting companies are contracted by MOE to perform tasks related to QC of the inventory, mainly prepared by MOE and GIO.

The Committee, run by MOE, considers the methods, AD and EFs used. Under the Committee, the inventory WG that examines crosscutting issues, and breakout groups that consider sector-specific problems (Breakout group on Energy and Industrial Processes, Breakout group on Transport, Breakout group on F-gases, Breakout group on Agriculture, Breakout group on Waste, Breakout group on LULUCF, and Breakout group on NMVOC), as well as the Sub-breakout group on CCU are set up.

The emissions and removals are prepared in accordance with the Inventory Reporting Guidelines (See sectoral chapters for details). The key category analysis is performed in accordance with the *2006 IPCC Guidelines*, and both Approach 1 and 2 are applied (See section 1.5 for results). The key category analysis is used to prioritize inventory improvements. No additional key categories were identified using the qualitative approach. The uncertainty analysis is carried out in accordance with the *2006 IPCC Guidelines*, and Approach 1 is applied (See section 1.6 for results).

QC procedures are used in the inventory and are documented as part of the QA/QC plan (See section 1.2.3 for details). As part of inventory QA, detailed reviews (expert peer reviews) are regularly performed by experts not directly involved in inventory compilation for each emission source and sink.

Japan has a centralized archiving system, which includes the archiving of disaggregated EFs and AD, and documentation on how these factors and data have been generated and aggregated for the preparation of the inventory. The archived information also includes internal documentation on QA/QC procedures, UNFCCC review and QA peer review, and documentation on annual key categories identification and planned inventory improvements. The archiving system is run by GIO and is comprised of electronic and paper versions of documents.

1.2.3. Quality Assurance, Quality Control and Verification Plan

1.2.3.1. QA/QC Procedures Applied

When compiling the inventory in Japan, inventory quality is controlled by performing QC activities (such as checking the correctness of calculations and archiving of documents) at each step, in accordance with *2006 IPCC Guidelines*. In Japan, the QC activities relating to inventory compilation performed by personnel belonging to agencies involved in inventory compilation—that is, the MOE (including the GIO and private consultant companies), relevant ministries and agencies—are considered to be QC. External reviews by experts who are outside the inventory compilation system are considered to be QA. They assess data quality from the perspectives of scientific knowledge and data availability with respect to current calculation methods. Table 1-1 sketches Japan's QA/QC activities.

Table 1-1 Summary of Japan's QA/QC activity

	Implementing entity	Main contents of activity
QC (Quality Control)	Ministry of the Environment (Decarbonized Society Promotion Office, Global Environment Bureau)	・Coordinating QA/QC activities for inventory preparation ・Checking and approving the QA/QC plan ・Checking and approving the inventory improvement plan
	Greenhouse Gas Inventory Office of Japan, Center for Global Environmental Research, Earth System Division, National Institute for Environmental Studies (GIO)	・Conducting general QC check ・Archiving QA/QC activity records and relevant data and documents ・Developing inventory improvement plan ・Revising QA/QC plan
	Relevant Ministry and Agencies	・Checking data necessary for inventory preparation ・Checking JNGI files and inventory prepared by GIO (Category-specific QC)
	Committee for the Greenhouse Gas Emissions Estimation Methods	・Discussing and assessing estimation methods, EFs, and AD (Category-specific QC)
	Private Consultant Companies	・Checking JNGI files and inventory prepared by GIO (Category-specific QC)
QA (Quality Assurance)	Inventory Quality Assurance Working Group (QAWG)	・Conducting expert peer review of inventory

1.2.3.1.a. QC activity

a) General QC procedures

In accordance with Table 6.1, Chapter 6, Vol.1 of the *2006 IPCC Guidelines*, general QC procedures include the general items to be confirmed which are related to the calculation, data processing, completeness, and documentation applicable to all emission source and sink categories. General QC procedures are implemented by each inventory compiler.

Following are the QC activities conducted by GIO's sectoral experts (SEs), who perform the work of compiling the emissions/removals estimation files for each category, the CRF transition files and NIR; the National Inventory compiler (NIC), who integrates the information from the individual SEs and compiles the inventory; and the data providers, who provide the AD and other data used to calculate emissions and removals.

1) Sectoral expert (SE)

SEs perform mainly the following QC activities.

- Checking for transcription errors in data entry and referencing
- Checking to ensure that emissions are accurately estimated
- Checking to see that parameters and emission units are accurately recorded, and that proper conversion factors are used
- Checking the conformity of databases and/or files
- Checking the consistency of data from one category to another
- Checking the accuracy of inventory data behavior from one processing step to the next
- Checking completeness
- Checking time series consistency
- Checking trends
- Conducting comparisons with past estimated values

- Checking that uncertainties in emissions and removals are accurately estimated and calculated
- Carrying out reviews of internal documentation
- Checking that the assumptions and criteria for selecting AD and EFs are documented

2) National inventory compiler (NIC)

The NIC performs mainly the following QC activities.

- Confirming that CRF Reporter data provided by SEs are imported without omission
- Confirming that the information needed for the documentation box is properly entered
- Confirming that the reasons for "NE" and "IE" are correctly entered
- Confirming that the key category analysis results are correctly outputted
- Confirming that the reasons for recalculations are provided for all categories
- Confirming that emissions and removals are correctly aggregated
- Confirming that data are corrected after the coordination with the relevant ministries and agencies

b) QC procedures for each source and sink category

The following category-specific QC activities are performed in Japan:

1) QC by private consultant companies (External QC)

QC on the estimation files and CRF and NIR drafts prepared by the GIO, are performed by mutual checks of estimation results with private consultant companies, through the use of estimation files like those of the GIO, and confirming the data entered into estimation files for each source and sink category and the equations for calculating emissions and removal.

2) QC through coordination with the relevant ministries and agencies (External QC)

The relevant ministries and agencies are sent the sets of files for estimation, CRF, NIR, and the drafts of documents for domestic release showing estimated values for emissions and removals. Through this, category-specific QC is implemented for the content of categories relevant to each ministry or agency.

3) Committee for the Greenhouse Gas Emissions Estimation Methods

Since the Committee considers and selects the methodologies, AD and parameters including EFs, which are actually applied to the estimation of emissions/removals from each category, it also implements category-specific QC activities.

c) QC activities of the documentation and archiving of inventory information

GIO promptly implements QC activities of the documentation and archiving of inventory information, after the inventory submission to the UNFCCC.

1.2.3.1.b. QA activity

QA refers to assessment of inventory quality by third units that are not directly involved in inventory compilation. In Japan, the expert peer review is held by the GHG Inventory Quality Assurance Working Group (QAWG) as a QA activity, to assure inventory quality.

a) GHG Inventory Quality Assurance Working Group (QAWG)

1) Summary

The QAWG performs detailed reviews by experts (expert peer reviews) not directly involved in inventory compilation for each emission source and sink in order to assure inventory quality and to identify places that need improvement.

The secretariat for the QAWG is established within the GIO. The secretariat and the MOE determine the sectors/categories to be reviewed by the QAWG. The experts for the QAWG are selected by taking the following requirements into account.

<Requirements for QAWG review experts>

a. No direct involvement in the inventory preparation process for estimating emissions/ removals from the sectors/categories to be reviewed (i.e., no involvement in the Committee, the data creation and the data provision for those sectors/categories)
b. No specific interests related to the inventory and the capability to judge objectively without being affected by any specific organizations and/or stakeholders
c. Sufficient skills, knowledge and experiences to assure the quality of the inventory

2) Scope of review

The QAWG performs reviews mainly in the following areas. The results are utilized for the preparation of the inventory for the next submission.

- Confirming the soundness of estimation methods, AD, EFs, and other items.
- Confirming the soundness of content reported in the CRF and NIR.

3) Recent activities

The LULUCF sector was reviewed by two experts in FY2021. It was confirmed by the QAWG that the inventory for the LULUCF sector was generally valid. Identified issues by this QAWG were brought up to the Committee and the relevant breakout group in the Committee for discussion, and some issues were improved in this submitted inventory. In addition, the QAWG also identified insufficient explanations in the NIR. These findings lead to improve transparency and accuracy of the NIR.

The MOE and the secretariat determine the sectors/categories reviewed by the QAWG, and the entire GHG inventory is covered over the course of several years.

1.2.3.2. QA/QC Plan

The QA/QC Plan is an internal document that documents, among other things, the specifics of all QA/QC activities in all processes from the start of inventory compilation to the final report, the compilation schedule, and the apportionment of all involved entities' roles. It organizes and systematizes the QA/QC activities of inventory compilation and clarifies what each entity involved in compilation is supposed to do. Additionally, it is prepared for the purpose of guaranteeing the implementation of QA/QC activities.

The QA/QC Plan's scope includes the processes of preparing, reporting, and reviewing the inventory under the UNFCCC.

1.2.3.3. Verification Activities

Confirmation such as the following have been undertaken in the Breakout groups of the Committee for the Greenhouse Gas Emission Estimation Methods: checking the appropriateness of EFs which were established based on actual measurements in the past, against new measurements, or checking the appropriateness of applying specific EFs based on models, to the national inventory. Additionally, the inventory emissions are checked against entity-based emission data reported under the Mandatory GHG Accounting and Reporting System[5] - a system that aims to reduce emissions from entities by requiring them to estimate and understand the amount of GHG emissions originating from their own activities. This mutual verification activity is to avoid any possible large omission of emissions.

1.2.3.4. Treatment of Confidential Information

Part of the AD and EFs, other parameters, and emissions obtained from ministries or the private sector correspond to confidential information. These are listed and archived. At the stage of obtaining and archiving data, and in the QC process, data is protected by using a password, and confidential files are distinguished from others, together with restricted access. When sending data to relevant ministries for checks, confidential data are sent only to the ministry which provided the data. At the stage of UN reporting, a minimum level of aggregation with other sub-categories is performed, and the notation key “C” (confidential) is used.

1.2.4. Changes in the National Inventory Arrangements since the Previous Annual GHG Inventory Submission

In line with paragraph 50 (J) of the *UNFCCC Inventory Reporting Guidelines*, Japan reports the changes in its national inventory arrangements from the previous inventory submission.

- No changes have been made since the previous inventory submission.

1.3. Inventory Preparation, and Data Collection, Processing and Storage

1.3.1. Annual cycle of inventory preparation

Table 1-3 shows the annual cycle of inventory preparation. The inventory preparation cycle is set in conjunction with Japan's fiscal year calendar (starting April 1 and ending March 31 of the next year).

[5] This system was established in 2006 under the Act on Promotion of Global Warming Countermeasures and requires entities that emit GHGs over a certain amount to estimate and report their emissions to the government. It generally covers all sectors excluding the LULUCF sector and part of the Energy sector (residential and transport (private vehicles)). The methods used to calculate emissions are generally consistent with those used in compiling the inventory.

Table 1-2 Annual cycle of the inventory preparation

Process	Relevant Entities	Calender Year n+1								CY n+2			
		Fiscal Year n+1											FY n+2
		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Holding the meeting of the QAWG	MOE, GIO	→	→	→	→								
Discussion on inventory improvement	MOE, GIO		→	→	→	→							
Holding the meeting of the Committee	MOE, (GIO, Private consultant)		→	→	→	→	→	→	→	→			
Collection of data for the national inventory	MOE, GIO, Relevant Ministries/Agencies, Relevant organization, Private consultant								→	→	→	→	
Preparation of the draft CRF tables	GIO, Private consultant									→	→	→	
Preparation of the draft NIR	GIO, Private consultant									→	→	→	
Implementation of external QC and coordination with relevant ministries and agencies	MOE, GIO, Relevant Ministries/Agencies, Private consultant										→	→	→
Correction of the draft CRF tables and NIR	MOE, GIO, Private consultant											→	→
Submission and official announcement of the national inventory	MOE, GIO												★

1.3.2. Process of the inventory preparation

1) Holding the meeting of the Greenhouse Gas Inventory Quality Assurance Working Group (QAWG) (Step 1)

The QAWG, which is composed of experts who are not directly involved in nor related to the inventory preparation process, is organized in order to conduct peer review and assure the inventory's quality and to find possible improvements.

This QAWG reviews the appropriateness of the estimation methodologies, AD, EFs, and the contents of the CRF and NIR. The GIO utilizes the items identified for improvement by the QAWG in discussions on the inventory estimation methods and in subsequent inventory preparation.

2) Discussion on inventory improvement (Step 2)

The MOE and the GIO identify the items that need to be addressed by the Committee, based on the results of the previous inventory review of the UNFCCC, the recommendations of the QAWG, the items needing improvement as identified at former Committee meetings, and any other items requiring revision, as determined during previous inventory preparations. The schedule for the expert evaluation (step 3) is developed by taking the above-mentioned information into account.

3) Holding meetings of the Committee for the Greenhouse Gas Emission Estimation Methods [evaluation and examination of estimation methods by experts] (Step 3)

The MOE holds meetings of the Committee, in which estimation methodologies for an annual inventory and the issues that require technical reviews are discussed by experts with different scientific backgrounds.

4) Collection of data for the national inventory (Step 4)

The data required for preparing the national inventory and other additional information are collected.

5) Preparation of a draft of the CRF [including the implementation of the key category analysis and the uncertainty assessment] (Step 5)

The data input and estimation of emissions and removals are carried out simultaneously by utilizing JNGI files, which have interconnecting links based on the calculation formulas for emissions and removals. Subsequently, the key category analysis and the uncertainty assessment are also carried out.

6) Preparation of a draft of NIR (Step 6)

The GIO identifies the points that need to be revised in the NIR or that require an additional description by taking the discussion at step 2 into account. The organization of the NIR is generally the same every year, but if large modifications such as changes in chapters are envisaged, this is proposed to the MOE and approval is sought. The GIO prepares the new NIR draft by updating the data and by adding and revising descriptions.

7) Implementation of the external QC and the coordination with the relevant ministries and agencies (Step 7)

As a QC activity, the selected private consulting companies check the JNGI files and the initial draft of the CRF (the 0^{th} draft) prepared by the GIO (external QC). The companies not only check the input data and the calculation formulas in the files but also check the estimations by calculating the amount of GHG emissions and removals by utilizing the same files. Because of this crosscheck, any possible data input and emission estimation mistakes are avoided. They also check the content and descriptions of the initial draft of the NIR (the 0^{th} draft) prepared by the GIO. JNGI files, draft CRF and draft NIR, which have been checked by the private consulting companies, are regarded as the primary drafts of inventories.

Subsequently, the GIO sends out the primary drafts of the inventories and press releases as electronic computer files to the MOE and the relevant ministries and agencies and asks them to check the contents of the primary drafts. The data, which are estimated based on confidential data, are only sent out for confirmation to the ministries and/or agencies that provided the confidential data.

For some sources/sinks, emissions/removals are estimated by entities other than GIO, and the QC implemented in these entities are checked.

8) Correction of the drafts of CRF and NIR (Step 8)

When revisions are requested as a result of the check of the primary drafts of the inventories and official announcements by the relevant ministries and agencies (step 7), the MOE, GIO, and relevant ministries and/or agencies that submit requests for revision then coordinate the details of any revision, revise the primary drafts, and prepare the secondary drafts. The secondary drafts are sent out again to the relevant ministries and/or agencies for conclusive confirmation. If there is no additional request for revision, the secondary drafts are considered the final versions.

9) Submission and official announcement of the national inventory (Step 9)

The completed inventory is submitted to the UNFCCC Secretariat. At the same time of the submission, information on the estimated GHG emissions and removals are officially announced and published on the MOE's website (https://www.env.go.jp/earth/ondanka/ghg-mrv/index.html) with additional relevant information. The inventory is also published on the GIO's website (https://www.nies.go.jp/gio/en/index.html).

1.3.3. Documentation and Archiving of Inventory Information

In Japan, the information needed for inventory compilation is documented and as a rule archived by the agency which compiles the inventory (GIO).

The main files (all JNGI files, NIR word files, and CRFs) needed for inventory compilation is electronically archived at MOE as well.

1.3.3.1. Documentation of information

The GIO documents all the inventory-related information in electronic or printed form and archives it. Examples of information that must be archived follow.

- The inventory related files submitted every year to the UNFCCC Secretariat
- Published materials for finalized data
- Statistical data and provided data (including data providers, time period when provided, and other related information) used in compiling the inventory and part of the activity data
- Information on the discussion process and discussion results related to the selection of AD, estimation methods, EFs, and other items (relevant source materials for the discussion process by the Committee for the Greenhouse Gas Emissions Estimation Methods)
- Records of communications with related entities in the inventory compilation process
- Information on inventory recalculations (such as reasons for recalculations, and when performed)
- QA/QC Plan and records of QA/QC activities conducted, including holding the QAWG
- Comments by experts on the inventory
- In relation to UNFCCC inventory reviews, review reports and records of questions and answers with ERTs

1.3.3.2. Archiving of information

1) Archiving electronic information

i) Inventory-related electronic information

- Each year’s JNGI files and CRF- and NIR-related files have file names with the year when the estimation was performed, and files are saved in folders prescribed for each year.
- Electronic files of statistical data, provided data, etc. used to prepare the inventory’s emissions/removals estimates and other related data are given file names, etc. with the date on which the data were obtained and the data provider, and saved in prescribed folders.
- Source materials in electronic form (files in Word, PDF, or other format) used when considering emissions/removals estimation methods are labeled with the source material title and the date the file was obtained (and if necessary, the file provider), and saved in prescribed folders.
- If the exchange of information on the inventory has been conducted by email, the email files are saved in prescribed folders.

ii) Backup and risk management of electronic information

- The server, hosted by the National Institute for Environmental Studies (in which GIO is included), and where inventory-related information is stored, is automatically backed up every day. Access to the server is restricted to specific ID holders only.
- Once a year, after submission of the annual inventory to the UNFCCC Secretariat, all inventory-related electronic information is saved to CD-ROMs and other electronic media and archived.

2) Archiving in printed form

- Books of statistics, data and source materials in printed form that have been provided, and other source materials in printed form that have been used in inventory emissions/removals estimates are filed in a prescribed storage location.

1.3.3.3. QC activity for documentation and archiving of inventory information

Immediately after the inventory is submitted to the UNFCCC Secretariat, the GIO carries out QC activities related to the documentation and archive of inventory information.

1.4. Brief General Description of Methodologies and Data Sources Used (including tiers used)

The methodology used in estimation of GHG emissions or removals is basically in accordance with the *2006 IPCC Guidelines*. The country-specific methodologies are also used for some source/sink categories in order to more accurately reflect the actual emission status in Japan.

The results of the actual measurements or estimates based on research conducted in Japan are used to determine the EFs (country-specific emissions factors). The default values given in the *2006 IPCC Guidelines* are used for some categories, emissions of which are assumed to be quite low (e.g., "1.B.2.a.ii fugitive emissions from fuel (oil and natural gas (CO_2 and CH_4))") etc.

1.4.1. Collection Process of Activity Data

When the AD needed for calculations are available from sources such as publications and the internet, the necessary data are gathered from these media. Data that are not released in publications, the internet, or in other media, and unpublished data that are used when compiling the inventory are obtained by the MOE or the GIO by requesting them from the relevant ministries and agencies and the relevant organizations which control those data. The main relevant ministries, agencies, and relevant organizations, and their statistics and data are as shown in Table 1-4.

Table 1-3 Main relevant ministries, agencies, and the relevant organizations, and their statistics and data

<table>
<tr><th colspan="2">Ministries/Agencies/Organizations</th><th>Major data or statistics</th></tr>
<tr><td rowspan="4">Relevant Ministries/ Agencies</td><td>MOE</td><td>Research of Air Pollutant Emissions from Stationary Sources/ Waste Treatment in Japan/ Report of the research on the state of wide-range movement and cyclical use of wastes (the volume on cyclical use)/ Survey of Industrial Waste Treatment Facilities</td></tr>
<tr><td>METI</td><td>General Energy Statistics / Current Production Statistics / Amount of nitric acid production/ Documents of Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council</td></tr>
<tr><td>MLIT</td><td>Statistical Yearbook of Motor Vehicle Fuel Consumption / Land Use Status Survey</td></tr>
<tr><td>MAFF</td><td>Livestock Statistics / Statistics of Arable and Planted Land Area / Yearbook of Fertilizer Statistics (Pocket Edition)/ A Move and Conversion of Cropland / National Forest Resources Database/ Report on Forest GHG Inventory Information Development Project</td></tr>
<tr><td rowspan="5">Relevant Organizations</td><td>Federation of Electric Power Companies</td><td>Amount of Fuel Used by Pressurized Fluidized Bed Boilers</td></tr>
<tr><td>Japan Coal Frontier Organization</td><td>Coal Production/ History of Coal Policy</td></tr>
<tr><td>Japan Cement Association</td><td>Amount of clinker production / Cement Handbook</td></tr>
<tr><td>Japan Iron and Steel Federation</td><td>Emissions from Coke Oven Covers, Desulfurization Towers, and Desulfurization Recycling Towers</td></tr>
<tr><td>Japan Paper Association</td><td>Amount of final disposal of industrial waste / Amount of RPF incineration</td></tr>
</table>

1.4.2. Selection Process of Emission Factors and Estimation Methods

Calculation methods for Japan’s emission and removal amounts are determined by having the Committee explore calculation methods suited to Japan’s situation for all the activity categories necessary for calculating Japan’s greenhouse gas emission and removal amounts, based on the *2006 IPCC Guidelines*.

1.4.3. Improvement Process of Estimations for Emissions and Removal

In Japan, improvements in the calculation methods are considered in accordance with necessity whenever an inventory item requiring improvement is identified because of, for example, a UNFCCC review or an observation by the QAWG, progress in international negotiations such as the creation of new guidelines, progress or changes in scientific research or in the compilation of statistics, or the acquisition of new information by the Mandatory GHG Accounting and Reporting System. Proposals for improving the estimation of emissions and removals are considered by scientific research or the Committee, and the results are incorporated into the inventory. Figure 1-4 is a diagram of the inventory improvement process.

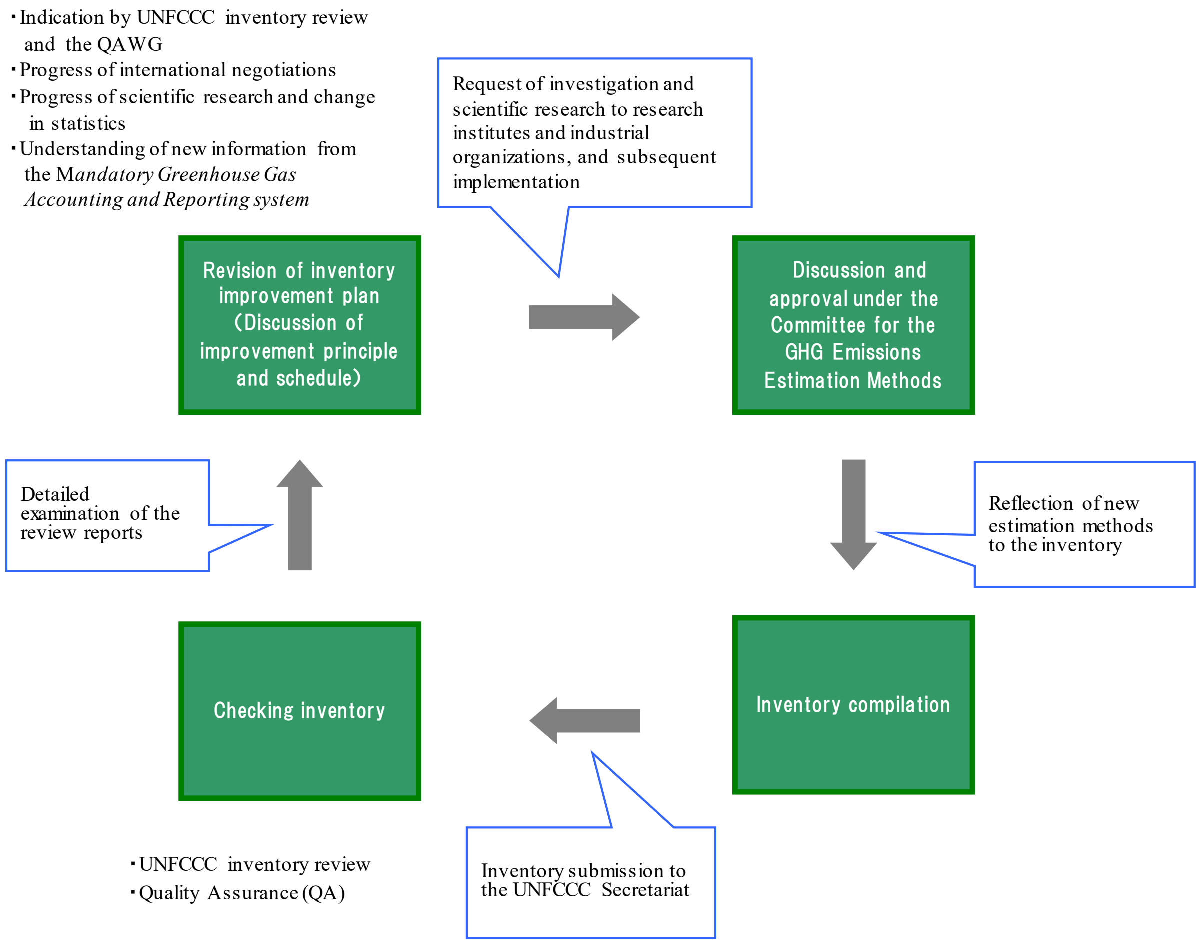


Figure 1-4 Diagram of the inventory improvement process

1.5. Brief Description of Key Categories

Key category analysis was carried out in accordance with the *2006 IPCC Guidelines* (Approach 1 and Approach 2 level/trend assessment).

1.5.1. GHG Inventory

In FY2021, 51 sources and sinks were identified as Japan's key categories (Table 1-5). For the base year of the UNFCCC (FY1990), 43 sources and sinks were identified as key categories (Table 1-6). More detailed information is described in Annex 1.

Table 1-4 Japan's key categories in FY2021

	A IPCC Code	B IPCC Category		C GHGs	Ap1-L	Ap1-T	Ap2-L	Ap2-T
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	#1	#1	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#20	#11	
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#3	#7	#2	#10
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#4	#4	#8	#17
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#6	#24	#22
#6	4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	#6	#8	#4	#7
#7	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#7	#2	#30	#14
#8	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#8	#3	#31	#19
#9	2.F.	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	#9	#5	#6	#6
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#10	#9	#29	
#11	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#11	#10	#34	
#12	2.A.	Mineral Industry	1. Cement Production	CO_2	#12	#12	#21	#24
#13	3.C.	Rice Cultivation		CH_4	#13		#28	
#14	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	#14	#18	#9	#15
#15	5.C.	Incineration and Open Burning of Waste		CO_2	#15		#13	
#16	1.A.3.	Transport	d. Domestic Navigation	CO_2	#16			
#17	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#17		#14	#25
#18	3.A.	Enteric Fermentation		CH_4	#18		#7	
#19	1.A.3.	Transport	a. Domestic Aviation	CO_2	#19			
#20	1.A.4.	Other Sectors	Solid Fuels	CO_2	#20	#19		#29
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#21			
#22	2.A.	Mineral Industry	2. Lime Production	CO_2	#22			
#23	4.B.	Cropland	1. Cropland remaining Cropland	CO_2			#20	#20
#24	3.B.	Manure Management		N_2O			#5	
#25	4.E.	Settlements	2. Land converted to Settlements	CO_2		#15	#12	#3
#26	3.D.	Agricultural Soils	1. Direct Emissions	N_2O			#25	
#27	2.F.	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs		#23	#15	#12
#28	2.B.	Chemical Industry	Other products except Anmonia	CO_2			#16	#27
#29	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O			#3	#16
#30	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2			#19	
#31	5.D.	Wastewater Treatment and Discharge		N_2O			#27	
#32	1.A.1.	Energy Industries		N_2O			#32	
#33	2.E.	Electronics Industry		PFCs			#17	
#34	4.G.	Harvested Wood Products		CO_2				#28
#35	5.A.	Solid Waste Disposal		CH_4		#14		#9
#36	4.E.	Settlements	1. Settlements remaining Settlements	CO_2			#33	
#37		Indirect CO_2	from IPPU sector	Ind CO_2			#26	#11
#38	2.G.	Other Product Manufacture and Use		SF_6		#16	#10	#2
#39	2.F.	Product uses as substitutes for ODS	5. Solvents	PFCs		#24		
#40	5.C.	Incineration and Open Burning of Waste		N_2O			#22	
#41	1.A.3.	Transport	b. Road Transportation	N_2O			#18	#8
#42	4.A.	Forest Land	2. Land converted to Forest Land	CO_2		#13		#18
#43	1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH_4		#21		#4
#44	4.F.	Other Land	2. Land converted to Other Land	CO_2				#13
#45	2.E.	Electronics Industry		SF_6			#23	
#46	4.(III)	Direct N_2O emissions from N mineralization/immobilization		N_2O				#23
#47	2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs		#11		
#48	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O				#5
#49	4.(IV)	Indirect N_2O Emissions from Managed Soils		N_2O				#26
#50	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O		#17		#21
#51	2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF_6		#22		

Note1: Ap1-L: Approach 1-Level Assessment, Ap1-T: Approach 1-Trend Assessment,
Ap2-L: Approach 2-Level Assessment, Ap2-T: Approach 2-Trend Assessment

Note2: Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

Table 1-5 Japan's key categories in FY1990

	A IPCC Code	B IPCC Category		C GHGs	Ap1-L	Ap2-L
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#1	#2
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#14
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#3	#15
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#4	#21
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#22
#6	1.A.1.	Energy Industries	Solid Fuels	CO_2	#6	#5
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#7	#23
#8	4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	#8	#4
#9	2.A.	Mineral Industry	1. Cement Production	CO_2	#9	#20
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#10	
#11	2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	#11	
#12	1.A.3.	Transport	d. Domestic Navigation	CO_2	#12	
#13	5.C.	Incineration and Open Burning of Waste		CO_2	#13	#17
#14	3.C.	Rice Cultivation		CH_4	#14	
#15	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#15	
#16	4.E.	Settlements	2. Land converted to Settlements	CO_2	#16	#7
#17	5.A.	Solid Waste Disposal		CH_4	#17	#13
#18	4.A.	Forest Land	2. Land converted to Forest Land	CO_2	#18	#32
#19	3.A.	Enteric Fermentation		CH_4	#19	#11
#20	2.G.	Other Product Manufacture and Use		SF_6	#20	#1
#21	4.B.	Cropland	1. Cropland remaining Cropland	CO_2	#21	#19
#22	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	#22	
#23	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#23	
#24	1.A.3.	Transport	a. Domestic Aviation	CO_2	#24	
#25	2.A.	Mineral Industry	2. Lime Production	CO_2	#25	
#26	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#26	#25
#27	1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH_4	#27	#8
#28	2.F.	Product uses as substitutes for ODS	5. Solvents	PFCs	#28	
#29		Indirect CO_2	from IPPU sector	Ind CO_2		#12
#30	3.D.	Agricultural Soils	1. Direct Emissions	N_2O		#28
#31	3.B.	Manure Management		N_2O		#6
#32	2.B.	Chemical Industry	Other products except Anmonia	CO_2		#16
#33	1.A.3.	Transport	b. Road Transportation	N_2O		#10
#34	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O		#3
#35	5.D.	Wastewater Treatment and Discharge		N_2O		#30
#36	4.F.	Other Land	2. Land converted to Other Land	CO_2		#18
#37	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2		#29
#38	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O		#9
#39	2.E.	Electronics Industry		PFCs		#26
#40	5.C.	Incineration and Open Burning of Waste		N_2O		#27
#41	4.(III)	Direct N_2O emissions from N mineralization/immobilization		N_2O		#31
#42	2.E.	Electronics Industry		SF_6		#24
#43	4.(IV)	Indirect N_2O Emissions from Managed Soils		N_2O		#33

Note1: Ap1-L: Approach 1-Level Assessment, Ap2-L: Approach 2-Level Assessment
Note2: Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

1.6. General Uncertainty Assessment, including Data on the Overall Uncertainty for the Inventory Totals

1.6.1. GHG Inventory

Total net GHG emissions in Japan for FY2021 were approximately 1,118 million tonnes (CO_2 equivalents). The total net emissions uncertainties calculated by approach 1 (propagation of error) were -3% to +2% and the uncertainties introduced into the trend in the total emissions were -3% to +2%. More detailed information on the uncertainty assessment is described in Annex 2.

Table 1-6 Uncertainty of Japan's total net emissions

A	B	C	D	G-1990		G-2021		I	J	
Category	GHGs	1990 emissions / removals	2021 emissions / removals	Combined uncertainty in 1990		Combined uncertainty in 2021		Inventory trend in national emissions for 2021 increase with respect to 1990	Uncertainty introduced into the trend in total national emissions	
		kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	%	(-) %	(+) %
1A. Fuel Combustion (CO_2)	CO_2	1,078,663	1,007,257	-2%	+1%	-3%	+2%	-6.6%	-3.2%	+2.2%
1A. Fuel Combustion (Stationary:CH_4,N_2O)	CH_4, N_2O	3,896	5,147	-23%	+29%	-24%	+28%	32.1%	0.0%	+0.0%
1A. Fuel Combustion (Transport:CH_4,N_2O)	CH_4, N_2O	4,031	1,501	-32%	+92%	-30%	+87%	-62.8%	0.0%	+0.0%
1B. Fugitive Emissions from Fuels	CO_2, CH_4, N_2O	5,302	1,044	-38%	+78%	-22%	+40%	-80.3%	0.0%	+0.0%
2. IPPU (CO_2,CH_4,N_2O)	CO_2, CH_4, N_2O	74,558	44,114	-6%	+6%	-5%	+5%	-40.8%	-0.1%	+0.1%
2. IPPU (HFCs,PFCs,SF_6,NF_3)	HFCs, PFCs, SF_6, NF_3	35,378	59,144	-7%	+36%	-6%	+7%	67.2%	-0.6%	+0.6%
3. Agriculture	CO_2, CH_4, N_2O	37,516	32,174	-11%	+28%	-10%	+25%	-14.2%	0.0%	+0.0%
4. LULUCF	CO_2, CH_4, N_2O	-63,272	-51,695	-15%	15%	-11%	+11%	-18.3%	-0.4%	+0.4%
5. Waste	CO_2, CH_4, N_2O	29,990	17,712	-10%	+10%	-12%	+12%	-40.9%	-0.2%	+0.2%
Indirect CO_2	Ind CO_2	5,482	1,872	-26%	+48%	-25%	+46%	-65.9%	0.0%	+0.0%
Total Net Emissions		1,211,543	1,118,272	-2.0%	+2.1%	-2.5%	+2.0%	-7.7%	-3.2%	+2.3%

1.7. General Assessment of the Completeness

In this inventory report, emissions from some categories are not estimated and reported as "NE (Not Estimated)". Source categories reported as "NE" in this year's report include those whose emissions are thought to be very small, those whose emissions are unknown, and those for which emission estimation methods have not been developed. For these categories, further investigation on their emission possibility and the development of estimation methodologies will be carried out in accordance with Japan's QA/QC plan. See Annex 5 for a list of not-estimated emission source categories.

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
2. IPCC, *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, 2014.
3. IPCC, *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*, 2014.
4. IPCC, *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2019.
5. UNFCCC, *Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention*, Decision 24/CP.19, FCCC/CP/2013/10/Add.3, 2014.
6. UNFCCC, *Guidelines for the technical review of information reported under the Convention related to greenhouse gas inventories, biennial reports and national communications by Parties included in Annex I to the Convention*, Decision 13/CP.20 Annex, FCCC/CP/2014/10/Add.3, 2015.

Chapter 2. Trends in GHG Emissions and Removals

2.1. Description and Interpretation of Emission and Removal Trends for Aggregate GHGs

2.1.1. Overview of GHGs Emissions and Removals

Total GHG emissions in FY2021[1,2] (excluding LULUCF[3], including indirect CO_2[4], hereafter, definition omitted) were 1,170 million tonnes (in CO_2 eq.). They decreased by 8.2% compared to the emissions in FY1990.

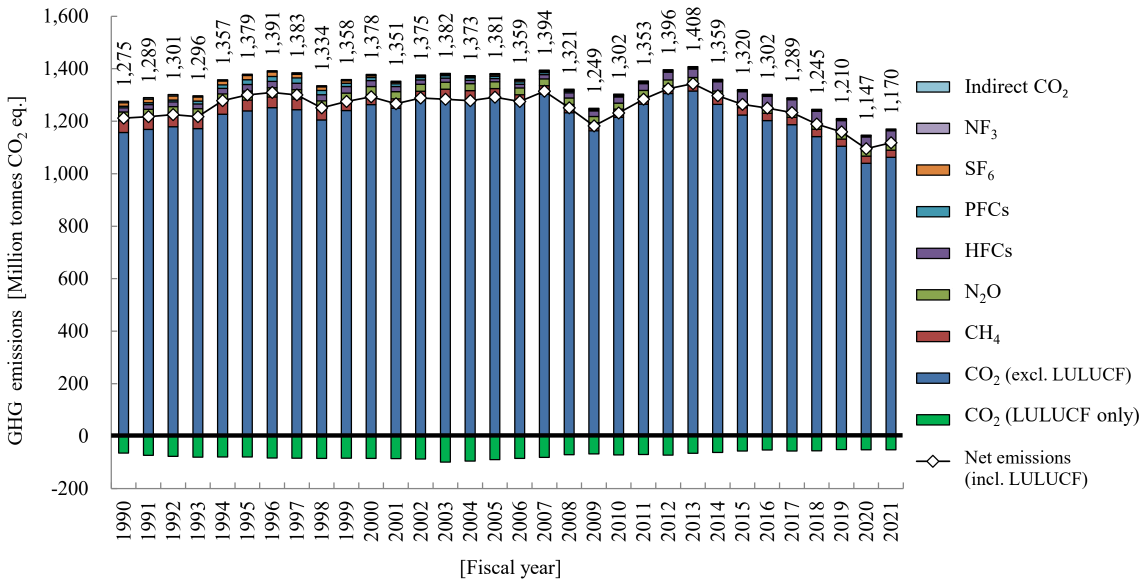


Figure 2-1 Trends in GHG emissions and removals in Japan

CO_2 emissions in FY2021 were 1,062 million tonnes (excluding LULUCF, excluding indirect CO_2, hereafter, definition omitted), accounting for 90.8% of total GHG emissions. They decreased by 8.2% since FY1990 and increased by 2.1% compared to the previous year. CO_2 removals[5] in FY2021 were 52.2 million tonnes, which were equivalent to 4.5% of total GHG emissions. They decreased by 18.9% since FY1990 and increased by 0.2% compared to the previous year.

---

1 Fiscal year (FY), from April of the reporting year through March of the next year, is used because CO_2 is the primary GHGs emissions and estimated on a fiscal year basis. "CY" stands for calendar year.

2 The sum of CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3 emissions converted to CO_2 equivalents, multiplied by their respective global warming potential (GWP). The GWP is a coefficient by means of which greenhouse gas effects of a given gas are made relative to those of an equivalent amount of CO_2. The coefficients (100-year time horizon) are drawn from the *Fourth Assessment Report* (2007) issued by the Intergovernmental Panel on Climate Change (IPCC).

3 Abbreviation of "Land Use, Land-Use Change and Forestry"

4 Carbon monoxide (CO), methane (CH_4) and non-methane volatile organic compounds (NMVOC) are oxidized in the atmosphere in the long term and converted to CO_2. Indirect CO_2 means the CO_2 equivalent value of these emissions. However, emissions derived from combustion-origin and biomass-origin CO, CH_4, and NMVOC are excluded to avoid double counting.

5 Since the inventory to be submitted under the UNFCCC reports all GHG emissions and removals from the LULUCF sector, these values do not correspond to emissions and removals in the NDC.

Table 2-1 Trends in GHG emissions and removals in Japan

[Million tonnes CO_2 eq.]	GWP	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2 (excl. LULUCF) *1	1	1,157.2	1,168.9	1,178.7	1,171.7	1,226.7	1,239.0	1,251.5	1,244.3	1,204.4	1,241.0	1,263.8	1,249.2	1,278.8	1,287.3	1,282.7	1,290.1	1,267.1	1,302.8	1,232.0	1,163.1
CO_2 (incl. LULUCF) *1	1	1,092.9	1,095.8	1,101.9	1,091.6	1,146.9	1,159.6	1,168.3	1,160.0	1,119.8	1,157.2	1,178.8	1,163.6	1,191.4	1,188.4	1,187.3	1,200.5	1,182.4	1,222.2	1,161.2	1,095.4
CO_2 (LULUCF only)	1	-64.3	-73.1	-76.8	-80.0	-79.8	-79.5	-83.2	-84.2	-84.6	-83.9	-84.9	-85.6	-87.3	-98.8	-95.4	-89.6	-84.7	-80.6	-70.8	-67.7
CH_4 (excl. LULUCF)	25	44.5	43.9	43.8	42.9	42.9	41.8	40.5	40.0	38.3	37.9	37.3	36.1	35.3	34.4	34.1	34.1	33.5	32.9	32.1	31.5
CH_4 (incl. LULUCF)	25	44.6	44.0	43.9	43.0	43.1	41.9	40.6	40.1	38.4	38.0	37.4	36.2	35.4	34.5	34.2	34.1	33.6	32.9	32.2	31.6
N_2O (excl. LULUCF)	298	32.2	31.9	32.1	32.0	33.2	33.5	34.6	35.4	33.8	27.7	30.2	26.6	26.0	25.8	25.7	25.3	25.2	24.7	23.8	23.2
N_2O (incl. LULUCF)	298	33.2	32.8	33.0	32.8	34.0	34.3	35.4	36.2	34.6	28.4	31.0	27.3	26.7	26.6	26.4	26.0	25.9	25.3	24.4	23.8
HFCs	HFC-134a: 1,430 etc.	15.9	17.4	17.8	18.1	21.1	25.2	24.6	24.4	23.7	24.4	22.9	19.5	16.2	16.2	12.4	12.8	14.6	16.7	19.3	20.9
PFCs	PFC-14: 7,390 etc.	6.6	7.5	7.6	11.0	13.5	17.7	18.3	20.1	16.6	13.2	11.9	9.9	9.2	8.9	9.2	8.6	9.0	7.9	5.8	4.1
SF_6	22,800	12.9	14.2	15.6	15.7	15.0	16.4	17.0	14.5	13.2	9.2	7.0	6.1	5.7	5.4	5.3	5.0	5.2	4.7	4.2	2.4
NF_3	17,200	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	1.5	1.4	1.6	1.5	1.4
Indirect CO_2	1	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.5	4.2	4.2	4.2	3.8	3.6	3.4	3.3	3.2	3.2	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,269.3	1,283.8	1,295.6	1,291.4	1,352.4	1,373.8	1,386.7	1,378.8	1,330.3	1,353.7	1,373.3	1,347.6	1,371.6	1,378.5	1,369.8	1,377.5	1,356.1	1,391.3	1,318.5	1,246.5
Net Total (including LULUCF, excluding indirect CO_2)		1,206.1	1,211.7	1,219.8	1,212.4	1,273.6	1,295.3	1,304.5	1,295.5	1,246.6	1,270.7	1,289.2	1,262.8	1,285.1	1,280.4	1,275.2	1,288.6	1,272.1	1,311.4	1,248.4	1,179.5
Gross Total (excluding LULUCF, including indirect CO_2)		1,274.8	1,289.1	1,300.6	1,296.2	1,357.2	1,378.5	1,391.5	1,383.4	1,334.5	1,357.8	1,377.5	1,351.4	1,375.2	1,381.9	1,373.2	1,380.7	1,359.2	1,394.3	1,321.2	1,249.1
Net Total (including LULUCF, including indirect CO_2)		1,211.5	1,217.0	1,224.9	1,217.1	1,278.4	1,299.9	1,309.2	1,300.1	1,250.7	1,274.8	1,293.5	1,266.6	1,288.7	1,283.8	1,278.5	1,291.9	1,275.3	1,314.4	1,251.1	1,182.0

[Million tonnes CO_2 eq.]	GWP	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Changes in emissions/removals (2021)	
														1990	Previous year
CO_2 (excl. LULUCF) *1	1	1,214.7	1,264.6	1,305.9	1,315.2	1,264.1	1,223.2	1,202.5	1,186.8	1,141.7	1,104.5	1,039.8	1,062.1	-8.2%	2.1%
CO_2 (incl. LULUCF) *1	1	1,143.2	1,194.9	1,233.4	1,250.0	1,201.8	1,166.5	1,149.7	1,130.0	1,085.4	1,053.4	987.7	1,010.0	-7.6%	2.3%
CO_2 (LULUCF only)	1	-71.5	-69.7	-72.5	-65.2	-62.3	-56.6	-52.8	-56.8	-56.3	-51.2	-52.1	-52.2	-18.9%	0.2%
CH_4 (excl. LULUCF)	25	31.1	29.9	29.2	29.1	28.6	28.3	28.2	28.0	27.7	27.5	27.4	27.4	-38.6%	-0.1%
CH_4 (incl. LULUCF)	25	31.2	29.9	29.3	29.2	28.7	28.3	28.3	28.1	27.7	27.6	27.4	27.4	-38.5%	0.0%
N_2O (excl. LULUCF)	298	22.7	22.3	22.0	21.9	21.5	21.2	20.6	20.9	20.4	20.0	19.7	19.5	-39.6%	-1.1%
N_2O (incl. LULUCF)	298	23.3	22.9	22.5	22.4	21.9	21.6	21.1	21.3	20.8	20.4	20.1	19.9	-40.1%	-1.1%
HFCs	HFC-134a: 1,430 etc.	23.3	26.1	29.4	32.1	35.8	39.3	42.6	45.0	47.1	50.0	52.2	53.6	236.0%	2.6%
PFCs	PFC-14: 7,390 etc.	4.3	3.8	3.5	3.3	3.4	3.3	3.4	3.5	3.5	3.4	3.5	3.2	-51.9%	-9.9%
SF_6	22,800	2.4	2.2	2.2	2.1	2.0	2.1	2.2	2.1	2.1	2.0	2.0	2.0	-84.1%	0.9%
NF_3	17,200	1.5	1.8	1.5	1.6	1.1	0.6	0.6	0.4	0.3	0.3	0.3	0.4	1065.6%	12.8%
Indirect CO_2	1	2.4	2.3	2.3	2.3	2.2	2.2	2.1	2.1	2.1	2.0	1.9	1.9	-65.9%	0.3%
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,300.0	1,350.7	1,393.6	1,405.4	1,356.5	1,317.8	1,300.1	1,286.7	1,242.7	1,207.7	1,144.9	1,168.1	-8.0%	2.0%
Net Total (including LULUCF, excluding indirect CO_2)		1,229.2	1,281.6	1,321.7	1,340.7	1,294.8	1,261.7	1,247.9	1,230.5	1,186.9	1,157.0	1,093.3	1,116.4	-7.4%	2.1%
Gross Total (excluding LULUCF, including indirect CO_2)		1,302.5	1,353.1	1,395.9	1,407.6	1,358.7	1,320.0	1,302.3	1,288.8	1,244.8	1,209.7	1,146.8	1,170.0	-8.2%	2.0%
Net Total (including LULUCF, including indirect CO_2)		1,231.6	1,284.0	1,324.0	1,343.0	1,297.0	1,263.9	1,250.0	1,232.6	1,189.0	1,159.0	1,095.2	1,118.3	-7.7%	2.1%

*1 Excluding indirect CO_2

*2 LULUCF: Land Use, Land-Use Change and Forestry

CH_4 emissions in FY2021 (excluding LULUCF) were 27.4 million tonnes (in CO_2 eq.), accounting for 2.3% of total GHG emissions. They decreased by 38.6% since FY1990 and decreased by 0.1% compared to the previous year. N_2O emissions in FY2021 (excluding LULUCF) were 19.5 million tonnes (in CO_2 eq.), accounting for 1.7% of total GHG emissions. They decreased by 39.6% since FY1990 and decreased by 1.1% compared to the previous year. HFC emissions in CY2021 were 53.6 million tonnes (in CO_2 eq.), accounting for 4.6% of total GHG emissions. They increased by 236% since CY1990 and increased by 2.6% compared to the previous year. PFC emissions in CY2021 were 3.2 million tonnes (in CO_2 eq.), accounting for 0.3% of total GHG emissions. They decreased by 51.9% since CY1990 and decreased by 9.9% compared to the previous year. SF_6 emissions in CY2021 were 2.0 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 84.1% since CY1990 and increased by 0.9% compared to the previous year. NF_3 emissions in CY2021 were 0.4 million tonnes (in CO_2 eq.), accounting for 0.03% of total GHG emissions. They increased 1,070% since CY1990 and increased by 12.8% compared to the previous year.

Indirect CO_2 emissions in FY2021 were 1.9 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 65.9% since FY1990 and increased by 0.3% compared to the previous year.

2.1.2. CO_2

CO_2 emissions in FY2021 were 1,062 million tonnes, accounting for 90.8% of total GHG emissions. They decreased by 8.2% since FY1990 and increased by 2.1% compared to the previous year.

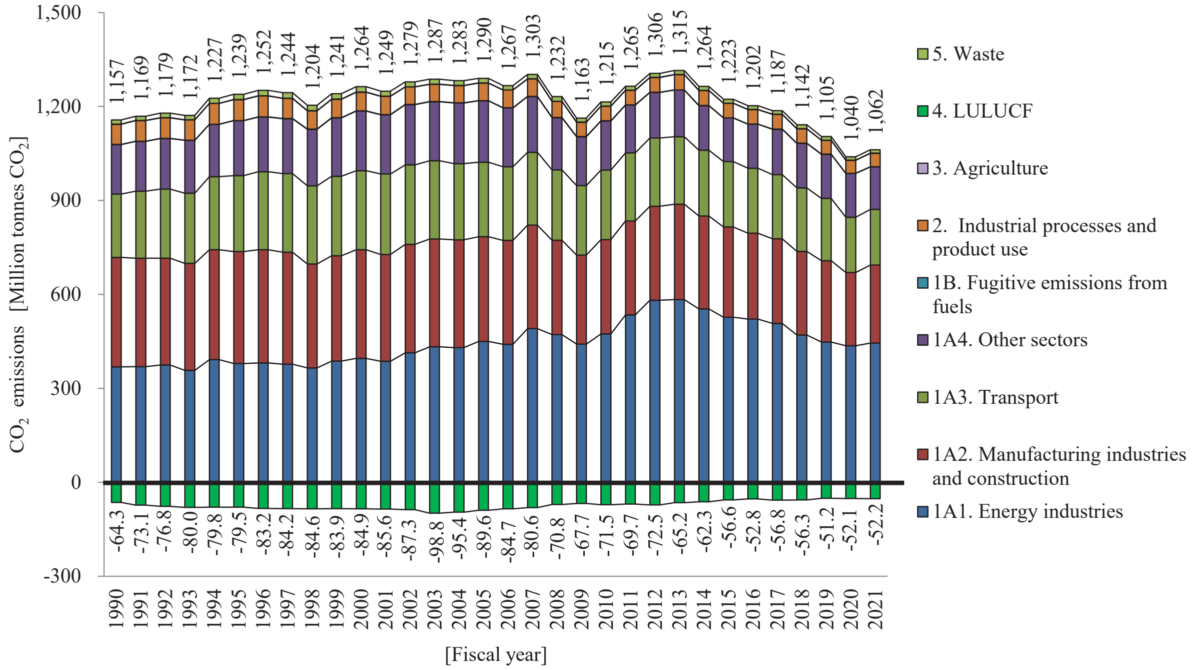


Figure 2-2 Trends in CO_2 emissions

The breakdown of CO_2 emissions in FY2021 shows that fuel combustion accounts for 94.8% and is followed by industrial processes and product use (4.1%) and waste sectors (1.0%). As for the breakdown of CO_2 emissions within the fuel combustion category, energy industries accounts for 41.8% and is followed by manufacturing industries and construction at 23.5%, transport at 16.8%, and other sectors[6] at 12.8%. The main driving factor for the increase in CO_2 emissions compared to the previous year is the increase in CO_2 emissions from the manufacturing industries and construction sector and the energy industries sector.

By looking at the changes in emissions by sector, emissions from fuel combustion in the energy industries increased by 20.6% since FY1990 and increased by 1.9% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increased emissions from solid and gaseous fuel consumption for electricity power generation, despite the decreased emissions from liquid fuel consumption. Emissions from manufacturing industries and construction decreased by 28.7% since FY1990 and increased by 6.8% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased emissions from solid fuel consumption for the iron and steel industry. Emissions from transport decreased by 12.0% compared to FY1990 and increased by 0.8% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decrease in emissions from diesel fuel in road transportation. Emissions from other sectors decreased by 14.3% since FY1990 and decreased by 3.3% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased emissions from the liquid fuel consumption for the commercial/institutional sub-sectors.

CO_2 removals in FY2021 were 52.2 million tonnes, which were equivalent to 4.5% of total GHG emissions. They decreased by 18.9% since FY1990 and increased by 0.2% compared to the previous year.

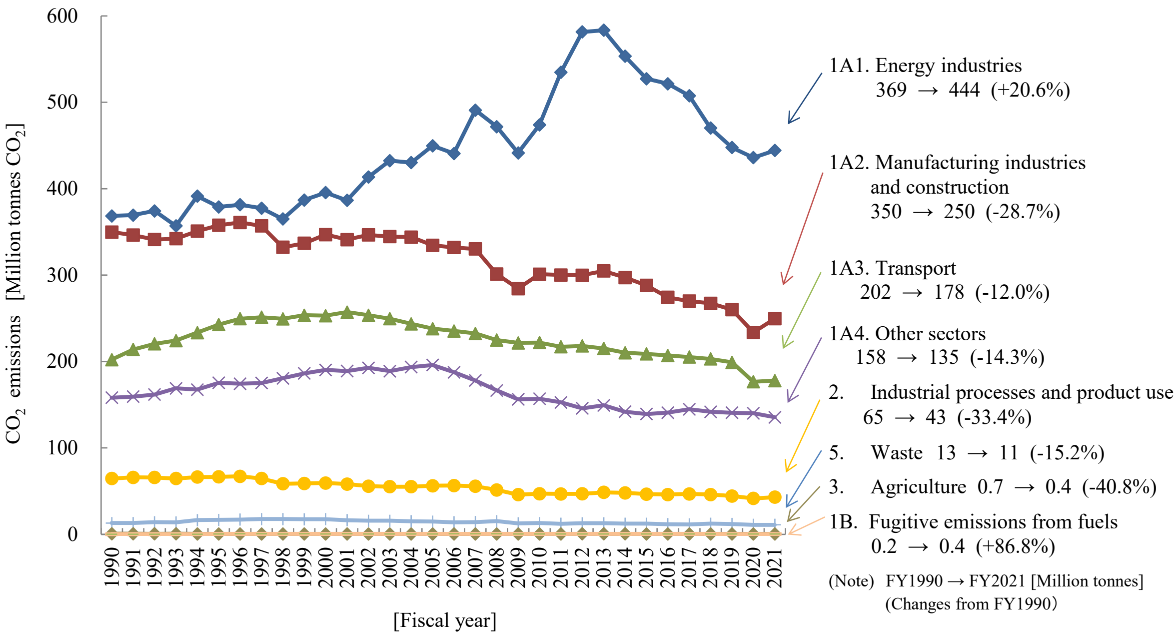


Figure 2-3 Trends in CO_2 emissions in each sector

Note: Figures in brackets indicate relative increase or decrease to the FY1990 values

6 It covers emissions from commercial/institutional, residential and agriculture/forestry/fishing.

Table 2-2 Trends in CO_2 emissions and removals in each sector

[Thousand tonnes CO_2]

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1A. Fuel combustion	1,078,663	1,154,838	1,185,785	1,218,316	1,153,802	1,245,124	1,252,764	1,202,705	1,163,462	1,143,716	1,127,565	1,082,459	1,047,371	986,431	1,007,257
1A1. Energy industries	368,530	378,905	395,494	449,664	473,846	581,481	583,474	553,352	527,291	521,496	507,711	470,166	447,654	435,984	444,313
Public electricity and heat production	303,055	317,587	330,118	378,044	404,239	516,376	521,862	493,837	468,472	466,072	454,136	414,706	395,384	391,560	396,750
Petroleum refining	36,397	41,085	46,978	50,888	47,715	43,298	42,943	41,103	41,664	37,609	36,811	37,600	35,909	29,496	31,267
Manufacture of solid fuels and other energy industries	29,078	20,232	18,398	20,732	21,892	21,807	18,670	18,412	17,155	17,816	16,763	17,860	16,361	14,928	16,296
1A2. Manufacturing industries and construction	349,816	357,726	346,942	334,558	301,071	299,834	304,851	297,269	288,073	274,254	269,935	267,446	259,973	233,704	249,549
Iron and steel	150,691	143,097	152,106	154,168	153,154	151,286	157,550	155,101	148,878	142,757	139,752	136,179	134,140	111,995	124,784
Non-ferrous metals	8,429	7,381	6,311	5,686	3,964	3,994	3,743	3,635	3,242	3,499	3,120	3,283	2,869	2,778	3,016
Chemicals	58,039	64,339	59,518	54,952	50,118	47,332	48,266	46,579	45,564	42,362	42,878	42,207	42,119	39,598	42,619
Pulp, paper and print	27,106	31,428	31,672	29,732	22,646	23,812	23,832	22,899	23,308	20,847	20,489	20,430	18,984	17,870	17,728
Food processing, beverages and tobacco	7,649	10,133	11,468	12,169	9,830	10,535	9,811	9,521	8,471	8,414	7,762	8,738	7,689	8,189	7,988
Non-metallic minerals	43,634	46,461	40,100	35,443	28,716	28,839	29,804	28,989	28,059	27,096	26,880	26,996	25,844	25,160	24,886
Other	54,267	54,888	45,766	42,407	32,642	34,036	31,846	30,545	30,551	29,279	29,055	29,614	28,329	28,113	28,528
1A3. Transport	202,140	242,797	253,091	238,065	221,969	218,004	215,115	210,149	208,875	207,066	205,253	203,016	199,022	176,575	177,911
Domestic aviation	7,162	10,278	10,677	10,799	9,193	9,524	10,149	10,173	10,067	10,187	10,399	10,537	10,488	5,238	6,819
Road transportation	180,367	217,028	226,690	213,605	201,457	197,158	193,437	188,540	187,641	185,722	183,803	181,451	177,628	160,907	160,345
Railways	935	822	711	647	574	554	540	524	523	499	520	492	490	468	468
Domestic navigation	13,675	14,669	15,012	13,014	10,745	10,769	10,989	10,912	10,645	10,659	10,530	10,537	10,417	9,962	10,279
1A4. Other sectors	158,178	175,411	190,258	196,029	156,916	145,805	149,324	141,936	139,223	140,900	144,667	141,830	140,722	140,168	135,485
Commercial/institutional	79,069	88,210	98,179	105,958	74,900	66,992	74,228	69,192	67,111	67,284	67,349	74,393	70,692	68,805	68,202
Residential	58,167	67,477	72,226	70,395	64,217	62,626	60,319	58,014	55,392	55,712	59,260	52,156	53,361	55,807	51,573
Agriculture/forestry/fishing	20,942	19,723	19,853	19,676	17,800	16,186	14,777	14,730	16,720	17,905	18,058	15,280	16,669	15,556	15,710
1A5. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B. Fugitive emissions from fuels	192	523	513	509	476	492	441	451	427	460	439	428	389	393	359
1C. CO_2 transport and storage	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO,NA	NE,NO,NA	NE,NO,NA	NE,NO,NA	NE,NO	NE,NO
2. Industrial processes and product use	64,586	66,536	59,416	56,175	46,967	46,879	48,588	48,010	46,515	46,104	46,834	46,031	44,389	41,510	43,042
3. Agriculture	732	473	501	428	427	542	594	567	474	461	502	450	450	441	434
4. LULUCF	-64,342	-79,494	-84,947	-89,608	-71,486	-72,465	-65,202	-62,285	-56,648	-52,781	-56,755	-56,291	-51,181	-52,071	-52,178
5. Waste	13,022	16,678	17,540	14,715	13,036	12,847	12,805	12,338	12,291	11,713	11,462	12,301	11,941	11,021	11,038
Total (including LULUCF)	1,092,853	1,159,554	1,178,808	1,200,536	1,143,221	1,233,419	1,249,990	1,201,787	1,166,520	1,149,674	1,130,047	1,085,378	1,053,359	987,725	1,009,951
Total (excluding LULUCF)	1,157,196	1,239,048	1,263,755	1,290,145	1,214,708	1,305,884	1,315,192	1,264,072	1,223,169	1,202,455	1,186,802	1,141,669	1,104,540	1,039,796	1,062,129

*1 Excluding indirect CO_2

*2 LULUCF: Land Use, Land-Use Change and Forestry

CO_2 emissions per capita in FY2021 were 8.46 tonnes. They decreased by 9.6% since FY1990 and increased by 2.7% compared to the previous year.

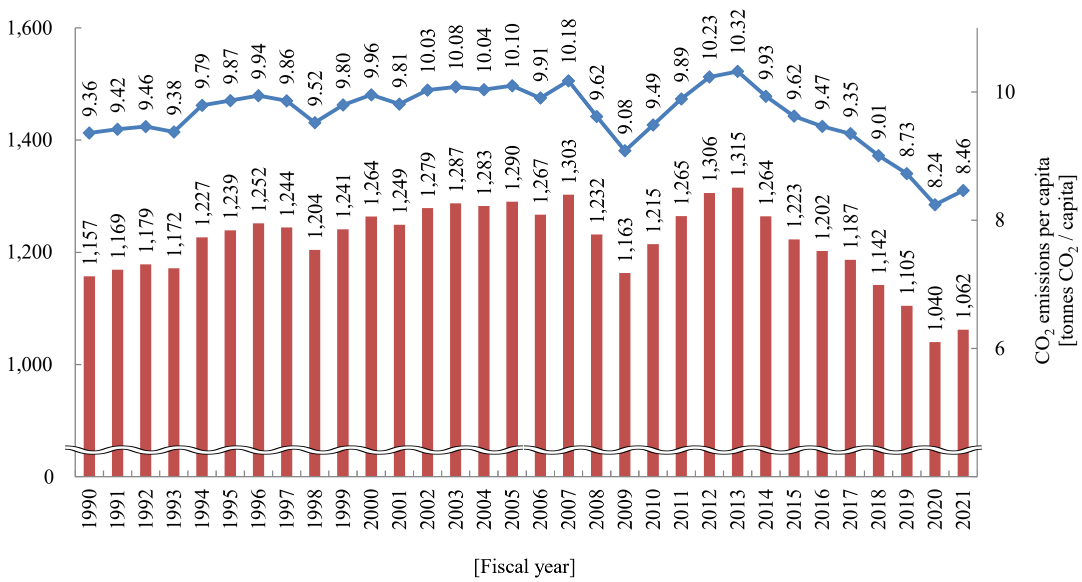


Figure 2-4 Trends in total CO_2 emissions and CO_2 emissions per capita

Reference of population data: *Population Census* and *Annual Report of Population Estimates* (Ministry of Internal Affairs and Communications, Statistics Bureau)

CO_2 emissions per unit of GDP (million yen) in FY2021 were 1.96 tonnes. They decreased by 26.9% since FY1990 and decreased by 0.4% compared to the previous year.

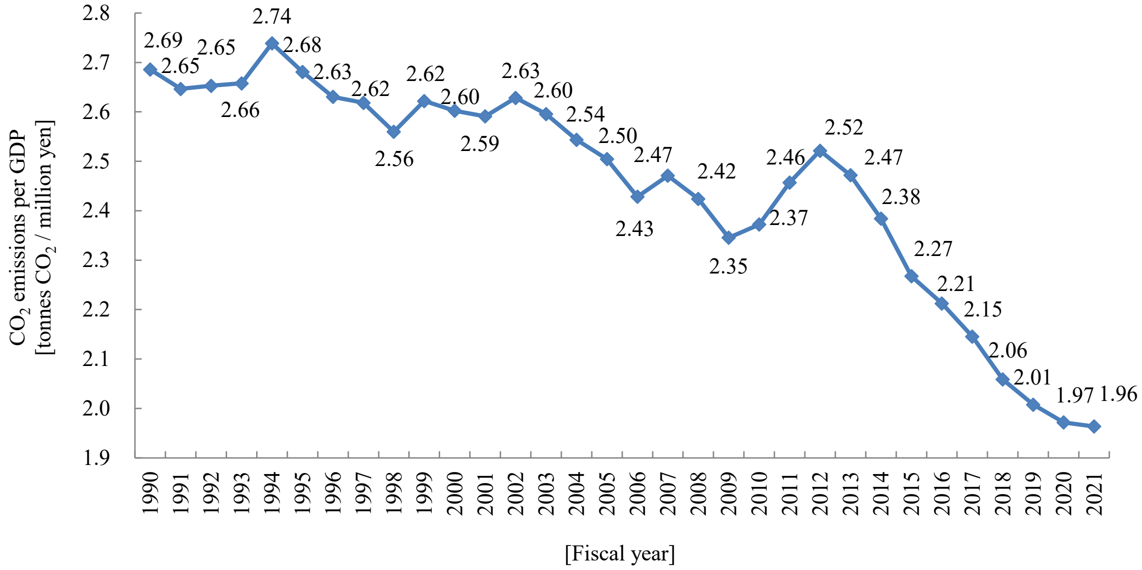


Figure 2-5 Trends in CO_2 emissions per unit of GDP

Reference of GDP data: *Annual Report on National Accounts* (Cabinet Office, Government of Japan)

2.1.3. CH_4

CH_4 emissions in FY2021 were 27.4 million tonnes (in CO_2 eq., including LULUCF), accounting for 2.3% of total GHG emissions. They decreased by 38.5% since FY1990 and decreased by 0.04% compared to the previous year. Their decrease since FY1990 is mainly a result of a 75.3% decrease in emissions from the waste sector (e.g. solid waste disposal).

The breakdown of the FY2021 emissions showed that the largest source was rice cultivation accounting for 44%. It is followed by enteric fermentation (28%) and manure management (9%).

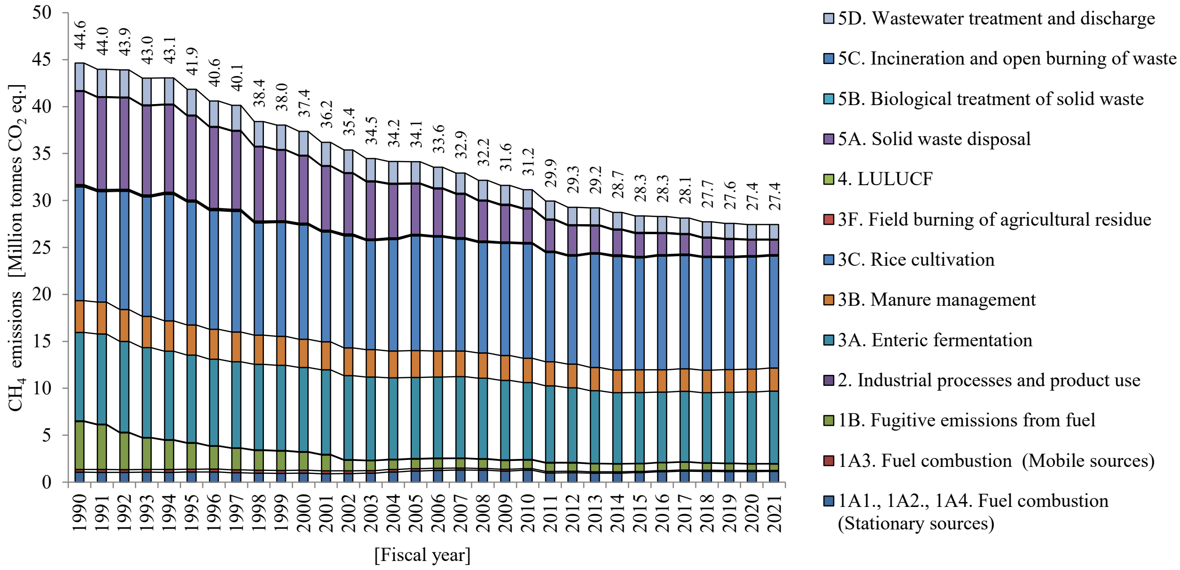


Figure 2-6 Trends in CH_4 emissions

Table 2-3 Trends in CH_4 emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1A. Fuel combustion	1,349	1,381	1,273	1,433	1,437	1,165	1,111	1,097	1,145	1,234	1,299	1,263	1,243	1,238	1,243
1A1. Energy industries	459	400	263	249	270	300	239	225	277	354	390	374	355	401	403
1A2. Manufacturing industries and construction	360	378	370	442	538	465	495	518	526	540	563	568	568	530	547
1A3. Transport	291	309	312	247	174	159	151	143	137	132	127	124	119	106	104
1A4. Other sectors	239	293	327	496	455	241	225	211	205	208	219	198	202	202	189
1B. Fugitive emissions from fuels	5,107	2,773	1,922	1,026	920	882	848	838	816	824	834	764	727	697	685
1B1. Solid fuels	4,895	2,520	1,649	704	600	577	565	570	549	540	554	499	478	469	456
1B2. Oil and natural gas and other emissions	213	253	273	322	321	305	283	268	267	284	280	265	249	228	229
2. Industrial processes and product use	61	58	54	54	54	46	46	43	48	43	43	40	41	38	44
3. Agriculture	25,062	25,734	24,245	23,795	23,036	22,064	22,354	22,139	21,962	22,058	22,028	21,925	21,973	22,076	22,182
3A. Enteric fermentation	9,423	9,318	8,966	8,651	8,202	7,953	7,737	7,543	7,534	7,481	7,494	7,465	7,563	7,631	7,718
3B. Manure management	3,383	3,213	3,007	2,843	2,576	2,530	2,467	2,424	2,420	2,382	2,395	2,396	2,414	2,424	2,458
3C. Rice cultivation	12,129	13,092	12,175	12,216	12,185	11,511	12,078	12,101	11,941	12,128	12,075	12,000	11,931	11,958	11,942
3F. Field burning of agricultural residue	127	111	96	86	74	71	72	70	67	67	64	65	64	64	64
4. LULUCF	104	95	88	86	78	72	74	92	75	69	91	70	72	70	76
5. Waste	12,963	11,810	9,791	7,746	5,626	5,044	4,785	4,528	4,302	4,075	3,840	3,668	3,500	3,330	3,207
5A. Solid waste disposal	9,940	8,977	7,160	5,353	3,568	3,076	2,861	2,639	2,440	2,248	2,092	1,939	1,807	1,682	1,569
5B. Biological treatment of solid waste	54	53	54	95	93	101	100	100	102	103	90	89	82	74	74
5C. Incineration and open burning of waste	28	29	21	18	12	11	12	10	10	9	10	11	10	9	9
5D. Wastewater treatment and discharge	2,942	2,750	2,556	2,280	1,954	1,855	1,811	1,779	1,749	1,714	1,648	1,629	1,601	1,565	1,555
Total (including LULUCF)	44,646	41,851	37,374	34,140	31,151	29,275	29,217	28,737	28,348	28,303	28,134	27,730	27,556	27,450	27,438
Total (excluding LULUCF)	44,542	41,756	37,286	34,054	31,073	29,202	29,143	28,645	28,273	28,234	28,044	27,660	27,484	27,380	27,361

* LULUCF: Land Use, Land-Use Change and Forestry

2.1.4. N_2O

N_2O emissions in FY2021 were 19.9 million tonnes (in CO_2 eq., including LULUCF), accounting for 1.7% of total GHG emissions. They decreased by 40.1% since FY1990 and decreased by 1.1% compared to the previous year. Their decrease since FY1990 is mainly a result of an 89.6% decrease in emissions from industrial processes and product use (e.g. adipic acid production in the chemical industry). There is a sharp decline in emissions from the industrial processes and product use from FY1998 to 1999, as N_2O abatement equipment came on stream in the adipic acid production plant in March 1999. However, the N_2O emissions increased in FY2000 because of a decrease in the equipment's operation rate due to mechanical failure; the emissions decreased again in FY2001 with the resumption of normal operation.

Breakdown of the FY2021 emissions showed that the largest source was agricultural soils accounting for 28%. It is followed by fuel combustion (stationary sources) (20%) and manure management (20%).

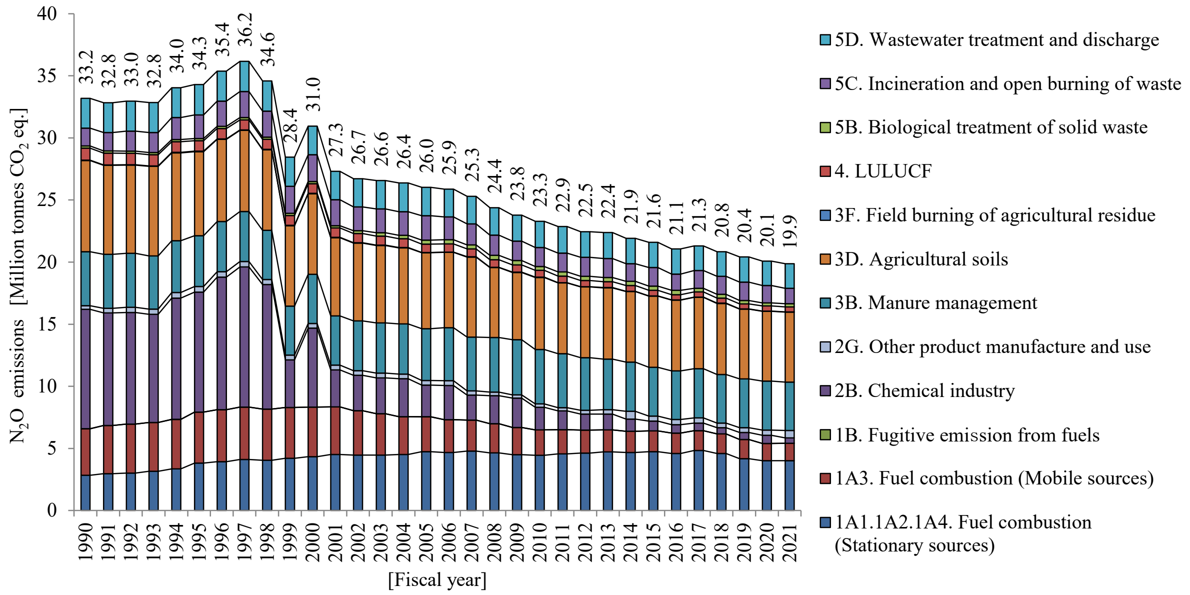


Figure 2-7 Trends in N_2O emissions

Table 2-4 Trends in N_2O emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1A. Fuel combustion	6,578	7,925	8,329	7,545	6,497	6,474	6,497	6,383	6,403	6,228	6,432	6,169	5,723	5,388	5,405
1A1. Energy industries	889	1,353	1,613	2,117	2,072	2,290	2,358	2,347	2,388	2,254	2,442	2,263	1,879	1,863	1,904
1A2. Manufacturing industries and construction	1,260	1,706	1,879	1,868	1,724	1,737	1,762	1,722	1,735	1,672	1,672	1,645	1,605	1,483	1,475
1A3. Transport	3,739	4,104	3,997	2,818	2,054	1,859	1,775	1,708	1,667	1,630	1,608	1,583	1,552	1,379	1,398
1A4. Other sectors	689	761	839	742	646	587	602	605	613	672	711	679	688	663	629
1B. Fugitive emissions from fuels	2	2	2	1	1	1	1	1	1	1	1	1	1	1	0
2. Industrial processes and product use	9,911	10,114	6,720	2,926	2,088	1,600	1,618	1,606	1,199	1,105	1,020	876	941	1,087	1,029
2B. Chemical industry	9,620	9,665	6,348	2,558	1,813	1,293	1,259	979	798	676	599	506	551	663	446
2G. Other product manufacture and use	291	449	371	368	275	308	359	627	402	429	420	370	390	424	583
3. Agriculture	11,722	10,889	10,493	10,304	10,204	9,949	9,834	9,668	9,683	9,623	9,726	9,648	9,567	9,584	9,558
3B. Manure management	4,346	4,091	3,968	4,163	4,376	4,235	4,070	3,968	3,932	3,907	3,958	3,912	3,926	3,939	3,911
3D. Agricultural soils	7,336	6,763	6,496	6,115	5,806	5,692	5,742	5,679	5,730	5,695	5,749	5,715	5,622	5,626	5,628
3F. Field burning of agricultural residue	39	34	30	26	23	22	22	22	21	21	20	20	20	20	20
4. LULUCF	966	838	773	681	554	497	474	458	441	426	416	411	409	407	407
5. Waste	4,006	4,525	4,638	4,563	3,939	3,931	3,952	3,801	3,865	3,683	3,714	3,738	3,779	3,621	3,467
5B. Biological treatment of solid waste	181	179	181	319	309	338	335	333	340	343	298	296	274	247	245
5C. Incineration and open burning of waste	1,438	1,908	2,156	1,963	1,515	1,523	1,535	1,423	1,498	1,312	1,423	1,453	1,473	1,395	1,239
5D. Wastewater treatment and discharge	2,387	2,439	2,301	2,280	2,115	2,069	2,082	2,045	2,027	2,028	1,992	1,990	2,033	1,979	1,982
Total (including LULUCF)	33,184	34,294	30,954	26,020	23,283	22,452	22,376	21,917	21,592	21,065	21,308	20,842	20,420	20,087	19,867
Total (excluding LULUCF)	32,218	33,456	30,181	25,339	22,729	21,955	21,901	21,459	21,151	20,639	20,892	20,431	20,011	19,680	19,460

* LULUCF: Land Use, Land-Use Change and Forestry

2.1.5. HFCs

HFC emissions in CY2021[7] were 53.6 million tonnes (in CO_2 eq.), accounting for 4.6% of total GHG emissions. They increased by 236% since CY1990, and increased by 2.6% compared to the previous year. Their increase since CY1990 is mainly a result of an increase in emissions from refrigeration and air conditioning (+49.5 million tonnes CO_2 eq.) substituting for HCFC (an ozone depleting substance), despite a decrease in emissions of HFC-23 (-99.2%) produced as a by-product of HCFC-22 production due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures. (Act No.53, 1988)

The breakdown of the CY2021 emissions showed that the largest source was refrigerants of refrigeration and air conditioning equipment accounting for 92%. It is followed by foam blowing agents (5%).

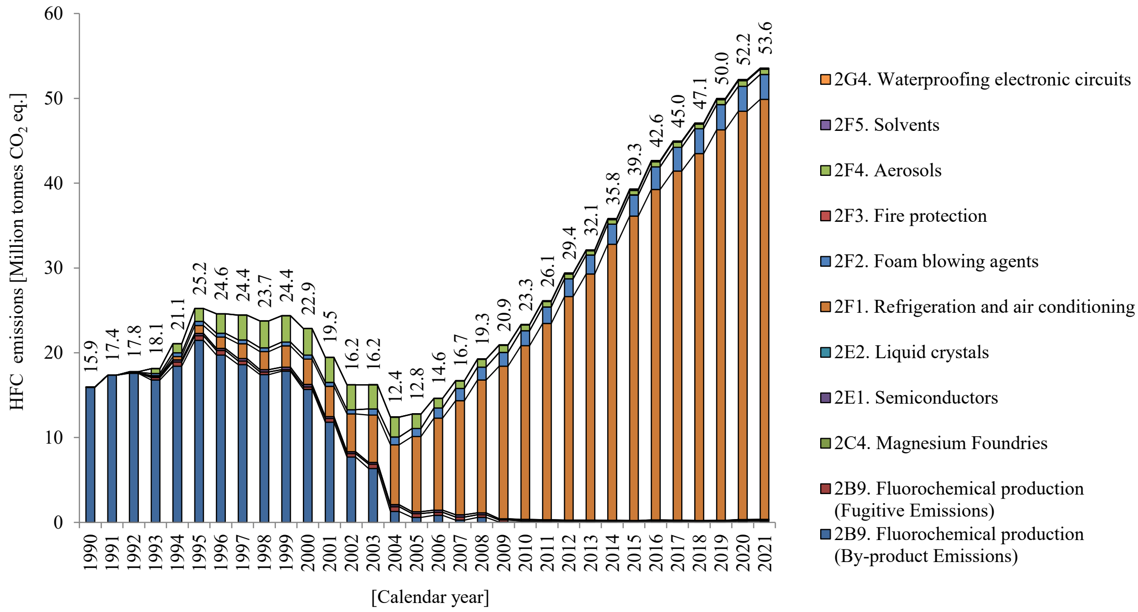


Figure 2-8 Trends in HFC emissions

Table 2-5 Trends in HFC emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
2B9. Fluorochemical production	15,930	22,019	15,984	1,035	181	138	147	124	113	172	133	100	132	216	251
By-product Emissions	15,929	21,460	15,688	586	53	18	16	24	30	24	38	12	13	141	132
Fugitive Emissions	2	559	296	449	128	120	131	101	83	149	95	88	119	76	120
2C4. Magnesium production	NO	NO	NO	NO	NO	1	1	1	1	1	1	2	1	1	2
2E. Electronics industry	1	271	285	227	168	124	112	115	115	119	125	115	101	109	107
2E1. Semiconductors	1	271	283	224	165	122	109	113	113	117	123	113	99	108	106
2E2. Liquid crystals	0.001	0.3	2	3	3	2	2	2	2	2	2	2	2	1	1
2F. Product uses as substitutes for ODS	1	2,923	6,582	11,511	22,979	29,115	31,866	35,562	39,052	42,350	44,694	46,867	49,727	51,877	53,194
2F1. Refrigeration and air conditioning	NO	925	2,976	8,865	20,495	26,370	29,030	32,554	35,893	38,972	41,167	43,274	46,044	48,157	49,517
2F2. Foam blowing agents	1	497	484	937	1,749	2,081	2,229	2,373	2,484	2,651	2,801	2,922	2,979	2,925	2,941
2F3. Fire protection	NO	NO	5	7	8	9	9	9	9	10	10	10	10	10	10
2F4. Aerosols	NO	1,502	3,117	1,695	666	561	489	503	540	587	600	544	572	659	599
2F5. Solvents	NO	NO	NO	6	60	94	109	122	126	130	116	117	122	127	128
2G4. Waterproofing electronic circuits	7.7	6.5	7.7	5.2	3.9	3.5	2.8	2.9	2.9	3.0	2.7	2.9	5.8	6.3	6.6
Total	15,940	25,219	22,858	12,779	23,332	29,382	32,129	35,805	39,283	42,645	44,956	47,087	49,968	52,210	53,561

[7] Emissions of HFCs, PFCs, SF_6, and NF_3 are estimated on a calendar year (CY) basis.

2.1.6. PFCs

PFC emissions in CY2021 were 3.2 million tonnes (in CO_2 eq.), accounting for 0.3% of total GHG emissions. They decreased by 51.9% since CY1990 and decreased by 9.9% compared to the previous year. Their decrease since CY1990 is mainly the result of a decrease in emissions from the solvents. (-69.6%)

The breakdown of the CY2021 emissions showed that the largest source was semiconductor manufacturing accounting for 49%. It is followed by solvents such as those for washing metals (44%).

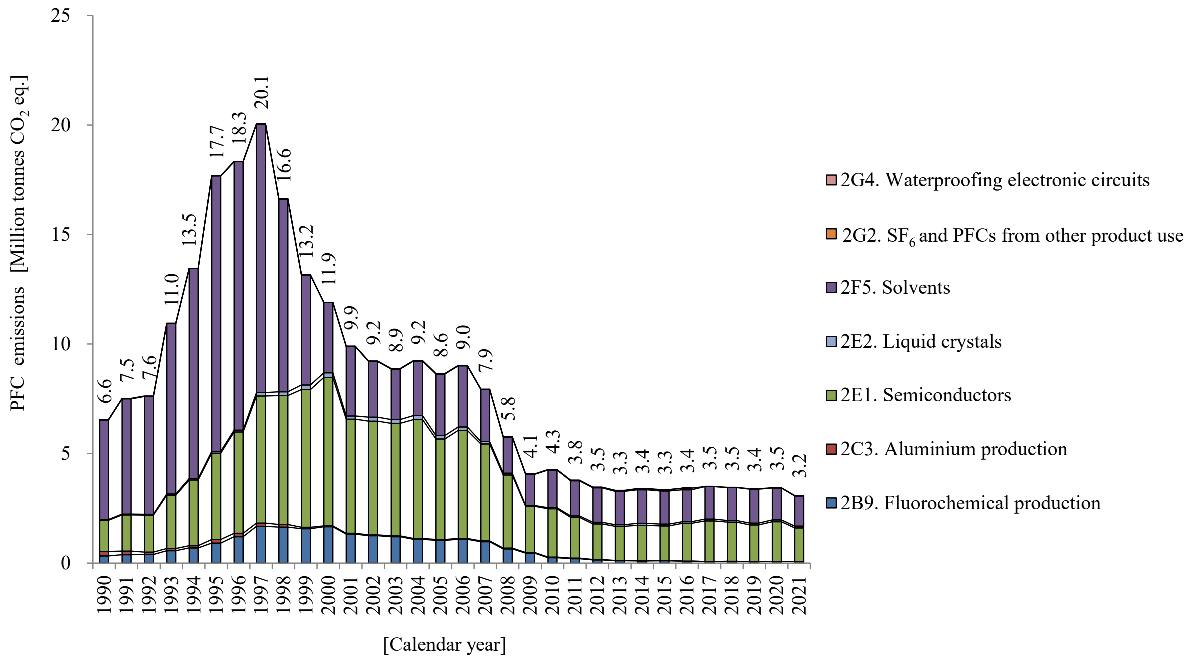


Figure 2-9 Trends in PFC emissions

Table 2-6 Trends in PFC emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
2B9. Fluorochemical production	331	914	1,661	1,041	248	148	111	107	115	97	81	87	64	74	79
2C3. Aluminium production	204	171	44	36	25	22	16	3	NO	NO	NO	NO	NO	NO	NO
2E. Electronics industry	1,455	4,020	6,986	4,746	2,261	1,692	1,631	1,707	1,669	1,792	1,931	1,863	1,761	1,901	1,612
2E1. Semiconductors	1,423	3,933	6,771	4,594	2,214	1,624	1,556	1,617	1,582	1,721	1,847	1,784	1,686	1,824	1,534
2E2. Liquid crystals	31	87	214	152	46	68	76	90	86	71	84	79	75	77	78
2F5. Solvents	4,550	12,572	3,200	2,815	1,721	1,583	1,518	1,537	1,517	1,465	1,484	1,505	1,558	1,457	1,382
2G. Other product manufacture and use	16	14	16	11	13	7	16	15	14	27	25	45	61	70	82
2G2. SF_6 and PFCs from other product use	NO	NO	NO	0.3	4	NO	10	9	8	21	20	39	49	56	69
2G4. Waterproofing electronic circuits	16	14	16	11	8	7	6	6	6	6	6	6	12	13	14
Total	6,555	17,691	11,906	8,648	4,268	3,452	3,292	3,369	3,314	3,382	3,521	3,501	3,444	3,501	3,156

2.1.7. SF_6

SF_6 emissions in CY2021 were 2.0 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 84.1% since CY1990 and increased by 0.9% compared to the previous year. Their decrease since CY1990 is mainly a result of a decrease from electrical equipment, due to an enhancement of gas management system such as gas recovery largely in electric power companies. (-92.6%)

The breakdown of the CY2021 emissions showed that the largest source was other product use (e.g. accelerator, etc.) accounting for 38%. It is followed by electrical equipment (29%) and magnesium production (16%).

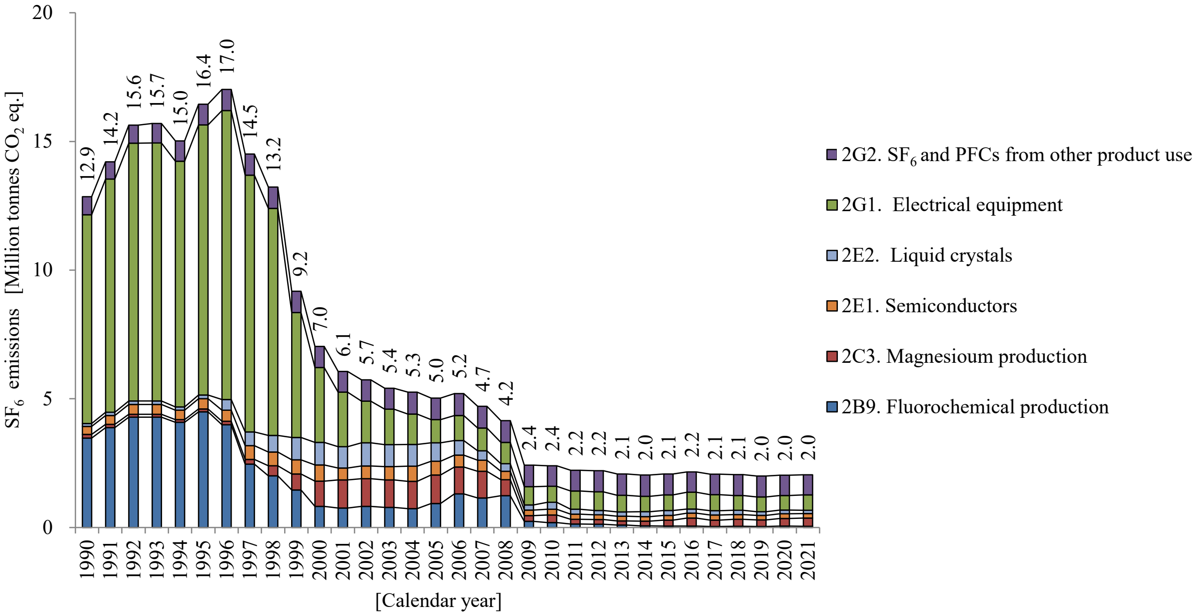


Figure 2-10 Trends in SF_6 emissions

Table 2-7 Trends in SF_6 emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
2B9. Fluorochemical production	3,471	4,492	821	930	189	123	93	62	52	50	41	46	40	52	46
2C3. Magnesium production	147	114	980	1,104	294	182	160	182	228	315	246	274	251	296	319
2E. Electronics industry	419	542	1,506	1,252	494	356	351	366	375	349	363	349	321	324	299
2E1. Semiconductors	309	400	629	540	225	184	181	175	184	192	200	182	174	185	171
2E2. Liquid crystals	110	142	877	712	269	172	170	191	191	157	163	167	147	139	129
2G. Other product manufacture and use	8,814	11,300	3,724	1,741	1,422	1,546	1,472	1,429	1,419	1,445	1,421	1,387	1,389	1,356	1,383
2G1. Electrical equipment	8,112	10,498	2,910	899	622	719	643	602	610	655	620	572	573	571	597
2G2. SF_6 and PFCs from other product use	702	802	815	842	799	827	829	827	809	789	801	815	816	784	786
Total	12,850	16,448	7,031	5,027	2,398	2,207	2,075	2,039	2,075	2,158	2,071	2,055	2,001	2,028	2,047

2.1.8. NF_3

NF_3 emissions in CY2021 were 0.4 million tonnes (in CO_2 eq.), accounting for 0.03% of total GHG emissions. They increased by 1,070% since CY1990 and increased by 12.8% compared to the previous year. The increase since CY1990 is mainly a result of an increase in emissions from semiconductor manufacture, owing to shifts to use NF_3. (by 1,140%)

The breakdown of the CY2021 emissions showed that the largest source was semiconductor manufacture accounting for 89%. It is followed by fluorochemical production (6%) and liquid crystal manufacture (5%).

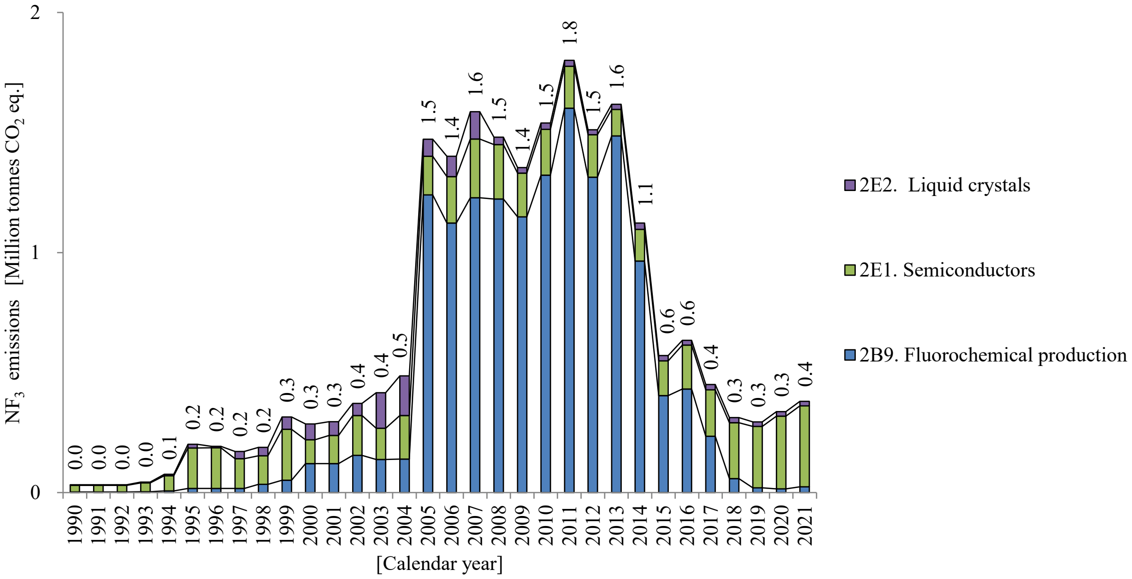


Figure 2-11 Trends in NF_3 emissions

Table 2-8 Trends in NF_3 emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
2B9. Fluorochemical production	3	17	120	1,240	1,323	1,314	1,486	965	404	432	234	58	19	15	24
2E. Electronics industry	30	184	165	232	217	198	131	158	167	203	216	254	275	322	356
2E1. Semiconductors	27	168	100	161	191	177	110	132	145	183	194	233	257	303	337
2E2. Liquid crystals	3	16	66	71	26	21	21	26	22	20	22	21	19	19	19
Total	33	201	286	1,472	1,540	1,512	1,617	1,123	571	634	450	312	295	337	380

2.1.9. Indirect CO_2

Indirect CO_2 emissions[8] in FY2021 were 1.9 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 65.9% since FY1990 and increased by 0.3% compared to the previous year. Their decrease since FY1990 was due to the decrease in emissions from the use of paint through the wider use of low VOC paint and VOC removal by adsorption devices.

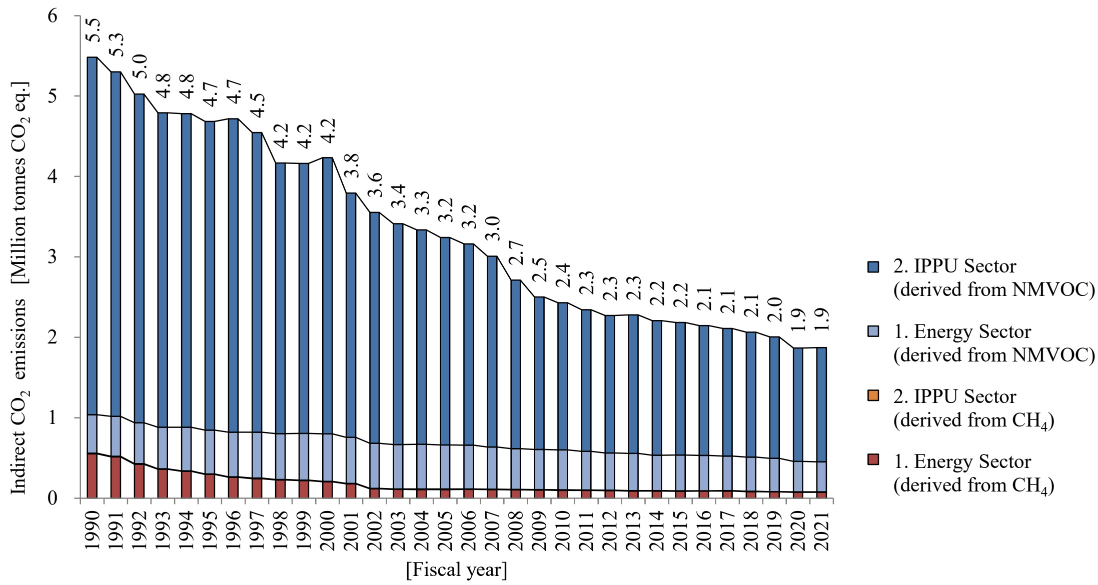


Figure 2-12 Trends in Indirect CO_2 emissions

Table 2-9 Trends in Indirect CO_2 emissions

[Thousand tonnes CO_2 eq.]

Emission Source	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Derived from CH_4	559	302	210	114	103	99	95	94	92	93	94	86	82	79	78
1. Energy Sector	553	296	204	108	97	94	90	89	87	88	89	82	78	74	73
2. IPPU Sector	7	6	6	6	6	5	5	5	5	5	5	4	5	4	5
Derived from NMVOC	4,922	4,381	4,023	3,126	2,327	2,173	2,184	2,114	2,093	2,054	2,017	1,977	1,924	1,788	1,793
1. Energy Sector	480	545	589	547	496	465	463	441	443	438	431	426	413	380	375
2. IPPU Sector	4,442	3,836	3,433	2,579	1,830	1,709	1,721	1,674	1,650	1,616	1,586	1,552	1,511	1,408	1,418
Total	5,482	4,683	4,233	3,240	2,430	2,272	2,279	2,208	2,185	2,147	2,111	2,063	2,006	1,867	1,872

8 Emissions derived from fuel combustion-origin, waste incineration-origin, and biomass-origin CO, CH_4, and NMVOC are excluded to avoid double counting and/or by concept of carbon neutrality.

2.2. Description and Interpretation of Emission and Removal Trends by Categories

The breakdown of GHG emissions and removals in FY2021 by sector[9] showed that energy (excluding indirect CO_2, hereafter, definition omitted) accounted for 86.8% of total GHG emissions. It is followed by industrial processes and product use (excluding indirect CO_2, hereafter, definition omitted) (8.8%), agriculture (2.8%), waste (1.5%), and indirect CO_2 emissions (0.2%).

Removals by LULUCF in FY2021 were equivalent to 4.4% of total GHG emissions.

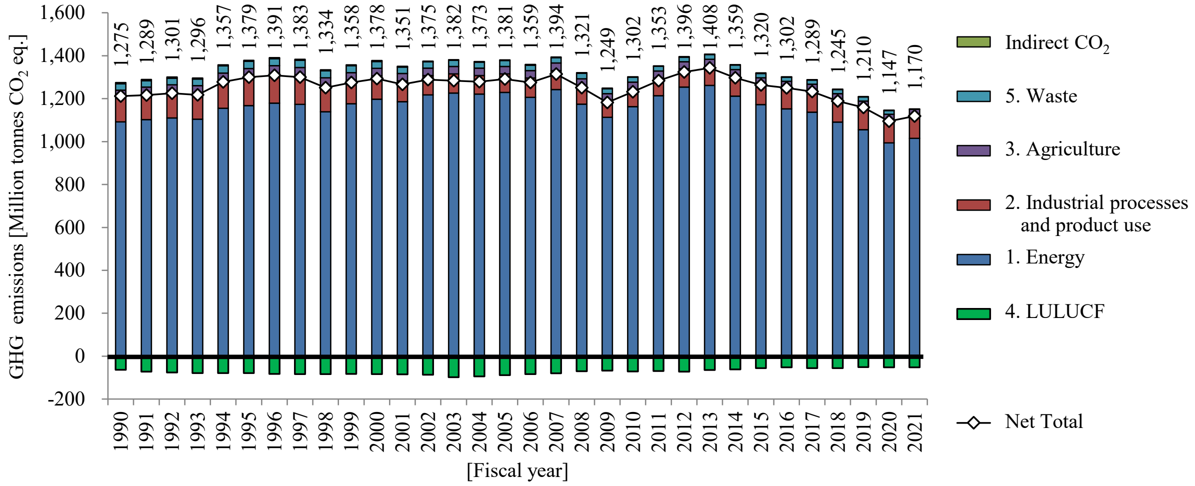


Figure 2-13 Trends in GHG emissions and removals in each sector

9 As indicated in the *2006 IPCC Guidelines* and the CRF.

Table 2-10 Trends in GHG emissions and removals in each sector

[Million tonnes CO_2 eq.]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy*1	1,091.9	1,102.3	1,110.4	1,104.4	1,155.4	1,167.4	1,178.9	1,173.5	1,139.3	1,175.9	1,197.8	1,185.6	1,217.2	1,226.1	1,221.9	1,228.8	1,206.1	1,242.3	1,174.4	1,113.0
2. Industrial processes and product use*1	109.9	114.5	116.4	118.6	126.1	136.3	138.4	135.5	122.8	110.2	108.3	97.3	90.6	89.4	86.0	87.1	89.9	89.0	84.6	77.4
3. Agriculture	37.5	37.1	37.9	37.9	38.0	37.1	36.3	36.4	35.2	35.3	35.2	34.5	34.7	34.3	34.1	34.5	34.4	34.7	33.6	33.4
4. LULUCF*2	-63.3	-72.1	-75.8	-79.0	-78.8	-78.6	-82.3	-83.3	-83.7	-83.0	-84.1	-84.7	-86.5	-98.0	-94.6	-88.8	-84.0	-79.9	-70.1	-67.0
5. Waste	30.0	29.9	31.0	30.5	32.9	33.0	33.1	33.5	33.0	32.3	32.0	30.2	29.1	28.7	27.8	27.0	25.7	25.3	25.9	22.8
Indirect CO_2	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.5	4.2	4.2	4.2	3.8	3.6	3.4	3.3	3.2	3.2	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,269.3	1,283.8	1,295.6	1,291.4	1,352.4	1,373.8	1,386.7	1,378.8	1,330.3	1,353.7	1,373.3	1,347.6	1,371.6	1,378.5	1,369.8	1,377.5	1,356.1	1,391.3	1,318.5	1,246.5
Net Total (including LULUCF, excluding indirect CO_2)	1,206.1	1,211.7	1,219.8	1,212.4	1,273.6	1,295.3	1,304.5	1,295.5	1,246.6	1,270.7	1,289.2	1,262.8	1,285.1	1,280.4	1,275.2	1,288.6	1,272.1	1,311.4	1,248.4	1,179.5
Gross Total (excluding LULUCF, including indirect CO_2)	1,274.8	1,289.1	1,300.6	1,296.2	1,357.2	1,378.5	1,391.5	1,383.4	1,334.5	1,357.8	1,377.5	1,351.4	1,375.2	1,381.9	1,373.2	1,380.7	1,359.2	1,394.3	1,321.2	1,249.1
Net Total (including LULUCF, including indirect CO_2)	1,211.5	1,217.0	1,224.9	1,217.1	1,278.4	1,299.9	1,309.2	1,300.1	1,250.7	1,274.8	1,293.5	1,266.6	1,288.7	1,283.8	1,278.5	1,291.9	1,275.3	1,314.4	1,251.1	1,182.0

[Million tonnes CO_2 eq.]	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1. Energy*1	1,163.1	1,213.8	1,254.1	1,261.7	1,211.5	1,172.3	1,152.5	1,136.6	1,091.1	1,055.5	994.1	1,015.0
2. Industrial processes and product use*1	80.6	82.5	85.1	89.4	92.0	93.0	96.1	98.9	99.9	101.1	100.7	103.3
3. Agriculture	33.7	32.9	32.6	32.8	32.4	32.1	32.1	32.3	32.0	32.0	32.1	32.2
4. LULUCF*2	-70.9	-69.1	-71.9	-64.7	-61.7	-56.1	-52.3	-56.2	-55.8	-50.7	-51.6	-51.7
5. Waste	22.6	21.6	21.8	21.5	20.7	20.5	19.5	19.0	19.7	19.2	18.0	17.7
Indirect CO_2	2.4	2.3	2.3	2.3	2.2	2.2	2.1	2.1	2.1	2.0	1.9	1.9
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,300.0	1,350.7	1,393.6	1,405.4	1,356.5	1,317.8	1,300.1	1,286.7	1,242.7	1,207.7	1,144.9	1,168.1
Net Total (including LULUCF, excluding indirect CO_2)	1,229.2	1,281.6	1,321.7	1,340.7	1,294.8	1,261.7	1,247.9	1,230.5	1,186.9	1,157.0	1,093.3	1,116.4
Gross Total (excluding LULUCF, including indirect CO_2)	1,302.5	1,353.1	1,395.9	1,407.6	1,358.7	1,320.0	1,302.3	1,288.8	1,244.8	1,209.7	1,146.8	1,170.0
Net Total (including LULUCF, including indirect CO_2)	1,231.6	1,284.0	1,324.0	1,343.0	1,297.0	1,263.9	1,250.0	1,232.6	1,189.0	1,159.0	1,095.2	1,118.3

*1 Excluding indirect CO_2

*2 LULUCF: Land Use, Land-Use Change and Forestry

2.2.1. Energy

Emissions from the energy sector in FY2021 were 1,015 million tonnes (in CO_2 equivalents). They decreased by 7.0% since FY1990 and increased by 2.1% compared to the previous year.

The breakdown of the FY2021 emissions showed that CO_2 from fuel combustion accounted for 99.2%. The largest source within fuel combustion[10] was solid fuel CO_2, which accounted for 42%, and is then followed by liquid fuel CO_2 (35%) and gaseous fuel CO_2 (21%).

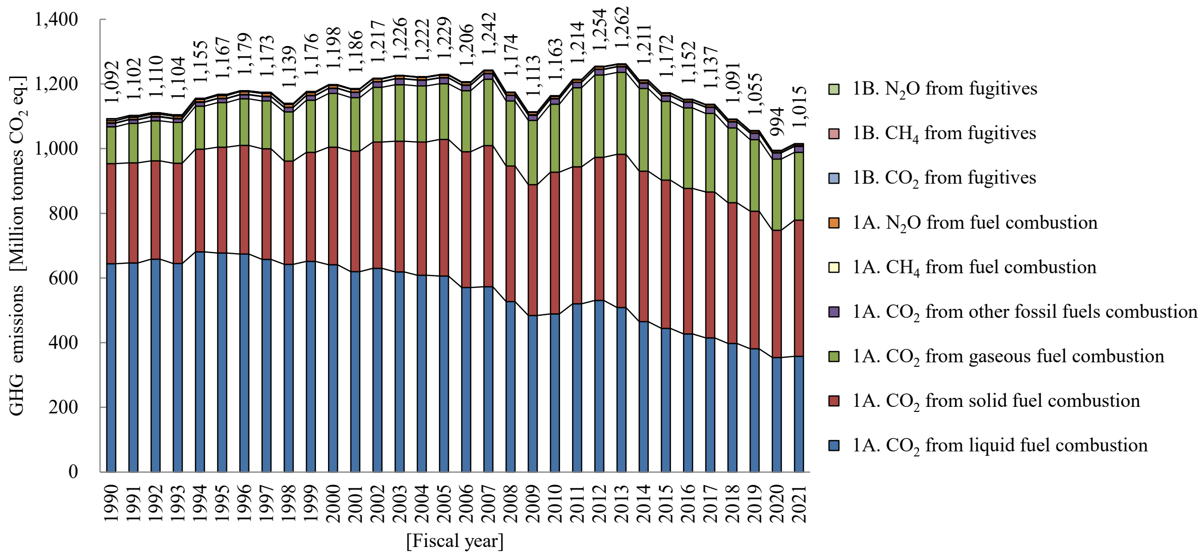


Figure 2-14 Trends in GHG emissions from the energy sector

Table 2-11 Trends in GHG emissions from the energy sector

[Thousand tonnes CO_2 eq.]

Source category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1A. Fuel combustion	1,086,590	1,164,144	1,195,386	1,227,295	1,161,735	1,252,763	1,260,372	1,210,185	1,171,010	1,151,177	1,135,296	1,089,891	1,054,337	993,057	1,013,906
Liquid fuel CO_2	644,302	677,416	640,667	606,113	488,924	530,754	508,466	464,737	444,007	427,215	414,494	397,440	380,868	354,279	357,817
Solid fuel CO_2	309,482	327,201	364,079	422,447	438,513	442,778	473,817	465,630	458,776	449,606	451,606	435,175	425,704	393,154	421,340
Gaseous fuel CO_2	114,167	137,927	166,073	172,415	209,932	254,051	253,378	255,508	243,368	248,829	242,817	231,347	221,419	220,219	209,252
Other fossil fuels (Waste) CO_2	10,712	12,294	14,966	17,341	16,433	17,541	17,104	16,830	17,311	18,066	18,648	18,497	19,381	18,778	18,848
CH_4	1,349	1,381	1,273	1,433	1,437	1,165	1,111	1,097	1,145	1,234	1,299	1,263	1,243	1,238	1,243
N_2O	6,578	7,925	8,329	7,545	6,497	6,474	6,497	6,383	6,403	6,228	6,432	6,169	5,723	5,388	5,405
1B. Fugitive emissions from fuel	5,302	3,297	2,437	1,536	1,397	1,375	1,289	1,290	1,243	1,285	1,273	1,193	1,116	1,091	1,044
CO_2	192	523	513	509	476	492	441	451	427	460	439	428	389	393	359
CH_4	5,107	2,773	1,922	1,026	920	882	848	838	816	824	834	764	727	697	685
N_2O	2.1	2.1	1.7	1.2	0.9	0.8	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.5
1C. CO_2 transport and storage	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO,NA	NE,NO,NA	NE,NO,NA	NE,NO,NA	NE,NO	NE,NO
Total	1,091,892	1,167,442	1,197,824	1,228,831	1,163,132	1,254,138	1,261,661	1,211,475	1,172,253	1,152,462	1,136,570	1,091,083	1,055,453	994,148	1,014,950

2.2.2. Industrial Processes and Product Use

Emissions from the industrial processes and product use sector in FY2021 were 103.3 million tonnes (in CO_2 eq.). They decreased by 6.1% since FY1990 and increased by 2.5% compared to the previous year.

The breakdown of GHG emissions from this sector in FY2021 showed that the largest source was HFC emissions from product uses as ODS substitutes, accounting for 52%. It was followed by the mineral industry emissions such as CO_2 emissions from cement production (30%) and CO_2 emissions from the metal industry (5%).

10 Fuel types are categorized in accordance with classification indicated in the *2006 IPCC Guidelines* and the CRF.

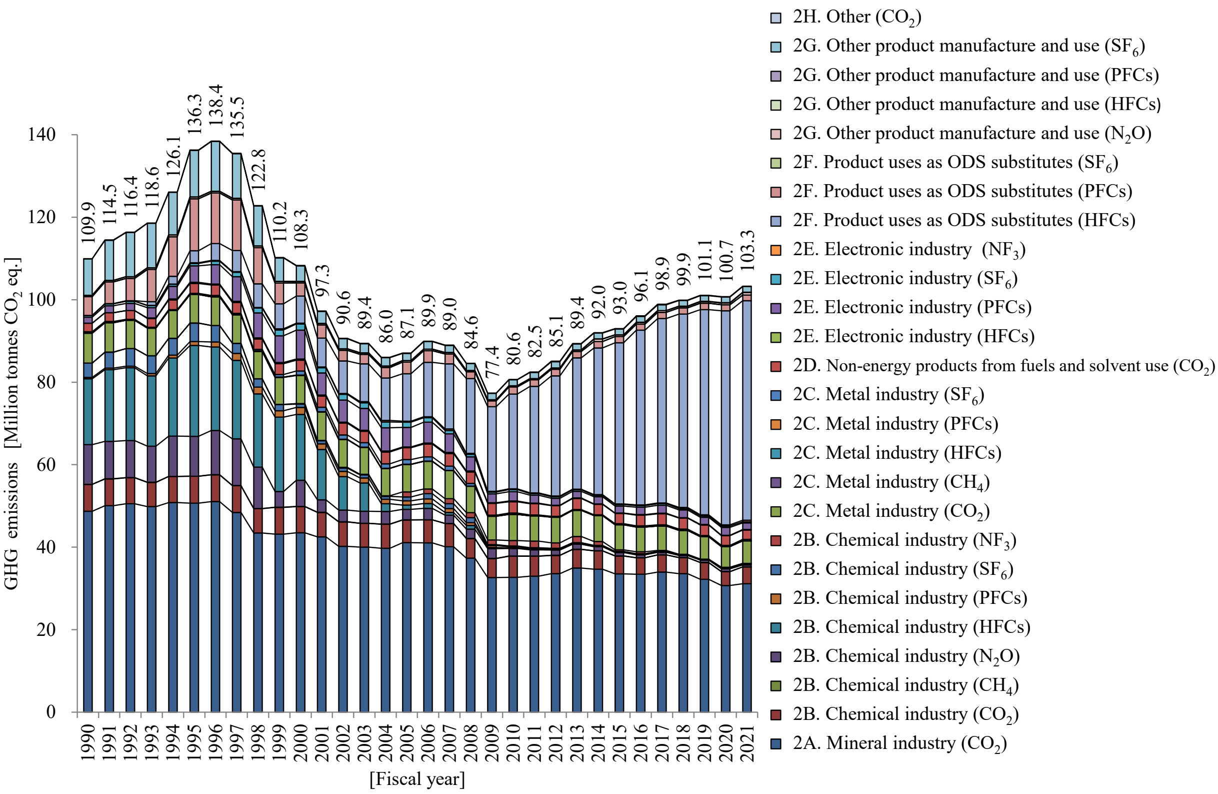


Figure 2-15 Trends in GHG emissions from the industrial processes and product use sector

Table 2-12 Trends in GHG emissions from the industrial processes and product use sector

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
2A. Mineral industry (CO_2)	48,714	50,689	43,487	41,112	32,676	33,595	34,930	34,678	33,526	33,421	33,940	33,565	32,232	30,703	31,137
2B. Chemical industry	35,895	43,639	31,312	12,309	8,933	7,444	7,648	6,704	5,854	5,449	5,293	4,734	4,874	4,409	4,945
CO_2	6,503	6,494	6,343	5,471	5,142	4,400	4,524	4,443	4,341	3,995	4,179	3,915	4,042	3,366	4,072
CH_4	37	37	34	34	36	28	28	25	32	27	25	23	25	24	27
N_2O	9,620	9,665	6,348	2,558	1,813	1,293	1,259	979	798	676	599	506	551	663	446
HFCs	15,930	22,019	15,984	1,035	181	138	147	124	113	172	133	100	132	216	251
PFCs	331	914	1,661	1,041	248	148	111	107	115	97	81	87	64	74	79
SF_6	3,471	4,492	821	930	189	123	93	62	52	50	41	46	40	52	46
NF_3	3	17	120	1,240	1,323	1,314	1,486	965	404	432	234	58	19	15	24
2C. Metal industry	7,639	7,211	7,885	7,797	6,659	6,454	6,546	6,471	6,305	6,323	6,169	6,069	5,718	5,335	5,796
CO_2	7,266	6,905	6,841	6,637	6,322	6,230	6,351	6,267	6,059	5,990	5,904	5,776	5,450	5,023	5,459
CH_4	23	21	20	20	18	18	18	18	17	16	17	18	16	14	17
HFCs	NO	NO	NO	NO	NO	1	1	1	1	1	1	2	1	1	2
PFCs	204	171	44	36	25	22	16	3	NO	NO	NO	NO	NO	NO	NO
SF_6	147	114	980	1,104	294	182	160	182	228	315	246	274	251	296	319
2D. Non-energy products from fuels and solvent use (CO_2)	2,040	2,377	2,659	2,865	2,750	2,554	2,689	2,532	2,493	2,591	2,700	2,670	2,565	2,332	2,293
2E. Electronic industry	1,904	5,016	8,941	6,457	3,140	2,370	2,225	2,346	2,326	2,463	2,634	2,581	2,458	2,656	2,375
HFCs	1	271	285	227	168	124	112	115	115	119	125	115	101	109	107
PFCs	1,455	4,020	6,986	4,746	2,261	1,692	1,631	1,707	1,669	1,792	1,931	1,863	1,761	1,901	1,612
SF_6	419	542	1,506	1,252	494	356	351	366	375	349	363	349	321	324	299
NF_3	30	184	165	232	217	198	131	158	167	203	216	254	275	322	356
2F. Product uses as ODS substitutes	4,551	15,495	9,782	14,326	24,699	30,698	33,384	37,098	40,569	43,815	46,178	48,372	51,285	53,333	54,576
HFCs	1	2,923	6,582	11,511	22,979	29,115	31,866	35,562	39,052	42,350	44,694	46,867	49,727	51,877	53,194
PFCs	4,550	12,572	3,200	2,815	1,721	1,583	1,518	1,537	1,517	1,465	1,484	1,505	1,558	1,457	1,382
SF_6	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2G. Other product manufacture and use	9,129	11,769	4,119	2,125	1,713	1,865	1,849	2,074	1,838	1,903	1,870	1,805	1,846	1,856	2,055
N_2O	291	449	371	368	275	308	359	627	402	429	420	370	390	424	583
HFCs	8	6	8	5	4	4	3	3	3	3	3	3	6	6	7
PFCs	16	14	16	11.3	13	7	16	15	14	27	25	45	61	70	82
SF_6	8,814	11,300	3,724	1,741	1,422	1,546	1,472	1,429	1,419	1,445	1,421	1,387	1,389	1,356	1,383
2H. Other (CO_2)	65	72	87	90	77	100	94	91	97	107	111	105	100	87	81
Total	109,936	136,267	108,272	87,082	80,646	85,078	89,366	91,994	93,007	96,072	98,894	99,902	101,078	100,711	103,258

Despite the increase in HFC emissions from product uses as substitutes for ODS compared to 1990, emissions from the industrial processes and product use sector decreased in the same period. The main driving factors for the decrease in emissions since FY1990 were the decrease in CO_2 emissions from cement production (mineral industry) as the clinker production declined, the decrease in emissions of

HFC-23 produced as a by-product of HCFC-22 production (chemical industry) due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures, and the decrease in N_2O emissions from adipic acid production (chemical industry) as the N_2O abatement equipment came on stream.

2.2.3. Agriculture

Emissions from the agriculture sector in FY2021 were 32.2 million tonnes (in CO_2 eq.). They decreased by 14.2% since FY1990 and increased by 0.2% compared to the previous year.

The breakdown of the FY2021 emissions from this sector showed that the largest source was the rice cultivation (CH_4) accounting for 37%. It was followed by enteric fermentation (CH_4) (24%), and agricultural soils (N_2O) (17%) as a result of the nitrogen-based fertilizer applications.

The main driving factor for the decrease in emissions since FY1990 was the decrease in N_2O emissions from agricultural soils due to the decrease in the amount of inorganic nitrogen fertilizers applied and organic fertilizers from livestock manure applied, and the decrease in CH_4 emissions from enteric fermentation due to the decrease in the number of cattle.

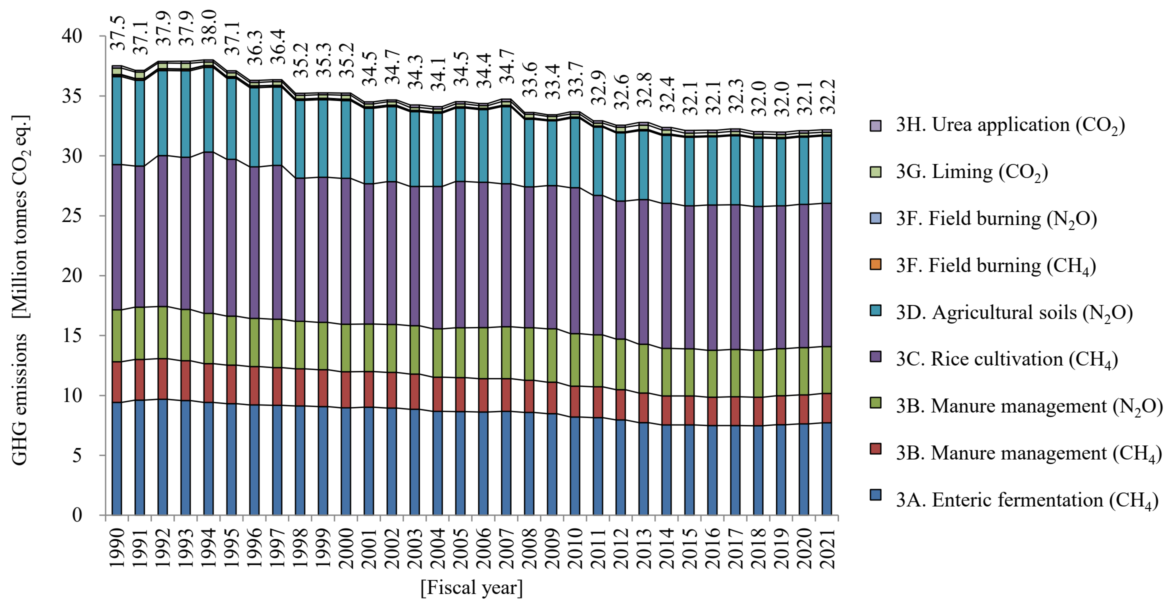


Figure 2-16 Trends in GHG emissions from the agriculture sector

Table 2-13 Trends in GHG emissions from the agriculture sector

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
3A. Enteric fermentation (CH_4)	9,423	9,318	8,966	8,651	8,202	7,953	7,737	7,543	7,534	7,481	7,494	7,465	7,563	7,631	7,718
3B. Manure management	7,729	7,304	6,975	7,005	6,951	6,764	6,537	6,391	6,352	6,289	6,353	6,308	6,340	6,362	6,369
CH_4	3,383	3,213	3,007	2,843	2,576	2,530	2,467	2,424	2,420	2,382	2,395	2,396	2,414	2,424	2,458
N_2O	4,346	4,091	3,968	4,163	4,376	4,235	4,070	3,968	3,932	3,907	3,958	3,912	3,926	3,939	3,911
3C. Rice cultivation (CH_4)	12,129	13,092	12,175	12,216	12,185	11,511	12,078	12,101	11,941	12,128	12,075	12,000	11,931	11,958	11,942
3D. Agricultural soils (N_2O)	7,336	6,763	6,496	6,115	5,806	5,692	5,742	5,679	5,730	5,695	5,749	5,715	5,622	5,626	5,628
3F. Field burning of agricultural residues	166	145	126	112	96	93	94	92	88	88	84	85	84	84	84
CH_4	127	111	96	86	74	71	72	70	67	67	64	65	64	64	64
N_2O	39	34	30	26	23	22	22	22	21	21	20	20	20	20	20
3G. Liming (CO_2)	550	304	333	231	243	370	380	363	259	253	294	242	242	233	225
3H. Urea application (CO_2)	182	170	168	197	184	172	214	204	215	208	208	208	208	208	208
Total	37,516	37,096	35,239	34,528	33,667	32,555	32,782	32,374	32,119	32,142	32,256	32,023	31,991	32,101	32,174

2.2.4. Land Use, Land Use Change and Forestry (LULUCF)

Net removals (including CO_2, CH_4 and N_2O emissions) from the LULUCF sector in FY2021 was 51.7 million tonnes (in CO_2 eq.). They decreased by 18.3% since FY1990 and increased by 0.2% compared to the previous year. The long-term declining trend in removals from 2003 is largely due to the maturity of Japanese forests.

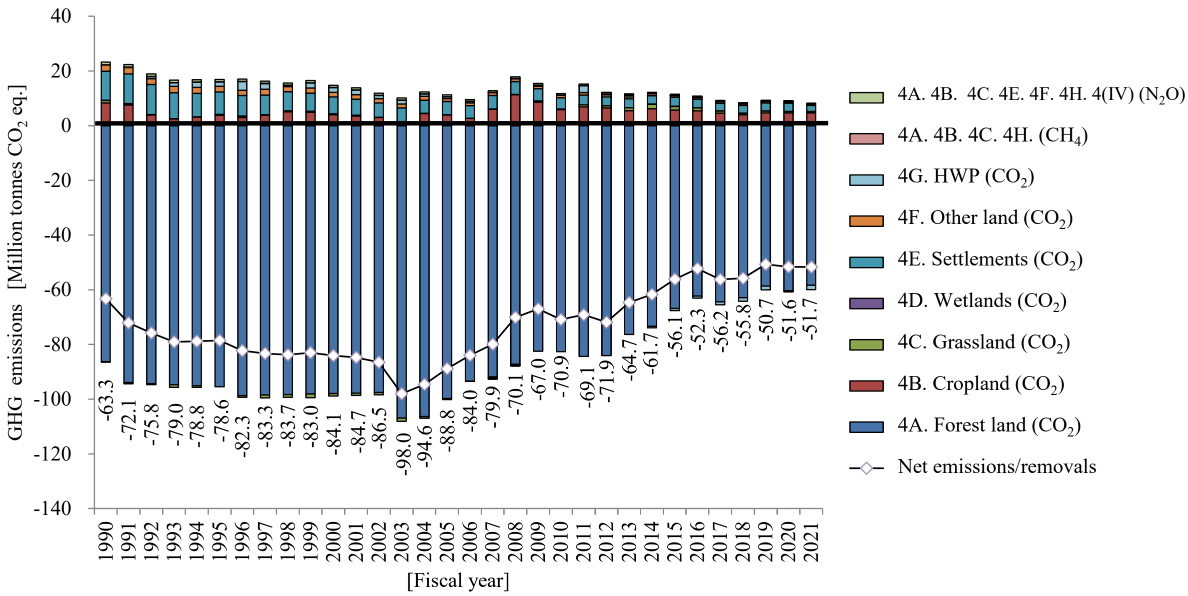


Figure 2-17 Trends in GHG emissions and removals from the LULUCF sector

Table 2-14 Trends in GHG emissions and removals from the LULUCF sector

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
4A. Forest land	-86,200	-95,370	-97,888	-99,741	-82,548	-83,999	-76,251	-73,282	-66,821	-62,282	-64,315	-62,828	-58,621	-60,294	-58,272
CO_2	-86,265	-95,436	-97,953	-99,808	-82,608	-84,056	-76,311	-73,363	-66,884	-62,341	-64,398	-62,890	-58,686	-60,357	-58,343
CH_4	10	10	9	11	5	2	4	23	6	1	23	2	5	3	9
N_2O	55	56	56	56	56	55	56.0	58.0	57.1	57.6	59.9	59.0	60.0	60.0	61.1
4B. Cropland	8,408	3,895	4,062	3,966	5,897	6,558	5,522	6,242	5,747	5,492	4,601	4,016	4,730	4,699	4,715
CO_2	8,331	3,827	4,002	3,912	5,846	6,508	5,472	6,193	5,698	5,443	4,552	3,968	4,681	4,650	4,666
CH_4	49	47	45	44	42	41	41	41	40	40	39	39	39	38	38
N_2O	28	21	15	11	8	8	9	9	9	9	9	10	10	10	11
4C. Grassland	885	96	-866	-282	161	785	1,100	1,711	1,381	1,085	843	604	724	587	518
CO_2	855	65	-896	-312	131	753	1,069	1,680	1,349	1,055	813	574	694	557	488
CH_4	15	15	15	15	15	15	15	15	16	15	15	15	15	15	15
N_2O	15	15	15	15	15	17	16	16	16	15	15	15	15	15	15
4D. Wetlands	68	277	329	34	94	51	18	18	63	62	24	24	24	24	35
CO_2	68	277	329	34	94	51	18	18	63	62	24	24	24	24	35
CH_4	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO
N_2O	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO
4E. Settlements	11,139	8,575	6,571	5,230	4,428	3,417	3,447	3,306	3,414	3,287	2,970	2,997	3,108	3,159	2,376
CO_2	10,646	8,155	6,180	4,888	4,156	3,182	3,226	3,095	3,213	3,095	2,785	2,815	2,927	2,980	2,197
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	493	420	391	342	272	235	222	211	201	193	185	182	180	180	179
4F. Other land	2,367	2,095	1,724	1,109	891	792	718	685	666	650	591	578	528	497	394
CO_2	2,287	2,022	1,659	1,056	852	758	686	655	638	624	567	555	506	476	374
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	80	74	65	53	38	34	31	29	28	26	24	23	22	21	20
4G. HWP (CO_2)	-264	1,597	1,732	623	42	338	638	-563	-725	-719	-1,098	-1,337	-1,327	-400	-1,596
4H. Other (Organic soil in settlements	34	25	21	19	17	15	15	15	14	14	14	15	15	15	16
CH_4	31	23	19	17	16	14	14	13	13	13	13	13	14	14	14
N_2O	3	2	2	2	2	1	1	1	1	1	1	1	1	1	1
4(IV) Indirect N_2O	290	250	230	202	163	146	139	134	129	125	121	121	120	119	119
Total	-63,272	-78,560	-84,086	-88,841	-70,854	-71,896	-64,654	-61,734	-56,132	-52,286	-56,248	-55,810	-50,700	-51,594	-51,695

The breakdown of the FY2021 emissions and removals from this sector showed that the largest was CO_2 removals from forest land of 58.3 million tonnes, accounting for 113% of this sector's net total emissions / removals.

2.2.5. Waste

Emissions from the waste sector in FY2021 were 17.7 million tonnes (in CO_2 eq.). They decreased by 40.9% since FY1990 and by 1.4% compared to the previous year.

The breakdown of the FY2021 emissions from this sector showed that the largest source was waste incineration, etc (CO_2), associated with waste derived from fossil fuels such as waste plastic and waste oil, accounting for 58%. It was followed by wastewater treatment and discharge (N_2O) (11%), solid waste disposal (CH_4) (9%) and wastewater treatment and discharge (CH_4) (9%).

The main driving factor for the decrease in emissions since FY1990 was the decrease in CH_4 emissions from solid waste disposal on land as a result of decrease in the amount of disposal of biodegradable waste due to improvement in the volume reduction ratio by intermediate treatment under the Waste Management and Public Cleansing Act (Act No.137, 1970) and the Basic Law for Establishing the Recycling-based Society (Act No.110, 2000), and other recycling law.

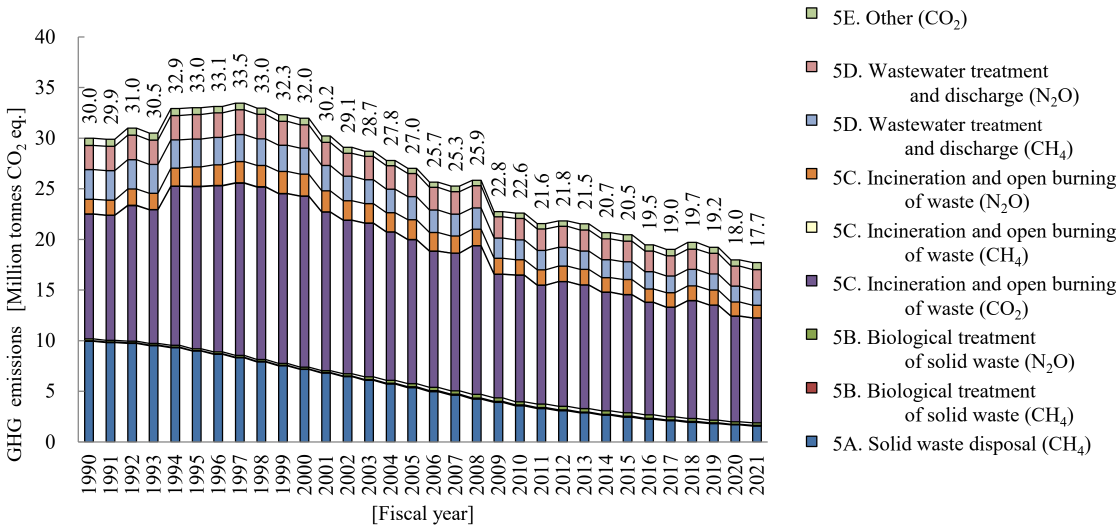


Figure 2-18 Trends in GHG emissions from the waste sector

Table 2-15 Trends in GHG emissions from the waste sector

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
5A. Solid waste disposal (CH_4)	9,940	8,977	7,160	5,353	3,568	3,076	2,861	2,639	2,440	2,248	2,092	1,939	1,807	1,682	1,569
5B. Biological treatment of solid waste	235	233	235	414	402	440	435	433	441	446	388	385	356	321	319
CH_4	54	53	54	95	93	101	100	100	102	103	90	89	82	74	74
N_2O	181	179	181	319	309	338	335	333	340	343	298	296	274	247	245
5C. Incineration and open burning of waste	13,785	17,947	19,061	16,190	14,035	13,853	13,747	13,154	13,174	12,416	12,259	13,091	12,841	11,828	11,606
CO_2	12,319	16,010	16,884	14,209	12,509	12,319	12,200	11,721	11,666	11,095	10,826	11,628	11,358	10,424	10,359
CH_4	28	29	21	18	12	11	12	10	10	9	10	11	10	9	9
N_2O	1,438	1,908	2,156	1,963	1,515	1,523	1,535	1,423	1,498	1,312	1,423	1,453	1,473	1,395	1,239
5D. Wastewater treatment and discharge	5,329	5,189	4,857	4,560	4,069	3,925	3,893	3,825	3,777	3,742	3,640	3,618	3,633	3,544	3,537
CH_4	2,942	2,750	2,556	2,280	1,954	1,855	1,811	1,779	1,749	1,714	1,648	1,629	1,601	1,565	1,555
N_2O	2,387	2,439	2,301	2,280	2,115	2,069	2,082	2,045	2,027	2,028	1,992	1,990	2,033	1,979	1,982
5E. Other (CO_2)	703	668	656	507	527	528	605	617	625	619	637	673	582	597	679
Total	29,990	33,013	31,969	27,024	22,601	21,822	21,541	20,668	20,457	19,471	19,016	19,707	19,220	17,972	17,712

2.2.6. Indirect CO_2

See Section 2.1.9. above.

2.3. Description and Interpretation of Emission Trends for Indirect GHGs and SO_X

Under the revised UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention, it is required to report emissions not only of the 7 types of GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3), but also emissions of indirect GHGs (NO_X, CO, and NMVOC) as well as SO_X. Their emission trends are indicated below.

Nitrogen oxide (NO_X) emissions in FY2021 were 1.0 million tonnes. They decreased by 46.7% since FY1990 and increased by 0.6% compared to the previous year.

Carbon monoxide (CO) emissions in FY2021 were 2.8 million tonnes. They decreased by 36.7% since FY1990 and 1.3% compared to the previous year[11].

Non-methane volatile organic compounds (NMVOC) emissions in FY2021 were 0.8 million tonnes. They decreased by 62.4% since FY1990 and increased by 0.1% compared to the previous year.

Sulfur oxide (SO_X)[12] emissions in FY2021 were 0.3 million tonnes. They decreased by 73.1% since FY1990 and increased by 0.6% compared to the previous year.

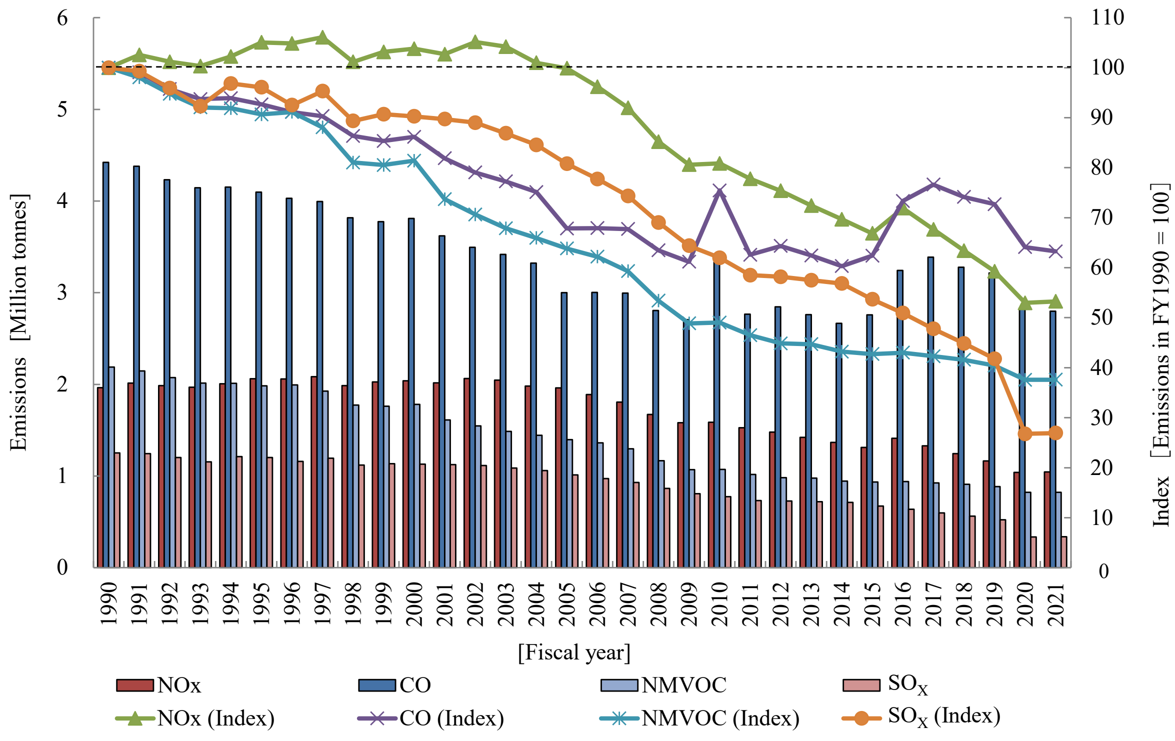


Figure 2-19 Trends in emissions of indirect GHGs and SO_X

Note: The line chart shows the trend as an index of FY1990 emissions set at 100.

11 The reason for the increase in CO emissions in FY2010 compared to the previous year was the change in the EF for road transportation, and the reason for the decrease in CO emissions in FY2011 compared to the previous year was the change in the share of furnace types in the iron and steel industry.

12 Most SO_X consists of SO_2. For major sources, SO_2 emissions are estimated.

References

1. Cabinet Office, Government of Japan, *Annual Report on National Accounts.*
2. IPCC, *Fourth Assessment Report,* 2007.
3. Ministry of Internal Affairs and Communications, Statistics Bureau, *Annual Report of Population Estimates.*
4. Ministry of Internal Affairs and Communications, Statistics Bureau, *Population Census*.

Chapter 3. Energy (CRF sector 1)

3.1. Overview of Sector

The energy sector consist of two main categories: fuel combustion and fugitive emissions from fuels. Fuel combustion includes emissions released into the atmosphere when fossil fuels (e.g., coal, oil products, and natural gas) are combusted. Fugitive emissions are intentional or unintentional releases of gases from fossil fuels by anthropogenic activities.

In Japan, fossil fuels are used to produce energy for a wide variety of purposes (e.g., production, transportation, and consumption of energy products) and CO_2 (carbon dioxide), CH_4 (methane), N_2O (nitrous oxide), NO_X (nitrogen oxide), CO (carbon monoxide), and NMVOC (non-methane volatile organic compounds) are emitted in the process.

In FY2021, GHG emissions (CO_2, CH_4 and N_2O) from the energy sector accounted for 1,014,950 kt-CO_2 eq., and represented 86.8% of Japan's total GHG emissions (excluding LULUCF). The emissions from the energy sector had decreased by 7.0% compared to FY1990.

The methodologies are shown in the below table.

Table 3-1 Methodologies used in the energy sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
1.A. Fuel combustion	CS,T2	CS	CS,T1,T2,T3	CR,CS,D	CS,T1,T2,T3	CR,CS,D
1. Energy industries	CS,T2	CS	CS,T3	CS	CS,T3	CS
2. Manufacturing industries and construction	CS,T2	CS	CS,T1,T3	CR,CS,D	CS,T1,T3	CR,CS,D
3. Transport	T2	CS	T1,T2,T3	CS,D	T1,T2,T3	CS,D
4. Other sectors	CS,T2	CS	CS,T1,T3	CR,CS,D	CS,T1,T3	CR,CS,D
5. Other						
1.B. Fugitive emissions from fuels	CS,T1,T2,T3	CS,D	CS,T1,T2,T3	CS,D	T1	D
1. Solid fuels	CS,T2	CS	T1,T2,T3	CS,D	T1	D
2. Oil and natural gas	CS,T1,T3	CS,D	CS,T1,T2	CS,D	T1	D
1.C. CO_2 transport and storage						

Note:
D: IPCC default, T1: IPCC Tier 1, T2: IPCC Tier 2, T3: IPCC Tier 3, CS: country-specific method or EF, CR: CORINAIR

3.2. Fuel Combustion (1.A.)

This category covers GHG emissions from combustion of fossil fuels such as coal, oil, and natural gas, and incineration of waste for energy purposes and with energy recovery.[1]

This section includes GHG emissions from five sources: energy industries (1.A.1): emissions from power generation and heat supply; manufacturing industries and construction (1.A.2): emissions from manufacturing industry and construction; transport (1.A.3): emissions from transport of passenger and freight; other sectors (1.A.4): emissions from commercial/institutional, residential, and agriculture/forestry/fishing sources; and other (1.A.5): emissions from other sources.

[1] The emissions from waste incineration had been reported in the waste sector in the 2008 submission, regardless of their use as energy or energy recovery. However, to comply with ERT recommendations and the requirements of the IPCC Guidelines, the emissions are reported in the energy sector since the 2009 submission.

Table 3-2 Trends in GHGs emissions from fuel combustion (1.A)

Gas	Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	1.A.1. Energy industries	kt-CO_2	368,530	378,905	395,494	449,664	473,846	581,481	583,474	553,352	527,291	521,496	507,711	470,166	447,654	435,984	444,313
	a. Public electricity and heat production	kt-CO_2	303,055	317,587	330,118	378,044	404,239	516,376	521,862	493,837	468,472	466,072	454,136	414,706	395,384	391,560	396,750
	b. Petroleum refining	kt-CO_2	36,397	41,085	46,978	50,888	47,715	43,298	42,943	41,103	41,664	37,609	36,811	37,600	35,909	29,496	31,267
	c. Manufacture of solid fuels and other energy industries	kt-CO_2	29,078	20,232	18,398	20,732	21,892	21,807	18,670	18,412	17,155	17,816	16,763	17,860	16,361	14,928	16,296
	1.A.2. Manufacturing industries and construction	kt-CO_2	349,816	357,726	346,942	334,558	301,071	299,834	304,851	297,269	288,073	274,254	269,935	267,446	259,973	233,704	249,549
	a. Iron and steel	kt-CO_2	150,691	143,097	152,106	154,168	153,154	151,286	157,550	155,101	148,878	142,757	139,752	136,179	134,140	111,995	124,784
	b. Non-ferrous metals	kt-CO_2	8,429	7,381	6,311	5,686	3,964	3,994	3,743	3,635	3,242	3,499	3,120	3,283	2,869	2,778	3,016
	c. Chemicals	kt-CO_2	58,039	64,339	59,518	54,952	50,118	47,332	48,266	46,579	45,564	42,362	42,878	42,207	42,119	39,598	42,619
	d. Pulp, paper and print	kt-CO_2	27,106	31,428	31,672	29,732	22,646	23,812	23,832	22,899	23,308	20,847	20,489	20,430	18,984	17,870	17,728
	e. Food processing, beverages and tobacco	kt-CO_2	7,649	10,133	11,468	12,169	9,830	10,535	9,811	9,521	8,471	8,414	7,762	8,738	7,689	8,189	7,988
	f. Non-metallic minerals	kt-CO_2	43,634	46,461	40,100	35,443	28,716	28,839	29,804	28,989	28,059	27,096	26,880	26,996	25,844	25,160	24,886
	g. Other	kt-CO_2	54,267	54,888	45,766	42,407	32,642	34,036	31,846	30,545	30,551	29,279	29,055	29,614	28,329	28,113	28,528
	1.A.3. Transport	kt-CO_2	202,140	242,797	253,091	238,065	221,969	218,004	215,115	210,149	208,875	207,066	205,253	203,016	199,022	176,575	177,911
	a. Domestic aviation	kt-CO_2	7,162	10,278	10,677	10,799	9,193	9,524	10,149	10,173	10,067	10,187	10,399	10,537	10,488	5,238	6,819
	b. Road transportation	kt-CO_2	180,367	217,028	226,690	213,605	201,457	197,158	193,437	188,540	187,641	185,722	183,803	181,451	177,628	160,907	160,345
	c. Railways	kt-CO_2	935	822	711	647	574	554	540	524	523	499	520	492	490	468	468
	d. Domestic navigation	kt-CO_2	13,675	14,669	15,012	13,014	10,745	10,769	10,989	10,912	10,645	10,659	10,530	10,537	10,417	9,962	10,279
	e. Other transportation	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.A.4. Other sectors	kt-CO_2	158,178	175,411	190,258	196,029	156,916	145,805	149,324	141,936	139,223	140,900	144,667	141,830	140,722	140,168	135,485
	a. Commercial/institutional	kt-CO_2	79,069	88,210	98,179	105,958	74,900	66,992	74,228	69,192	67,111	67,284	67,349	74,393	70,692	68,805	68,202
	b. Residential	kt-CO_2	58,167	67,477	72,226	70,395	64,217	62,626	60,319	58,014	55,392	55,712	59,260	52,156	53,361	55,807	51,573
	c. Agriculture/forestry/fishing	kt-CO_2	20,942	19,723	19,853	19,676	17,800	16,186	14,777	14,730	16,720	17,905	18,058	15,280	16,669	15,556	15,710
	1.A.5 Other	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	a. Stationary	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	b. Mobile	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	kt-CO_2	1,078,663	1,154,838	1,185,785	1,218,316	1,153,802	1,245,124	1,252,764	1,202,705	1,163,462	1,143,716	1,127,565	1,082,459	1,047,371	986,431	1,007,257
CH_4	1.A.1. Energy industries	kt-CH_4	18.37	16.01	10.53	9.94	10.79	12.02	9.57	9.00	11.07	14.15	15.59	14.95	14.19	16.03	16.14
	a. Public electricity and heat production	kt-CH_4	0.82	1.02	1.31	1.21	1.19	5.02	3.61	3.36	5.63	8.45	10.33	9.92	9.29	11.60	11.66
	b. Petroleum refining	kt-CH_4	0.09	0.11	0.22	1.51	2.50	0.12	0.12	0.11	0.21	0.26	0.32	0.34	0.33	0.26	0.28
	c. Manufacture of solid fuels and other energy industries	kt-CH_4	17.46	14.88	9.01	7.22	7.10	6.88	5.84	5.52	5.24	5.45	4.94	4.69	4.57	4.17	4.20
	1.A.2. Manufacturing industries and construction	kt-CH_4	14.39	15.14	14.82	17.68	21.52	18.58	19.82	20.74	21.04	21.59	22.53	22.70	22.71	21.21	21.88
	a. Iron and steel	kt-CH_4	4.66	4.28	5.03	7.03	9.19	6.57	6.84	7.08	7.82	8.57	9.13	9.10	9.12	7.85	8.71
	b. Non-ferrous metals	kt-CH_4	0.39	0.36	0.29	0.23	0.18	0.25	0.24	0.25	0.24	0.27	0.27	0.28	0.24	0.23	0.26
	c. Chemicals	kt-CH_4	0.31	0.32	0.49	1.27	2.38	0.87	0.87	0.78	0.72	0.67	0.64	0.68	0.63	0.63	0.66
	d. Pulp, paper and print	kt-CH_4	1.06	1.06	1.13	1.34	1.60	1.33	1.43	1.50	1.51	1.43	1.48	1.56	1.47	1.33	1.42
	e. Food processing, beverages and tobacco	kt-CH_4	0.09	0.13	0.15	0.16	0.14	0.37	0.50	0.59	0.75	0.93	1.02	1.14	1.03	1.08	1.07
	f. Non-metallic minerals	kt-CH_4	4.16	4.96	3.94	3.63	3.08	2.89	3.18	3.18	2.98	2.81	2.71	2.83	2.71	2.66	2.63
	g. Other	kt-CH_4	3.72	4.02	3.79	4.03	4.95	6.30	6.75	7.36	7.02	6.92	7.28	7.11	7.50	7.41	7.12
	1.A.3. Transport	kt-CH_4	11.65	12.36	12.48	9.88	6.97	6.37	6.03	5.70	5.46	5.28	5.09	4.94	4.76	4.23	4.14
	a. Domestic aviation	kt-CH_4	0.23	0.26	0.29	0.22	0.07	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.04	0.05
	b. Road transportation	kt-CH_4	10.10	10.68	10.76	8.43	5.87	5.28	4.96	4.64	4.42	4.24	4.06	3.92	3.75	3.28	3.15
	c. Railways	kt-CH_4	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	d. Domestic navigation	kt-CH_4	1.27	1.36	1.39	1.20	1.00	1.00	0.98	0.97	0.95	0.95	0.94	0.94	0.93	0.89	0.92
	e. Other transportation	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.A.4. Other sectors	kt-CH_4	9.55	11.73	13.10	19.83	18.20	9.63	9.01	8.46	8.22	8.31	8.75	7.92	8.07	8.07	7.57
	a. Commercial/institutional	kt-CH_4	1.30	3.01	4.23	10.27	8.96	2.34	2.08	1.76	1.74	1.72	1.81	1.86	1.88	1.60	1.64
	b. Residential	kt-CH_4	7.04	7.71	7.88	7.69	6.89	6.69	6.38	6.12	5.82	5.88	6.27	5.46	5.54	5.81	5.30
	c. Agriculture/forestry/fishing	kt-CH_4	1.21	1.02	0.99	1.86	2.35	0.59	0.55	0.58	0.66	0.71	0.67	0.60	0.64	0.66	0.64
	1.A.5 Other	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	a. Stationary	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	b. Mobile	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	kt-CH_4	53.96	55.24	50.93	57.33	57.46	46.60	44.42	43.89	45.80	49.34	51.96	50.52	49.73	49.54	49.73
		kt-CO_2 eq.	1,349	1,381	1,273	1,433	1,437	1,165	1,111	1,097	1,145	1,234	1,299	1,263	1,243	1,238	1,243
N_2O	1.A.1. Energy industries	kt-N_2O	2.98	4.54	5.41	7.10	6.95	7.68	7.91	7.88	8.01	7.56	8.19	7.59	6.31	6.25	6.39
	a. Public electricity and heat production	kt-N_2O	1.72	3.09	3.72	5.32	5.13	6.12	6.61	6.64	6.69	6.27	6.92	6.43	5.31	5.27	5.30
	b. Petroleum refining	kt-N_2O	1.05	1.31	1.58	1.61	1.61	1.42	1.21	1.17	1.26	1.22	1.21	1.10	0.95	0.93	1.04
	c. Manufacture of solid fuels and other energy industries	kt-N_2O	0.22	0.14	0.12	0.17	0.21	0.14	0.09	0.07	0.06	0.07	0.07	0.06	0.05	0.05	0.05
	1.A.2. Manufacturing industries and construction	kt-N_2O	4.23	5.73	6.30	6.27	5.79	5.83	5.91	5.78	5.82	5.61	5.61	5.52	5.38	4.98	4.95
	a. Iron and steel	kt-N_2O	1.12	1.34	1.40	1.47	1.50	1.26	1.32	1.32	1.34	1.33	1.33	1.28	1.35	1.20	1.18
	b. Non-ferrous metals	kt-N_2O	0.25	0.23	0.21	0.08	0.05	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05
	c. Chemicals	kt-N_2O	0.74	1.19	1.20	1.04	0.96	1.03	1.07	1.00	1.00	0.91	1.01	0.94	0.93	0.87	0.94
	d. Pulp, paper and print	kt-N_2O	0.48	0.91	0.95	0.98	1.14	1.18	1.23	1.26	1.26	1.22	1.19	1.19	1.07	0.84	0.87
	e. Food processing, beverages and tobacco	kt-N_2O	0.04	0.05	0.07	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05
	f. Non-metallic minerals	kt-N_2O	0.80	1.06	1.73	1.98	1.56	1.62	1.65	1.62	1.66	1.59	1.53	1.54	1.51	1.51	1.38
	g. Other	kt-N_2O	0.80	0.94	0.76	0.64	0.50	0.62	0.52	0.45	0.45	0.45	0.45	0.46	0.43	0.46	0.47
	1.A.3. Transport	kt-N_2O	12.55	13.77	13.41	9.46	6.89	6.24	5.96	5.73	5.59	5.47	5.39	5.31	5.21	4.63	4.69
	a. Domestic aviation	kt-N_2O	0.21	0.29	0.32	0.32	0.28	0.29	0.30	0.30	0.30	0.30	0.31	0.31	0.30	0.15	0.20
	b. Road transportation	kt-N_2O	11.60	12.77	12.41	8.53	6.10	5.45	5.17	4.95	4.82	4.70	4.62	4.55	4.45	4.04	4.04
	c. Railways	kt-N_2O	0.37	0.32	0.28	0.25	0.23	0.22	0.21	0.20	0.20	0.19	0.20	0.19	0.19	0.18	0.18
	d. Domestic navigation	kt-N_2O	0.36	0.39	0.40	0.34	0.28	0.29	0.28	0.28	0.27	0.27	0.27	0.27	0.27	0.25	0.26
	e. Other transportation	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.A.4. Other sectors	kt-N_2O	2.31	2.55	2.82	2.49	2.17	1.97	2.02	2.03	2.06	2.26	2.38	2.28	2.31	2.22	2.11
	a. Commercial/institutional	kt-N_2O	1.51	1.78	2.08	1.79	1.56	1.40	1.49	1.52	1.52	1.70	1.81	1.78	1.79	1.69	1.62
	b. Residential	kt-N_2O	0.28	0.32	0.35	0.34	0.29	0.28	0.27	0.25	0.24	0.24	0.26	0.22	0.22	0.23	0.21
	c. Agriculture/forestry/fishing	kt-N_2O	0.53	0.45	0.38	0.36	0.32	0.29	0.26	0.26	0.29	0.32	0.31	0.28	0.30	0.30	0.28
	1.A.5 Other	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	a. Stationary	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	b. Mobile	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	kt-N_2O	22.07	26.59	27.95	25.32	21.80	21.73	21.80	21.42	21.49	20.90	21.58	20.70	19.21	18.08	18.14
		kt-CO_2 eq.	6,578	7,925	8,329	7,545	6,497	6,474	6,497	6,383	6,403	6,228	6,432	6,169	5,723	5,388	5,405
Total of all gases		kt-CO_2 eq.	1,086,590	1,164,144	1,195,386	1,227,295	1,161,735	1,252,763	1,260,372	1,210,185	1,171,010	1,151,177	1,135,296	1,089,891	1,054,337	993,057	1,013,906

In FY2021, emissions from fuel combustion were 1,013,906 kt-CO_2 eq., which accounted for 86.7% of Japan's total GHG emissions (excluding LULUCF). By looking at the share of the emissions by gas, CO_2 comprises 99.3% of the GHG emissions from fuel combustion.

The CO_2 emissions in FY2021 increased by 2.1% compared to the previous year. The main driving factor for the increase is the CO_2 emissions from manufacturing industries and construction (1.A.2).

By looking at the changes in CO_2 emissions by subcategory, emissions from the energy industries (1.A.1) increased by 20.6% since FY1990 and increased by 1.9% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increase in thermal power generation. From FY1990 to FY2007, the emissions increased with an increase in electricity demand. From FY2011 to FY2013, the emissions increased mainly due to an increase in the share of thermal power generation as a result of the suspension of operation of the nuclear power plants triggered by the Great East Japan Earthquake. Since then, the enhancement of introduction of renewable energy and the resumption of operation of the nuclear power plants are in progress.

The CO_2 emissions from manufacturing industries and construction (1.A.2) decreased by 28.7% since FY1990 and increased by 6.8% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption. The emissions are considered to have a moderate correlation with the *Indices of Industrial Production* (IIP) (Ministry of Economy, Trade and Industry (METI)). In the middle of 2000s, the CO_2 emissions were stable while the IIP increased, that implies the improvement of energy efficiency. (Agency for Natural Resources and Energy, 2020)

The CO_2 emissions from transport (1.A.3) decreased by 12.0% compared to FY1990 and increased by 0.8% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decrease in emissions from freight transportation, compensating for the increase in emissions from passenger vehicles. Although the emissions from road transportation increased in 1990s due to an increase in distance traveled, the emissions have decreased in the 2000s mainly due to an improvement of fuel efficiency. The distance traveled significantly dropped in FY2020 due to the influence of COVID-19 pandemic.

The CO_2 emissions from other sectors (1.A.4) decreased by 14.3% since FY1990 and decreased by 3.3% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption. The CO_2 emissions from commercial/institutional (1.A.4.a) are considered to have a moderate correlation with the *Indices of Tertiary Industry Activity* (METI) until 2005. The emissions have decreased since then due to the decrease in the demand of liquid fuels.

On the annual review in 2012 (FCCC/ARR/2012/JPN, paragraph 33), the Expert Review Team (ERT) recommended that Japan improve the transparency of the information on the drivers of emission trends in the energy sector. In response to the recommendation, the table below provides some indicators that might have relations to the emission trends. Please note that these indicators are not used for estimating the emissions. Also, please refer to Chapter 2 for the charts of emission trends.

Table 3-3 Trends in indicators that might have relations to the GHGs emissions from fuel combustion (1.A)

No.	Related subcategories	Indicators	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	1.A. Fuel combustion	Final electricity consumption	TWh	765	872	973	1,025	1,035	991	990	974	949	951	965	946	927	913	924
2	1.A.2. Manufacturing industries and construction	Indices of Industrial Production	CY2015=100	109.1	103.3	107.7	109.3	101.2	97.8	101.1	100.5	99.8	100.6	103.5	103.8	99.9	90.3	95.5
3	1.A.3.b. Road transportation	Vehicle kilometers traveled (VKT)	billion VKT	585	673	728	727	708	723	724	718	721	730	740	748	745	666	650
4	1.A.4.a.Commercial/ institutional	Indices of Tertiary Industry Activity	CY2015=100	83.8	90.8	95.2	100.7	97.6	99.6	100.8	99.2	100.3	100.5	101.9	103.0	102.3	95.3	97.5

Reference: 1: *General Energy Statistics* by Agency for Natural Resources and Energy (ANRE), 2: Ministry of Economy, Trade and Industry (METI), 3: *Statistical Yearbook of Motor Vehicle Fuel Consumption*, etc. by Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 4: METI

3.2.1. Comparison of the Sectoral Approach with the Reference Approach

This chapter explains a comparison between reference approach and sectoral approach in accordance with the *UNFCCC Inventory Reporting Guidelines* (Decision 24/CP.19 Annex I, paragraph 40). For the methodological issues of the sectoral approach, please refer to section 3.2.4. b).

3.2.1.1. Methodological Issues of the Reference Approach

The reference approach is to calculate the CO_2 emissions from combustion, using a country's energy supply data. The CO_2 emissions estimated by the reference approach are not included in the national total and used for verification purpose. The CO_2 emissions by the reference approach are estimated by the following formula:

$$E = \sum_i [(A_i - N_i) \times GCV_i \times 10^{-3} \times EF_i \times OF_i] \times 44/12$$

E : CO_2 emissions from fossil fuel combustion [t-CO_2]
A : Apparent energy consumption (original unit [t, kL, $10^3 \times m^3$])
N : Non-energy use of fossil fuels (original unit)
GCV : Gross calorific value (higher heating value) [MJ/original unit]
EF : Carbon content of the fuel [t-C/TJ]
OF : Oxidation factor
i : Type of fuel

The apparent energy consumptions A are estimated by the following formula:

Primary fuels: $A = P + IM - EX \pm SC - IB$

Secondary fuels: $A = IM - EX \pm SC - IB$

Table 3-4 Sources of each term of reference approach estimation equation

Symbol	Term	Source[2]
P	Production	• Indigenously Produced (#110000) in Agency for Natural Resources and Energy's *General Energy Statistics* (Japan's Energy Balance Table) • (Waste only) Consumption of sectoral approach[3]
IM	Imports	Imported (#120000) in the statistics + International bunker fuels (see section 3.2.2.)
EX	Exports	Export (#160000) in the statistics
SC	Stock change	Stockpile Change / Supply (#170000) in the statistics
IB	International bunkers	See section 3.2.2.
N	Non-energy use	Non-energy and feedstock use (#950000) in the statistics (see section 3.2.3.)

The carbon contents of the fuels, the oxidation factors and the gross calorific values are in common with the sectoral approach (refer to section 3.2.4. b).

The details of estimation results by reference approach are shown in the Common Reporting Format (CRF) table 1.A(b). The correspondence between fuels of the *General Energy Statistics* and those of the table is shown in Annex 4.

➢ *Discrepancies between the figures reported in the CRF tables and the IEA statistics*

Some discrepancies exist between the fuel data of energy supply and demand in the CRF tables and the

[2] Numbers with # indicate the corresponding sector (row) numbers in the *General Energy Statistics* (Japan's Energy Balance Table).
[3] In response to the recommendation on the annual review in 2018 (FCCC/ARR/2018/JPN, E.11)

data of energy supply and demand reported in the International Energy Agency (IEA) statistics. Please refer to the details of discrepancies and their reasons in Annex 4 (A4.1).

3.2.1.2. Difference in Energy Consumption

As shown in Table 3-5, fluctuations of difference[4] of energy consumption between the reference approach and the sectoral approach during FY1990-2021 range between -1.79% (FY2012) and +1.76% (FY2004).

Energy consumption from wastes used for energy and from the incineration of wastes with energy recovery is calculated in the sectoral approach in accordance with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

There is a large difference between those two approaches for solid fuels in FY2004 (+10.63%). It means that, in FY2004, because stocks of the coal on the consumer side (steel making coal [$0110[5]]) increased, the large difference occurred between the reference approach estimated from the provider side and the sectoral approach estimated from the consumer side. In addition, there is a large difference between those two approaches for solid fuels in FY2008 (+6.82%). This is because stocks of the coal on the consumer side (imported steam coal [$0121]) increased, like in FY2004. It should be noted that the stock changes explained here are not ‘Stockpile change / supply’ in ‘Primary energy supply’ sector, but ‘Transformation and consumption stockpile change’ in ‘Energy transformation & own use’ sector and ‘Final energy consumption’ sector.

3.2.1.3. Difference in CO_2 Emissions

As shown in Table 3-6, fluctuations of a difference of CO_2 emissions between the reference approach and the sectoral approach during FY1990-2021 range between -0.74% (FY1990) and +3.83% (FY2004).

Emissions from wastes used for energy and from the incineration of wastes with energy recovery are not reported in waste incineration (5.C.) but reported in fuel combustion (1.A.) in accordance with the *2006 IPCC Guidelines*.

The differences between both approaches for solid fuels were large values in FY2004 and FY2008 (+9.94%, +6.24%), and small values in FY2005 and FY2009 (+2.05%, -1.92%). It is because of the same reason as the difference of energy consumption which is described in the previous section.

---

[4] Difference = (RA-SA)/SA
RA: Reference Approach, SA: Sectoral Approach

[5] Numbers with $ indicate the corresponding energy source (column) numbers in the *General Energy Statistics* (Japan’s Energy Balance Table).

Table 3-5 Comparison of energy consumption[6]

[PJ]

	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Reference Approach															
Liquid fuels	9,526	10,132	9,442	8,919	7,179	7,640	7,395	6,811	6,501	6,271	6,180	5,821	5,545	5,144	5,333
Solid fuels	3,285	3,603	4,180	4,763	4,979	4,864	5,284	5,079	5,137	5,022	5,024	4,927	4,830	4,401	4,789
Gaseous fuels	2,042	2,465	3,050	3,275	3,979	4,854	4,882	4,948	4,646	4,718	4,686	4,499	4,271	4,262	3,988
Other fossil fuels	281	318	373	457	452	473	462	468	464	496	507	494	510	489	487
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Total RA	**15,135**	**16,518**	**17,045**	**17,415**	**16,589**	**17,831**	**18,024**	**17,306**	**16,747**	**16,507**	**16,396**	**15,741**	**15,155**	**14,296**	**14,596**
Sectoral Approach															
Liquid fuels	9,459	9,973	9,451	8,949	7,261	7,850	7,463	6,839	6,544	6,294	6,122	5,885	5,636	5,246	5,300
Solid fuels	3,368	3,598	3,986	4,638	4,819	4,878	5,223	5,124	5,049	4,956	4,981	4,826	4,723	4,374	4,676
Gaseous fuels	2,209	2,667	3,226	3,355	4,093	4,954	4,939	4,981	4,744	4,850	4,731	4,535	4,341	4,319	4,101
Other fossil fuels	281	318	373	457	452	473	462	468	464	496	507	494	510	489	487
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Total	**15,318**	**16,556**	**17,035**	**17,399**	**16,626**	**18,155**	**18,088**	**17,412**	**16,802**	**16,596**	**16,341**	**15,739**	**15,210**	**14,429**	**14,563**
Difference (%)															
Liquid fuels	0.71%	1.60%	-0.09%	-0.33%	-1.13%	-2.68%	-0.91%	-0.40%	-0.66%	-0.37%	0.94%	-1.08%	-1.61%	-1.93%	0.62%
Solid fuels	-2.46%	0.15%	4.87%	2.70%	3.32%	-0.29%	1.17%	-0.87%	1.73%	1.34%	0.86%	2.11%	2.25%	0.60%	2.41%
Gaseous fuels	-7.56%	-7.58%	-5.43%	-2.38%	-2.80%	-2.01%	-1.16%	-0.67%	-2.08%	-2.72%	-0.96%	-0.79%	-1.61%	-1.33%	-2.76%
Other fossil fuels	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Total	**-1.20%**	**-0.23%**	**0.06%**	**0.09%**	**-0.22%**	**-1.79%**	**-0.35%**	**-0.61%**	**-0.32%**	**-0.54%**	**0.34%**	**0.02%**	**-0.36%**	**-0.92%**	**0.23%**

Table 3-6 Comparison of CO_2 emissions

[Mt-CO_2]

	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Reference Approach															
Liquid fuels	659.9	701.9	656.2	621.1	501.8	532.9	512.2	472.1	450.1	433.6	427.7	402.3	382.9	354.1	368.0
Solid fuels	295.7	323.8	377.9	431.1	450.8	439.9	474.5	457.2	462.1	451.1	450.8	440.8	431.6	392.3	428.3
Gaseous fuels	104.4	126.1	155.9	167.4	203.5	248.4	249.9	253.2	237.8	241.5	239.9	228.9	217.2	216.6	202.7
Other fossil fuels	10.7	12.3	15.0	17.3	16.4	17.5	17.1	16.8	17.3	18.1	18.6	18.5	19.4	18.8	18.8
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Total RA	**1,071**	**1,164**	**1,205**	**1,237**	**1,173**	**1,239**	**1,254**	**1,199**	**1,167**	**1,144**	**1,137**	**1,090**	**1,051**	**982**	**1,018**
Sectoral Approach															
Liquid fuels	644.3	677.4	640.7	606.1	488.9	530.8	508.5	464.7	444.0	427.2	414.5	397.4	380.9	354.3	357.8
Solid fuels	309.5	327.2	364.1	422.4	438.5	442.8	473.8	465.6	458.8	449.6	451.6	435.2	425.7	393.2	421.3
Gaseous fuels	114.2	137.9	166.1	172.4	209.9	254.1	253.4	255.5	243.4	248.8	242.8	231.3	221.4	220.2	209.3
Other fossil fuels	10.7	12.3	15.0	17.3	16.4	17.5	17.1	16.8	17.3	18.1	18.6	18.5	19.4	18.8	18.8
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Total	**1,079**	**1,155**	**1,186**	**1,218**	**1,154**	**1,245**	**1,253**	**1,203**	**1,163**	**1,144**	**1,128**	**1,082**	**1,047**	**986**	**1,007**
Difference (%)															
Liquid fuels	2.42%	3.62%	2.43%	2.47%	2.64%	0.40%	0.74%	1.58%	1.38%	1.50%	3.19%	1.22%	0.53%	-0.06%	2.84%
Solid fuels	-4.47%	-1.05%	3.80%	2.05%	2.79%	-0.65%	0.15%	-1.80%	0.72%	0.34%	-0.18%	1.29%	1.38%	-0.22%	1.65%
Gaseous fuels	-8.56%	-8.61%	-6.11%	-2.89%	-3.06%	-2.24%	-1.39%	-0.92%	-2.29%	-2.93%	-1.20%	-1.07%	-1.91%	-1.64%	-3.13%
Other fossil fuels	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Total	**-0.74%**	**0.80%**	**1.62%**	**1.53%**	**1.62%**	**-0.52%**	**0.07%**	**-0.28%**	**0.33%**	**0.06%**	**0.84%**	**0.74%**	**0.35%**	**-0.48%**	**1.05%**

3.2.1.4. Comparison between Differences in Energy Consumption and that of CO_2 Emissions

The difference in energy consumption and the difference in CO_2 emissions generally show a similar tendency for their trends.

[6] In this chapter, soild fuels mean coal and coal products (including coal derived gas), liquid fuels mean crude oil and oil products (including LPG, etc.), and gaseous fuels mean natural gas (including LNG, etc.) and city gas, unless otherwise specified. (cf. *2006 IPCC Guidelines*, Vol.2, Table 1.1) Peat is included in solid fuels.

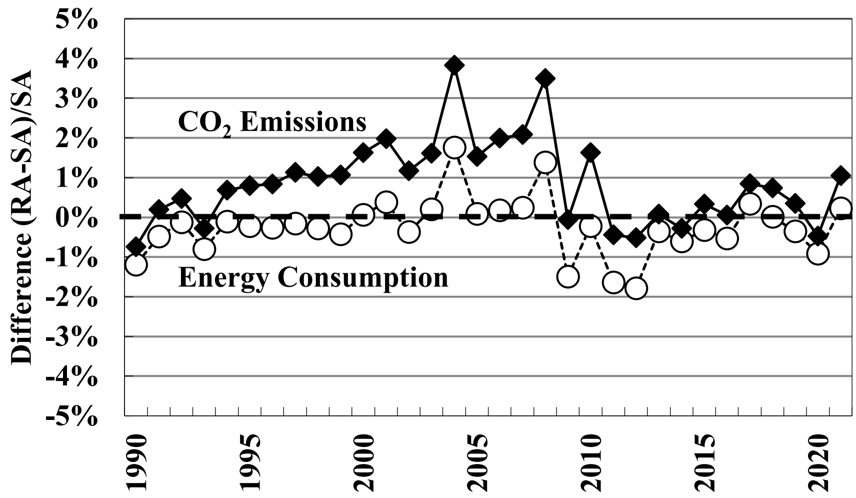


Figure 3-1 Trends in difference of energy consumption and CO_2 emissions

Note: RA: Reference Approach, SA: Sectoral Approach

3.2.1.5. Causes of the difference between Reference Approach and Sectoral Approach

The difference in energy consumption and in CO_2 emissions can be explained mainly by the difference of the amount of non-energy use which was deducted under energy transformation & own use sector of the Energy Balance Table (*General Energy Statistics*).

1) Matters not sufficiently considered in the calculation process of Reference Approach

In the current estimation of reference approach, the energy consumption amount, which is obtained by subtracting the amount of non-energy use from the amount supplied inside the country, is assumed to be completely combusted. However, in real situation, some of the energy amount is not combusted but stored, and the increase or decrease of the stored amount is not reflected in reference approach.

- ***Other Transformation [#289000]***

In Energy transformation & own use sector such as oil refining, energy source shipment/drawdown amounts do not necessarily match production/receipt amounts. Other than energy received through one's own imports or that produced by refining, factors involved include returns from consumption/sales sectors of products once shipped, transactions of small amounts of byproduct energy from other companies, stock buildups and drawdowns due to product storage tank installation or decommissioning at factories and business sites, and losses due to accidents or fires.

When energy source inconsistencies due to such causes in the Energy transformation & own use sector are determined, the other transformation sector represents its amount. However, this input/output are not reflected in reference approach emission calculation.

- ***Transformation and Consumption Stockpile Change [#350000]***

This sector represents the increase or decrease of stock in Energy transformation & own use sector and Final energy consumption sector. However, this increase/decrease was not reflected in reference approach emission calculation.

- ***Other factors***

Some emissions are not calculated for the sources that the emissions are relatively low compared to total emissions in reference approach, in order not to be too complicated (cf. *2006 IPCC Guidelines*, Vol.2, page 6.12). For example, the emissions from lubricants used in two stroke engines are not accounted for in the reference approach emission calculation.

The CO_2 amount captured for geological storage is not subtracted in the reference approach emission calculation, although it is subtracted in the sectoral approach emission calculation.

2) Matters which cannot be avoided for the characteristics of survey data

- ***Statistical Discrepancy [#400000]***

Statistical discrepancy is originally the intrinsic error arising at the sampling stage in statistical studies (source error), and mutual discrepancies among the statistics for supply, conversion, and consumption. It is sometimes difficult to guess where the discrepancies come from (relative error).

These errors induce the discrepancies among domestic supply, conversion, and final energy consumption, calculated as difference between both approaches.

3) Matters related to the difference of energy and carbon balance between energy input and output

- ***'Coal Blending' [#211000], 'Oil Product Blending' [#221000], 'Coal Products Secondary Transformation' [#281000], 'Oil Products Secondary Transformation' [#282000]***

This sector represents energy conversion that does not belong to any of the sectors from Coke production [#212000] to Steel process gas [#215000] and from Oil refinery [#222000] to District heat supply [#270000], and actions considered to be energy conversion in which coal or oil product brands are changed by only simple operations such as blending or moisture adjustment.

Carbon weight is considered to be consistent before and after blending or conversions. However, given that carbon content per calorific value is changed following such as blending, in statistics, carbon weight could be varied before and after blending or conversions. This difference can generate the variation between two approaches.

4) Matters related to the conversion to another fuel type

- ***Gas Conversion and Production [#231000]***

This sector represents energy conversion arising from city gas production. City gas is made from liquid and solid fuels such as liquefied petroleum gas (LPG) and coke oven gas (COG) as well as gaseous fuels such as liquefied natural gas (LNG). Thus, the fact that some liquid and solid fuels are converted to gaseous fuels is not reflected in reference approach emission calculation. The emissions calculated by the sectoral approach tend to be larger than those by reference approach for gaseous fuels and smaller for liquid and solid fuels. This sector does not affect the difference between two approaches in total.

Table 3-7 Comparison of CO_2 emissions (detail)

[Mt-CO_2]

	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
RA	**1,071**	**1,164**	**1,205**	**1,237**	**1,173**	**1,239**	**1,254**	**1,199**	**1,167**	**1,144**	**1,137**	**1,090**	**1,051**	**982**	**1,018**
Liquid fuels	659.9	701.9	656.2	621.1	501.8	532.9	512.2	472.1	450.1	433.6	427.7	402.3	382.9	354.1	368.0
Solid fuels	295.7	323.8	377.9	431.1	450.8	439.9	474.5	457.2	462.1	451.1	450.8	440.8	431.6	392.3	428.3
Gaseous fuels	104.4	126.1	155.9	167.4	203.5	248.4	249.9	253.2	237.8	241.5	239.9	228.9	217.2	216.6	202.7
Other fossil fuels	10.7	12.3	15.0	17.3	16.4	17.5	17.1	16.8	17.3	18.1	18.6	18.5	19.4	18.8	18.8
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
SA	**1,079**	**1,155**	**1,186**	**1,218**	**1,154**	**1,245**	**1,253**	**1,203**	**1,163**	**1,144**	**1,128**	**1,082**	**1,047**	**986**	**1,007**
Liquid fuels	644.3	677.4	640.7	606.1	488.9	530.8	508.5	464.7	444.0	427.2	414.5	397.4	380.9	354.3	357.8
Solid fuels	309.5	327.2	364.1	422.4	438.5	442.8	473.8	465.6	458.8	449.6	451.6	435.2	425.7	393.2	421.3
Gaseous fuels	114.2	137.9	166.1	172.4	209.9	254.1	253.4	255.5	243.4	248.8	242.8	231.3	221.4	220.2	209.3
Other fossil fuels	10.7	12.3	15.0	17.3	16.4	17.5	17.1	16.8	17.3	18.1	18.6	18.5	19.4	18.8	18.8
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
RA-SA	**-8.0**	**9.2**	**19.2**	**18.7**	**18.7**	**-6.5**	**0.9**	**-3.4**	**3.9**	**0.7**	**9.5**	**8.0**	**3.7**	**-4.7**	**10.6**
Liquid fuels	15.6	24.5	15.6	15.0	12.9	2.1	3.7	7.4	6.1	6.4	13.2	4.8	2.0	-0.2	10.2
Solid fuels	-13.8	-3.4	13.8	8.6	12.2	-2.9	0.7	-8.4	3.3	1.5	-0.8	5.6	5.9	-0.9	7.0
Gaseous fuels	-9.8	-11.9	-10.1	-5.0	-6.4	-5.7	-3.5	-2.3	-5.6	-7.3	-2.9	-2.5	-4.2	-3.6	-6.6
Other fossil fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peat	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Statistical discrepancy	**-12.0**	**4.6**	**13.1**	**11.6**	**8.7**	**-5.0**	**-2.2**	**-1.5**	**0.7**	**0.1**	**5.0**	**7.4**	**10.7**	**2.4**	**14.6**
Liquid fuels	1.4	7.2	0.8	0.5	-0.5	-1.8	-2.4	-2.3	-0.1	-1.0	1.6	-1.4	-0.2	-0.9	1.9
Solid fuels	-14.3	-2.7	13.0	11.1	11.0	-2.0	-0.7	-1.3	1.2	2.5	3.7	6.9	10.0	3.5	11.2
Gaseous fuels	0.9	0.0	-0.7	0.0	-1.7	-1.2	0.9	2.1	-0.4	-1.4	-0.4	1.9	1.0	-0.2	1.4
Coal blending	**0.3**	**0.4**	**0.5**	**0.7**	**0.7**	**0.7**	**-0.2**	**-0.2**	**0.0**	**-0.1**	**-0.1**	**-0.1**	**-0.1**	**0.1**	**-0.1**
Liquid fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solid fuels	0.3	0.4	0.5	0.7	0.7	0.7	-0.2	-0.2	0.0	-0.1	-0.1	-0.1	-0.1	0.1	-0.1
Gaseous fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oil product blending	**-1.8**	**-0.5**	**0.2**	**0.4**	**0.1**	**-0.1**	**-1.4**	**-1.3**	**-1.4**	**-1.5**	**-1.5**	**-1.6**	**-1.4**	**-1.3**	**-1.3**
Liquid fuels	-1.8	-0.5	0.2	0.4	0.1	-0.1	-1.4	-1.3	-1.4	-1.5	-1.5	-1.6	-1.4	-1.3	-1.3
Solid fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gaseous fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal products secondary transformation	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Liquid fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solid fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gaseous fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oil products secondary transformation	**1.1**	**0.4**	**0.4**	**0.8**	**1.5**	**1.4**	**1.2**	**1.3**	**1.2**	**1.2**	**1.9**	**2.1**	**1.9**	**1.3**	**1.8**
Liquid fuels	1.1	0.4	0.4	0.8	1.5	1.4	1.2	1.3	1.2	1.2	1.9	2.1	1.9	1.3	1.8
Solid fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gaseous fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gas conversion and production	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Liquid fuels	9.7	10.9	9.0	5.9	4.4	4.7	4.7	4.9	4.1	4.2	4.6	4.6	4.6	4.6	5.2
Solid fuels	0.8	0.5	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gaseous fuels	-10.5	-11.4	-9.4	-6.0	-4.4	-4.7	-4.7	-4.9	-4.1	-4.2	-4.6	-4.6	-4.6	-4.6	-5.2
Other transformation	**-0.4**	**-0.5**	**2.2**	**2.8**	**2.7**	**-5.6**	**-1.1**	**-4.5**	**-0.9**	**-2.1**	**-0.8**	**-6.6**	**-7.1**	**-9.3**	**-3.3**
Liquid fuels	-0.5	-0.6	2.1	2.8	2.6	-5.7	-1.2	-4.6	-0.9	-2.2	-0.9	-6.4	-6.8	-9.0	-3.1
Solid fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gaseous fuels	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	-0.2	-0.3	-0.3	-0.3
Transformation and consumption stockpile change	**2.6**	**1.7**	**2.4**	**-0.3**	**2.7**	**2.8**	**1.3**	**-4.3**	**1.7**	**-2.9**	**-1.7**	**1.1**	**-3.4**	**-3.7**	**-5.4**
Liquid fuels	0.7	1.5	-0.9	-0.1	0.4	2.6	-2.9	-0.3	-1.6	-2.7	-1.4	-0.3	-1.2	-2.4	-0.5
Solid fuels	1.9	0.6	3.0	-1.6	2.4	-0.2	3.7	-4.6	4.3	1.4	-2.4	0.9	-2.1	-2.9	-2.5
Gaseous fuels	0.0	-0.3	0.3	1.4	-0.1	0.4	0.5	0.6	-0.9	-1.6	2.1	0.5	-0.1	1.6	-2.4
Total	**-10.4**	**6.0**	**18.7**	**16.0**	**16.4**	**-5.7**	**-2.6**	**-10.6**	**1.3**	**-5.3**	**2.8**	**2.3**	**0.6**	**-10.5**	**6.3**
Liquid fuels	10.5	18.9	11.6	10.3	8.5	1.1	-2.1	-2.4	1.2	-2.0	4.4	-3.0	-3.0	-7.7	4.0
Solid fuels	-11.4	-1.2	16.9	10.3	14.1	-1.5	2.7	-6.1	5.5	3.8	1.2	7.6	7.7	0.7	8.7
Gaseous fuels	-9.5	-11.6	-9.8	-4.6	-6.2	-5.4	-3.2	-2.1	-5.4	-7.1	-2.8	-2.4	-4.1	-3.5	-6.5
(RA-SA)-(Total)	**2.4**	**3.2**	**0.5**	**2.6**	**2.3**	**-0.7**	**3.5**	**7.2**	**2.5**	**5.9**	**6.7**	**5.7**	**3.1**	**5.8**	**4.3**
Liquid fuels	5.1	5.6	3.9	4.7	4.4	1.0	5.8	9.7	4.9	8.4	8.9	7.8	5.1	7.5	6.1
Solid fuels	-2.4	-2.2	-3.0	-1.7	-1.8	-1.4	-2.0	-2.3	-2.1	-2.3	-2.1	-2.0	-1.9	-1.6	-1.8
Gaseous fuels	-0.3	-0.3	-0.4	-0.4	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1

3.2.2. International Bunker Fuels

a) Category Description

This section provides the estimation methods for determining CO_2, CH_4, and N_2O emissions from the fuel consumed for international navigation and aviation.

The emissions from bunker fuels used for international navigation and aviation are not included in the national totals but are reported as the memo item in the CRFs in accordance with the *UNFCCC*

Inventory Reporting Guidelines and the *2006 IPCC Guidelines*.

b) Methodological Issues

- ***Estimation Method***

The emissions of CO_2, CH_4 and N_2O from this source are derived by multiplying the consumption of each fuel type handled by bonds by the emission factor.

- ***Emission Factors***

➢ *CO_2*

The emission factors used for CO_2 are the same as those from 1.A.1 fuel combustion (CO_2) in the energy sector (Refer to section 3.2.4. b)).

On the annual review in 2012 (FCCC/ARR/2012/JPN) and 2013 (FCCC/ARR/2013/JPN), the ERT noted that the Japanese carbon emission factor (EF) for jet kerosene (18.3 t-C/TJ based on the gross calorific value) is lower than the EF for jet kerosene included in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (18.5 t-C/TJ based on the gross calorific value[7]). The ERT recommended that Japan provide additional information.

The Japanese carbon emission factor for jet kerosene is obtained from actual measurement. In addition, the 95% confidence interval of EF for jet kerosene is 18.1-19.3 t-C/TJ (based on the gross calorific value) in the *2006 IPCC Guidelines* (Vol.2, Table 1.4) and the Japanese EF is inside the range. Therefore, Japan considers that this country-specific EF is appropriate value, comparing to the default value.

➢ *CH_4, N_2O*

The default values given in the *2006 IPCC Guidelines* are used for CH_4 and N_2O emission factors.

Table 3-8 Emission factors for CH_4 and N_2O from international bunkers

Transport mode	Type of fuel	CH_4 emission factor [kg-CH_4/TJ(NCV)]	N_2O emission factor [kg-N_2O/TJ(NCV)]
Aircraft	Jet fuel	0.5 [1)]	2 [1)]
Shipping	Fuel oil A, fuel oil B, fuel oil C, diesel oil, kerosene	7 [2)]	2 [2)]

Note:
1) *2006 IPCC Guidelines* Vol. 2, Table 3.6.5
2) *2006 IPCC Guidelines* Vol. 2, Table 3.5.3. According to the *2006 IPCC Guidelines* Vol. 3 page 5.7, CH_4 and N_2O emissions from lubricants are very small in comparison to CO_2, and these can be neglected for the greenhouse gas calculation. Therefore, the emissions are not estimated.

- ***Activity Data***

The totals for bonded imports and bonded exports given in *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) (METI) are used for the emissions of CO_2, CH_4, and N_2O from the relevant source.

A and B in the diagram below correspond to the items under bonded exports and bonded imports, respectively, in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*). C equals to the sum of A and B and it is used as the activity data for this source of emissions. This is considered to be approximately equivalent to the amount of the fuels sold in Japan for international aviation and navigation.

7 This value is also the default value in the *2006 IPCC Guidelines*.

It is assumed that jet fuel is used by aircrafts, while fuel oil A, B, C, diesel oil, kerosene and lubricants are used by vessels. Fuel oil A, B, and C are used for the propulsion of international water-borne vessels. Diesel oil and kerosene are used only for fuels of private power generators (e.g. air heating). All lubricants are assumed to be oxidized during use from the viewpoint of conservativeness as lubricants consumption by type is unknown.

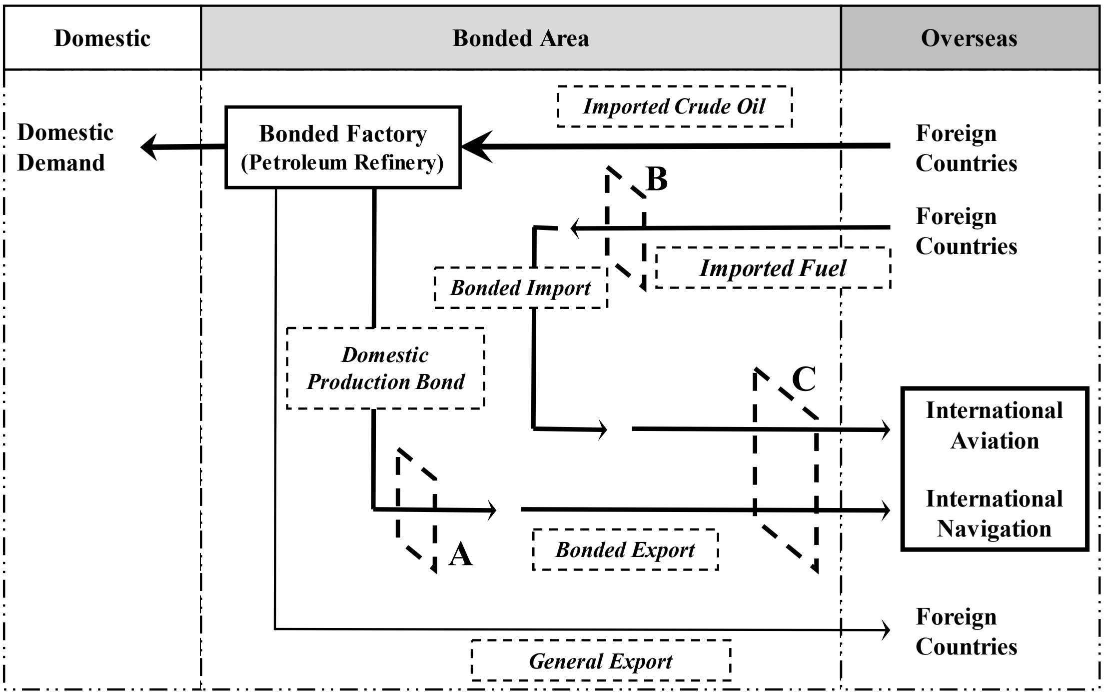


Figure 3-2 Activity data for international bunkers

➢ *CO_2*

The kiloliter-based consumption data given in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) are converted to Joule-based data using the actual calorific values given in the *General Energy Statistics*.

➢ *CH_4, N_2O*

The *2006 IPCC Guidelines* provide default emission factors that are based on net calorific values. Therefore, the activity data in gross calorific values are converted to net calorific values by multiplying them by the conversion rate.

- ***Glossary***

<u>Bonded Jet Fuel</u>

Under the Tariff Law, aircraft (Japanese and non-Japanese) flying international routes are deemed to be "aircraft for international use", and the fuel they consume is tariff-free, subject to the completion of the required procedures. The application of this legislation means that if fuel is refined from crude oil imported to Japanese refinery, both the crude oil import tariff and the petroleum and coal tax are waived. Similarly, if fuel has been imported as a product, the product import tariff is waived. The foregoing is termed as "bonded jet fuel".

<u>Bonded Fuel Oil</u>

Vessels that ply between Japan and other countries are deemed to be "foreign trade vessels", under the

Tariff Law. The majority of their fuel is consumed outside Japanese territorial waters, and, therefore, both the tariffs and the petroleum and coal tax are waived. The foregoing is termed as “bonded fuel oil”.

Bonded Export

The demand for fuel supplied to aircraft (Japanese and non-Japanese) flying international routes and ships (Japanese and non-Japanese) that ply foreign ocean routes is termed as “bonded demand”. Jet fuel is supplied to aircraft while fuel oil is supplied to ships. Of these bonded demands, the fuel supplied from products that was produced from crude oil is counted as bonded export by *Yearbook of Mineral Resources and Petroleum Products Statistics*.

Bonded Import (Bond to Bond)

Fuel products that are imported from foreign countries, landed in a bonded area and supplied from the bonded area to bonded demand without going through domestic customs, is counted as bonded import by *Yearbook of Mineral Resources and Petroleum Products Statistics*.

3.2.3. Feedstocks and Non-Energy Use of Fuels

The *General Energy Statistics* is used as the activity data for estimating GHG emissions from fuel combustion (1.A.). The Total energy consumption (#500000) in the statistics includes the amount of energy used as feedstocks without the combustion and oxidation process. The energy consumption in the category of Non-energy and feedstock use (#950000) represents such amount of energy. For the purpose of estimating the emissions, the consumption in the category of Non-energy and feedstock use was deducted from Total energy consumption.

The consumption in the category of Non-energy and feedstock use includes the following: (1) Consumption which can be confirmed as clearly non-energy uses by official statistics, such as surveys of feedstock inputs according to the *Yearbook of the Current Survey of Energy Consumption* (METI) which is the reference of the *General Energy Statistics*; and (2) Amount of products which are produced for the purpose of non-energy use from the beginning. (However, the portion which is confirmed from official statistics such as the *Yearbook of the Current Survey of Energy Consumption* as having been employed for energy uses is treated as energy consumption and is excluded from non-energy use.)

The feedstocks and non-energy use of fuels are reported in “Fuel quantity for NEU” and “Carbon excluded” columns of the the Common Reporting Format (CRF) table 1.A(d). The correspondence between fuels of the *General Energy Statistics* and those of the table is shown in Annex 4.

The CO_2 emissions from combustion or oxidation of the fuel used for non-energy purpose such as feedstock use of products in any process of manufacturing, use and abandonment of products are separately reported in other sectors shown in Table 3-9. (For detail, see each related chapter.) The emissions are reported in “Reported CO_2 emissions” column of the CRF table 1.A(d).

Among emissions from manufacturing processes of iron and steel and non-ferrous metals, emissions from fuel combustion should be reported in Energy sector (1.A) and emissions from reducing agent should be reported in Industrial processes and product use sector (2.C). Both emissions are reported together in Energy sector (1.A), because Japan considers that it is the most appropriate to grasp all emissions from manufacturing processes of iron and steel, and non-ferrous metals comprehensively from the viewpoints of accuracy, and avoiding double-counting and omissions. Each manufacturing process and category is shown in Table 3-10.

Table 3-9 Allocation of CO_2 emissions from fuel used for non-energy purpose such as feedstock

CO_2 emitting process	CRF Category	Type of fuel used for non-energy purpose such as feedstock	Emission factor	
				Calorific value
Ammonia production	2.B.1	Naphtha	See Table 3-11	See Table 3-19
		Liquefied petroleum gas (LPG), (until FY2002)		
		Refinery gas (off-gas) (until FY2011)		
		Indigenous natural gas		
		Coal (steam coal, imports)		
		Petroleum coke		
		Liquefied natural gas (LNG)		
		Coke oven gas (COG) (until FY2001)		
Silicon carbide production	2.B.5.a	Petroleum coke	2.3 [t-CO_2/t] (per petroleum coke consumption amount)	
Calcium carbide production	2.B.5.b	Coke	From reducing agent in production: 1.09 [t-CO_2/t] (confidential information in and after FY2008), from use: 1.10 [t-CO_2/t] (both EFs per calcium carbide production amount)	
Titanium dioxide production	2.B.6	Petroleum coke, etc.	Rutile TiO_2: confidential information Synthetic rutile: 1.43 [t-CO_2/t] (per production amount)	
Methanol production	2.B.8.a	Natural gas (until FY1995)	0.67 [t-CO_2/t] (per methanol production amount)	
Ethylene production	2.B.8.b	Naphtha, LPG, etc.	Confidential information	
Carbon black production	2.B.8.f	Coal tar, etc.	2.06 [t-CO_2/t] (per carbon black production amount)	
Maleic anhydride production	2.B.8.g	LPG	1.65 [t-CO_2/t] (per maleic anhydride production amount made by oxidation of n-butane)	
Hydrogen production	2.B.8.g	Natural gas, etc.	Report by member companies of the Japan Industrial and Medical Gases Association	
Automobile and marine engine oils (excluding total loss type) 1)	2.D.1	Lubricants	See Table 3-11	
Paraffin wax use	2.D.2	Bitumen	See Table 3-11	

Note:
1) CO_2 emissions from automobile and marine engine oils (total loss type) are included in Transport (1.A.3).
2) CO_2 emissions from fuel used for non-energy purpose may occur when fossil-fuel derived waste is incinerated or decomposed, and when fossil-fuel derived chemical products are used as feedstock to produce other chemical products. These CO_2 emissions are reported under 1.A (other fossil fuels), 2.D.3, 2.B.8, 2.H.2, 5.C or 5.E. However, This table and "Reported CO_2 emissions" column of CRF table 1.A(d) do not include these emissions in accordance with the *2006 IPCC Guidelines*, Vol.3, page 1.16.

Table 3-10 Reported category of CO_2 emissions from iron and steel and non-ferrous metals process

CO_2 emitting process	Main fuel used for non-energy purpose such as feedstock	Allocation as per IPCC Guidelines	Allocation used by the Party
Production of Steel and Pig iron	Coke, pulverized coal, waste plastics, coke oven gas, blast furnace gas	2.C.1	1.A.2.a (Iron and steel)
Sinter production	Coke	2.C.1	1.A.2.a (Iron and steel)
Pellet production	Coke	2.C.1	1.A.2.a (Iron and steel)
Ferroalloys production	Coke, steam coal	2.C.2	1.A.2.a (Iron and steel)
Aluminium production	Coke (Main ingredient in the anode paste)	2.C.3	1.A.2.f (Non-metallic minerals)
Lead production	Coke	2.C.5	1.A.2.b (Non-ferrous metals)
Zinc production	Coke	2.C.6	1.A.2.b (Non-ferrous metals)

3.2.4. CO_2 Emissions from Energy Industries (1.A.1.: CO_2)

a) Category Description

This section provides the methods for estimating CO_2 emissions from public electricity and heat production (1.A.1.a), petroleum refining (1.A.1.b), and manufacture of solid fuels and other energy industries (1.A.1.c). In Japan, manufacture of solid fuels and other energy industries (1.A.1.c) includes city gas production as well as coke production.

In FY2021, CO_2 emissions from this category accounted for 444,313 kt-CO_2, and represented 38.0% of Japan's total GHG emissions (excluding LULUCF). Public electricity and heat production (1.A.1.a) accounts for 89.3% and is the largest subcategory in energy industries (1.A.1).

The CO_2 emissions from liquid fuels in Public electricity and heat production (1.A.1.a) has been on a long-term decreasing trend. In FY1970, about 60% of electricity was generated by oil (ANRE, 2022). However, since the Oil Crisis in 1970s, the oil consumption at the oil power plants has decreased because Japan has diversified electricity sources. The electricity generation by oil temporarily increased in FY2011 and 2012, since the operation of nuclear power plants was suspended due to the Great East Japan Earthquake in 2011. However, the share of oil to the total electricity generation became less than 10% in FY2015.

The CO_2 emissions from gaseous fuels in Manufacture of solid fuels and other energy industries (1.A.1.c) are considerably lower for 2019 and 2020 than the previous years. It is caused by the decrease in the activity data, mainly "own use" of "city gas conversion and production" under the *General Energy Statistics*. This was because a duplication was found since FY2019 between the city gas consumptions for power generation reported under the *Electric Power Statistics* and the amount of own use reported under the *Current Survey of Production Concerning Gas Industry*. The amount of the duplication was subtracted from own use of city gas conversion and production. The background that caused the duplication was that electricity companies can sell city gas as well as city gas companies can now sell electricity due to the liberalization of electricity retail since FY2016 and the liberalization of city gas retail since FY2017.

The IEFs (Implied Emission Factors)[8] of CO_2 emissions from solid fuels in Manufacture of solid fuels and other energy industries (1.A.1.c) have been pulled up and down by fluctuation of carbon balances

[8] Indicators obtained by dividing the emissions in the common reporting format (CRF) by the activity data in the CRF.

derived from the transformation of solid fuels by the manufacture of solid fuels. The apparent annual change of this category is caused by the mass-balance, energy-balance and carbon-balance between coking coal, coke and other coal products, and may be influenced by statistical error, unobserved stockpiles in the process and/or spontaneous input-output unbalance.

b) Methodological Issues

- ***Estimation Method***

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2) because country-specific emission factors are available.

$$E = \sum_{ij} \left[(A_{ij} - N_{ij}) \times GCV_i \times 10^{-3} \times EF_i \times OF_i \right] \times 44/12$$

E	: CO_2 emissions from fossil fuel combustion [t-CO_2]
A	: Energy consumption (original unit [t, kL, $10^3 \times m^3$])
N	: Non-energy use of fossil fuels (original unit)
GCV	: Gross calorific value [MJ/original unit]
EF	: Carbon content of the fuel [t-C/TJ]
OF	: Oxidation factor
i	: Type of fuel
j	: Sector

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as "other fossil fuels" and "biomass" in accordance with the *2006 IPCC Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The CO_2 emissions from biomass are not included in the national totals[9] but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*. In the *General Energy Statistics*, the consumptions of biofuels are included in those of gasoline and diesel oil, but the CO_2 emissions from biofuels are not considered as fossil fuel origin by adjusting the calorific value and the carbon emission factors of gasoline and diesel oil.

CO_2 generated from an oil refinery plant was captured and stored from fiscal year 2004 to 2007 and 2016 through 2019, and it is reported under "CO_2 amount captured" in liquid fuels of 1.A.1.b Petroleum refining of the CRF table 1.A(a). It is subtracted from the emissions estimated by the above formula. Please refer to section 3.4.4. for details.

- ***Emission Factors***

➢ *Carbon emission factors*

The carbon content of fuels expressed as the unit of gross calorific value (higher heating value) was used for carbon emission factors (CEF). The emission factors are mostly country-specific values.

The emission factors were developed based on three different concepts; (a) Energy sources other than

[9] The reason of non-inclusion is to avoid double counting with the CO_2 emissions resulting from carbon stock changes estimated in LULUCF sector. (See *2006 IPCC Guidelines*, Vol.2, Page 2.33.)

Blast Furnace Gas (BFG) and City gas, (b) BFG, and (c) City gas.

Table 3-11 provides the emission factors for CO_2 by fuel types.

The CEFs for the residual and straight-run fuel oil for refinery use declined by 8.0% between 2012 and 2013, because the GCVs of the fuel increased by around 8.3% between 2012 and 2013 as a result of the survey conducted by METI and the Ministry of the Environment (MOE) on the GCVs and CEFs in FY2013 and FY2014 (see page 3-21). The crude oil for refinery use is major (99.9% of input volume to atmospheric distillation units in 2018), and the residual and straight-run fuel oil for refinery use is minor (0.1%) and it is not used for direct combustion.

Table 3-11 Carbon emission factors for fuel combustion in gross calorific value (Unit: t-C/TJ)

Fuel				Code [1]	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Solid fuels	Coal		Steel making coal	$0110	24.5	24.5	24.5	24.5	24.5	24.5	24.6	24.6	24.6	24.6	24.6	24.6	24.6	24.6	24.6
			Coking coal	$0111	24.5	24.5	24.5	24.5	24.5	24.5	24.4	24.4	24.4	24.4	24.4	24.5	24.5	24.5	24.5
			Pulverized coal injection (PCI) coal	$0112	24.5	24.5	24.5	24.5	24.5	24.5	25.1	25.1	25.1	25.1	25.1	25.1	25.1	25.1	25.1
			Imported steam coal	$0121	24.7	24.7	24.7	24.7	24.7	24.7	24.4	24.4	24.4	24.4	24.4	24.3	24.3	24.3	24.3
			Imported steam coal for general use	$0122	24.7	24.7	24.7	24.7	24.7	24.7	24.4	24.4	24.4	24.4	24.4	24.3	24.3	24.3	24.3
			Imported steam coal for power generation use	$0123	24.7	24.7	24.7	24.7	24.7	24.7	24.4	24.4	24.4	24.4	24.4	24.3	24.3	24.3	24.3
			Indigenous produced steam coal	$0124	24.9	24.9	24.9	24.9	24.9	24.9	23.7	23.7	23.7	23.7	23.7	24.2	24.2	24.2	24.2
			Hard coal, anthracite & lignite	$0130	25.5	25.5	25.5	25.5	25.5	25.5	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9
	Coal Products		Coke	$0211	29.4	29.4	29.4	29.4	29.4	29.4	30.2	30.2	30.2	30.2	30.2	29.9	29.9	29.9	29.9
			Coal tar	$0212	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9
			Coal briquette	$0213	29.4	29.4	29.4	29.4	29.4	29.4	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9
			Coke oven gas	$0221	11.0	11.0	11.0	11.0	11.0	11.0	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
			Blast furnace gas	$0222	27.2	26.9	26.7	26.5	26.4	26.2	26.5	26.6	26.5	26.5	26.5	26.3	26.3	26.4	26.3
			Converter furnace gas	$0225	38.4	38.4	38.4	38.4	38.4	38.4	41.7	41.7	41.7	41.7	41.7	42.0	42.0	42.0	42.0
Liquid fuels	Oil		Crude oil for refinery use	$0310	19.1	19.0	19.0	19.1	19.1	19.1	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
			Crude oil for refinery use	$0311	19.1	19.0	19.0	19.1	19.1	19.1	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
			Residual and straight run fuel oil for refinery use	$0312	21.3	21.4	21.4	21.4	21.4	21.5	19.7	19.6	19.5	19.6	19.4	19.4	19.4	19.3	19.3
			Crude oil for power generation use	$0320	19.1	19.1	19.2	19.6	19.2	19.1	19.2	19.2	19.3	19.3	19.3	19.3	19.2	19.5	19.1
			Bituminous mixture fuel	$0321	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
			Natural gas liquid (NGL) & condensate	$0330	16.1	16.7	17.5	18.2	18.4	18.3	18.3	18.3	18.3	18.3	18.3	18.2	18.3	18.3	18.2
			NGL&condensate for refinery use	$0331	17.4	18.1	18.0	18.3	18.4	18.4	18.3	18.3	18.3	18.3	18.3	18.2	18.3	18.3	18.3
			NGL&condensate for power generation use	$0332	17.5	17.6	17.6	18.2	17.9	17.9	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2
			NGL&condensate for petrochemical use	$0333	15.6	16.2	16.8	17.6	18.0	18.2	18.3	18.2	18.2	18.3	18.2	18.2	18.2	18.2	18.2
	Oil Products		Pure naphtha	$0420	18.2	18.2	18.2	18.2	18.2	18.2	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
			Reformate	$0421	18.3	18.3	18.3	18.3	18.3	18.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
		Fuel oil	Gasoline (crude oil origin)[2]	$0431	18.3	18.3	18.3	18.3	18.3	18.3	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7
			Gasoline (biofuel blended)[3]		18.3	18.3	18.3	18.3	18.2	18.2	18.6	18.6	18.6	18.5	18.5	18.5	18.5	18.5	18.5
			Jet fuel oil	$0432	18.3	18.3	18.3	18.3	18.3	18.3	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
			Kerosene	$0433	18.5	18.5	18.5	18.5	18.5	18.5	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7
			Gas oil or diesel oil (crude oil origin)[2]	$0434	18.7	18.7	18.7	18.7	18.7	18.7	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8
			Gas oil or diesel oil (biofuel blended)[3]		18.7	18.7	18.7	18.7	18.7	18.7	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.8
			Fuel oil A	$0436	18.9	18.9	18.9	18.9	18.9	18.9	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3	19.3
			Fuel oil C	$0437	19.5	19.5	19.5	19.5	19.5	19.5	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2
			Fuel oil B	$0438	19.2	19.2	19.2	19.2	19.2	19.2	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
			Fuel oil C for general use	$0439	19.5	19.5	19.5	19.5	19.5	19.5	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2
			Fuel oil C for power generation use	$0440	19.5	19.5	19.5	19.5	19.5	19.5	19.8	19.8	19.8	19.8	19.8	20.1	20.1	20.1	20.0
		Miscellaneous oil products	Lubricant oil	$0451	19.2	19.2	19.2	19.2	19.2	19.2	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9
			Other heavy oil products	$0452	20.8	20.8	20.8	20.8	20.8	20.8	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4
			Oil coke	$0455	25.4	25.4	25.4	25.4	25.4	25.4	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.8
			Galvanic furnace gas	$0456	38.4	38.4	38.4	38.4	38.4	38.4	41.7	41.7	41.7	41.7	41.7	42.0	42.0	42.0	42.0
			Refinery gas	$0457	14.2	14.2	14.2	14.2	14.2	14.2	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
			Liquefied petroleum gas (LPG)	$0458	16.5	16.5	16.5	16.5	16.5	16.5	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.3	16.3
Gaseous fuels	Natural Gas		Liquefied natural gas (LNG)	$0510	13.9	13.9	13.9	13.9	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.9	13.9	13.9	13.9
			Indigenous natural gas	$0520	13.9	13.9	13.9	13.9	13.9	13.9	14.0	14.0	14.0	14.0	14.0	13.9	13.9	13.9	13.9
			Indigenous natural gas	$0521	13.9	13.9	13.9	13.9	13.9	13.9	14.0	14.0	14.0	14.0	14.0	13.9	13.9	13.9	13.9
			Coal mining gas	$0522	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
			Boil off gas from crude oil	$0523	13.9	13.9	13.9	13.9	13.9	13.9	14.0	14.0	14.0	14.0	14.0	13.9	13.9	13.9	13.9
	City Gas		City gas	$0610	14.4	14.4	14.2	14.1	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
			Small scale community gas	$0620	16.5	16.5	16.5	16.5	16.5	16.5	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.3	16.3
(Reference)	Biomass		Woods	$N131	30.2	30.2	30.2	30.9	30.9	30.9	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6
			Waste woods	$N132	30.2	30.2	30.2	30.9	30.9	30.9	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6	29.6
			Bioethanol	$N134	17.2	17.2	17.2	17.2	17.2	17.2	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
			Biodiesel	$N135	17.2	17.2	17.2	17.2	17.2	17.2	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6	17.6
			Thermal use of black liquor	$N136	26.8	26.8	26.8	25.6	25.6	25.6	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9
			Gas biomass	$N137	12.4	12.4	12.4	12.4	12.4	12.4	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5

1) Code number for fuels of the *General Energy Statistics* (Energy Balance Table)
2) Used in the reference approach.
3) Used in the sectoral approach.

Table 3-12 References and methodologies of carbon emission factors for fuel combustion (FY1990-2012)

Fuel				Code	FY1990-2012
Solid fuels	Coal		Steel making coal	$0110	Same as coking coal
			Coking coal	$0111	Kainou (2005)
			Pulverized coal injection (PCI) coal	$0112	Same as coking coal
			Imported steam coal	$0121	Same as imported steam coal for general use
			Imported steam coal for general use	$0122	Environmental Agency (1992)
			Imported steam coal for power generation use	$0123	Same as imported steam coal for general use
			Indigenous produced steam coal	$0124	Environmental Agency (1992)
			Hard coal, anthracite & lignite	$0130	Kainou (2005)
	Coal Products		Coke	$0211	Environmental Agency (1992)
			Coal tar	$0212	Kainou (2005)
			Coal briquette	$0213	Environmental Agency (1992)
			Coke oven gas	$0221	Kainou (2005)
			Blast furnace gas	$0222	Values based on the carbon balance in blast furnace and converter furnace in the *General Energy Statistics*
			Converter furnace gas	$0225	Kainou (2005)
Liquid fuels	Oil		Crude oil for refinery use	$0310	Same as crude oil for refinery use
			Crude oil for refinery use	$0311	Weighted average of brand-specific CEFs based on the share of imports
			Residual and straight run fuel oil for refinery use	$0312	
			Crude oil for power generation use	$0320	Estimated by interpolating by approximate equation of crude oil for refinery use
			Bituminous mixture fuel	$0321	Kainou (2005)
			Natural gas liquid (NGL) / condensate	$0330	Weighted average of brand-specific CEFs based on the share of imports
			NGL/condensate for refinery use	$0331	
			NGL/condensate for power generation use	$0332	
			NGL/condensate for petrochemical use	$0333	
	Oil Products		Pure naphtha	$0420	Environmental Agency (1992)
			Reformate	$0421	Values of gasoline
		Fuel oil	Gasoline (crude oil origin)	$0431	Environmental Agency (1992)
			Gasoline (biofuel blended)		Weighted average of CEFs of crude oil origin and biomass origin based on the share of domestic consumption
			Jet fuel oil	$0432	Environmental Agency (1992)
			Kerosene	$0433	Environmental Agency (1992)
			Gas oil or diesel oil (crude oil origin)	$0434	Environmental Agency (1992)
			Gas oil or diesel oil (biofuel blended)		Weighted average of CEFs of crude oil origin and biomass origin based on the share of domestic consumption
			Fuel oil A	$0436	Environmental Agency (1992)
			Fuel oil C	$0437	Same as fuel oil C for general use
			Fuel oil B	$0438	Environmental Agency (1992)
			Fuel oil C for general use	$0439	Environmental Agency (1992)
			Fuel oil C for power generation use	$0440	Environmental Agency (1992)
		Miscellaneous oil products	Lubricant oil	$0451	Environmental Agency (1992)
			Other heavy oil products	$0452	Environmental Agency (1992)
			Petroleum coke	$0455	Environmental Agency (1992)
			Galvanic furnace gas	$0456	Values of converter furnace gas
			Refinery gas	$0457	Environmental Agency (1992)
			Liquefied petroleum gas (LPG)	$0458	Weighted average of theoretical CEFs of propane and butane based on the share of these matters in indigenous production and imports of the fuel
Gaseous fuels	Natural Gas		Liquefied natural gas (LNG)	$0510	Weighted average of CEFs by production area based on the share of imports by country
			Indigenous natural gas	$0520	Kainou (2005)
			Indigenous natural gas	$0521	Values of indigenous natural gas
			Coal mining gas	$0522	Environmental Agency (1992)
			Boil off gas from crude oil	$0523	Values of indigenous natural gas
	City Gas		City gas	$0610	Estimated from the carbon balance of "city gas conversion and production" in the *General Energy Statistics*
			Small scale community gas	$0620	Values of liquefied petroleum gas
(Reference)	Biomass		Woods	$N131	Actual measurements provided by JPA
			Waste woods	$N132	
			Bioethanol	$N134	Theoretical carbon emission factor of ethanol in normal condition
			Biodiesel	$N135	
			Thermal use of black liquor	$N136	Actual measurements provided by JPA
			Gas biomass	$N137	Theoretical carbon emission factor of methane in normal condition

Note:
FEPC: Federation of Electric Power Companies of Japan, JCIA: Japan Chemical Industry Association, JGA: Japan Gas Association,
JISF: Japan Iron and Steel Federation, JNGA: Japan Natural Gas Association, JPA: Japan Paper Association,
PAJ: Petroleum Association of Japan, SATP: Standard ambient temperature and pressure

Table 3-13 References and methodologies of carbon emission factors for fuel combustion (FY2013-2017)

Fuel				Code	FY2013-2017
Solid fuels	Coal		Steel making coal	$0110	Weighted average of CEFs of coking coal and PCI coal using consumptions of the fuels
			Coking coal	$0111	Simple average of CEFs obtained from actual measurements provided by JISF
			Pulverized coal injection (PCI) coal	$0112	Simple average of CEFs obtained from actual measurements provided by JISF
			Imported steam coal	$0121	Same as imported steam coal for general use
			Imported steam coal for general use	$0122	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.
			Imported steam coal for power generation use	$0123	Same as imported steam coal for general use
			Indigenous produced steam coal	$0124	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.
			Hard coal, anthracite & lignite	$0130	Estimated by interpolating by the approximate equation of imported steam coal
	Coal Products		Coke	$0211	Simple average of CEFs obtained from actual measurements provided by JISF
			Coal tar	$0212	Continuous use of the current value
			Coal briquette	$0213	Values of hard coal, anthracite & lignite
			Coke oven gas	$0221	Simple average of CEFs estimated from actual measurements provided by JISF
			Blast furnace gas	$0222	Values based on the carbon balance in blast furnace and converter furnace in the *General Energy Statistics*
			Converter furnace gas	$0225	Simple average of CEFs estimated from actual measurements provided by JISF
Liquid fuels	Oil		Crude oil for refinery use	$0310	Same as crude oil for refinery use
			Crude oil for refinery use	$0311	Weighted average of brand-specific CEFs based on imports by brand. The brand-specific CEFs were estimated by the approximate equation of crude oil based on brand-specific GCV obtained from actual measurements provided by PAJ.
			Residual and straight run fuel oil for refinery use	$0312	
			Crude oil for power generation use	$0320	Weighted average of monthly CEFs using monthly receipts. The monthly CEFs were estimated by approximate equation of crude oil using GCV from *Electric Power Statistics* (ANRE).
			Bituminous mixture fuel	$0321	Continuous use of the current value
			Natural gas liquid (NGL) / condensate	$0330	Weighted average of brand-specific CEFs based on imports and shipments by brand. The brand-specific CEFs were estimated by approximate equation of crude oil using brand-specific GCV obtained from actual measurements provided by PAJ.
			NGL/condensate for refinery use	$0331	
			NGL/condensate for power generation use	$0332	
			NGL/condensate for petrochemical use	$0333	
	Oil Products		Pure naphtha	$0420	Value of regular gasoline, which is simple average of CEF obtained from actual measurements provided by PAJ
			Reformate	$0421	Value of premium gasoline, which is simple average of CEF obtained from actual measurements provided by PAJ
		Fuel oil	Gasoline (crude oil origin)	$0431	Weighted average of CEFs of regular and premium gasoline using domestic shipments by type. The CEF of each gasoline were obtained from actual measurements provided by PAJ.
			Gasoline (biofuel blended)		Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption
			Jet fuel oil	$0432	Weighted average of CEFs of kerosene type jet fuel and gasoline type jet fuel using the final consumptions by type in the *General Energy Statistics.* The CEFs of each type were obtained from actual measurements provided by PAJ.
			Kerosene	$0433	Simple average of CEFs obtained from actual measurements provided by PAJ
			Gas oil or diesel oil (crude oil origin)	$0434	Simple average of CEFs obtained from actual measurements provided by PAJ
			Gas oil or diesel oil (biofuel blended)		Weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption
			Fuel oil A	$0436	Simple average of CEFs obtained from actual measurements provided by PAJ
			Fuel oil C	$0437	Same as fuel oil C for general use
			Fuel oil B	$0438	Estimated by interpolating by approximate equation of oil products using GCV obtained from actual measurements provided by PAJ
			Fuel oil C for general use	$0439	Simple average of CEFs obtained from actual measurements provided by PAJ
			Fuel oil C for power generation use	$0440	Estimated by approximate equation of oil products using GCV from *Electric Power Statistics* (ANRE).
		Miscellaneous oil products	Lubricant oil	$0451	Estimated by interpolating by approximate equation of oil products based on GCV obtained from actual measurements provided by PAJ
			Other heavy oil products	$0452	Estimated by interpolating by approximate equation of oil products based on GCV estimated from energy balance of slack fuel oil input and fuel oil C output
			Petroleum coke	$0455	Simple average of CEFs obtained from actual measurements provided by JCIA
			Galvanic furnace gas	$0456	Values of converter furnace gas
			Refinery gas	$0457	Simple average of CEFs estimated from actual measurements provided by PAJ
			Liquefied petroleum gas (LPG)	$0458	Weighted average of theoretical CEFs of propane and butane using domestic supply amount of each gas
Gaseous fuels	Natural Gas		Liquefied natural gas (LNG)	$0510	Weighted average of CEFs by production area using imports by country. The CEFs by production area were estimated from *Gas Industry Handbook* (JGA).
			Indigenous natural gas	$0520	Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA.
			Indigenous natural gas	$0521	Values of indigenous natural gas ($0520)
			Coal mining gas	$0522	Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA.
			Boil off gas from crude oil	$0523	Values of indigenous natural gas ($0520)
	City Gas		City gas	$0610	Estimated from the carbon balance of "city gas conversion and production" in the *General Energy Statistics*
			Small scale community gas	$0620	Values of liquefied petroleum gas
(Reference)	Biomass		Woods	$N131	Simple average of CEFs obtained by actual measurements provided by JPA
			Waste woods	$N132	
			Bioethanol	$N134	Theoretical carbon emission factor of ethanol in SATP condition
			Biodiesel	$N135	
			Thermal use of black liquor	$N136	Actual measurements provided by JPA
			Gas biomass	$N137	Theoretical carbon emission factor of methane in SATP condition

Note:
FEPC: Federation of Electric Power Companies of Japan, JCIA: Japan Chemical Industry Association, JGA: Japan Gas Association,
JISF: Japan Iron and Steel Federation, JNGA: Japan Natural Gas Association, JPA: Japan Paper Association,
PAJ: Petroleum Association of Japan, SATP: Standard ambient temperature and pressure

Table 3-14 References and methodologies of carbon emission factors for fuel combustion (FY2018 onward)

Fuel				Code	FY2018 onward
Solid fuels	Coal		Steel making coal	$0110	Weighted average of CEFs of coking coal and PCI coal using consumptions of the fuels
			Coking coal	$0111	Simple average of CEFs obtained from actual measurements provided by JISF
			Pulverized coal injection (PCI) coal	$0112	Simple average of CEFs obtained from actual measurements provided by JISF
			Imported steam coal	$0121	Same as imported steam coal for general use
			Imported steam coal for general use	$0122	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.
			Imported steam coal for power generation use	$0123	Same as imported steam coal for general use
			Indigenous produced steam coal	$0124	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.
			Hard coal, anthracite & lignite	$0130	Continuous use of the current value
	Coal Products		Coke	$0211	Simple average of CEFs obtained from actual measurements provided by JISF
			Coal tar	$0212	Continuous use of the current value
			Coal briquette	$0213	Continuous use of the current value
			Coke oven gas	$0221	Simple average of CEFs estimated from actual measurements provided by JISF
			Blast furnace gas	$0222	Values based on the carbon balance in blast furnace and converter furnace in the *General Energy Statistics*
			Converter furnace gas	$0225	Simple average of CEFs estimated from actual measurements provided by JISF
Liquid fuels	Oil		Crude oil for refinery use	$0310	Same as crude oil for refinery use
			Crude oil for refinery use	$0311	Weighted average of brand-specific CEFs based on imports by brand. The brand-specific CEFs were estimated by the approximate equation of crude oil based on brand-specific GCV obtained from actual measurements provided by PAJ.
			Residual and straight run fuel oil for refinery use	$0312	
			Crude oil for power generation use	$0320	Weighted average of monthly CEFs using monthly receipts. The monthly CEFs were estimated by approximate equation of crude oil using GCV from *Electric Power Statistics* (ANRE).
			Bituminous mixture fuel	$0321	Continuous use of the current value
			Natural gas liquid (NGL) / condensate	$0330	Weighted average of brand-specific CEFs based on imports and shipments by brand. The brand-specific CEFs were estimated by approximate equation of crude oil using brand-specific GCV obtained from actual measurements provided by PAJ.
			NGL/condensate for refinery use	$0331	
			NGL/condensate for power generation use	$0332	
			NGL/condensate for petrochemical use	$0333	
	Oil Products		Pure naphtha	$0420	Continuous use of the current value
			Reformate	$0421	Continuous use of the current value
		Fuel oil	Gasoline (crude oil origin)	$0431	Weighted average of CEFs of regular and premium gasoline using domestic shipments by type. The CEF of each gasoline were obtained from actual measurements provided by PAJ.
			Gasoline (biofuel blended)		Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption
			Jet fuel oil	$0432	Weighted average of CEFs of kerosene type jet fuel and gasoline type jet fuel using the final consumptions by type in the *General Energy Statistics.* The CEFs of each type were obtained from actual measurements provided by PAJ.
			Kerosene	$0433	Continuous use of the current value
			Gas oil or diesel oil (crude oil origin)	$0434	Continuous use of the current value
			Gas oil or diesel oil (biofuel blended)		Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption
			Fuel oil A	$0436	Continuous use of the current value
			Fuel oil C	$0437	Same as fuel oil C for general use
			Fuel oil B	$0438	Continuous use of the current value
			Fuel oil C for general use	$0439	Continuous use of the current value
			Fuel oil C for power generation use	$0440	Estimated by approximate equation of oil products using GCV from *Electric Power Statistics* (ANRE).
		Miscellaneous oil products	Lubricant oil	$0451	Continuous use of the current value
			Other heavy oil products	$0452	Estimated by interpolating by approximate equation of oil products based on GCV estimated from energy balance of slack fuel oil input and fuel oil C output
			Petroleum coke	$0455	Continuous use of the current value
			Galvanic furnace gas	$0456	Values of converter furnace gas
			Refinery gas	$0457	Continuous use of the current value
			Liquefied petroleum gas (LPG)	$0458	Weighted average of theoretical CEFs of propane and butane using domestic supply amount of each gas
Gaseous fuels	Natural Gas		Liquefied natural gas (LNG)	$0510	Weighted average of CEFs by production area using imports by country. The CEFs by production area were estimated from actual measurements provided by FEPC and JGA.
			Indigenous natural gas	$0520	Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA.
			Indigenous natural gas	$0521	Values of indigenous natural gas ($0520)
			Coal mining gas	$0522	Continuous use of the current value
			Boil off gas from crude oil	$0523	Values of indigenous natural gas ($0520)
	City Gas		City gas	$0610	Estimated from the carbon balance of "city gas conversion and production" in the *General Energy Statistics*
			Small scale community gas	$0620	Values of liquefied petroleum gas
(Reference)	Biomass		Woods	$N131	Continuous use of the current value
			Waste woods	$N132	
			Bioethanol	$N134	Continuous use of the current value
			Biodiesel	$N135	Continuous use of the current value
			Thermal use of black liquor	$N136	Continuous use of the current value
			Gas biomass	$N137	Continuous use of the current value

Note:
FEPC: Federation of Electric Power Companies of Japan, JCIA: Japan Chemical Industry Association, JGA: Japan Gas Association,
JISF: Japan Iron and Steel Federation, JNGA: Japan Natural Gas Association, JPA: Japan Paper Association,
PAJ: Petroleum Association of Japan, SATP: Standard ambient temperature and pressure

(a) Energy sources other than Blast Furnace Gas (BFG) and City gas

The carbon emission factors of energy sources other than blast furnace gas (BFG) and city gas were established based on Environmental Agency (1992), Ministry of the Environment (2002a), Kainou (2005), Kainou (2014), and Agency for Natural Resources and Energy (2020).

- ***Methodological issues of carbon emission factors from FY1990 to FY2012***

The evaluation results in Kainou (2005) were adopted for setting emission factors. In the choice of carbon emission factors, an adequacy assessment of emission factors was conducted in Environmental Agency (1992), which were used in the inventories submitted up to 2005. These were assessed based on the following three criteria. The values assessed as adequate continue to be used in this inventory.

1) Evaluation and analysis by comparison of theoretical upper and lower limits
2) Evaluation and analysis by comparison with the *Revised 1996 IPCC Guidelines* default values
3) Group evaluation and analysis by carbon balance using the *General Energy Statistics*

The summaries of evaluations are indicated below.

1) Evaluation and analysis by comparison of theoretical upper and lower limits

The validity of carbon emission factors is evaluated by comparing the intended emission factor and the emission factor calculated theoretically from standard enthalpy change of the formation of pure matter, such as hydrogen, methane and carbon monoxide, because most of the fuels for which carbon emission factors are required to be evaluated are hydrocarbons containing a few impurities, and because a physicochemical correspondence exists between the gross calorific values of pure hydrocarbons and carbon emission factors.

2) Evaluation and analysis by comparison with the *Revised 1996 IPCC Guidelines* default values

The validity of carbon emission factors is judged by using the *Revised 1996 IPCC Guidelines* default values or the *2006 IPCC Guidelines* reference values[10] and their statistical reliability (uncertainty) information. However, because the average properties of fuels envisaged in the IPCC Guidelines and those of the fuels used in Japan are not necessarily the same, carbon emission factors can be evaluated based on the statistical examination of the group evaluation and analysis mentioned below even when figures deviate, as long as a valid reason for the deviation exists.

3) Group evaluation and analysis by carbon balance using the *General Energy Statistics*

The validity of fuel-specific carbon emission factors for some petroleum and coal product factor groups can be evaluated using the *General Energy Statistics* to analyze the carbon balance in coal and oil products.

With regard to those judged there is no validity, the values shown in Ministry of the Environment (2002a) and *2006 IPCC Guidelines* were compared and verified, and values considered valid were used.

- ***Methodological issues of carbon emission factors from FY2013 to FY2017***

The values through the survey conducted by METI and MOE on the calorific values (CV) and carbon

[10] When *Evaluating and Analyzing the Validity of Carbon Emission Factors for Different Fuels* was submitted, the *2006 IPCC Guidelines* had not been published yet. These values were reference values, and some of these reference values were revised.

emission factors (CEF) in FY2013 and FY2014 were adopted. The outline is described below.

1) Outline of the Survey

The METI and MOE collected the data such as physical properties of various energy sources that relevant industrial associations had, and conducted the survey on the actual measurements of physical properties of samples provided by relevant industrial associations in FY2013 and FY2014. The CVs and CEFs from FY2013 were established using the methodologies presented in Kainou (2014) based on the physical properties of various energy sources obtained from the survey.

2) Basic Methodology of Estimation of Carbon Emission Factors

The CVs and CEFs by energy source were established, based on the properties and priority in accuracy of various energy sources, by the following methods: (1) estimation from theoretical values; (2) estimation from the actual measurements provided by the relevant industrial associations and the actual measurements by the METI and MOE; (3) estimation from the values of major energy sources, and from the weighted average and/or regression analysis using those values; (4) continuous use of the current values.

The estimation methods of the CVs and CEFs of solid, liquid and gaseous fuels based on the theoretical values and the actual measurements (corresponding to the methods (1) and (2)) are as follows:

Gaseous fuels

In the cases where component composition can be measured by such techniques as gas chromatography in some energy sources like gaseous fuels, CVs and CEFs are derived by weighted average of those of pure matters by composition. Theoretical CVs and CEFs of pure matters such as methane and propane are estimated from physical properties like standard enthalpy change of the formation.

Solid and liquid fuels

In the cases where energy sources are solid fuels or liquid fuels that the weighted average by pure matters are not feasible, CVs and carbon contents are estimated by statistical treatment of the actual measurements of physical properties such as gross calorific values and carbon contents.

The method (3) is that the CVs and CEFs of subject energy sources are estimated by interpolating by the approximate equations. The equations were established based on the actual measurements of steam coal, crude oil and oil products, and they can estimate CVs and CEFs from the physical properties such as density and water content.

3) Quality Control

The CVs and CEFs estimated above were compared with the current values and the default values of the *2006 IPCC Guidelines*, and then the validity is confirmed.

- ***Methodological issues of carbon emission factors from FY2018 onward***

The CEFs from FY2018 onward were established in combination of the CVs, based on the survey conducted by METI and MOE on the CV and CEF in FY2017 through FY2019. The fuels to be revised were selected, considering that the major revision of the CV and CEF has already been done in FY2013, the composition of some fuels does not significantly change during five years or so, the balance between cost and work load of the measurements and impact on emissions.

The CV and CEF were established basically by the following methods: (1) They were established in place of the current values using the data provided by industry organizations; (2) They were established in place of the current values using the existing statistics and references, the estimation equations, and other means; (3) The current values were used continuously. For (1) and (2), Kainou (2014) was referred to if the same estimation methodologies and references were adopted as in FY2013 values.

The CV and CEF estimated above were compared with the FY2013 values and the default values of the *2006 IPCC Guidelines* to evaluate the validity. In addition, the balance of energy and carbon in the coal products manufacturing and petroleum product manufacturing categories was confirmed: the output did not exceed the input due to the establishment of the CV and CEF described above.

(b) Blast Furnace Gas (BFG)

During the iron and steel production process, in the blast furnace and converter furnace, the amount of energy and carbon contained in coke and Pulverized Coal Injection (PCI) coal which are injected to the processes and those contained in BFG and Converter Furnace Gas (CFG, or Linz-Donawitz converter gas (LDG)) which are calculated should be theoretically balanced. Since the composition of BFG is unstable, the emission factors for BFG were established with annually calculated values in order to keep the carbon balance in the blast furnace and converter furnace during the iron and steel production process.

The amount of carbon (excluding the carbon contained in CFG from the carbon contained in 'Coke' and 'PCI coal') injected to the blast furnace indicated under 'Steel process gas' is considered to be carbon contained in BFG. The emission factor for BFG was established as the carbon described above divided by the calorific value of the BFG generated. The equation for the emission factor, the overview of the carbon flow for iron and steel and the calculation process are shown below.

The calculation to establish the emission factor for BFG is conducted every year.

$$EF_{BFG} = [(A_{coal} \times EF_{coal} + A_{coke} \times EF_{coke}) - A_{CFG} \times EF_{CFG}] / A_{BFG}$$

EF	: Carbon emission factor [t-C/TJ]
A	: Fuel consumption [TJ]
BFG	: Blast Furnace Gas
coal	: PCI coal
coke	: Coke
CFG	: Converter Furnace Gas

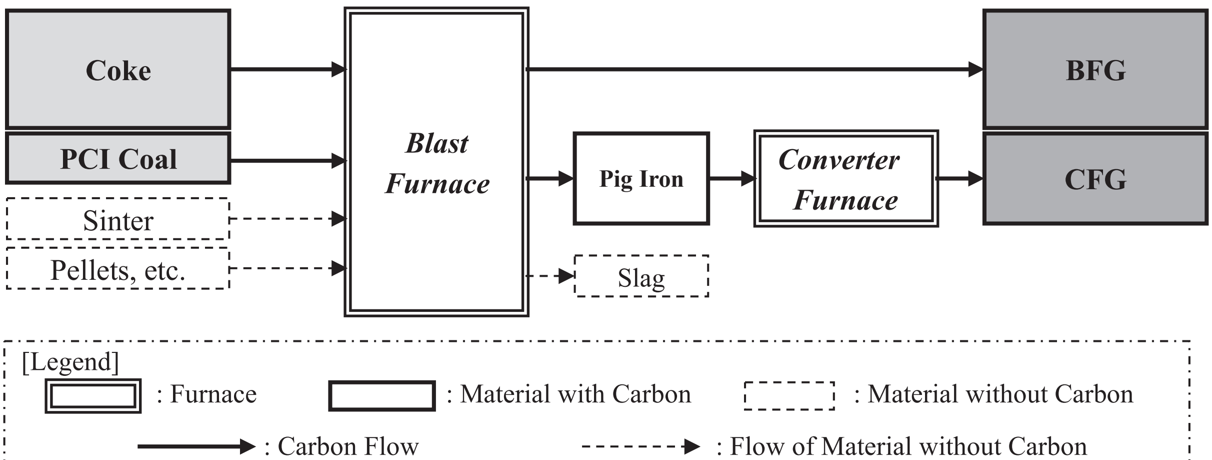


Figure 3-3 Overview of carbon flow for iron & steel manufacturing

Table 3-15 Calculation process of emission factors for BFG

Steel process gas		1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Note
Input																	
PCI coal	kt-C	1,650	2,619	3,351	3,014	3,444	4,019	4,401	4,283	4,180	4,206	4,250	4,094	4,043	2,965	4,039	A
Coke	kt-C	12,739	11,400	12,221	11,497	11,194	10,187	10,870	10,917	10,270	10,196	9,739	9,586	9,273	7,833	8,764	B
Input total	kt-C	14,389	14,019	15,572	14,511	14,637	14,206	15,271	15,200	14,449	14,402	13,989	13,680	13,316	10,799	12,803	C: A + B
Output																	
CFG (LDG)	kt-C	2,541	2,359	2,726	2,804	2,798	2,612	2,955	2,941	2,778	2,770	2,589	2,552	2,478	2,066	2,308	D
Difference	kt-C	11,848	11,660	12,846	11,707	11,839	11,594	12,316	12,260	11,671	11,632	11,400	11,127	10,838	8,733	10,494	E: C - D
Output																	
BFG	PJ	434.8	433.5	481.8	441.4	448.7	442.8	464.5	461.7	440.1	438.9	429.8	423.2	412.4	331.1	399.3	F
EF BFG	t-C/TJ	27.2	26.9	26.7	26.5	26.4	26.2	26.5	26.6	26.5	26.5	26.5	26.3	26.3	26.4	26.3	E / F

(c) City gas

"City gas" consists of "city gas" (general gas) provided by gas retailers, general gas pipeline companies, and specified gas pipeline companies (former general gas supplier, etc.) and "small-scale community gas" provided by gas retailers that generate gas in specified gas generation facilities and supply it through conduits (former small-scale community gas supplier).

Small-scale community gas:

Because most of the small-scale community gas is LPG, the same emission factor was adopted as for LPG.

General gas:

City gas (general gas) is produced from a mixture of raw materials and air dilution. In order to calculate the city gas emission factors, the total carbon contained in fossil fuel used as raw materials was divided by the total calorific value of the produced city gas. The emission factors for city gas were established based on the carbon balance in "city gas production". To calculate the city gas emission factors, the total carbon in fossil fuel inputs used as raw materials (COG, Kerosene, Refinery gas, LPG, LNG and Indigenous natural gas) was divided by the total calorific value of the city gas production.

The calculation to establish the emission factor for city gas is conducted every year.

$$EF_{CG} = \sum_i (A_i \times EF_i) / P_{CG}$$

EF : Carbon emission factor [t-C/TJ]
A : Fuel consumption [TJ]
P : Calorific value of the city gas production [TJ]
CG : City gas
i : Feedstocks (COG, Kerosene, Refinery gas, LPG, LNG, Indigenous natural gas)

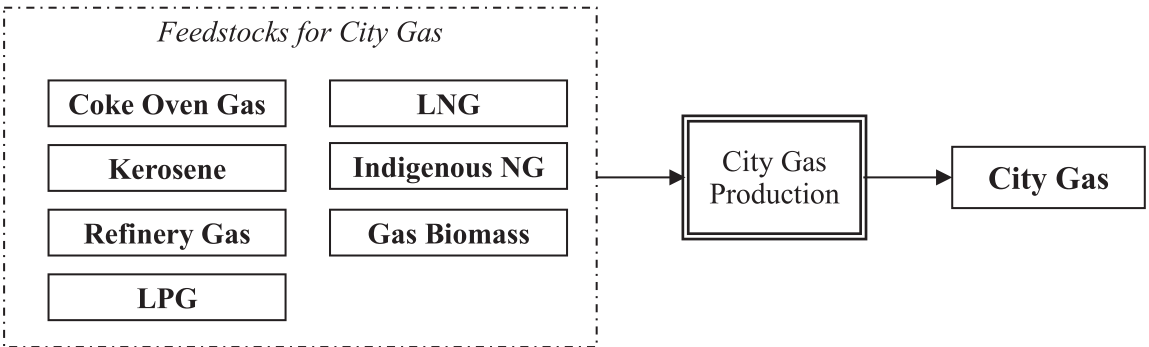


Figure 3-4 Manufacturing flow for city gas

Table 3-16 Calculation process of emission factors for city gas

City gas		1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Note
Input																	
COG	kt-C	211	134	105	22	0	0	0	0	0	0	0	0	0	0	0	a1
Kerosene	kt-C	200	275	69	6	0	0	0	0	0	0	0	0	0	0	0	a2
Refinery gas	kt-C	186	199	186	145	89	82	67	56	37	48	43	46	77	81	83	a3
LPG	kt-C	1,957	2,129	1,809	1,092	786	891	930	992	818	837	947	965	942	932	1,108	a4
LNG	kt-C	6,473	9,429	12,051	17,146	21,357	22,216	21,709	21,863	21,868	22,907	23,252	22,682	21,960	21,239	22,085	a5
Indigenous NG	kt-C	551	661	848	1,190	1,603	1,557	1,498	1,479	1,435	1,415	1,347	1,187	1,048	991	950	a6
Input total	kt-C	9,577	12,827	15,068	19,601	23,834	24,746	24,205	24,390	24,159	25,205	25,589	24,879	24,028	23,243	24,226	A: Σa
Output																	
City gas	PJ	664.7	892.3	1,061.1	1,392.0	1,700.3	1,764.1	1,724.3	1,737.3	1,722.1	1,796.5	1,822.5	1,781.9	1,720.8	1,664.7	1,732.9	B
EF City gas	t-C/TJ	14.4	14.4	14.2	14.1	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	A/B

➢ *Oxidation factor*

For each type of energy, country-specific oxidation factors were established considering the actual conditions of fuel combustion in Japan based on survey on related industrial associations, manufacturing corporations and experts.

Gaseous Fuels

Every measurement result of soot concentration of boilers to generate power by the Federation for Electric Power Companies Japan (FEPC) in 2004 for gaseous fuels combustion showed that no soot was emitted; therefore, it is assumed that gaseous fuels are completely combusted. The results of questionnaires also showed that gaseous fuels were completely combusted. Hence, the oxidation factor for gaseous fuel combustion was set to 1.0.

Liquid Fuels

The carbon contained in liquid fuels is considered to be almost completely combusted; however, unburned fuel loss, about 0.5%, may occur depending on its fired condition. Because data of actual measurements were not available, considering meticulous combustion management and smoke treatment in Japan, the oxidation factor for liquid fuels combustion was set to 1.0.

Solid Fuels

The oxidation factor for solid fuels varies depending on the fired condition, type of furnace, and coal property; therefore, it is quite difficult to obtain a representational data set of actual measurements of unburned fuel loss. Meanwhile, almost all the unburned carbon generated during combustion in furnace is considered to be contained in coal ash. Coal ash is effectively utilized or landfilled. Carbon contained in coal ash which is used as raw material of cement is oxidized to CO_2 and emitted into the atmosphere during the calcinations process.

The average oxidation factor from 1990 to 2003 considering unburned carbon oxidized in the firing process of coal ash was 0.996, expressed as 3 digits. Usually 2 digits are considered to be adequate in the view of other coefficients' accuracy; therefore, the oxidation factor for solid fuels was set to 1.0 rounded off to two digits.

● ***Activity Data***

The fuel consumption data given in the *General Energy Statistics* were used for the activity data. Table 3-17 shows the trend of energy consumption.

Table 3-17 Energy consumptions in Energy Industries (1.A.1) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Liquid fuels	2,596	2,198	1,618	1,669	1,352	2,166	1,866	1,465	1,312	1,154	1,021	880	777	675	781
Solid fuels	1,235	1,542	1,951	2,586	2,757	2,835	3,121	3,061	3,038	3,039	3,096	2,917	2,850	2,744	2,913
Gaseous fuels	1,564	1,786	2,167	2,021	2,624	3,475	3,488	3,552	3,300	3,394	3,218	3,033	2,846	2,925	2,641
Other fossil fuels	IE	IE	0	5	5	5	0	1	1	1	1	1	1	1	1
Biomass	0	0	0	26	28	28	31	32	32	48	84	92	140	156	186
Total	5,395	5,526	5,737	6,308	6,766	8,510	8,506	8,111	7,683	7,636	7,421	6,922	6,614	6,502	6,523

Note: Fuel type is in accordance with the Common Reporting Format (CRF).

The *General Energy Statistics* (Energy Balance Table) provides a comprehensive overview of domestic energy supply and demand to grasp what are converted from energy sources, such as coal, oil and natural gas, provided in Japan, and what are consumed in what sectors. The objective of this *General Energy Statistics* is to help to quantitatively understand energy supply and demand and to make judgments about the situation, in addition to helping with planning for energy and environmental policy, and with measuring, assessing, and otherwise gauging policy effectiveness.

The *General Energy Statistics* shows the main energy sources used in Japan as "Columns" and the supply, conversion and consumption sectors as "Rows" in a matrix. Specifically, the columns comprise 13 major categories (coal, coal products, crude oil, oil products, natural gas, city gas, renewable energy (excl. hydro), hydraulic power generation (excl. pumped), pumped storage, effective recovery use of wasted energy, nuclear power generation, electricity, and heat) and the necessary sub-categories and a more detailed breakdown of the sub-categories. The rows comprise 3 major sectors: primary energy supply (primary supply), energy transformation & own use (conversion), and final energy consumption (final consumption). The rows also contain the necessary sub-categories and a more detailed breakdown of the sub-categories.

In calculating the energy supply and demand amounts for the *General Energy Statistics*, it is assumed that each energy source, such as gasoline or electricity, is homogeneous in terms of gross calorific value per original unit (MJ/kg, MJ/L, MJ/m^3), and that homogeneous energy sources are supplied, converted and consumed. The values for supply, conversion and consumption in original units as determined from official statistical sources are multiplied by the gross calorific value per original unit to obtain energy supply and demand amounts.

The calculation process in the *General Energy Statistics* is as follows:

1. Setting calorific values and carbon emission factors.
2. Building an energy supply and demand module.
3. Preparing original unit tables (preparing a detailed table, a main table and a summary table through the module from relevant official statistics) (units in t, kL, 10^3 m^3, etc.).
4. Preparing energy unit tables (unit in J).
5. Preparing energy-derived carbon tables (carbon content).

The complete Energy Balance Tables for the years since FY1990 are available on the following internet site:

https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline2 (Japanese version only)

Please refer to the simplified energy balance tables provided in Annex 4 (A4.2).

For the activity data for energy industries, the data reported in the following sectors in the *General Energy Statistics* were used: “manufacture of coal products” [#210000]; “oil products” [#220000]; “gas conversion and production” [#230000]; “power generation” [#240000] which reports energy consumption associated with electric power generation by electric power suppliers; “district heat supply” [#270000] which provides energy consumption associated with heat energy and cold energy by thermal energy suppliers; “own use, coal products” [#301100] which reports energy consumption associated with captive (own) use of energy industries; “own use, oil products” [#301200]; “own use, gas conversion and production” [#301300]; “own use, power generation” [#301400]; “own use, district heat supply” [#301500].

In addition, fossil fuel consumption of “Auto power production” in “production, transmission and distribution of electricity” [#255330] is also included in the energy industries from FY1990 to FY2015. This is because electricity utilities whose main business is power generation should be included in public electricity and heat production (1.A.1.a) in accordance with the *2006 IPCC Guidelines*, and “production, transmission and distribution of electricity” until FY2015 mainly includes independent power producers (IPP) whose main business is power generation. Since the definition and coverage of the sector of “Electric Utilities” was changed due to the enforcement of the revised Electricity Business Act, which stipulates the full liberalization of the electricity retail market in April 2016, electricity utilities whose main business is power generation such as IPP from FY2016 onwards are included in not “production, transmission and distribution of electricity” [#255330] but “power generation” [#240000].

Table 3-18 shows the correspondence between the sectors of Japan’s Energy Balance Table from the *General Energy Statistics* and those of the CRF.

Table 3-18 Correspondence between sectors of Japan’s Energy Balance Table and those of the CRF (1.A.1)

CRF		General Energy Statistics	
1A1	Energy industries		
1A1a	Public electricity and heat production	Public Power generation	#240000
		Own use; Public Power generation	#301400
		District heat supply	#270000
		Own use; District heat supply	#301500
		Auto power generation; Production, transmission and distribution of electricity (until 2015)	#255330
1A1b	Petroleum refining	Oil products	#220000
		Own use; Oil products	#301200
		Auto power generation; Manufacture of petroleum products	#253171
		Auto steam generation, Manufacture of petroleum products	#263171
		Final energy consumption, Manufacture of petroleum products	#626510
		Non-energy and feedstock use; Manufacture of petroleum products	#951540
1A1c	Manufacture of solid fuels and other energy industries	Manufacture of coal products	#210000
		Own use; Coal products	#301100
		Auto power generation; Manufacture of coal products and miscellaneous	#253175
		Auto steam generation, Manufacture of coal products and miscellaneous	#263175
		Final energy consumption; Manufacture of coal products and miscellaneous	#626550
		Gas conversion and production	#230000
		Own use; Gas conversion and production	#301300

Note: #95xxxx items are subtracted as non-energy use activities.

➢ *Gross calorific value*

The gross calorific values (GCV) used in *General Energy Statistics* are adopted. Table 3-19 shows the trends in GCV for each fuel type. *General Energy Statistics* adopts "actual calorific values" calculated based on annual official statistics for some fuel types which can be recalculated. For other fuel types which cannot be recalculated and whose composition is stable, "standard calorific values" based on latest measurement data available at the time, relevant official statistics and documents are adopted.

The "standard calorific values" are revised approximately once in every 5 years. The revision was conducted to the values of FY2000, 2005, 2013 and 2018.

The GCV trends for solid fuels are declining since 1990. From 1970 to 1990, Japanese steel manufacturers used conventional coking coal for feedstock for coke, but due to the shortage of coking coal and the increase of price, they developed a new coke making technology to use steam coal with pre-treatment as feedstock for coke instead. Similarly, they changed PCI coal from coking coal and steam coal mixture to steam coal with pre-treatment. The Japanese steel manufacturers have been trying to make high-quality coke from cheap coal for economic reasons. Because conventional coking coal has a higher carbon content and GCV than steam coal, and because the new technology was introduced gradually, the apparent GCV gradually decreased in these years.

Table 3-19 Trends in gross calorific value of each fuel type

Fuel				Code	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Solid fuels	Coal		Steel making coal	$0110	MJ/kg	31.8	30.5	29.0	29.0	28.9	28.9	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.8	28.7
			Coking coal	$0111	MJ/kg	31.8	30.5	29.1	29.1	29.1	29.1	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9	28.9
			Pulverized coal injection (PCI) coal	$0112	MJ/kg	31.8	30.5	28.2	28.2	28.2	28.2	28.0	28.0	28.0	28.0	28.0	28.3	28.3	28.3	28.3
			Imported steam coal	$0121	MJ/kg	26.0	26.0	26.6	25.7	25.7	25.7	26.0	26.0	26.0	26.0	26.0	26.1	26.1	26.1	26.1
			Imported steam coal for general use	$0122	MJ/kg	26.0	26.0	26.6	25.7	25.7	25.7	26.0	26.0	26.0	26.0	26.0	26.1	26.1	26.1	26.1
			Imported steam coal for power generation use	$0123	MJ/kg	24.9	26.1	26.4	25.5	25.3	25.3	26.0	25.5	25.3	25.1	25.0	24.8	24.5	24.4	24.8
			Indigenous produced steam coal	$0124	MJ/kg	24.3	24.3	22.5	22.5	22.5	22.5	25.3	25.3	25.3	25.3	25.3	24.2	24.2	24.2	24.2
			Hard coal, anthracite & lignite	$0130	MJ/kg	27.2	27.2	27.2	26.9	26.9	26.9	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8
	Coal Products		Coke	$0211	MJ/kg	30.1	30.1	30.1	29.4	29.4	29.4	29.2	29.2	29.2	29.2	29.2	29.0	29.0	29.0	29.0
			Coal tar	$0212	MJ/kg	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3
			Coal briquette	$0213	MJ/kg	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9
			Coke oven gas	$0221	MJ/m^3	21.5	21.6	21.3	21.4	21.3	20.7	18.9	18.9	18.9	18.9	18.9	18.4	18.4	18.4	18.4
			Blast furnace gas	$0222	MJ/m^3	3.5	3.6	3.6	3.4	3.4	3.4	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
			Converter furnace gas	$0225	MJ/m^3	8.4	8.4	8.4	8.4	8.4	8.4	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Liquid fuels	Oil		Crude oil for refinery use	$0310	MJ/L	38.3	38.3	38.2	38.1	38.2	38.1	38.2	38.2	38.2	38.2	38.2	38.2	38.1	38.1	38.1
			Crude oil for refinery use	$0311	MJ/L	38.3	38.3	38.2	38.1	38.2	38.1	38.2	38.2	38.2	38.2	38.2	38.2	38.1	38.1	38.1
			Residual and straight run fuel oil for refinery use	$0312	MJ/L	38.3	38.3	38.2	38.1	38.2	38.1	41.3	40.9	40.6	40.8	40.3	40.2	40.1	39.9	39.8
			Crude oil for power generation use	$0320	MJ/L	39.1	39.2	39.6	38.5	39.7	39.3	39.3	39.4	39.8	40.0	39.5	39.8	40.1	40.4	40.5
			Bituminous mixture fuel	$0321	MJ/kg	30.1	30.3	29.9	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4
			Natural gas liquid (NGL) & condensate	$0330	MJ/L	35.7	35.5	35.4	35.0	34.8	34.8	34.8	34.7	34.6	34.8	34.5	34.5	34.6	34.6	34.5
			NGL&condensate for refinery use	$0331	MJ/L	35.7	35.5	35.4	35.0	34.8	34.8	34.8	34.7	34.7	34.8	34.6	34.5	34.7	34.6	34.6
			NGL&condensate for power generation use	$0332	MJ/L	35.7	35.5	35.4	35.0	34.8	34.8	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.5
			NGL&condensate for petrochemical use	$0333	MJ/L	35.7	35.5	35.4	35.0	34.8	34.8	34.6	34.5	34.4	34.7	34.4	34.3	34.3	34.3	34.5
	Fuel oil		Pure naphtha	$0420	MJ/L	33.6	33.6	33.6	33.5	33.5	33.5	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3
			Reformate	$0421	MJ/L	35.1	35.1	35.1	35.1	35.1	35.1	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7
			Gasoline (crude oil origin)[1]	$0431	MJ/L	34.6	34.6	34.6	34.6	34.6	34.6	33.4	33.4	33.4	33.4	33.4	33.4	33.4	33.4	33.4
			Gasoline (biofuel blended)[2]		MJ/L	34.6	34.6	34.6	34.6	34.5	34.5	33.3	33.3	33.2	33.2	33.2	33.2	33.2	33.1	33.2
			Jet fuel oil	$0432	MJ/L	36.4	36.4	36.7	36.7	36.7	36.7	36.3	36.3	36.2	36.3	36.4	36.4	36.3	36.3	36.3
			Kerosene	$0433	MJ/L	36.8	36.8	36.8	36.7	36.7	36.7	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5	36.5
			Gas oil or diesel oil (crude oil origin)[1]	$0434	MJ/L	38.1	38.1	38.2	37.8	38.1	37.9	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
			Gas oil or diesel oil (biofuel blended)[2]		MJ/L	38.1	38.1	38.2	37.8	38.1	37.9	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0
			Fuel oil A	$0436	MJ/L	39.7	39.6	39.3	39.1	39.9	39.8	38.9	38.9	38.9	38.9	38.9	38.9	38.9	38.9	38.9
			Fuel oil C	$0437	MJ/L	40.2	40.3	40.3	40.3	40.4	40.6	41.2	40.9	41.4	41.0	41.0	41.1	41.0	41.1	41.0
			Fuel oil B	$0438	MJ/L	40.2	40.2	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4
			Fuel oil C for general use	$0439	MJ/L	40.2	40.3	40.3	40.3	40.4	40.6	41.2	40.9	41.4	41.0	41.0	41.1	41.0	41.1	41.0
			Fuel oil C for power generation use	$0440	MJ/L	41.1	41.1	41.3	41.2	41.3	41.2	41.2	41.4	41.0	41.5	41.6	41.6	41.7	41.6	41.6
		Miscellaneous oil products	Lubricant oil	$0451	MJ/L	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2
			Other heavy oil products	$0452	MJ/kg	39.2	39.3	39.4	39.4	39.4	39.6	40.2	39.9	40.4	40.0	40.0	40.1	40.0	40.1	40.0
			Oil coke	$0455	MJ/kg	35.6	35.6	35.6	29.9	29.9	29.9	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	34.1
			Galvanic furnace gas	$0456	MJ/m^3	8.4	8.4	8.4	8.4	8.4	8.4	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
			Refinery gas	$0457	MJ/m^3	39.3	39.3	44.9	44.9	44.9	44.9	46.1	46.1	46.1	46.1	46.1	46.1	46.1	46.1	46.1
			Liquefied petroleum gas (LPG)	$0458	MJ/kg	50.5	50.6	50.7	50.7	50.8	50.8	50.1	50.1	50.1	50.1	50.1	50.1	50.1	50.1	50.1
Gaseous fuels	Natural Gas		Liquefied natural gas (LNG)	$0510	MJ/kg	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.7	54.7	54.7	54.7
			Indigenous natural gas	$0520	MJ/m^3	42.1	42.4	42.6	42.9	44.7	44.8	39.6	39.6	39.6	39.6	39.6	38.4	38.4	38.4	38.4
			Indigenous natural gas	$0521	MJ/m^3	42.1	42.4	42.6	42.9	44.7	44.8	39.6	39.6	39.6	39.6	39.6	38.4	38.4	38.4	38.4
			Coal mining gas	$0522	MJ/m^3	36.0	36.0	16.7	16.7	16.7	16.7	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1
			Boil off gas from crude oil	$0523	MJ/m^3	42.1	42.4	42.6	42.9	44.7	44.8	39.6	39.6	39.6	39.6	39.6	38.4	38.4	38.4	38.4
	City gas		City gas	$0610	MJ/m^3	41.9	41.9	41.1	44.8	44.8	44.8	40.8	40.8	40.7	40.7	40.8	40.0	40.0	39.9	40.0
			Small scale community gas	$0620	MJ/m^3	105.4	103.6	102.3	101.5	101.1	101.0	96.0	95.7	95.3	95.3	95.0	94.8	94.9	94.3	94.1
(Reference)	Biomass		Woods	$N131	MJ/kg	15.4	15.4	15.4	19.9	17.4	17.9	17.6	17.2	17.0	13.1	12.9	13.6	14.8	14.5	14.8
			Waste woods	$N132	MJ/kg	16.7	16.7	16.7	16.3	16.3	16.3	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1
			Bioethanol	$N134	MJ/L	23.9	23.9	23.9	23.9	23.9	23.9	23.4	23.4	23.4	23.4	23.4	23.4	23.4	23.4	23.4
			Biodiesel	$N135	MJ/L	23.9	23.9	23.9	23.9	23.9	23.9	23.4	23.4	23.4	23.4	23.4	23.4	23.4	23.4	35.6
			Thermal use of black liquor	$N136	MJ/kg	12.6	12.6	12.6	13.2	13.2	13.2	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6
			Gas biomass	$N137	MJ/m^3	23.4	23.4	23.4	23.4	23.4	23.4	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2

1) Used in the reference approach.
2) Used in the sectoral approach.
3) Until FY2012, in principle, the values of gases are indicated at 0 °C and 1 atm (273.15 K, 101.325 kPa) (normal condition), those of liquids are indicated at normal temperature, those of solids are indicated "with moisture and ash" state. After FY2013, in principle, the values of gases and liquids are indicated at 25 °C and 1 bar (298.15 K, 100 kPa) (standard ambient temperature and pressure (SATP)), and those of solids are indicated "with moisture and ash" state.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties of emission factors are set by the upper and lower limits of 95% confidence intervals derived from the actual measurements of carbon emission factors. The upper and lower limits of uncertainties of activity data are set by the standard deviations of the statistical discrepancies [#400000] divided by domestic primary energy supply [#190000] from 1990 to 2017 for solid, liquid and gaseous fuels respectively, taking account of difficulty to set the uncertainties of energy consumption by each fuel and sector from the *General Energy Statistics*, or the reference of activity data. As a result, the uncertainty was determined to be −4% to +2% for CO_2 emissions from combustion of solid, liquid and gaseous fuels as a whole for the fuel combustion category. See section 7.4.3 for the uncertainty of CO_2 emissions from waste incineration for energy purposes and with energy recovery.

- ***Time-series Consistency***

The emissions were calculated in a consistent manner in all time-series.

The carbon emission factors of all energy sources have been calculated by a consistent estimation method in all time-series.

The activity data was used from data in the *General Energy Statistics* in all time-series, and the statistics were made by a consistent estimation method in all time-series.

The fossil fuel consumption of "Production, Transmission and Distribution of Electricity" [#255330] under "Auto power production" of the *General Energy Statistics* for the period of FY1990 through FY2015 are included in the activity data of Public electricity and heat production subcategory (1.A.1.a) in light of time-series consistency. See the Activity Data section under 3.2.4. b).

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY2016-2020 were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, CO_2 emissions from other fossil fuels for the period of FY2005-FY2020 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

- ***Recalculations made to the General Energy Statistics***

The past data in the *General Energy Statistics* were revised due to the following reasons.

1) Change of the estimation methodology for compiling the *General Energy Statistics*

There is no change of the estimation methodology for compiling the *General Energy Statistics* in FY2021.

2) Change due to the update of the statistical data used in the *General Energy Statistics*

Various statistical data related to energy are used for compiling the *General Energy Statistics*, and they are sometimes revised in the next year. For example, respondents of statistical surveys may correct their reported values due to mistakes. In this case, the *General Energy Statistics* may reflect these updated statistical values. The table below shows the FY2020 data that were updated during the compilation of the *General Energy Statistics* in FY2021.

Table 3-20 Update of the statistical data used for the *General Energy Statistics*

No	Statistical data used for the *General Energy Statistics*	Place where the data are reflected in the *General Energy Statistics*
1	*Mineral Resources and Petroleum Products Statistics* (The data for Jan. - Dec. 2020 after the annual revision were applied.)	$0300 Crude oil, $0500 Natural Gas; #110000 Indigenously Produced, #120000 Imports, #160000 Exports, #190000 Stockpile Change / Supply $0400 Oil Products, #222000 Oil Refinery
2	*Trade Statistics of Japan*	$0100 Coal, $0200 Coal Products, $0455 Petroleum Coke, $0458 LPG, $0510 LNG, $N130 Biomass; #120000 Imports, #160000 Exports
3	*Current Survey of Energy Consumption* (The data for Jan. - Dec. 2020 after the annual revision were applied.)	Large scale manufacturing industries under #250000 Auto Power Generation, #260000 Auto Steam Generation, and #500000 Final Energy Consumption. #355000 Manufacturing Industry, Large Scale, Stockpile Change
4	*Current Survey of Production Concerning Gas Industry*	$0610 City Gas; #231000 City Gas Conversion and Production, #700000 Residential $0620 Small Scale Community Gas; #232000 Small Scale Community Gas Conversion and Production, #650000 Commercial Industry, #700000 Residential
5	*Forestry Output*	Estimation for #611200 Forestry
6	Domestic production of biodiesels	$N135 Biodiesel, #110000 Indigenously Produced
7	Data regarding heat utilization of biomass and waste	$N130 Biomass, $N210 Refuse Energy Use; #260000 Auto Steam Generation
8	*Statistical Survey on Farm Management*	Estimation for #611100 Agriculture
9	*Statistical Survey on Agriculture Commodity Price Index*	Estimation for #611100 Agriculture
10	*Survey on Petroleum Products Retail Price*	Estimation for #611100 Agriculture, #611200 Forestry, #611300 Fishery Except Aquaculture
11	City gas consumption by region	Regional breakdown of $0610 City Gas; #700000 Residential
12	Diesel oil and heavy fuel oil for water passenger transport	$0434 Diesel Oil; #814000 Water Passenger Transport $0435 Heavy Fuel Oil; #814000 Water Passenger Transport
13	*Railway Statistical Yearbook*	$0434 Diesel oil; $1200 Electricity; #813000 Railway Passenger Transport, #852000 Railway Freight Transport

Note:
1) "$0000" means a column number of the *General Energy Statistics*. "#000000" means a row number of the statistics.
2) The waste data shown in No 7 are not used for the estimation of the GHG emissions to avoid double counting.

In addition, ANRE inquired of the electric utilities that reported Bituminous Mixture Fuel / Orimulsion ($0321) to the *Electric Power Statistics*, then it was revealed that some electric utilities actually combusted Miscellaneous Heavy Oil Products ($0454) or Petroleum coke ($0455). It led to a recalculation for the period of FY2016 through FY2020.

For some energy types, if total supply amount is more than total demand amount, the supply excess amount is regarded as the consumption by unknown sectors, and it is allocated to "Unable to classify" under the Commercial Industry sector and/or "Own Use" under the Energy Transformation & Own Use sector.

If total demand amount is more than total supply amount, the demand excess amount is propotionally subtracted from the sectors where sample surveys (the *Structural Survey of Energy Consumption* and the *Statistical Survey of Motor Vehicle Fuel Consumption*) are used for estimation, because overestimation can occur in these sectors.

Therefore, the consumption under the sectors such as Manufacturing, Commercial Industry, Transportation can slightly changes for these energy types if the consumption under sectors elsewhere changes due to the updates of data. In any cases, the total consumption remains unchanged because it is capped with the supply amount.

f) Category-specific Planned Improvements

It is planned to revise the "standard calorific values" and their corresponding carbon emission factors approximately once in every 5 years. The consideration of the next revision is in progress.

3.2.5. CH_4 and N_2O Emissions from Energy Industries (1.A.1.: CH_4, N_2O)

a) Category Description

This section provides the methods for estimating CH_4 and N_2O emissions from public electricity and heat production (1.A.1.a), petroleum refining (1.A.1.b), and manufacture of solid fuels and other energy industries (1.A.1.c).

CH_4 is generated as a result of incomplete combustion, and as such, if sufficient care is taken to ensure complete combustion, CH_4 will not be generated. N_2O is generated through the reaction of nitrogen monoxide (NO), which is generated by combustion, with nitrogen-containing volatile components in fuels. Consequently, the higher the nitrogen content of the fuel used, the more likely it is that N_2O will be generated. However, the reaction that produces N_2O is also dependent on temperature, with N_2O more likely to be generated at lower temperatures. More N_2O will accordingly be generated by furnaces such as fluidized bed boilers that burn fuel at low temperatures (800–900°C). N_2O can also be generated when NO_X contacts catalysts for NO_X removal.

The contribution of CH_4 and N_2O emissions from this category relative to total GHG emissions is small in Japan. The N_2O emissions from fluidized bed boilers are relatively large in this category. The N_2O emissions from fluidized bed boilers contributed to the increase of GHG emissions from this category, since fluidized bed boilers have been introduced in Japan from 1990. The N_2O emissions from solid fuel in 1.A.1.a (Public electricity and heat production) increased between FY1994 and FY1995. The reason for the increase was that a new large sized fluidized-bed boiler for power generation was introduced in FY1995. As a result, the solid fuel consumption of fluidized-bed boilers for public power generation increased in FY1995, resulting in an increase of N_2O emissions from solid fuels in this category. In recent years, some fluidized bed boilers have been decommissioned, resulting in an decrease of the emissions.

CH_4 emitted in coke production is reported in this category. We have no measurements of the concentration of N_2O in the gas leaking from coking furnace lids, but we decided that N_2O emissions from this source are not applicable the reason being that experts say that N_2O is likely not produced because the atmosphere in a coke oven is normally at least 1,000°C, and is reducing.

b) Methodological Issues

- ***Estimation Method***

➢ *Furnaces*

Because it is possible to use fuel-specific, sector-specific and furnace-specific activity data, and also to set country-specific emission factors by furnace, CH_4 and N_2O emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2).

The estimation equation is as follows. The emissions were calculated by multiplying fuel-specific, furnace-specific and sector-specific activity data by fuel-specific and furnace-specific emission factors.

$$E = \sum_{ij} \left(EF_{ij} \times A_{ijk} \right)$$

E	: Emissions from combustion of fuel by stationary sources [kg-CH_4, kg-N_2O]
EF_{ij}	: Emission factor for fuel type *i*, furnace type *j* [kg-CH_4/TJ, kg-N_2O/TJ]
A_{ijk}	: Fuel consumption for fuel type *i*, furnace type *j*, sector *k* [TJ]
i	: Fuel type
j	: Furnace type
k	: Sector

➢ *Biomass boilers*

Because it is possible to use country-specific emission factors of power generation facility and heat utilization facility, CH_4 and N_2O emissions from combustion in biomass boilers are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2). However, CH_4 and N_2O emissions of gas biomass are calculated by using Tier 1, as country-specific emission factors are not available.

➢ *Coke Production*

CH_4 emissions from coke production were calculated by multiplying coke production amount by Japan's country-specific emission factor, based on the method given in the *2006 IPCC Guidelines*. The emissions were reported under manufacture of solid fuels and other energy industries (1.A.1.c).

➢ *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3

- ***Emission Factors***

➢ *Furnaces*

Chimney flue CH_4, N_2O and O_2 concentrations, theoretical (dry) exhaust gas volumes, theoretical air volumes, and higher heating values (gross calorific values (GCV)) shown in Table 3-21 were employed based on data obtained from surveys conducted in Japan (Table 3-22) to establish emission factors for each kind of facility using the following combustion calculation formula.

$$EF = C_{CH_4,N_2O} \times \{G_0' + (m-1) \times A_0\} \times MW/V_m/GCV$$

EF	:	Emission factor [kg-CH_4/TJ, kg-N_2O/TJ]
$C_{CH4\ or\ N2O}$	:	CH_4 or N_2O concentration in exhaust gas [ppm]
G_0'	:	Theoretical exhaust gas volume for each fuel combustion (dry) [m^3N/original unit]
A_0	:	Theoretical air volume for each fuel combustion [m^3N/original unit]
m	:	Air ratio = actual air volume / theoretical air volume [-]
MW	:	Molecular weight of CH_4 (constant) =16 [g/mol]

		Molecular weight of N_2O (constant) =44 [g/mol]
V_m	:	One mole ideal gas volume in standardized condition (constant) =22.4 [$10^{-3}m^3$/mol]
GCV	:	Gross calorific value for each fuel combustion [MJ/ original unit]

However, the air ratio "*m*" is approximately provided with O_2 concentration in exhaust gas, as shown in the equation below.

$$m = \frac{21}{21 - C_{O_2}}$$

C_{O_2}	:	O_2 concentration in exhaust gas [%]

CH_4 and N_2O emission factors by each fuel and furnace types were averaged after dividing the emission factor of each kind of facilities according to fuel and furnace types (Table 3-23, Table 3-24). Anomalous values were excluded according to t-testing or expert judgment when calculating the average values. Please refer to MOE (2006a) for the actual measurement data to establish the emission factors.

- ***Emission Factors with Air-Intake Adjustment***

In Japan, until the GHG inventory was submitted in 2005, based on the results of past discussions (e.g., Japan Society for Atmospheric Environment (1996) relating to methodologies for calculating emissions, the non-CO_2 emission factors from stationary combustion were established after accounting for the differences between emission gas concentrations and intake gas concentrations (i.e., air-intake adjustment). With this methodology, it was possible to obtain negative emission factors for some emission sources if the measurement data showed that concentrations in emission gas were lower than those in intake gas, possibly because CH_4 and N_2O present in the intake gas had been either oxidized or decomposed through the combustion process.

However, during the in-country review that was conducted in 2003, the Expert Review Team recommended Japan to replace negative emission factors by the corresponding positive ones, because, in the interest of enabling better international comparisons, the *Revised 1996 IPCC Guidelines* as well as *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (hereinafter referred to as *GPG2000*) indicate that positive emission factors should be used for calculations of emissions based on actual emissions of CH_4 and N_2O in the flue gases, though air-intake adjustments might enable accurate determination of emissions. Thus, in the inventories submitted in 2006 and thereafter, the air-intake adjustments were not made, and emission factors were determined by using the actual measured CH_4 and N_2O concentrations in emission gases.

Table 3-21 Theoretical exhaust gas and air volumes, and higher heating values for different fuels

Fuel type	Original unit	Theoretical exhaust gas volume (dry) G_0' 1)	Gross calorific value GCV 2)	Theoretical air volume A_0 1)	Remarks
		m^3N/L, kg, m^3N	kJ/L, kg, m^3N, kWh	m^3N/L, kg, m^3N	
Fuel oil A	L	8.900	39,100	9.500	a
Fuel oil B	L	9.300	40,400	9.900	a
Fuel oil C	L	9.500	41,700	10.100	a
Diesel oil	L	8.800	38,200	9.400	a
Kerosene	L	8.400	36,700	9.100	a
Crude oil	L	8.747	38,200	9.340	a
Naphtha	L	7.550	34,100	8.400	a
Other liquid fuels	L	9.288	37,850	9.687	b
Other liquid fuels (heavy)	L	9.064	37,674	9.453	b
Other liquid fuels (light)	L	9.419	35,761	9.824	b
Steam coal	kg	7.210	26,600	7.800	a
Coke	kg	7.220	30,100	7.300	a
Harvested wood	kg	3.450	14,367	3.720	b
Charcoal	kg	7.600	30,500	7.730	c
Other solid fuels	kg	7.000	33,141	7.000	b
City gas	m^3	9.850	46,047	10.949	b
Coke oven gas (COG)	m^3	4.500	21,100	4.800	a
Blast furnace gas (BFG)	m^3	1.460	3,410	0.626	a
Liquefied natural gas (LNG)	kg	11.766	54,500	13.093	a
Liquefied petroleum gas (LPG)	kg	11.051	50,200	12.045	a
Converter furnace gas (CFG) (Linz-Donawitz gas: LDG)	m^3	2.200	8,410	1.500	a
Refinery gas (off-gas)	m^3	11.200	44,900	12.400	a
Other gaseous fuels	m^3	4.587	28,465	4.096	b
Other gaseous fuels (petroleum)	m^3	7.889	40,307	7.045	b
Other gaseous fuels (steel)	m^3	2.812	19,097	2.511	b
Other gaseous fuels (mining)	m^3	3.396	38,177	3.032	b
Other gaseous fuels (other)	m^3	4.839	23,400	4.321	b
Pulping waste liquor	kg	3.245	13,898	3.499	b
Electricity	kWh		3,600		a

Note:

1) Theoretical exhaust gas and air volumes are the standard values given in the *General Survey of the Emissions of Air Pollutants* (MOE), except for city gas, LNG, and LPG, for which values calculated from constituent data were used. For city gas, the constituents of city gas (13A) were considered to be representative.

2) Regarding higher heating value, the standard calorific values given in the *General Energy Statistics* were used for items marked a, and the standard values given in *General Survey of the Emissions of Air Pollutants* (based on the 1992 survey) for items marked b in the Remarks column. The higher heating value for steam coal (imported) was used as the higher heating value of steam coal. The item marked c in the Remarks column was set by the 2005 Committee for the Greenhouse Gases Emissions Estimation Methods based on reference materials.

Table 3-22 References for measurement data used in the establishment of emission factors

	References
1	Hokkaido Prefecture, *Report of GHG Emissions Intensity from Stationary Combustion*, 1991
2	Hyogo Prefecture, *Report of GHG Emissions Intensity from Stationary Combustion*, 1991
3	Osaka Prefecture, *Study of GHG Emissions Intensity from Stationary Combustion*, 1991
4	Hokkaido Prefecture, *Report of GHG Emissions Intensity from Stationary Combustion*, 1992
5	Hyogo Prefecture, *Report of GHG Emissions Intensity from Stationary Combustion*, 1992
6	City of Kitakyushu, *Report of GHG Emissions Intensity from Stationary Combustion*, 1992
7	Hyogo Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1993
8	Hyogo Prefecture, *Report of GHG Emissions Intensity from Stationary Combustion*, 1994
9	Kanagawa Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1995
10	Niigata Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1995
11	Osaka Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1995
12	Hiroshima Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1995
13	Fukuoka Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1995
14	City of Osaka, *Study of GHG Emission Factors from Stationary Combustion*, 1995
15	City of Kobe, *Study of GHG Emission Factors from Stationary Combustion*, 1995
16	Hokkaido Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
17	Ishikawa Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
18	Kyoto Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
19	Osaka Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
20	Hyogo Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
21	Hiroshima Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
22	Fukuoka Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1996
23	Kyoto Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1997
24	Hyogo Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1997
25	Fukuoka Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1997
26	Japan Society for Atmospheric Environment, *Report on Emission Factor Results for Combustion Facilities*, 1996
27	Osaka Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1999
28	Hyogo Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 2000
29	The Institute of Applied Energy, *Report for Trend of Fuel Quality in Lowering Environmental Atmospheric Quality*, 2000
30	MOE, Measurement Data prepared by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY1999, 1999
31	Data prepared by the Federation of Electric Power Companies of Japan
32	IPCC, *2006 IPCC Guidelines*, 2006
33	Forestry Agency Wood Use Promotion Division, *Promotion of Wood Use and Energy-saving and CO_2 Reduction Demonstration Project Fiscal Year 2014*, 2015
34	MOE, *Survey on Grasp of the Actual Condition of Greenhouse Gas Emissions from Biomass Boilers Fiscal Year 2017*, 2018

Table 3-23 CH_4 emission factors for different fuels and furnaces in GCV basis (unit: kg-CH_4/TJ)

<table>
<tr><th rowspan="2" colspan="3"></th><th rowspan="2"></th><th>Boilers</th><th colspan="9">Industrial furnaces</th><th colspan="3">Internal combustion engines</th></tr>
<tr><th>Boiler</th><th>Sintering furnace for smelting of metals (except copper, lead, and zinc)</th><th>Pelletizing furnace (steel and non-ferrous metal)</th><th>Metal rolling furnace, metal treating furnace, metal forging furnace</th><th>Oil and gas furnaces</th><th>Catalytic regenerator</th><th>Kilns for ceramic products (except cement kiln)</th><th>Drying kilns for aggregate, cement raw material, brick raw material and mold</th><th>Detergent drying kiln, Other drying kilns</th><th>Other industrial furnaces</th><th>Gas turbine</th><th>Diesel engine</th><th>Gas engine, gasoline engine</th></tr>
<tr><th colspan="3">Fuel</th><th>Code[1)]</th><th>0100</th><th>0306
0307</th><th>0312
0313</th><th>0600</th><th>0202
0700</th><th>0801</th><th>0906
-
0914</th><th>1101
-
1104</th><th>1105
1106</th><th>2)</th><th>2900</th><th>3000</th><th>3100
3200</th></tr>
<tr><td rowspan="8">Coal</td><td colspan="2">Steel Making Coal</td><td>$0110</td><td rowspan="8">0.13</td><td rowspan="8">31</td><td rowspan="8">1.7</td><td rowspan="8">13</td><td rowspan="8">13</td><td rowspan="8">NA</td><td rowspan="8">1.5</td><td rowspan="8">29</td><td rowspan="8">6.6</td><td rowspan="8">13</td><td rowspan="8">NA</td><td rowspan="8">NA</td><td rowspan="8">NA</td></tr>
<tr><td colspan="2">Coking Coal</td><td>$0111</td></tr>
<tr><td colspan="2">Pulverized Coal Injection Coal</td><td>$0112</td></tr>
<tr><td colspan="2">Imported Steam Coal</td><td>$0121</td></tr>
<tr><td colspan="2">Imported Coal for General Use</td><td>$0122</td></tr>
<tr><td colspan="2">Imported Coal for Power Generation</td><td>$0123</td></tr>
<tr><td colspan="2">Indigenous Produced Steam Coal</td><td>$0124</td></tr>
<tr><td colspan="2">Hard Coal, Anthracite & Lignite</td><td>$0130</td></tr>
<tr><td rowspan="6">Coal Products</td><td colspan="2">Coke</td><td>$0211</td><td rowspan="3">0.13</td><td rowspan="6">31</td><td rowspan="6">1.7</td><td rowspan="3">13</td><td rowspan="3">13</td><td rowspan="3">0.054</td><td rowspan="6">1.5</td><td rowspan="6">29</td><td rowspan="6">6.6</td><td rowspan="3">13</td><td rowspan="3">NA</td><td rowspan="3">NA</td><td rowspan="3">NA</td></tr>
<tr><td colspan="2">Coal Tar</td><td>$0212</td></tr>
<tr><td colspan="2">Coal Briquette</td><td>$0213</td></tr>
<tr><td colspan="2">Coke Oven Gas</td><td>$0221</td><td rowspan="3">0.23</td><td rowspan="3">0.43</td><td rowspan="3">0.16</td><td rowspan="3">NA</td><td rowspan="3">2.3</td><td rowspan="3">0.81</td><td rowspan="3">0.70</td><td rowspan="3">54</td></tr>
<tr><td colspan="2">Blast Furnace Gas</td><td>$0222</td></tr>
<tr><td colspan="2">Converter Furnace Gas</td><td>$0225</td></tr>
<tr><td rowspan="4">Oil</td><td colspan="2">Crude Oil for Refinery</td><td>$0310</td><td rowspan="4">0.10</td><td rowspan="4">31</td><td rowspan="4">1.7</td><td rowspan="4">0.43</td><td rowspan="4">0.16</td><td rowspan="4">NA</td><td rowspan="4">1.5</td><td rowspan="4">29</td><td rowspan="4">6.6</td><td rowspan="4">0.83</td><td rowspan="4">0.81</td><td rowspan="4">0.70</td><td rowspan="4">54</td></tr>
<tr><td colspan="2">Crude Oil for Power Generation</td><td>$0320</td></tr>
<tr><td colspan="2">Bituminous Mixture Fuel</td><td>$0321</td></tr>
<tr><td colspan="2">Natural Gas Liquid & Condensate</td><td>$0330</td></tr>
<tr><td rowspan="17">Oil Products</td><td colspan="2">Pure Naphtha</td><td>$0420</td><td rowspan="7">0.26</td><td rowspan="17">31</td><td rowspan="17">1.7</td><td rowspan="12">0.43</td><td rowspan="12">0.16</td><td rowspan="12">NA</td><td rowspan="17">1.5</td><td rowspan="17">29</td><td rowspan="17">6.6</td><td rowspan="12">0.83</td><td rowspan="12">0.81</td><td rowspan="12">0.70</td><td rowspan="12">54</td></tr>
<tr><td colspan="2">Reformate</td><td>$0421</td></tr>
<tr><td colspan="2">Gasoline</td><td>$0431</td></tr>
<tr><td colspan="2">Jet Fuel Oil</td><td>$0432</td></tr>
<tr><td colspan="2">Kerosene</td><td>$0433</td></tr>
<tr><td colspan="2">Gas Oil / Diesel Oil</td><td>$0434</td></tr>
<tr><td colspan="2">Fuel Oil A</td><td>$0436</td></tr>
<tr><td colspan="2">Fuel Oil C</td><td>$0437</td><td rowspan="4">0.10</td></tr>
<tr><td colspan="2">Fuel Oil B</td><td>$0438</td></tr>
<tr><td colspan="2">Fuel Oil C for General Use</td><td>$0439</td></tr>
<tr><td colspan="2">Fuel Oil C for Power Generation</td><td>$0440</td></tr>
<tr><td colspan="2">Lublicant Oil</td><td>$0451</td><td>0.26</td></tr>
<tr><td colspan="2">Other Heavy Oil Products</td><td>$0452</td><td rowspan="2">0.13</td><td rowspan="2">13</td><td rowspan="2">13</td><td rowspan="2">0.054</td><td rowspan="2">13</td><td rowspan="2">NA</td><td rowspan="2">NA</td><td rowspan="2">NA</td></tr>
<tr><td colspan="2">Petroleum Coke</td><td>$0455</td></tr>
<tr><td colspan="2">Galvanic Furnace Gas</td><td>$0456</td><td rowspan="3">0.23</td><td rowspan="3">0.43</td><td rowspan="3">0.16</td><td rowspan="3">NA</td><td rowspan="3">2.3</td><td rowspan="3">0.81</td><td rowspan="3">0.70</td><td rowspan="3">54</td></tr>
<tr><td colspan="2">Refinary Gas</td><td>$0457</td></tr>
<tr><td colspan="2">Liquified Petroleum Gas</td><td>$0458</td></tr>
<tr><td rowspan="5">Natural Gas</td><td colspan="2">Liquefied Natural Gas</td><td>$0510</td><td rowspan="5">0.23</td><td rowspan="5">31</td><td rowspan="5">1.7</td><td rowspan="5">0.43</td><td rowspan="5">0.16</td><td rowspan="5">NA</td><td rowspan="5">1.5</td><td rowspan="5">29</td><td rowspan="5">6.6</td><td rowspan="5">2.3</td><td rowspan="5">0.81</td><td rowspan="5">0.70</td><td rowspan="5">54</td></tr>
<tr><td colspan="2">Indigenous Natural Gas</td><td>$0520</td></tr>
<tr><td colspan="2">Indigenous Natural Gas</td><td>$0521</td></tr>
<tr><td colspan="2">Coal Mining Gas</td><td>$0522</td></tr>
<tr><td colspan="2">Boil Off Gas from Crude Oil</td><td>$0523</td></tr>
<tr><td rowspan="2">City Gas</td><td colspan="2">City Gas</td><td>$0610</td><td rowspan="2">0.23</td><td rowspan="2">31</td><td rowspan="2">1.7</td><td rowspan="2">0.43</td><td rowspan="2">0.16</td><td rowspan="2">NA</td><td rowspan="2">1.5</td><td rowspan="2">29</td><td rowspan="2">6.6</td><td rowspan="2">2.3</td><td rowspan="2">0.81</td><td rowspan="2">0.70</td><td rowspan="2">54</td></tr>
<tr><td colspan="2">Small Scale Community Gas</td><td>$0620</td></tr>
<tr><td rowspan="7">Biomass Energy</td><td rowspan="2">Woods</td><td>Power generation</td><td rowspan="2">$N131</td><td>0.2</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Heat utilization</td><td>16</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td rowspan="2">Waste Wood</td><td>Power generation</td><td rowspan="2">$N132</td><td>0.2</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Heat utilization</td><td>16</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td colspan="2">Thermal Use of Black Liquor</td><td>$N136</td><td>4.3</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td colspan="2">Gas Biomass</td><td>$N137</td><td>0.9</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td colspan="2">Non Specified Biomass</td><td>$N138</td><td>16</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td><td>NA</td></tr>
</table>

1) The code of energy sources is from the *General Energy Statistics,* and the code of furnaces is from the *General Survey of the Emissions of Air Pollutants.*
2) Other industrial furnaces include industrial furnaces (0200-1100, 1400-2801) not specified in this table. However, for gas producing furnace (0201), blast furnace, converter furnace and open-hearth furnace (except for smelting copper, lead, and zinc) (0400), emission factors are not established in order to avoid double-counting with the generated gas used in the other furnaces. For coke oven (2801), the emission factor is established otherwise (see main text). For electric arc furnace (1200), see Chapter 4.

Table 3-24 N_2O emission factors for different fuels and furnaces in GCV basis (unit: kg-N_2O/TJ)

			Boilers			Industrial furnaces					Internal-combustion engines		
			Boiler (other than fluidized-bed boiler)	Normal pressure fluidized-bed boiler	Pressurized fluidized-bed boiler	Blast furnace (except for smelting copper, lead, and zinc)	Oil and gas furnaces	Catalytic regenerator	Coke oven	Other industrial furnaces	Gas turbine	Diesel engine	Gas engine, gasoline engine
Fuel		Code 1)	0100	0100	0100	0401 0402	0202 0700	0801	2801	2)	2900	3000	3100 3200
Coal	Steel Making Coal	$0110											
	Coking Coal	$0111			0.85								
	Pulverized Coal Injection Coal	$0112											
	Imoorted Steam Coal	$0121											
	Imported Coal for General Use	$0122	0.85	54		NA	1.1	NA	NA	1.1	NA	NA	NA
	Imported Coal for Power Generation	$0123			5.2								
	Indigenous Produced Steam Coal	$0124											
	Hard Coal, Anthracite & Lignite	$0130			0.85								
Coal Products	Coke	$0211											
	Coal Tar	$0212	0.85	54	0.85	NA	1.1	7.3	NA	1.1	NA	NA	NA
	Coal Briquette	$0213											
	Coke Oven Gas	$0221											
	Blast Furnace Gas	$0222	0.17	0.17	0.17	0.047	0.21	NA	0.14	1.2	0.58	2.2	0.85
	Converter Furnace Gas	$0225				NA							
Oil	Crude Oil for Refinery	$0310											
	Crude Oil for Power Generation	$0320	0.22	0.22	0.22	NA	0.21	NA	NA	1.8	0.58	2.2	0.85
	Bituminous Mixture Fuel	$0321											
	Natural Gas Liquid & Condensate	$0330											
Oil Products	Pure Naphtha	$0420											
	Reformate	$0421											
	Gasoline	$0431											
	Jet Fuel Oil	$0432	0.19	0.19	0.19								
	Kerosene	$0433											
	Gas Oil / Diesel Oil	$0434					0.21	NA		1.8	0.58	2.2	0.85
	Fuel Oil A	$0436											
	Fuel Oil C	$0437							NA				
	Fuel Oil B	$0438	0.22	0.22	0.22								
	Fuel Oil C for General Use	$0439				NA							
	Fuel Oil C for Power Generation	$0440											
	Lublicant Oil	$0451	0.19	0.19	0.19								
	Other Heavy Oil Products	$0452	0.85	54	0.85		1.1	7.3		1.1	NA	NA	NA
	Petroleum Coke	$0455											
	Galvanic Furnace Gas	$0456											
	Refinary Gas	$0457	0.17	0.17	0.17		0.21	NA	0.14	1.2	0.58	2.2	0.85
	Liquified Petroleum Gas	$0458							NA				
Natural Gas	Liquefied Natural Gas	$0510							NA				
	Indigenous Natural Gas	$0520											
	Indigenous Natural Gas	$0521	0.17	0.17	0.17	NA	0.21	NA	0.14	1.2	0.58	2.2	0.85
	Coal Mining Gas	$0522											
	Boil Off Gas from Crude Oil	$0523											
City Gas	City Gas	$0610	0.17	0.17	0.17	NA	0.21	NA	0.14	1.2	0.58	2.2	0.85
	Small Scale Community Gas	$0620											
Biomass Energy	Woods – Power generation	$N131	0.87	0.87	0.87	NA	NA	NA	NA	NA	NA	NA	NA
	Woods – Heat utilization		1.6	1.6	1.6	NA	NA	NA	NA	NA	NA	NA	NA
	Waste Wood – Power generation	$N132	0.87	0.87	0.87	NA	NA	NA	NA	NA	NA	NA	NA
	Waste Wood – Heat utilization		1.6	1.6	1.6	NA	NA	NA	NA	NA	NA	NA	NA
	Thermal Use of Black Liquor	$N136	0.17	0.17	0.17	NA	NA	NA	NA	NA	NA	NA	NA
	Gas Biomass	$N137	0.09	0.09	0.09	NA	NA	NA	NA	NA	NA	NA	NA
	Non Specified Biomass	$N138	1.6	1.6	1.6	NA	NA	NA	NA	NA	NA	NA	NA

1) The code of energy sources is from the *General Energy Statistics,* and the code of furnaces is from the *General Survey of the Emissions of Air*
2) Other industrial furnaces include industrial furnaces (0200-1100, 1400-2801) not specified in this table. However, for gas producing furnace (0201), converter furnace (except for smelting copper, lead, and zinc) (0403, 0404) and open-hearth furnace (0405, 0406), emission factors are not established in order to avoid double-counting with the generated gas used in the other furnaces. For electric arc furnace (1200), see Chapter 4.

➢ *Biomass boilers*

CH_4 and N_2O emission factors by each fuel and each faciliy in biomass boilers are shown in Table 3-23 and Table 3-24.

The country-specific emission factors of woods, waste woods and non-specified biomass were established based on the actual measurements from MOE (2018) and Forestry Agency (2015), considering the utilization situation of woody biomass.

The emission factors of black liquor were established by using theoretical (dry) exhaust gas volumes, theoretical air volumes, and higher heating values shown in Table 3-21.

For the emission factors of gas biomass, the default values of the *2006 IPCC Guidelines* (Vol.2, page 2.16-2.23, table 2.2-2.5) were adopted. As the default values are based on net calorific values, they were converted to the GCV basis by multiplying them by 0.9 (for fuels with gaseous state) (*2006 IPCC Guidelines*, Vol.2, page 1.16).

➢ *Coke production*

CH_4 emissions from coke production come from two sources: CH_4 in combustion exhaust gas from gas leakage from the carbonization chamber to the combustion chamber, and CH_4 emitted from the coking furnace lid, the desulfurization tower, or the desulfurization recycling tower, in the carbonization process of coal.

- ***Combustion exhaust gas***

The concentration of CH_4 in the exhaust gas from coking furnaces operated by five companies at seven operating sites (surveyed by the Japan Iron and Steel Federation (JISF), actual results for FY1999) was weighted by the production amount of coke to derive a weighted average, which was established as the emission factor. The emission factor is 0.089 [kg-CH_4/t].

- ***Coking furnace lid, desulfurization tower, and desulfurization recycling tower***

JISF has had a voluntary plan in place since FY1997 to manage noxious atmospheric pollutants, and CH_4 emissions have been estimated from emissions of other substances from the lid of coking furnaces. The emission factor has been established by taking a weighted average using this data and the amount of production of coke.

Table 3-25 Emission factor of CH_4 from coking furnace lids, desulfurization towers, and desulfurization recycling towers

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Emission factors	kg-CH_4/t	0.238	0.238	0.119	0.043	0.031	0.045	0.039	0.038	0.036	0.033	0.031	0.027	0.030	0.028	0.028

Reference: JISF data

Note: Emission factor change is assumed to be small for FY1990-1996. Therefore, actual data values for FY1995 is used for other years with no data. For FY1997-1999, it is assumed that values for 1998 and 1999 are the same as those of 1997 (0.18). For FY2000 and on, actual data values are adopted.

- ***CH_4 emission factor for coke production***

The aforementioned Combustion Exhaust Gas and Coking Furnace Lids, Desulfurization Towers, and Desulfurization Recycling Towers have been added, and the resulting figure has been used as the emission factor.

- ***Activity Data***

➢ *Furnaces*

In the estimation of the activity data, data on the *General Survey of the Emissions of Air Pollutants* (MOE) (see next page for the outline of this survey), which provides details of the fuel consumption for each type of furnace and fuel, and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries* (METI), *Structural Survey of Energy Consumption* (ANRE), *Electric Power Statistics* (ANRE), and *Current Survey of Production Concerning Gas Industry* (ANRE)) are used, because data on stationary combustion fuel consumption for each type of furnace are not available in the *General Energy Statistics*.

The fuel consumption by each sector (energy transformation & own use, industry, commercial & others) for each type of fuels as presented in the *General Energy Statistics* was further divided among each furnace type proportionally to the fuel consumption ratio for each furnace type estimated from the *General Survey of the Emissions of Air Pollutants* and from the fuel consumption statistics to obtain the activity data for each sector, each fuel type and each furnace type. However, because the data in the *General Survey of the Emissions of Air Pollutants* do not differentiate between pressurized fluidized-bed boilers, normal pressure fluidized-bed boilers, and other boilers, the fuel consumption of these fluidized-bed boilers is calculated separately. The fuel consumption data of pressurized fluidized-bed furnaces were provided by the Federation of Electric Power Companies. The fuel consumption data of normal pressure fluidized-bed furnaces were provided from companies which had past operation records of normal pressure fluidized-bed furnaces since 1990.

The data of solid fuel boilers excluding fluidized-bed furnaces were estimated by subtracting the data of fluidized-bed furnace from the data of whole solid fuel boilers.

The *General Survey of the Emissions of Air Pollutants* for all facilities emitting soot and smoke is exhaustively carried out approximately every three years. The fuel consumption ratio for each furnace type and each fiscal year is assumed as shown in Table 3-26.

Table 3-26 Setting method of fuel consumption ratio for each furnace type

Fiscal year	Setting method
1990 – 1991	Set by linear interpolation using the FY1989 and FY1992 survey results
1992	FY1992 survey result is used
1993 – 1994	Set by linear interpolation using the FY1992 and FY1995 survey results
1995	FY1995 survey result is used
1996	FY1996 survey result is used
1997 – 1998	Set by linear interpolation using the FY1996 and FY1999 survey results
1999	FY1999 survey result is used
2000 – 2007	Set by linear interpolation using the FY1999 and FY2008 survey results
2008	FY2008 survey result is used
2009 – 2010	FY2008 survey result is intentionally used 1)
2011	FY2011 survey result is used
2012 – 2013	Set by linear interpolation using the FY2011 and FY2014 survey results
2014	FY2014 survey result is used
2015 – 2016	Set by linear interpolation using the FY2014 and FY2017 survey results
2017	FY2017 survey result is used
2018 –	FY2017 survey result is intentionally used

Note:
1) The survey result of FY2011 is quite different from that of FY2008 because of the influence of the Great East Japan Earthquake which occurred in March 2011, thus the FY2008 data is intentionally used without interpolation.

The procedure for calculating activity data is as follows:

1) Fuel consumption data from the *General Survey of the Emissions of Air Pollutants* is collated respectively for each fuel type, furnace type and sector.

2) The percentage of fuel consumption accounted for by each furnace type is calculated for each fuel type and sector.

3) Fuel consumption for different fuel types and sectors provided in the *General Energy Statistics* is multiplied by the percentage calculated in (2) to obtain fuel-specific, furnace-specific, and sector-specific activity data.

$$A_{ijk} = A_{EB_{ik}} \times w_{ijk}$$

$$w_{ijk} = A_{MAP_{ijk}} / \sum_m A_{MAP_{ijk}}$$

A_{EBik} : Fuel consumption for fuel type *i*, sector *k* from the *General Energy Statistics* [TJ]
w_{ijk} : Ratio of furnace type *j* associated with consumption of fuel type *i* in sector *k*
i : Fuel type
j : Furnace type
k : Sector
A_{MAPijk} : Fuel consumption for fuel type *i*, furnace type *j*, sector *k* according to the *General Survey of the Emissions of Air Pollutants* [TJ]

- ***Outline of the General Survey of the Emissions of Air Pollutants***

The *General Survey of the Emissions of Air Pollutants* is a statistical survey conducted to (1) promote a reasonable and effective atmospheric environmental policy, (2) obtain information on current activities within the context of the Air Pollutant Control Law (e.g., the current status of regulation of stationary sources that emit soot and smoke in facilities registered to a local government and in facilities emitting ordinary soot or particular soot, and the current status of air pollutant control), (3) develop the submitted data on facilities emitting soot and smoke, and (4) estimate the amounts of air pollutant emissions from facilities that emit soot and smoke. This survey is conducted in the form of questionnaires. The response sheets and this survey's explanations are distributed to the target facilities mentioned above.

- ***Influence of Great East Japan Earthquake on Fuel Consumption Ratio by Furnace Type***

The Great East Japan Earthquake which occurred on March 2011 largely influences the result of the *General Survey of the Emissions of Air Pollutants* in FY2011. It leads to the fluctuation of the fuel consumption ratio by furnace type in some categories in the previous and following fiscal years.

In the recommendation by UNFCCC inventory review on Japan's inventory submission in 2018 (FCCC/ARR/2018/JPN, paragraph E.12), the ERT noted that the IEFs of gaseous fuels for oil refinery category (1.A.1.b) largely reduced in CH_4 emissions from FY2010 (6.32 kg/TJ) to FY2011 (0.28 kg/TJ) and also in N_2O emissions from FY2010 (0.42 kg/TJ) to FY2011 (0.20 kg/TJ). This is because the fuel consumption ratio by furnace type in this survey has been reflected in the activity data, and the gaseous fuel consumption by the furnaces with high emission factors such as "Gas Engine" (CH_4 EF: 54 kg/TJ, N_2O EF: 0.85 kg/TJ) and "Other Industrial Furnaces" (CH_4 EF: 2.29 kg/TJ, N_2O EF: 1.2 kg/TJ) is significantly reduced from FY2010 to FY2011.

On the other hand, in the same recommendation, the ERT also pointed out that the recalculated IEFs of gaseous fuels for the same category submitted in 2018 are larger than those in 2017 for FY2012-2015.

Specifically, the CH_4 IEFs increased by 15.3% in FY2012, by 33.9% in FY2013, by 50.7% in FY2014 and by 36.5% in FY2015 respectively, and the N_2O IEFs increased by 15.1% in FY2012, by 33.0% in FY2013, by 49.4% in FY2014 and by 37.6% in FY2015 respectively. This is because, on the contrary to the former case, the fuel consumption ratio by furnace type in the *General Survey of the Emissions of Air Pollutants* in FY2014 has been adopted to the inventory in the same fiscal year. In FY2014 survey, the consumption of some gaseous fuels by furnaces with high emission factors such as "Gas Turbine" (CH_4 EF: 0.81 kg/TJ, N_2O EF: 0.58 kg/TJ) and "Other Industrial Furnaces" (see above for EFs) have significantly increased from the FY2011 survey conducted right after the Earthquake. In the 2017 inventory submission, the fuel consumption ratio by furnace type in FY2011 survey was applied to the FY2011-2015 activity data. In the 2018 inventory submission, the fuel consumption ratio by furnace type in FY2014 survey has been reflected to the FY2014 activity data by furnace type at first, then the interpolation of fuel consumption ratio by furnace type has been adopted to FY2012-2013 activity data and FY2014 survey data has been used for FY2015 activity data. As a result of the recalculation, the emissions and the IEFs from FY2012 to FY2015 have largely increased.

➢ *Biomass boilers*

As the activity data of woods, waste woods, black liquor, gas biomass and non-specified biomass for the biomass boilers, the fuel consumption by each sector in the *General Energy Statistics* was used. It was assumed that woods and waste woods under "power generation sector" and "Auto power generation sector" of the *General Energy Statistics* were used in the power generation facilities, while those under the rest of the sectors were used in the heat utilization facilities.

➢ *Coke production*

As the activity data of CH_4 emissions from coke production, the coke production amount was given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

Table 3-27 Coke production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Coke production	kt	47,338	42,279	38,511	38,009	37,036	35,024	35,082	33,785	32,439	33,138	32,587	32,659	32,640	29,287	30,219

c) Uncertainties and Time-series Consistency

● ***Uncertainties***

➢ *Furnaces (including biomass boilers)*

In case of using the default emission factor of the *2006 IPCC Guidelines*, the default uncertainties were applied. In case of using country specific emission factor, country specific uncertainties were established.

Since the uncertainty by fuel and sector of energy consumption in the *General Energy Statistics* were not available, upper value and lower value of uncertainty were established from standard deviation of the rate of statistics error of "Coal, Coal Products", "Oil, Oil Products", Natural Gas, LPG" and "Biomass Energy" from 1990 to 2016.

The uncertainties at furnaces were estimated to be −33% to +46% for CH_4 emissions and −33% to +33% for N_2O emissions as a whole for the fuel combustion category.

➢ *Coke production*

For the uncertainty of the emission factor for coke production, the uncertainty of fuel combustion emissions from the coking furnace and coking furnace lids were estimated separately. The uncertainty of fuel combustion emissions from the coking furnace and coking furnace lids was estimated as 98.5% and 61.8%, respectively. For the uncertainty of activity data, the standard value of 5% given by MOE (2006a) was used.

➢ *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3

- ***Time-series Consistency***

➢ *Furnaces (including biomass boilers)*

The emissions were calculated in a consistent manner in all time-series.

The emission factors for CH_4 and N_2O have been calculated by a consistent estimation method since FY1990.

The activity data was used from data in the *General Energy Statistics* in all time-series, and the statistics were made by a consistent estimation method in all time-series. For the activity data of “Production, Transmission and Distribution of Electricity” under “Auto power generation” of the *General Energy Statistics*, see section 3.2.4. c) (1.A.1).

➢ *Coke production*

The activity data for coke production are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*, by a consistent method throughout the time-series from FY1990 to the most recent year. The emission factor is based on the information provided by JISF and estimated using a consistent methodology throughout the time-series. Therefore, CH_4 emissions from coke production have been estimated in a consistent manner throughout the time-series.

➢ *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3

d) Category-specific QA/QC and Verification

- ***QA/QC***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

- ***Verification***

N_2O emission factors of fuel combustion currently used are established based on the actual measurements conducted in 1990s. Since then, the change of combustion conditions due to the progress of energy saving may change the emission factors, and the necessity of periodical review of the emission factors were pointed out by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2009. In addition, the Expert Review Team strongly recommended that Japan provided additional information in its annual submission to transparently justify the appropriateness of the measurements to the current boiler types/technologies in the individual review of the 2013 submission. (FCCC/ARR/2013/JPN)

In response to this, the actual measurement conducted in FY2009 is described here. The object of measurement was the N_2O emission factor of fluidized-bed boilers combusting solid fuels. As a result, the validity of measurements in 1990s is confirmed because the result of the measurement in FY2009 is almost the same level of the emission factor based on the measurements in the 1990s.

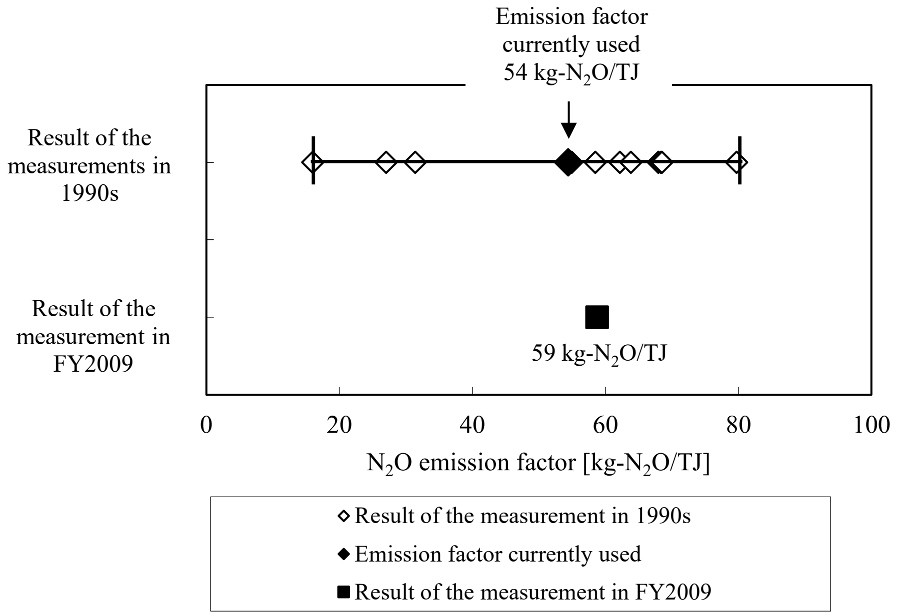


Figure 3-5 Comparison of the 1990s and FY2009 measurement results

Note: The result of the measurement in FY2009 in the figure is the average of three measurements in a boiler.

e) Category-specific Recalculations

Since the activity data for FY2016-2020 in the *General Energy Statistics* were revised, the CH_4 and N_2O emissions in those years were recalculated. Since the emission factor of coking furnace lid and other facilities for FY2020 was provided by JISF, the CH_4 emissions in that year were recalculated. Since the activity data of the pressurized fluidized-bed boilers for FY2002 were revised, the N_2O emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.6. CO_2 Emissions from Manufacturing Industries and Construction (1.A.2.: CO_2)

a) Category Description

This section provides the estimation methods for determining CO_2 emissions from iron and steel (1.A.2.a); non-ferrous metals (1.A.2.b); chemicals (1.A.2.c); pulp, paper, and print (1.A.2.d); food processing, beverages, and tobacco (1.A.2.e); non-metallic minerals (1.A.2.f) and other (1.A.2.g).

In FY2021, CO_2 emissions from this category accounted for 249,549 kt-CO_2, and represented 21.3% of

Japan's total GHG emissions (excluding LULUCF). The iron and steel (1.A.2.a) accounts for 50.0%, and is the largest source within the manufacturing industries and construction category in FY2021.

b) Methodological Issues

- ***Estimation Method***

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2) to calculate emissions, as was the case for the energy industries (1.A.1). See section 3.2.4. b) (1.A.1).

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as "other fossil fuels" and "biomass" in accordance with the *2006 IPCC Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The CO_2 emissions from biomass are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*.

- ***Emission Factors***

The emission factors elaborated in the energy industries (1.A.1) are also used in this category. See section 3.2.4. b) (1.A.1).

- ***Activity Data***

The data presented in the *General Energy Statistics* were used for activity data, as was the case for the energy industries (1.A.1).

Table 3-28 Energy consumptions in Manufacturing Industries and Construction category (1.A.2) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Liquid fuels	1,960	2,114	1,909	1,544	1,050	1,043	1,020	962	891	837	811	822	767	751	782
Solid fuels	2,130	2,054	2,034	2,051	2,043	2,031	2,087	2,051	2,000	1,889	1,863	1,828	1,802	1,560	1,693
Gaseous fuels	227	344	408	599	629	648	611	594	595	603	601	630	601	578	599
Other fossil fuels	86	99	115	174	203	210	214	221	224	221	228	233	241	231	232
Biomass	227	227	240	273	298	286	309	303	300	272	281	286	286	259	273
Total	4,629	4,837	4,705	4,641	4,224	4,218	4,241	4,131	4,010	3,821	3,784	3,799	3,697	3,379	3,578

The activity data for the manufacturing industry sectors were calculated by totaling the energy consumption from production activities in factories and offices (final energy consumption: #6xxxxx[11]), energy consumption related to non-utility power generation for use in one's own factories and offices (auto power generation: #25xxxx), and energy consumption related to steam production for use in own factories and offices (auto steam generation: #26xxxx) shown in the *General Energy Statistics*. Because the energy consumption for production activities in factories and offices contained a certain amount used as raw materials (non-energy and feedstock use: #95xxxx), this amount was subtracted.

The auto power generation and auto steam generation sectors are included in the energy transformation & own use sector in the *General Energy Statistics*. However, the *2006 IPCC Guidelines* allocates CO_2 emissions from energy consumption for power or steam generation to the sectors generating that power or steam. As such, these CO_2 emissions are added to those from each industry in the final energy

[11] x indicates any number.

consumption sector and are reported in 1.A.2.

Table 3-29 shows the correspondence between the sectors of Japan's Energy Balance Table and those of the CRF (1.A.2).

Table 3-29 Correspondence between sectors of Japan's Energy Balance Table and of the CRF (1.A.2)

CRF	General Energy Statistics	
1A2 Manufacturing industries and construction		
1A2a Iron and steel	Auto power generation; Manufacture of iron and steel	#253250
	Auto steam generation; Manufacture of iron and steel	#263220
	Final energy consumption; Manufacture of iron and steel	#629100
	Non-energy and feedstock use; Manufacture of iron, steel and steel products	#951560
1A2b Non-ferrous metals	Auto power generation; Manufacture of non-ferrous metals and products	#253230
	Auto steam generation; Manufacture of non-ferrous metals and products	#263260
	Final energy consumption; Manufacture of non-ferrous metals and products	#629300
	Non-energy and feedstock use; Primary smelting and refining of copper, lead, zinc and aluminium	#951570
1A2c Chemicals	Auto power generation; Manufacture of chemical and allied products	#253160
	Auto steam generation; Manufacture of chemical and allied products	#263160
	Final energy consumption; Manufacture of chemical and allied products	#626100
	Non-energy and feedstock use; Manufacture of petrochemical, ammonia, soda products	#951530
1A2d Pulp, paper and print	Auto power generation; Manufacture of pulp, paper and paper products	#253140
	Auto power generation; Printing and allied industries	#253150
	Auto steam generation; Manufacture of pulp, paper and paper products	#263140
	Auto steam generation; Printing and allied industries	#263150
	Final energy consumption; Manufacture of pulp, paper and paper products	#624000
	Final energy consumption; Printing and allied industries	#625000
	Non-energy and feedstock use; Manufacture of pulp, paper and paper products, large scale	#951520
1A2e Food processing, beverages and tobacco	Auto power generation; Manufacture of food	#253090
	Auto power generation; Manufacture of beverages, tobacco and feed	#253100
	Auto steam generation; Manufacture of food	#263090
	Auto steam generation; Manufacture of beverages, tobacco and feed	#263100
	Final energy consumption; Manufacture of food, beverages, tobacco and feed	#621000
1A2f Non-metallic minerals	Auto power generation; Manufacture of ceramic, stone and clay products	#253210
	Auto steam generation; Manufacture of ceramic, stone and clay products	#263210
	Final energy consumption; Manufacture of ceramic, stone and clay products	#628100
	Non-energy and feedstock use; Manufacture of ceramic, stone and clay products	#951550
1A2g Other	Auto power generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#251010-#251040])	#251000
	Auto power generation; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#252000
	Auto steam generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#261010-#261040])	#261000
	Auto steam generation; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#262000
	Final energy consumption; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#611000])	#610000
	Final energy consumption; Manufacturing (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#620000
	Non-energy and feedstock use; Agriculture, fishery, mining and construction (except for agriculture, forestry and fishery)	#951100
	Non-energy and feedstock use; Manufacturing industry, large scale (except for the industries listed in 1A1b, 1A1c, 1A2a through 1A2f)	#951500
	Non-energy and feedstock use; Manufacturing industry, small and medium scale	#951700

Note: #95xxxx items are subtracted as non-energy use activities.

c) Uncertainties and Time-series Consistency

Same as 3.2.4 Energy Industries (1. A. 1). See section 3.2.4. c).

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY2016-FY2020 were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, CO_2 emissions from other fossil fuels in FY2005-FY2020 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.7. CH_4 and N_2O Emissions from Manufacturing Industries and Construction (1.A.2.: CH_4, N_2O)

a) Category Description

This section provides the estimation methods for determining CH_4 and N_2O emissions from iron and steel (1.A.2.a); non-ferrous metals (1.A.2.b); chemicals (1.A.2.c); pulp, paper, and print (1.A.2.d); food processing, beverages, and tobacco (1.A.2.e); non-metallic minerals (1.A.2.f); and other (1.A.2.g).

This section also provides the estimation methods for determining CH_4 and N_2O emissions from off-road vehicles, work ships and other machineries.

b) Methodological Issues

- ***Estimation Method***

➢ *Furnaces*

Same with Energy Industries (1.A.1), CH_4 and N_2O emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2). See section 3.2.5. b) (1.A.1).

➢ *Biomass boilers*

See section 3.2.5. b) (1.A.1).

➢ *Off-road vehicles and other machinery*

The emissions from off-road vehicles, work ships and other machinery of manufacturing industries and construction are estimated by Tier 1 in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 3.34, Fig. 3.3.1) to calculate emissions and reported in each sub-category of manufacturing industries and construction (1.A.2).

➢ *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3.

● ***Emission Factors***

➢ *Furnaces*

The emission factors which were established in Energy Industries (1.A.1) were used. See Table 3-23 and Table 3-24, See section 3.2.5. b) (1.A.1).

➢ *Biomass boilers*

See section 3.2.5. b) (1.A.1).

➢ *Off-road vehicles and other machinery*

The emission factors of fuel oil A of work ships were estimated using the default values of Ocean-going Ships which were provided in the *2006 IPCC Guidelines* (Vol.2, page 3.50, Table 3.5.3) after conversion to the gross calorific value by multiplying them by 0.95 (*2006 IPCC Guidelines*, Vol.2, page 1.16). The emission factors of gasoline, diesel oil and fuel oil A for other than work ships were estimated from the values of European Environment Agency (EEA, 2016) (Table 3-1, 1.A.2.g.vii) after conversion to the gross calorific value.

Table 3-30 Emission factors of CH_4 and N_2O for off-road vehicles and other machinery in manufacturing industries and construction (1.A.2)

Fuel	Unit	CH_4 emission factor	N_2O emission factor	Reference
Gasoline	g/t	665	59	EEA (2016), Non-road mobile sources and machinery, Table 3-1
Diesel oil (includes fuel oil A used for other than ships)	g/t	83	135	
Fuel oil A used for ships	kg/TJ(NCV)	7	2	*2006 IPCC Guidelines*, Vol.2, Table 3.5.3

● ***Activity Data***

➢ *Furnaces*

The fuel consumption of mobile combustion and stationary combustion are estimated by multiplying the fuel consumption of each category and each fuel type in the *General Energy Statistics* by the ratios of mobile and stationary combustion on the Table 3-31, which are the survey results executed by MOE in FY2014 and FY2015.

In addition, the fuel consumption, which is estimated by multiplying the fuel consumption of stationary combustion obtained as described above by the fuel consumption ratio of each furnace type, is assumed as the activity data for the stationary combustion (namely combustion in furnaces). Same with Energy Industries (1.A.1), the ratio of fuel consumption of each furnace type was estimated from data on the *General Survey of the Emissions of Air Pollutants* and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries*, *Structural Survey of Energy Consumption*, *Electric Power Statistics*, and *Current Survey of Production Concerning Gas Industry*). See section 3.2.5. b) (1.A.1).

➢ *Biomass boilers*

As the activity data from the biomass boilers, the inventory used the fuel consumption for each sector, each fuel type in the *General Energy Statistics*. However, the consumption of non-specified biomass for each industry type before FY2001 under "Auto steam generation sector" in the *General Energy Statistics* was not available because it was not investigated. Therefore, for this period, it was estimated on the assumption that it is proportional to the amount of steam generation for each industry type before FY2001, based on the amount of steam generation in FY2002.

➢ *Off-road vehicles and other machinery*

The fuel consumption, which is estimated by multiplying the fuel consumption of each category and each fuel type in the *General Energy Statistics* by the fuel consumption ratio in the Table 3-31, is assumed to be the activity data of the mobile combustion, namely the off-road vehicles and other machinery.

In relation to the Table 3-31, all fuel consumption of fuel oil A and diesel oil of construction in the *General Energy Statistics* were used for activity data of mobile combustion. According to Japan Federation of Construction Contractors, the fuel consumption of electric generator as stationary combustions is included in the value of fuel oil A and diesel oil of construction, however the emission factors of mobile combustion are applied for electric generator, because a combustion engine of electric generator is similar with diesel engine.

Table 3-31 Fuel consumption ratio of mobile combustion and stationary combustion in manufacturing industries and construction (1.A.2)

CRF code	Category in General Energy Statistics	Gasoline		Diesel oil		Fuel oil A		
		Mobile combustion	Stationary combustion	Mobile combustion	Stationary combustion	Mobile combustion (ships)	Mobile combustion	Stationary combustion
1A2a	Manufacture of iron and steel	1%	99%	16%	84%			
1A2b	Manufacture of non-ferrous metals and products	24%	76%	1%	99%			
1A2c	Manufacture of chemical and allied products	100%	0%	1%	99%			
1A2d	Manufacture of pulp, paper and paper products	74%	26%	10%	90%			
	Printing and Allied Industries			0%	100%			
1A2e	Manufacture of food, beverages, tobacco and feed			1%	99%			
1A2f	Manufacture of Ceramic, Stone and Clay Products	7%	93%	1%	99%			
1A2g	Manufacture of Fabricated Metal Products			1%	99%			
	Manufacture of Machinery	2%	98%	1%	99%			
	Mining, Quarrying of Stone and Gravel			100%	0%	17%	25%	58%
	Manufacture of Lumber and Wood Products, except Furniture and Fixtures			2%	98%			
	Construction Work Industry			100%	0%	0%	100%	0%
	Manufacture of Textile Mill Products	100%	0%					
	Manufacture of Leather Tanning, Leather Products and Fur Skins			0%	100%			
	Manufacture of Furniture and Fixtures			0%	100%			
	Manufacture of Rubber Products			0%	100%			
	Manufacture of Plastic Products, except Otherwise Classified			0%	100%			
	Miscellaneous Manufacturing Industry			4%	96%			

Reference: Estimated based on MOE (2015b) and MOE (2016).

c) Uncertainties and Time-series Consistency

- *Furnaces (including Biomass boilers)*

Same as Energy Industries (1.A.1). See section 3.2.5. c).

The consumption of non-specified biomass for each industry type before FY2001 was not available because it was not investigated. Therefore, time-series consistency is ensured by estimating the consumption on the assumption that it is proportional to the amount of steam generation for each industry type before FY2001, based on the amount of steam generation in FY2002.

- *Off-road vehicles and other machinery*

The default values of the *2006 IPCC Guidelines* were substituted for the uncertainties of emission factors. The uncertainties of the activity data were established from the standard deviation of the rate of statistical discrepancy of liquid and gaseous fuels of the *General Energy Statistics*. For the activity data obtained from the fuel consumption ratio of mobile combustion, the uncertainties of the ratio were estimated from the survey conducted by MOE in FY2014 and FY2015 and they were combined by the error propagation formula. As a result, the uncertainties were determined to be −29% to +41% for CH_4 emissions and −23% to +91% for N_2O emissions from off-road vehicles and other machinery as a whole for the fuel combustion category.

- *Incineration of waste for energy purposes and with energy recovery*

See section 7.4.3.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

Since the activity data for FY2016-2020 in the *General Energy Statistics* were revised, the CH_4 and N_2O emissions in those years were recalculated.

Updating the statistical data in the waste sector, CH_4 and N_2O emissions for FY2020 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Same as Energy Industries (1.A.1). See section 3.2.5. f).

3.2.8. CO_2 Emissions from Transport (1.A.3.: CO_2)

a) Category Description

This section provides the methods used to estimate CO_2 emissions from domestic aviation (1.A.3.a), road transportation (1.A.3.b), railways (1.A.3.c), domestic navigation (1.A.3.d), and other transportation (1.A.3.e). The emissions from mobile sources that the main purpose is other than transport of passenger or freight (e.g. off-road vehicles, work ships and fishing boats) are included in manufacturing industries and construction (1.A.2) and other sectors (1.A.4).

In FY2021, CO_2 emissions from this category accounted for 177,911 kt-CO_2, and represented 15.2% of Japan's total GHG emissions (excluding LULUCF). The road transportation (1.A.3.b) accounts for 90.1% and is the largest within the Transport category in FY2021.

b) Methodological Issues

- ***Estimation Method***

➢ *Fuels such as gasoline and diesel oil*

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2), as was the case for the energy industries (1.A.1). See section 3.2.4. b)). In the CRFs, the CO_2 emissions from biofuels are estimated from domestic supply [#190000] of biofuels from the *General Energy Statistics* and reported in Road transportation (1.A.3.b) as reference values. (The CO_2 emissions from biomass are not included in the national totals in accordance with the *2006 IPCC Guidelines*.)

➢ *Lubricants*

CO_2 is emitted by oxidation of lubricants in engines during use. According to the *2006 IPCC Guidelines* (Vol.3, page 5.6), in the case of 2-stroke (2-cycle) engines, where the lubricant is mixed with another fuel and thus on purpose co-combusted in the engine, the emissions should be estimated and reported as part of the combustion emissions in the energy sector. 2-stroke engine oil for automobile and marine diesel engine oil correspond to be reported in the energy sector. The emissions are estimated by the following equation. The emissions from 2-stroke engine oil are reported in 1.A.3.b and those from marine diesel oil are reported in 1.A.3.d.

$$E = \sum_i (LC_i \times CC_i \times ODU_i \times 44/12)$$

E	: CO_2 emissions from lubricants oxidized during use [kt-CO_2]
LC_i	: Consumption of lubricant [TJ]
CC_i	: Carbon content of lubricant [kt-C/TJ]
ODU_i	: Oxidized During Use (ODU) factor
i	: Lubricant type (2-stroke engine oil for automobile and marine diesel engine oil)

- ***Emission Factors***

➢ *Fuels such as gasoline and diesel oil*

The emission factors elaborated in the energy industries (1.A.1) are also used in this category. See section 3.2.4. b).

The carbon emission factor for liquid fuels (diesel oil) in 1.A.3.b (Road transportation) is the lowest in Annex I Parties for two reasons. One is because the quality standard for diesel oil in Japan is different from other countries. Crude oil with high sulfur content imported from the Middle East must be decomposed and go through ultra-deep desulfurization to become low-sulfur diesel oil (<10 ppm) according to Japanese automobile exhaust gas regulations. The other reason is because gas oil used for purposes other than road transport is called "fuel oil A" to distinguish it from diesel oil. The carbon balance of Japanese petroleum refineries including diesel oil and fuel oil A nearly matches according to statistics, so these carbon emission factors are not irregular.

Please refer to the quality standard for diesel oil in Japan provided in Annex 4 (A4.3).

➢ *Lubricants*

The carbon content *CC* is the carbon emission factor of lubricants elaborated in the energy industries (1.A.1). The ODU factor is 1.0 assuming that all lubricants are combusted.

● ***Activity Data***

Table 3-32 Energy consumptions in Transport (1.A.3.) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Liquid fuels	2,982	3,581	3,735	3,514	3,286	3,228	3,135	3,065	3,049	3,024	2,999	2,967	2,908	2,581	2,599
Solid fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaseous fuels	0	0	1	4	5	4	4	4	3	3	2	2	2	1	1
Other fossil fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	NO	NO	NO	0	9	9	10	12	15	18	19	20	19	20	20
Total	2,983	3,581	3,736	3,518	3,299	3,241	3,149	3,081	3,067	3,045	3,021	2,988	2,928	2,602	2,621

➢ *Fuels such as gasoline and diesel oil*

The data given in the *General Energy Statistics* were used for activity data.

The values subtracting final energy consumption reported under 'non-energy and feedstock use' [#953000] from energy consumption reported under 'air transport' [#815000] [#854000], 'road transport' [#811000] [#851000] [#811500] [#812000], 'railway transport' [#813000] [#852000] and 'water transport' [#814000] [#853000] in Japan's Energy Balance Table (*General Energy Statistics*) are used for activity data. Because energy consumption reported under 'non-energy and feedstock use' was used for purposes other than combustion and was considered not emitting CO_2, these values were deducted. (see Table 3-33)

Table 3-33 Correspondence between sectors of Japan's Energy Balance Table and those of the CRF (1.A.3)

CRF			General Energy Statistics	
1A3	Transport			
1A3a	Domestic aviation		Final energy consumption; Passenger; Air passenger transport	#815000
			Final energy consumption; Freight; Air freight transport	#854000
			Non-energy and feedstock use; Transportation (air)	#953000
1A3b	Road transportation			
	i	Cars	Final energy consumption; Passenger; Passenger vehicle	#811000
			Non-energy and feedstock use; Transportation (passenger vehicle)	#953000
	ii	Light duty trucks	IE (1A3biii)	-
	iii	Heavy duty trucks and buses	Final energy consumption; Passenger; Bus	#811500
			Final energy consumption, Freight; Freight truck and lorry	#851000
			Non-energy and feedstock use; Transportation (bus, freight truck and lorry)	#953000
	iv	Motorcycles	Final energy consumption; Passenger; Motorcycles	#812000
			Non-energy and feedstock use; Transportation (Motorcycles)	#953000
	v	Other	IE (1A3biii)	-
1A3c	Railways		Final energy consumption; Passenger; Railway passenger transport	#813000
			Final energy consumption; Freight; Railway freight transport	#852000
			Non-energy and feedstock use; Transportation (railways)	#953000
1A3d	Domestic navigation		Final energy consumption; Passenger; Water passenger transport	#814000
			Final energy consumption; Freight; Water freight transport	#853000
			Non-energy and feedstock use; Transportation (water)	#953000
1A3e	Other transportation		NO	-

Note: #95xxxx items are subtracted as non-energy use activities.

➢ *Lubricants*

The sales of engine oils for automobiles and navigation are estimated from the total sales of lubricants, and then they are used to estimate the consumptions of total loss type engine oils.

The sales of engine oils for automobile (gasoline engine oil and diesel engine oil) and marine diesel engine oil in cubic volume basis are estimated by multiplying *DS*, or the domestic sales of all lubricants shown in *Yearbook of Mineral Resources and Petroleum Products Statistics* and *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, by R_i, or the proportion of each of engine oil to all lubricants sold to consumers, wholesalers and retailers[12] estimated from these yearbooks. They are multiplied by R_{TLi}, or the proportions of total loss type lubricants to each of engine oil, to obtain the consumptions of total loss type engine oils. R_{TLi} is derived by dividing the productions and imports of 2-stroke engine oils and marine cylinder oil in fiscal year 2011 shown in Japan Lubricating Oil Society (2013) by the domestic sales of engine oils for automobiles and marine diesel engine oil estimated above, respectively (0.92% for engine oils for automobiles and 83% for marine diesel engine oil).

LC_i, or the consumptions of total loss type engine oils in quantity of heat basis, are obtained by converting the consumptions in cubic volume basis by using the gross calorific values of lubricants shown in the *General Energy Statistics*, and they are set as activity data.

$$LC_i = DS \times R_i \times R_{TLi} \times GCV$$

LC_i : Consumption of each of engine oil [TJ]
DS : Domestic sales of all lubricants [1,000 kL]
R_i : Proportion of each of engine oil to all lubricants sold to consumers, wholesalers and retailers
R_{TLi} : Proportions of total loss type lubricants to each of engine oil
i : Lubricant type (engine oils for automobile and marine diesel engine oil)
GCV : Gross calorific values of lubricants [GJ/kL]

Table 3-34 Consumption of total loss type engine oils

Item		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Two stroke engine oil for automobiles	LC_1	TJ	207	215	210	194	183	157	158	154	142	135	137	149	149	144	142
Cylinder oil for navigation	LC_2	TJ	5,318	5,503	7,144	6,250	4,627	3,638	3,502	3,301	3,124	2,843	2,766	3,095	3,036	2,831	2,601
Total sales of lubricants	DS	1000 kL	2,439	2,335	2,192	2,047	1,763	1,538	1,531	1,511	1,460	1,414	1,433	1,590	1,548	1,430	1,444
Proportion of sales of engine oils for automobiles	R_1	-	23%	25%	26%	26%	28%	28%	28%	28%	26%	26%	26%	26%	26%	27%	27%
Proportion of sales of marine diesel engine oils	R_2	-	6.5%	7.1%	9.8%	9.1%	7.9%	7.1%	6.8%	6.5%	6.4%	6.0%	5.8%	5.8%	5.9%	5.9%	5.4%
Gross calorific value of lubricants	GCV	GJ/kL	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2

c) Uncertainties and Time-series Consistency

Same as 3.2.4 Energy Industries (1. A. 1). See section 3.2.4. c).

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY2019-FY2020 were recalculated.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

[12] Lubricants sold to consumers, for FY1990-2001.

3.2.9. CH_4 and N_2O Emissions from Transport (1.A.3.: CH_4, N_2O)

This section provides the estimation methods for CH_4 and N_2O emissions from domestic aviation (1.A.3.a), road transportation (1.A.3.b), railways (1.A.3.c), domestic navigation (1.A.3.d), and other transportation (1.A.3.e). The emissions from mobile sources that the main purpose is other than transport of passenger or freight (e.g. off-road vehicles, work ships and fishing boats) are included in manufacturing industries and construction (1.A.2) and other sectors (1.A.4).

3.2.9.1. Domestic Aviation (1.A.3.a.)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from energy consumption in domestic aviation. Greenhouse gases associated with the domestic operation of Japanese airliners are mainly emitted from jet fuels. In addition, a small amount of aviation gasoline used by light aircraft and helicopters is also a source of CH_4 and N_2O emissions.

b) Methodological Issues

- ***Estimation Method***

In accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.60, Fig. 3.6.1), the emissions from jet fuel for jet aircraft are estimated using the Tier 2 method by each operation phase: Landing/Take-Off (LTO) cycle and cruise. For LTO phase, the emissions by aircraft type are estimated by multiplying the emission factor per LTO 1 cycle by the number of LTO cycles for each aircraft type on domestic routes, and then they are aggregated. However, the emissions prior to FY2000 are estimated by multiplying the weighted average emission factor for all type of aircraft in FY2001 by the total activity data due to lack of activity data by aircraft type prior to FY2000. For cruise phase, the emissions are estimated from the total jet fuel consumption during cruising on domestic routes.

The emissions from aviation gasoline, which is used for light aircraft and helicopters, are estimated by the Tier 1 method from the total domestic fuel consumption.

$$E_{jet} = \sum_i (EF_{LTO,i} \times AD_{LTO,i}) + EF_{cruise} \times AD_{cruise}$$

E_{jet}	: CH_4 and N_2O emissions from domestic airliners using jet fuel
$EF_{LTO,i}$	: Emission factor per LTO 1 cycle by aircraft type of domestic airliner
$AD_{LTO,i}$	: Number of LTO cycles by aircraft type on domestic routes
EF_{cruise}	: Emission factor associated with jet fuel consumption
AD_{cruise}	: Jet fuel consumption during cruising on domestic routes
i	: Aircraft type

$$E_{gasoline} = EF_{gasoline} \times AD_{gasoline}$$

$E_{gasoline}$	: CH_4 and N_2O emissions associated with flight of gasoline-powered domestic aircraft
$EF_{gasoline}$	: Emission factor associated with the consumption of aviation gasoline
$AD_{gasoline}$	: Consumption of aviation gasoline by aircraft on domestic routes

- ***Emission Factors***

➢ *Jet fuel*

The default values given in the *2006 IPCC Guidelines* (Vol. 2, page 3.70, Table 3.6.9) are used for the emission factors of CH_4 and N_2O during LTO. As for during cruising, the default values given in the

2006 IPCC Guidelines (Vol. 2, page 3.64, Table 3.6.5) are used. (See Table 3-35)

➢ *Aviation gasoline*

The default values given in the *2006 IPCC Guidelines* (Vol. 2, page 3.64, Table 3.6.5) are used for emission factors of CH_4 and N_2O (see Table 3-35).

Table 3-35 CH_4 and N_2O emission factors for aircraft

Type of aircraft (fuel)	Flight phase	CH_4	N_2O
Jet aircraft (Jet fuel)	LTO	Varies per aircraft type (see Table 3-36)	
	Cruise	- 1)	2 [kg-N_2O/TJ(NCV)]
Other than jet aircraft (Aviation gasoline)	-	0.5 [kg-CH_4/TJ(NCV)]	2 [kg-N_2O/TJ(NCV)]

Reference: *2006 IPCC Guidelines*, Volume 2, page 3.64, Table 3.6.5
Note:
LTO: Landing and take-off
1) Excluded from calculations, as the emissions are assumed as negligible in the guidelines.

Table 3-36 CH_4 and N_2O emission factors and fuel consumption for major types of jet aircraft

Aircraft type	CH_4 emission factor [kg/CH_4/LTO] 1)	N_2O emission factor [kg/N_2O/LTO] 1)	Fuel consumption [kg/LTO] 1)
B737-300/400/500	0.08	0.1	780
B737-800	0.07	0.1	880
B747SR (B747-100, -200, -300)	4.84 2)	0.4 2)	3,440 3)
B747-400	0.22	0.3	3,240
B767-300	0.12	0.2	1,780
B777-200/300	0.07	0.3	2,560
A320	0.06	0.1	770
Average of emission factors of all aircraft types in FY 2001 (adopted for the emission factor of all types of aircraft before 2001)	0.34	0.15	—

Reference: *2006 IPCC Guidelines*, Vol. 2, page 3.70, Table 3.6.9
Note:
1) LTO: Landing and take-off
2) Maximum value of B747-100, -200, and -300 is used
3) Average value of B747-100, -200, and -300 is used

● ***Activity Data***

➢ *Jet fuel*

The number of LTO (landing and take-off) by aircraft type given in the *PRTR Outside Notification Emissions Estimated Data* (MOE) is used as activity data for LTO. However, these data involve the international flights LTO, thus the number of international flights LTO is subtracted for each aircraft type used for both domestic and international flights in same ratio of domestic and international flights from total LTO, so as to keep the total number of domestic LTO in the *Airport Management Status Study Report* (MLIT).

The fuel consumption during LTO is calculated by multiplying the fuel amount consumed per one LTO, which is given in the 2006 *IPCC Guidelines* for each aircraft type, by the number of LTO given above.

The fuel consumption for cruising is estimated by subtracting the amount of jet fuel consumed during LTO from the total jet fuel consumption in the *Statistical Yearbook of Air Transport* (MLIT).

➢ *Aviation gasoline*

The consumption of gasoline in the domestic aviation, which is taken from the *General Energy Statistics*, is used for activity data.

Table 3-37 Activity data used for emission estimates of aircraft

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of LTO cycle	1000 LTO	669	783	865	895	882	938	993	1,006	997	994	999	1,003	1,002	628	793
Jet fuel consumption during cruise	1000 kL	1,621	2,425	2,742	3,031	2,629	2,758	2,933	2,996	3,005	3,072	3,145	3,172	3,408	1,557	1,946
Aviation gasoline consumption	1000 kL	5.3	6.0	4.3	7.7	1.9	1.9	1.9	1.7	1.7	1.7	1.9	2.6	2.8	2.4	2.4

Table 3-38 Number of LTO cycle of major types of jet aircraft since FY2001

Aircraft type	Unit	2001	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
B737-300/400/500	1000 LTO	123	103	84	129	131	132	80	68	38	54	15	7	11
B737-800		NO	NO	97	97	118	130	166	165	178	210	157	134	203
B747SR		43	30	3	1	1	NO	1	1	NO	NO	NO	NO	NO
B747-400		56	54	22	16	14	8	5	7	5	2	1	2	3
B767-300		146	103	101	95	87	79	75	73	80	82	52	26	39
B777-200/300		69	76	89	91	93	87	78	74	71	74	46	19	29
A320		59	47	48	88	95	102	103	97	54	54	63	71	107

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

As for the uncertainty of emission factors, the default values by each aircraft type per one LTO given in the *2006 IPCC Guidelines* (Tier 2) are applied for the emission factors, and the estimation is considered to be more accurate than Tier 1. Therefore, the values of the Tier 1 default uncertainty in the guideline (CH_4: -57% to +100%, N_2O: -70% to +150%) are considered to be the upper limit, and are adopted. As for the uncertainty of activity data, because the *Airport Management Status Study Report* is a complete survey executed by MLIT, the values in the *2006 IPCC Guidelines* (-5% to +5%) are used. As a result, the uncertainty of the emissions from domestic aviation is evaluated as -57% to +100% for CH_4, and -70% to +150% for N_2O.

- ***Time-series Consistency***

For the emission factors per LTO, the same value is used for every fiscal year since FY2001 by each aircraft type. For the emission factors prior to FY2000, because the activity data by each aircraft type are not available, the average emission factor for all aircraft type is established from the FY2001 data, and it is used for the fiscal years back to FY1990. In addition, the jet fuel consumption in the *Statistical Yearbook of Air Transport* and the aviation gasoline consumption in the *General Energy Statistics* are used as activity data consistently from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

The CH_4 and N_2O emissions from jet fuel for the period of FY2019-FY2020 were recalculated due to an update of the total number of LTO in FY2019 in the *Airport Management Status Study Report* and an update of the number of LTO by aircraft type in FY2020 in the *PRTR Outside Notification Emissions Estimated Data.* See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.9.2. Road Transportation (1.A.3.b.)

This section provides the estimation methods for CH_4 and N_2O emissions from the following vehicle categories:

Table 3-39 Reporting categories and definitions of emissions from automobiles

Vehicle type	Definition	Fuel type for emission reporting			
		Gasoline	Diesel	LPG	Natural gas
Light passenger vehicle	Light vehicle used for transportation of people	Yes	-	-	-
Passenger vehicle	Regular vehicle or small vehicle used for transportation of people, with a capacity of 10 persons or less	Yes	Yes	Yes	Yes
Bus	Regular vehicle or small vehicle used for transportation of people, with a capacity of 11 persons or more	Yes	Yes	-	Yes
Light cargo truck	Light vehicle used for transportation of cargo	Yes	-	-	-
Small cargo truck	Small vehicle used for transportation of cargo	Yes	Yes	-	Yes (Cargo truck)
Regular cargo truck	Regular vehicle used for transportation of cargo	Yes	Yes	-	
Special-purpose vehicle	Regular, small or light vehicle used for special purposes, including flushers, advertising vans, hearses, and others	Yes	Yes	-	Yes
Motorcycle	Two-wheeled vehicle	Yes	-	-	-

Table 3-40 Correspondence between vehicle type and sectors of the CRF (1.A.3.b)

CRF	Vehicle type, or notation key
1A3b Road transportation	
i. Cars	Light passenger vehicle and passenger vehicle
ii. Light duty trucks	IE (included in iii. Heavy duty trucks and buses)
iii. Heavy duty trucks and buses	Bus, light cargo truck, small cargo truck, regular cargo truck, and special-purpose vehicle
iv. Motorcycles	Motorcycle
v. Other	IE (included in iii. Heavy duty trucks and buses)

Different estimation methods are used between motorcycles and other road transportation vehicles, Road transportation vehicles other than motorcycles (3.2.4.2.a) and Motorcycles (3.2.4.2.b) are separately described in the following sections.

3.2.9.2.a. Road transportation: vehicles other than motorcycles

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from road transportation vehicles other than motorcycles, namely light passenger vehicles, light cargo trucks, passenger vehicles, buses, small cargo trucks, regular cargo trucks, and special-purpose vehicles.

b) Methodological Issues

- ***Estimation Method***

The emissions are calculated by using the Tier 3 method, in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.14, Fig. 3.2.3).

$$E = \sum_i (EF_i \times AD_i)$$

E : CH_4 and N_2O emissions from road transportation (vehicles other than motorcycles)
EF_i : Emission factor per distance traveled by vehicle type
AD_i : Distance traveled by vehicle type
i : Vehicle type

- ***Emission Factors***

The emission factors for CH_4 and N_2O are established for each fuel type for each vehicle type, using the data shown in Table 3-41.

For "JAMA etc. data", the emission factors are established on the basis of the raw emission factors data provided by Japan Automobile Manufacturers Association (hereinafter referred to as JAMA) and other organizations[13]. For "JAMA data", the emission factors are established on the basis of the raw emission factors data provided by JAMA only. The raw emission factors are arranged as combined mode emission factors[14] by vehicle exhaust gas regulation[15] year. The emission factors are estimated by averaging the arranged emission factors weighted by the number of vehicles of each regulation year of each car type. The main reference of the number of vehicles is *Statistics of AIRIA/ Number of Motor Vehicle* compiled by the Automobile Inspection and Registration Information Association (AIRIA). (See Table 3-42, Table 3-43.)

For "Measured data", the emission factors are established on the basis of actual Japanese data. The emission factors are developed as weighted averages calculated from emission factors estimated by each class of running speed and proportion of distance traveled for each class of running speed given in *Road Transport Census* (MLIT). The emission factors reflect the actual operation of vehicles in Japan because the proportion of distance traveled by each class of running speed during rush hour was applied.

The N_2O emission factors for natural gas trucks are established from actual measurement data. The emission factors are developed as weighted averages calculated from emission factors of each class of running speed based on actual measurements taken in Japan and the proportion of distance traveled for each class of running speed reported in the *Road Transport Census*. However, N_2O emission factors for passenger vehicles, buses, and special-purpose vehicles, and CH_4 emission factors for special-purpose vehicles are established by the method indicated in Table 3-41, because of the absence of actual measurement data in Japan.

The detailed method for establishing the emission factors is described in the *GHGs Estimation Methods Committee Report Part 2 – Transportation* (MOE, August 2006).

[13] MOE, Bureau of Environment of Tokyo Metropolitan Government, NIES, National Traffic Safety and Environment Laboratory (NTSEL), and Japan Petroleum Energy Center (JPEC)
[14] The data were provided by test mode. The emission factors were calculated using "combined driving mode". "Combined JC08 driving mode" = "hot start driving mode" ×0.75 + "cold start driving mode" ×0.25
[15] The regulated gases include CO, non-methane hydrocarbons (NMHC), NOx and particulate matter (PM).

Table 3-41 Data source of the emission factors of vehicle

Vehicle type \ Fuel	Gasoline		Diesel		Natural gas	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Light passenger vehicle	JAMA etc. data	JAMA etc. data				
Passenger vehicle	JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA data	The EF of small cargo truck is used considering the standard of vehicle type
Bus	2006GL	2006GL	Measured data	2006GL	JAMA data	Established by correcting the EF of regular cargo truck by the equivalent inertial weight ratio considering vehicle weight.
Light cargo truck	JAMA etc. data	JAMA etc. data				
Small cargo truck	JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA etc. data		Established based on the actual measured data (classified as cargo truck)
Regular cargo truck	2006GL	2006GL	JAMA etc. data	JAMA etc. data	JAMA data	
Special-purpose vehicle	2006GL	2006GL	Measured data	2006GL	Established using the corrected travel distance ratio by each running speed, considering the EFs by each speed of regular cargo truck and running pattern of special-purpose vehicle.	

Note:
1) JAMA etc. data: Calculated by using driving mode test data provided by Japan Automobile Manufacturers Association (JAMA) and other organizations
2) JAMA data: Calculated by using driving mode test data provided by JAMA
3) Measured data: Using actual Japanese data other than the above JAMA data
4) 2006GL: Using the default values in the *2006 IPCC Guidelines*.
5) EFs of LPG vehicle are the same as those of gasoline passenger vehicle.

Table 3-42 CH_4 emission factors for road transportation

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	Light passenger vehicle	mg-CH_4/km	8.3	8.3	8.2	6.9	5.0	4.5	4.2	4.0	3.8	3.6	3.5	3.4	3.3	3.3	3.2
	Passenger vehicle (non-hybrid)		14.5	14.5	14.3	11.3	8.0	7.1	6.6	6.3	6.0	5.7	5.5	5.3	5.2	5.0	5.0
	Passenger vehicle (hybrid)		NO	NO	NO	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	2.0	2.1	2.2	2.3
	Bus		14														
	Light cargo truck		18.7	18.7	18.0	11.7	7.2	6.3	5.8	5.5	5.2	4.9	4.7	4.5	4.3	4.2	4.0
	Small cargo truck		21.2	21.2	21.2	14.5	8.7	7.4	6.8	6.2	5.8	5.4	5.0	4.7	4.4	4.2	4.0
	Regular cargo truck		14														
	Special-purpose vehicle		14														
Diesel	Passenger vehicle		11.3	12.2	12.6	12.8	12.8	12.8	12.9	12.7	12.4	12.1	12.1	11.8	11.1	10.5	10.1
	Bus		19.0	18.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
	Small cargo truck		9.6	10.7	10.1	8.7	8.3	8.1	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1
	Regular cargo truck		17.0	16.0	15.0	13.9	11.1	10.1	9.6	9.0	8.5	7.9	7.4	6.9	6.4	5.9	5.6
	Special-purpose vehicle		17.0	15.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
LPG	Passenger vehicle		14.5	14.5	14.3	11.3	8.0	7.1	6.6	6.3	6.0	5.7	5.5	5.3	5.2	5.0	5.0
Natural gas	Passenger vehicle		13														
	Bus		50														
	Cargo truck		93														
	Special-purpose vehicle		105														

Table 3-43 N_2O emission factors for road transportation

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	Light passenger vehicle	mg-N_2O/km	14.2	14.2	13.9	9.3	5.2	4.1	3.6	3.2	2.9	2.6	2.4	2.2	2.1	2.0	1.9
	Passenger vehicle (non-hybrid)		23.7	23.7	20.3	12.2	6.3	5.0	4.4	4.0	3.7	3.4	3.2	3.0	2.9	2.8	2.7
	Passenger vehicle (hybrid)		NO	NO	NO	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9
	Bus		25														
	Light cargo truck		23.7	23.7	21.7	12.8	7.3	6.2	5.7	5.3	5.0	4.7	4.4	4.2	4.0	3.8	3.7
	Small cargo truck		21.1	21.6	21.8	13.1	7.8	6.6	6.1	5.6	5.2	4.9	4.6	4.3	4.1	3.9	3.7
	Regular cargo truck		25														
	Special-purpose vehicle		25														
Diesel	Passenger vehicle		5.7	4.7	4.4	4.4	4.9	5.2	5.4	5.3	5.1	4.9	4.8	4.7	4.5	4.3	4.2
	Bus		3.0														
	Small cargo truck		9.3	10.3	11.1	11.7	12.2	12.4	12.5	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1
	Regular cargo truck		15.0	15.0	14.9	16.9	31.8	34.1	35.2	36.4	37.6	38.6	39.3	39.7	40.1	40.2	40.2
	Special-purpose vehicle		3.0														
LPG	Passenger vehicle		23.7	23.7	20.3	12.2	6.3	5.0	4.4	4.0	3.7	3.4	3.2	3.0	2.9	2.8	2.7
Natural gas	Passenger vehicle		0.2														
	Bus		38														
	Cargo truck		13														
	Special-purpose vehicle		15														

- ***Activity Data***

The estimates of annual distance traveled by each vehicle type and by each fuel type are used as activity data.

As for gasoline, diesel and LPG vehicles, the method of estimating the distance traveled by each vehicle type and by each fuel type up to FY2009 is to multiply the proportion of distance traveled for each fuel type, which is calculated from fuel consumption and fuel efficiency, by the distance traveled for each vehicle type given in *Statistical Yearbook of Motor Vehicle Transport* (MLIT). To separate out hybrid passenger vehicle (PV) from gasoline PV, the distance traveled by hybrid PV is estimated by multiplying the number of the vehicle by the annual distance traveled per vehicle. Before estimating the distance traveled, the values of *Statistical Yearbook of Motor Vehicle Transport* are converted to be consistent with the activity data since FY2010, using the overlap factors given by MLIT.

The annual distance traveled by vehicle type and by fuel type since FY2010 for gasoline, diesel and LPG vehicles is given in *Statistical Yearbook of Motor Vehicle Fuel Consumption* (MLIT). *Monthly Report of Motor Vehicle Transport Statistics* (MLIT) are also used supplementarily to estimate the annual distance for some vehicle types.

As for the natural gas vehicle, the annual distance traveled per vehicle type is determined by multiplying the number of natural gas-powered vehicles by the annual distance traveled per vehicle. From FY1990 to FY1996, the number of these vehicles is taken from the number of introduced natural gas-powered vehicles per type in the data compiled by the Japan Gas Association, and from FY1997, the number of registered natural gas-powered vehicles reported in the *Statistics of AIRIA/ Number of Motor Vehicle*. For the annual distance traveled per vehicle, the activity data are calculated using the annual total distance traveled by natural gas-powered vehicles, reported in the *Statistical Yearbook of Motor Vehicle Fuel Consumption*, the annual distance traveled by each vehicle type reported in the *Statistical Yearbook of Motor Vehicle Transport*, and the number of registered vehicle by each vehicle type reported in the *Statistics of AIRIA/ Number of Motor Vehicle*.

Table 3-44 Distance traveled of automobile

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
	Light passenger vehicle		16	41	72	106	137	146	150	157	161	170	176	180	181	163	159
	Passenger vehicle (non-hybrid)		273	304	343	349	319	316	303	282	273	267	260	255	244	209	193
	Passenger vehicle (hybrid)		NO	NO	NO	3	14	29	38	48	58	67	78	88	97	91	95
	Bus		0.09	0.03	0.02	0.04	0.31	0.18	0.19	0.19	0.21	0.21	0.21	0.22	0.23	0.17	0.19
Gasoline	Light cargo truck		91	90	80	78	75	75	77	78	76	76	75	73	71	66	62
	Small cargo truck		29	20	20	21	22	23	23	23	23	21	21	21	21	20	18
	Regular cargo truck	Billion vehicle-km	0	0	0	1	1	2	1	1	1	1	1	1	1	1	1
	Special-purpose vehicle		1	1	1	1	3	3	3	2	2	2	2	3	3	2	3
	Passenger vehicle		40	63	55	29	10	8	8	8	9	9	11	12	14	13	14
	Bus		7	7	6	7	6	6	6	6	6	6	6	6	5	4	4
Diesel	Small cargo truck		44	49	45	33	23	23	23	22	22	20	20	19	19	18	18
	Regular cargo truck		58	68	72	69	63	59	59	59	59	59	60	60	60	56	58
	Special-purpose vehicle		9	14	17	17	21	21	21	21	21	21	21	21	21	19	20
LPG	Passenger vehicle		18	17	15	14	12	11	10	10	9	8	8	7	6	4	4
	Passenger vehicle		0.05	0.10	1.93	5.91	6.00	3.99	3.01	2.17	1.57	1.17	0.70	0.28	0.19	0.09	0.06
Natural gas	Bus	Million vehicle-km	NO	1.9	15	48	52	47	39	34	28	22	15	11	9	5	3
	Cargo truck		0.22	10	79	254	303	283	265	254	230	198	170	141	110	85	68
	Special-purpose vehicle		0.05	2.2	18	57	67	65	62	56	49	39	33	27	23	17	13

- ***N_2O emissions from gasoline passenger vehicles in Japan***

With the enhancement of the regulation of exhaust emissions of air pollutants on gasoline passenger vehicles in 1978, the under-floor type three-way catalyst started to be installed in Japan, leading to an increase in N_2O emissions per distance traveled until around 1986 when the three-way catalyst became widely used. New emission regulations on gasoline passenger vehicles were not stipulated for the time being. Therefore, N_2O emissions per distance traveled were stable from 1986 to 1997. From 1997, low emission vehicles were introduced. From 2000, with the stipulation of the “2000 Emission Regulation”, N_2O emissions per distance traveled started to decrease in response to the introduction of the close-coupled catalytic converter (or directly exhaust manifold type catalyst). Since 1997, the trend of N_2O emissions per distance traveled is on the decrease.

The purification of toxic gas by catalyst does not start if the catalyst temperature has not exceeded a certain threshold level. Therefore, the early activation (or quick temperature raise) of catalyst at cold start has been projected, and the catalyst was relocated directly under the exhaust manifold, and this structure is introduced to close-coupled catalytic converter. N_2O is produced at medium temperature range, however the temperature of close-coupled catalytic converter reaches over this range in a short time period, thus the N_2O emissions can be reduced. (Goto et al., 2003; Yoda et al., 2010)

The figure below shows the N_2O emissions from a vehicle with the under-floor type catalyst and a vehicle with the directly exhaust manifold type catalyst on the condition of the same test mode.

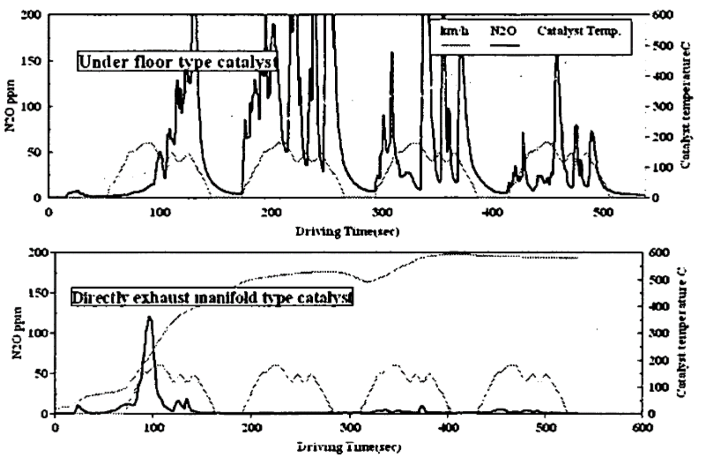


Figure 3-6 Difference of N_2O emissions by catalyst fitting position

Note: Test mode is 11 mode. Reference: Goto et al. (2003)

- ***Completeness***

➢ *Biofuels*

Biofuels have been used in recent years, however the CH_4 and N_2O emissions are estimated from activity data, which are not fuel consumption but mileage by vehicle type, and it is impossible to extract mileage only for biofuels. Therefore, CH_4 and N_2O emissions from biofuels are reported as "IE", assuming those emissions are already included in the existing emissions from gasoline or diesel oil.

➢ *Methanol*

The number of methanol vehicles owned in Japan was only 9 at the end of March 2016 (data surveyed by AIRIA). Therefore, activity data is negligible, and is not reported, as it is assumed that the emissions are also negligible.

➢ *Lubricants*

Since CH_4 and N_2O emissions from use of lubricants are very small in comparison to CO_2, these can be neglected for the greenhouse gas calculation according to the *2006 IPCC Guidelines* (Vol.3, page 5.7). Therefore, the emissions are reported as "NE".

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The emission factors of road transportation vehicle are established from the data provided by JAMA and other organizations. For the emission factors established from the samples more than five, the uncertainty is calculated from 95% confidence interval with the assumption of logarithmic standard deviation. For the emission factors established from the samples less than five, the default values of uncertainty in the *2006 IPCC Guidelines* are adopted. As for the uncertainty of activity data, because the *Statistical Yearbook of Motor Vehicle Fuel Consumption* is used for the activity data, the sample error rate of the Motor Vehicle Fuel Consumption Survey shown at the Service Statistics and Business Statistics Section Meeting by Cabinet Office, Government of Japan is used for the uncertainty. As a result, the uncertainty of emissions from road transportation vehicles including motorcycles is evaluated as -36% to +104% for CH_4, and -37% to +107% for N_2O.

- ***Time-series Consistency***

The emission factors are developed by using the same method throughout the time-series. The activity data of gasoline, diesel and LPG vehicles by FY2009 are estimated using the overlap factors given by MLIT, to be consistent with the activity data since FY2010. The activity data of natural gas vehicle are estimated based on the number of registered vehicles reported in the *Statistics of AIRIA/ Number of Motor Vehicle* after the accurate data has become available in 1997, and using the Japan Gas Association data for the total number of vehicles introduced before 1996 when the natural gas-powered vehicle was not popular. As for other activity data of natural vehicle, the data are estimated based on the *Statistical Yearbook of Motor Vehicle Transport* and the *Statistics of AIRIA/ Number of Motor Vehicle* by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

- ***QA/QC***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

- ***Verification***

On the annual review in 2014 (FCCC/ARR/2014/JPN, paragraph 40), the ERT recommended to provide additional information on the annual number of vehicles by type, the annual mileage per vehicle and the fuel efficiency per vehicle type. The ERT also recommended to compare the annual mileage and fuel efficiency by vehicle category with the fuel consumption reported by the energy balance to ensure that no discrepancies occur.

The following tables show the annual number of vehicles by type, the annual mileage per vehicle and the fuel efficiency per vehicle type. Please note that not all these data are used for the estimation of the activity data as stated in the previous section.

Table 3-45 Annual number of vehicles by type

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	Light passenger vehicle	1000 vehicles	2,715	5,966	10,084	14,350	18,004	19,348	20,230	21,026	21,477	21,761	22,051	22,325	22,528	22,736	22,850
	Passenger vehicle (non-hybrid)		29,140	33,891	37,794	40,104	37,594	36,178	35,023	33,793	32,685	31,733	30,688	29,525	28,413	27,469	26,416
	Passenger vehicle (hybrid)		NO	NO	NO	253	1,404	2,851	3,823	4,685	5,559	6,544	7,513	8,453	9,281	10,014	10,805
	Bus		8	3	2	5	9	11	13	14	15	16	16	17	18	18	19
	Light cargo truck		12,312	11,377	9,958	9,548	8,923	8,784	8,708	8,624	8,520	8,421	8,345	8,322	8,279	8,284	8,299
	Small cargo truck		2,820	2,144	1,901	1,988	1,826	1,788	1,772	1,760	1,750	1,750	1,747	1,742	1,725	1,709	1,692
	Regular cargo truck		41	38	39	90	128	138	140	146	150	153	155	157	160	162	163
	Special-purpose vehicle		141	198	393	330	287	290	291	293	297	299	302	304	309	313	317
Diesel	Passenger vehicle		2,994	4,924	4,254	2,126	905	744	730	761	855	953	1,063	1,197	1,318	1,437	1,528
	Bus		238	240	233	225	216	212	212	212	214	215	215	214	211	202	196
	Small cargo truck		3,711	4,002	3,480	2,545	1,954	1,853	1,824	1,801	1,780	1,767	1,755	1,749	1,746	1,748	1,749
	Regular cargo truck		2,164	2,544	2,534	2,350	2,105	2,086	2,100	2,116	2,130	2,151	2,169	2,197	2,223	2,243	2,258
	Special-purpose vehicle		628	804	994	903	820	814	818	822	829	840	850	856	862	869	873
LPG	All types		318	303	286	295	257	239	232	224	216	207	194	178	161	145	133
Natural gas	Passenger vehicle		0.01	0.01	0.2	0.6	0.7	0.4	0.3	0.2	0.2	0.1	0.1	0.03	0.02	0.01	0.01
	Bus		NO	0.04	0.3	1.1	1.2	1.1	0.9	0.8	0.7	0.6	0.4	0.3	0.2	0.2	0.1
	Cargo truck		0.01	0.5	3.9	12.8	15.0	13.7	12.9	12.1	11.0	9.5	8.2	7.0	5.7	4.9	3.9
	Special-purpose vehicle		0.004	0.2	1.5	4.8	5.6	5.2	4.9	4.4	3.9	3.3	2.8	2.3	1.9	1.5	1.3

Reference: *Statistics of AIRIA/ Number of Motor Vehicle* and Japan Gas Association

Table 3-46 Annual mileage per vehicle

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	Light passenger vehicle	1000 km /vehicle	5.8	6.8	7.2	7.4	7.6	7.6	7.4	7.5	7.5	7.8	8.0	8.1	8.0	7.1	7.0
	Passenger vehicle (non-hybrid)		9.4	9.0	9.1	8.7	8.5	8.7	8.6	8.3	8.3	8.4	8.5	8.6	8.6	7.6	7.3
	Passenger vehicle (hybrid)[1)]		NO	NO	NO	10.1	10.2	10.3	10.0	10.3	10.5	10.3	10.4	10.5	10.5	9.0	8.8
	Bus		11.9	9.3	9.0	8.6	34.7	15.8	14.9	14.2	14.5	13.6	12.9	12.7	12.5	9.3	10.1
	Light cargo truck		7.4	7.9	8.0	8.2	8.4	8.6	8.9	9.0	8.9	9.1	9.0	8.8	8.6	8.0	7.5
	Small cargo truck		10.3	9.5	10.3	10.5	12.2	13.0	13.1	13.2	13.1	12.3	12.2	12.3	12.3	11.7	10.9
	Regular cargo truck		8.8	7.7	6.9	6.7	11.0	10.9	9.9	9.2	9.4	9.0	8.7	8.7	8.7	7.4	7.5
	Special-purpose vehicle		4.7	3.5	3.3	3.9	9.9	9.4	8.9	8.4	8.3	8.1	8.2	8.3	8.2	7.4	8.0
Diesel	Passenger vehicle		13.3	12.8	13.0	13.7	11.4	11.4	11.1	10.4	10.1	9.7	10.0	10.2	10.5	9.2	9.3
	Bus		28.9	27.6	27.9	28.9	28.6	28.4	28.2	27.9	27.4	26.5	26.0	25.8	25.3	18.7	18.7
	Small cargo truck		11.8	12.2	12.9	12.9	11.8	12.2	12.4	12.3	12.1	11.5	11.3	11.1	11.1	10.2	10.1
	Regular cargo truck		26.7	26.8	28.6	29.5	29.9	28.5	28.1	27.9	27.9	27.5	27.4	27.2	26.8	24.9	25.9
	Special-purpose vehicle		14.6	16.9	17.2	18.9	25.3	25.6	25.9	25.9	25.9	25.2	24.8	24.6	24.2	22.4	23.3
LPG	All types		56.6	55.5	52.7	46.4	47.3	44.5	44.3	43.8	42.8	40.9	41.6	41.5	40.4	26.1	27.9
Natural gas	Passenger vehicle		10.2	9.8	9.8	9.2	8.9	9.1	9.0	8.8	8.9	8.9	9.0	9.2	9.2	8.1	7.8
	Bus		NO	47.6	45.9	44.9	43.3	42.5	41.9	41.3	39.9	38.3	37.2	36.7	36.1	26.8	26.0
	Cargo truck		18.7	18.9	20.2	19.9	20.2	20.6	20.6	21.0	20.9	20.9	20.6	20.1	19.1	17.5	17.2
	Special-purpose vehicle		11.1	11.2	12.0	11.8	12.0	12.5	12.7	12.7	12.6	11.8	11.7	11.6	11.6	10.8	10.3

Note: Estimated by dividing the distance traveled on Table 3-41 by number of vehicle on Table 3-42.

1) Due to absence of mileage statistical data, the values until FY2009 are assumed to be the mean value of FY2010-2014.

Table 3-47 Fuel efficiency per vehicle type

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	Light passenger vehicle	km/L	14.2	12.9	12.0	12.6	12.6	13.0	13.3	13.5	13.7	14.0	14.1	14.4	14.8	15.1	15.0
	Passenger vehicle (non-hybrid)[1)]	km/L	10.0	9.2	9.0	9.8	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.5	10.6	10.6
	Passenger vehicle (hybrid)	km/L	NO	NO	NO	IE	16.3	16.2	15.7	15.5	16.0	16.2	16.5	16.9	16.9	17.1	16.8
	Bus[2)]	km/L	4.1	3.9	4.1	4.3	5.8	6.2	6.5	6.7	6.8	7.1	7.3	7.6	7.7	7.7	7.5
	Light cargo truck	km/L	12.3	11.4	11.1	11.7	12.1	12.0	12.0	12.0	12.1	12.3	12.4	12.6	12.8	13.0	12.9
	Small cargo truck[3)]	km/L	8.2	7.7	8.2	8.5	9.3	9.2	9.1	9.0	9.0	9.2	9.3	9.4	9.7	9.9	9.8
	Regular cargo truck	km/L	4.4	4.2	4.4	4.6	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Special-purpose vehicle	km/L	5.1	4.8	5.2	6.4	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Diesel	Passenger vehicle	km/L	9.7	7.8	7.0	6.9	9.0	9.0	9.0	9.2	9.3	9.6	10.0	10.5	10.9	12.3	12.7
	Bus	km/L	3.6	3.4	3.4	3.6	3.6	3.5	3.5	3.5	3.6	3.5	3.6	3.6	3.6	3.4	3.4
	Small cargo truck	km/L	9.7	10.0	9.7	10.1	9.1	8.9	8.7	8.6	8.6	8.6	8.7	8.7	8.7	8.6	8.6
	Regular cargo truck	km/L	3.3	3.2	3.4	3.7	3.7	3.8	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8
	Special-purpose vehicle	km/L	3.0	3.0	3.2	3.8	4.0	4.0	4.1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
LPG	All types	km/L	6.0	5.6	5.3	5.4	5.4	5.3	5.3	5.4	5.4	5.5	5.5	5.6	5.6	5.8	5.9
Natural gas	All types[4)]	km/m^3	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.2	4.2	4.2	4.1	4.1	4.0	4.0	3.9

Note: Mileage in *Statistical Yearbook of Motor Vehicle Fuel Consumption* and *Statistical Yearbook of Motor Vehicle Transport* are divided by fuel consumption in each statistics.
1) Hybrid passenger vehicle is included until FY2009.
2) Passenger car for business-noncargo-use and special-purpose car for private-noncargo-use are included since FY2010.
3) Regular cargo truck and special-purpose car for business cargo are included since FY2010.
4) Due to absence of fuel consumption statistical data, the values until FY2009 are assumed to be the same as the value of FY2010.

In regard to the relation between mileage and fuel consumption used for emission estimation, *Statistical Yearbook of Motor Vehicle Transport* and *Statistical Yearbook of Motor Vehicle Fuel Consumption* provide the annual total mileage, the fuel consumption (and the fuel efficiency derived from them). The annual total mileage from these statistics are used as a basis of the activity data to estimate CH_4 and N_2O emissions. The CO_2 emissions are estimated by using *General Energy Statistics* (Japan's energy balance tables). *General Energy Statistics* uses the fuel consumption given in the above mentioned MLIT's statistics as primary statistics. Therefore, the same statistics are used as a basis in estimating both CO_2, CH_4 and N_2O emissions.

e) Category-specific Recalculations

New measurements of raw emission factors for vehicles were provided by JAMA, MOE and Bureau of Environment of Tokyo Metropolitan Government. Therefore, the emission factors were revised for gasoline hybrid passenger vehicles since FY2003, gasoline and LPG passenger vehicles since FY2005, and gasoline light passenger vehicles since FY2018. In addition, the emission factors were revised for diesel regular cargo trucks since FY2011, because the number of truck by NOx control technology was revised. In response to these revision, the CH_4 and N_2O emissions for the period of FY2003-FY2020 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

The emission factors will be reviewed, as appropriate, in order to represent Japan's circumstances more suitably.

3.2.9.2.b. Motorcycles

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from motorcycles.

b) Methodological Issues

- ***Estimation Method***

The CH_4 and N_2O emissions from motorcycles are established by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.14, Fig. 3.2.3). According to the Tier 3 method (Vol. 2, page 3.15, Equation 3.2.5), the equation indicates the aggregation of two types of emissions in different condition, one is the emissions in "hot" (running) condition when the engine is warm, and the other is "cold start" condition when the engine is cold at starting.

In Japan, the emission control regulation[16] for motorcycle has been established in 1999, and JAMA has collected the CH_4 and N_2O emission data measured by test from "hot" and "cold start" condition engines of each type of emission controlled motorcycles. For these motorcycles, the emission factors are established from these measured data, and for emission uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used. The CH_4 and N_2O emissions are estimated and aggregated by using the equations below.

$$E = \sum_{i,j} (EF_{hot,i,j} \times AD_{hot,i,j} + EF_{cold,i,j} \times AD_{cold,i,j})$$

E : CH_4 and N_2O emissions from motorcycles
$EF_{hot,i,j}$: Emission factor for vehicle-km by type of motorcycle and by emission control status
$AD_{hot,i,j}$: Total annual distance traveled by motorcycles by type and by emission control status
$EF_{cold,i,j}$: Emission factor per startup by type and by emission control status
$AD_{cold,i,j}$: Number of engine startups per year by each type of motorcycle and by emission control status
i : Vehicle type
j : Emission control status

- ***Emission Factors***

➢ *"Hot" condition*

The CH_4 and N_2O emission factors established by JAMA are used for the emission controlled motorcycles, and for uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used.

Table 3-48 CH_4 and N_2O emission factors of motorcycle in "hot" condition [mg/km]

Vehicle type (displacement)	3rd Regulation 1)		1st and 2nd Regulation 1)		Uncontrolled 2)	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Motor-driven cycles class 1 (50cc and under)	2.1	0.18	13.3	2.64	53	4
Motor-driven cycles class 2 (51cc-125cc)	3.4	1.39	16.7	0.23		
Mini-sized motorcycles (126cc-250cc)	6.2	0.61	12.5	0.85		
Small-sized motorcycles (Over 250cc)	2.4	0.47	22.2	1.09		

Note:
1) Data provided by JAMA
2) *2006 IPCC Guidelines*, Vol. 2, page 3.22, Table 3.2.3 Motorcycles/Uncontrolled/Running(hot)

➢ *"Cold start" condition*

The CH_4 and N_2O emission factors established by JAMA are used for the emission controlled motorcycles, and for uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used.

16 The regulated gases are CO, hydrocarbons (HC) and NOx.

Table 3-49 CH_4 and N_2O emission factors for motorcycles in "cold start" condition [mg/start]

Vehicle type (displacement)	3rd Regulation 1)		1st and 2nd Regulation 1)		Uncontrolled 2)	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Motor-driven cycles class 1 (50cc and under)	32.3	5.6	15.8	11.2	33	15
Motor-driven cycles class 2 (51cc-125cc)	41.7	18.9	18.3	4.2		
Mini-sized motorcycles (126cc-250cc)	51.3	14.7	30.2	13.7		
Small-sized motorcycles (Over 250cc)	78.0	21.3	26.1	6.9		

Note:
1) Data provided by JAMA
2) *2006 IPCC Guidelines*, Vol. 2, page 3.22, Table 3.2.3 Motorcycles/Uncontrolled/cold start

- ***Activity Data***

➢ *"Hot" condition*

For the estimation of annual distance traveled by each vehicle type and by each emission control status, firstly and based on the number of owned vehicle by each vehicle type (*Monthly Report Statistics of Vehicle*s (JAMA)), the number of sold vehicle by each sales year and by each vehicle type (JAMA and Japan Light Motor Vehicle and Motorcycle Association) is multiplied by the survival ratio by each past year (Japan Automobile Research Institute, 2008), and then the ratio of number of owned vehicle of each year by each past year is obtained, and the number of owned vehicle by each sales year and by each vehicle type is calculated. Secondary, this number is multiplied by annual travel distance by each vehicle type per one vehicle (calculated from *Survey of Motorcycle Market Trends* (JAMA)) and multiplied by use factor by each vehicle type and by each past year (Japan Automobile Research Institute, 2007), then the annual travel distance by each sales year and by each vehicle type is obtained. The emission control status is judged by the sales year.

➢ *"Cold start" condition*

For the estimation of annual number of startup by each vehicle type and by emission control status, the number of owned vehicle by each vehicle type and by each emission control status, which is obtained through the calculation of "hot" condition activity data, is multiplied by annual number of startup by each vehicle type per one vehicle (calculated from *Survey of Motorcycle Market Trends*) and multiplied by use factor by each vehicle type and by each past year (Japan Automobile Research Institute, 2007), and then the annual number of startup by each sales year and by each vehicle type is obtained. The emission control status is judged by the sales year.

Table 3-50 Activity data of motorcycles

Activity data	Vehicle type (Displacement)	Emission control by regulation	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Distance traveled	Motor-driven cycles class 1 (50cc and under)	3rd regulation	Million vehicle-km	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	522	856	955	1,108	1,291
		1st & 2nd regulation		NO	NO	1,773	4,165	3,643	3,092	3,325	3,248	2,829	2,646	1,905	1,434	933	693	523
		Uncontrolled		10,623	6,268	3,153	753	112	42	29	18	10	6	3	2	1	0	0
	Motor-driven cycles class 2 (51cc-125cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	531	1,091	1,250	1,577	1,847
		1st & 2nd regulation		NO	NO	243	1,237	2,192	2,695	2,877	2,992	2,909	2,993	2,427	1,970	1,257	1,008	741
		Uncontrolled		2,060	1,853	1,568	686	172	91	61	39	23	14	8	5	2	1	1
	Mini-sized motorcycles (126cc-250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	478	926	1,206	1,674	2,003
		1st & 2nd regulation		NO	NO	565	2,664	3,127	3,053	3,141	3,208	3,268	3,277	2,494	2,131	1,617	1,352	1,052
		Uncontrolled		6,111	3,577	2,209	1,055	330	195	147	109	79	56	35	23	14	9	5
	Small-sized motorcycles (over 250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	474	920	1,235	1,634	1,991
		1st & 2nd regulation		NO	NO	317	1,662	2,751	2,952	2,883	3,037	3,471	3,568	2,896	2,552	2,017	1,761	1,418
		Uncontrolled		3,568	3,083	2,505	1,292	559	367	271	212	179	136	93	69	44	31	20
Number of startup	Motor-driven cycles class 1 (50cc and under)	3rd regulation	Million	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	110	180	222	257	279
		1st & 2nd regulation		NO	NO	349	739	626	574	577	564	550	513	400	301	217	161	113
		Uncontrolled		1,838	1,131	621	134	19	8	5	3	2	1	1	0	0	0	0
	Motor-driven cycles class 2 (51cc-125cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	58	119	164	207	225
		1st & 2nd regulation		NO	NO	31	140	228	259	274	285	325	334	264	214	165	132	90
		Uncontrolled		285	255	203	78	18	9	6	4	3	2	1	0	0	0	0
	Mini-sized motorcycles (126cc-250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	28	54	77	107	117
		1st & 2nd regulation		NO	NO	41	177	193	196	179	183	204	204	146	124	104	86	62
		Uncontrolled		361	223	159	70	20	13	8	6	5	4	2	1	1	1	0
	Small-sized motorcycles (over 250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	10	20	38	50	63
		1st & 2nd regulation		NO	NO	19	78	111	117	95	87	111	114	62	55	62	54	45
		Uncontrolled		187	177	154	60	23	14	9	6	6	4	2	1	1	1	1

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainty of the emissions from motorcycle is included and reported in "3.2.9.2.a Road transportation: vehicles other than motorcycles". Therefore, please refer to the description in the uncertainties of the section.

- ***Time-series Consistency***

The same estimation factors are used throughout the time-series. As for the activity data, the number of owned vehicle, travel distance per one vehicle, and number of startup per one vehicle are estimated using the data provided by JAMA, Japan Light Motor Vehicle and Motorcycle Association, and MOE by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

The number of motor-driven cycles owned for FY2020 were obtained. Actual values of emission factors for mini-sized motorcycles which comply with the 3^{rd} regulation were provided by JAMA. Therefore, CH_4 and N_2O emissions since FY2017 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.9.3. Railways (1.A.3.c.)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from railways. Emissions from railways come mainly from diesel-engine railway cars. In addition, there are small amounts of emissions from coal-fired steam locomotives.

b) Methodological Issues

- ***Estimation Method***

The emissions are calculated by using Tier 1 method in accordance with the *2006 IPCC Guidelines* (Vol. 2, page 3.41, Fig. 3.4.2).

$$E = \sum_i (EF_i \times AD_i)$$

E : CH_4 and N_2O emissions from railways
EF_i : Emission factor of fuel consumption in railways by fuel type
AD_i : Annual consumptions by fuel type
i : Fuel type (diesel oil and coal)

- ***Emission Factors***

For emission factors for diesel-powered railway cars, the default values of “Diesel” shown in the *2006 IPCC Guidelines* are used after conversion to a per-liter value using the calorific value of diesel oil.

For the emission factors for steam locomotives, the default values of “sub-bituminous coal” shown in the *2006 IPCC Guidelines* are used after conversion to a per-weight value using the calorific value of imported steam coal.

Table 3-51 Default values for railway emission factors

Gas	Unit	Diesel engines	Steam locomotives
CH_4	kg-CH_4/TJ(NCV)	4.15	2
N_2O	kg-N_2O/TJ(NCV)	28.6	1.5

Reference: *2006 IPCC Guidelines*, Vol. 2, p. 3.43, Table 3.4.1

- ***Activity Data***

For the consumption of diesel oil by diesel engines in railways and coal consumption by steam locomotives, the diesel oil and coal consumption in the railway shown in the *General Energy Statistics* is used as activity data, respectively.

Table 3-52 Activity data used for estimation of emissions from railways

Fuel type	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel oil	1000 kL	356	313	270	248	218	211	205	199	198	189	197	186	186	178	178
Coal	kt	1.3	1.2	1.7	1.4	1.7	1.6	1.5	1.5	1.5	1.6	1.5	1.4	1.5	0.6	0.6

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

Since the default values in the *2006 IPCC Guidelines* are adopted for the emission factors of railways, the uncertainties indicated in the *2006 IPCC Guidelines* (-60% to +151% for CH_4 and -50% to +200% for N_2O) are adopted. Also, since the values in the *General Energy Statistics* are used for the activity data, the default values in the *2006 IPCC Guidelines* (-5% to +5%) are adopted for the uncertainty of activity data. As a result, the uncertainty of the emissions from railways is evaluated as -60% to +151% for CH_4 and -50% to +200% for N_2O.

- ***Time-series Consistency***

The same emission factors are used throughout the time-series. The data given in the *General Energy Statistics* are used as activity data consistently throughout the time-series.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

The emissions for FY2020 were recalculated due to a revision of the energy consumption of the *General Energy Statistics*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.9.4. Domestic Navigation (1.A.3.d.)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from domestic navigation of ships for passenger and freight transport.

b) Methodological Issues

- ***Estimation Method***

The emissions were calculated by using Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.49, Fig. 3.5.1).

$$E = \sum_i (EF_i \times AD_i)$$

E : CH_4 and N_2O emissions associated with the navigation of domestic vessels
EF_i : Emission factor of fuel consumption in domestic vessels
AD_i : Consumption of each type fuel by domestic vessels
i : Fuel type (diesel oil, fuel oil A, B and C)

- ***Emission Factors***

The default values for Ocean-Going Ships (diesel engines) given in the *2006 IPCC Guidelines* (see the following table) are converted to emission factors per liter using the calorific value for each type of fuel (diesel oil, fuel oil A, B and C).

Table 3-53 Default emission factors for navigation

Gas	Emission factor
CH_4	7 [kg-CH_4/TJ(NCV)]
N_2O	2 [kg-N_2O/TJ(NCV)]

Reference: *2006 IPCC Guidelines* Vol. 2, page 3.50, Table 3.5.3

- ***Activity Data***

The consumption of each fuel type in the domestic navigation taken from the *General Energy Statistics* is used for activity data.

Table 3-54 Activity data used for estimation of emissions from ships

Fuel type	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Diesel oil	1000 kL	133	208	204	195	154	141	142	157	148	147	155	149	150	109	109
Fuel oil A	1000 kL	1,602	1,625	1,728	1,324	1,007	1,006	994	984	980	1,013	1,010	993	1,020	1,036	1,213
Fuel oil B	1000 kL	526	215	152	63	18	16	14	12	9	7	7	5	3	0	0
Fuel oil C	1000 kL	2,446	3,002	3,055	2,873	2,482	2,517	2,487	2,482	2,386	2,392	2,347	2,361	2,300	2,178	2,131

- ***Completeness***

According to the *2006 IPCC Guidelines* (Vol. 3, page 5.7), CH_4 and N_2O emissions from use of lubricants are very small in comparison to CO_2, and these can be neglected for the greenhouse gas calculation. Therefore, the estimation is not done.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

Since the default values in the *2006 IPCC Guidelines* are adopted for the emission factors of domestic navigation, the uncertainties indicated in the *2006 IPCC Guidelines* (-50% to +50% for CH_4 and -40% to +140% for N_2O) are adopted. Also, since the values in the *General Energy Statistics* are used for the activity data, the default values in the *2006 IPCC Guidelines* (-13% to +13%) are adopted for the uncertainty of activity data. As a result, the uncertainty of the emissions from domestic navigation is evaluated as -52% to +52% for CH_4 and -42% to +141% for N_2O.

- ***Time-series Consistency***

The same values for emission factors are throughout the time-series. The values given in the *General Energy Statistics* are used as activity data for domestic navigation consistently throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

The emissions for FY2020 were recalculated due to a revision of the energy consumption of the *General Energy Statistics*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.9.5. Other Transportation (1.A.3.e.)

This subcategory is reported as “NO”, since fossil fuels are not combusted to transport materials by pipelines and no other activities to be reported are found.

3.2.10. CO_2 Emissions from Other Sectors and Other (1.A.4., 1.A.5: CO_2)

a) Category Description

This section provides the estimation methods for CO_2 emissions from the commercial/institutional

(1.A.4.a), residential (1.A.4.b), agriculture/forestry/fishing (1.A.4.c) and other (1.A.5) sectors. The emissions from fuel combustion for the national defense purpose are included in commercial/institutional (1.A.4.a).

In FY2021, CO_2 emissions from this category accounted for 135,485 kt-CO_2, and represented 11.6% of Japan's total GHG emissions (excluding LULUCF). The commercial/institutional (1.A.4.a) accounts for 50.3%, and is the largest subcategory within the "Other sectors" category in FY2021.

b) Methodological Issues

- ***Estimation Method***

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2), as was the case for the energy industries (1.A.1). See section 3.2.4. b).

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as "other fossil fuels" and "biomass" in accordance with the *2006 IPCC Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The CO_2 emissions from biomass are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*.

- ***Emission Factors***

The emission factors elaborated in the energy industries (1.A.1) were also used in this category. See section 3.2.4. b).

- ***Activity Data***

The data given in the *General Energy Statistics* were used for activity data, as was the case for the energy industries (1.A.1).

The activity data for each sub-category were calculated by totaling the final energy consumption in the commercial industry (#650000), residential (#700000), and agriculture, forestry and fishery (#611000) sectors, energy consumption related to non-utility power generation for use in one's own offices (auto power generation: #25xxxx), and energy consumption related to steam production for use in own offices (auto steam generation: #26xxxx) shown in the *General Energy Statistics*. Because the final energy consumption above includes the amount of non-energy use which was used for purposes other than combustion (non-energy and feedstock use: #951100, #951800 and #952000), these values were deducted from the energy consumption in each category.

The energy consumption of each fuel in the agriculture, forestry and fishery (#611000) sector in the *General Energy Statistics* is classified to mobile combustion and stationary combustion according to the ratio in the Table 3-57, which is the survey results by MOE in FY2014 and FY2015. Please refer to the Table 3-56 for which category the emissions from mobile or stationary combustion to be allocated in the CRF table.

The auto power generation and auto steam generation sectors are included in the energy transformation

& own use sector in *General Energy Statistics*. However, the *2006 IPCC Guidelines* allocates CO_2 emissions from energy consumption for power or steam generation to the sectors generating that power or steam. As such, these CO_2 emissions are added to those from each office in the final energy consumption sector and are reported in 1.A.4.

Table 3-55 Energy consumptions in Other Sectors (1.A.4) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Liquid fuels	1,921	2,080	2,190	2,222	1,573	1,413	1,441	1,346	1,292	1,279	1,291	1,217	1,184	1,238	1,137
Solid fuels	3	2	1	1	19	12	15	12	12	29	21	81	71	70	70
Gaseous fuels	418	537	649	731	835	826	836	832	846	850	909	870	893	815	860
Other fossil fuels	196	219	257	278	243	257	248	246	239	274	278	260	268	258	254
Biomass	15	18	22	44	59	63	65	73	84	64	68	72	67	54	68
Total	2,553	2,856	3,118	3,277	2,729	2,571	2,606	2,509	2,473	2,495	2,568	2,499	2,482	2,435	2,389

Table 3-56 Correspondence between sectors of Japan's Energy Balance Table and those of the CRF (1.A.4 and 1.A.5)

CRF			General Energy Statistics	
1A4	Other sectors			
	1A4a	Commercial/institutional	Auto power generation (except for Production, transmission and distribution of electricity [#255330] (until 2015), Agriculture, fishery, mining and construction [#251000] and Manufacturing [#252000])	#255000
			Auto steam generation (except for Agriculture, fishery, mining and construction [#261000] and Manufacturing [#262000])	#265000
			Final energy consumption; Commercial industry	#650000
			Non-energy and feedstock use; Commercial	#951800
	1A4b	Residential	Final energy consumption; Residential	#700000
			Non-energy and feedstock use; Household	#952000
	1A4c	Agriculture/forestry/fishing		
		i Stationary	Auto power generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#251000
			Auto steam generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#261000
			Final energy consumption; Agriculture, forestry and fishery [#610000]; stationary sources (estimates)	
			Non-energy and feedstock use; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#951100
		ii Off-road vehicles and other machinery	Final energy consumption; Agriculture [#611100]; mobile sources (estimates)	
			Final energy consumption; Forestry [#611200]; mobile sources (estimates)	
		iii Fishing	Final energy consumption; Fishery, except aquaculture [#611300]; mobile sources (estimates)	
			Final energy consumption; Aquaculture [#611400]; mobile sources (estimates)	
1A5	Other		NO	-

Note: #95xxxx items are subtracted as non-energy use activities.

Table 3-57 Ratio of mobile and stationary combustion by fuel in the agriculture/forestry/fishing (1.A.4.c)

Fuel	Agriculture		Forestry		Aquaculture			Fishery, except Aquaculture		
	Mobile com-bustion	Station-ary com-bustion	Mobile com-bustion	Station-ary com-bustion	Mobile com-bustion (ships)	Mobile com-bustion	Station-ary com-bustion	Mobile com-bustion (ships)	Mobile com-bustion	Station-ary com-bustion
Diesel oil	99%	1%	100%	0%	0%	100%	0%	0%	100%	0%
Fuel oil A	5%	95%	0%	100%	100%	0%	0%	100%	0%	0%
Kerosene	2%	98%	0%	100%	0%	0%	100%	0%	0%	100%
LPG and city gas	5%	95%	0%	100%	0%	0%	100%	0%	0%	100%

Reference: MOE (2015a)

c) Uncertainties and Time-series Consistency

Same as 3.2.4 Energy Industries (1. A. 1). See section 3.2.4. c).

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.*

The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY2016-FY2020 were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, CO_2 emissions from other fossil fuels for the period of FY2005-FY2020 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.11. CH_4 and N_2O Emissions from Other Sectors and Other (1.A.4., 1.A.5: CH_4 and N_2O)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from the Commercial/institutional (1.A.4.a), Residential (1.A.4.b), Agriculture/forestry/fishing (1.A.4.c), and Other (1.A.5) sectors.

This section also provides the estimation methods for determining CH_4 and N_2O emissions from mobile combustion such as off-road vehicles, fishing boats and other machinery. The emissions from fuel combustion for the national defense purpose are included in Commercial/institutional (1.A.4.a).

b) Methodological Issues

- ***Estimation Method***

➢ *Furnaces*

For Commercial/institutional (1.A.4.a) and the stationary combustion in Agriculture/forestry/fishing (1.A.4.c), same with Energy Industries (1.A.1), CH_4 and N_2O emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2). See section 3.2.5. b) (1.A.1).

➢ *Biomass boilers*

See section 3.2.5. b) (1.A.1).

➢ *Residential*

For Residential (1.A.4.b), CH_4 and N_2O emissions from fuel combustion in this category are calculated by using Tier 1 method, since furnace-specific activity data is not available.

➢ *Off-road vehicles and other machinery*

The emissions from mobile combustion in Agriculture/forestry/fishing (1.A.4.c) are estimated by Tier 1 in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 3.34, Fig. 3.3.1).

- ***Emission Factors***

➢ *Furnaces*

For Commercial/institutional (1.A.4.a) and the stationary combustion in Agriculture/forestry/fishing (1.A.4.c), the emission factors which were established in Energy Industries (1.A.1) were used. See Table 3-23 and Table 3-24 (1.A.1).

➢ *Biomass boilers*

See section 3.2.5. b) (1.A.1).

➢ *Residential*

For Residential (1.A.4.b), the emission factors which were provided in the *2006 IPCC Guidelines* (Vol. 2, pages 2.22-2.23, Table 2.5) were used.

Table 3-58 CH_4 and N_2O emission factors for residential (1.A.4.b)

Furnace type	Fuel type	CH_4 Emission factor [kg-CH_4/TJ]	N_2O Emission factor [kg-N_2O/TJ]
Household equipment	Liquid fuels	9.5	0.57
	Solid fuels	290	1.4
	Gaseous fuels	4.5	0.090
	Biomass fuels	290	3.8

Note: Conversion to the GCV basis by multiplying the IPCC default values by 0.95 (liquid, solid and biomass fuels) or 0.9 (gaseous fuels) (*2006 IPCC Guidelines*, Vol.2, page 1.16)

➢ *Off-road vehicles and other machinery*

The emission factors of diesel oil used for the mobile combustion in agriculture, fishing and aquaculture were estimated from the values of "1.A.4.c.ii-Agriculture/ Diesel" in the Table 3-1 of EEA (2016). The emission factors of fuel oil A and kerosene used for agriculture were not shown in the guidebook but were applied the same value of diesel oil since most of the fuel oil A and kerosene are also used for tractors. The emission factors of LPG and city gas were estimated from the value of "LPG" in the same Table, and the emission factors of diesel oil for forestry were estimated from the values of "1.A.4.c.ii-Forestry/ Diesel" in the same Table.

The emission factors of fuel oil A used for fishing and aquaculture were estimated from the values on Table 3.5.3 "Default water-borne navigation CH_4 and N_2O emission factors" in the *2006 IPCC Guidelines* vol. 2, page3.50.

Table 3-59 Emission factors of CH_4 and N_2O for off-road vehicles and other machinery in Agriculture/forestry/fishing (1.A.4.c)

Fuel	Unit	CH_4 emission factor	N_2O emission factor	Reference
Diesel oil, kerosene, fuel oil A used for other than ships	g/t	87	136	EEA (2016), Non-road mobile sources and machinery, Table 3-1
Diesel oil for forestry	g/t	49	138	
LPG, city gas	g/t	354	161	
Fuel oil A for ships	kg/TJ(NCV)	7	2	*2006 IPCC Guidelines*, Vol.2, Table 3.5.3

- ***Activity Data***

➢ *Furnaces*

The fuel consumption, obtained by multiplying the fuel consumption of each sector and each fuel type in the *General Energy Statistics* by the ratio of stationary combustion in the Table 3-57 and the fuel consumption ratio by furnace type, is assumed to be the activity data for the stationary combustion namely combustion in furnaces. Same with Energy Industries (1.A.1), the fuel consumption ratios by furnace were estimated from data by furnace on the *General Survey of the Emissions of Air Pollutants* and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries, Structural Survey of Energy Consumption, Electric Power Statistics*, and *Current Survey of Production Concerning Gas Industry*). See section 3.2.5. b) (1.A.1).

➢ *Biomass boilers*

See section 3.2.5. b) (1.A.2).

➢ *Residential*

The fuel consumption by fuel type in the *General Energy Statistics* was used for the activity data of residential (1.A.4.b).

➢ *Off-road vehicles and other machinery*

The fuel consumption, estimated by multiplying the fuel consumption of each fuel type in Agriculture, Forestry and Fishery in the *General Energy Statistics* by the ratios of fuel consumption of mobile combustion (Table 3-57), were used for the activity data of mobile combustion namely off-road vehicles and other machinery.

c) Uncertainties and Time-series Consistency

➢ *Furnaces (including biomass boilers)*

See section 3.2.7. c).

➢ *Residential*

The uncertainties of the emission factors are set by the default values. The uncertainties of the activity data are set by the values established in section 3.2.4. c).

➢ *Off-road vehicles and other machinery*

See section 3.2.7. c).

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

Since the activity data for FY2016-2020 in the *General Energy Statistics* were revised, the CH_4 and N_2O emissions in those years were recalculated.

Updating the statistical data in the waste sector, CH_4 and N_2O emissions in FY2020 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

See section 3.2.5. f).

3.2.12. Emissions from waste incineration with energy recovery

The three cases below in which waste is utilized as raw material or fuel meet the definition of emissions from waste incineration with energy recovery.

- Waste incineration with energy recovery
- Direct use of waste as alternative fuel
- Incineration of waste processed as fuel

The estimation method for emissions from these sources is applied for waste incineration (5.C) in accordance with the *2006 IPCC Guidelines*. The emissions are included in fuel combustion (1.A.) in accordance with the *2006 IPCC Guidelines.* Please refer to Chapter 7 for the details of the estimation methods.

The reporting category of the emissions for each type of waste is either “energy industries (category 1.A.1)”, “manufacturing industries and construction (1.A.2)” or “other sectors (1.A.4)” according to the use of waste as raw material or fuel. The fuel type is classified as “other fossil fuels” and “biomass”.

Greenhouse gas emissions during the direct use of waste as a raw material, such as plastics used as reducing agents in blast furnaces or as a chemical material in coking furnaces, or the use of intermediate products manufactured using the waste as a raw material, are also subject to the estimation of emissions.

Refuse-derived solid fuels (RDF: Refuse-Derived Fuel, RPF: Refuse Paper and Plastic Fuel) are also subject to the estimation of emissions as fuels produced from waste.

Table 3-60 Waste types whose emissions are estimated for “Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)”

Category	Waste type			Fuel type to be allocated to CRF	Treatment type		CO2	CH4	N2O
1.A.4. (7.4.3.1)[7]	Municipal solid waste (MSW)	Plastics	Fossil-fuel derived plastics	Other fossil fuels	Incineration with energy recovery	* Incinerator -continuous, -semi-continuous -batch type * Gasification melting furnace	○	○[2]	○[2]
			Biomass-based plastics	Biomass[8]			NA[1]		
		PET bottles	Fossil- fuel derived PET bottles	Other fossil fuels			○		
			Biomass-based PET bottles	Biomass[8]			NA[1]		
		Paper/ cardboard	Fossil-fuel derived fraction	Other fossil fuels[9]			○		
			Biogenic fraction	Biomass			NA[1]		
		Nappies	Fossil-fuel derived fraction	Other fossil fuels			○		
			Biogenic fraction	Biomass			NA[1]		
		Textiles	Synthetic textiles	Other fossil fuels			○		
			Natural fiber	Biomass			NA[1]		
		Other (biogenic)		Biomass			NA[1]		
	Industrial solid waste (ISW)	Waste oil	Fossil-fuel derived oil	Other fossil fuels		Incinerator	○	○	○
			Animal and vegetable oil	Biomass			NA[1]	○	○
		Plastics	Fossil-fuel derived plastics	Other fossil fuels			○	○	○
			Biomass-based plastics	Biomass[8]			NA[1]	IE[3]	IE[3]
		Food waste [Animal and vegetable residues/animal carcasses]		Biomass			NA[1]	○	○
		Paper/ cardboard	Fossil-fuel derived fraction	Other fossil fuels[9]			○	IE[4]	IE[4]
			Biogenic fraction	Biomass			NA[1]	○	○
		Wood		Biomass			NA[1]	○	○
		Textile	Synthetic textile	-			IE[5]	IE[5]	IE[5]
			Natural fiber	Biomass			NA[1]	○	○
		Sludge	Sewage sludge	-			NO	NO	NO
			Other than sewage sludge	Biomass			NA[1]	○	○
	Specially controlled industrial waste			-			IE[5]	IE[5]	IE[5]
1.A.1, 1.A.2 and 1.A.4 (7.4.3.2)[7]	Municipal solid waste	Plastics	Fossil-fuel derived plastics	Other fossil fuels	Direct use as alternative fuel		○	○	○
			Biomass-based plastics	Biomass[8]			NA[1]	IE[3]	IE[3]
		PET bottles		-			NO	NO	NO
	Industrial solid waste	Waste oil	Fossil-fuel derived oil	Other fossil fuels			○	○	○
			Animal and vegetable oil	Biomass			NA[1]	○	○
		Plastics	Fossil-fuel derived plastics	Other fossil fuels			○	○	○
			Biomass-based plastics	Biomass[8]			NA[1]	IE[3]	IE[3]
		Wood		Biomass			NA[1]	○	○
	Waste tire		Fossil-fuel derived fraction	Other fossil fuels			○	○	○
			Biogenic fraction	Biomass[8]			NA[1]	IE[6]	IE[6]
1.A.1 and 1.A.2 (7.4.3.3)[7]	Refuse Derived Fuel (RDF)		Fossil-fuel derived fraction	Other fossil fuels	Incineration of waste processed as fuel		○	○	○
			Biogenic fraction	Biomass[8]			NA[1]	IE[6]	IE[6]
	Refuse Paper and Plastic Fuel (RPF)		Fossil-fuel derived fraction	Other fossil fuels			○	○	○
			Biogenic fraction	Biomass[8]			NA[1]	IE[6]	IE[6]

Note:
1) CO_2 emissions from the incineration of biomass-derived waste are not included in the total emissions; instead it is estimated as a reference value and reported as “Biomass” fuel in the CRF tables.
2) CH_4 and N_2O emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported as “Other fossil fuels” in the CRF tables.
3) Included in fossil-fuel derived plastics in ISW
4) Included in biogenic fraction of paper/cardboard
5) Included in “Specially controlled industrial waste” incineration without energy recovery
6) Included in the fossil-fuel derived fraction
7) For details of categories to be reported in the CRF, see descriptions on each section.
8) For the biomass fraction in solid waste, etc. such as plastics, waste tire, RPF and RDF, it is difficult to distinguish the activity data on calorie basis for energy sector from the fossil-fuel derived fraction since there are no appropriate way to decompose calorimetric data of mixed solid waste. Hence, the activity data is reported as “IE”, and is included in “other fossil fuels”.
9) For the fossil-fuel derived fraction in “paper/cardboard”, it is difficult to distinguish the activity data on calorie basis for energy sector from the biogenic fraction. Hence, the activity data is reported as “IE”, and is included in “biomass”.

Table 3-61 Reporting categories on the energy sector whose emissions are estimated for waste incineration and energy use

Treatment type	Waste type		Application breakdown	Major application	Reporting category on the energy sector	CO_2 2)	CH_4	N_2O
Waste incineration with energy recovery	MSW		(Unclassified)	Waste incineration with energy recovery	1.A.4.a. Commercial/institutional	○	○	○
	ISW					○	○	○
Direct use of waste as alternative fuel	MSW Plastics		Liquefaction	Fuel	1.A.2.g. Other	○	○	○
			Blast furnace reducing agent	Reducing agent in blast furnace	1.A.2.a. Iron and steel	○	NO 3)	NO 3)
			Coke oven chemical feedstock	Alternative fuel or raw material in coke oven	1.A.1.c. Manufacture of solid fuels	○	IE 4)	NO 5)
			Gasification	Fuel	1.A.2.g. Other	○	NE 6)	NE 6)
	Industrial waste	Waste oil	(Unclassified)	Fuel	1.A.2.g. Other	○	○	○
		Plastics	Blast furnace reducing agent	Blast furnace reducing agent	1.A.2.a. Iron and steel	○	NO 3)	NO 3)
			Chemical industry	Boiler fuel	1.A.2.c. Chemicals	○	○	○
			Paper industry	Boiler fuel	1.A.2.d. Pulp, paper and print	○	○	○
			Cement burning	Cement burning	1.A.2.f. Non-metallic minerals	○	○	○
			Automobile manufacturer	Boiler fuel	1.A.2.g. Other	○	○	○
			Liquefaction	Fuel	1.A.2.g. Other	○	○	○
			Gasification	Fuel	1.A.2.g. Other	○	NE 6)	NE 6)
		Wood	(Unclassified)	Fuel	1.A.2.g. Other	NA	○	○
	Waste tire		Cement burning	Cement burning	1.A.2.f. Non-metallic minerals	○	○	○
			Boiler	Fuel	1.A.2.g. Other	○	○	○
			Iron manufacture	Alternative fuel or raw materials in iron manufacturing	1.A.2.a. Iron and steel	○	NO 3)	NO 3)
			Gasification	Fuel in iron manufacturing	1.A.2.a. Iron and steel	○	○	○
			Metal refining	Fuel in metal refining	1.A.2.b. Non-ferrous metals	○	○	○
			Tire manufacture	Fuel in tire manufacturing	1.A.2.c. Chemicals	○	○	○
			Paper manufacture	Fuel in paper manufacturing	1.A.2.d. Pulp, paper and print	○	○	○
			Power generation	Power generation	1.A.4.a. Commercial/institutional	○	○	○
Incineration of waste processed as fuel	Refuse-derived fuel (RDF)		(Unclassified)	Fuel use (including power generation)	1.A.2.g. Other 1)	○	○	○
	Refuse paper and plastic fuel (RPF)		Petroleum product manufacturer	boiler fuel	1.A.1.b. Petroleum refining	○	○	○
			Chemical industry	boiler fuel	1.A.2.b. Chemicals	○	○	○
			Paper industry	Fuel use in paper manufacturing	1.A.2.d. Pulp, paper and print	○	○	○
			Cement manufacturer	Cement burning	1.A.2.f. Non-metallic minerals	○	○	○

Note:

1) Emissions from power generation and heat supply excluding in-house use should be included in the category 1.A.1.a. However, they are reported in the category 1.A.2.g., because the actual circumstances are not understood at the moment.
2) CO_2 emissions from the incineration of biomass-derived fraction are not included in the total emissions; instead it is estimated as a reference value and reported as "Biomass" fuel in the CRF tables. For detail, see Table 3-60.
3) Blast furnace gas generated from steel industry is entirely recovered.
4) These emissions are included in "solid fuels" in the same category 1.A.1.c.
5) N_2O is likely not produced since the atmosphere in coke oven is normally at least 1,000 degree Celsius, and reducing.
6) Considering that small fraction of these sources is combusted as alternative fuel but these are mostly used to obtain feedstock for ammonia productions, the emissions are not estimated.

Table 3-62 shows the greenhouse gas emissions from waste incineration and energy use (reported on energy sector) (1.A.).

Table 3-62 GHG emissions from waste incineration and energy use (reported on energy sector) (1.A.)

Category		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1.A.1. Energy industries	a. Public electricity and heat production	kt-CO_2	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	b. Petroleum refining	kt-CO_2	NO	NO	0.6	6.4	5.8	5.5	4.5	5.0	6.1	4.5	5.0	0.3	0.1	0.6	NO
	c. Manufacture of solid fuels and other energy industries	kt-CO_2	NO	NO	15	246	248	240	NO	24	41	35	45	24	34	33	33
1.A.2. Manufacturing industries and construction	a. Iron and steel	kt-CO_2	NO	NO	312	639	549	538	474	580	562	590	626	532	570	411	485
	b. Non-ferrous metals	kt-CO_2	119	63	51	17	2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	c. Chemicals	kt-CO_2	14	64	89	67	73	84	82	65	68	63	65	63	48	29	20
	d. Pulp, paper and print	kt-CO_2	NO	56	114	998	1,804	1,850	1,930	1,986	2,044	2,089	2,150	2,181	2,073	2,055	2,157
	e. Food processing, beverages and tobacco	kt-CO_2	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	f. Non-metallic minerals	kt-CO_2	197	492	879	1,088	1,324	1,358	1,453	1,636	1,590	1,711	1,780	1,965	2,050	2,047	2,111
	g. Other	kt-CO_2	3,878	4,474	4,462	5,874	5,625	5,724	5,608	5,357	5,742	5,399	5,434	5,827	5,995	5,677	5,705
1.A.4	a. Commercial/institutional	kt-CO_2	6,505	7,146	9,043	8,406	6,804	7,741	7,552	7,176	7,258	8,174	8,543	7,904	8,610	8,524	8,337
Total		kt-CO_2	10,712	12,294	14,966	17,341	16,433	17,541	17,104	16,830	17,311	18,066	18,648	18,497	19,381	18,778	18,848
1.A.1. Energy industries	a. Public electricity and heat production	kt-CH_4	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	b. Petroleum refining	kt-CH_4	NO	NO	1.7.E-06	1.8.E-05	1.6.E-05	1.5.E-05	1.3.E-05	1.4.E-05	1.7.E-05	1.2.E-05	1.4.E-05	8.6.E-07	3.2.E-07	1.6.E-06	NO
	c. Manufacture of solid fuels and other energy industries	kt-CH_4	NO	NO	IE	IE	IE	IE	NO	IE	IE	IE	IE	IE	IE	IE	IE
1.A.2. Manufacturing industries and construction	a. Iron and steel	kt-CH_4	NO	NO	NO	7.7.E-04	1.4.E-03	1.3.E-03	1.2.E-03	1.4.E-03	1.4.E-03	1.4.E-03	1.6.E-03	1.7.E-03	1.6.E-03	2.8.E-04	2.8.E-05
	b. Non-ferrous metals	kt-CH_4	3.2.E-04	1.8.E-04	1.4.E-04	7.7.E-05	7.7.E-06	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	c. Chemicals	kt-CH_4	2.0.E-05	1.0.E-04	1.5.E-04	1.7.E-04	1.9.E-04	2.2.E-04	2.2.E-04	1.8.E-04	1.9.E-04	1.7.E-04	1.7.E-04	1.6.E-04	1.2.E-04	6.4.E-05	3.9.E-05
	d. Pulp, paper and print	kt-CH_4	NO	1.0.E-04	2.2.E-04	2.7.E-03	4.8.E-03	5.0.E-03	5.2.E-03	5.4.E-03	5.6.E-03	5.7.E-03	5.9.E-03	6.0.E-03	5.7.E-03	5.7.E-03	6.0.E-03
	e. Food processing, beverages and tobacco	kt-CH_4	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	f. Non-metallic minerals	kt-CH_4	0.03	0.08	0.14	0.20	0.22	0.22	0.23	0.26	0.25	0.27	0.28	0.31	0.32	0.32	0.33
	g. Other	kt-CH_4	1.8	1.8	2.2	2.9	4.2	4.5	4.8	5.3	5.0	4.9	5.2	5.1	5.5	5.4	5.1
1.A.4	a. Commercial/institutional	kt-CH_4	0.54	0.54	0.60	0.15	0.14	0.17	0.15	0.15	0.14	0.15	0.15	0.14	0.14	0.14	0.14
Total		kt-CH_4	2.3	2.4	3.0	3.3	4.6	4.9	5.2	5.7	5.4	5.4	5.7	5.5	6.0	5.9	5.6
		kt-CO_2 eq.	59	60	74	81	114	122	129	142	135	134	142	138	149	147	140
1.A.1. Energy industries	a. Public electricity and heat production	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	b. Petroleum refining	kt-N_2O	NO	NO	1.1.E-05	1.2.E-04	1.0.E-04	1.0.E-04	8.1.E-05	9.0.E-05	1.1.E-04	8.0.E-05	9.1.E-05	5.6.E-06	2.1.E-06	1.0.E-05	NO
	c. Manufacture of solid fuels and other energy industries	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.A.2. Manufacturing industries and construction	a. Iron and steel	kt-N_2O	NO	NO	NO	9.1.E-04	1.6.E-03	1.5.E-03	1.5.E-03	1.7.E-03	1.6.E-03	1.7.E-03	1.9.E-03	2.0.E-03	1.9.E-03	3.4.E-04	3.4.E-05
	b. Non-ferrous metals	kt-N_2O	2.4.E-04	1.3.E-04	1.1.E-04	5.6.E-05	5.6.E-06	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	c. Chemicals	kt-N_2O	8.5.E-03	6.8.E-03	8.5.E-03	4.5.E-03	3.3.E-03	3.2.E-03	2.4.E-03	1.7.E-03	1.9.E-03	1.5.E-03	5.8.E-03	6.5.E-03	6.8.E-03	8.2.E-03	7.8.E-03
	d. Pulp, paper and print	kt-N_2O	NO	6.6.E-04	5.9.E-03	2.2.E-02	5.9.E-02	5.7.E-02	5.6.E-02	6.2.E-02	6.1.E-02	6.4.E-02	6.7.E-02	6.8.E-02	6.5.E-02	6.3.E-02	6.8.E-02
	e. Food processing, beverages and tobacco	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	f. Non-metallic minerals	kt-N_2O	2.7.E-03	6.9.E-03	1.2.E-02	1.7.E-02	1.9.E-02	1.9.E-02	2.0.E-02	2.3.E-02	2.2.E-02	2.4.E-02	2.5.E-02	2.7.E-02	2.8.E-02	2.8.E-02	2.9.E-02
	g. Other	kt-N_2O	5.8.E-02	5.1.E-02	5.3.E-02	6.1.E-02	6.8.E-02	7.1.E-02	7.4.E-02	7.9.E-02	7.7.E-02	7.5.E-02	7.8.E-02	7.8.E-02	8.3.E-02	8.0.E-02	7.8.E-02
1.A.4	a. Commercial/institutional	kt-N_2O	1.2	1.3	1.6	1.1	0.9	1.0	1.0	1.0	0.9	1.0	1.0	1.0	1.0	0.9	0.9
Total		kt-N_2O	1.3	1.4	1.6	1.2	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.1	1.2	1.1	1.1
		kt-CO_2 eq.	379	416	488	372	328	342	334	335	319	358	363	340	347	334	331

Note:

1) Include fossil-fuel derived component only.
   CO_2 emissions from the incineration of biomass-derived waste (including biomass-based plastics and waste animal and vegetable oil) is not included in the total emissions in accordance with the *2006 IPCC Guidelines*; instead it is estimated as a reference value and reported under "Biomass" in CRF table 1.A(a).
2) Include both fossil-fuel derived component and biogenic component.

3.3. Fugitive Emissions from Fuels (1.B.)

The Fugitive Emissions subsector consists of intentional and unintentional GHG emissions from unburned fossil fuels during their mining, production, processing, refining, transportation, storage, and distribution, and from geothermal power plants.

There are two main source categories in this sector: solid fuels (1.B.1): emissions from coal mining and handling, and oil and natural gas (1.B.2): emissions from the oil and natural gas industries. The main source of emissions from solid fuels is CH_4 contained in coal bed, whereas fugitive emissions, venting, flaring, volatilization, and accidents are the main emission sources in the oil and natural gas industries. The emissions from geothermal power generation are also reported in 1.B.2.d.

In FY2021, GHG emissions from fugitive emissions from fuels were 1,044 kt-CO_2 eq. and accounted for 0.1% of Japan's total GHG emissions (excluding LULUCF). The emissions have decreased by 80.3% compared to 1990.

The contribution of the GHG emissions from this category relative to the national total is small in Japan. Japan mostly depends on fossil fuel imports. The domestic production of fossil fuels have comprised less than 5% of domestic supply since FY1990.

Table 3-63 Emission trends of the fugitive emissions subsector (1.B)

Gas	CRF Category		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	1.B.1 Solid Fuels	a. Coal Mining	kt-CO_2	5.4	2.5	1.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4
		b. Solid Fuel Transformation		0.5	1.0	1.6	1.6	1.7	1.9	2.1	2.2	2.2	2.5	2.6	2.8	3.0	2.8	3.0
		c. Other (Uncontrolled Combustion and Burning Coal Dump)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and Natural Gas	a. Oil		0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		b. Natural Gas		0.6	0.7	0.8	1.0	1.0	1.0	0.9	0.9	0.8	0.9	0.9	0.8	0.8	0.7	0.7
		c. Venting and Flaring		81.2	109.1	122.6	164.3	221.7	232.2	222.0	209.8	223.3	245.2	264.7	242.3	222.0	197.6	162.8
		d. Other (Geothermal Generation)		104.4	409.2	386.6	341.9	251.2	256.5	215.2	237.9	200.1	210.5	170.0	181.7	162.6	191.9	191.9
	Total		kt-CO_2	192	523	513	509	476	492	441	451	427	460	439	428	389	393	359
CH_4	1.B.1 Solid Fuels	a. Coal Mining	kt-CH_4	192.4	97.5	63.3	26.3	22.6	21.9	21.4	21.7	20.9	20.7	21.2	19.1	18.3	18.0	17.5
		b. Solid Fuel Transformation		3.4	3.3	2.7	1.8	1.4	1.2	1.2	1.1	1.0	1.0	0.9	0.9	0.9	0.8	0.7
		c. Other (Uncontrolled Combustion and Burning Coal Dump)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and Natural Gas	a. Oil		1.0	1.1	1.1	1.2	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.7	0.7
		b. Natural Gas		7.0	7.8	8.8	10.7	11.1	10.5	9.8	9.2	9.3	10.0	9.9	9.4	8.7	7.8	8.0
		c. Venting and Flaring		0.3	0.5	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		d. Other (Geothermal Generation)		0.2	0.8	0.7	0.7	0.5	0.5	0.4	0.5	0.4	0.4	0.3	0.4	0.3	0.4	0.4
	Total		kt-CH_4	204.3	110.9	76.9	41.0	36.8	35.3	33.9	33.5	32.6	33.0	33.4	30.6	29.1	27.9	27.4
			kt-CO_2 eq.	5,107	2,773	1,922	1,026	920	882	848	838	816	824	834	764	727	697	685
N_2O	1.B.1 Solid Fuels	a. Coal Mining	kt-N_2O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		b. Solid Fuel Transformation		0.007	0.007	0.005	0.004	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001
		c. Other (Uncontrolled Combustion and Burning Coal Dump)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and Natural Gas	a. Oil		IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA
		b. Natural Gas																
		c. Venting and Flaring		0.0004	0.0005	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0003	0.0003	0.0002
		d. Other (Geothermal Generation)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total		kt-N_2O	0.0070	0.0071	0.0058	0.0040	0.0031	0.0027	0.0027	0.0025	0.0023	0.0022	0.0021	0.0020	0.0020	0.0018	0.0016
			kt-CO_2 eq.	2.09	2.11	1.72	1.18	0.91	0.82	0.80	0.75	0.70	0.65	0.63	0.59	0.59	0.55	0.49
	Total of all gases		kt-CO_2 eq.	5,302	3,297	2,437	1,536	1,397	1,375	1,289	1,290	1,243	1,285	1,273	1,193	1,116	1,091	1,044

(Reference) Biomass-origin CO_2 emissions

CO_2	1.B.1 Solid Fuels	b. Solid Fuel Transformation	kt-CO_2	130.7	129.2	105.9	70.5	53.5	47.5	46.5	43.6	40.6	37.3	36.3	34.1	33.5	31.0	27.4

3.3.1. Solid Fuels (1.B.1.)

3.3.1.1. Coal Mining and Handling (1.B.1.a.)

3.3.1.1.a. Underground Mines (1.B.1.a.i.)

a) Category Description

This category includes CH_4 and CO_2 emissions from coal mining, post-mining process, and abandoned mines.

Coal contains CH_4 which was formed during the coalification process. Most will have been naturally released from the ground surface before mine development, but mining releases the CH_4 remaining in coal beds into the atmosphere. Also, CH_4 may be released during post-mining activities, i.e. subsequent handling, processing and transportation of coal. In addition, some of the coal mines still emit CH_4 after they have been abandoned. Also, relatively low-density CO_2 is included in coal in comparison with CH_4, and is emitted to the air through the similar process with the CH_4.

The number of operational coal mines in Japan has decreased and coal production has decreased greatly as well. As a result, the amount of CH_4 emissions from coal mining has decreased year by year.

Furthermore, the coal mining practices have changed recently, resulting in the decreasing trend of CH_4 IEF. Specifically, coal is now mined in more shallow areas. Therefore, emitting less CH_4. This is because deep areas are costly to mine compared to coal in shallow areas. Additionally, areas which have been previously mined, thus already releasing CH_4, are re-mined for coal, using the latest technology. This contributes to low CH_4 emissions per amount of coal mined, even if compared with other countries.

The mining activities in Japan are elaborated in Matsumoto (2006) and Matsumoto *et al.* (2018).

The N_2O emissions are reported as "NE," because the existence of such activities in underground mines and surface mines has not been confirmed and no methodology is provided by the *2006 IPCC Guidelines*.

b) Methodological Issues

- ***Estimation Method***

➢ *CH_4*

- ***Mining Activities***

CH_4 emissions from mining activities are drawn from actual measurements obtained from individual coal mines using the Tier 3 method, in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.11, Fig. 4.1.1).

- ***Post-Mining Activities***

CH_4 emissions from post-mining activities are estimated using the Tier 1 method, which uses default emission factors in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.11, Fig. 4.1.1). The emissions are estimated by multiplying the amount of coal mined from underground mines by the emission factor.

- ***Abandoned Underground Mines***

In accordance with the decision tree in the *2006 IPCC Guidelines* (Vol 2, page 4.22, Fig4.1.3), the Tier 2 method is used. The CH_4 emissions from abandoned underground mines are estimated by multiplying the number of abandoned mines which are not submerged by emission factors which are established with consideration of types of coal and period of being abandoned as shown in the following equation.

$$E = N \times F \times ER \times EF \times CF, \quad EF = (1 + a \times T)^b$$

E	: Amount of GHG fugitive emissions from abandoned coal mine [kt/year]
N	: Number of abandoned mines which is not submerged [sites]
F	: The percentage of mines that release fugitive emissions
ER	: GHG emissions from mines before mine closure [m^3/year]
EF	: Emissions reduction factor

a,b : Parameters determining emission decline curve
T : Time period of mine closure [year]
CF : CH_4 density (0.67×10^{-6} [kt/m^3])

➢ *CO_2*

The method applied is reported as "CS" (country-specific) in CRF Summary 3, since the *2006 IPCC Guidelines* do not provide a method to estimate CO_2 emissions but a country-specific CO_2 emission factor is available.

- ***Mining Activities***

CO_2 emissions are estimated by multiplying the production amount of coal by CO_2 emission factor.

- ***Post-Mining Activities***

CO_2 emissions are estimated by multiplying the production amount of coal by CO_2 emission factor.

- ***Abandoned Underground Mines***

The estimation method of CO_2 emissions is similar to that of CH_4 described above, and the CO_2 emission factor is established based on CH_4 emission factor.

● ***Emission Factors***

➢ *CH_4*

- ***Mining Activities***

CH_4 emission factor for mining activities is established by converting the total emissions of CH_4 gas (in volume unit) identified in a survey by J-COAL (Japan Coal Frontier Organization; former Japan Coal Energy Center) into weight basis using the density of CH_4 (0.67 [kt/10^{6}m^3]) at 20°C and 1 atmosphere, and then dividing it by the production amount of coal from underground mines. From FY1991 to 1994, since actual measurement data cannot be obtained, the emission factors for those years are interpolated using FY1990 and 1995 values.

Table 3-64 Emission factors for mining activities: underground mines

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Reference
Coal production of underground mines (A)	kt	9,471	8,118	4,016	1,635	1,225	1,100	1,103	1,124	980	1,102	1,275	660	459	565	468	Survey by J-COAL
CH_4 total emissions (B)	10^6m^3	262	92	57	4.2	2.0	1.8	1.9	2.3	2.4	2.4	2.9	1.5	1.3	1.2	1.3	Survey by J-COAL
CH_4 total emissions (C)	kt-CH_4	176	62	38	2.8	1.3	1.2	1.2	1.5	1.6	1.6	1.9	1.0	0.9	0.8	0.9	=(B)*0.67
Emission factor	kg-CH_4/t	19	8	9	1.7	1.1	1.1	1.1	1.4	1.6	1.4	1.5	1.5	1.9	1.4	1.8	=(C)/(A)*1000

- ***Post-Mining Activities***

Due to the lack of data for emissions from post-mining activities in Japan, the emission factors are calculated as 1.675 [kg-CH_4/t] by converting the average value (2.5 [m^3/t]) of the default values given in the *2006 IPCC Guidelines* with the density of CH_4 (0.67 [kt/10^{6}m^3]) at 20°C and 1 atmosphere.

- ***Abandoned Underground Mines***

To establish emission factor for abandoned underground mines, following values are used for the formula on the previous page;

The median of default values which is indicated in Table 4.1.5 in page 4.24 in the *2006 IPCC Guidelines* Vol.2 (1990-1925: 5%, 1926-1950: 26.5%, 1951-1975: 40%, 1976-2000: 54%, 2001-: 54.5%) are used for (*F*), the percentage of mines that release fugitive emissions.

The lower default value (1.3 million cubic meter/year/site) indicated in Table 4.1.8 in page 4.27 in the *2006 IPCC Guidelines* Vol.2 is used for (*ER*), GHG emissions from mines before mine closure, by taking scale of mine into consideration.

The coefficients for sub-bituminous coal (a = 0.27, b = -1.00) indicated in Table 4.1.9 in page 4.27 in the *2006 IPCC Guidelines* Vol.2 are used for parameters to determine declining curve for emissions.

➢ *CO_2*

- ***Mining Activities***

CO_2 emission factor for mining activities is established by multiplying CH_4 emission factor (volume basis) by proportion of volume fraction of CO_2 in coalbed gas to that of CH_4 (0.0088), which is estimated by using Hokkaido Development Agency (1965), and by CO_2 density (1.84 kg/m^3).

- ***Post-Mining Activities***

In the same way as calculated for mining activities, the emissions factors for post-mining activities are established by multiplying CH_4 emission factor (volume basis) by 0.0088.

- ***Abandoned Underground Mines***

In the same way as calculated for mining activities, the emissions factors for post-mining activities are established by multiplying CH_4 emission factor (volume basis) by 0.0088.

● ***Activity Data***

- ***Mining Activities, Post-Mining Activities***

The values used for activity data for underground mining and post-mining activities during the period of FY1990 through FY2000 are derived by subtracting the surface mining production from the total raw coal production as given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke.* The data for FY2001 onward are provided by J-COAL.

Table 3-65 Trends in coal production

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total coal production	kt	10,676	8,814	4,625	2,146	1,782	1,819	1,824	1,903	1,774	1,855	1,991	1,307	1,014	1,042	861
Surface mines		1,205	695	610	511	557	719	721	778	795	753	716	647	555	477	393
Underground mines		9,471	8,118	4,016	1,635	1,225	1,100	1,103	1,124	980	1,102	1,275	660	459	565	468

- ***Abandoned Underground Mines***

For activity data, the number of abandoned mines which were not submerged, estimated from the list of abandoned mine in J-COAL (2002).

Table 3-66 The number of abandoned mines which were not submerged

Fiscal year of abandonment	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Number of abandoned coal mine without submergence	39	34	28	48	12	32	91	103	61	46	33	42	21	42	29
Fiscal year of abandonment	1971	1972	1973	1974	1975	1976	1977	1978	1980	1987	1989	1992	1994	1995	Total
Number of abandoned coal mine without submergence	13	20	12	1	2	3	1	2	2	2	3	1	1	1	725

● ***Recovery and flaring***

- ***Mining Activities***

There is no flaring activity of CH_4 which has been emitted from the coal bed during mining in Japan, however there are activities of recovering CH_4 and using it as fuel. Therefore, the net amount of the emissions is estimated by subtracting the recovered value from the total CH_4 emissions. The values of recovery were provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* (FY1990-FY1997) and the data provided by J-COAL (since FY1998).

Table 3-67 Trends in CH_4 recovery from mining activities

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Recovery	1000 m^3	50,139	11,112	9,810	2,044	941	591	826	448	844	955	482	301	293	303	303

- ***Post-Mining Activities***

The CH_4 recovery/flaring are reported as "NE," because the existence of such activities has not been confirmed.

- ***Abandoned Underground Mines***

Reported as "NO" since any activities for CH_4 recovery or flaring has not been implemented.

c) Uncertainties and Time-series Consistency

● ***Uncertainties***

For the uncertainties of CH_4 emissions during mining activities, the actual measurement values provided by J-COAL are used for reporting. However, it is difficult to evaluate the uncertainties of these data; therefore, for evaluating the uncertainties, the figures (combined the uncertainty due to measurement error and the uncertainty of error due to the change of flow rate, by using error propagation equation) given in the *2006 IPCC Guidelines* are used, and the uncertainties are established at -5% to +5%. For the uncertainties of CO_2 emissions during mining activity, the uncertainty of CH_4 emissions and the uncertainty of proportion of volume fraction of CO_2 in coalbed gas to that of CH_4 (-18% to +18%), which was calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainties are established at -19% to +19%.

For the uncertainties in CH_4 emission factors during post-mining activities, since the default values given in the *2006 IPCC Guidelines* are used for the estimation factors, the uncertainty values given in the *2006 IPCC Guidelines* (-33% to +300%) are used. For the uncertainties in CO_2 emission factors during post-mining activities, the uncertainty in CH_4 emission factors and the uncertainty in proportion of volume fraction of CO_2 in coalbed gas to that of CH_4, which is calculated using data provided by Hokkaido Development Agency are combined by error propagation equation, and the uncertainties are evaluated at -38% to +301%. For the uncertainties in activity data of CH_4 and CO_2, during post-mining activities, the actual measurement values provided by J-COAL are used for reporting. However, it is difficult to evaluate the uncertainties of these data; therefore, for evaluating the uncertainties, the figures given in the *2006 IPCC Guidelines* (-2% to +2%) are used, as a result, the uncertainties in emissions during post-mining activities are evaluated at -33% to +300% for CH_4 emissions and -38% to +301% for CO_2 emissions.

The uncertainties in CH_4 emissions from abandoned mines are established at -50% to +100% based on the description on the uncertainty in Tier 2 given in the *2006 IPCC Guidelines*. For the uncertainties in CO_2 emissions from abandoned mines, the uncertainties in CH_4 emissions and the uncertainties in proportion of volume fraction of CO_2 in coalbed gas to that of CH_4, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainties are evaluated at -53% to +102%.

● ***Time-series Consistency***

The CH_4 total emissions data for mining activities in underground mines are consistently derived from J-COAL statistics for FY1990 and since FY1995. From FY1991 to FY1994, time-series consistency is ensured by interpolating the emission factors.

The total coal production and coal production in surface mines are provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared from FY1990 to FY2000. Thereafter, they are provided by J-COAL, because the categories of surface mining production and total coal production in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* are no longer provided. The data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared until 2000 are provided by J-COAL. Therefore, the total coal production data from both of these sources are the same and are used in a consistent manner since FY1990.

The CH_4 recovery data for mining activities are consistent, as were the case for the total coal production and coal production in surface mines.

The numbers of abandoned coal mines, which are the activity data for the abandoned coal mines, are derived from the J-COAL (2002). The default values in the *2006 IPCC Guidelines* are used for the ratio of gas emitting coal mines, the amount of CH_4 emissions from the coal mine before the closure, and the parameters to determine the decreasing curve of the emissions. Also, the CO_2 emissions from the coal mine before closure are estimated from the CH_4 emissions by assuming the ratio of volume is constant, so that the time-series consistency is ensured.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

In order to ensure the safety of coal mine workers in Japan, monitoring the concentration of CH_4 and CO in coal mines is ordained by law. Under the law, mining companies must set rules on monitoring management. Mining companies monitor accurately under strict management and checks, and compile relevant reports. Furthermore, national authorities regularly check the monitoring measurements and safety reports.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.1.1.b. Surface Mines (1.B.1.a.ii.)

a) Category Description

This category includes fugitive emissions of CH_4 and CO_2 occurring during coal mining and post-mining activities in surface mines. The emissions of CH_4 recovered/flared during coal mining in surface mines are reported as “NE,” because the existence of such activities has not been confirmed.

b) Methodological Issues

- ***Estimation Method***

➢ *CH_4*

- ***Mining Activities***

The CH_4 emissions from mining activities are calculated using the Tier 1 method and the default emission factor in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.18, Fig.4.1.2).

- ***Post-Mining Activities***

The CH_4 emissions from post-mining activities are calculated using the Tier 1 method and the default emission factor in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.18, Fig.4.1.2).

Both are calculated by multiplying the amount of coal mined from surface mines by the relevant emission factor.

➢ *CO_2*

The method applied is reported as "CS" (country-specific) in CRF Summary 3, since the *2006 IPCC Guidelines* do not provide a method to estimate CO_2 emissions but a country-specific CO_2 emission factor is available.

- ***Mining Activities***

CO_2 emissions are estimated by multiplying the production amount of coal by CO_2 emission factor.

- ***Post-Mining Activities***

CO_2 emissions are estimated by multiplying the production amount of coal by CO_2 emission factor.

- ***Emission Factors***

➢ *CH_4*

- ***Mining Activities***

The value of 0.804 kg-CH_4/t is used as emission factor for mining activities. It was derived by converting the average (1.2 m^3/t) of the default values given in the *2006 IPCC Guidelines*, using the concentration of CH_4 at one atmospheric pressure and 20°C (0.67 kt/$10^6 m^3$).

- ***Post-Mining Activities***

The value of 0.067 kg-CH_4/t is used as emission factor for post-mining activities. It was derived by converting the average (0.1 m^3/t) of the default values given in the *2006 IPCC Guidelines*, using the concentration of CH_4 at one atmospheric pressure and 20°C (0.67 kt/$10^6 m^3$).

➢ *CO_2*

- ***Mining Activities***

CO_2 emission factor for mining activities is established by multiplying CH_4 emission factor (volume basis) by proportion of volume fraction of CO_2 in coalbed gas to that of CH_4 (0.0088), which is obtained by using Hokkaido Development Agency (1965), and by CO_2 density (1.84 kg/m^3).

- ***Post-Mining Activities***

In the same way as calculated for mining activities, the CO_2 emissions factors for post-mining activities are established by multiplying CH_4 emission factor (volume basis) by 0.0088.

- ***Activity Data***

The figure for the surface production given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the data provided by the J-COAL were used as activity data for mining and post-mining activities (see Table 3-65).

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the uncertainty in CH_4 emission factor during mining activities, since the default value given in the *2006 IPCC Guidelines* is used for emission factor, the uncertainty values given in the *2006 IPCC Guidelines* (-50% to +200%) are used. For the uncertainty in CO_2 emission factor during mining activities, the uncertainty in CH_4 emission factor and the uncertainty in proportion of volume fraction of CO_2 in coalbed gas to that of CH_4, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainty is calculated as -53% to +201%. For the activity data of CH_4 and CO_2 during mining activities, the actually measured data provided by J-COAL are reported, however it is difficult to evaluate the uncertainty of the data. Therefore, the uncertainty values of -2% to +2% in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in emissions during mining were evaluated at -50% to +200% for CH_4 and -53% to +201% for CO_2.

For the uncertainty in CH_4 emission factor during post-mining activities, since the default value given in the *2006 IPCC Guidelines* is used for emission factor, the values given in the *2006 IPCC Guidelines* (-33% to +300%) are used. For the uncertainty in CO_2 emission factor during post-mining activities, the uncertainty in CH_4 emission factor and the uncertainty in proportion of volume fraction of CO_2 in coalbed gas to that of CH_4, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainties are evaluated at -38% to +301%. For activity data for CH_4 and CO_2 during post-mining activities, the actual measurement data provided by J-COAL are reported. However, it is difficult to evaluate the uncertainties in these data, the figures (-2% to +2%) given by the *2006 IPCC Guidelines* are used. As a result, the uncertainties in emissions during post-mining activities are evaluated at -33% to +300% for CH_4 and -38% to +301% for CO_2.

- ***Time-series Consistency***

The total coal production and coal production in surface mines were provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared from FY1990 to FY2000. Thereafter, they have been provided by J-COAL, because the categories of surface mining production and total coal production in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* are no longer provided. The data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared by METI until 2000 are provided by J-COAL. Therefore, the total coal production data from both of these sources are the same and have been used in a consistent manner since FY1990.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.1.2. Solid Fuel Transformation (1.B.1.b.)

a) Category Description

This category includes the GHG emissions in the process of manufacturing charcoal and coke. Although the *2006 IPCC Guidelines* do not specify emission sources to be included in this category, fugitive emissions from charcoal and coke production may be included in this category according to the Common Reporting Format (CRF). Because the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereinafter, *2019 Refinement*) provides estimation methods of fugitive emissions from charcoal and coke production, these emissions are estimated.

CH_4 emissions are released in the process of manufacturing charcoal due to imperfect combustion of carbon contained wood material which is raw material of charcoal.

Coke oven gas (COG) is a by-product of coke production by coal pyrolysis. COG contains H_2, CH_4, CO and other gases. Most of COG is used as fuel and the emissions are included in Fuel Combustion (1.A.). The *2019 Refinement* provides estimation methods for flaring of COG for operational safety reasons and equipment maintenance purposes.

According to the interview with the Japan Iron and Steel Federation (JISF), flaring is not conducted during the usual operation, but it is conducted rarely during the suspension or construction of consumption process. Nevertheless, most of the factories report productions and consumptions of COG, including the amount of flaring, to the *Current Survey of Energy Consumption*, which is one of the primary statistics of the *General Energy Statistics* (Japan's energy balance tables). Therefore, the amount already reported is included in Fuel Combustion (1.A.). Because the amount of flaring from unreported factories was provided by JISF, the emissions are estimated and reported in this category.

b) Methodological Issues

- ***Estimation Method***

- ***Charcoal Production***

The emissions from manufacturing charcoal are estimated by using the Tier 1 method in accordance with the decision tree of the *2019 Refinement* (Vol.2, Page 4.101, Fig. 4.3.1), multiplying production amount of charcoal by the default emission factor.

CO_2 are also emitted by charcoal production, but the emissions are not included in the national totals but are reported in the NIR as reference because they are of biomass origin.

The CH_4 recovery/flaring in the CRF are reported as "NE" because the existence of such activities during charcoal production has not been confirmed.

- ***Flaring of Coke Oven Gas***

The CO_2 emissions from flaring of COG are estimated using the Tier 2 method in accordance with the decision tree of the *2019 Refinement* (Vol.2, Page 4.114, Fig. 4.3.4) because flaring amount and country-specific emission factors are available.

$$E=AD \times EF \times 44/12$$

E	: CO_2 emissions from flaring of COG [t-CO_2]
AD	: Flaring amount of COG not reported to the *Current Survey of Energy Consumption* [TJ]
EF	: Carbon emission factor of COG [t-C/TJ]

The CH_4 recovery/flaring in the CRF Table 1.B.1 are reported as "NE". It is assumed that this cell is used for reporting the reduced amount of CH_4 through flaring of fugitive gas from coke oven. The reduced amount of fugitive CH_4 is not estimated since the CH_4 leaking from coking furnace lids are reported in Manufacture of solid fuels and other energy industries (1.A.1.c) and CH_4 content of coke oven gas is not established.

● ***Emission Factors***

\- ***Charcoal Production***

The default values of the charcoal production given in the *2019 Refinement* are used. Although the *2019 Refinement* provides the default values for the production of biochar (charcoal for amendment in cropland), the default values of charcoal production are also applied for the emission estimation of biochar production, considering the national circumstances. The default values of biochar are for products by flame curtain biochar kilns, but charcoal kilns, mechanical kilns, and open-hearth furnaces are mainly used for biochar manufacturing in Japan. It is appropriate to apply the default values of charcoal for biochar manufacturing.

Table 3-68 Emission factors for charcoal production

Item	Unit	CO_2	CH_4	N_2O
Charcoal production	g/kg	1,570	40.3	0.08

Reference: *2019 Refinement,* Vol. 2, page 4.103, Table 4.3.3

\- ***Flaring of Coke Oven Gas***

The emission factor is the same as the carbon emission factor of COG used in Fuel Combustion (1.A.) (see Table 3-11).

● ***Activity Data***

\- ***Charcoal Production***

The activity data are the production amount of charcoal (hard charcoal, soft charcoal, bamboo charcoal, fine charcoal and sawdust charcoal), which is obtained from *Basic Data for Special Forest Product* (Forestry Agency) and *Data for Charcoal* (Forestry Agency).

Table 3-69 Production Amount of Charcoal

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Charcoal Production	kt	83.2	82.3	67.4	44.9	34.1	30.3	29.6	27.7	25.9	23.7	23.1	21.7	21.3	19.8	17.4

\- ***Flaring of Coke Oven Gas***

The amount of flaring not reported to the *Current Survey of Energy Consumption* is used as activity data. Since JISF only has data on the unreported flaring amount for FY2020 and all flaring amount for FY1990, 2000, 2010 and 2020, the other years are estimated using the formula below.

$$AD=P \times R \times U \times GCV$$

AD : Unrepored flaring amount of COG [TJ]

P : Production amount of COG [million m^3]
R : Flaring rate
U : Unreported rate
GCV : Gross calorific value (GCV) of COG [MJ/m^3]

The production amount of COG *P* is obtained from the values shown in Metallurgical Coke (#212100) and Coke Oven Gas ($0221) of the *General Energy Statistics*. The flaring rate *R* for FY1990, 2000, 2010 and 2020 is obtained from dividing the flaring amount of each year (provided by JISF) by *P* of the same year. *R* for the other years is estimated by interpolation or extrapolation. The unreported rate *U* for FY2020 is obtained from dividing the unreported flaring amount of the year (provided by JISF) by the all flaring amount of the same year. *U* for the other years is the same as *U* for FY2020. *GCV* is the same as the GCV of COG used in Fuel Combustion (1.A.) (see Table 3-19).

The gas volume is shown in normal condition (273.15 K, 101.325 kPa) for the values of the *General Energy Statistics* (FY1990-2012) and the values provided by JISF, and it is shown in SATP condition (298.15 K, 100 kPa) for the values of the *General Energy Statistics* (FY2013 onward). The values are converted from normal condition to SATP condition by multiplying 1.0773, as appropriate.

Table 3-70 Flaring Amount of Coke Oven Gas
not Reported to the *Current Survey of Energy Consumption*

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Unreported flaring amount of COG	TJ	11.6	25.5	38.8	38.5	41.2	48.3	52.9	54.3	55.9	61.6	65.3	69.4	74.1	70.6	75.6

- ***Completeness***

The emissions from charcoal use are included in "1.A Fuel Combustion", however the CO_2 emissions are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*.

The flaring amount of COG already reported to the *Current Survey of Energy Consumption* is included in Fuel Combustion (1.A.). For the sources of coke production other than flaring of COG presented in the *2019 Refinement*, the emissions are taken into account through the activity data (fuel consumption of the *General Energy Statistics*) or the CH_4 emission factor of coking furnace lid.

In Japan, the production of coal briquettes is considered to meet the description of the activity of solid fuel transformation. The process of coal briquette production includes introducing water to coal, and squeeze-drying it. Therefore, the process is not thought to involve any chemical reactions, but the emissions of CO_2, CH_4 or N_2O cannot be denied. However, the emissions are not estimated as no actual measurement has been taken and no default value is provided.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

- ***Charcoal Production***

As for emission factors, the uncertainties for the default emission factors for charcoal production provided in the *2019 Refinement* are adopted. (-68% to +121% for CH_4 and -75% to +163% for N_2O)
As for activity data, the uncertainties are substituted by the uncertainties for coal mining and handling (1.B.1.a) given in the *2006 IPCC Guidelines* (-2% to +2%), because the uncertainties for charcoal production are not available in the *Basic Data for Special Forest Product*.
As a result, uncertainties for emissions from charcoal production are evaluated as -68% to +121% for CH_4 and -75% to +163% for N_2O.

- ***Flaring of coke oven gas***

The uncertainties of emission factors are set by the upper and lower limits of 95% confidence intervals derived from the original data of carbon emission factors of COG (-0.46% to +0.46%). For the uncertainties of activity data, the uncertainties in flaring amount and the uncertainties in the GCV are combined by error propagation equation. As for the uncertainties in flaring amount, the values shown in the 2006 IPCC Guidelines (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used since neither JISF nor the 2019 Refinement provide the uncertainties in flaring amount. The uncertainties of the GCV are set by the upper and lower limits of 95% confidence intervals derived from the original data of the GCV of COG (-1.2% to +1.2%). As a result, the uncertainty for the CO_2 emissions from flaring of COG are evaluated to be -15% to +15%.

● ***Time-series Consistency***

- ***Charcoal Production***

The reference of the charcoal production amount in FY1990, which is the *Data for Charcoal*, is different from the reference in and after FY1991, which is the *Basic Data for Special Forest Product*. However, both data are provided by the Forestry Agency and the data capturing ranges are set to be the same. The default values in the *2019 Refinement* are used for the emission factors throughout the time-series so that the consistency is ensured.

- ***Flaring of coke oven gas***

As for the activity data, the production amount of COG from the *General Energy Statistics* is used as a surrogate parameter to ensure time-series consistency. The emission factors are the same as Energy Industries (1.A.1). See 3.2.4. c).

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

The CO_2 emissions from flaring of COG were newly estimated. Since the charcoal production amount for FY2020 in *Basic Data for Special Forest Product* were revised, the CH_4 and N_2O emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

The reporting instructions of the *Current Survey of Energy Consumption* in and after FY2022 will clarify the amount of production and consumption of COG should include flaring. The emissions from flaring of COG, including factories that have not reported flaring amount so far, will be included in Fuel Combustion (1.A.). The emissions will be reported as “IE” in this category from FY2022.

3.3.1.3. Others (Uncontrolled combustion and burning coal dumps) (1.B.1.c)

This category includes CO_2 emissions generated by unintentional coal combustion due to mine fire. The *2006 IPCC Guidelines* recognize uncontrolled combustion and burning coal dumps as a potential emission source, but do not provide an emission estimation method.

As for FY1999, coal combustion was occurred by the fire in Ikejima Coal Mine. However, since the amount of combusted coal is not available, it is reported as “NE”. As for other fiscal years, any fire resulted in coal combustion was not occurred; therefore, it is reported as “NO”.

It is impossible to specify from the official statistics whether fires occur at coal dumps as well as the amount of combusted coal there.

3.3.2. Oil, Natural Gas and Other Emissions from Energy Production (1.B.2.)

3.3.2.1. Oil (1.B.2.a.)

3.3.2.1.a. Exploration (1.B.2.a.i.)

This category deals with fugitive emissions of CO_2, CH_4 and N_2O from the exploratory drilling of oil fields.

In Japan, GHG emissions by the exploratory drilling of oil and natural gas fields are basically only from flaring. Therefore, the flaring emissions associated with exploratory drilling are included in “1.B.2.c.Flaring.iii Flaring (Combined)”.

“1.B.2.a.i. Exploration of Oil” and “1.B.2.b.1 Exploration of Natural Gas” are reported as “IE”, because the fugitive emissions other than flaring are also conceptionally included in “1.B.2.c.Flaring.iii Flaring (Combined)” since the default emission factors in the *GPG2000*, which covers all fugitive emissions as well as venting and flaring emissions, are used in “1.B.2.c.Flaring.iii Flaring (combined)” as described later.

3.3.2.1.b. Production (1.B.2.a.ii.)

a) Category Description

This category includes fugitive emissions of CO_2 and CH_4 occurring at production of crude oil and in lowering measuring instrument into well at servicing of operating oil fields.

The emissions associated with fugitive emissions during oil production are estimated for offshore and onshore oil field. The emissions from operating oil fields occur in servicing are reported in “1.B.2.b.ii Production of Natural Gas” and not included in this category, because the activity data of number of wells in production is not able to be divided into the numbers of oil producing wells and natural gas producing wells.

b) Methodological Issues

- ***Estimation Method***

The fugitive emissions from oil production are estimated using the Tier 1 method, in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol. 2, page 4.39, Fig.4.2.2).

- ***Emission Factors***

- ***Production***

For emission factors for fugitive emissions from oil production, the default values for fugitive emissions of conventional oil from offshore and offshore oil fields, which are indicated in the *2006 IPCC*

Guidelines, are used. As for emission factors for onshore fields, the medians of default values are used.

Table 3-71 Emission factors for fugitive emissions from oil production

		Unit	CH_4	CO_2	N_2O 3)
Conventional Oil	Fugitive emissions from offshore fields	$kt/10^3m^3$	5.9×10^{-7}	4.3×10^{-8}	NA
	Fugitive emissions from onshore fields	$kt/10^3m^3$	1.8×10^{-3} 1)	1.3×10^{-4} 2)	NA

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.50, Table 4.2.4
Note:
1) The default value is 1.5×10^{-6} - 3.6×10^{-3}
2) The default value is 1.1×10^{-7} - 2.6×10^{-4}
3) Excluded from calculations, as the default value is "NA"

- ***Servicing***

As the fugitive emissions from the servicing of oil and natural gas wells are reported in "1.B.2.b.ii Production of natural gas", refer to that section for the emission factors as well.

- ***Activity Data***

- ***Production***

The amount of crude oil production by offshore and onshore oil field (excluding condensate[17]) is used for activity data.

The amount of condensate production in offshore gas field is estimated by multiplying the production amount of condensate by the percentage of production volume in offshore in total production volume of natural gas.

The estimated value above is deducted from total volume of domestic crude production in offshore oil field to obtain the production amount of crude oil from offshore oil field (excluding condensate).
The production amount of crude oil in onshore oil field (excluding condensate) is estimated by deducting crude oil production in offshore (excluding condensate) from total amount of crude oil production (excluding condensate).

Total production volume of natural gas, crude oil, and condensate is obtained from the data given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*. The production amount of natural gas and crude oil from offshore is obtained from *Natural Gas Data Yearbook* (Japan Natural Gas Association).

Table 3-72 Amount of oil production excluding condensate from offshore and onshore oil fields

Item		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Oil production excluding condensate	offshore	1000 kL	175	391	167	76	78	72	70	82	76	67	70	59	104	89	90
	onshore	1000 kL	245	232	218	295	215	209	195	180	164	152	141	136	142	165	132

- ***Servicing***

Because the fugitive emissions from the servicing of oil and natural gas wells are reported in "1.B.2.b.ii Production of natural gas", please refer to that section also for the activity data.

- ***Completeness***

In this category, the amount of crude oil production excluding condensate is used as activity data. The

17 Light, liquid hydrocarbon that is produced from natural gas wells associated with natural gas production

GHG emissions associated with condensate production are included in 1.B.2.b.ii and 1.B.2.b.iii, because emission factors of these categories include emission from condensate production.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties for emission factors given in the *2006 IPCC Guidelines* (-100% to +100%) are used for emission factors for oil production, since the default values in the guidelines are used exclusively. For activity data, because the uncertainties of statistical data used as reference are not available, the values given in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used. As a result, the uncertainties for fugitive emissions of CO_2 and CH_4 from oil production are evaluated as -101% to +101% for each.

- ***Time-series Consistency***

Consistent values are used for emission factors from FY1990 to the nearest year, using the above-described method. The activity data for oil production are calculated by using the annual data from the *Yearbook of Mineral Resources and Petroleum Products*, the *Natural Gas Data Yearbook* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* by the consistent estimation method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

Since the activity data for FY2020 in the *Natural Gas Data Yearbook* were revised, the CO_2 and CH_4 emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

As for the fugitive emissions from the servicing of oil and natural gas wells, the correlative relationships between emissions and production volume of crude oil remains unclear when using estimation method in accordance with the *2006 IPCC Guidelines*, and it is likely that the result of the estimating dos not reflect the actual status. Therefore, the estimation method in the *GPG2000* is adopted. In the future, the background information of the estimation method regarding the *2006 IPCC Guidelines* and the *2019 Refinement* will be collected, and if new information is obtained, the currently adopted method will be reconsidered.

3.3.2.1.c. Transport (1.B.2.a.iii.)

a) Category Description

This category includes fugitive emissions of CO_2 and CH_4 occurring during the transportation of crude oil and condensate through pipelines, tank trucks, and tank cars to refineries.

b) Methodological Issues

- ***Estimation Method***

The fugitive emissions from transport of crude oil and condensate are estimated using the Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.40, Fig.4.2.3) by multiplying the amount of crude oil and condensate production by the emission factors.

In this category, fugitive emissions from ocean transportation of crude oil which are produced at domestic offshore oil fields and are shipped from ocean to land, and the fugitive emissions from land transportation are estimated. Crude oil is transported on sea entirely by pipeline, and is not expected to generate any fugitive emissions from other transportation modes. Land transport includes a number of methods, including pipeline, tank trucks, and tank cars, but it is difficult to differentiate them statistically. For that reason, the emissions were estimated under the assumption that all of the produced oil is transported by tank trucks and rail cars[18].

- ***Emission Factors***

The default values given in the *2006 IPCC Guidelines* were used as emission factors.

Table 3-73 Emission factors for transportation of crude oil and condensate

Item	Unit	CH_4	CO_2	N_2O
Oil Transport/ Tanker Trucks and Rail Cars	$kt/10^3m^3$	2.5×10^{-5}	2.3×10^{-6}	NA
Natural Gas Liquids Transport/ Condensate	$kt/10^3m^3$	1.1×10^{-4}	7.2×10^{-6}	ND

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.50 and 4.53, Table 4.2.4
Note: N_2O is excluded from calculations, as the default value is “NA” or “ND”.

- ***Activity Data***

The amount of oil and condensate production in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* are used as activity data for fugitive emissions from transport.

Table 3-74 Production of crude oil and condensate in Japan

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Oil production excluding condensate	1000 kL	420	623	386	370	293	281	265	262	240	219	210	195	247	254	222
Condensate production		234	243	375	541	560	478	403	365	339	331	336	301	278	259	252
Oil production (total)		655	866	761	911	853	759	668	626	578	549	546	496	524	513	473

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the uncertainty of emission factors for CO_2 and CH_4 fugitive emissions from transportation of crude oil and condensate, the values given in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values given in the guidelines are used exclusively. As for the uncertainty for activity data, the values given in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used since the uncertainties of statistical data used as reference are not available. As a result, the uncertainties for the CO_2 and CH_4 emissions from

[18] As the default values of tanker trucks and rail cars are higher than those of pipelines, this assumption does not lead to underestimation.

oil and condensate transport are evaluated to be -101% to +101% for each.

- ***Time-series Consistency***

For the emission factors, consistent values are used from FY1990 to the nearest year with the above-mentioned method. The activity data are calculated based on the annual data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke,* the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.2.1.d. Refining / Storage (1.B.2.a.iv.)

a) Category Description

This category includes fugitive emissions of CH_4 occurring when crude oil is refined or stored at oil refineries.

The CO_2 emissions from this source are reported as “NE”. Refining/storage activities exist in Japan and an extremely small amount of CO_2 is considered to be released into the atmosphere from these activities if CO_2 is included in crude oil. Because there are neither actual measurements of the CO_2 content of crude oil nor any default values for emission factors, CO_2 emissions from this source are not estimated.

b) Methodological Issues

- ***Estimation Method***

Although the *Revised 1996 IPCC Guidelines* provided the default emission factors for refining and storage tanks separately, the *2006 IPCC Guidelines* provide the default emission factor for refining only. As a country-specific emission factor for storage is available, the emissions from storage as well as refining are estimated.

- ***Oil Refining***

The fugitive emissions from oil refining are estimated using the Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol. 2, page 4.40, Fig. 4.2.3).

- ***Oil Storage***

The fugitive emissions from oil storage are estimated using a country-specific emission factor. This method is equivalent to Tier 2 if the decision tree in the *2006 IPCC Guidelines* (Vol. 2, page 4.40, Fig.

4.2.3) is applied.

- ***Emission Factors***

- ***Oil Refining***

The amount of CH_4 emitted during the crude oil refining process is considered to be negligible because no fugitive emission of CH_4 is likely to occur in Japan during crude oil refining at normal operation. For that reason, the lower limit of the default values shown in the *2006 IPCC Guidelines* is adopted for the emission factors for fugitive emissions during the refining process.

Table 3-75 Emission factor during crude oil refining

Emission factor [kg-CH_4/10^3m^3]	
Oil refining	2.6×10^{-6}

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.53, Table 4.2.4
Note: The default value is 2.6×10^{-6} - 41.0×10^{-6}

- ***Oil Storage***

Oil is stored in either corn-roof tanks or floating-roof tanks. All oil storage in Japan adopts floating-roof tanks, which means that the fugitive CH_4 emissions are considered to be very small. If fugitive CH_4 emissions were to occur, they could only occur by vaporization of oil left on the exposed wall wet with oil when the floating roof descends as the stored oil is removed; thus, the amount of fugitive CH_4 emissions would be small.

The Petroleum Association of Japan conducted experiments relating to the evaporation of CH_4 from tank walls by making the model of floating-roof tank, and based on the result the CH_4 emissions are estimated.

The emission factor associated with the storage of crude oil is obtained by dividing the emissions estimated by the Petroleum Association (0.007 kt-CH_4/year as of 1998) by the amount of the crude oil put into the oil refining industry (from *General Energy Statistics*).

Table 3-76 Assumptions for calculation of emission factor during oil storage

CH_4 emissions [kt-CH_4/year]	Input of crude oil to oil refining industry [10^3kL]	Emission factor [kt-CH_4/10^3kL]
7×10^{-3}	242,861	2.9×10^{-8}

- ***Activity Data***

The values used for activity data during refining and storing are the values (in volume) of refined NGL (Natural Gas Liquids) and crude oil in the petroleum refining industry taken from the *General Energy Statistics*.

Table 3-77 Amount of crude oil and NGL refined in Japan

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Oil and NGL refined	10^6m^3	204	241	242	241	209	197	200	189	188	191	184	177	174	139	147

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the uncertainties of emission factors for fugitive emissions of CH_4 from refining crude oil and NGL, the values shown in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. The uncertainties for activity data for the fugitive emissions from refining crude oil and NGL are evaluated to be -21% to +21% respectively by error propagation method using the uncertainties of the standard calorific value and statistics used for estimating consumption.

However, since the uncertainties of statistical data used for estimating consumption (*Yearbook of Mineral Resources and Petroleum Products* and *Yearbook of the Current Survey of Energy Consumption*) are not available, the default values provided in the *2006 IPCC Guidelines* (the uncertainties associated with measurement of flow rate (excluding sales volumes)) are substituted. As a result, the uncertainties for CH_4 fugitive emissions associated with refining of crude oil and NGL are evaluated at -102% to +102% for each.

As for the uncertainties of emission factors for fugitive emissions of CH_4 during storage of crude oil and NGL, the country-specific values were used. However, it is difficult to evaluate uncertainties; therefore, the values evaluated in the *2006 IPCC Guidelines* (-100% to +100%) are applied. The uncertainties for activity data for the fugitive emissions during storage of crude oil and NGL are evaluated to be -21% to +21% respectively by error propagation method using the uncertainties of standard calorific value and statistics used for estimating consumption. However, since the uncertainties of statistical data used for estimating consumption (*Yearbook of Mineral Resources and Petroleum Products* and Y*earbook of the Current Survey of Energy Consumption*) are not available, the default values provided in the *2006 IPCC Guidelines* (the uncertainties associated with measurement of flow rate (excluding sales volumes)) are substituted. As a result, the uncertainties for CH_4 fugitive emissions associated with storage of crude oil and NGL are evaluated at -102% to +102% for each.

- ***Time-series Consistency***

Consistent values are used for emission factors from FY1990 to the nearest year by using above–mentioned method. The activity data for refining and storage are calculated using the data from the *General Energy Statistics,* by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

- ***QA/QC***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

- ***Verification***

In 2022, the ERT recommended that Japan explain the rationale for its selection of the lowest value of the default emission factors (EFs) shown in the *2006 IPCC Guidelines* for fugitive emissions during the refining process. The rationale including history is explained below.

In the 1999 submission, Japan used to use the median of the default EFs in the *Revised 1996 IPCC Guidelines* (745 kg-CH_4/PJ for oil refining and 135 kg-CH_4/PJ for oil storage). Then, a country-specific emission factor (CSEF) of storage was obtained (0.7 kg-CH_4/PJ). The EF for refining (745 kg/PJ) was about 1,000 times higher than the new CSEF for storage. The Breakout group on Energy and Industrial Processes of the Committee for the Greenhouse Gas Emission Estimation Methods held in 1999 was unable to justify the large gap of two EFs between refining and storage. Therefore, the lowest value of the default EFs for refining shown in the *Revised 1996 IPCC Guidelines* and the CSEF of storage had been applied since the 2000 submission.

In the 2015 submission, the EF for refining was replaced with the default value of the *2006 IPCC Guidelines*, but the notion of using the lowest value was unchanged. Although the *2006 IPCC*

Guidelines do not provide the default emission factor for storage, the CSEF for storage is still used. It is unknown if the default EF of refining in the *2006 IPCC Guidelines* takes storage into consideration.

According to the interview with the Petroleum Association of Japan (PAJ) held in 2022, the PAJ said CH_4 generated in the oil refineries in Japan is recovered and utilized by gas recovery facilities and the emissions are limited. The CO_2 emissions from utilization of the recovered CH_4 are estimated under Fuel Combustion (1.A.) as refinery gas. This is the additional rationale of using the lowest value of the default EFs.

The default EF provided in the *2019 Refinement* is not applied because it is unclear how the EF is established.

Table 3-78 Comparison of emission factors during refining and storage process

Item	Emission factor of refining	Emission factor of storage	Remarks
Value used in the calculation	2.6 [kg/10^3 m^3]	0.029 [kg/10^3 m^3]	Refining: the lowest value of the *2006 IPCC Guidelines* Storage: CSEF
Revised 1996 IPCC Guidelines	90 – 1400 [kg/PJ] (3 – 51 [kg/10^3 m^3]) 1)	20 – 250 [kg/PJ] (0.7 – 9.2 [kg/10^3 m^3]) 1)	Survey by the United States Environmental Protection Agency
2006 IPCC Guidelines	2.6 – 41.0 [kg/10^3 m^3]	Not provided	
2019 Refinement	30 [kg/10^3 m^3]	Not provided	

Note:
1) Converted value using the net calorific value of the United States (42.71 [TJ/kt] from Vol.3, Table 1-2) and the density of crude oil (860 [kg/m^3] from Vol.2, page 1.72) in the *Revised 1996 IPCC Guidelines*.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.2.1.e. Distribution of Oil Products (1.B.2.a.v.)

Petroleum products are distributed in Japan, and where CO_2 and CH_4 are dissolved, it is conceivable that either or both will be emitted as a result of the relevant activity. The level of CO_2 or CH_4 emitted by the activity is probably negligible in light of the composition of the petroleum products, but because there is no measurement of the CO_2 or CH_4 content in petroleum products, it is not currently possible to calculate emissions. The emissions are reported as “NE” due to the absence of default emission factors.

3.3.2.1.f. Other (abandoned oil wells) (1.B.2.a.vi.)

The emissions from abandoned oil wells are reported under this category, since the estimation method for greenhouse gas emissions from abandoned oil wells was not provided in the *2006 IPCC Guidelines* but was provided in the *2019 Refinement*.

In accordance with the Enforcement Ordinance of the Mine Safety Act, systems are in place to prevent gas leakage from abandoned mines, as examples of measures to be taken by holders of mining rights, the following are listed: “Method of sealing wells”, “Method of installing cement plugs”, “Filling with muddy water, etc.”, “Examination after measures and confirmation of sealing condition” and “Method of restoration around the mine entrance area” (Ministry of Economy, Trade and Industry, 2012). Also, in the event of gas outburst or outflow of hazardous gas, this Enforcement Ordinance imposes an obligation to report the status of the disaster to the Minister of Economy, Trade and Industry immediately after the occurrence of the disaster, and management systems have been established to enable immediate identification of any leakage in this activity.

In addition, according to the Japan Natural Gas Association, the abandoned petroleum mines[19] in Japan have been taking measures to prevent gas leakage in accordance with the Mine Safety Act, and there have been no leaks from the wells. Also, each operator reportedly conducts regular inspections (about once a year) even after waiving the mining rights.

Judging from the above-mentioned measures regime in the abandoned mines, there are no emissions from the abandoned oil wells in Japan. Therefore, it is reported as “NA” in this category, which means that “the activity does occur, but do not result in emissions or removals of a specific gas”.

3.3.2.2. Natural Gas (1.B.2.b.)

The natural gas supply network and the inventory categorization of GHG fugitive emissions from each process of the network are shown in Figure 3-7.

[19] In Enforcement Ordinance of the Mine Safety Act, “petroleum” includes combustible natural gas (excluding those collected in connection with the mining of coal or lignite in mines intended for the mining of coal or lignite).

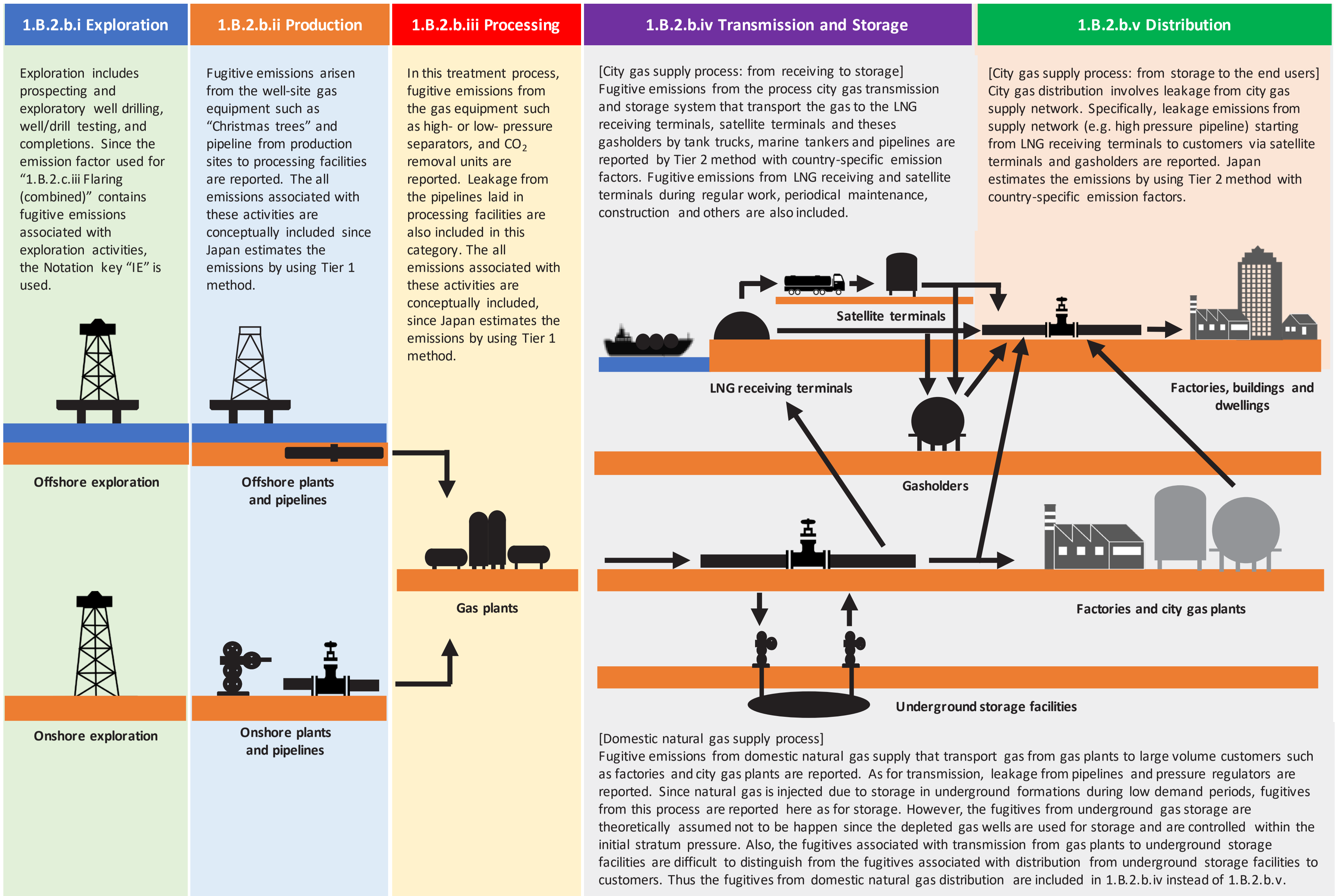


Figure 3-7 Supply network and inventory categorization of natural gas

3.3.2.2.a. Exploration (1.B.2.b.i.)

This category deals with fugitive emissions of CO_2, CH_4, and N_2O from the explorative drilling of natural gas fields. As well as "1.B.2.a.i Exploration of oil" , the emissions by the explorative drilling are basically only from flaring in Japan. Also, it is difficult to distinguish between oil fields and gas fields prior to exploration. Therefore, the emissions are included in "1.B.2.c.Flaring.iii Flaring (combined)". In addition, similar to the "1.B.2.a.1 Exploration of oil", all fugitive emissions as well as venting and flaring emissions are also conceptually included in "1.B.2.c.Flaring.iii Flaring (Combined)". Therefore, the emissions from this category are reported here as "IE".

3.3.2.2.b. Production (1.B.2.b.ii.)

a) Category Description

This category includes fugitive CO_2 and CH_4 emissions from natural gas production and from the lowering work of measuring instruments during the servicing of natural gas wells. The fugitive emissions from natural gas production are estimated by offshore oil fields and onshore oil fields.

b) Methodological Issues

- ***Estimation Method***

The fugitive emissions from the production of natural gas are estimated using Tier 1 method, in accordance with the *2006 IPCC Guidelines* (Vol. 2, page 4.38, Fig. 4.2.1).

For the fugitive emissions related to well servicing, the estimation method of multiplying the amount of crude oil production by emission factors is provided in the *2006 IPCC Guidelines*, however, in Japan, correlation between the amount of crude oil production and the emissions related to well servicing is not clear. Therefore, the Tier1 method provided in the *GPG2000* (the estimation method of multiplying the number of production wells by the emission factors), which is considered to be more appropriate for the actual status in Japan, is used.

- ***Emission Factors***

- ***Production***

The default values given in the *2006 IPCC Guidelines* are used for the emission factors of fugitive emissions during the production of natural gas.

Table 3-79 Emission factors of fugitive emissions during production of natural gas

		Unit	CH_4	CO_2	N_2O
Natural gas production	Fugitive emissions from offshore field	$kt/10^6m^3$	3.8×10^{-4}	1.4×10^{-5}	NA
	Fugitive emissions from onshore field	$kt/10^6m^3$	2.3×10^{-3}	8.2×10^{-5}	NA

Reference: *2006 IPCC Guidelines* Vol. 2, page 4.48, Table 4.2.4
Note: N_2O is excluded from calculations, as the default value is "NA".

- ***Servicing***

The default values for fugitive emissions during the servicing of natural gas production wells given in the *GPG2000* were used.

Table 3-80 Emission factors during servicing of natural gas production wells

	Unit	CH_4	CO_2	N_2O
Production well (servicing)	kt/number of wells	6.4×10^{-5}	4.8×10^{-7}	0

Reference : *GPG2000,* Table 2.16

Note: N_2O is excluded from calculations, as the default value is 0 (zero)

- ***Activity Data***

\- ***Production***

The production volume of natural gas from offshore in the *Natural Gas Data Yearbook* is used for the production volume of natural gas from offshore gas field. The production volume of natural gas from onshore gas field is estimated by subtracting the production volume of natural gas from offshore gas field above from the total production volume of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

\- ***Servicing***

Because it is impossible to statistically differentiate between oil fields and natural gas fields in the time-series, the total number of oil fields and natural gas fields are used for the estimation. As for activity data for fugitive emissions from well servicing, the number of natural gas and oil wells in production provided in *Natural Gas Data Yearbook* is used. As for the latest fiscal year, the values in the previous fiscal year are provisionally used.

Table 3-81 Natural gas production and the number of natural gas and oil wells in production

Item		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Natural gas production	offshore	$10^6 m^3$	342	374	350	361	188	196	196	197	190	176	148	113	120	87	87
	onshore		1,724	1,863	2,149	2,779	3,155	2,981	2,744	2,549	2,525	2,621	2,777	2,544	2,347	2,202	2,175
	total		2,066	2,237	2,499	3,140	3,343	3,177	2,940	2,746	2,715	2,797	2,926	2,657	2,467	2,290	2,262
Number of gas and oil wells in production		well	1,230	1,205	1,137	1,115	1,046	1,038	1,059	1,046	1,034	1,019	1,001	1,042	1,045	1,047	1,047

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the uncertainties of emission factors for fugitive emissions of CO_2 and CH_4 from production of natural gas, the values provided in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values provided in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used, since the uncertainties for statistical data used as reference are not available. As a result, the uncertainties of fugitive emissions of CO_2 and CH_4 from production of natural gas are evaluated to be -101% to +101% for each.

For the emission factors related to servicing of production well, the values provided in the *GPG2000* (-25% to +25%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values provided in the *2006 IPCC Guidelines* (-25% to +25% of the uncertainties associated with the factor of production facility number) are used, since the uncertainties for statistical data used as reference are not available. As a result, the uncertainties of fugitive emissions of CO_2 and CH_4 from servicing of production well are determined to be -35% to +35% for each.

- ***Time-series Consistency***

Consistent values are used for emission factors from FY1990 to the nearest year by using the above-mentioned method. The activity data are calculated by using the data on the production volume of natural gas from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials*

Statistics and on the number of oil/natural gas wells from the *Natural Gas Data Yearbook.* A consistent method is used throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

Since the activity data for FY2020 in the *Natural Gas Data Yearbook* were revised, the CO_2 and CH_4 emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

As the *2019 Refinement* provided the refined estimation method of this category, it is necessary to consider if the method is appropriate for Japan's circumstances.

3.3.2.2.c. Processing (1.B.2.b.iii.)

a) Category Description

This category deals with fugitive CO_2 and CH_4 emissions from the processing of natural gas including adjustment of its constituent elements.

b) Methodological Issues

- ***Estimation Method***

The fugitive emissions associated with processing natural gas are estimated using Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.38, Fig.4.2.1).

- ***Emission Factors***

For the emission factors for the fugitive emissions during processing of natural gas, the median values between upper limit and lower limit indicated in the *2006 IPCC Guidelines* are used.

Table 3-82 Emission factors of fugitive emissions during natural gas processing

		Unit	CH_4	CO_2	N_2O 3)
Natural gas processing	Fugitive emissions from sweet gas plants	$kt/10^6m^3$	7.55×10^{-4} 1)	2.35×10^{-4} 2)	NA

Reference: *2006 IPCC Guidelines* Vol. 2, page 4.48, Table 4.2.4
Note:
1) The default value of CH_4 is 4.8×10^{-4} - 10.3×10^{-4}
2) The default value of CO_2 is 1.5×10^{-4} - 3.2×10^{-4}
3) Excluded from calculations, as the default value is "NA".

- ***Activity Data***

The production volume of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* is used as activity data during processing. (Refer to Table 3-81).

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the uncertainties of emission factors for fugitive emissions of CO_2 and CH_4 during natural gas processing, the values provided in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values provided in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used, since the uncertainties of the statistical data used are not available. As a result, the uncertainties of fugitive emissions of CO_2 and CH_4 during natural gas processing are evaluated to be -101% to +101% for each.

- ***Time-series Consistency***

The default values are consistently used for emission factors from FY1990 to the nearest year. The activity data during natural gas processing are calculated by using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*. A consistent method is used throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

As the *2019 Refinement* provided the refined estimation method of this category, it is necessary to consider if the method is appropriate for Japan's circumstances.

3.3.2.2.d. Transmission and Storage (1.B.2.b.iv.)

a) Category Description

This category includes CH_4 emissions from transmission of domestically produced natural gas, such as the release of gas when relocating and building pipelines, and the release of gas used to operate pressure regulators. This category also includes CH_4 emissions from storage facilities of natural gas, such as the emissions occurring by normal operation, regular maintenance, and construction works in receiving domestic LNG (liquefied natural gas) facilities, city gas production facilities, and satellite facilities.

The CO_2 emissions in this source are reported as insignificant "NE". Approximately 90% of city gas is based on LNG and is free of CO_2. This is because the liquefaction process requires the removal of all CO_2 prior to the cooling process to prevent CO_2 ice from forming within the liquefaction equipment. However, domestically produced natural gas from some of Japan's natural gas strata contains CO_2. Nearly all of this CO_2 is removed at the natural gas production plants, and the CO_2 are included in Venting (Gas) (1.B.2.c.Venting.ii). Because domestically produced natural gas is sent to pipelines after

CO_2 removal, almost no CO_2 in natural gas is emitted from natural gas pipelines, and the natural gas provided by city gas suppliers most likely contains no CO_2. The four major gas providers in Japan (Tokyo Gas, Osaka Gas, Toho Gas and Saibu Gas) demonstrated through composition analysis that their gas contains no CO_2 as of 2022. The approximate results of emissions estimated are less than 3 kt-CO_2, which is a criterion to include the emissions in the national totals established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the CO_2 emissions are reported as insignificant "NE". The treatment of insignificant "NE" is described in Annex 5.

b) Methodological Issues

- ***Estimation Method***

CH_4 emissions from transmission of natural gas are estimated using Tier 2 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.38, Fig.4.2.1). The emissions are estimated by multiplying the sales volume of natural gas by the country-specific emission factors.

CH_4 emissions from storage facilities of natural gas are estimated by multiplying the amount of LNG and indigenous natural gas, which are utilized as raw material for city gas, by the country-specific emission factors. Since city gas is not recognized in the *2006 IPCC Guidelines*, the method applied is reported as "CS" (country-specific) in CRF Summary 3.

- ***Emission Factors***

\- ***Transmission***

CH_4 emissions associated with the release of gas from the facilities of Japan Natural Gas Association member companies in relocating and building of pipelines have been surveyed in FY2004, FY2008 and onward; and CH_4 emissions associated with the release of gas used to operate pressure regulators have been surveyed in FY2004, FY2011 and onward by Japan Natural Gas Association. To establish country-specific emission factors for Japan, the results of the surveys are used.

The emission factors for emissions from relocating and building of pipelines, and for emissions from the release of gas used to operate pressure regulators are estimated respectively as shown in the following Table 3-83 and the total values are applied to the emission factors. For the sales volume of indigenous natural gas which is used for establishing emission factors, the data are sourced from the member companies of Japan Natural Gas Association and provided by the association.

Table 3-83 The method of estimating emission factors of natural gas transmission

<table>
<tr><th>Fiscal year</th><th>Relocation and building work of pipeline</th><th>Release of gas used to operate pressure regulators</th></tr>
<tr><td>1990 - 2003</td><td colspan="2">The same value as FY2004 is consistently used.</td></tr>
<tr><td>2004</td><td colspan="2">Estimated by dividing the actual CH4 emissions in FY2004 by the sales volume of natural gas in the same fiscal year.</td></tr>
<tr><td>2005 - 2007</td><td>Estimated by interpolating the emission factor in FY2004 and that in FY2008 which is estimated by the same method as FY2004.</td><td rowspan="2">Estimated by interpolating the emission factor in FY2004 and that in FY2011 which is estimated by the same method as FY2004.</td></tr>
<tr><td>2008 - 2010</td><td>Estimated by dividing the actual CH4 emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.</td></tr>
<tr><td>2011 -</td><td colspan="2">Estimated by dividing the actual CH4 emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.</td></tr>
</table>

As a result of the above estimation, the emission factors in each fiscal year are estimated as shown on the Table 3-84.

Table 3-84 The estimation result of emission factors of natural gas transmission

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Pipeline relocation & installation	t-CH_4/10^6m^3	0.220	0.220	0.220	0.190	0.071	0.073	0.062	0.070	0.115	0.217	0.077	0.129	0.119	0.029	0.073
Gas for operating pressure regulators	t-CH_4/10^6m^3	0.087	0.087	0.087	0.077	0.028	0.013	0.009	0.005	0.001	0.001	0.001	0.001	0.003	0.003	0.003
Total	t-CH_4/10^6m^3	0.306	0.306	0.306	0.267	0.099	0.087	0.071	0.075	0.116	0.218	0.078	0.131	0.122	0.032	0.075

- ***Storage***

The emission factor is calculated by dividing the CH_4 emissions actually measured during regular maintenance or construction in the major LNG receiving terminals, city gas production facilities, and satellite terminals in Japan, by the calorific value of the raw material input (LNG and indigenous natural gas). The emission factor calculated using the FY1998 data is 905.41 [kg-CH_4/PJ], while that calculated using the FY2007 data is 264.07 [kg-CH_4/PJ]. The main reason of such change in emission factor is the reduction in CH_4 emissions, which is due to the progress in reduction measures such as the installation of new sampling and recovery lines used for gas analyses (changes to gas recovery lines from atmospheric dispersion) in LNG receiving terminals and city gas production facilities. Because the measures to reduce CH_4 emissions have been implemented gradually, the emission factors for the period from FY1999 to FY2006 are set by linear interpolation. At present, measures to reduce CH_4 emissions have been generally implemented, thereby affording little expectation of any major change in the emission factor for the time being. Therefore, the FY2007 emission factor value is kept for FY2008 and subsequent years.

- ***Activity Data***

- ***Transmission***

The sales volume of indigenous natural gas provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* is used for activity data.

Table 3-85 Sales amount of natural gas

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Natural gas sales amount	10^6m^3	2,067	2,339	2,617	3,329	4,020	3,928	3,790	3,792	3,709	3,806	4,000	3,980	3,903	3,768	3,902

- ***Storage***

The amount of LNG and indigenous natural gas used as raw material for city gas, provided in the *General Energy Statistics*, is used for activity data

Table 3-86 LNG and natural gas used for the feedstock of city gas

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
LNG consumption with city gas production	PJ	464	676	864	1,230	1,531	1,592	1,555	1,567	1,567	1,641	1,665	1,635	1,584	1,532	1,593
Natural gas consumption with city gas production	PJ	40	48	61	86	115	112	107	106	103	101	96	85	75	71	68

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

A country-specific emission factor is used for CH_4 emissions from transmission of natural gas, however, since it is difficult to assess the uncertainties, the values given in the *2006 IPCC Guidelines* (-100% to +100%) are applied. As for activity data, because the uncertainties of statistical data used as reference are not available, the values given in the *2006 IPCC Guidelines* (-2% to +2% of the uncertainties associated with measurement of flow rate (sales volumes)) are applied. As a result, the uncertainties of fugitive emissions of CO_2 and CH_4 from natural gas transmission are assessed to be -100% to +100%.

For the emission factors for fugitive CH_4 emissions associated with storage of natural gas, a country-specific emission factor is used; however, since it is difficult to assess the uncertainties, the values given in the *2006 IPCC Guidelines* (-20% to +500%) are applied. As for the activity data, the values given in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used, since the uncertainties for statistical data used as reference are not available. As a result, the uncertainties of CH_4 fugitive emissions from natural gas storage are assessed to be -25% to +500%.

- ***Time-series Consistency***

Regarding emission factors for transmission of natural gas in and after FY2004, the values are established by dividing the measured emissions by corresponding natural gas production amount for the fiscal years when emission measurement was implemented. For fiscal years when emission measurement was not implemented, emission factors are established by interpolating. For emissions before FY2003, the established values for FY2004 are used for all fiscal years. In addition, the natural gas sales volume used for activity data is provided in the *Yearbook of Production Supply and Demand of Petroleum, Cool and Coke*, in the *Yearbook of Mineral Resources and Petroleum Products Statistics* and in the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

For emission factors for storage of natural gas, as described above and based on the emission factors established from the survey in FY1998 and FY2007, the emission factor for FY1998 is used for before FY1997, the emission factor for FY2007 is used for FY2008 and onward, and the emission factors for FY1999-2006 are established by interpolation using the FY1998 and FY2007 factors.

To ensure the consistency, the figures provided in the *General Energy Statistics* are adopted consistently for activity data of LNG and indigenous natural gas which are used as raw material of city gas.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

Since the CH_4 emissions for FY2019 and FY2020 provided by the Japan Natural Gas Association were revised, the CH_4 emissions in those years were recalculated. The notation key of CO_2 was changed from “NA” to “NE” in response to a review recommendation. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.2.2.e. Distribution (1.B.2.b.v.)

a) Category Description

This category includes CH_4 emitted from city gas supply networks.

In Japan, liquefied petroleum gas, coal, coke, naphtha, crude oil, and natural gas are refined and blended at gas plants into gas, which, after being conditioned to produce a certain calorific value, is supplied to urban areas through gas lines. Such gas fuel is called "city gas", of which more than 90% is LNG-based. As for detail of city gas, please refer to the explanation of city gas emission factor in 3.2.1.b. Methodological issues (Figure 3-4 , Table 3-16, etc.).

The CO_2 emissions in this source are reported as insignificant "NE". Although CO_2 is basically not included in the city gas constituents, it is impossible to say no CO_2 is included at all. (See section 3.3.2.2.d.a) for details.) The treatment of insignificant "NE" is described in Annex 5.

b) Methodological Issues

- ***Estimation Method***

CH_4 emissions from high-pressure pipelines, from medium- and low-pressure pipelines and holders, and from service pipes are calculated by multiplying the sales volume of city gas by the country-specific emission factors. Since city gas is not recognized in the *2006 IPCC Guidelines*, the method applied is reported as "CS" (country-specific) in CRF Summary 3.

- ***Emission Factors***

The emission sources in the supply of domestically produced city gas are (i) high-pressure pipelines, (ii) medium- and low-pressure pipelines and holders, and (iii) service pipes. Table 3-87 shows the CH_4 emissions from the city gas pipelines of former general gas companies calculated by Japan Gas Association from the actual data by each emission source. The emissions are estimated by CH_4 contents in the city gas, pipeline length of construction, number of inspections, etc. The value of 9.5×10^{-6} kt-CH_4/10^6m^{3}N, which is obtained by dividing the CH_4 emissions (292 t-CH_4) in FY2004 by the city gas amount sold by former general gas companies in the same fiscal year of $30{,}696\times10^6$m^{3}N (Derived from *Current Survey of Production Concerning Gas Industry*), is used for the emission factor per sales amount.

Table 3-87 CH_4 emissions from city gas pipelines (FY2004 actual data)

Emission sources		CH_4 emissions [t/year]
High-pressure pipelines	New pipeline installation, and pipeline relocation	180
Medium- and low-pressure pipelines and holders	Construction, demolition, fugitive emissions, inspection of governor and others, holder construction, and overhauling	93
Service pipes	Installation of service pipes, post-installation purging, removal, change of meters, fugitive emissions, go around for opening valves and regular maintenance, and equipment repairs (mainly the emissions occur when the work is done at user sites (homes))	19

- ***Activity Data***

The city gas sales amount in calorific value in the *Current Survey of Production Concerning Gas Industry* is divided by the calorific value per volume in the *General Energy Statistics* to get the amount in volume, and the result is used for the activity data. The city gas sales amount is classified as industrial use, commercial use, residential use and other use. As the activity data include all of them, the emissions from city gas supplied to industrial plants are included in the estimation.

Table 3-88 Sales amount of city gas

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Sales amount of city gas	PJ	643	877	1,064	1,419	1,644	1,688	1,667	1,681	1,671	1,738	1,776	1,740	1,692	1,654	1,723
Calorific value per volume	MJ/m^3	41.9	41.9	41.1	44.8	44.8	44.8	40.8	40.8	40.7	40.7	40.8	40.0	40.0	39.9	40.0
Sales amount of city gas in volume	10^6m^3	15,367	20,952	25,899	31,684	36,705	37,686	40,894	41,226	41,073	42,721	43,543	43,522	42,342	41,437	43,009

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For emission factor in CH_4 fugitive emissions accompanied by city gas distribution, country-specific figure is used. However, it is difficult to evaluate the uncertainties in this figure; therefore, values (-20% to +500%) provided in the *2006 IPCC Guidelines* are adopted. As for activity data, since it is unable to evaluate the uncertainties in statistical data used as reference, the setting values (-2% to +2% of the uncertainties associated with measurement of flow rate (sales volumes)) given in the *2006 IPCC Guidelines* are adopted. As a result, the uncertainties in CH_4 fugitive emissions accompanied by city gas distribution are evaluated at -20% to +500%.

- ***Time-series Consistency***

For the emission factor, the consistent value is used from FY1990 to the nearest year, by using the above-mentioned method. The activity data are calculated using the data from the *Current Survey of Production Concerning Gas Industry* with a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

- ***QA/QC***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

- ***Verification***

During the review held in 2022, the ERT recommended that Japan described its national circumstances relating to natural gas distribution in its NIR, and explain the logical basis for using a CH_4 EF that is significantly lower than the default value of the *2006 IPCC Guidelines* (1.1×10^{-3} kt-CH_4/10^6m^3).

The default value is an emission factor per utility sales. However, at the moment, such an emission factor per utility sales is not found in the original references of the default value. Therefore, it is difficult to compare the default value with the country-specific emission factor (CSEF). According to the *2006 IPCC Guidelines* (Vol.2, page 4.37), a Tier 1 approach should only be used as a last resort option for the estimation of the fugitive emissions from oil and gas. Since the CSEF specifies emission sources as described above, it is regarded that the CSEF reflects Japan’s circumstances better than the default value.

e) Category-specific Recalculations

Since the city gas sales amount for FY2013 and FY2020 in the *Current Survey of Production Concerning Gas Industry* were revised, the CH_4 emissions in those years were recalculated. The notation key of CO_2 was changed from “NA” to “NE” in response to the review recommendation. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.2.2.f. Other (post-meter and abandoned gas wells) (1.B.2.b.vi.)

The leakage of greenhouse gases from post-meter and abandoned gas wells is reported under this category.

The conceivable sources of emissions from post-meter include gas pipe work in buildings, but because these emissions are included in those of “Natural Gas Distribution” (distribution through the city gas network) (1.B.2.b.v), emissions from this source are reported as “IE.”

The *2019 Refinement* provides the estimation method for abandoned gas wells that was not provided in the *2006 IPCC Guidelines*. As mentioned in Section 3.3.2.1.f. (1.B.2.a.vi Other), for abandoned gas wells as well as for abandoned oil wells, systems to prevent gas leakage has been established in Japan based on the Mine Safety Act and the Enforcement Ordinance of the Mine Safety Act. Therefore, the emissions from abandoned gas wells are reported as “NA”.

3.3.2.3. Venting and Flaring (1.B.2.c.)

This section includes fugitive emissions of CO_2 and CH_4 occurring from venting during oil field development, crude oil transportation, refining processes, and product transportation in the petroleum industry, as well as during gas field development, natural gas production, transmission, and processing in the natural gas industry.

It also includes CO_2, CH_4 and N_2O emissions from flaring during the above processes.

3.3.2.3.a. Venting (Oil) (1.B.2.c.Venting.i.)

a) Category Description

This category includes CO_2 and CH_4 emissions from venting in the petroleum industry.

b) Methodological Issues

- ***Estimation Method***

The emissions from venting in the petroleum industry were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.39, Fig. 4.2.2) by multiplying the amount of crude oil production by the default emission factors.

- ***Emission Factors***

The default values for conventional oil given in the *2006 IPCC Guidelines* were used for the emission factors of oil field venting.

Table 3-89 Emission factors of oil field venting

		Unit	CH_4	CO_2	N_2O
Oil production/ Conventional oil	Venting	kt/1000 m^3	7.2×10^{-4}	9.5×10^{-5}	NA

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.50, Table 4.2.4
Note: N_2O is excluded from calculations, as the default value is “NA”

- ***Activity Data***

The production volume of oil in Japan given in its *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, *Yearbook of Mineral Resources and Petroleum Products Statistics* and *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* is used as activity data of the fugitive emissions from oil field venting. The production of condensate was excluded from the calculation (see Table 3-74).

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the uncertainties in emission factors for CO_2 and CH_4 fugitive emissions from venting (oil), since the default values given in the *2006 IPCC Guidelines* are used for emission factors, the uncertainty values (-50% to +50%) provided in the *2006 IPCC Guidelines* are used. As for activity data, it is unable to evaluate the uncertainties in statistical data used as reference, the values (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) provided in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in CO_2 and CH_4 fugitive emissions from venting (oil) are evaluated at -52% to +52% for each.

- ***Time-series Consistency***

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics,* by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

As the *2019 Refinement* provided the refined estimation method of this category, it is necessary to consider if the method is appropriate for Japan's circumstances.

3.3.2.3.b. Venting (Gas) (1.B.2.c.Venting.ii.)

a) Category Description

This category deals with CO_2 emissions accompanied by separation and diffusion of CO_2 which is contained in natural gas produced in natural gas production facilities when CO_2 contents does not meet the standard of non-combustion gas content provided by users.

As for other emission source in this category, intentional CO_2 and CH_4 emissions during transmission of natural gas are considered to be included in this category, because their emission factors are provided in the *2006 IPCC Guidelines*. However, the intentional CO_2 emissions from pipeline of natural gas are reported as "NE" in transmission of natural gas (1.B.2.b.iv.) in case of Japan. Therefore, the emissions are not reported. As for CH_4 emissions, the emissions are reported as "IE", because they are included in emissions from transmission of natural gas (1.B.2.b.iv).

b) Methodological Issues

- ***Estimation Method***

Tier 3 method is used for the years when the actual measurement data are available and Tier 2 method is used for the other years, in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.38, Fig.4.2.1).

For the emissions from this category in FY1990, FY1995 and onward, actual measurement data of CO_2 emission provided by Japan Petroleum Development Association is used for reporting.

For FY1991-1994, the natural gas amount produced from gas field, where separation of CO_2 from natural gas has been implemented (Minami Nagaoka and Katagai gas fields), is used for the activity data, and the emissions are estimated by multiplying the activity data by emissions factors. As for the emission factors, nominal emission factors are estimated by dividing the emissions in FY1990 and FY1995 provided by Japan Petroleum Development Association by activity data in the same fiscal years, and the emission factors for FY1991-1994 are estimated by interpolation using the values for FY1990 and FY1995.

- ***Emission Factors***

For FY1990, FY1995 and onward, the values are estimated by dividing emissions data provided by Japan Petroleum Development Association by activity data. As for FY1991 – FY1994, the values are estimated by interpolation using the values for FY1990 and FY1995. (The emission factors are used only for FY1991-1994 for emission estimation.)

Table 3-90 Emission factors of natural gas field venting

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Emission factor	kg-CO_2/m^3	0.133	0.117	0.126	0.114	0.120	0.122	0.122	0.124	0.128	0.129	0.127	0.129	0.128	0.122	0.100

- ***Activity Data***

The total production amount of Minami Nagaoka gas field and Katagai gas field indicated in *Natural Gas Data Yearbook* are used for activity data. (The activity data are used only for FY1991-1994 for emission estimation.)

Table 3-91 Production amount of natural gas from Minami-nagaoka and Katagai gas field

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Natural gas production from Minami-nagaoka and Katagai gas field	10^6 m^3	432	657	789	1,229	1,660	1,731	1,664	1,542	1,598	1,761	1,944	1,755	1,593	1,474	1,474

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

As for emissions from venting (natural gas), actual measurement emission data provided by Japan Petroleum Development Association is used for reporting for FY1990, FY1995 and onward. However, it is difficult to evaluate the uncertainty for the data. Therefore, the standard value of uncertainty associated with measurement of flow rate (-15% to +15%) provided in the *2006 IPCC Guidelines* is adopted.

- ***Time-series Consistency***

For the emissions from this source, the emission data provided by *Japan Petroleum Development Association* are consistently used for FY1990, FY1995 and onward. As for FY1991-1994, the emissions are estimated from the FY1990 and FY1995 emission data provided by *Japan Petroleum Development Association*.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There have been no major planned improvements in this category.

3.3.2.3.c. Venting (Combined) (1.B.2.c.Venting.iii.)

Statistical data are reported for two categories of petroleum and natural gas in Japan. As a result, fugitive emissions from venting in the combined petroleum and natural gas industries were reported as "IE" since they were accounted for in the emissions from venting in the petroleum industry (1.B.2.c.Venting.i) and the natural gas industry (1.B.2.c.Venting.ii).

3.3.2.3.d. Flaring (Oil) (1.B.2.c.Flaring.i.)

a) Category Description

This category includes CO_2, CH_4, and N_2O from flaring in the petroleum industry.

b) Methodological Issues

- ***Estimation Method***

The CO_2, CH_4, and N_2O emissions from flaring in the petroleum industry were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines*, by multiplying the amount of crude oil production in Japan by the default emissions factors.

- ***Emission Factors***

In the absence of actual measurement data or country-specific emission factors in Japan, the default values shown in the *2006 IPCC Guidelines* were used.

Table 3-92 Emission factors for flaring in the oil industry

	Unit	CH_4	CO_2	N_2O
Flaring (conventional oil)	$kt/10^3 m^3$	2.5×10^{-5}	4.1×10^{-2}	6.4×10^{-7}

Reference : *2006 IPCC Guidelines* Vol. 2, p 4.50, Table 4.2.4

- ***Activity Data***

For the calculation of activity data for this emission source, the amounts of crude oil production shown in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Natural Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* are used. The production of condensate is excluded from the calculation (see Table 3-74).

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For emission factors for CO_2, CH_4, and N_2O fugitive emissions from flaring (oil), since the default values given in the *2006 IPCC Guidelines* are used for the emission factors, the values (-50% to +50%) provided in the *2006 IPCC Guidelines* are used. As for activity data, it is unable to evaluate the uncertainties in statistical data used as reference, the values (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) provided in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in CO_2 CH_4, and N_2O fugitive emissions from flaring (oil) are evaluated at -52% to +52% for each.

- ***Time-series Consistency***

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data of the flaring in oil industry are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics,* by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

As the *2019 Refinement* provided the refined estimation method of this category, it is necessary to consider if the method is appropriate for Japan's circumstances.

3.3.2.3.e. Flaring (Gas) (1.B.2.c.Flaring.ii.)

a) Category Description

This category includes CO_2, CH_4, and N_2O from flaring in the natural gas industry.

b) Methodological Issues

- ***Estimation Method***

The CO_2, CH_4, and N_2O emissions associated with flaring in the natural gas industry were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.38, Fig. 4.2.1). The emissions were calculated by multiplying the amount of natural gas production by the emission factors. The total emissions associated with flaring both during gas production and processing were reported as the emissions from flaring in the natural gas industry.

- ***Emission Factors***

The default values for fugitive emissions from flaring in the natural gas industry given in the *2006 IPCC*

Guidelines are used.

Table 3-93 Emission factors for flaring in the natural gas industry

		Unit	CH_4	CO_2	N_2O
Flaring in the natural gas industry	Gas production	$kt/10^6m^3$	7.6×10^{-7}	1.2×10^{-3}	2.1×10^{-8}
	Gas processing/Sweet gas plants	$kt/10^6m^3$	1.2×10^{-6}	1.8×10^{-3}	2.5×10^{-8}

Reference: *2006 IPCC Guidelines* Vol. 2, page 4.48, Table 4.2.4

- ***Activity Data***

For the calculation of activity data for this emission source, the amounts of domestic production of natural gas shown in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Natural Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* were used (see Table 3-81).

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the uncertainty of CO_2, CH_4, and N_2O emission factors for flaring (natural gas), the default values given in the *2006 IPCC Guidelines* are used for the emission factors exclusively. Therefore, the uncertainty of -25% to +25% in the *2006 IPCC Guidelines* is applied. For the activity data, the uncertainty of the statistics used is not clear. Therefore, the value in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) is used. As a result, the uncertainty of CO_2, CH_4, and N_2O emissions from flaring (natural gas) are evaluated to be -29% to +29% for each.

- ***Time-series Consistency***

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data of flaring in natural gas industry are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics,* by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

As the *2019 Refinement* provided the refined estimation method of this category, it is necessary to consider if the method is appropriate for Japan's circumstances.

3.3.2.3.f. Flaring (Combined) (1.B.2.c.Flaring.iii.)

a) Category Description

In Japan, the statistical data are reported for two categories of oil and natural gas. Therefore, the fugitive emissions which can be distinguished of their category are reported in Flaring (Oil) (1.B.2.c.Flaring.i) or in Flaring (Natural gas) (1.B.2.c.Flaring.ii) respectively. In this category, CO_2, CH_4, and N_2O emissions accompanied by exploration and test before production of oil and natural gas, which are unable to be distinguished of their categories of oil industry or natural gas industry, are reported.

b) Methodological Issues

● ***Estimation Method***

For the fugitive emissions accompanied by exploration and test before production of oil and natural gas, the emission factors, which are established using the crude oil production as activity data, are indicated as default values in the *2006 IPCC Guidelines*.

However, in case of Japan, the correlation between CO_2, CH_4, and N_2O emissions, which are accompanied by exploratory drilling and pre-production testing, and crude oil production, and the correlation between the GHG emissions, which are accompanied by the production during exploration and testing, and the production amount from commercial plants are not clear, thus there is a possibility of deviation between the estimated result and the actual condition, if the estimation method of using the crude oil production as activity data, which is indicated in the *2006 IPCC Guidelines*, is adopted. Therefore, the Tier 1 method in *GPG2000*, which is considered to be closer to actual condition, is used in this category. The method used is to multiply the activity data of number of exploratory drilling well or testing well by the default emission factor.

● ***Emission Factors***

The default values indicated in the *GPG2000* are adopted.

Table 3-94 Emission factors for exploratory drilling and testing wells

	Unit	CH_4	CO_2	N_2O
Drilling	kt/number of wells	4.3×10^{-7}	2.8×10^{-8}	0
Testing	kt/number of wells	2.7×10^{-4}	5.7×10^{-3}	6.8×10^{-8}

Reference: *GPG2000*, page 2.86, Table 2.16

● ***Activity Data***

The values described in *Natural Gas Data Yearbook* are used for the number of exploratory drilled wells. As for the number of tested wells, it is difficult to grasp statistically, and the tested wells don't always become the succeeded wells. Therefore, the median of the number of wells drilled and the number of wells tested in the *Natural Gas Data Yearbook* is used as the number of wells tested. For the most recent year, the data of the previous year are provisionally used.

Table 3-95 Number of wells drilled and tested

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of wells drilled	well	8	7	7	10	2	4	5	1	2	2	0	0	1	1	1
Number of wells succeeded		1	3	4	5	0	2	3	1	1	0	0	0	0	0	0
Number of wells tested		5	5	6	8	1	3	4	1	2	1	0	0	1	1	1

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the uncertainty of CO_2, CH_4, and N_2O emission factors for flaring (combined), the default values given in the *GPG2000* are used for the emission factors exclusively. Therefore, the uncertainty of -25% to +25% in *GPG2000* is applied. For the activity data, the uncertainty of the statistics used is not clear. Therefore, the value in the *2006 IPCC Guidelines* (-25% to +25%: uncertainty accompanied with the factor for number of production facilities) is used. As a result, the uncertainty of CO_2, CH_4, and N_2O emissions from flaring (combined) are evaluated to be -35% to +35% for each.

- ***Time-series Consistency***

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data are calculated using the data from the *Natural Gas Data Yearbook* by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

As the *2019 Refinement* provided the refined estimation method of this category, it is necessary to consider if the method is appropriate for Japan’s circumstances.

3.3.2.4. Other (Fugitive Emissions Associated with the Geothermal Power Generation) (1.B.2.d.)

a) Category Description

This category deals with the CO_2 and CH_4 emissions in geothermal power plants, where the CO_2 and CH_4 from steam production wells are emitted from cooling towers into the atmosphere.

b) Methodological Issues

- ***Estimation Method***

The emissions from this category are estimated by multiplying the amount of steam production (weight base) in each geothermal power plant by mass concentration rate of CO_2 and CH_4, since any descriptions for estimation methods for this category are not provided in the *2006 IPCC Guidelines*. However, as for CO_2 and CH_4 in the steam produced in production well, even though there is a possibility that the steam dissolves in water during transmitting in condenser, it is difficult to estimate the dissolved amount. Therefore, the emissions are estimated assuming that the total amount of CO_2 and CH_4 in the produced steam is emitted into the air. Binary geothermal power plants are excluded from emission estimation, because non-condensable gas in the steam is not emitted into the air. In a binary geothermal power plant, a thermal circulating cycle with hot water is independent from that with working liquid of low boiling point.

Since this source is not recognized in the *2006 IPCC Guidelines*, the method applied is reported as "CS" (country-specific) in CRF Summary 3.

- ***Emission Factors***

Mass concentration rate of CO_2 in steam is estimated by using volume concentration of non-condensable gas in steam and volume concentration of CO_2 in non-condensable gas in each geothermal power plant (Japan Geothermal Energy Association, 2000).

Mass concentration rate of CH_4 is estimated by using volume concentration of non-condensable gas in steam in each geothermal power plant (Japan Geothermal Energy Association, 2000) and concentration of CH_4 in non-condensable gas (Geothermal Energy Association, 2012).

- ***Activity Data***

The amount of steam production in each geothermal power plant is basically estimated by multiplying an amount of steam production per hour in each plant provided in *Trend of Geothermal Power in Japan* (JGEA) and *Current Status and Trend of Geothermal Power* (Thermal and Nuclear Power Engineering Society), by operating time of production well. The operating time of production well is assumed as the same as the power generating time of each power plant in *Current Status and Trend of Geothermal Power*.

Each emission factor for CO_2 and CH_4 for geothermal power plants in Japan and the trend of the produced amount of steam are indicated in the Table 3-96.

Table 3-96 Emission factor and produced amount of steam of geothermal power plants

Power plant name	Emission factor		Production amount of steam [kt]														
	CO_2 [t-CO_2/kt]	CH_4 [t-CH_4/kt]	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Matsukawa	12.2	0.025	1,884	1,493	1,708	1,115	813	745	872	857	666	412	610	737	604	683	683
Ohtake	3.1	0.006	1,173	995	995	774	789	770	937	885	867	935	1,013	955	721	468	468
Ohnuma	0.6	0.002	694	682	535	651	600	518	537	521	489	521	510	522	507	506	506
Onikobe	2.6	0.008	1,018	1,015	1,035	982	1,185	348	357	381	334	402	NO	NO	NO	NO	NO
Hatchobaru 1	6.5	0.013	2,883	2,366	2,598	2,602	2,287	2,353	2,347	1,887	1,963	2,097	1,729	1,365	2,129	2,417	2,417
Hatchobaru 2	5.8	0.011	2,514	2,686	2,532	2,452	2,291	2,219	2,342	2,264	2,209	1,848	2,107	1,646	1,693	2,532	2,532
Kakkonda 1	0.3	0.001	3,498	3,126	1,966	2,021	1,535	1,276	1,374	1,400	1,362	1,455	1,371	881	1,228	1,248	1,248
Kakkonda 2	0.4	0.001	NO	209	1,823	2,004	1,440	1,255	1,269	1,225	1,142	1,058	1,286	1,171	1,212	884	884
Suginoi	8.5	0.019	220	284	203	144	129	170	147	136	140	137	110	115	122	122	122
Mori	28.1	0.053	1,367	1,990	1,981	1,501	1,068	1,182	1,001	1,105	934	1,015	1,121	1,001	869	711	711
Kirishima International Hotel	1.1	0.003	48	97	70	NO	30	58	68	38	NO	NO	NO	NO	NO	NO	NO
Uenotai	6.5	0.014	NO	1,882	2,070	1,601	482	1,846	1,784	1,717	1,512	1,521	1,449	1,501	1,203	1,443	1,443
Yamakawa	5.8	0.012	NO	1,451	1,336	639	1,026	1,026	989	702	744	1,031	1,047	1,034	879	1,191	1,191
Sumikawa	1.4	0.004	NO	3,234	2,846	2,908	2,611	1,853	2,038	2,903	2,903	2,676	2,334	2,082	2,100	2,372	2,372
Yanaizu-Nishiyama	68.8	0.130	NO	3,912	3,425	3,197	2,229	2,203	1,626	1,998	1,537	1,691	1,064	1,363	904	1,230	1,230
Ohgiri	0.4	0.001	NO	219	2,373	2,306	2,286	1,983	1,969	2,073	1,928	1,910	1,457	1,892	1,943	1,777	1,777
Takigami	1.9	0.004	NO	NO	2,111	2,075	2,239	2,251	2,374	2,087	2,422	2,299	2,239	2,059	2,249	2,184	2,184
Hachijo-jima	18.1	0.041	NO	NO	187	156	152	142	149	151	147	153	165	76	NO	NO	NO
Kuju	8.5	0.019	NO	NO	10	136	124	26	120	58	108	108	108	108	108	108	108
Waita	8.5	0.019	NO	NO	NO	NO	NO	NO	NO	NO	148	174	181	193	207	195	195
Wasabizawa	8.5	0.019	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	1,978	2,096	2,096

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

As for the emission factors, because the emissions were estimated from the concentration of non-condensable gas in the steam and the concentration of GHG in the non-condensable gas, the uncertainty was estimated at -7% to +7% based on the uncertainty of measurement of gas concentration given in the *2006 IPCC Guidelines*. As for the activity data, because the uncertainty of the referred statistics was not available, the values given in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) were used. As a result, the uncertainty of CO_2 and CH_4 emissions from the steam generated in production well in geothermal production was evaluated as -17% to +17%.

- ***Time-series Consistency***

For the emission factors, consistent values are used from FY1990 to the nearest year, by using the above-mentioned method. The activity data are calculated by a consistent method throughout the time-series from FY1990 to the nearest year, based on the *Current Status and Trend of Geothermal Power*.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Chapter 1.

e) Category-specific Recalculations

Since the activity data for FY2018 and FY2020 in the *Current Status and Trend of Geothermal Power* were obtained, the CO_2 and CH_4 emissions in FY2018 through 2020 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There have been no major planned improvements in this category.

3.4. CO_2 transport and storage (1.C.)

CO_2 transport and storage sector includes CO_2 emissions associated with the carbon dioxide capture and storage (CCS). CCS is the technology or methodology that captures the CO_2 which would be emitted to the atmosphere and stores it underground or under seabed.

This sector consists of three categories; Transport of CO_2 (1.C.1): emissions in the stage of CO_2 transport, Injection and storage (1.C.2): emissions in the stage of CO_2 injection and storage, and Other (1.C.3). There are five projects of CO_2 injected underground in the past in Japan. CO_2 emissions in the stage of transport and injection can occur during the period of injection, and CO_2 emissions in the stage of storage can have occurred continuously since CO_2 is injected. Table 3-97 shows the emissions from CO_2 transport and storage (1.C).

Table 3-97 Past projects of CO_2 underground injection in Japan

Injection site	Period of injection	Purpose
Kubiki	March 1991 – June 1993	Enhanced oil recovery
Sarukawa	September 1997 – September 1999	Enhanced oil recovery
Nagaoka	July 2003 – January 2005	Demonstration of geological storage of CO_2
Yubari	November 2004 – October 2007	Enhanced coal bed methane recovery
Tomakomai	April 2016 – November 2019	Demonstration of geological storage of CO_2

Table 3-98 CO_2 emissions from CO_2 transport and storage (1.C)

IPCC Category		1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1.C.1 Transport of CO_2	a. Pipelines	NE	NO	NO	NE	NO	NO	NO	NO	NO	NA	NA	NA	NA	NO	NO
	b. Ships	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	c. Other	NE	NO	NO	NE	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1.C.2 Injection and storage	a. Injection	NE	NO	NO	NE	NO	NO	NO	NO	NO	NA	NA	NA	NA	NO	NO
	b. Storage	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
1.C.3 Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

3.4.1. Transport of CO_2 (1.C.1)

3.4.1.1. Pipelines (1.C.1.a.)

This category includes fugitive emissions of CO_2 in the stage of CO_2 transport by pipeline.

According to the interview to the entities of the projects shown in Table 3-97, the fugitive emissions in the stage of CO_2 transport by pipeline do not occur basically or the amount is quite small even if the fugitive emissions occur. Especially in the case of Tomakomai injection site, the pipeline is structurally designed to allow no gas leaks, and the assurance of airtightness is confirmed by execution of airtightness test. In addition, the approximate results of emissions estimated using the default emission factor of the *2006 IPCC Guidelines* (vol. 2, page 5.10, Table 5.2) are less than 3 kt-CO_2, which is a criterion to include the emissions in the national totals established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE in the year CO_2 injection was conducted (but reported as NA in the year CO_2 injection was conducted only in Tomakomai site where the airtightness is assured) and reported as NO in the other years. The treatment of insignificant NE is described in Annex 5.

3.4.1.2. Ships (1.C.1.b.)

This category includes fugitive emissions of CO_2 in the stage of CO_2 transport by ships. The emissions are reported as NO, because ships were not used in the past projects in Japan.

3.4.1.3. Other (1.C.1.c.)

This category includes fugitive emissions of CO_2 in the stage of liquefied CO_2 transport by a lorry from a plant to an injection site or from a storage tank of liquefied CO_2. It is hard to consider the annual fugitive emissions become larger than 3 kt-CO_2 for following reasons: First, according to the interview to the entities of the projects shown in Table 3-97 (excluding the Tomakomai project), the fugitive emissions shown above do not occur basically or the amount is quite small even if the fugitive emissions occur. Second, the maximum amount of annual injection is about 6 kt-CO_2. Therefore, the emissions from this category are reported as insignificant NE in the years CO_2 injection were conducted in the projects other than Tomakomai. The treatment of insignificant NE is described in Annex 5. The emissions from this category are reported as NO in the years CO_2 injection were conducted only in Tomakomai site because there were no related activities. The emissions are reported as NO in the years CO_2 injection was not conducted in any of the projects.

3.4.2. Injection and Storage (1.C.2)

3.4.2.1. Injection (1.C.2.a.)

This category includes fugitive emissions of CO_2 in the stage of a compressor or an injection well at an injection site.

According to the interview to the entities of the projects shown in Table 3-97, the fugitive emissions in the stage of injection do not occur basically or the amount is quite small even if the fugitive emissions occur. In addition, the approximate results of emissions estimated using the emission factors shown in Koornneef *et al*. (2008) are less than 3 kt-CO_2, which is a criterion to include the emissions in the national total established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE in the year CO_2 injection was conducted (but reported as NA in the year CO_2 injection was conducted only in Tomakomai site where the airtightness is assured) and reported as NO in the other years. The treatment of insignificant NE is described in Annex 5.

3.4.2.2. Storage (1.C.2.b.)

This category includes fugitive emissions from a storage site.

According to the interview to the entities of the projects shown in Table 3-97, the fugitive emissions from a storage site do not occur basically or the amount is quite small even if the fugitive emissions occur. In addition, the approximate results of emissions estimated using the ratio of stored CO_2 in a storage reservoir to the injected CO_2 shown in the IPCC (2005) are less than 3 kt-CO_2, which is a criterion to include the emissions in the national total established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE through all reporting years. The treatment of insignificant NE is described in Annex 5.

3.4.3. Other (1.C.3)

This category includes any other emissions from CCS not reported in Transport of CO_2 (1.C.1) and Injection and storage (1.C.2). The emissions are reported as NO, because there are no emissions to be reported in this subcategory.

3.4.4. Information item

This section describes the amount of CO_2 captured for geological storage. CRF Table 1.C contains the column ‘Information item’ for checking if the amount of CO_2 from capture to storage process is accurately reported. It should be noted that reporting values under ‘Total amount captured for storage’ in ‘Information item’ does not mean that the amount of CO_2 captured is subtracted from CO_2 transport and storage (1.C.) category. The amount of CO_2 captured is subtracted from CO_2 emissions from categories where capture takes place. (See the *2006 IPCC Guidelines*, Volume 2, Chapter 2, Equation 2.7.)

The amount of CO_2 captured is considered to be nearly equal to that of CO_2 injected in the past projects of geological injection of CO_2 conducted in Japan. Thus, the amount of CO_2 injected that was provided by the entities of the projects is reported as the amount of CO_2 captured in the fiscal years when the injections were conducted. The captured amount is reported in 1.A.1.b Petroleum refining or 2.B.1 Ammonia production in accordance with the source of CO_2 used in each project.

Table 3-99 Amount of CO_2 captured for geological storage

Injection site	Unit	1990	1991	1992	1993	1997	1998	1999	2003	2004	2005	2006	2007	2016	2017	2018	2019	2020	2021	Reported under
Kubiki	kt	0.23	3.93	4.46	1.17	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	2.B.1 Ammonia production
Sarukawa	kt	NO	NO	NO	NO	2.37	4.87	2.71	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	2.B.1 Ammonia production
Nagaoka	kt	NO	NO	NO	NO	NO	NO	NO	3.98	6.43	NO	NO	NO	NO	NO	NO	NO	NO	NO	2.B.1 Ammonia production
Yubari	kt	NO	NO	NO	NO	NO	NO	NO	NO	0.04	0.12	0.36	0.37	NO	NO	NO	NO	NO	NO	1.A.1.b Petroleum refining
Tomakomai	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	29.22	126.80	79.58	64.51	NO	NO	1.A.1.b Petroleum refining

References

1. IPCC, *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, 1997.
2. IPCC, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, 2000.
3. IPCC, *IPCC Special Report on Carbon Dioxide Capture and Storage*, 2005.
4. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
5. IPCC, *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2019.
6. UNFCCC, *Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention*, Decision 24/CP.19, FCCC/CP/2013/10/Add.3, 2013a.
7. UNFCCC, *Report of the individual review of the annual submission of Japan submitted in 2012*, FCCC/ARR/2012/JPN, July 2013b.
8. UNFCCC, *Report of the individual review of the annual submission of Japan submitted in 2013,* FCCC/ARR/2013/JPN, March 2014.
9. UNFCCC, *Report of the individual review of the annual submission of Japan submitted in 2014,* FCCC/ARR/2014/JPN, June 2015.
10. UNFCCC, *Report of the individual review of the annual submission of Japan submitted in 2018,* FCCC/ARR/2018/JPN, September 2019.
11. European Environment Agency (EEA), *EMEP/EEA air pollutant emission inventory guidebook 2016,* August 2016.
12. Environmental Agency, *The Report on Estimation of CO_2 Emissions in Japan*, 1992.
13. Environmental Agency Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 1*, September 2000a.
14. Environmental Agency Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 2*, September 2000b.
15. Environmental Agency Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 3*, September 2000c.
16. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 1*, August 2002a.
17. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 2*, August 2002b.
18. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 3*, August 2002c.
19. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 1*, August 2006a.
20. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 2*, August 2006b.
21. Ministry of the Environment, *Actual condition survey of GHG emissions from non-manufacturing industry, Fiscal year 2014*, March 2015a.
22. Ministry of the Environment, *Actual condition survey of GHG emissions from manufacturing industry, Fiscal year 2014*, March 2015b.
23. Ministry of the Environment, *Actual condition survey of GHG emissions from non-manufacturing*

industry, Fiscal year 2015, March 2016.
24. Ministry of the Environment, *Survey on Grasp of the Actual Condition of Greenhouse Gas Emissions from Biomass Boilers Fiscal Year 2017*, 2018.
25. Ministry of the Environment, *General Survey of the Emissions of Air Pollutants*.
26. Ministry of the Environment, *PRTR Outside Notification Emissions Estimated Data*.
27. Ministry of Economy, Trade and Industry, *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*.
28. Ministry of Economy, Trade and Industry, *Yearbook of Mineral Resources and Petroleum Products Statistics*.
29. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics.*
30. Ministry of Economy, Trade and Industry, *Yearbook of the Current Survey of Energy Consumption*.
31. Ministry of Economy, Trade and Industry, *Indices of Industrial Production.*
32. Ministry of Economy, Trade and Industry, *Indices of Tertiary Industry Activity.*
33. Ministry of Economy, Trade and Industry, *Examples of Measures to be Taken by Holders of Mining Rights*, 2012.
34. Agency for Natural Resources and Energy, *Current Survey of Production Concerning Gas Industry.*
35. Agency for Natural Resources and Energy, *General Energy Statistics*.
36. Agency for Natural Resources and Energy, *Structural Survey of Energy Consumption.*
37. Agency for Natural Resources and Energy, *Electric Power Statistics.*
38. Agency for Natural Resources and Energy, *Japan's Energy White Paper*, 2020.
39. Agency for Natural Resources and Energy, *Japan's Energy White Paper*, 2022.
40. Agency for Natural Resources and Energy, *Explanation on Standard Calorific Values and Carbon Emission Factors for Fuel Combustion Revised in FY2018*, 2020.
41. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Air Transport.*
42. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Motor Vehicle Transport*, and its *Monthly Report.*
43. Ministry of Land, Infrastructure, Transport and Tourism, *Road Transport Census.*
44. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Motor Vehicle Fuel Consumption.*
45. Ministry of Land, Infrastructure, Transport and Tourism, *Airport Management Status Study Report*.
46. Hokkaido Development Agency, *Research Report on Gas Chemical Industry Development, FY1960-64, Reserves in Coal fields,* 1965.
47. Forestry Agency, *Basic Data for Special Forest Product*.
48. Forestry Agency, *Data for Charcoal*.
49. Forestry Agency, *Promotion of Wood Use and Energy-saving and CO_2 Reduction Demonstration Project Fiscal Year 2014*, 2015.
50. Automobile Inspection and Registration Information Association, *Statistics of AIRIA/ Number of Motor Vehicle.*
51. Japan Automobile Manufacturers Association, *Survey of Motorcycle Market Trends.*

52. Japan Automobile Manufacturers Association, *Monthly Report Statistics of Vehicles*.
53. Japan Society for Atmospheric Environment, *Report on Emission Factor Results for Combustion Facilities*, 1996. (The English translation was published in 1997.)
54. Japan Natural Gas Association, *Natural Gas Data Yearbook.*
55. Japan Lubricating Oil Society, *Report on the Subsidized Project of Environmental Measures of Lubricants Fiscal Year 2012*, March 2013.
56. Japan Gas Association website (https://www.gas.or.jp/en).
57. Japan Automobile Manufacturers Association website (https://www.jama.or.jp/english/).
58. Japan Light Motor Vehicle and Motorcycle Association website (https://www.zenkeijikyo.or.jp/).
59. Japan Coal Energy Center, *History of Coal Policy*, 2002.
60. Japan Geothermal Energy Association, *Directory for Geothermal Power Plant Facilities in Japan*, 2000.
61. Japan Geothermal Energy Association, *Trend of Geothermal Power in Japan.*
62. Thermal and Nuclear Power Engineering Society, *Current Status and Trend of Geothermal Power*.
63. Geothermal Energy Association, *Geothermal Energy and Greenhouse Gas Emissions*, 2012.
64. Japan Automobile Research Institute, *FY2007 JAMA Trust Research Report; Detailed Examination in Research Method of Number of Owned Light Two-wheel Vehicles*, March 2008.
65. Japan Automobile Research Institute, *FY2006 JAMA Trust Research Report; Research in Contribution Rate of the Emissions from Motorcycles*, March 2007.
66. Koornneef, J., van Keulen, T., Faaij, A., Turkenburg, W., *Life cycle assessment of a pulverized coal power plant with post-combustion capture, transport and storage of* CO_2, International Journal of Greenhouse Gas Control, Volume 2, Issue 4, 448–467, 2008.
67. Kainou, K., *Evaluating and Analyzing the Validity of Carbon Emission Factors for Different Fuels*, Submission to the Inventory Working Group under the Committee for the Greenhouse Gases Emissions Estimation Methods, 2005.
68. Kainou, K., *Explanation of General Energy Statistics*, April 2012.
69. Kainou, K., *Recommendation of the Draft Revised Standard Calorific Value and Carbon Emission Factor for Fossil Fuel Energy Sources in Japan*, RIETI Discussion Paper Series 14-J-047, October 2014.
70. Goto, Y., Koike, N., Suzuki, H., *Research on Estimation of* N_2O *Total Emissions of Automobiles, and Generalization and Popularization of the Core Technology of the Reduction Technique*, Final Report of the Global Environment Research Fund FY2002, B-51, 2003.
71. Matsumoto, H., *Technical and Human Exchange between Kushiro Coal Mine and Asian Coal Producing Countries*, Shigen-to-Sozai, Vol.122, 542-545, 2006.
72. Matsumoto, H., Kawashima, S., Uchida, K., Ichihara, Y., Suzuki, Y., *Recovery of Coal Mine Methane and Its Utilization with a Newly Developed Gas Concentration System*, Journal of MMIJ, Vol.134, No.8, 99-104, 2018.
73. Yoda, K., Yamashita, T., Mogi, K., *Analysis of Nitrous Oxide Emission from Gasoline Vehicles and Study of Measurement Accuracy*, Proceedings of Society of Automotive Engineers of Japan (JSAE) Annual Congress, No.109-10, 3-6, 2010.

Chapter 4. Industrial Processes and Product Use (CRF sector 2)

4.1. Overview of Sector

Chemical and physical transformation in industrial processes releases GHGs into the atmosphere. This chapter describes the methodologies of estimating industrial process and product use emissions shown in Table 4-1. The estimation methods, emission factors, activity data, etc of each source are considered and approved by the breakout groups on Energy and Industrial Processes, and F-gases, of the Committee for Greenhouse Gas Emissions Estimation Methods, consisting of experts from various fields. (See Chapter 1)

Emissions have been estimated for all years, with zero emissions for some years and sources. To the extent that space and confidentiality concerns allow, relative indices are shown in the tables under each sub-category. Emissions by each sub-category and by gas are shown in the first table of each category.

Table 4-1 Categories in the industrial processes and product use sector

Source categories				CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
2.A Mineral industry	2.A.1	Cement Production		○						
	2.A.2	Lime Production		○						
	2.A.3	Glass Production		○						
	2.A.4	Other Process Uses of Carbonates	Ceramics	○						
			Other Uses of Soda Ash	○						
			Non-metallurgical Magnesia Production	IE						
			Other	○						
2.B Chemical Industry	2.B.1	Ammonia Production		○	NE	NA				
	2.B.2	Nitric Acid Production				○				
	2.B.3	Adipic Acid Production		NA		○				
	2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	Caprolactam			○				
			Glyoxal			○				
			Glyoxylic Acid			○				
	2.B.5	Carbide Production	Silicon Carbide	○	○					
			Calcium Carbide	○	NA					
	2.B.6	Titanium Dioxide Production		○						
	2.B.7	Soda Ash Production		IE						
	2.B.8	Petrochemical and Carbon Black Production	Methanol	NO	NO					
			Ethylene	○	○					
			Ethylene Dichloride and Vinyl Chloride Monomer	○	○					
			Ethylene Oxide	○	○					
			Acrylonitrile	○	NA					
			Carbon Black	○	○					
			Styrene		○					
			Phthalic Anhydride	○						
			Maleic Anhydride	○						
			Hydrogen	○						
	2.B.9	Fluorochemical Production	By-product Emissions: Production of HCFC-22				○			
			Fugitive emissions				○	○	○	○
2.C Metal Industry	2.C.1	Iron and Steel Production	Steel	IE	NA					
			Use of Electric Arc Furnaces in Steel Production	○	○					
			Pig Iron	○	NA					
			Limestone and dolomite use in Iron and Steel Production	○						
			By-product Gas Flaring in Iron and Steel Production	○						
			Direct Reduced Iron	NO	NO					
			Sinter	IE	IE					
			Pellet	IE	IE					
	2.C.2	Ferroalloys Production		IE	○					
	2.C.3	Aluminium Production	By-product Emissions	○				○		
			F-gases Used in Foundries						NO	
	2.C.4	Magnesium Production					○		○	
	2.C.5	Lead Production		IE						
	2.C.6	Zinc Production		IE						
	2.C.7	Rare Earths Production		NE				NE		
2.D Non-energy Products from Fuels and Solvent Use	2.D.1	Lubricant Use		○						
	2.D.2	Paraffin Wax Use		○						
	2.D.3	Other	Urea-based Catalysts	○						
			NMVOC Incineration	○						
			Road Paving with Asphalt							
			Asphalt Roofing							
2.E Electronics Industry	2.E.1	Integrated Circuit or Semiconductor					○	○	○	○
	2.E.2	TFT Flat Panel Display					○	○	○	○
	2.E.3	Photovoltaics						IE		
	2.E.4	Heat Transfer Fluid						IE		
	2.E.5	Microelectromechanical systems					IE	IE		

Table 4-1 Categories in the industrial processes and product use sector (continued)

Source categories						CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
2.F Product Uses as Substitutes for ODS	2.F.1	Refrigeration and Air-Conditioning	Domestic Refrigeration		manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				○	NO	NO	NO
			Commercial Refrigeration	Commercial Refrigeration	manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				○	NO	NO	NO
				Automatic Vending Machines	manufacturing				○	NO	NO	NO
					stocks				IE	NO	NO	NO
					disposal				IE	NO	NO	NO
			Transport Refrigeration		manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				○	NO	NO	NO
			Industrial Refrigeration		manufacturing				IE	NO	NO	NO
					stocks				IE	NO	NO	NO
					disposal				IE	NO	NO	NO
			Stationary Air-Conditioning (Household)		manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				○	NO	NO	NO
			Mobile Air-Conditioning (Car Air Conditioners)		manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				○	NO	NO	NO
	2.F.2	Foam Blowing Agents	Closed Cells	Urethane Foam	manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				IE	NO	NO	NO
				Extruded Polystyrene Foam	manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				IE	NO	NO	NO
			Open Cells	High Expanded Polyethylene Foam	manufacturing				○	NO	NO	NO
					stocks				NO	NO	NO	NO
					disposal				NO	NO	NO	NO
	2.F.3	Fire Protection			manufacturing				NO	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				NO	NO	NO	NO
	2.F.4	Aerosols	Metered Dose Inhalers		manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				IE	NO	NO	NO
			Aerosols		manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				IE	NO	NO	NO
	2.F.5	Solvents			manufacturing				NO	NO	NO	NO
					stocks				○	○	NO	NO
					disposal				IE	IE	NO	NO
	2.F.6	Other Applications										
2.G Other Product Manufacture and Use	2.G.1	Electrical Equipment			manufacturing						○	
					stocks						○	
					disposal						IE	
	2.G.2	SF_6 and PFCs from Other Product Use	Military Applications		manufacturing					NE	NE	
					stocks					NE	○	
					disposal					NE	NE	
			Accelerators		manufacturing					NE	NE	
					stocks					NO	○	
					disposal					NE	NE	
			Soundproof Windows		manufacturing					NE	NE	
					stocks					NE	NE	
					disposal					NE	NE	
			Adiabatic Properties: Shoes and Tyres		manufacturing					NE	NE	
					stocks					NO	NO	
					disposal					NE	NE	
			Other Railway Silicon Rectifiers		manufacturing					NA	NA	
					stocks					NA	NA	
					disposal					○	NA	
	2.G.3	N_2O from Product Uses	Medical Applications					○				
			Use During Semiconductor/Liquid Crystal Manufacturing					○				
	2.G.4	Waterproofing electronic circuits							○	○		
2.H Other	2.H.2	Food and Beverages Industry				○						
	2.H.3	Emissions from Imported Carbonated Gas				○						

In FY2021, total GHG emissions from this sector amounted to approximately 103,258 kt-CO_2 eq., and accounting for 8.8% of national total emissions (excluding LULUCF) in Japan. The emissions of CO_2, CH_4, and N_2O from this sector have decreased by 40.8% compared to FY1990. The emissions of HFCs, PFCs, SF_6, and NF_3 from this sector have increased by 67.2% compared to 1990.

The main driving factors for the decrease in emissions for this sector since FY1990 are the decrease in emissions of HFC-23 produced as a by-product of HCFC-22 production due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures (chemical industry), the decrease in CO_2 emissions from cement production (mineral industry) as the clinker production declined, the decrease in N_2O emissions from adipic acid production (chemical industry) as the N_2O abatement equipment came on stream. However, HFC emissions from the product uses as ODS substitutes have largely increased.

For FY2019 to 2020, the decreases in CO_2 emissions observed for 2.A.4.b (Other uses of soda ash), 2.B.1 (Ammonia production), 2.B.8.f (Carbon black production), and 2.C.1.a (Use of electric arc furnaces in steel production), and the decrease in N_2O emissions observed for 2.B.2 (Nitric acid production) are due to the decrease in production owing to the coronavirus disease 2019 pandemic, etc.

The methodological tiers used in the IPPU sector are as shown in the below Table 4-2.

Table 4-2 Methodological tiers used in the IPPU sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O			
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor		
2.A. Mineral industry	CS,T2	CS						
2.B. Chemical industry	CS,T1,T2,T3	CS,D	CS,T1	CS	CS,T1,T2,T3	CS,PS		
2.C. Metal industry	CS,T1	CS,D	CS	CS				
2.D. Non-energy products from fuels and solvent use	D,T1,T2	CS,D	NA	NA	NA	NA		
2.E. Electronics industry								
2.F. Product uses as substitutes for ODS								
2.G. Other product manufacture and use					CS	OTH		
2.H. Other	CS		NA	NA	NA	NA		

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	HFCs		PFCs		SF_6		NF_3	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
2.A. Mineral industry								
2.B. Chemical industry	T2,T3	CS,OTH	T3	OTH	T3	OTH	T3	OTH
2.C. Metal industry	CS	CS	T2	D,CS	T2	OTH		
2.D. Non-energy products from fuels and solvent use								
2.E. Electronics industry	T2	D,CS	T2	D,CS	T2	D,CS	T2	D,CS
2.F. Product uses as substitutes for ODS	CS	D,CS	CS	CS				
2.G. Other product manufacture and use	T1	T1	T1,CS	T1,CS	CS,T1,T2	CS,D		
2.H. Other								

Note: D: IPCC default, T1-T3: IPCC Tier 1-3, CS: country specific, PS: plant specific, OTH: other

4.2. Mineral Industry (2.A.)

This category covers CO_2 emissions from the calcination of mineral raw material such as $CaCO_3$, $MgCO_3$, Na_2CO_3, etc. This section includes the following sources: Cement production (2.A.1.), Lime production (2.A.2.), Glass production (2.A.3.), and Other process uses of carbonates (2.A.4.).

In FY2021, emissions from this category were 31,137 kt-CO_2 and represented 2.7% of total GHG emissions (excluding LULUCF). The emissions decreased by 36.1% compared to FY1990.

Table 4-3 CO_2 Emissions from 2.A. Mineral Industry

Gas				Units	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	2.A.1	Cement production		kt-CO_2	38,701	42,142	35,086	32,280	24,321	25,625	26,805	26,557	25,936	25,969	26,429	26,183	25,328	24,490	24,396
	2.A.2	Lime production		kt-CO_2	6,674	5,795	5,900	6,646	6,285	5,679	5,767	5,812	5,477	5,504	5,583	5,615	5,200	4,504	4,971
	2.A.3	Glass production		kt-CO_2	313	283	233	244	188	200	212	209	211	206	213	217	198	164	174
	2.A.4	Other process uses of carbonates	Ceramics	kt-CO_2	928	1,065	980	771	880	928	966	955	829	758	748	647	645	698	738
			Other uses of soda ash	kt-CO_2	119	118	102	79	62	51	46	49	47	48	43	47	44	36	37
			Other	kt-CO_2	1,978	1,285	1,187	1,093	940	1,112	1,135	1,096	1,026	935	924	856	817	811	821
	Total			kt-CO_2	48,714	50,689	43,487	41,112	32,676	33,595	34,930	34,678	33,526	33,421	33,940	33,565	32,232	30,703	31,137

4.2.1. Cement Production (2.A.1.)

a) Category Description

CO_2 is emitted by the calcination of limestone, the main component of which is calcium carbonate, during the production of clinker[1)], an intermediate product of cement and the main component of which is calcium oxide. Although to a lesser extent than calcium carbonate, limestone also contains magnesium carbonate, which by calcination emits CO_2.

<u>CO_2 emission mechanism of the cement production process</u>

$$CaCO_3 \rightarrow CaO + CO_2$$
$$MgCO_3 \rightarrow MgO + CO_2$$

1) Cement clinker, a black nodule like a volcanic rock with a diameter of 1 cm or so is formed, by introducing a mixture of raw materials such as clay, silica stone, or iron materials, in addition to the main material limestone, into a large rotating kiln after pre-heating, and calcining them under high temperatures, and then rapidly cooling by air. This is ground up, and with the addition of gypsum, is transformed into cement. (from Japan Cement Association's website, partially edited)

b) Methodological Issues

● ***Estimation Method***

Following the Tier 2 method in the *2006 IPCC Guidelines*, the CO_2 emissions from this source was estimated by multiplying the amount of clinker produced by a country-specific emission factor.

$$E = EF_{cl} \times M_{cl} \times CF_{ckd}$$

E	: CO_2 emissions from cement production [t-CO_2]
EF_{cl}	: Emission factor [t-CO_2/t-clinker]
M_{cl}	: Clinker production [t]
CF_{ckd}	: Cement kiln dust correction coefficient

● ***Emission Factors***

Since Japan's cement industry takes in large amounts of waste and byproducts from other industries and recycles them as substitute raw materials for cement production, clinker contains CaO and MgO from sources other than carbonates. This CaO and MgO do not go through the limestone calcination stage, and therefore does not emit CO_2 during the clinker production process. For that reason, emission factors were determined by estimating the CaO and MgO content of clinker from carbonates, by subtracting CaO and MgO originating from waste and other sources from the total CaO and MgO content of clinker. Japan applies 1.00 for the cement kiln dust (CKD) correction coefficient, because normally almost all

CKD is recovered and used again in the production process, as confirmed by the Cement Association.

The emission factors for CO_2 emitted from cement production were established as follows.

$$EF = EF_{CaO} + EF_{MgO}$$

EF_{CaO} : $CaCO_3$-origin CO_2 emission factor (established by the following equation)
EF_{MgO} : $MgCO_3$-origin CO_2 emission factor (established by the following equation)

Where,

$$EF_{CaO} = (CaO_{cl} - CaO_{Cl\text{-}Waste}) \times 0.785$$

$$CaO_{Cl\text{-}Waste} = W_{dry} \times CaO_{waste} / M$$

CaO_{Cl} : CaO content of clinker
$CaO_{Cl\text{-}waste}$: CaO content of clinker (waste-origin)
0.785 : Molecular weight ratio of CO_2 to CaO
W_{dry} : Weight of inputs of waste and other materials (dry)
CaO_{Waste} : CaO content of waste and other materials
M : Production amount of clinker

$$EF_{MgO} = (MgO_{Cl} - MgO_{Cl\text{-}Waste}) \times 1.092$$

$$MgO_{Cl\text{-}Waste} = W_{dry} \times MgO_{waste} / M$$

MgO_{Cl} : MgO content of clinker
$MgO_{Cl\text{-}Waste}$: MgO content of clinker (waste-origin)
1.092 : Molecular weight ratio of CO_2 to MgO
W_{dry} : Weight of inputs of waste and other materials (dry)
MgO_{Waste} : MgO content of waste and other materials
M : Production amount of clinker

➢ ***Dry weight of waste and other materials input in raw material processing***

The following 13 types of waste and other materials were chosen for this calculation: coal ash (incineration residue), sewage sludge incineration ash, municipal solid waste incineration ash, glass refuse/ceramics refuse, concrete refuse, blast furnace slag (water granulated), blast furnace slag (slow-cooled), steelmaking slag, nonferrous slag, casting sand, particulates/dust, coal ash (fluidized bed furnace ash), and coal ash (from dust collectors) (these waste account for over 90% of the CaO and 80% of the MgO from waste and other materials). Waste amounts (emission-based) and the water content of each waste and other material were determined from studies by Japan Cement Association (only for 2000 and thereafter).

➢ ***Content of CaO and MgO from waste and other materials in clinker***

The dry weights of each type of waste and other materials are multiplied by the respective CaO and MgO content for each type as found by Japan Cement Association, thereby yielding the respective total CaO and MgO amounts in clinker derived from waste and other materials. This is divided by clinker production amount to find the CaO and MgO content from waste and other materials in clinker.

➢ ***CaO and MgO content of clinker, excluding the CaO and MgO from waste and other materials***

CaO and MgO content in waste and other materials is subtracted from the respective average CaO and MgO content of clinker as determined by Japan Cement Association, which yields the respective proportion of CaO and MgO in clinker that is used to set emission factors.

Table 4-4 Composition of waste-origin materials[2)]

Group	Types of waste	Water content	CaO content	MgO content
Incineration residue	Coal ash	7.2 - 16.6%	5.0 - 5.8%	1.0 - 1.1%
	Sewage sludge incineration ash [1)]	10.9 - 17.8%	7.4 - 12.5%	3.5 - 3.8%
	Municipal solid waste incineration ash [1)]	15.6 - 24.6%	10.0 - 26.5%	2.6 - 2.8%
Glass refuse, Concrete refuse, and Ceramics refuse	Glass refuse, Ceramics refuse [1)]	12.1 - 32.7%	17.5 - 31.1%	1.0 - 2.5%
	Concrete refuse [1)]	0 - 37.2%	6.4 - 43.9%	1.0 - 1.1%
Slag	Blast furnace slag (water granulated)	5.0 - 16.9%	40.0 - 42.4%	4.7 - 5.8%
	Blast furnace slag (slow-cooled)	5.5 - 16.4%	40.8 - 41.5%	6.1 - 6.5%
	Steelmaking slag	7.7 - 14.3%	34.8 - 40.5%	2.0 - 3.0%
	Nonferrous slag	3.8 - 8.4%	6.4 - 10.0%	1.1 - 1.5%
	Casting sand [1)]	9.6 - 14.0%	6.5%	1.3 - 1.6%
Particulates (dust collector dust)	Particulates/dust	8.9 - 14.3%	9.0 - 13.4%	1.2 - 1.5%
	Coal ash (fluidized bed furnace ash) [1)]	0.1 - 3.2%	14.5 - 20.7%	0.7 - 0.9%
	Coal ash	1.0 - 3.9%	4.1 - 5.0%	1.0 - 1.1%

Note: 1) Newly added from FY2009.

2) CO_2 emissions from unburned carbon contained in coal ash and particulates, etc will be accounted for under Fuel combustion (1.A.) and Waste incineration (5.C.1.) categories since an oxidation factor of 1 is used for emission estimation of these sources in Japan. The CO_2 emissions from unburned carbon contained in sewage sludge incineration ash are not included in the total emissions because sewage sludge is of biogenic origin.

Table 4-5 CO_2 emission factors for cement production

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Average CaO content in clinker	%	65.9	65.9	66.0	65.9	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8
Waste origin CaO content in clinker	%	2.6	2.6	2.9	2.0	1.7	1.8	1.7	1.6	1.6	1.6	1.7	1.8	1.8	1.6	1.6
CaO content in clinker excluding waste origin CaO	%	63.3	63.3	63.0	63.9	64.1	64.0	64.1	64.1	64.2	64.1	64.1	64.0	64.0	64.2	64.2
CO_2/CaO		0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Emission factor	t-CO_2/t	0.497	0.497	0.495	0.501	0.503	0.502	0.503	0.503	0.504	0.503	0.503	0.502	0.502	0.504	0.504
Average MgO content in clinker	%	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Waste origin MgO content in clinker	%	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
MgO content in clinker excluding waste origin MgO	%	1.0	1.0	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.1	1.1
CO_2/MgO		1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092
Emission factor	t-CO_2/t	0.010	0.010	0.010	0.011	0.011	0.011	0.012	0.012	0.012	0.012	0.012	0.011	0.011	0.012	0.012
Combined emission factor	t-CO_2/t	0.508	0.508	0.505	0.512	0.514	0.514	0.514	0.515	0.516	0.515	0.515	0.514	0.514	0.515	0.515

- ***Activity Data***

Cement Association provides the data on the amount of clinker produced. Because there is no statistics on clinker production from FY1990 to FY1999, an estimation is made for past (FY1990 - FY1999) clinker production using the average values of the FY2000 - FY2003 ratios of clinker production (Cement Association data) to limestone consumption (*Yearbook of Ceramics and Building Materials Statistics* (Ministry of Economy, Trade and Industry, hereafter METI)).

Table 4-6 Clinker production

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Consumption of limestone (actual)	kt (dry)	89,366	97,311	81,376	-	-	-	-	-	-	-	-	-	-	-	-
Clinker production (actual)	kt	-	-	69,528	63,003	47,279	49,883	52,105	51,573	50,307	50,436	51,351	50,979	49,293	47,522	47,338
Ratio of actual clinker production to actual consumption of limestone		0.853	0.853													
Estimated clinker production after correction	kt	76,253	83,032													

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the CO_2 emission factor and activity data for cement production, the default value given in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of emissions was estimated to be 4%.

- ***Time-series Consistency***

CO_2 emissions from cement production from FY1990 to FY1999 is estimated using estimated activity data and emission factors based on values provided by Japan Cement Association. For years from FY2000 and onward, the methodology described in the sections above is consistently applied using the data provided by Japan Cement Association.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.2. Lime Production (2.A.2.)

a) Category Description

CO_2 is emitted during the calcination of $CaCO_3$, $MgCO_3$ in limestone used as raw material to produce quicklime.

CO_2 generation mechanism of quicklime production process

$$CaCO_3 \rightarrow CaO + CO_2$$
$$MgCO_3 \rightarrow MgO + CO_2$$

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions are calculated by multiplying limestone consumption by the country-specific emission factor.

$$E = EF \times M$$

E	: CO_2 emissions generated by use of raw materials in quicklime production [t-CO_2]
EF	: Emission factor [t-CO_2/t-raw material]
M	: Amount of limestone consumed [t-raw material]

- ***Emission Factors***

An emission factor per unit raw material (limestone) (0.428 t-CO_2/t-raw material)[1] provided by Japan Lime Association was used.

[1] The emission factor per lime produced can be derived as follows: 0.428 [t-CO_2/t-material] / (1-0.428) [t-lime/t-material] = 0.748 [t-CO_2/t-lime]

The Emission factor per unit raw material was calculated by finding the CO_2 emissions per unit raw material estimated from the amounts of carbon and other substances in raw material constituents and quicklime products, and then finding the weighted average using production amounts of each district. The emission factor for lime production is the same for all years because annual change is thought to be small. This emission factor is country-specific, as described above.

- ***Activity Data***

Limestone consumption data for quicklime and slaked lime use, categorized under 'Ceramic and quarry products- other ceramics and quarry products' in the *Adjusted Price Transaction Table* is used. It is converted to dry weight using the water content from limestone used for cement.

> The *Adjusted Price Transaction Table*:
>
> The *Adjusted Price Transaction Table* is a table created by integrating supply/demand information on limestone, dolomite and related derivatives obtained from the input table in the Input-Output Table/ industrial statistics, etc, and is an application of similar estimation methods which were used in the *General Energy Statistics* (the Energy Balance Table) (Agency for Natural Resources and Energy). The items for which supply/demand information are not available are supplemented by estimation.
>
> In the existing transaction table on quantity attached to the Input-Output Table, although expressing the domestic supply and demand of products without any omission/duplication, there exists the possibility of over/under evaluation of transaction depending on the sector if the actual price differs, since transaction in each sector is based on the input from the average price across all industries. In contrast, the *Adjusted Price Transaction Table* attempts to eliminate differences between sectors, by taking into consideration the uneven transaction prices based on the differences in product quality/form in each sector, and through using statistical values in industrial statistics, etc to the extent which possible.
>
> By using consumption data in the *Adjusted Price Transaction Table* as activity data, it is considered possible to capture activity data for all industries without omission/duplication, and to achieve a correct categorization of emission/non-emission related use, based on its detailed breakdown of sectors. See Kainou (2010) for more details on the *Adjusted Price Transaction Table.*
>
> In the inventory, limestone/dolomite consumption data by sector in the *Adjusted Price Transaction Table* will be used as activity data for each limestone related source, excluding that for Cement production (2.A.1.).

As for the dolomite consumed in dolomitic lime production, it is accounted for under Other process uses of carbonates (2.A.4.), and therefore will not be included under Lime production (2.A.2.). The re-absorption of CO_2 by the production of light calcium carbonate is already deducted in the *Adjusted Price Transaction Table*.

As regards lime production in sugar mills, according to an interview conducted with three domestic producers documented in the *Report on the Development of the Foundation for the Mandatory GHG Accounting and Reporting System (2010)* by Ministry of the Environment (MOE), as regards cane sugar, slaked lime is acquired from outside to make the lime milk at all domestic producers, and as for beet sugar, in cases when limestone is calcined, the CO_2 emitted is reabsorbed into the lime cake. On the basis of this information, CO_2 emissions from sugar manufacturing are not estimated.

As regards aluminium production in Japan, it was confirmed that lime has never been produced from FY1990 onward according to information from Japan Aluminum Association. (Aluminium production ended in 2014.) Therefore, the CO_2 emissions are not estimated.

Table 4-7 Limestone consumption

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Limestone consumption (dry)	kt	15,595	13,540	13,785	15,527	14,684	13,269	13,474	13,579	12,797	12,860	13,045	13,119	12,150	10,524	11,614

c) Uncertainties and Time-series Consistency

● ***Uncertainty***

For the uncertainty of the emission factor, the default value of 2% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 4%.

● ***Time-series consistency***

Limestone consumption data provided in the *Adjusted Price Transaction Table* is used as lime production activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, CO_2 emission from lime production has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred due to updates in the *Adjusted Price Transaction Table* for FY2002, 2003, 2009, 2010, 2019 and 2020. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.3. Glass Production (2.A.3.)

a) Category Description

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases CO_2 derived from $CaCO_3$ and $MgCO_3$. Similarly, CO_2 is emitted from soda ash, barium carbonate, potassium carbonate, strontium carbonate, and lithium carbonate. There is still no detailed information available regarding the use of bone ash in glass production in Japan.

<u>CO_2 generating mechanism of limestone and dolomite use</u>

$$CaCO_3 \rightarrow CaO + CO_2$$
$$MgCO_3 \rightarrow MgO + CO_2$$

b) Methodological Issues

● ***Estimation Method***

The amounts of limestone, dolomite, soda ash, barium carbonate, potassium carbonate, strontium carbonate, and lithium carbonate used in glass production are multiplied by the emission factors to calculate emissions.

- ***Emission Factors***

➢ ***Limestone***

The emission factor is calculated by adding the value obtained when multiplying the molecular weight ratio of CO_2 and $CaCO_3$ by the $CaCO_3$ content, calculated from the percentage of CaO that can be extracted from limestone (55.4%, the median value of the "54.8% to 56.0%" given in *The Story of Lime* (Japan Lime Association)), and the value obtained when multiplying the molecular weight ratio of CO_2 and $MgCO_3$ by the $MgCO_3$ content, calculated from the percentage of MgO that can be extracted from limestone (0.5%, the median value of the "0.0% to 1.0%" given in *The Story of Lime*). The emission factor is country-specific, as shown below. A review of this EF was conducted in 2009, and it was confirmed that it remains valid.

・Proportion of CaO extractable from limestone : 55.4 % (Median of 54.8% to 56.0% [b])
・Proportion of MgO extractable from limestone : 0.5 %[b] (Median of 0.0% to 1.0% [b])
・Molecular weight of $CaCO_3$ (primary constituent of limestone) : 100.0869[a]
・Molecular weight of $MgCO_3$: 84.3139[a]
・Molecular weight of CaO : 56.0774[a]
・Molecular weight of MgO : 40.3044[a]
・Molecular weight of CO_2 : 44.0095[a]

・$CaCO_3$ content = proportion of CaO extractable from limestone × molecular weight of $CaCO_3$ / molecular weight of CaO
・$MgCO_3$ content = proportion of MgO extractable from limestone × molecular weight of $MgCO_3$ / molecular weight of MgO

○Emission factor = (molecular weight of CO_2 / molecular weight of $CaCO_3$ × $CaCO_3$ content)
+ (molecular weight of CO_2 / molecular weight of $MgCO_3$ × $MgCO_3$ content)
= 440 [kg-CO_2/t]

Reference:
a) *Atomic Weights of the Elements 1999* [http://www.ciaaw.org/pubs/TSAW-1999.pdf] (IUPAC)
b) *The Story of Lime*

➢ ***Dolomite***

The emission factor is calculated by adding the value obtained when multiplying the molecular weight ratio of CO_2 and $CaCO_3$ by the $CaCO_3$ content, calculated from the percentage of CaO that can be extracted from dolomite (34.5%, the median value of the 33.1% to 35.85% range given in *The Story of Lime*), and the value obtained when multiplying the molecular weight ratio of CO_2 and $MgCO_3$ by the $MgCO_3$ content, calculated from the percentage of MgO that can be extracted from dolomite (18.3%, the median value of the 17.2% to 19.5% range given in *The Story of Lime*). The emission factor is country-specific, as shown below. A review of this EF was conducted in 2009, and it was confirmed that it remains valid.

・Proportion of CaO extractable from dolomite : 34.5% (Median value of the 33.1% to 35.85% [a])
・Proportion of MgO extractable from dolomite : 18.3% (Median value of the 17.2% to 19.5% [a])
・Molecular weight of $CaCO_3$ (major constituent of dolomite) : 100.0869
・Molecular weight of $MgCO_3$ (major constituent of dolomite) : 84.3142
・Molecular weight of CaO : 56.0774
・Molecular weight of MgO : 40.3044
・Molecular weight of CO_2 : 44.0098

・$CaCO_3$ content = proportion of CaO extractable from dolomite × molecular weight of $CaCO_3$/ molecular weight of CaO

・$MgCO_3$ content = proportion of MgO extractable from dolomite ×
molecular weight of $MgCO_3$/ molecular weight of MgO
〇Emission factor = molecular weight of CO_2 / molecular weight of $CaCO_3$ × $CaCO_3$ content
+ molecular weight of CO_2 / molecular weight of $MgCO_3$ × $MgCO_3$ content
= 471 [kg-CO_2/t]

Reference:
a) *The Story of Lime*

➢ *Soda ash*

See section 2.A.4.b Other uses of soda ash.

➢ *Other materials*

For barium carbonate ($BaCO_3$), 0.22 t-CO_2/t, based on molecular weight ratio of CO_2 to $BaCO_3$, is used. For potassium carbonate (K_2CO_3), 0.32 t-CO_2/t, based on molecular weight ratio of CO_2 to K_2CO_3, is used. For strontium carbonate ($SrCO_3$), 0.30 t-CO_2/t, based on molecular weight ratio of CO_2 to $SrCO_3$, is used. For lithium carbonate (Li_2CO_3), 0.60 t-CO_2/t, based on molecular weight ratio of CO_2 to Li_2CO_3, is used.

● *Activity Data*

➢ *Limestone, Dolomite, and Soda ash*

Of the limestone, dolomite, and soda ash consumption data in the *Adjusted Price Transaction Table*, all limestone, dolomite, soda ash consumption categorized under 'emissive use' that are under the Glass products related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-8 Main uses and corresponding sectors in the *Adjusted Price Transaction Table*

Use	Corresponding sectors (Limestone)	Corresponding sectors (Dolomite)	Corresponding sectors (Soda ash)
Glass products	251 Ceramic and quarry products - glass/glass products	251 Ceramic and quarry products - glass/glass products	251 Ceramic and quarry products -glass/glass products

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-9 Amounts of limestone, dolomite, and soda ash consumption

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Limestone consumption (dry)	kt	66	42	26	31	17	20	23	23	23	22	24	25	20	12	14
Dolomite consumption (dry)	kt	264	250	203	221	184	194	203	201	202	199	204	207	192	166	174
Soda ash consumption (dry)	kt	358	320	257	279	217	232	249	245	247	241	250	255	230	187	201

➢ *Other materials*

For barium carbonate, shipment amounts for cathode-ray tube optical glass given in the *Mineral Resources Material Flow* (Japan Oil, Gas and Metals National Corporation) converted to pure substance mass (69%) are used for years FY2000 to FY2010. For other years, extrapolation using production amounts of glass bulbs for lights and electron tubes (including tubes and rods) given in the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials* (METI) are applied.

For potassium carbonate, domestic demand obtained by subtracting export quantities from import quantities given in the *Trade Statistics of Japan* (Ministry of Finance) converted to pure substance mass (57%) are used for years FY1991 and onward.

For strontium carbonate, demand amounts of tube glass (including flat panel glass and other glass) converted to pure substance mass (59%) are used for years FY2000 to FY2006, FY2008, and FY2010. For FY2007 and FY2009, interpolation was applied. For years FY1990 to FY1999, extrapolation using production amounts of glass bulbs for lights and electron tubes (including tubes and rods) given in the *Yearbook of Ceramics and Building Materials Statistics* was applied, and for years from FY2011 and onward extrapolation using demand amounts of $SrCO_3$ given in the *Mineral Resources Material Flow* are applied.

For lithium carbonate, demand amounts of ceramic additives (19%) given in the *Mineral Resources Material Flow* are used for years FY2002 and onward. For years FY1998 to FY2001, extrapolation using demand amounts for glass additives given in the *Mineral Resources Material Flow* are applied. For years FY1990 to FY1997, production amounts of plate glass given in the *Yearbook of Ceramics and Building Materials Statistics* for years FY1990 to FY1997 are applied.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 5% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 6%.

- ***Time-series consistency***

For activity data, the same source-data are used as much as possible throughout the time series. The emission factors are constant for all years from FY1990. Therefore, CO_2 emission has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred due to updates made to limestone (FY1990, 1991, and 2001 to 2020) and dolomite consumption (FY2004 to 2020), and soda ash consumption (FY1990, 1994, 1995, 1997, and FY2000 to 2020) in the *Adjusted Price Transaction Table* and demand amounts of lithium carbonate (FY2019 and 2020) in the *Mineral Resources Material Flow*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.4. Other Process Uses of Carbonates (2.A.4.)

4.2.4.1. Ceramics (2.A.4.a)

a) Category Description

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases CO_2 derived from $CaCO_3$ and $MgCO_3$.

b) Methodological Issues

● ***Estimation Method***

The amounts of limestone and dolomite used in ceramics production are multiplied by the emission factors to calculate emissions.

● ***Emission Factors***

➢ ***Limestone***

See section 4.2.3. b).

➢ ***Dolomite***

See section 4.2.3. b).

● ***Activity Data***

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use' that are under the Ceramics products related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-10 Corresponding sectors in the *Adjusted Price Transaction Table*

Uses	Corresponding sectors in the *Adjusted Price Transaction Table* (Limestone)		Corresponding sectors in the *Adjusted Price Transaction Table* (Dolomite)	
Ceramics products			063	Mining industry - non-metallic minerals
	2531-01	Ceramic and quarry products-ceramics	2531-01	Ceramic and quarry products - ceramics
	2591-01	Ceramic and quarry products - clay refractories	2591-01	Ceramic and quarry products - clay refractories
			2599-01 2599-09	Ceramic and quarry products - carbon graphite products Ceramic and quarry products - other ceramic and quarry products
			2811-01 to 2899-09	Metal Products - metal products for construction use Metal Products - other metal products
			6741-09	Private services - other amusement

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-11 Amounts of limestone and dolomite consumption for ceramic products

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Limestone consumption (dry)	kt	438	1,107	1,135	463	365	455	630	737	720	664	683	617	591	658	635
Dolomite consumption (dry)	kt	1,561	1,227	1,020	1,204	1,527	1,545	1,462	1,339	1,087	989	950	797	818	866	973

c) Uncertainties and Time-series Consistency

● ***Uncertainty***

Same as 4.2.3 Glass Production. See section 4.2.3.c).

● ***Time-series consistency***

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, CO_2 emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred due to updates made to limestone (FY1990 to FY2020) and dolomite consumption (FY1992, and 1999 to 2020) in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.4.2. Other uses of soda ash (2.A.4.b)

a) Category Description

CO_2 is released during the use of soda ash (Na_2CO_3).

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions from soda ash use are calculated by multiplying soda ash consumption by the country-specific emission factor.

- ***Emission Factors***

Soda ash consumption data categorized under 'for emission purpose' in the *Adjusted Price Transaction Table* does not differentiate between domestic products and imported products, and therefore the emission factor is established by taking a weighted average of the below emission factors for domestic soda ash and imports, by total domestic shipment and total import amounts.

For domestic soda ash, the emission factor is set as follows using data on the purity of soda ash. (The inter-annual fluctuation in the purity of soda ash is small, and therefore the emission factor will be set constant over the time-series.)

$$EF = P \times MW_{CO2} / MW_{Na2CO3}$$
$$= 0.995 \times 44.01 / 105.99$$
$$= 0.413 \text{ [t-CO}_2\text{/t]}$$

EF : Emission factor for domestic soda ash

P : Purity of soda ash (arithmetic mean between the 2 domestic companies)

MW_{CO2} : Molecular weight of CO_2

MW_{Na2CO3} : Molecular weight of Na_2CO_3

For soda ash imported, and other disodium carbonate imported, there is not enough information to set representative emission factors. Therefore, the default value (0.415 [t-CO_2/t-Na_2CO_3]) specified in the *2006 IPCC Guidelines* (vol. 3 p. 2.7) is used.

- ***Activity Data***

Soda ash consumption data categorized under 'for emission purpose' in the *Adjusted Price Transaction Table* is used. (excluding consumption for glass production)

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 5% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 6%.

- ***Time-series consistency***

Soda ash consumption data provided in the *Adjusted Price Transaction Table* is used as soda ash use activity data for all years from FY1990. The emission factor is constant for all years from FY1990. Therefore, CO_2 emission from soda ash use has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred for FY1993 to 1995, 1998 to 2020 due to updates made to soda ash consumption in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.4.3. Non-metallurgical Magnesium Production (2.A.4.c)

Emissions are included under 2.A.4.d. Other, and are therefore reported as IE.

4.2.4.4. Other (2.A.4.d)

a) Category Description

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases CO_2 derived from $CaCO_3$ and $MgCO_3$.

<u>CO_2 generating mechanism of limestone and dolomite use</u>

$$CaCO_3 \rightarrow CaO + CO_2$$
$$MgCO_3 \rightarrow MgO + CO_2$$

b) Methodological Issues

- ***Estimation Method***

The amounts of limestone and dolomite used in desulfurization of exhaust gas and production of chemical products are multiplied by the emission factors to calculate emissions.

- ***Emission Factors***

➢ ***Limestone***

See section 4.2.3. b).

➢ ***Dolomite***

See section 4.2.3. b).

● ***Activity Data***

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use,' that are under related sectors for desulfurization of exhaust gas, and production of chemical products excluding chemical fertilizers will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-12 Uses and corresponding sectors in the *Adjusted Price Transaction Table*

Uses	Corresponding sectors in the *Adjusted Price Transaction Table* (Limestone)		Corresponding sectors in the *Adjusted Price Transaction Table* (Dolomite)	
Desulfurization of exhaust gas	063	Mining industry - non-metallic minerals		
Chemical products	2029-09	Chemical Products - other inorganic chemical industry products	2029-09	Chemical Products - other inorganic chemical industry products
			2081-011	Chemical Products - processed oil and fat products
	2049-09	Chemical Products - other organic chemical industry products	2049-09	Chemical Products - other organic chemical industry products
			2071-01	Chemical Products - medicaments
			2089-09	Chemical Products - catalytic and other chemical end products

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-13 Amounts of limestone and dolomite consumption

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Limestone consumption																
For desulfurization of exhaust gas (dry)	kt	1,950	2,163	1,842	2,077	1,840	2,182	2,124	1,975	1,853	1,726	1,700	1,594	1,530	1,489	1,529
For chemical products (dry)	kt	2,458	713	812	367	260	310	421	482	451	375	376	331	307	332	313
Dolomite consumption																
For chemical products (dry)	kt	82	43	42	37	34	34	33	31	25	23	22	18	19	20	22

c) Uncertainties and Time-series Consistency

● ***Uncertainty***

See section 4.2.3. c).

● ***Time-series consistency***

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, CO_2 emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

In order to avoid double counting, limestone and dolomite consumption for chemical fertilizers in the *Adjusted Price Transaction Table* was excluded, and the updates of limestone consumption data for desulfurization of exhaust gas, etc, resulting in recalculations for all years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.3. Chemical Industry (2.B.)

This category covers CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3 emissions from the processes of chemical productions.

This section includes the following sources: Ammonia production (2.B.1.), Nitric acid production (2.B.2.), Adipic acid production (2.B.3.), Caprolactam, glyoxal and glyoxylic acid production (2.B.4), Carbide production (2.B.5.), Titanium dioxide production (2.B.6.), Petrochemical and carbon black production (2.B.8.), and Fluorochemical production (2.B.9.).

In FY2021, emissions from this category were 4,945 kt-CO_2 eq. and represented 0.4% of Japan's total GHG emissions (excluding LULUCF). The total emissions of CO_2, CH_4, and N_2O from this category had decreased by 71.9% compared to FY1990. The total of HFCs, PFCs, SF_6, and NF_3 had decreased by 98.0% compared to 1990.

Table 4-14 Emissions from 2.B. Chemical Industry

Gas				Units	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	2.B.1	Ammonia production		kt-CO_2	2,879	2,937	2,716	1,844	1,838	1,603	1,669	1,649	1,697	1,353	1,420	1,152	1,399	1,104	1,458
	2.B.5	Carbide production	Silicon carbide	kt-CO_2	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
			Calcium carbide	kt-CO_2	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	2.B.6	Titanium dioxide production		kt-CO_2	102	39	53	59	62	51	60	62	53	58	58	59	57	49	60
	2.B.8	Petrochemical and carbon black production	Methanol	kt-CO_2	56	51	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
			Ethylene	kt-CO_2	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
			Ethylene dichloride and vinyl chloride monomer	kt-CO_2	150	171	193	200	184	130	148	150	169	170	175	172	176	174	177
			Ethylene oxide	kt-CO_2	171	191	231	240	202	204	220	214	221	212	227	214	211	190	196
			Acrylonitrile	kt-CO_2	440	476	536	509	524	404	364	342	315	319	323	341	334	306	325
			Carbon black	kt-CO_2	1,633	1,563	1,590	1,659	1,505	1,261	1,294	1,253	1,161	1,168	1,230	1,259	1,178	980	1,198
			Phthalic anhydride	kt-CO_2	117	124	118	81	60	60	59	58	60	58	61	58	60	51	57
			Maleic anhydride	kt-CO_2	123	138	163	114	102	78	89	88	90	91	94	92	85	79	92
			Hydrogen	kt-CO_2	6	21	39	34	34	31	28	24	27	29	29	29	21	20	17
	Total			kt-CO_2	6,503	6,494	6,343	5,471	5,142	4,400	4,524	4,443	4,341	3,995	4,179	3,915	4,042	3,366	4,072
CH_4	2.B.5	Carbide production	Silicon carbide	kt-CH_4	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	2.B.8	Petrochemical and carbon black production	Methanol	kt-CH_4	0.19	0.17	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
			Ethylene	kt-CH_4	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
			Ethylene dichloride and vinyl chloride monomer	kt-CH_4	0.01	0.02	0.02	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
			Ethylene oxide	kt-CH_4	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
			Carbon black	kt-CH_4	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
			Styrene	kt-CH_4	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	Total			kt-CH_4	1.50	1.48	1.37	1.35	1.45	1.13	1.13	1.01	1.27	1.07	1.01	0.91	1.00	0.95	1.08
	Total			kt-CO_2 eq.	37	37	34	34	36	28	28	25	32	27	25	23	25	24	27
N_2O	2.B.2	Nitric acid production		kt-N_2O	2.47	2.46	2.57	2.52	1.81	1.53	1.54	1.55	1.40	1.28	1.16	1.07	1.02	0.68	0.86
	2.B.3	Adipic acid production		kt-N_2O	24.20	24.03	12.56	1.68	1.66	0.51	0.77	0.48	0.38	0.49	0.30	0.20	0.31	1.14	0.16
	2.B.4	Caprolactam, glyoxal and glyoxylic acid production	Caprolactam	kt-N_2O	4.66	4.93	5.20	3.36	2.56	2.30	1.92	1.26	0.90	0.50	0.55	0.43	0.51	0.40	0.47
			Glyoxal	kt-N_2O	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
			Glyoxylic acid	kt-N_2O	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	Total			kt-N_2O	32.28	32.43	21.30	8.58	6.08	4.34	4.22	3.28	2.68	2.27	2.01	1.70	1.85	2.22	1.50
	Total			kt-CO_2 eq.	9,620	9,665	6,348	2,558	1,813	1,293	1,259	979	798	676	599	506	551	663	446
Total of CO_2, CH_4, and N_2O				kt-CO_2 eq.	16,160	16,197	12,725	8,063	6,991	5,721	5,811	5,447	5,170	4,697	4,804	4,443	4,618	4,052	4,545
Gas				Units	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFCs	2.B.9	Fluorochemical production	By-product emissions: Production of HCFC-22	kt-CO_2 eq.	15,929	21,460	15,688	586	53	18	16	24	30	24	38	12	13	141	132
			Fugitive emissions	kt-CO_2 eq.	2	559	296	449	128	120	131	101	83	149	95	88	119	76	120
	Total			kt-CO_2 eq.	15,930	22,019	15,984	1,035	181	138	147	124	113	172	133	100	132	216	251
PFCs	2.B.9	Fluorochemical production	Fugitive emissions	kt-CO_2 eq.	331	914	1,661	1,041	248	148	111	107	115	97	81	87	64	74	79
SF_6			Fugitive emissions	t	152.23	197.00	36.00	40.80	8.30	5.40	4.07	2.70	2.30	2.20	1.78	2.00	1.76	2.28	2.00
				kt-CO_2 eq.	3,471	4,492	821	930	189	123	93	62	52	50	41	46	40	52	46
NF_3			Fugitive emissions	t	0.16	1.00	7.00	72.10	76.90	76.40	86.40	56.09	23.50	25.10	13.61	3.37	1.12	0.88	1.39
				kt-CO_2 eq.	3	17	120	1,240	1,323	1,314	1,486	965	404	432	234	58	19	15	24
Total of F-gases				kt-CO_2 eq.	19,735	27,442	18,587	4,246	1,942	1,723	1,837	1,258	684	751	489	291	256	357	400

4.3.1. Ammonia Production (2.B.1.)

a) Category Description

1) CO_2

In ammonia production, CO_2 is emitted when hydrocarbon feedstock is broken down to make H_2.

<u>CO_2 generating mechanism of ammonia production</u>

$$0.88CH_4 + 1.26air + 1.24H_2O \rightarrow 0.88CO_2 + N_2 + 3H_2$$

Ammonia synthesis

$$N_2 + 3H_2 \rightarrow 2NH_3$$

2) CH_4

Emission of CH_4 from the ammonia production has been confirmed by actual measurements. As there are not enough examples to enable the establishment of an emission factor, it is currently not possible to calculate emissions. The *2006 IPCC Guidelines* also do not give a default emission factor. Therefore, CH_4 was reported as “NE”.

3) N_2O

Emission of N_2O from ammonia production is theoretically impossible, and given that even in actual measurements the emission factor for N_2O is below the limits of measurement, N_2O was reported as “NA”.

b) Methodological Issues

● ***Estimation Method***

Following the Tier 2 method in the *2006 IPCC Guidelines*, CO_2 emissions are calculated by multiplying the amount of fuels consumed as ammonia feedstock by country-specific emission factors. Since carbonated gas, mainly provided from Ammonia production plants, was injected and geologically stored in years 1990 to 1993, 1997 to 1999, 2003, and 2004, this amount is deducted from emissions. (See section 3.4.4 (1.C.) for details) CO_2 recoveries for urea production are subtracted from CO_2 emissions for ammonia production. CO_2 emissions from urea use are accounted for under the categories of Urea used as a catalyst (2.D.3.-) and Urea application (3.H.).

$$E = \Sigma_i (AD_i \times GCV_i \times EF_i \times 44/12 - R_{ccs} - R_{urea})$$

E : CO_2 emissions from ammonia production [kt-CO_2]
AD_i : Consumption amount of feedstock i [t, kL, $10^3 m^3$]
GCV_i : Gross calorific value (higher heating value) for feedstock i [MJ/kg, MJ/L, MJ/m^3]
EF_i : Carbon content of feedstock i [t-C/TJ]
R_{ccs} : CO_2 recoveries due to CCS [t-CO_2]
R_{urea} : CO_2 recoveries due to urea production [t-CO_2]

Where,

$$R_{urea} = AD_{urea} \times 44/60$$

AD_{urea} : Production amount of urea [t]
44/60 : Molecular weight ratio of CO_2 to urea

● ***Emission Factors***

The same carbon emission factors and gross calorific values that are used to calculate CO_2 emissions from the Fuel combustion category (Chapter 3, 1.A.) are used for each feedstock listed in Table 4-15. It should be noted that the implied emission factor changes every year, since the composition of the feedstocks consumed for ammonia production varies annually.

Table 4-15 Emission factors and calorific values of feedstocks used when producing ammonia

Item		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Naphtha	GCV	MJ/L	33.63	33.63	33.57	33.55	33.53	33.53	33.31	33.31	33.31	33.31	33.31	33.31	33.31	33.31	33.31
	CEF	t-C/TJ	18.17	18.17	18.17	18.17	18.17	18.17	18.63	18.63	18.63	18.63	18.63	18.63	18.63	18.63	18.63
LPG	GCV	MJ/kg	50.53	50.63	50.70	50.75	50.77	50.78	50.07	50.09	50.10	50.10	50.11	50.10	50.10	50.12	50.13
	CEF	t-C/TJ	16.54	16.51	16.49	16.48	16.47	16.47	16.38	16.37	16.36	16.36	16.35	16.36	16.36	16.34	16.34
Off gas	GCV	MJ/m^3	39.35	39.35	44.90	44.90	44.90	44.90	46.12	46.12	46.12	46.12	46.12	46.12	46.12	46.12	46.12
	CEF	t-C/TJ	14.15	14.15	14.15	14.15	14.15	14.15	14.44	14.44	14.44	14.44	14.44	14.44	14.44	14.44	14.44
Natural gas	GCV	MJ/m^3	42.09	42.39	42.55	42.87	44.67	44.75	39.62	39.62	39.62	39.62	39.62	38.38	38.38	38.38	38.38
	CEF	t-C/TJ	13.90	13.90	13.90	13.90	13.90	13.90	13.97	13.97	13.97	13.97	13.97	13.91	13.91	13.91	13.91
Coal	GCV	MJ/kg	25.95	25.95	26.60	25.70	25.70	25.70	25.97	25.97	25.97	25.97	25.97	26.08	26.08	26.08	26.08
	CEF	t-C/TJ	24.71	24.71	24.71	24.71	24.71	24.71	24.42	24.42	24.42	24.42	24.42	24.29	24.29	24.29	24.29
Oil coke	GCV	MJ/kg	35.58	35.58	35.60	29.90	29.90	29.90	33.29	33.29	33.29	33.29	33.29	33.29	33.29	33.29	34.11
	CEF	t-C/TJ	25.35	25.35	25.35	25.35	25.35	25.35	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.80
LNG	GCV	MJ/kg	54.54	54.53	54.52	54.51	54.49	54.47	54.46	54.46	54.46	54.46	54.46	54.70	54.71	54.73	54.73
	CEF	t-C/TJ	13.94	13.95	13.94	13.94	13.95	13.96	13.96	13.95	13.96	13.96	13.96	13.87	13.87	13.86	13.86
COG	GCV	MJ/m^3	21.51	21.57	21.27	21.42	21.32	20.75	18.87	18.87	18.87	18.87	18.87	18.38	18.38	18.38	18.38
	CEF	t-C/TJ	10.99	10.99	10.99	10.99	10.99	10.99	10.93	10.93	10.93	10.93	10.93	10.88	10.88	10.88	10.88

Reference: *General Energy Statistics*

- ***Activity Data***

For consumption of feedstock for ammonia production, the original units (including weight and volume) for the fuel types in Table 4-16 below, which are from the *Yearbook of the Current Survey of Energy Consumption* (METI), were converted using the calorific values in the *General Energy Statistics*, and results were used as activity data. Consumption data for some fuel types are confidential. For production amount of urea (calendar year basis), the values provided by the *Yearbook of Fertilizer Statistics (Pocket Edition)* (Ministry of Agriculture, Forestry and Fisheries) were used.

Table 4-16 Amount of feedstocks used for ammonia production

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Naphtha	kL	189,714	477,539	406,958	92,453	70,067	67,869	71,494	66,079	73,612	18,421	NO	NO	NO	NO	NO
LPG	t	226,593	45,932	5,991	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Off gas	10^3m^3	C	230,972	240,200	147,502	143,634	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Natural gas	10^3m^3	C	100,468	86,873	77,299	41,640	45,808	47,956	51,858	17,498	637	979	1,011	906	941	278
Coal	t	C	209,839	726	1,239	629	390	919	787	362	891	483	928	450	845	499
Oil coke	t	C	273,125	420,862	353,983	394,116	405,557	401,721	426,743	468,684	416,722	462,107	371,819	454,952	347,107	450,097
LNG	t	C	46,501	23,395	165,606	157,918	169,109	168,155	127,824	122,453	131,446	122,081	122,818	122,555	132,158	131,465
COG	10^3m^3	C	35,860	55,333	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Note: C: Confidential

- ***Point to Note***

Fuel consumption in this category has been deducted from energy sector activity data (see Chapter 3).

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty of each fuel was estimated. For the uncertainty of emission factors, the upper limit and lower limit values of the 95% confidence interval for the carbon emission factors were applied. For the uncertainty of the activity data, the same values were applied as in Fuel combustion category. As a result, the uncertainty of emissions are the following: naphtha -3 to +1%; LPG -3 to +1%; hydrocarbon gas -4 to +3%; natural gas -1 to +1%; coal (steam coal, imported coal) -4 to +3%; oil coke -3 to +1%; LNG -1 to +1%; and COG -4 to +3%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series, from the *Current Survey of Energy Consumption*. The emission factor is constantly based on the *General Energy Statistics* throughout the time series. Therefore, CO_2 emission from ammonia production has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Methodology was revised to subtract CO_2 emissions used for domestic urea production from CO_2 emissions from ammonia production in accordance with the *2006 IPCC Guidelines,* resulting in recalculations for all years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.2. Nitric Acid Production (2.B.2.)

a) Category Description

N_2O is emitted when nitric acid (HNO_3) is produced from ammonia.

<u>N_2O generating mechanism in nitric acid production</u>

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$
$$2NO + H_2O \rightarrow 2NO_2$$
$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO \quad (\rightarrow N_2O)$$

In Japan, the main processes used in nitric acid production are the New Fauser Process (medium pressure) and Chemico Process (high pressure), both based on the Ostwald chemical process. With regard to N_2O decomposition, there are catalytic decomposition units in operation.

b) Methodological Issues

- ***Estimation Method***

N_2O emissions were estimated by multiplying the nitric acid production amount by an emission factor, based on the Tier 2 method given in the *2006 IPCC Guidelines*. Emission data for individual factories are confidential, and therefore the nitric acid production amount and the emission factor were set for all of Japan. The amount of N_2O destroyed is currently unavailable but is reflected in the emission factor.

$$E = EF \times NAP$$

E : N_2O emissions from nitric acid production [kg-N_2O]

EF : Emission factor [kg-N_2O/t]

NAP : Nitric acid production amount [t]

- ***Emission Factors***

Data for individual factories are confidential, and therefore the emission factor was set by using each factory's nitric acid production amount to find the weighted average of Japan's 10 nitric acid producing factories' emission factors (measurement data). These emission factors take N_2O recovery and destruction into account.

Table 4-17 N_2O emission factors for nitric acid production

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
EFs for nitric acid production	kg-N_2O/t	3.50	3.51	3.92	4.18	3.58	3.38	3.55	3.54	3.60	3.59	3.27	3.26	3.28	3.00	3.47

- ***Activity Data***

Production amounts of nitric acid are directly provided by METI.

Table 4-18 Amount of nitric acid production

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Nitric acid production	kt	706	701	656	602	506	453	434	437	388	356	355	328	311	227	248

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The standard deviation was calculated for the emission factors and production amounts of each plant, and the uncertainty of the emission factor was assessed to be 73%. For the uncertainty of activity data, the default value of 2% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated as 73%.

- ***Time-series Consistency***

Emissions throughout the time series are consistently estimated using the activity data and emission factors provided by METI.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.3. Adipic Acid Production (2.B.3.)

a) Category Description

N_2O is emitted in the adipic acid ($C_6H_{10}O_4$) production process through the reaction of cyclohexanone, cyclohexanol, and nitric acid.

b) Methodological Issues

- ***Estimation Method***

Emissions were estimated using the N_2O generation rates, N_2O decomposition amount, and adipic acid production amount of the relevant operating sites.

- ***Emission Factors***

Country-specific emission factors were established using the following parameters. Relevant emission factor/parameter data are confidential.

- ***Nitrous oxide generation rate***

Actual measurement data provided from the sole producer of adipic acid as an end product in Japan.

- ***Nitrous oxide decomposition rate***

The figure used is the result of measurement of the rate of decomposition of nitrous oxide in the operating site.

- ***Decomposition unit operation rate***

A full-scale survey on the number of operation hours is conducted annually for N_2O decomposition units and adipic acid production plants. The operating rate is based on this survey.

- ***Activity Data***

The activity data for nitrous oxide emissions associated with the manufacturing of adipic acid is the amount of adipic acid produced provided to METI by the manufacturer. Relevant data used in estimation is confidential.

- ***Point to Note***

From 1990 to 1997, N_2O emissions from adipic acid production increased gradually. However, N_2O decomposition units were installed in adipic acid production plants in March 1999, and emissions since then have decreased dramatically. There was a temporary growth in the emissions in 2000 and 2020 due to the low operating rate of N_2O decomposition units caused by mechanical and instrumental failures of the decomposition units.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty of the emission factor for adipic acid was estimated by combining the uncertainty of the N_2O generation rate, N_2O decomposition rate, and the operating rate of the decomposition unit. As a result, the uncertainty of the emission factor was estimated as 9%. A 2% uncertainty given by the *2006 IPCC Guidelines* was applied for activity data. As a result, the uncertainty for adipic acid was estimated as 9%.

- ***Time-series Consistency***

Activity data and emission factors consistently provided by the producer of adipic acid are used to estimate emissions throughout the time series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.4. Caprolactam, Glyoxal and Glyoxylic Acid Production (2.B.4.)

4.3.4.1. Caprolactam Production (2.B.4.a)

a) Category Description

Caprolactam is a monomer for nylon-6 which transforms into Nylon 6 by ring-opening polymerization. Nylon 6 is used as fibers for carpets, etc, or resin material. N_2O is emitted from ammonia oxidation during the manufacturing process.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated by multiplying the amount of caprolactam produced by a weighted average emission factor, based on plant-specific emission factors established in accordance with Tier 1 - 3 methods in the *2006 IPCC Guidelines*.

- ***Emission Factors***

A country-specific emission factor per production amount was established by dividing total emissions by total production amounts. This was based on data provided from Japan Chemical Industry Association, including production amounts, emission factors, and emissions for all three plants producing caprolactam in Japan. Each plant's emission factor fluctuates by year.

- ***Activity Data***

Caprolactam production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* (METI) were used as activity data.

Table 4-19 Caprolactam production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Caprolactam production	kt	516	546	575	455	411	366	342	266	241	220	223	210	190	196	217

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

As for the uncertainty of the emission factor, the standard deviation was calculated from the emission factors and production amounts of each plant and was assessed to be 99%. For the uncertainty of activity data, the default value of 2% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 99%.

- ***Time-series Consistency***

For the activity data, data from the *Yearbook of Current Production Statistics – Chemical Industry* are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.4.2. Glyoxal Production (2.B.4.b)

a) Category Description

Glyoxal is mainly used as a crosslinking agent for acrylic resins, disinfectant, gelatin hardening agent, and textile finishing agent, etc. It's produced from oxidation of acetaldehyde with concentrated nitric acid, or from the catalytic oxidation of ethylene glycol, and N_2O is emitted in the process of oxidation of acetaldehyde. (See below)

$$2C_2H_4O + 2HNO_3 \rightarrow 2C_2H_2O_2 + N_2O + H_2O$$

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated in accordance with the Tier 3 method in the *2006 IPCC Guidelines*, by multiplying the amount of glyoxal produced by an emission factor. There is no production from FY2010 onward, but emissions for FY1990 to FY2011 are reported as “C” due to confidentiality reasons of Glyoxylic acid for FY2010 and FY2011.

- ***Emission Factors***

A country-specific emission factor per production amount based on information provided by the manufacturer was used. This was established based on the amounts of gas emitted in the manufacturing process of each product, and measurements of N_2O concentrations, and will be applied to all years.

- ***Activity Data***

No statistics are available on glyoxal production amounts, and therefore the production amounts at one manufacturer that had been producing until recent were used as activity data. There is no production from FY2010 onward.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 10% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 2% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 10%.

- ***Time-series Consistency***

For the activity data, data from the one manufacturer that had been producing until recent are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.4.3. Glyoxylic acid Production (2.B.4.c)

a) Category Description

Glyoxylic acid is used for the production of synthetic aromas, agrochemicals, and pharmaceutical intermediates. It is produced by nitric acid oxidation of glyoxal, and N_2O is emitted in the process of reduction of nitric acid.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated in accordance with the Tier 3 method in the *2006 IPCC Guidelines*, by multiplying the amount of glyoxylic acid produced by an emission factor. There is no production from FY2012 onward.

- ***Emission Factors***

A country-specific emission factor per production amount based on information provided by the manufacturer was used. This was established based on the amounts of gas emitted in the manufacturing process of each product, and measurements of N_2O concentrations, and will be applied to all years.

- ***Activity Data***

No statistics are available on glyoxylic acid production amounts, and therefore the production amounts at one manufacturer that had been producing until recent were used as activity data. There is no production from FY2012 onward.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 10% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 2% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 10%.

- ***Time-series Consistency***

For the activity data, data from the one manufacturer that had been producing until recent are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.5. Carbide Production (2.B.5.)

4.3.5.1. Silicon Carbide Production (2.B.5.a)

a) Category Description

1) CO_2

CO_2 is emitted by the reaction of petroleum coke with silica as raw materials in the production of silicon carbide.

CO₂ generating mechanism in the silicon carbide production process
$SiO_2 + 3C \rightarrow SiC + 2CO \quad (\rightarrow CO_2)$

2) CH_4

In Japan, silicon carbide is produced in electric arc furnaces, and it is believed that CH_4 is generated from the oxidation of coke, which is used as a reducing agent in silicon carbide production.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions are calculated by multiplying the amount of petroleum coke used as silicon carbide feedstock by an emission factor.

- ***Emission Factors***

Because Japan does not have measurement data or emission factor data, the default value 2.3 [t-CO_2/t] for silicon carbide production in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for CO_2 emissions from silicon carbide production is the amount of petroleum coke consumed, provided by Japan's only silicon carbide production facility. The data is confidential.

2) CH_4

- ***Estimation Method***

Emissions were calculated by multiplying an emission factor based on actual measurements obtained from electric arc furnace facilities in Japan by the energy consumption of electric arc furnaces.

- ***Emission Factors***

The emission factor of energy consumption in electric arc furnaces (12.8 kg-CH_4/TJ) was determined from CH_4 concentrations in the flue gas, measured dry flue gas amounts per hour, and measured quantity of heat generated per hour. See section 4.4.2.b) for the process of deriving the emission factor.

- ***Activity Data***

The activity data for CH_4 emissions from silicon carbide production is the amount of energy consumed, provided by Japan's only silicon carbide production facility. The data is confidential.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

1) CO_2

For the uncertainty of the emission factor, the default value of 10% was applied as provided by the *2006 IPCC Guidelines*. For the uncertainty of activity data, the default value of 5% given by *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 11%.

2) CH_4

The uncertainty of the emission factor, the default value of 10% was applied as provided by the *IPCC 2006 Guidelines*. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 11%.

- ***Time-series Consistency***

For both CO_2 and CH_4 activity data, the same sources are consistently used throughout the time series-from the manufacturing facility. The emission factors for both gases are constant throughout the time series. Therefore, CO_2 and CH_4 emissions from silicon carbide have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.5.2. Calcium Carbide Production and Use (2.B.5.b)

a) Category Description

1) CO_2

CO_2 is generated in the process of making the quicklime and is also emitted by the combustion of CO occurring from calcium carbide production. However, the former is included in emissions from Other process uses of carbonates (2.A.4.), and therefore only reducing agent-origin emissions are accounted for here. Further, CO_2 is generated by the combustion of acetylene, which is generated by reacting calcium carbide with water, and these emissions are reported here.

<u>CO_2 generator mechanism in the calcium carbide production process</u>

(Production)

$$CaCO_3 \rightarrow CaO + CO_2$$

$$CaO + 3C \rightarrow CaC_2 + CO\ (\rightarrow CO_2)$$

(Use)

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2\ (\rightarrow CO_2)$$

2) CH_4

Byproduct gases (mainly CO) generated in carbide production include a small amount of CH_4, all of which is recovered and burned as fuel, with none being emitted outside the system. Therefore, emissions from this source are reported as “NA”.

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions are calculated by multiplying calcium carbide production by the following emission factor, based on the Tier 2 method in the *2006 IPCC Guidelines*.

- ***Emission Factors***

For years FY1990 to FY2007, because Japan does not have measurement data or emission factor data, the below default values in the *2006 IPCC Guidelines* is used.

Table 4-20 CO_2 Emission factors for calcium carbide production and consumption (FY1990- FY2007)

Unit	From reducing agent in production	From use
t-CO_2/t	1.09	1.10

For years after FY2008, country-specific emission factors from reducing agents during production (changes annually) are used, which are based on measurement data from the two calcium carbide producing companies in Japan. These emission factors are confidential.

The default emission factor (1.10 t-CO_2/t) for calcium carbide use is also used for FY2008 and onwards.

The calcium carbide production amount used for calculating the CO_2 EF includes not only CaC_2 but also unreactive CaO used as raw material. This is the reason for the EF being lower than the stoichiometric value derived from a reaction only involving CaC_2. In Japan, CaC_2 is produced under conditions with excessive CaO. With CaC_2, the higher the purity, the higher is the melting point. Therefore, to avoid the rise in viscosity and hardening in the cooler parts of the plant which impairs production, the melting point is suppressed through intentionally maintaining a lower purity. Purity is also kept low to reduce reactivity from the viewpoint of safety.

- ***Activity Data***

Calcium carbide production data provided by Carbide Industry Association are used as the calcium carbide production amount. It includes not only CaC_2 but also unreactive CaO used as raw material. The data are confidential.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the CO_2 emission factor, the 10% default value was applied as provided by the *2006 IPCC Guidelines* for both reducing agent origin and from use. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* for both reducing agent origin and from use. As a result, the uncertainty for emissions for both reducing agent origin and from use was estimated as 11%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant from FY1990 to FY2007, and for years from FY2008 and onward, country-specific emission factors are used. This is because there is no data available on the scale of production or improvements in manufacturing technology to establish country-specific emission factors for earlier years, and therefore default emission factors are used for FY1990 to FY2007.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.6. Titanium Dioxide Production (2.B.6)

a) Category Description

Titanium dioxide (TiO_2) is a kind of white pigment, generally used in paper, plastics, rubber, ceramics, fabrics, floor covering, printing ink, and paint, etc. The two forms of TiO_2, anatase TiO_2 and rutile TiO_2 (both tetragonal), differ in terms of the crystalline structure, and the anatase TiO_2 is produced by hydrolyzing titanium sulfate and calcination (the sulfate process), or from titanium slag. Rutile TiO_2 is produced through the carbothermal chlorination of synthetic rutile to produce titanium tetrachloride ($TiCl_4$) and oxidation of the $TiCl_4$ vapors to TiO_2. (the chloride route)

CO_2 is emitted from the oxidization of carbon electrodes in the production of titanium slag in electric furnaces, from the oxidization of black coal during the production of synthetic rutile, and from the oxidization of oil coke in the chloride route. The following reactions occur to in the chloride route.

$$2\mathrm{TiO_2} + 4\mathrm{Cl_2} + 3\mathrm{C} \rightarrow 2\mathrm{TiCl_4} + 2\mathrm{CO} + \mathrm{CO_2}$$
$$\mathrm{TiCl_4} + \mathrm{O_2} \rightarrow \mathrm{TiO_2} + 2\mathrm{Cl_2}$$

b) Methodological Issues

- ***Estimation Method***

For rutile titanium dioxide (the chloride route), emissions are calculated by multiplying titanium dioxide production amounts (rutile TiO_2) produced through the chloride route which entails CO_2 emissions, by an emission factor provided by the manufacturer, based on the Tier 1 method in the *2006 IPCC Guidelines*.

For rutile titanium dioxide (from synthetic rutile), emissions are calculated by multiplying synthetic rutile production amounts by the default emission factor, based on the Tier 1 method in the *2006 IPCC Guidelines*.

- ***Emission Factors***

For rutile TiO_2 (the chloride route), an emission factor calculated as follows, based on coke input, etc into the process at the manufacturer, is used.

$$E = (CI - CO) \times CC \times 44/12$$
$$EF = E \,/\, AD$$

E	: CO_2 emissions
CI	: Coke input amount
CO	: Carry-over amount (Raw material left over without reacting)
CC	: Carbon content of coke
EF	: CO_2 emission factor
AD	: Titanium dioxide production amounts

Emission factors that can be drawn from the above equation, are only for FY2011 to FY2013, and therefore for years FY1990 – FY2010, the average for FY2011- FY2013 are used. (For years from FY2011 and onward, country-specific emission factors provided by Japan Titanium Dioxide Industry Association are used)

CO_2 EF for rutile TiO_2 is lower than the IPCC default because in the case of Japanese manufacturers, reactions take place under high temperatures such as 1,000 degrees Celsius, and therefore a second reaction ($TiO_2 + 2Cl_2 + 2CO \rightarrow TiCl_4 + 2CO_2$) is simultaneously taking place, in addition to the above-mentioned reactions described in the *2006 IPCC Guidelines* (yielding 3 mol of CO_2 from 2 mol of TiO_2), and uses CO. Because of this, and assuming that this CO is used completely in the first-mentioned reaction, 1 mol of TiO_2 only yields 1 mol of CO_2. (There does not exist any excess carbon. CO_2 occurs only from input coke.)

For rutile titanium dioxide (from synthetic rutile), the default value of 1.43 t-CO_2/t from the *2006 IPCC Guidelines* is used.

- ***Activity Data***

For rutile titanium dioxide production amounts (the chloride route), the titanium dioxide amounts produced in the chloride route process (provided by Japan Titanium Dioxide Industry Association) which entails CO_2 emissions is used.

For rutile titanium dioxide production amounts (from synthetic rutile), synthetic rutile production amounts (provided by METI) is used.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of emission factors for rutile titanium dioxide and synthetic rutile, the default values from the *IPCC 2006 Guidelines* of 15% and 10%, were respectively used. For the uncertainty of activity data, the default value of 5% from the *2006 IPCC Guidelines* was used for both rutile titanium dioxide and synthetic rutile. As a result, the uncertainty of emissions was estimated as 16% and 11%, respectively.

- ***Time-series Consistency***

For the activity data, data from Japan Titanium Dioxide Industry Association and METI are consistently used throughout the time series. The emission factors are constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.7. Soda Ash Production (2.B.7.)

In Japan, the ammonium chloride soda process is used to produce soda ash (Na_2CO_3). The soda ash production process involves calcinating limestone and coke in a lime kiln, which emits CO_2. Almost all lime-derived CO_2 is stored in the product.

In the soda ash production process, purchased CO_2 is sometimes input through a pipeline, but because these CO_2 emissions are from the ammonia industry, they are already included in Ammonia production (2.B.1.). Also, the coke consumed is listed as that for heating in the *Yearbook of the Current Survey of Energy Consumption*, and thus CO_2 emissions from coke are already counted under Fuel combustion (1.A.). Therefore, all emissions from this source are already included in other categories and are reported as "IE". Coke is input as a heat-source and CO_2 source. The thinking on where to account for CO_2 emissions from coke is the same as that for Iron and steel production.

The *2006 IPCC Guidelines* offer a method to calculate CO_2 emissions from calcinating trona (Na_2CO_3-$NaHCO_3$-$2H_2O$), but these emissions are not estimated because in Japan soda ash has never been manufactured by trona calcination.

4.3.8. Petrochemical and Carbon Black Production (2.B.8.)

4.3.8.1. Methanol Production (2.B.8.a)

a) Category Description

CO_2 and CH_4 are emitted during the production of methanol.

b) Methodological Issues

- ***Estimation Method***

CO_2 and CH_4 emissions from methanol production are calculated using the Tier 1 method given in the *2006 IPCC Guidelines*.

According to industry organizations, the production (synthesis) of methanol stopped in Japan in 1995 due to the price difference with overseas methanol. Since then all methanol has been imported, and methanol production plants disappeared from Japan in about 1995.

Accordingly, from FY1990 to FY1995, emissions are reported using the production amounts from industry organization statistics. For FY1996 and thereafter, emissions are reported as "NO" because it is assumed that methanol has not been produced (synthesized) since 1995.

- ***Emission Factors***

The default value for CO_2 from methanol given in the *2006 IPCC Guidelines* which corresponds to Japan's country-specific production method was used. The emission factor is 0.67 [t-CO_2/t] (Refer to the *2006 IPCC Guidelines* vol. 3 p 3.73, Table 3.12).

The default value for CH_4 from methanol given in the *2006 IPCC Guidelines* was used. The emission factor is 2.3 [kg-CH_4/t] (Refer to the *2006 IPCC Guidelines* vol. 3 p 3.74).

- ***Activity Data***

Production amounts of methanol (calendar year basis) given by Methanol and Formalin Association were used as activity data for CO_2 and CH_4 emissions from methanol production.

Table 4-21 Methanol production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Methanol production	kt	84	75	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor, the default values from the *IPCC 2006 Guidelines* of -30 to +30% (CO_2) and -80 to +30% (CH_4) were used. For the uncertainty of activity data, the default values of similar chemical products from the *IPCC 2006 Guidelines* of -5 to +5% were used. As a result, the uncertainty of CO_2 and CH_4 emissions were estimated as -30 to +30% and -80 to +30%, respectively.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CO_2 and CH_4 emissions from methanol production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.2. Ethylene Production (2.B.8.b)

a) Category Description

1) CO_2, CH_4

CO_2 is emitted in the ethylene production process. CH_4 is emitted by naphtha cracking through steam cracking in the ethylene production process.

Carbon losses in the ethylene production process are accounted for under petrochemicals in the Energy transformation & own use sector of the *General Energy Statistics* (Energy Balance Table). The petrochemicals sector represents the process of production of by-products such as refinery gas, fuels, and other oil products, from the factories that produce basic chemical feedstock from naphtha and reformed material oil, by regarding it as energy conversion.

2) N_2O

There is almost no nitrogen contained in naphtha, the raw material of ethylene, and the ethylene production process takes place under conditions that are almost completely devoid of oxygen. In accordance with expert judgment, there is theoretically no N_2O emissions.

b) Methodological Issues

- ***Estimation Method***

CH_4 and CO_2 emissions from ethylene production were calculated by multiplying ethylene production by Japan's country-specific emission factor, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*. CO_2 emissions from the energy use of industrial process off gases obtained from the feedstocks in Japan's ethylene production (steam cracking process) are considered to be included in emissions from Refinery Gas under Petrochemical - Energy Use in the *General Energy Statistics*. These emissions are already accounted for in '1.A.2.c. Manufacturing industries and construction - Chemicals'.

- ***Emission Factors***

➢ ***CO_2***

The country-specific emission factor was set, based on a survey conducted by Japan Petrochemical Industry Association (JPIA) in 2009 on the CO_2 emission factor from ethylene production. This CO_2 EF was established based on CO_2 emissions from decoking, etc and ethylene production data from all ethylene manufacturers collected by JPIA. Based on confirmation of the coverage of this country specific EF with JPIA, the emission processes investigated for establishing the country-specific EF includes decoking, and therefore processes that emit CO_2 from non-energy origins are covered in this survey.

Additionally, Japan considers that there is a difference between the IPCC default EF, which includes CO_2 emissions from the energy use of by-product gases obtained from feedstocks, and the country-specific EF, which does not, because CO_2 emissions from the energy use of by-product gases obtained from feedstocks are allocated under the category 1.A.2.c as described above. Japan also confirmed that the scale of and trend in CO_2 emissions accounted for under the category 1.A.2.c are roughly consistent with trial estimations obtained using the IPCC default value. This emission factor is confidential.

➢ ***CH_4***

Estimates of amount of exhaust gas from flare stacks at a normal operation and an unsteady operation at operating sites in Japan (assuming that 98% of the amount that enters is combusted[2]), and measured amount of exhaust gas from naphtha cracking furnaces and furnaces heated by re-cycled gas, were divided by the production amount to calculate emission factors for each company. The weighted average based on production from each company was then applied to establish the emission factor. (Surveyed by JPIA) This emission factor is confidential.

According to JPIA, fugitive emissions in plants are controlled to be below detectable levels (nearly zero) under the High Pressure Gas Safety Act. Therefore, it is considered that there are nearly no fugitive emissions from flanges, valves, and other process equipment during the steam cracking of naphtha.

- ***Activity Data***

Ethylene production amounts from the *Yearbook of Current Production Statistics – Chemical Industry* were used as activity data for emissions of CH_4 and CO_2 from ethylene production.

---

2 The assumption was set based on a flaring efficiency of 98% shown in the IPCC GPG (Table 2.16 note e).

Table 4-22 Ethylene production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Ethylene production	kt	5,966	6,951	7,566	7,549	6,999	6,261	6,764	6,687	6,780	6,286	6,459	6,186	6,282	6,043	6,102

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty for both CO_2 and CH_4 emission factors for ethylene were calculated by finding the 95% confidence interval of emission factors. The estimated uncertainty for both CO_2 and CH_4 was 77%. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for both CO_2 and CH_4 was estimated as 77%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CO_2 and CH_4 emissions from ethylene production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.3. 1,2-Dichloroethane and Chloroethylene (2.B.8.c)

a) Category Description

1) CO_2

1,2-dichloroethane (Ethylene Dichloride) is a precursor of polyvinyl chloride and is mainly used for chloroethylene (VCM) production. It is also used for cleaning agents, solvents, pesticides, and fumigants, etc. It is manufactured by the direct chlorination process or the oxychlorination process, or by a process combining the two. The direct chlorination process involves gas-phase reaction of ethylene with chlorine to produce ethylene dichloride, and the oxychlorination process involves gas-phase reaction of ethylene with hydrochloric acid and oxygen to produce ethylene dichloride. The oxychlorination process produces CO_2 from the oxidation of the ethylene. (See the below)

$$C_2H_4 + 0.5O_2 + 2HCl \rightarrow C_2H_4Cl_2 + H_2O$$
$$[C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O]$$

The ethylene dichloride is cracked to produce chloroethylene monomer, a precursor of polyvinyl chloride, and hydrochloric acid. The ethylene dichloride is cracked to produce chloroethylene monomer, a precursor of polyvinyl chloride, and hydrochloric acid. Since the hydrochloric acid can be utilized in the oxychlorination process, the combined process of the two spread widely. CO_2 is emitted through the same chemical reactions as the above in the combined process.

2) CH_4

1,2-dichloroethane passes through washing, refining, and thermolysis processes to become chloroethylene (C_2H_3Cl). A very small amount of CH_4 is contained in the exhaust gases of the reaction, and of the washing and refining processes.

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions are calculated by multiplying the production amount by Japan's country-specific emission factor, based on plant-specific data, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*.

For years FY1990 to FY2000, CH_4 emissions are calculated by multiplying the production amount by Japan's country-specific emission factor, based on plant-specific data, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*. According to Vinyl Environmental Council, equipment installation for exhaust gas combustion was completed for all plants, and the CH_4 contained in the tail gas is below detectable levels. Therefore, emissions are reported as NO for years FY2001 and onward. (The amount combusted is reported as recovered)

- ***Emission Factors***

➢ ***CO_2***

A CO_2 emission factor (0.0647 t-CO_2/tVCM) per chloroethylene production provided by the Vinyl Environmental Council was applied for all years.

This emission factor was established by dividing the total measured CO_2 emissions across all five plants producing 1,2-dichloroethane and chloroethylene in 2012, by the total chloroethylene production amounts in 2012.

The default value 0.294 t-CO_2/ tVCM also accounts for CO_2 emitted from combustion of auxiliary fuel, but for the above country-specific emission factor, this is removed in order to avoid double-counting with the energy sector, resulting in a lower value than the default.

➢ ***CH_4***

The concentration of CH_4 in waste gas from three member companies of the Vinyl Environmental Council (representing approximately 70% of total 1,2-dichloroethane production in Japan) was measured, and a weighted average was calculated to establish the emission factor. (Years FY1990 to FY2000) The emission factor is 0.0050 [kg-CH_4/t]. Based on the information on the production processes in each Dichloroethane producing company, the representativeness of the EF has been confirmed. (Surveyed by the Vinyl Environmental Council) The installation of equipment for exhaust gas combustion has progressed, and due to this, the fraction of CH_4 in the tail gas is lower than the default value and is now below detectable levels. No emission factors are set for years FY2001 and onward.

- ***Activity Data***

VCM (Chloroethylene) production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* were used as activity data for CO_2 emissions

1,2-Dichloroethane production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* were used as activity data for CH_4 emissions.

Table 4-23 VCM (Chloroethylene) production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
VCM production amount	kt	2,316	2,648	2,976	3,098	2,850	2,009	2,286	2,315	2,616	2,621	2,706	2,664	2,713	2,690	2,735

Table 4-24 1,2-Dichloroethane production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1,2-Dichloroethane production	kt	2,683	3,014	3,346	3,639	3,155	2,558	2,733	2,730	3,003	3,012	3,158	3,113	3,297	3,263	3,451

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the CO_2 and CH_4 emission factors for 1,2-dichloroethane production, the default values of -50 to +20% and -10 to +10% in the *2006 IPCC Guidelines* were respectively applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of 1,2-dichloroethane production was estimated as -50 to +21% and -11 to +11%, respectively.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CH_4 emissions from 1,2-Dichloroethane production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.4. Ethylene Oxide Production (2.B.8.d)

a) Category Description

Ethylene oxide is produced by reacting ethylene with oxygen over a catalyst, with CO_2 released as a by-product. (See below) There are two methods in providing oxygen; one through providing air, and the other through providing pure oxygen separated from air.

$$C_2H_4 + 0.5O_2 \rightarrow C_2H_4O$$
$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

The CO_2 emitted is partially vented into the atmosphere, and is partially recovered by a carbonate solution to be used in food and beverage production, etc.

Generally, ethylene oxide production is a process where gases are recycled, and therefore it is necessary to partially purge the gases out of the system so to suppress the rise in pressure due to the accumulation of non- reactive fine impurities (such as argon or nitrogen) contained in the raw material gas, which results in gas emissions. This contains gases such as ethylene, methane, oxygen, or argon, and are generally flared as they are, but CH_4 may be emitted through leakage or venting.

b) Methodological Issues

- ***Estimation Method***

➢ ***CO_2***

Following the Tier 3 method of the *2006 IPCC Guidelines*, emissions are estimated by multiplying the total domestic production amount by a country-specific emission factor established based on factory-specific data. The difference between emissions estimated using an EF which does not reflect recovery, and emissions estimated using an EF which reflects recovery (the actual EF used for this sub-category) is reported under CO_2 from carbonated gas and dry ice production (2.H.2). (See below)

$$E_{CO_2} = EO \times EF_1$$

E_{CO2}	: CO_2 emissions from ethylene oxide production
EO	: Ethylene oxide production amount per year
EF_1	: CO_2 emissions per ethylene oxide production amount (reflecting recovery)

$$R_{CO_2} = EO \times EF_2 - E_{CO_2}$$

R_{CO2}	: CO_2 recovery amount from ethylene oxide production processes
EO	: Ethylene oxide production amount per year
EF_2	: CO_2 emissions per ethylene oxide production amount (without reflecting recovery)

➢ ***CH_4***

Following the Tier 1 method of the *2006 IPCC Guidelines*, emissions are estimated by multiplying the total domestic production amount by a country-specific emission factor established based on factory-specific data.

- ***Emission Factors***

➢ ***CO_2***

EFs per production amount (recovery reflected: 0.24 t-CO_2/t, recovery not reflected: 0.33 t-CO_2/t) are used. (provided by Japan Petrochemical Industry Association) The EFs are a simple average of factory-specific EFs for all factories in Japan, and are based on the carbon balance, etc of the amounts of raw or secondary material input, and amounts of product or by-product output. The production amounts per factory are confidential, and therefore a weighted average cannot be taken. Additionally, since all ethylene oxide is produced by the same process (the Oxygen method), it is considered that a simple average would not divert far from the actual conditions. In the Oxygen method applied in Japan, the selectivity of the catalyst is higher than that of the default, and therefore the EF not reflecting recovery is lower than the default value of 0.663 t-CO_2/t.

➢ ***CH_4***

An EF based on measured data and specific to the manufacturer is used. The CH_4 emission data used to establish the EF is estimated by the manufacturer based on an estimation of CH_4 emissions into the atmosphere, which is further based on the CH_4 amount in the gas introduced from outside when gases are purged from the process. Data are only available from FY2004, and therefore for the preceding years, a three-year average of data from FY2004 to FY2006 will be taken and applied. The data is confidential.

- ***Activity Data***

➢ ***CO_2***

The ethylene oxide production amounts in the *Yearbook of Current Production Statistics - Chemical Industry* are used. (Table 4-25)

Table 4-25 Ethylene oxide production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Ethylene oxide production	kt	714	795	961	1,001	843	849	915	894	923	882	945	893	878	790	818

➢ ***CH_4***

The ethylene oxide production amount at the one manufacturer is used. The data is confidential.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty for the CO_2 emission factor, the default value of 10% in the *2006 IPCC Guidelines* was applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 11%.

For the uncertainty for the CH_4 emission factor, the default value of 60% in the *2006 IPCC Guidelines* was applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 60%.

- ***Time-series Consistency***

For activity data, the same source – the *Yearbook of Current Production Statistics - Chemical Industry* and data from one manufacturer are used throughout the time series. The emission factor is set based on data from the same sources. Therefore, CO_2 and CH_4 emissions from ethylene oxide production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.5. Acrylonitrile Production (2.B.8.e)

a) Category Description

1) CO_2

Acrylonitrile (C_3H_3N) is used as raw material for acrylic fiber or synthetic resin and is mainly manufactured by way of direct ammoxidation of propylene with ammonia and oxygen over a metal catalyst. (SOHIO process) On the order of 85 percent of the propylene feedstock is converted to either the primary product acrylonitrile or secondary products acetonitrile or hydrogen cyanide. (See below chemical equations 1 to 3) The remainder of the propylene feedstock is either converted to other hydrocarbons through side reactions in the ammoxidation process or converted directly to CO_2 by direct oxidation of the feedstock in the ammoxidation process (See below chemical equation 4)

Equation 1: Acrylonitrile reaction

$$CH_2 = CHCH_3 + 1.5O_2 + NH_3 \rightarrow CH_2 = CHCN + 3H_2O$$

Equation 2: Hydrogen cyanide reaction

$$CH_2 = CHCH_3 + 3O_2 + 3NH_3 \rightarrow 3HCN + 6H_2O$$

Equation 3: Acetonitrile reaction

$$CH_2 = CHCH_3 + 1.5O_2 + 1.5NH_3 \rightarrow 1.5CH_3CN + 3H_2O$$

Equation 4: Feedstock oxidation

$$CH_2 = CHCH_3 + 4.5O_2 \rightarrow 3CO_2 + 3H_2O$$

2) CH_4

The CH_4 off-gases are analyzed in the plants manufacturing acrylonitrile, but since no emissions are detected, they are reported as NA.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated by multiplying the acrylonitrile production amount by Japan's country-specific emission factor, based on plant-specific data, in accordance with the Tier 3 method in the *2006 IPCC Guidelines*.

- ***Emission Factors***

A CO_2 emission factor per production (0.73 t-CO_2/t, provided by Japan Petrochemical Industry Association) is applied for all years. This emission factor is an arithmetic mean of plant-specific CO_2 emission factors for all plants, based on the carbon balance of raw material and secondary material input and product and by-product output for each plant. This is done due to the fact that production data for each plant are confidential and this does not allow for taking a weighted average, and that acrylonitrile is manufactured by the same process throughout Japan (SOHIO process), which means that taking an arithmetic mean will not deviate far from actual conditions.

In the acrylonitrile manufacturing processes in Japan, acetonitrile and hydrogen cyanide are collected as products, and therefore the emission factor is close to the default value in the *2006 IPCC Guidelines* (0.79 t-CO_2/t). The reason for it being slightly lower is due to efforts made to improve the efficiency of production.

- ***Activity Data***

Acrylonitrile production amounts given in the *Yearbook of Current Production Statistics - Chemical Industry* were used for activity data.

Table 4-26 Acrylonitrile production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Acrylonitrile production amount	kt	602	652	734	697	718	553	499	468	431	437	443	467	457	420	445

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor, the default value of 60% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 5% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 60%.

- ***Time-series Consistency***

For activity data, the same source, the *Yearbook of Current Production Statistics - Chemical Industry,* are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CO_2 emissions from acrylonitrile production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.6. Carbon Black Production (2.B.8.f)

a) Category Description

Carbon black is mainly produced from the partial combustion of byproduct oil and gas from the petroleum refining and metallurgical refining processes in a high temperature atmosphere. (furnace black process) The CO_2 and CH_4 in the tail gas (off gas) emitted from the carbon black production process is released into the atmosphere.

b) Methodological Issues

- ***Estimation Method***

➢ ***CO_2***

CO_2 emissions from carbon black production are calculated by multiplying the carbon black production amount by Japan's country-specific emission factor, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*.

➢ ***CH_4***

CH_4 emissions from carbon black production are calculated by multiplying the carbon black production amount by Japan's country-specific emission factor, established based on plant-specific data, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*.

- ***Emission Factors***

  ➢ ***CO_2***

Since it is considered that the CO_2 from natural gas that is used to heat the furnace (secondary feedstock origin) is already accounted for under Fuel combustion (1.A.), only CO_2 from the oil and gas used directly as raw material (primary feedstock origin) is accounted for here. A CO_2 emission factor per production (2.06 t-CO_2/t) provided by Carbon Black Association is used. This is established by taking a weighted average of total CO_2 measurements (subtracting out the carbon left over in the product from the carbon in the raw material, then dividing it by the weight of the product) for all five member companies' plants, with the production amounts of each company. Since these five companies cover over 95% of domestic production and sales, the emission factor is considered representative for Japan. All companies use the oil furnace process, and therefore emission factors do not differ much nor vary much annually.

  ➢ ***CH_4***

In carbon black manufacturing plants in Japan, CH_4 is only emitted into the atmosphere during non-steady operation, when venting is done at shutdowns and startups. According to the *Carbon Black Handbook* (Carbon Black Association), the concentrations of CH_4, and the concentrations of CO, CO_2, and CH_4 combined in the average tail gas is 0.6wt% and 21.5wt% respectively, and this is the same for during shutdowns and startups. Therefore, the CH_4 emission factor can be calculated from the CO_2 emission factor (2.06 t-CO_2/t) as the below. The data is confidential.

$$EF_{CH4} = 2.06\ [\text{t-CO}_2/\text{t}] \times R \times 0.6\ [\text{wt\%}] / 21.5\ [\text{wt\%}] \times 16/44$$

EF_{CH4} : EF for carbon black production

R : The ratio of venting time at shutdowns and startups to the total operation time

No gas leakage occurs from the system, since inside the process the air pressure is negative, and therefore only emissions associated with venting is estimated.

- ***Activity Data***

Carbon black production amounts given in the *Yearbook of Current Production Statistics - Chemical Industry* were used for activity data for both CO_2 and CH_4 emissions associated with the manufacturing of carbon black.

Table 4-27 Carbon black production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Carbon black production	kt	793	759	772	805	730	612	628	608	563	567	597	611	572	476	582

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty for the emission factor for carbon black was calculated by finding the 95% confidence interval of emission factors. The estimated uncertainty was 55% for both CO_2 and CH_4. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used for both CO_2 and CH_4. As a result, the uncertainty of carbon black production emissions was estimated at 55% for both CO_2 and CH_4.

- ***Time-series Consistency***

For activity data, the same source, the *Yearbook of Current Production Statistics - Chemical Industry*, are used throughout the time series. The emission factor is constant throughout the time series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.7. Styrene Production (2.B.8.g.-)

a) Category Description

CH_4 is emitted in the styrene production process.

b) Methodological Issues

- ***Estimation Method***

CH_4 emissions from styrene production were calculated by multiplying styrene production amount by Japan's country-specific emission factor, based on the method given in the *2006 IPCC Guidelines*.

- ***Emission Factors***

Estimates of amount of exhaust gas from flare stacks at a normal operation and an unsteady operation at operating sites in Japan (assuming that 98% of the amount that enters is combusted. See footnote 2), and measured amount of waste gas from heating furnaces, were divided by the production amount to calculate emission factors for each company. The weighted average by production from each company was then applied to establish the emission factor. (Surveyed by Japan Petrochemical Industry Association) This emission factor is confidential.

- ***Activity Data***

Styrene monomer production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* were used as activity data for CH_4 emissions from styrene production.

Table 4-28 Styrene monomer production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Styrene production	kt	2,227	2,952	3,020	3,375	3,019	2,426	2,539	2,518	2,260	1,952	2,100	1,994	1,980	1,874	1,898

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty for the CH_4 emission factor for styrene production was estimated by finding the 95% confidence interval of emission factors. The estimated uncertainty was 113%. For the uncertainty of activity data, the standard value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated as 113%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CH_4 emissions from styrene production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.8. Phthalic Anhydride Production (2.B.8.g.-)

a) Category Description

Phthalic anhydride is used as raw material for plasticizers, synthetic resins, paints, dyes, etc. CO and CO_2 are emitted during the oxidation of naphthalene and o-xylene in the production process of Phthalic anhydride. CO is also combusted and ultimately emitted as CO_2.

b) Methodological Issues

- ***Estimation Method***

The production amount of phthalic anhydride is multiplied by an emission factor per production amount to calculate emissions.

- ***Emission Factors***

The CO_2 generation rate (mol %) was calculated by assuming that carbon that did not become products or other by-products ultimately become CO_2, and by using the yield of products or other by-products (mol %) per production process of phthalic anhydride (*Petrochemical Processes* (The Japan Petroleum Institute)) The EFs in each production process are calculated from the CO_2 emissions per production amount, based on the generation rate of CO_2 and products and the molecular weight of each substance. The yield is shown with an upper limit and lower limit in *Petrochemical Processes*, and therefore EFs are set using the median value.

Table 4-29 Generation rate of each substance by production process of phthalic anhydride

Production process	Product yield [mol %]	Maleic Anhydride [mol %]	Other [mol %]	CO_2 * [mol %]	EF * [t-CO_2/t]
Oxidation of naphthalene	87-91	3-5	1	2-8	0.19
Oxidation of o-xylene	80-83	4-6	1-2	10-16	0.54

Reference: *Petrochemical Processes* (excluding*)

Following this, a weighted average is taken for each year to set the EF for all of Japan. This is based on the productive capacity by year and by production process in the *Chemicals Handbook* (The Heavy and Chemical Industries News Agency)

Table 4-30 The weighted average EF based on productive capacity of phthalic anhydride

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
EFs for phthalic anhydride production	t-CO_2/t	0.39	0.39	0.41	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37

Note: No information is available on the productive capacity per production process prior to FY1996, and therefore the FY1996 value is used for the preceding years.

- ***Activity Data***

The production amounts of phthalic anhydride in the *Yearbook of Current Production Statistics - Chemical Industry* are used.

Table 4-31 Phthalic anhydride production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Phthalic anhydride production	kt	300	319	288	216	160	162	158	156	159	156	163	155	160	137	151

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor, a 32% value, derived from the upper/lower limits of the theoretical value of the yield which was used to establish the emissions factor, was used. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 32%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is based on a consistent methodology throughout the time series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.9. Maleic Anhydride Production (2.B.8.g.-)

a) Category Description

Maleic anhydride is used as raw material for unsaturated polyester resins, or for resin improving agents, food additives, pharmaceutical ingredients, or synthetic raw material for organic acids such as malic acid and succinic acid. CO and CO_2 are emitted during the oxidation of benzene and n-butane in the production process of maleic anhydride. CO is also combusted and ultimately emitted as CO_2.

b) Methodological Issues

- ***Estimation Method***

The production amount of maleic anhydride is multiplied by an emission factor per production amount to calculate emissions.

- ***Emission Factors***

The CO_2 generation rate (mol %) was calculated by assuming that carbon that did not become products or other by-products ultimately become CO_2, and by using the yield of products or other by-products (mol %) per production process of maleic anhydride (*Petrochemical Processes*) The EFs in each production process are calculated from the CO_2 emissions per production amount, based on the generation rate of CO_2 and products and the molecular weight of each substance. The yield is shown with an upper limit and lower limit in *Petrochemical Processes*, and therefore EFs are set using the median value.

Table 4-32 Generation rate of each substance by production process of maleic anhydride

Production process	Product yield [mol %]	CO_2 * [mol %]	EF * [t-CO_2/t]
Oxidation of benzene	70-80	20-30	0.74
Oxidation of n-butane	55-60	40-45	1.65

Reference: *Petrochemical Processes* (excluding *)

Following this, a weighted average is taken for each year to set the EF for all of Japan. This is based on the productive capacity by year and by production process in the *Chemicals Handbook*

Table 4-33 The weighted average EF based on productive capacity of maleic anhydride

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
EFs for maleic anhydride production	t-CO_2/t	1.20	1.20	1.23	1.11	1.11	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.06	1.06	1.06

Note: No information is available on the productive capacity per production process prior to FY1996, and therefore the FY1996 value is used for the preceding years.

- ***Activity Data***

The production amounts of maleic anhydride in the *Yearbook of Current Production Statistics - Chemical Industry* are used.

Table 4-34 Maleic anhydride production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maleic anhydride production	kt	103	116	132	103	93	75	86	85	87	88	90	89	80	74	87

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor, a 16% value, derived from the upper/lower limits of the theoretical value of the yield which was used to establish the emissions factor, was used. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 17%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is based on a consistent methodology throughout the time series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.10. Hydrogen Production (2.B.8.g.-)

a) Category Description

CO_2 is emitted from the steam reforming process of fossil fuels such as natural gas, petroleum, etc during hydrogen production. Hydrogen is produced as a by-product during petroleum refining, ethylene production, etc, and is recovered and used, however relevant emissions are already captured under other categories. Therefore, CO_2 generated from hydrogen production from raw materials, where the sole purpose is to obtain hydrogen, is addressed here.

b) Methodological Issues

- ***Estimation Method***

The production amount of hydrogen is multiplied by an emission factor per production amount to calculate emissions.

- ***Emission Factors***

The aggregated CO_2 emissions from industrial gas producers was divided by the aggregated production amounts of hydrogen to establish a CO_2 EF per production. Both aggregated values are based on values reported by member companies of Japan Industrial and Medical Gases Association.

Table 4-35 Emission factors for hydrogen production

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
EFs for hydrogen production	$t\text{-}CO_2/10^3Nm^3$	0.82	0.83	0.83	0.88	0.87	0.88	0.86	0.85	0.85	0.84	0.86	0.86	0.84	0.83	0.82

- ***Activity Data***

The production amounts of hydrogen are for those processes that entail CO_2 emissions, and are based on values reported by member companies of Japan Industrial and Medical Gases Association.

Table 4-36 Hydrogen production amount

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hydrogen production	10^3Nm^3	7,431	25,116	46,562	37,911	38,889	34,846	32,170	28,394	32,257	34,235	34,095	33,574	24,788	23,567	20,348

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty value of 77% for ethylene production was used for the EF uncertainty. Similarly, for the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for CO_2 emissions from hydrogen production was estimated as 77%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is based on a consistent methodology throughout the time series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

The emission factor for FY2020 was revised, resulting in recalculations. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.9. Fluorochemical Production (2.B.9.)

4.3.9.1. By-product Emissions: Production of HCFC-22 (2.B.9.-)

a) Category Description

HFC-23 is generated as a by-product of HCFC-22 production.

b) Methodological Issues

- ***Estimation Method***

Emissions are estimated by subtracting the recovery and destruction amount of by-product HFC-23 (measured data) from the amount of by-product HFC-23 generated at HCFC-22 production plants in Japan. The amount of by-product HFC-23 was estimated by multiplying the production of HCFC-22 by the generation rate of HFC-23 (obtained from the results of composition analysis of the interior of a reactor). Emission factors are country-specific.

The recovery/destruction units are constantly running when the plants are in operation. If any trouble arises in the units, management practices are to stop the plant operation, and for any portion of emissions without recovery/destruction, this is reflected in the data.

$$E = P_{HCFC\text{-}22} \times EF - R$$

E : Emissions of by-product HFC-23 associated with the production of HCFC-22 [t]
$P_{HCFC\text{-}22}$: Production of HCFC-22 [t]
EF : Rate of generation of HFC-23 [%]
R : Amount of recovery and destruction [t]

Table 4-37 Indices related to By-product Emissions of HFC-23: Production of HCFC-22

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Production of HCFC-22	t	60,122	81,000	95,271	65,715	46,149	54,388	47,546	51,753	49,116	48,833	52,646	56,933	57,872	44,733	53,326
Rate of generation of HFC-23	%	2.13%	2.13%	1.70%	1.90%	2.01%	1.60%	1.41%	1.46%	1.46%	1.38%	1.47%	1.80%	1.88%	2.06%	1.81%
Emission rate to production of HCFC-22	%	1.79%	1.79%	1.11%	0.06%	0.01%	0.002%	0.002%	0.003%	0.004%	0.003%	0.005%	0.001%	0.002%	0.021%	0.017%
Emissions	t	1,076.27	1,450.00	1,060.00	39.60	3.60	1.20	1.10	1.60	2.00	1.60	2.60	0.80	0.90	9.50	8.90
	kt-CO_2 eq.	15,929	21,460	15,688	586	53	18	16	24	30	24	38	12	13	141	132

Reference: *Documents of Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council, Ministry of Economy, Trade and Industry* (hereafter, *Documents of Fluorocarbons etc Measures Working Group*), *Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods* (hereafter, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*)

Note: Emissions decreased because all manufacturing facilities were equipped with recovery/destruction units in 2004. The low emission rate to production is due to efforts made in preventing the fall of the operating rates through the improvement in techniques of operation management of destruction facilities and maintenance. Emission reduction has further advanced since, with continuous efforts made in improvement of operation management techniques etc.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using the combined HCFC-22 production amounts for the purpose of material for fluorocarbon polymers (estimated from the production amounts of fluorocarbon polymers and the ratio of HCFC-22 production amounts for the purpose of material for fluorocarbon polymers to the production amounts of fluorocarbon polymers (an average of 1995-2006 where data were available)) and HCFC-22 production amounts for the purpose of refrigerants (estimated from total HCFC-22 shipment amounts[3], and HCFC-22 shipment amounts for the purpose of refrigerants from 1995) as data for total HCFC-22 production amounts, and by using data on the emission rate to the production of HCFC-22 from 1995, and extrapolating for these years.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emissions, a 2% value from the *2006 IPCC Guidelines* was applied.

- ***Time-series Consistency***

For years after 1995, the Manufacturing Industries Sub-Group, Ministry of Economy, Trade and Industry annually collects and estimates F-gas emissions. For the years 1990 to 1994, estimates have been done by extrapolation, etc of relevant data from 1995 onward, and therefore time-series consistency is taken into account to the extent possible.

d) Category-specific QA/QC and Verification

The data collected and estimated by the Manufacturing Industries Sub-Group, Ministry of Economy, Trade and Industry, is checked by the Committee for Greenhouse Gas Estimation Methods and is used in the inventory. Emissions are surveyed for all production plants in Japan. Composition analysis is carried out frequently, as in the case where one plant takes measurements every day. Concentration measurements are implemented at the vent of the plant.

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.9.2. Fugitive Emissions (2.B.9.-)

a) Category Description

HFCs, PFCs, SF_6, and NF_3 are emitted as fugitive emissions during manufacturing. Regarding returned gas cylinders, when residual gas is decomposed and the containment shell is cleansed, or when there is release into the atmosphere, these emissions are reported under this subcategory.

[3] *Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council* (MITI).

b) Methodological Issues

- ***Estimation Method***

Emissions were reported based on measurement data at each of HFCs, PFCs, SF_6, and NF_3 manufacturing plant in Japan. Recovery, etc is hereby taken into account. The recovery/destruction units are constantly running when the plants are in operation. If any trouble arises in the units, management practices are to stop the plant operation.

The associated indices are given in the table below.

Table 4-38 Fugitive emissions from HFC production

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFCs Emissions	kt-CO_2 eq.	2	559	296	449	128	120	131	101	83	149	95	88	119	76	120

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Fluorocarbon Manufactures Association), and data provided by METI, *Documents of the first meeting of the Breakout Group on F-gases and FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods*

Note: With emission reduction measures such as installation of destruction units subsidized by the government, and re-evaluation of the production processes, emission reduction has advanced.

Table 4-39 Fugitive emissions from PFC production

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
PFCs Emissions	kt-CO_2 eq.	331	914	1,661	1,041	248	148	111	107	115	97	81	87	64	74	79

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Chemical Industry Association), *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: With emission reduction measures such as installation of destruction units subsidized by the government, and re-evaluation of the production processes, emission reduction has advanced. The installation of destruction units in 2011 for lean gas emitted further contributed to the achievement of emission reduction.

Table 4-40 Indices related to fugitive emissions from SF_6 production

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Production of SF_6	t	1,848.36	2,392.00	1,556.00	2,313.00	2,201.00	2,230.00	2,128.00	1,997.00	2,027.00	2,002.74	1,680.39	1,658.00	1,573.00	1,260.00	1,307.20
Emissions	t	152.23	197.00	36.00	40.80	8.30	5.40	4.07	2.70	2.30	2.20	1.78	2.00	1.76	2.28	2.00
	kt-CO_2 eq.	3,471	4,492	821	930	189	123	93	62	52	50	41	46	40	52	46

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Chemical Industry Association), *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: Emissions decreased because all manufacturing facilities were equipped with recovery/destruction units in 2009. Re-evaluation of the production processes and handling at shipment has also advanced emission reduction.

Table 4-41 Indices related to fugitive emissions from NF_3 production

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Production of NF_3	t	6.00	37.00	208.00	1,663.00	3,642.00	3,501.00	4,148.00	4,660.08	4,963.00	4,365.50	4,649.40	4,718.90	3,828.70	4,037.00	4,191.00
Emissions	t	0.16	1.00	7.00	72.10	76.90	76.40	86.40	56.09	23.50	25.10	13.61	3.37	1.12	0.88	1.39
	kt-CO_2 eq.	3	17	120	1,240	1,323	1,314	1,486	965	404	432	234	58	19	15	24

Reference: *Documents of Fluorocarbons etc Measures Working Group* (data from Japan Chemical Industry Association)

Note: Emission reduction has advanced through the expansion of destruction unit installation, etc from mid-2014.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using HFC, PFC, and SF_6 shipment amounts[4] which is thought to be proportional to HFC, PFC, and SF_6 production amounts, and the ratio of emissions to the HFC, PFC, SF_6, and NF_3 production amounts from 1995, and weighted average GWPs for HFCs and PFCs from 1995, and extrapolating for

[4] *Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council, 1997* (MITI). All further reference to 'shipment amounts' used for emission estimates for years 1990 to 1994 are from the same source.

these years.

c) Uncertainties and Time-series Consistency

● ***Uncertainty***

For the uncertainties of the emissions for all HFCs, PFCs, SF_6, and NF_3, a 2% value from the *2006 IPCC Guidelines* was applied.

● ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.4. Metal Industry (2.C.)

This category covers CO_2, CH_4, HFC, PFC and SF_6 emissions from the manufacturing processes of metal products.

This section includes the following sources: Iron and steel production (2.C.1.), Ferroalloys production (2.C.2.), Aluminum production (2.C.3.), Magnesium production (2.C.4.), Lead production (2.C.5.), Zinc production (2.C.6.), and Rare Earths Production (2.C.7.).

In FY2021, emissions from this category were 5,796 kt-CO_2 eq. and represented 0.5% of Japan's total GHG emissions (excluding LULUCF). The total emissions of CO_2 and CH_4 from this category had decreased by 24.9% compared to FY1990. The total of HFCs, PFCs and SF_6 had decreased by 8.4% compared to 1990.

Table 4-42 Emissions from 2.C. Metal Industry

Gas				Units	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	2.C.1	Iron and steel production	Use of electric arc furnaces in steel production	kt-CO_2	298	328	190	231	152	167	140	160	132	143	170	175	139	91	189
			Limestone and dolomite use in iron and steel production	kt-CO_2	6,884	6,492	6,537	6,222	5,919	5,844	5,950	5,861	5,705	5,634	5,542	5,420	5,143	4,799	5,120
			By-product gas flaring in iron and steel production	kt-CO_2	25	56	102	174	243	212	256	245	223	213	192	181	168	133	149
	2.C.3	Aluminium production		kt-CO_2	58	29	11	11	8	7	5	1	NO	NO	NO	NO	NO	NO	NO
	Total			kt-CO_2	7,266	6,905	6,841	6,637	6,322	6,230	6,351	6,267	6,059	5,990	5,904	5,776	5,450	5,023	5,459
CH_4	2.C.1	Iron and steel production	Use of electric arc furnaces in steel production	kt-CH_4	0.74	0.72	0.67	0.68	0.59	0.59	0.60	0.59	0.55	0.55	0.59	0.60	0.54	0.49	0.56
	2.C.2	Ferroalloys production		kt-CH_4	0.19	0.14	0.13	0.13	0.12	0.13	0.13	0.12	0.12	0.11	0.11	0.11	0.11	0.08	0.10
	Total			kt-CH_4	0.92	0.85	0.80	0.80	0.71	0.72	0.73	0.71	0.67	0.66	0.70	0.71	0.65	0.57	0.66
	Total			kt-CO_2 eq.	23	21	20	20	18	18	18	18	17	16	17	18	16	14	17
Total of CO_2 and CH_4				kt-CO_2 eq.	7,289	6,926	6,861	6,658	6,340	6,248	6,370	6,284	6,076	6,007	5,921	5,794	5,466	5,037	5,475
Gas				Units	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFCs	2.C.4	Magnesium production		kt-CO_2 eq.	NO	NO	NO	NO	NO	1	1	1	1	1	1	2	1	1	2
PFCs	2.C.3	Aluminium production		kt-CO_2 eq.	204	171	44	36	25	22	16	3	NO	NO	NO	NO	NO	NO	NO
SF_6	2.C.4	Magnesium production		t	6.43	5.00	43.00	48.42	12.88	8.00	7.00	8.00	10.00	13.80	10.80	12.00	11.00	13.00	14.00
				kt-CO_2 eq.	147	114	980	1,104	294	182	160	182	228	315	246	274	251	296	319
Total of F-gases				kt-CO_2 eq.	350	285	1,024	1,140	319	206	177	187	229	316	248	275	252	298	321

4.4.1. Iron and Steel Production (2.C.1.)

The *General Energy Statistics* (Energy Balance Table) is a statistic that provides a comprehensive overview of domestic energy supply and demand. As mentioned in section 4.2.1 of the *2006 IPCC Guidelines*, carbon serves a dual purpose in the iron making process, primarily as a reducing agent to convert iron oxides to iron, but also as an energy source to provide heat when carbon and oxygen react exothermically. Coke, etc used as a reducing agent are included in the fuel consumption amounts in the *General Energy Statistics* and related emissions are comprehensively captured in 1.A.2.a (Energy sector - iron and steel) in Japan. Therefore, allocating emissions from the consumption of reducing agents to the energy sector does not make a difference in total emissions, but is rather more accurate, because it ensures completeness. The sum of 1.A.2.a (energy sector - iron and steel) and 2.C.1 (IPPU sector - iron and steel production) are comparable to the emissions that are calculated in line with the *2006 IPCC Guidelines* (See the table below).

Table 4-43 CO_2 emissions from iron and steel production (for energy and reducing agent use)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1.A.2.a (Energy sector - iron and steel)	kt-CO_2	150,691	143,097	152,106	154,168	153,154	151,286	157,550	155,101	148,878	142,757	139,752	136,179	134,140	111,995	124,784
2.C.1 (IPPU sector - iron and steel production)	kt-CO_2	7,266	6,905	6,841	6,637	6,322	6,230	6,351	6,267	6,059	5,990	5,904	5,776	5,450	5,023	5,459
Total of CO_2	kt-CO_2	157,957	150,002	158,947	160,806	159,476	157,516	163,901	161,368	154,937	148,747	145,656	141,955	139,589	117,018	130,243

The 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (hereafter *2019 Refinement*, See section 4.2.2.5) recommends, to avoid double counting and to ensure completeness, to cross-check the proper allocation of the emissions between the Energy and IPPU sectors, and to document where and how they are reported. It is difficult for Japan to differentiate and allocate between energy use and reducing agents use completely, but we have confirmed that all emissions from reducing agent consumption have been allocated without double-counting or omissions, for certain. Explanation on the category where it is allocated is also provided in this NIR appropriately.

Japan would also like to note that the following was agreed at the 17th meeting of the Inventory Lead Reviewers (LR) meeting (para 8 (b)): “The LRs further concluded that, when the Party is using a different allocation of emissions from that recommended in the 2006 IPCC Guidelines and is reporting the emissions as ”IE” under the energy or IPPU sectors, the ERT should check whether the Party has transparently reported where the emissions have been included and ensured the accuracy of the estimates. If this is not the case, the ERT should follow up with a relevant recommendation" This indicates that there is possibility to report with a different allocation.

The main types of reducing agents (fuels) and the corresponding production processes are as follows: coke (steel production, pig iron production, sinter production, and pellet production), pulverized coal/waste plastics (pig iron production). See also Table 3-10 and Table 3-61.

4.4.1.1. Steel Production (2.C.1.a)

Coke oxidizes when it is used as a reduction agent in steel production, and CO_2 is generated. The amount of coke used has been included under consumption of fuel in the Fuel combustion category (1.A.), and the CO_2 generated through the oxidization of coke used as a reducing agent has already been calculated under Fuel combustion category (1.A.).

4.4.1.2. Use of Electric Arc Furnaces in Steel Production (2.C.1.a)

a) Category Description

CO_2 is emitted from carbon electrodes when using electric arc furnaces to make steel. CH_4 is also emitted from electric arc furnaces during iron and steel production.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

CO_2 emissions from arc furnaces for steel production are estimated by amount of carbon calculated by weight of production and import of carbon electrodes minus weight of export of carbon electrodes. This difference of the carbon is assumed to be diffused to the atmosphere as CO_2. The carbon included in electric furnaces gas given in the *General Energy Statistics* are subtracted from the CO_2 emission in this source since these emissions are included in category 1.A. Fuel combustion.

CO_2 emissions from carbon electrodes during aluminium production are accounted for under 2.C.3 (See section 4.4.3) and are deducted from the emissions from this category.

- ***Activity Data***

Production of carbon electrodes given in *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials* and import and export of carbon electrodes given in *Trade Statistics of Japan* are used.

Table 4-44 CO_2 emissions from carbon electrodes of furnaces

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
#A Import	t	12,341	18,463	11,363	15,075	17,321	20,027	19,960	19,226	18,209	19,773	16,653	15,720	18,056	17,380	23,099
#B Domestic production	t	211,933	186,143	184,728	216,061	205,081	197,278	180,322	180,555	151,979	141,193	161,919	160,049	119,233	76,338	103,026
#C Export	t	87,108	92,812	107,998	138,409	139,757	135,863	128,435	121,079	103,834	90,664	104,032	100,268	72,307	44,578	46,239
#D Electric furnaces gas	t	39,983	14,300	33,201	26,700	39,017	33,898	32,146	34,760	30,444	31,273	28,049	27,806	27,022	24,397	28,195
Domestic consumptions (#A + #B - #C - #D)	t	97,184	97,493	54,892	66,028	43,629	47,544	39,700	43,941	35,910	39,029	46,491	47,695	37,959	24,743	51,692
CO_2 emissions	kt-CO_2 eq.	356	357	201	242	160	174	145	161	132	143	170	175	139	91	189

2) CH_4

- ***Estimation Method***

Emissions were calculated by multiplying an emission factor based on actual measurements obtained from electric arc furnace facilities in Japan by the energy consumption of electric arc furnaces.

- ***Emission Factors***

The emission factor of energy consumption of electric arc furnaces (12.8 kg-CH_4/TJ) was used. (See section 4.3.5.1.b))

- ***Activity Data***

Energy consumption amounts included in the "electric furnace" category for the iron and steel industries of the *General Energy Statistics* were used.

Table 4-45 Energy consumption in electric arc furnaces

Electricity consumption	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Electric furnaces	TJ	57,564	55,986	52,457	52,747	45,793	46,195	46,786	46,156	42,919	43,045	46,109	46,697	41,978	38,160	43,839

c) Uncertainties and Time-series Consistency

1) CO_2

- ***Uncertainty***

Because all CO_2 from electric arc furnaces are assumed to escape into the atmosphere, no emission factor has been set. Therefore, by assessing the uncertainty for activity data the uncertainty for emissions is assessed. As a result of combining the uncertainties of the parameters for activity data, the uncertainty was estimated as 5%.

- ***Time-series Consistency***

For activity data (emissions), the same sources are used throughout the time series. Therefore, CO_2 emissions from electric arc furnaces have been estimated in a consistent manner throughout the time-series.

2) CH_4

- ***Uncertainty***

The uncertainty for the emission factor has been estimated as 163% and the uncertainty for activity data has been estimated as 5% (see chapter 3). As a result, the uncertainty for CH_4 emissions has been estimated as 163%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CH_4 emissions from electric arc furnaces in steel production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.1.3. Pig Iron Production (2.C.1.b)

1) CO_2

CO_2 generated from pig iron production is emitted when coke, pulverized coal, and waste plastics, are used as a reduction agent. The amount of coke, etc used has been included under consumption of fuel in the Fuel combustion category (1.A.), and the CO_2 generated through the oxidization of coke, etc used as a reducing agent has already been calculated under Fuel combustion category (1.A.).

2) CH_4

It is theoretically impossible for CH_4 generation in association with pig iron production, and it has been confirmed that CH_4 is not emitted from actual measurements. Therefore, emissions have been reported as “NA”.

4.4.1.4. Limestone and Dolomite Use in Iron and Steel Production (2.C.1.b)

a) Category Description

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases CO_2 derived from $CaCO_3$ and $MgCO_3$.

b) Methodological Issues

- ***Estimation Method***

The amounts of limestone and dolomite used in iron and steel production are multiplied by the emission factors to calculate emissions.

- ***Emission Factors***

➢ ***Limestone***
See section 4.2.3. b).

➢ ***Dolomite***
See section 4.2.3. b).

- ***Activity Data***

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use' that are under the Iron and steel/Refining related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-46 Corresponding sectors in the *Adjusted Price Transaction Table*

Uses	Corresponding sectors in the *Adjusted Price Transaction Table* (Limestone)		Corresponding sectors in the *Adjusted Price Transaction Table* (Dolomite)	
Iron and Steel/Refining	2611-01 to 2611-04	Steel - pig iron Steel - crude ore (electric furnace)	2611-01 to 2631-03	Steel - pig iron Steel - cast and forged materials (iron)
	2631-02 2631-03	Steel - cast pipe Steel - cast and forged materials (iron)		
	2711-01 2711-02	Non-ferrous metal - copper Non-ferrous metal lead and zinc	2711-02	Non-ferrous metal - lead and zinc
	2729-03	Non-ferrous metal - non-ferrous metal cast and forged products		

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-47 Amounts of limestone and dolomite consumption for steel and refinement

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Limestone consumption (dry)	kt	14,421	13,588	13,616	12,610	11,813	11,637	11,827	11,640	11,329	11,144	10,942	10,680	10,177	9,590	10,114
Dolomite consumption (dry)	kt	1,144	1,089	1,160	1,430	1,532	1,535	1,585	1,569	1,529	1,551	1,544	1,532	1,412	1,231	1,423

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of emission factors, a 3% default value in the *2006 IPCC Guidelines* was used for both limestone and dolomite. For the uncertainty for activity data, a 3% default value in the *2006 IPCC Guidelines* was used for both limestone and dolomite. As a result, the uncertainty for emissions was estimated as 4% for both limestone and dolomite.

- ***Time-series consistency***

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, CO_2 emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations of CO_2 emissions occurred due to updates made to limestone (FY1990 to 2020) and dolomite (FY1999 to 2020) consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.1.5. By-product Gas Flaring in Iron and Steel Production (2.C.1.b)

a) Category Description

CO_2 is emitted from the flaring of by-product gas (blast furnace gas and converter furnace gas) during emergencies or maintenance in iron and steel production.

b) Methodological Issues

● ***Estimation Method***

Emissions are estimated by multiplying the amount of the flaring of by-product gas by the gross calorific value and carbon emission factor for each by-product gas based on Tier 1 methodology provided in the *2019 Refinement*. (See below equation)

According to the survey by the Japan Iron and Steel Federation, part of the amounts of the flaring of the blast furnace gas and converter furnace gas are included in the *General Energy Statistics*, and associated emissions are already accounted for the Fuel combustion category (1.A.). Therefore, CO_2 emissions from flaring unaccounted in the *General Energy Statistics* are accounted for under this sub-category.

$$E = \Sigma_i (AD \times GCV \times EF \times 44/12)$$

E : CO_2 emissions from the flaring of by-product gas [kt-CO_2]
i : Type of by-product gas
AD : Amount of by-product gas unaccounted in the *General Energy Statistics* [MNm^3]
GCV : Gross calorific values [MJ/m^3]
EF : Carbon emission factor [t-C/GJ]

● ***Emission Factors***

The same carbon emission factors and gross calorific values as those used to calculate CO_2 emissions from the Fuel combustion category (1.A.) are used. (See Table 3-11 and Table 3-19)

● ***Activity Data***

Of the total amount of the flaring of by-product gas surveyed by the Japan Iron and Steel Federation (hereafter, ‘total flaring amount’), the amount unaccounted in the *General Energy Statistics* (hereafter, ‘unaccounted amount’) is used as activity data. Since ‘unaccounted amount’ is available only for FY2020, the other fiscal years are estimated by multiplying the ‘total flaring amount’ by the ratio of the ‘unaccounted amount’ for FY2020. Additionally, since ‘total flaring amount’ are available only for FY1990, FY2000, FY2010 and FY2020, the other fiscal years are estimated by multiplying the amount of by-product gas generated provided in the *General Energy Statistics* by the ratio of flaring. The flaring ratio for years other than FY1990, FY2000, FY2010 and FY2020 are estimated by interpolating between the flaring ratio for these years.

Table 4-48 Estimated amounts of the by-product gas flaring unaccounted in the *General Energy Statistics*

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Blast furnace gas	Million Nm^3	23	22	22	29	36	32	37	35	31	29	26	24	22	16	19
Converter furnace gas	Million Nm^3	14	41	80	139	195	170	211	203	185	177	159	150	139	111	124

c) Uncertainties and Time-series Consistency

● ***Uncertainty***

For the uncertainty of emission factors, the upper limit and lower limit values of the 95% confidence interval for the carbon emission factors of converter furnace gas were applied. Also, since the values in the *General Energy Statistics* are used for estimation of the activity data, the default values (-10% to +10%) in the *2019 Refinement* are adopted for the uncertainty of activity data. As a result, the uncertainty of the emissions from flaring of by-product gas is evaluated as 11%.

- ***Time-series consistency***

The activity data are estimated in a consistent manner based on the data provided by the Japan Iron and Steel Federation, and the *General Energy Statistics* from FY1990. The emission factor is based on the *General Energy Statistics* from FY1990.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred due to updates in the activity data for FY2013 to 2020. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.1.6. Direct Reduced Iron Production (2.C.1.c)

CO_2 and CH_4 are generated during the production of direct reduced iron, through the oxidation of natural gas or coal used as reductants. However, there has not been any production of direct reduced iron in Japan, and therefore, it has been reported as “NO”.

4.4.1.7. Sinter Production (2.C.1.d)

CO_2 and CH_4 from the manufacturing of sinter are generated by the combustion of ore powder with coke fines; these emissions come under the Fuel combustion category (1.A.). As they are already calculated in this 1.A. category, they are reported as “IE”.

CO_2 emissions from limestone and dolomite used when making sinter are counted under “4.4.1.4. Limestone and dolomite use in Iron and Steel Production”.

4.4.1.8. Pellet Production (2.C.1.e)

CO_2 and CH_4 from the manufacturing of pellets are generated by the combustion of fine ore powder with coke; these emissions come under the Fuel combustion category (1.A.). As they are already calculated in this 1.A. category, they are reported as “IE”.

CO_2 emissions from limestone and dolomite used when making pellets are counted under “4.4.1.4. Limestone and dolomite use in Iron and Steel Production”.

4.4.2. Ferroalloys Production (2.C.2.)

a) Category Description

1) CO_2

Ferroalloys are produced in Japan, and the CO_2 that is generated in association with the ferroalloys production is emitted as a result of the oxidization of coke used as a reducing agent. Consumption of coke is included in consumption of fuel under the Fuel combustion category (1.A.), and CO_2 generated as a consequence of the oxidization of coke used as a reduction agent has already been calculated under the Fuel combustion category (1.A.).The thinking on where to account for CO_2 emissions from coke is the same as that for Iron and steel production. Regarding reducing agents for ferroalloys production, see Table 3-10. Residual carbon in the ferroalloys is oxidized when the ferroalloys are used in the production of iron and steel, and are released into the atmosphere as CO_2.

CO_2 emissions from limestone and dolomite that are used as slag forming materials have already been accounted for under iron and steel production (2.C.1.) as CO_2 emissions occurring from limestone and dolomite used during production.

Therefore, CO_2 emissions have been reported as “IE”.

Regarding carbon in the ore, it is thought that the primary raw materials for ferroalloys in Japan (currently, imported manganese ores, nickel ores, and chromium ores) are rarely imported as carbonate ores[5]. Public sources of information such as *Mineral Resources Material Flow* do not provide data on distribution amounts that can be used for estimation, and therefore these emissions are not estimated.

2) CH_4

Ferroalloys are manufactured in Japan in electric arc furnaces, small-scale blast furnaces, and Thermit furnaces. CH_4 generated in association with ferroalloy production is thought to be generated when the oxidization of coke, a reduction agent, takes place.

b) Methodological Issues

- ***Estimation Method***

CH$_4$ emissions from ferroalloy production were calculated by multiplying an emission factor based on actual measurements obtained from electric arc furnace facilities in Japan by the energy consumption of electric arc furnaces.

- ***Emission Factors***

The value for the emission factor of electric arc furnaces (12.8 kg-CH_4/TJ) was used because these furnaces produce ferroalloys.

The EF is established using measured CH_4 concentration, measured dry gas emissions per hour, calories per hour, calories per electricity, and therefore needs to be per electricity (in TJ). Additionally, electricity consumption is determined by the operation of the furnaces and type of ferroalloy produced, and therefore we have used the electricity consumption, not production, as more accurate and available activity data. This EF reflects the average operation of furnaces/type of ferroalloy at the

5 Most of the manganese ores distributed in Japan are high grade manganese oxide ores (MnO_2) and it is thought that low grade manganese carbonates ores are rarely distributed.

time of measurement in Japan. The equation below shows the process of deriving the emission factor.

$$EF = C_{CH_4} \times G \times MW / V_m / H$$

EF : Emission factor [kg-CH_4/TJ]
C_{CH4} : Measured CH_4 concentration in the emitted gas [ppm]
G : Measured dry gas emissions per hour [$m^3{}_N$/h]
MW : Molecular weight of CH_4 = 16 [g/mol]
V_m : Volume of 1 mole of ideal gas at standard pressure = 22.4 [$10^{-3}m^3$/mol]
H : Calories per hour [MJ/h]

Some of the parameters were established using measurements which were conducted generally in line with the guidance in the *2006 IPCC Guidelines*, for instance with making efforts to cover a representative sample.

- ***Activity Data***

Energy consumption amounts included in the "ferroalloy" category for the iron and steel industries of the *General Energy Statistics* were used.

Table 4-49 Energy consumption for ferroalloy production

Electricity consumption	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Electric furnaces (for Ferroalloys)	TJ	14,456	10,699	10,181	10,072	9,510	10,038	9,956	9,102	9,228	8,507	8,362	8,894	8,766	6,404	8,017

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty for the emission factor has been estimated as 163% and the uncertainty for activity data has been estimated as 5% (see chapter 3). As a result, the uncertainty for CH_4 emissions has been estimated as 163%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CH_4 emissions from furnaces for ferroalloy have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.3. Aluminum Production (2.C.3.)

4.4.3.1. By-product emissions (2.C.3.-)

a) Category Description

CO_2 generated in association with aluminum smelting is emitted in conjunction with the oxidization of the anode paste used as a reducing agent. The *2019 Refinement* provides estimation methodology for CO_2 emissions from production of alumina, which is used as raw material for aluminum refining. However, estimation methodology for the conventional Bayer process used in Japan is not considered in the *2019 Refinement*.

PFCs are emitted during aluminum refining, due to the use of a fluoride melt consisting mainly of cryolite during electrolysis.

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions were estimated by multiplying the production amount of primary aluminum refining by the CO_2 emission factor per production amount, based on the Tier 1 method in the *2006 IPCC Guidelines*.

PFC emissions were estimated by multiplying the production amount of primary aluminum refining by Japan's country-specific emission factors calculated using the equation prescribed in the *2019 Refinement*. According to the Japan Aluminium Association, there is no aluminum production with low voltage anode effects in Japan.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by extrapolation, etc of relevant data for these years.

- ***Emission Factors***

The default CO_2 EF (1.7 t-CO_2/t (Soderberg technology)) in the *2006 IPCC Guidelines* was used.

The equation prescribed in the Tier 2a method of the *2019 Refinement*, and its associated slope coefficients set by technology, together with the weight fraction of gases was used to determine PFC emission factors, as shown in the table below. For the years 1990 to 1994, the emission factor for 1995 is used.

Table 4-50 PFC emission factors and aluminum production amounts

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
PFC-14 (CF_4) EF	kg-PFC-14/t	1.181	1.181	0.804	0.663	0.647	0.644	0.643	0.643	NA	NA	NA	NA	NA	NA	NA
PFC-116 (C_2F_6) EF	kg-PFC-116/t	0.091	0.091	0.062	0.051	0.050	0.050	0.050	0.050	NA	NA	NA	NA	NA	NA	NA
Production of aluminium	t	34,100	17,338	6,500	6,490	4,670	4,075	2,950	588	0	0	0	0	0	0	0

Reference: *Yearbook of Minerals and Non-Ferrous Metals Statistics* (METI), *Documents of Fluorocarbons etc Measures Working Group*

- ***Activity Data***

The aluminum production amounts given in the *Yearbook of Minerals and Non-Ferrous Metals Statistics* (1995 to 1997), and the *Documents of Fluorocarbons etc Measures Working Group* (previously the Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy, Trade and Industry) (1998 and beyond), were used. (Production ended in 2014.)

For the years 1990 to 1994, aluminum production amounts given in the *Yearbook of Minerals and Non-Ferrous Metals Statistics* were used.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the CO_2 emission factor and uncertainty of the activity data, the respective default values of 10% and 2% in the *2006 IPCC Guidelines* were applied. As a result, the uncertainty of the emissions was determined to be 10%.

For the uncertainty of the PFC emission factor and uncertainty of the activity data, the respective default values of –47% to +28% in the *2019 Refinement* and 2% in the *2006 IPCC Guidelines* were applied. As a result, the uncertainty of the emissions was determined to be –47% to +28%.

- ***Time-series Consistency***

See section 4.3.9.1. c)

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d)

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.3.2. F-gases used in foundries (2.C.3.-)

Emission from this source was reported as “NO” as it has been confirmed that Japan had no record of the use of SF_6 in aluminum forging processes.

4.4.4. Magnesium Production (2.C.4.)

a) Category Description

HFCs and SF_6 are emitted in magnesium foundries, due to its use as cover gas to prevent oxidation of molten magnesium.

b) Methodological Issues

Emissions are an aggregation of all HFCs and SF_6 used by magnesium foundries. The data that has been reported is given in documentation prepared by the Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group of the Ministry of Economy, Trade and Industry’s Industrial Structure Council, for emissions of HFCs and SF_6 used in magnesium foundries. The associated indices are given in the table below.

Table 4-51 Indices related to HFCs and SF_6 emitted from magnesium foundries

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Consumption of HFC-134a	t	0	0	0	0	0	0.9	0.9	0.9	0.6	0.8	1.0	1.2	1.0	0.9	1.2
Consumption of SF_6	t	6.4	5.0	43.0	48.4	12.9	8.0	7.0	8.0	10.0	13.8	10.8	12.0	11.0	13.0	14.0

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using other die cast production amounts (excluding aluminium and zinc) which is thought to be proportional to molten magnesium amounts, and the consumption amount of SF_6 from 1995, and extrapolating for these years.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty of emissions was set at the 5% value of the upper limit for the Tier 2 method in the *2006 IPCC Guidelines*.

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.5. Lead Production (2.C.5.)

CO_2 generated from lead production are emitted by the oxidization of coke used as reductants. The amount of coke consumed as reductant used in lead production is included under "Direct heating purposes" (a fuel category under non-ferrous bare metal industry) in the *Yearbook of the Current Survey of Energy Consumption*. Since emissions are already accounted for under 1.A.2. Manufacturing industries and construction in the Energy sector, emissions are reported as IE. The thinking on where to account for CO_2 emissions from coke is the same as that for Iron and steel production.

4.4.6. Zinc Production (2.C.6.)

Similar to lead, CO_2 generated from zinc production are emitted by the oxidization of coke used as reductants. The amount of coke consumed as reductants used in zinc production is included under "Direct heating purposes" (a fuel category under non-ferrous bare metal industry) in the *Yearbook of the Current Survey of Energy Consumption*. Since emissions are already accounted for under 1.A.2. Manufacturing industries and construction in the Energy sector, emissions are reported as IE. The thinking on where to account for CO_2 emissions from coke is the same as that for Iron and steel production.

When Smithsonite ($ZnCO_3$) which includes carbon in the ore are used as raw material, there is the possibility of CO_2 arising from the ore in the reduction process. However, there are currently no cases of Smithsonite use in Japan.

4.4.7. Rare Earths Production (2.C.7.)

CO_2 is emitted into the atmosphere from the consumption of carbon anodes in the electrolytic reaction which converts the raw material, rare earth oxides, to rare earth metals by molten salt electrolysis during rare earth metal and alloy smelting.

PFCs are also emitted from the reaction of the fluoride melt with the carbon in the anodes during the anode effects due to the use of a fluoride melt consisting of rare earth fluorides and lithium fluoride. CO_2 and PFCs emissions are estimated based on information provided by the Japan Society of Newer Metals regarding the rare earths smelting in Japan, and the Tier 1 methodology provided in the *2019 Refinement.* These emissions do not exceed 3,000 t-CO_2 eq, which is the threshold to estimate in this GHG inventory decided by the Committee for GHG Emissions Estimation Methods. Therefore, it was reported as "NE" (considered insignificant) (See Annex 5).

4.5. Non-energy Products from Fuels and Solvent Use (2.D.)

This category covers CO_2 emissions from the use of non-energy products from fuels and solvents. This section includes the following sources: Lubricant use (2.D.1.), Paraffin wax use (2.D.2.), and Other (2.D.3.).

In FY2021, emissions from this category were 2,293 kt-CO_2 and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The emissions had increased by 12.4% compared to FY1990.

Table 4-52 Emissions from 2.D. Non-energy Products from Fuels and Solvent Use

Gas				Units	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	2.D.1	Lubricant use		kt-CO_2	343	353	350	324	303	259	269	263	243	230	233	253	252	243	239
	2.D.2	Paraffin wax use		kt-CO_2	50	37	36	36	35	27	28	26	25	24	24	26	27	23	28
	2.D.3	Other	Urea-based catalysts	kt-CO_2	NO	NO	NO	0.3	3	6	8	10	12	15	17	20	24	25	29
			NMVOC incineration	kt-CO_2	1,648	1,986	2,273	2,504	2,410	2,261	2,385	2,234	2,213	2,323	2,426	2,371	2,263	2,041	1,997
	Total			kt-CO_2	2,040	2,377	2,659	2,865	2,750	2,554	2,689	2,532	2,493	2,591	2,700	2,670	2,565	2,332	2,293

4.5.1. Lubricant Use (2.D.1.)

a) Category Description

CO_2 is emitted from the oxidation of lubricants and grease during use. Emissions from the total loss type of engine oil are reported in the energy sector (See 1.A.3.), and emissions from other types than the above-mentioned type of engine oil are reported under this sector. The *2006 IPCC Guidelines* do not provide estimation methodology for CH_4/N_2O, and therefore these emissions were reported as "NE".

b) Methodological Issues

- ***Estimation Method***

Emissions were calculated by multiplying lubricant and grease consumption amounts per oil type, by the carbon content and oxidation during use (ODU) factor per oil type, based on the Tier 2 method given in the *2006 IPCC Guidelines*. (See below)

$$E = \Sigma_i (LC_i \times CC_i \times ODU_i \times 44/12)$$

E : Emissions from the oxidation of lubricants and grease during use [kt-CO_2]

LC_i : Lubricant and grease consumption amounts [TJ]

CC_i : Carbon content of fuel [kt-C/TJ]

ODU_i : ODU factor for oil
i : Type of lubricant and grease

- ***Emission Factors***

For carbon content, the carbon emission factors of lubricants and heavy oil products in the *General Energy Statistics* are used. For the ODU factor, the default values in the *2006 IPCC Guidelines* are used. (lubricants: 0.2, grease: 0.05)

- ***Activity Data***

For lubricants, the consumption amounts for types other than total loss types of engine oil are calculated by subtracting the consumption amounts of the total loss type from the total of consumption amounts of engine oil. (See section 3.2.8. Activity data)

For grease, the consumption amounts are calculated by multiplying the domestic sales amounts in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (METI) and the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* (METI), by the calorific values of heavy oil products in the *General Energy Statistics*. However, for years FY1992 to FY1999, the domestic sales data are not available from these statistics. Therefore, the domestic sales for these years are estimated by subtracting the total of exports and stocks at the end of the year, from the total of stocks at the start of the year and production and imports, which are respectively shown in these statistics.

Table 4-53 Consumption of engine oil (for types other than total loss types) and grease

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Consumption of engine oil (for types other than total loss types)	TJ	23,449	24,385	24,144	22,298	20,768	17,756	17,788	17,384	15,998	15,168	15,389	16,790	16,754	16,184	15,895
Consumption of grease	TJ	3,152	2,503	2,435	2,658	2,622	2,397	2,478	2,486	2,464	2,337	2,164	2,146	1,945	1,863	1,997

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of emission factors, a 50% default value in the *2006 IPCC Guidelines* was applied for both lubricants and grease. For the uncertainty of the activity data, a 5% default value in the *2006 IPCC Guidelines* was applied for both lubricants and grease. As a result, the uncertainty of emissions was assessed to be 50% for both lubricants and grease.

- ***Time-series Consistency***

For activity data, the same source the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* etc are used throughout the time series. The emission factors are constant throughout the time series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.5.2. Paraffin Wax Use (2.D.2.)

a) Category Description

CO_2 is emitted from the oxidation of paraffin wax during use. The *2006 IPCC Guidelines* do not provide estimation methodology for CH_4/N_2O emissions, and therefore these emissions were reported as “NE”.

b) Methodological Issues

- ***Estimation Method***

Emissions were calculated based on the Tier 1 method given in the *2006 IPCC Guidelines*. (See below)

$$E_{CO_2} = PW \times CC_{Wax} \times ODU_{Wax} \times 44/12$$

E_{CO2} : Emissions from paraffin wax during use [t-CO_2]
PW : Paraffin wax consumption amounts [TJ]
CC_{Wax} : Carbon content of paraffin wax [kg-C/GJ]
ODU_{Wax} : ODU factor for paraffin wax

- ***Emission Factors***

For carbon content, the carbon emission factor of heavy oil products in the *General Energy Statistics* is used. For the ODU factor, the default value in the *2006 IPCC Guidelines* is used. (0.2)

- ***Activity Data***

The consumption amounts are calculated by multiplying the domestic sales amounts in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and *Yearbook of Mineral Resources and Petroleum Products Statistics*, by the calorific values of heavy oil products in the *General Energy Statistics*.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of emission factors, a 100% default value in the *2006 IPCC Guidelines* was applied. For the uncertainty of the activity data, a 5% default value in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of emissions was assessed to be 100%.

- ***Time-series Consistency***

For activity data, the same source-the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* etc are used throughout the time series. The emission factors are constant throughout the time series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.5.3. Other (2.D.3.)

4.5.3.1. Urea used as a catalyst (2.D.3.-)

a) Category Description

The urea SCR system for cars is a technology to reduce NOx emissions, by the reduction of NOx in exhaust gas using ammonia and decomposing it into N_2 and H_2O. By spraying urea aqueous into high temperature exhaust gas, this is hydrolyzed to yield ammonia gas, and CO_2 is emitted as follows.

$$CO(NH_2)_2 + H_2O \rightarrow 2NH_3 + CO_2$$

b) Methodological Issues

- ***Estimation Method***

Emissions were calculated based on the *2006 IPCC Guidelines*. (See below)

$$E_{CO_2} = AD \times 12/60 \times P \times 44/12$$

AD : Consumption amount of urea-based additives in urea SCR systems [kt]
P : Ratio of urea in urea-based additives [%] (Default value: 32.5%)

- ***Emission Factors***

For the Ratio of urea in urea-based additives (P), the default value of 32.5% in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The cumulative number of cars with urea SCR systems (data provided by the Japan Automobile Manufacturers Association) is first multiplied by the consumption amount of diesel oil per car, and then further multiplied by ratio of consumption amount of urea-based additives to diesel, to yield the consumption amount of urea-based additives.[6].

$$AD = \Sigma_i (N_i \times L_i \times R \times D)$$

AD : Consumption amount of urea -based additives in urea SCR systems [kt]
N : Cumulative number of cars with urea SCR systems [thousand cars]
L : Consumption amount of diesel oil per car [kL/car]
R : Ratio of consumption amount of urea-based additives to diesel [%]
D : Density of diesel oil [t/kL]
i : Vehicle type (Regular cargo trucks, Buses, Special-purpose vehicles)

[6] Domestically produced urea is from CO_2 recovered from ammonia production processes. The CO_2 associated with it is already subtracted from the emissions allocated under 2.B.1. Ammonia production.

Table 4-54 Parameters used to calculate the consumption amount of urea -based additives, and their sources and methods of establishment

Item	Sources and methods of establishment
Cumulative number of cars with urea SCR systems [thousand cars]	Data provided by the Japan Automobile Manufacturers Association
Consumption amount of diesel oil per car [kL/car]	Calculated by dividing the total consumption amount of diesel based on the *Statistical Yearbook of Motor Vehicle Transport* and *Statistical Yearbook of Motor Vehicle Fuel Consumption* (Ministry of Land, Infrastructure, Transport and Tourism) by the total number of registered cars
Ratio of consumption amount of urea-based additives to diesel [%]	2%, as a median value of 1 to 3 % in the *2006 IPCC Guidelines*
Density of diesel oil [t/kL]	0.8831 t/kL, based on the *Handbook on the General Energy Statistics*

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of emission factor, a 5% default value in the *2006 IPCC Guidelines* (cars - combustion origin) was applied. For the uncertainty of the activity data, a 5% default value in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of emissions was assessed to be 7%.

- ***Time-series Consistency***

For activity data, the same source-data provided by the Japan Automobile Manufacturers Association, etc are used throughout the time series. The emission factors are constant throughout the time series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Following the *2006 IPCC Guidelines*, the methodology of estimation for activity data was revised in order to include domestic urea production-related consumption as well as imported urea-related consumption, resulting in recalculations for FY2004 to 2020. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.5.3.2. NMVOC Incineration (2.D.3.-)

a) Category Description

CO_2 is emitted in the process of NMVOC incineration from facilities, etc that use solvents. CH_4/N_2O emissions do not exceed 3,000 t-CO_2 eq, which is the threshold to estimate determined by the Committee for GHG Emissions Methods. Therefore, it was reported as “NE” (considered insignificant) (See Annex 5).

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions from NMVOC incineration were calculated, for five use types - Paint, Cleansing agents, Printing, Chemical products, and Other, by estimating the domestic supply of solvents, the emissions into the atmosphere, the material recycle amounts, and then subtracting emissions into the atmosphere and the material recycle amounts from the domestic supply of solvents, to yield the amounts incinerated. CO_2 emissions from the incineration of some used solvents are already accounted for in the energy sector (alternative fuel use) and waste sector (waste incineration without energy recovery), and therefore are subtracted out from emissions in this category.

$$E_{CO2} = \Sigma_i (I_i \times C_i \times 44/12)$$

E_{CO2}	: CO_2 emissions from NMVOC incineration [t]
I_i	: NMVOC incineration amounts for use type *i* [t]
C_i	: Average carbon content of NMVOCs for use type *i*

Where,

$$I_i = S_i - E_i - R_i$$

I_i	: NMVOC incineration amounts for use type *i* [t]
S_i	: Domestic supply of solvents for use type *i* [t]
E_i	: NMVOC emissions into the atmosphere for use type *i* [t]
R_i	: Material recycle amounts for use type *i* [t]

- ***Emission Factors***

The average carbon content is calculated by weighting it by the composition rate of each NMVOC substance emitted from each source. (Same values are used as those for conversion to indirect CO_2) The carbon contents of each substance is obtained from molecular formulae, and the type of substance and composition rate of NMVOCs are estimated based on the national emission inventory for volatile organic compounds (VOC) by MOE and other information. From FY2015, an average carbon content for this category (0.64) is used.

- ***Activity Data***

Parameters are set as follows:

➢ ***Domestic supply of solvents for use type i***

For paint, the data for total amount of solvents in paint from the *Compilation of Estimation Results of VOC Emissions from Paint* (Japan Paint Manufacturers Association), and shipment amounts of thinners for paint given in the *Survey on the Actual Conditions of the Paint Manufacturing Industry* (Japan Paint Manufacturers Association), etc, were used. For cleansing agents, printing, chemical products, and other, the data for national sales amounts of solvents by use from the *VOC Emission Inventory Report* (MOE, March 2007), and demand for 'other' use of acetone from the *Petrochemical Industry of Japan* (The Heavy and Chemical Industries News Agency), etc, were used. (For years lacking data, interpolation or extrapolation using product sales amounts, etc was applied to estimate)

➢ ***NMVOC emissions into the atmosphere for use type i***

For NMVOC emissions into the atmosphere E_i, NMVOC emissions by source was used. (For details of estimation methods, see Annex 3)

➢ ***Material recycle amounts for use type i***

The material recycle amounts of solvents for use type i in the year FY2011 was first estimated by multiplying the supply of solvents for use type i in the year FY2011, by the ratio of external recycle amounts for use type i in the year FY2011 (*Survey on Organic Solvents Use and Emission Treatment*, Japan Solvent Recycling Industry Association, May, 2012) to the solvent supply amounts for use type i in the year FY2011. This was then multiplied by the growth rate (based on the *Survey on Solvent Recycle*

Amounts, Japan Solvent Recycling Industry Association) of solvent collection amounts from FY2011.

Table 4-55 NMVOC incineration amounts by use type

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Paints	kt	266	289	331	339	296	264	263	260	285	303	329	308	304	286	263
Cleaning agents	kt	85	100	90	108	65	44	45	48	46	53	55	55	53	50	45
Printing solvents	kt	172	195	237	234	231	235	232	220	219	210	210	202	191	164	170
Chemical products	kt	51	79	131	150	182	179	190	183	193	201	204	210	197	183	194
Other	kt	155	208	209	302	336	331	366	346	367	381	394	399	388	347	353

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of emission factor, a 2%, uncertainty of the specially controlled industrial waste (waste oil) was applied. For the uncertainty of activity data, a 60%, uncertainty of the specially controlled industrial waste (waste oil) was applied. As a result, the uncertainty of emissions was assessed to be 60%.

- ***Time-series Consistency***

Consistent activity data and emission factors are used throughout the time series as much as possible.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

The amounts of domestic supply of solvents and NMVOC emissions into the atmosphere were updated due to updates in the *VOC Inventory* and the *Yearbook of Current Production Statistics - Chemical Industry*, etc, resulting in recalculations for FY2019 to FY2020. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.5.3.3. Road Paving with Asphalt (2.D.3.-)

Roads in Japan are paved with asphalt, but almost no CO_2 are thought to be emitted in the process. It is not possible, however, to be completely definitive about the absence of emissions. Emissions have also never been actually measured, and as no default emission factor is available, it is not currently possible to calculate emissions.

4.5.3.4. Asphalt Roofing (2.D.3.-)

Asphalt roofing is manufactured in Japan, but information on the manufacturing process and activity data is inadequate, and it is not possible to definitively conclude that CO_2 is not emitted from the manufacturing of asphalt roofing. Emissions have also never been actually measured, and as no default emission factor is available, it is not currently possible to calculate emissions.

4.6. Electronics Industry (2.E.)

This category covers HFC, PFC, SF_6, and NF_3 emissions from the manufacturing of the electronic devices. This section includes the following sources: Semiconductor (2.E.1.), Liquid Crystals (2.E.2.), Photovoltaics (2.E.3.), Heat transfer fluid (2.E.4.), and Microelectromechanical systems (2.E.5.).

In 2021, emissions from this category were 2,375 kt-CO_2 eq. and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The emissions had increased by 24.7% compared to 1990.

Table 4-56 Emissions from 2.E. Electronics Industry

Gas			Units	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFCs	2.E.1	Semiconductor	kt-CO_2 eq.	1	271	283	224	165	122	109	113	113	117	123	113	99	108	106
	2.E.2	Liquid crystals	kt-CO_2 eq.	0.001	0.3	2	3	3	2	2	2	2	2	2	2	2	1	1
	Total		kt-CO_2 eq.	1	271	285	227	168	124	112	115	115	119	125	115	101	109	107
PFCs	2.E.1	Semiconductor	kt-CO_2 eq.	1,423	3,933	6,771	4,594	2,214	1,624	1,556	1,617	1,582	1,721	1,847	1,784	1,686	1,824	1,534
	2.E.2	Liquid crystals	kt-CO_2 eq.	31	87	214	152	46	68	76	90	86	71	84	79	75	77	78
	Total		kt-CO_2 eq.	1,455	4,020	6,986	4,746	2,261	1,692	1,631	1,707	1,669	1,792	1,931	1,863	1,761	1,901	1,612
SF_6	2.E.1	Semiconductor	t	13.56	17.54	27.58	23.69	9.86	8.05	7.96	7.66	8.07	8.43	8.77	7.99	7.62	8.13	7.49
	2.E.2	Liquid crystals	t	4.81	6.22	38.48	31.22	11.79	7.55	7.45	8.38	8.39	6.87	7.13	7.32	6.45	6.09	5.64
	Total		t	18.36	23.77	66.05	54.91	21.65	15.60	15.41	16.04	16.46	15.30	15.90	15.31	14.08	14.22	13.13
	Total		kt-CO_2 eq.	419	542	1,506	1,252	494	356	351	366	375	349	363	349	321	324	299
NF_3	2.E.1	Semiconductor	t	1.59	9.78	5.79	9.36	11.09	10.29	6.38	7.67	8.41	10.65	11.26	13.56	14.92	17.61	19.61
	2.E.2	Liquid crystals	t	0.15	0.91	3.83	4.10	1.53	1.21	1.24	1.52	1.29	1.14	1.28	1.23	1.09	1.10	1.10
	Total		t	1.73	10.69	9.61	13.47	12.62	11.50	7.63	9.20	9.70	11.79	12.54	14.79	16.01	18.71	20.71
	Total		kt-CO_2 eq.	30	184	165	232	217	198	131	158	167	203	216	254	275	322	356
Total of All Gases			kt-CO_2 eq.	1,904	5,016	8,941	6,457	3,140	2,370	2,225	2,346	2,326	2,463	2,634	2,581	2,458	2,656	2,375

4.6.1. Semiconductor (2.E.1.)

a) Category Description

HFCs, PFCs, SF_6, and NF_3 are emitted from the manufacturing of semiconductors.

b) Methodological Issues

- ***Estimation Method***

The Tier 2a method of the *2006 IPCC Guidelines* is used to estimate emissions from semiconductors. These emissions are estimated with purchased amount of F-gases, process supply rates, use rates of F-gases, fractions of gas destroyed, by-product generation rates and fractions of gas destroyed for by-products. Default values are applied for the use rate of F-gases and the by-product generation rates.

Regarding the treatment of the 10% residue after process supply, these emissions are reported under this category when there is a 90% recharging and subsequent shipment. In cases of decomposing the residual 10% and cleansing the containment shell, or release into the atmosphere, these emissions are reported under "2.B.9. Fluorochemical production – fugitive emissions".

Japan Electronics and Information Technology Industries Association data are used for F-gases purchased.

Methods below are applied for each gas.

$$E = FC \times P \times (1 - U) \times (1 - a \times d)$$

E : HFC-23, PFCs (PFC-14, PFC-116, PFC-218, PFC-c318), SF_6, and NF_3 emissions

FC : Purchased amount of gas

P : Process supply rate
U : Use rate of gas
a : Fraction of gas controlled
d : Fraction of gas destroyed

$$BPE = FC \times B \times P \times (1 - a \times d)$$

BPE : By-produced PFC-14, etc emissions
FC : Purchased amount of gas
B : By-production rate
P : Process supply rate
a : Fraction of gas controlled
d : Fraction of gas destroyed

Relevant indices are shown in Table below. The fraction of gas controlled is not reported here due to confidentiality reasons.

Table 4-57 Indices related to emissions of F-gases from manufacturing of semiconductors

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFC-23 purchased	t	0.1	47.8	49.4	42.1	67.1	66.7	66.7	77.2	86.2	83.2	84.3	85.2	72.7	81.0	89.9
PFC-14 purchased	t	113.3	313.0	299.9	231.5	265.3	222.4	218.1	253.6	285.5	317.1	365.1	376.3	369.1	406.9	421.2
PFC-116 purchased	t	75.8	209.5	561.2	393.2	194.3	139.4	117.8	105.5	96.4	102.3	126.1	92.6	80.4	86.0	77.0
PFC-218 purchased	t	0.01	0.03	9.9	181.8	167.0	115.5	106.1	117.2	110.9	107.6	130.1	127.0	107.9	105.9	110.6
PFC-c318 purchased	t	0.2	0.6	38.6	24.8	35.8	39.7	42.2	52.6	63.3	70.4	106.6	166.8	208.3	265.9	310.5
SF_6 purchased	t	70.1	90.8	131.9	96.8	76.7	63.7	57.6	64.9	68.0	73.4	86.5	87.2	84.3	95.9	94.5
NF_3 purchased	t	8.8	54.4	106.3	406.7	860.7	880.5	905.4	1,055.3	1,232.1	1,310.1	1,597.4	1,876.3	2,009.7	2,282.7	2,560.6
Process supply rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Use rate of PFC etc	%	10 - 98 %														
Fraction of PFCs, and SF_6 destroyed	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Fraction of NF_3 destroyed	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
CF_4 etc by-production rate	%	2 - 20 %														
By-product CF_4 etc removal rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
HFC emissions	kt-CO_2 eq.	1	271	283	224	165	122	109	113	113	117	123	113	99	108	106
PFC emissions	kt-CO_2 eq.	1,423	3,933	6,771	4,594	2,214	1,624	1,556	1,617	1,582	1,721	1,847	1,784	1,686	1,824	1,534
SF_6 emissions	kt-CO_2 eq.	309	400	629	540	225	184	181	175	184	192	200	182	174	185	171
NF_3 emissions	kt-CO_2 eq.	27	168	100	161	191	177	110	132	145	183	194	233	257	303	337

Reference: the *Documents of Fluorocarbons etc Measures Working Group*, and data provided by METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-58 Use rate of gases during semiconductor manufacturing

Gas	Use rate
HFC-23	60%
PFC-14	10%
PFC-116	40%
PFC-218	60%
PFC-c318	90%
SF_6	80%
NF_3	80%
NF_3 remote	98%

Reference: Default values from the *2006 IPCC Guidelines* (Table 6.3 Tier 2a)

Table 4-59 CF_4 and C_2F_6 by-production rate during semiconductor manufacturing

Gas	CF_4 by-production rate	C_2F_6 by-production rate
HFC-23	7%	NA
PFC-116	20%	NA
PFC-218	10%	NA
PFC-c318	10%	10%
NF_3	9%	NA
NF_3 remote	2%	NA

Reference: Default values from the *2006 IPCC Guidelines* (Table 6.3 Tier 2a)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using available domestic HFC, PFC, and SF_6 shipment amount, and NF_3 production amount data which is thought to be proportional to HFC, PFC, SF_6, and NF_3 emissions, and extrapolating for these years.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emission factors, *2006 IPCC Guidelines* default values of 100%, 80%, 300%, and 70% were respectively applied for HFCs, PFCs, SF_6, and NF_3. For the uncertainties of the activity data, 10% was applied for all HFCs, PFCs, SF_6, and NF_3, using the upper limit value in the *2006 IPCC Guidelines*. As a result, the uncertainties of the emissions for HFCs, PFCs, SF_6, and NF_3, were determined to be 100%, 81%, 300%, and 71%, respectively.

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

Recalculations of PFCs and NF_3 emissions occurred due to corrections to the fraction of gas controlled, etc for 2018 to 2020. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.6.2. Liquid Crystals (2.E.2.)

a) Category Description

HFCs, PFCs, SF_6, and NF_3 are emitted from the manufacturing of liquid crystals.

b) Methodological Issues

- ***Estimation Method***

Methods applied to semiconductors are also applied to emissions from manufacturing of liquid crystals. In principle, default values are applied for the use rate of F-gases and the by-product generation rates. World LCD Industry Cooperation Committee has established a voluntary action plan to reduce PFC emissions and has engaged in reducing PFC emissions. In these activities, IPCC methods should be applied.

Relevant indices are shown in Table below. The fraction of gas controlled is not reported here due to confidentiality reasons.

Table 4-60 Indices related to emissions of F-gases from manufacturing of liquid crystals

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFC-23 purchased	t	0.0003	0.1	0.7	1.6	1.1	1.0	1.3	1.5	1.1	1.1	1.1	1.3	1.2	0.9	0.7
PFC-14 purchased	t	7.5	20.7	47.3	77.8	93.7	121.1	154.5	191.7	177.1	151.8	185.0	176.4	164.0	174.9	193.6
PFC-116 purchased	t	0.1	0.4	2.7	9.9	0	0	0	0	0	0	0	0	0	0	0
PFC-c318 purchased	t	0	0	0	0.8	1.6	1.7	1.4	1.8	1.1	1.1	1.1	0.6	0.9	0.9	0.4
SF_6 purchased	t	8.9	11.5	85.3	101.4	176.9	104.1	107.4	126.2	126.6	109.6	116.4	117.0	98.6	95.1	87.1
NF_3 purchased	t	1.3	8.1	106.9	232.2	764.1	668.0	783.8	918.9	808.0	691.9	813.2	767.0	664.5	718.1	805.7
Process supply rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Use rate of PFCs etc	%	40 - 97 %														
Fraction of PFCs, and SF_6 destroyed	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Fraction of NF_3 destroyed	%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
CF_4 etc by-production rate	%	0.9 - 7 %														
By-product CF_4 etc removal rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
HFC emissions	kt-CO_2 eq.	0.0007	0.3	2	3	3	2	2	2	2	2	2	2	2	1	1
PFC emissions	kt-CO_2 eq.	31	87	214	152	46	68	76	90	86	71	84	79	75	77	78
SF_6 emissions	kt-CO_2 eq.	110	142	877	712	269	172	170	191	191	157	163	167	147	139	129
NF_3 emissions	kt-CO_2 eq.	3	16	66	71	26	21	21	26	22	20	22	21	19	19	19

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-61 Use rate of gases during liquid crystal manufacturing

Gas	Use rate
HFC-23	80%
PFC-14	40%
PFC-116	0%
PFC-c318	90%
SF_6	40%
NF_3	70%
NF_3 remote	97%

Reference: Default values from the *2006 IPCC Guidelines* (Table 6.4 Tier 2a). Since there is no default for PFC-116, 0% was used so as not to underestimate emissions.

Table 4-62 CHF_3, CF_4, and C_2F_6, by-production rate during liquid crystal manufacturing

Gas	CHF_3 by-production rate	CF_4 by-production rate	C_2F_6 by-production rate
HFC-23	NA	7%	5%
PFC-c318	2%	0.9%	NA

Reference: Default values from the *2006 IPCC Guidelines* (Table 6.4 Tier 2a)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using available domestic HFC, PFC, SF_6 shipment, and NF_3 production amount data which is thought to be proportional to HFC, PFC, SF_6, and NF_3 emissions, and extrapolating for these years.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

See section 4.6.1. c).

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.6.3. Photovoltaics (2.E.3.)

Photovoltaics manufacturing using PFCs is only done by one company inside Japan. Therefore, emissions are confidential and included in PFC emissions from semiconductor manufacturing and reported as “IE”.

4.6.4. Heat Transfer Fluid (2.E.4.)

In the process of electronics manufacturing, fluorinated compounds are used for temperature control. These fluorinated compounds are released through evaporative losses during the cooling of process equipment, etc. Emissions were reported as “IE” since PFCs in this category are included in the total reported in 4.7.5. Solvents (2.F.5.), where liquid PFCs, etc are collectively captured.

4.6.5. Microelectromechanical systems (2.E.5.−)

Microelectromechanical systems (MEMS) manufacturing processes utilize fluorinated compounds during plasma etching of silicon containing materials or during the cleaning process. Typical MEMS manufacturers in Japan are electronic component manufactures. The Japan Electronics and Information Technology Industries Association collects data on HFC/PFC purchased amounts to use for cleaning electronic components and as solvents. The data includes the purchased amounts used for MEMS production. All of the purchased amount are already accounted under the category of Solvent (2.F.5.) as emissions. Therefore, emissions are reported as “IE”.

By-product gases from MEMS manufacturing processes are reported as “NE” since the actual status of emissions from this source is unknown.

4.7. Product Uses as Substitutes for ODS (2.F.)

This category covers HFC and PFC emissions from the use of the products that are substitutes for ozone depleting substances (ODS). This section includes the following sources: Refrigeration and air conditioning (2.F.1.), Foam blowing agents (2.F.2.), Fire protection (2.F.3.), Aerosols (2.F.4.), and Solvents (2.F.5.).

In 2021, emissions from this category were 54,576 kt-CO_2 eq., and represented 4.7% of Japan’s total GHG emissions (excluding LULUCF). The emissions are 12.0 times of 1990.

Table 4-63 Emissions from 2.F. Product uses as substitutes for ODS

Gas			Units	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFCs	2.F.1	Refrigeration and air conditioning	kt-CO_2 eq.	NO	925	2,976	8,865	20,495	26,370	29,030	32,554	35,893	38,972	41,167	43,274	46,044	48,157	49,517
	2.F.2	Foam blowing agents	kt-CO_2 eq.	1	497	484	937	1,749	2,081	2,229	2,373	2,484	2,651	2,801	2,922	2,979	2,925	2,941
	2.F.3	Fire protection	kt-CO_2 eq.	NO	NO	5	7	8	9	9	9	9	10	10	10	10	10	10
	2.F.4	Aerosols	kt-CO_2 eq.	NO	1,502	3,117	1,695	666	561	489	503	540	587	600	544	572	659	599
	2.F.5	Solvents	kt-CO_2 eq.	NO	NO	NO	6	60	94	109	122	126	130	116	117	122	127	128
	Total		kt-CO_2 eq.	1	2,923	6,582	11,511	22,979	29,115	31,866	35,562	39,052	42,350	44,694	46,867	49,727	51,877	53,194
PFCs	2.F.5	Solvents	kt-CO_2 eq.	4,550	12,572	3,200	2,815	1,721	1,583	1,518	1,537	1,517	1,465	1,484	1,505	1,558	1,457	1,382
Total of All Gases			kt-CO_2 eq.	4,551	15,495	9,782	14,326	24,699	30,698	33,384	37,098	40,569	43,815	46,178	48,372	51,285	53,333	54,576

4.7.1. Refrigeration and Air Conditioning Equipment (2.F.1.)

4.7.1.1. Domestic Refrigeration Production, Use and Disposal (2.F.1.-)

a) Category Description

1) HFCs

HFCs are emitted from the production, use (including failure of devices), and disposal of domestic refrigeration.

2) PFCs

Emission from this source in the “production” category was reported as “NO” as Japan had no record of their use in the production of the products. The emission was also reported as “NO” in the “use” and “disposal” categories, because it was unlikely that PFCs were used in imported products, or refrigerants were refilled.

b) Methodological Issues

- ***Estimation Method***

1) Fugitive refrigerants during manufacturing, 2) fugitive refrigerants during use (including failure of devices), and 3) refrigerants contained at the time of disposal minus the amount of HFCs collected under law were estimated separately and then were summed up.

Emissions from use and disposal were estimated by summing up the values calculated for each year of the production of devices. Emission factors are country-specific.

$$E_{total} = M_{manufacturing} \times k + \Sigma\,(N_{operated} \times m_{operation} \times x_{operation}) + \Sigma\,(N_{disposed} \times m_{disposal}) - R$$

E_{total}	: HFC emissions from domestic refrigeration
$M_{manufacturing}$	: Total refrigerant contained at production
k	: Fugitive refrigerant ratio at production
$N_{operated}$	: Number of operated devices containing HFCs
$m_{operation}$	: Refrigerant contained per operated device
$x_{operation}$	: Fugitive refrigerant ratio from use
$N_{disposed}$	: Number of disposed devices containing HFCs
$m_{disposal}$	: Refrigerant contained per disposed device
R	: Collected amount of HFCs

The associated indices are given in the table below.

Table 4-64 Indices related to emissions of HFCs from domestic refrigeration

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total HFCs charged in the year of production	t	NO	520	590	0.3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fugitive refrigerant ratio at production	%	1%	1%	1%	0.2%	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Number of operated HFC devices	1,000 devices	NO	7,829	33,213	41,796	28,085	20,984	17,637	14,520	11,691	9,182	7,045	5,280	3,862	2,747	1,881
Refrigerant charged per device at production	g	150	150	125	125	125	125	125	125	125	125	125	125	125	125	125
Operational fugitive ratio (including failure)	%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Number of HFC devices disposed	1,000 devices	NO	NO	177	1,839	3,588	3,456	3,204	2,850	2,451	2,027	1,620	1,249	929	672	467
Amount of HFCs collected under law	t/year	–	–	–	52	111	169	189	166	144	138	132	136	132	128	113
Emissions from manufacturing	kt-CO_2 eq.	NO	7	8	0.001	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions from stocks	kt-CO_2 eq.	NO	5	18	22	15	11	9	8	6	5	4	3	2	1	1
Emissions from disposal	kt-CO_2 eq.	NO	NO	31	246	460	352	279	251	213	149	87	18	NO	NO	NO
Emissions	kt-CO_2 eq.	NO	12	57	269	475	364	289	258	219	154	91	21	2	1	1

Reference: the *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: Emissions from disposal were estimated by summing up the values calculated for each year of the production of devices, and therefore the refrigerant contained per disposed device cannot be easily provided. However, based on the premise that refrigerators are sealed tight, the refrigerant contained per disposed device in the estimation model is considered equal to refrigerant charged per device.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic refrigeration shipment amounts, the ratio of devices with HFCs, and HFCs charged per shipment amount (derived from shipment amounts from 1995, the ratio of devices with HFCs from 1995, and total HFCs charged during production from 1995), fugitive refrigerant ratio at production from 1995, refrigerant charged per device at production from 1995, operational fugitive ratio from 1995, number of HFC devices disposed from 1995, and extrapolating, etc for these years.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment in the *2006 IPCC Guidelines* was applied for production and use. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for production, use, and disposal. As a result, the uncertainties of the emissions for production and use were determined to be 32%, and 10% for disposal.

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.1.2. Commercial Refrigeration Production, Use and Disposal (2.F.1.-)

4.7.1.2.a. Commercial Refrigeration

a) Category Description

1) HFCs

HFCs are emitted from the manufacturing, operation, maintenance, accidents, and disposal of commercial refrigeration.

2) PFCs

Emissions from manufacturing were reported as "NO" since Japan has no record from past to present of PFC use in the manufacturing of products. The emissions were also reported as "NO" for use and disposal, because according to survey results of Fluorocarbons in imported products in the past three years, no use of PFC was detected, and it is unlikely that PFCs are refilled into imported products. The Japan Refrigeration and Air Conditioning Industry Association (https://www.jraia.or.jp/english/index.html) confirmed with its member companies that no use of PFC was found in imported commercial refrigeration also for the previous years.

b) Methodological Issues

- ***Estimation Method***

Estimation is mainly conducted using a model, by taking into account the type of device and year of production, etc, and based on the principles of the *2006 IPCC Guidelines*. Using the number of devices produced per type and amount of refrigerant per type contained, etc for each year, emissions of each species of F-gases from 1) manufacturing, 2) installation, 3) operation and 4) disposal are estimated for the devices below, and then aggregated.

centrifugal refrigerating machine, screw refrigerating machine, refrigerator-freezer unit, transport refrigerator-freezer unit, separately placed showcase, built-in showcase, ice making machinery, water fountain, commercial refrigerator-freezer, all-in-one air conditioning system, gas heat pump, chilling unit

Emission factors were determined by a large sample survey conducted on the amount of refrigerant charge and the occurrence of failure in a certain time-period, by each type of equipment[7]. (260,000 sample units, conducted from 2007 to 2009).

Methods below are applied to each type of device and refrigerant.

- ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma\ (N_{produced} \times m_{manufacturing} \times x_{manufacturing})$$

$E_{manufacturing}$	: Emissions from manufacturing
$N_{produced}$	: Number of devices produced
$m_{manufacturing}$	: Amount of refrigerant contained
$x_{manufacturing}$	: Fugitive refrigerant ratio from manufacturing

[7] For details, refer to *document 1-1 and 1-2 of the 21st meeting of the Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry*, held on March 17, 2009.

➢ *Emissions from installation*

$$E_{installation} = \Sigma\ (N_{installation} \times m_{installation} \times x_{installation})$$

$E_{installation}$	: Emissions from installation
$N_{installation}$	: Number of devices charged at installation site
$m_{installation}$	: Amount of refrigerant contained
$x_{installation}$	: Fugitive refrigerant ratio from installation

➢ *Emissions from operation*

$$E_{operation} = \Sigma\ (N_{operated} \times m_{operation} \times x_{operation}) - R_{operation}$$

$E_{operation}$	: Emissions from maintenance
$N_{operated}$	: Number of devices operated
$m_{operation}$	: Amount of refrigerant contained
$x_{operation}$	: Fugitive refrigerant ratio from operation
$R_{operation}$	: Amount collected during servicing

➢ *Emissions from disposal*

$$E_{disposal} = \Sigma\ (N_{disposed} \times x_{disposal}) - R_{disposal}$$

$E_{disposal}$	: Emissions from disposal
$N_{disposed}$	: Number of devices disposed
$x_{disposal}$	: Average amount of refrigerant contained
$R_{disposal}$	: Amount collected after use

Note: In estimating the emissions from maintenance, the yearly decrease is reflected in the "amount of refrigerant contained." The "number of devices operated" and "number of devices disposed" are estimated from the amount of shipment and lifetime of device.

The associated indices are given in the table below.

Table 4-65 Indices related to emissions of HFCs from commercial refrigeration

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of HFC devices produced	1,000 devices	NO	214	373	1,241	1,122	1,212	1,303	1,250	1,228	1,296	1,350	1,355	1,400	1,167	1,237
Average amount of refrigerant charged at production	g/device	372	372	586	3,281	3,280	3,462	3,413	3,539	3,473	3,358	3,329	3,480	3,627	3,698	3,573
Fugitive refrigerant ratio at production	%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%
Number of devices charged in production place	1,000 devices	NO	9	32	130	171	238	225	260	240	246	249	229	217	190	170
Average amount of refrigerant during installation	g/device	17,806	17,806	9,221	24,251	24,527	22,829	20,754	20,394	20,073	19,520	18,388	19,620	22,150	23,388	28,813
Fugitive refrigerant ratio during installation	%	1%	1%	1%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Number of devices operated	1,000 devices	NO	375	1,957	6,770	11,843	13,706	14,653	15,498	16,215	16,939	17,642	18,249	18,792	18,999	19,206
Amount of refrigerant during operation	g/device	1,012	1,012	1,043	4,549	5,934	6,400	6,559	6,764	6,917	7,009	7,047	7,107	7,188	7,254	7,312
Fugitive refrigerant ratio during use	%	7.3%	7.3%	7.4%	5.3%	5.9%	6.2%	6.2%	6.3%	6.4%	6.4%	6.3%	6.3%	6.3%	6.4%	6.4%
Number of devices disposed	1,000 devices	NO	1	23	127	398	518	581	665	751	817	896	977	1,075	1,150	1,200
Amount of HFCs collected under law during maintenance	t	NO	NO	NO	NO	548	671	682	759	772	861	979	1,016	1,066	990	993
Amount of HFCs collected under law after use	t	NO	NO	NO	183	269	522	689	668	735	952	1,158	1,296	1,499	1,712	1,844
Emissions from manufacturing	kt-CO_2 eq.	NO	3	9	140	198	267	225	256	228	229	209	194	195	171	173
Emissions from stocks	kt-CO_2 eq.	NO	40	258	3,415	10,524	14,232	15,850	17,639	19,002	20,155	20,881	21,465	21,906	22,207	22,381
Emissions from disposal	kt-CO_2 eq.	NO	4	51	586	2,777	3,468	3,743	4,739	6,035	7,337	8,322	9,647	11,593	13,204	14,059
Emissions	kt-CO_2 eq.	NO	47	318	4,141	13,500	17,966	19,818	22,635	25,264	27,720	29,412	31,305	33,694	35,583	36,612

Reference: The *Documents of Fluorocarbons etc Measures Working Group*, and data provided by METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note 1: From 2002 onward, "amount of refrigerant" and "fugitive refrigerant ratio from operation" increased because devices became larger with the increase of commercial package AC devices.

Note 2: The weighted average GWP for manufacturing in 2021 is 1,933, 2,478 for stocks, and 2,199 for disposal. Emissions are calculated by gas but are reported as an unspecified mix due to confidentiality reasons.

Table 4-66 Type of HFC and emission factors during use, by type of commercial refrigeration

Type of commercial refrigeration	Type of HFC	Amount of refrigerant	Emission factor *	Share in the number of devices operated (2010)
Small-size refrigerators (built-ins, etc)	R-404A, HFC-134a, etc	0.1 - 3 kg	2%	40%
Separately installed showcases	R-404A, R-407C, etc	20 - 41 kg	16%	3%
Mid-size refrigerators (excluding Separately installed showcases)	R-404A, R-407C, etc	2 - 30 kg	13 - 17%	6%
Large-size refrigerators	HFC-134a, R404A, etc	300 - 2,300 kg	7 - 12%	0.05%
All-in-one air conditioning systems for buildings	R-410A, R-407C, etc	37 kg	3.5%	7%
Other commercial air conditioning devices (excluding All-in-one air conditioning systems for buildings)	R-410A, R-407C, etc	3 - 43 kg	3 - 5%	44%

Reference: *Documents of the 2nd Refrigerant Policy Working Group, Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry* (July 26, 2010), and data provided by METI

Note: * Includes for emissions during servicing, accidents, and breakdowns

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using HFC shipment amounts which is thought to be proportional to the number of HFC devices produced and number of devices charged in production place, and the average amount of refrigerant charged at production from 1995, fugitive refrigerant ratio at production from 1995, average amount of refrigerant during installation from 1995, fugitive refrigerant ration during installation from 1995, amount of refrigerant during operation from 1995, fugitive refrigerant ratio during use from 1995, and extrapolating, etc for these years.

The *2006 IPCC Guidelines* specifies estimation methods for fugitive emissions from refrigerant containers, however, upon consideration of emissions from non-refillable cylinders (NRCs) that are not captured under other sources, the emissions estimated does not exceed 500 kt-CO_2 eq. This combined with there being no statistics or survey data that can be used as activity data, estimation is not required, as determined by the Committee for Greenhouse Gas Emissions Estimation Methods. It is therefore reported as NE (considered insignificant) (See Annex 5). The fugitive emissions from NRCs were estimated by multiplying the refrigerant amount charged at the time of shipment of unrecovered NRCs by the ratio of the refrigerant remaining in used NRCs. The refrigerant amount charged at the time of shipment of unrecovered NRC was estimated by multiplying the total domestic shipment amount by NRCs, by the ratio of unrecovered NRCs.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment in the *2006 IPCC Guidelines* was applied for manufacturing. For use, a 5% value based on a METI survey was applied. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. As a result, the uncertainties of the emissions for manufacturing, use, and disposal were determined to be 32%, 11%, and 10%, respectively.

- ***Time-series Consistency***

See section 4.3.9.1. c). From 1995 onward, production amount is taken from the same industry organization of device manufacturers, and the EFs are values reported by Ministry of Trade and Industry in 2009.

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

Recalculations occurred due to corrections to the number of HFC devices, amount of refrigerant charged, and emission factors, etc used for estimation of emissions for 1996 to 2020. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.1.2.b. Automatic Vending machine Production, Use and Disposal

a) Category Description

1) HFCs

HFCs are emitted from manufacturing, accidents, and disposals of automatic vending machines.

2) PFCs

Emission from this source in the "production" category was reported as "NO" as Japan had no record of their use in production. The emissions were also reported as "NO" in the "use" and "disposal" categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

b) Methodological Issues

- ***Estimation Method***

Emissions of F-gases from 1) manufacturing, 2) accidents and 3) disposals are estimated, based on production and shipment amounts and amounts of refrigerants charged. Emission factors are country-specific.

➢ ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma\,(N_{produced} \times m_{manufacturing} \times x_{manufacturing})$$

$E_{manufacturing}$	: Emissions from manufacturing
$N_{produced}$	: Number of devices produced
$m_{manufacturing}$	: Amount of refrigerant contained
$x_{manufacturing}$	: Fugitive refrigerant ratio from manufacturing

➢ ***Emissions from accidents***

$$E_{accident} = \Sigma\ (N_{operated} \times m_{operation} \times A \times x_{accident})$$

$E_{accident}$	: Emissions from accident
$N_{operated}$	: Number of devices operated
$m_{operation}$	: Amount of refrigerant contained
A	: Incidence rate
$x_{accident}$	: Average fugitive rate in accident

➢ ***Emissions from disposals***

(a) until 2001 $\quad E_{disposal} = \Sigma\ \{N_{disposed} \times m_{disposal} \times (1 - \eta)\}$

(b) from 2002 onward $\quad E_{disposal} = \Sigma\ (N_{disposed} \times m_{disposal\text{-}avg}) - R$

$E_{disposal}$	: Emissions from disposal
$N_{disposed}$	: Number of devices disposed
$m_{disposal}$	: Amount of refrigerant contained
η	: Collection rate
$m_{disposal\text{-}avg}$	: Average amount of refrigerant contained
R	: Amount collected

For HFC emissions from automatic vending machines, the values shown in the *Documents of the Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry* is reported. The associated indices are given in the table below.

Table 4-67 Indices related to emissions of HFCs from automatic vending machines

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of HFC devices produced	1,000 devices	NO	NO	272	355	173	30	10	8	7	7	6	6	5	2	2
Refrigerant charged per device	g	NO	NO	300	220	219	219	219	219	219	219	219	219	219	219	219
Fugitive refrigerant ratio at production	%	NO	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Number of devices operated	1,000 devices	NO	NO	284	1,999	2,279	1,759	1,530	1,068	748	431	330	187	140	66	48
Incidence rate	%	NO	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Fugitive refrigerant ratio (failure)	%	NO	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fugitive refrigerant ratio (fixing)	%	NO	0.009	0.009	0.006	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Number of devices disposed	1,000 devices	NO	NO	NO	NO	286	277	273	299	266	264	196	188	148	77	20
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	1	0	0	0	0	0	0	0	0	0	0	0	0
Emissions from stocks	kt-CO_2 eq.	NO	NO	0	1	1	0	0	0	0	0	0	0	0	0	0
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	28	22	21	23	21	21	15	15	12	6	2
Emissions	t	NO	NO	0.39	0.54	16.05	15.42	15.16	16.49	14.69	14.51	10.80	10.33	8.13	4.22	1.10
	kt-CO_2 eq.	NO	NO	1	1	28	22	22	24	21	21	15	15	12	6	2

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

For the years 1990 to 1994, it was confirmed that no automatic vending machines with HFCs were used, and therefore emissions for these years are reported as NO. (Ministry of the Environment press release, July 31, 2000, *Projections of disposal etc of refrigerant CFCs, HCFCs, and HFCs (Reference material 1)*)

c) Uncertainties and Time-series Consistency

● ***Uncertainty***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. As a result, the uncertainties of the emissions for all manufacturing, use, and disposal were determined to be 32%.

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

Recalculations occurred due to corrections to the amount of refrigerant charged for 2001 to 2020. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.1.3. Transport Refrigeration Production, Use and Disposal (2.F.1.-)

a) Category Description

1) HFCs

HFCs are emitted from the manufacturing, operation, and disposal of transport refrigeration.

2) PFCs

Same as 4.7.1.2.a Commercial Refrigeration.

b) Methodological Issues

- ***Estimation Method***

Same as 4.7.1.2.a Commercial Refrigeration. The associated indices are given in the table below.

Table 4-68 Indices related to emissions of HFCs from transport refrigeration (railways)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of HFC devices produced[1)]	devices	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerant HFC charged per device at production[1)]	kg	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3
Fugitive refrigerant ratio at production	%	0%	0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Number of HFC devices disposed	devices	0	0	6	1	14	13	14	17	21	23	11	11	1	0	0
Refrigerant stock in device disposed	kg	0	0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Collection rate	%	0	0	0%	31%	31%	34%	34%	32%	38%	39%	38%	39%	38%	41%	40%
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	0.001	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions from stocks	kt-CO_2 eq.	NO	NO	0.1	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	0.1	0.1	0.1	0.1	0.1	0.1	0.04	0.04	0.00	NO	NO
Emissions (railways)	kt-CO_2 eq.	NO	NO	0.1	0.4	1	1	1	1	1	1	1	1	1	1	1

Reference: *Railway Statistical Yearbook* (Ministry of Land, Infrastructure, Transport and Tourism), IPCC default values.
1) are based on information from manufacturers.

Table 4-69 Indices related to emissions of HFCs from transport refrigeration (vessels)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fugitive refrigerant ratio at production	%	0%	0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Collection rate	%	0%	0%	0%	31%	31%	34%	34%	32%	38%	39%	38%	39%	38%	41%	40%
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	0.01	0.1	0.1	0.3	0.4	0.3	0.2	0.4	0.4	0.3	0.3	0.3	0.3
Emissions from stocks	kt-CO_2 eq.	NO	NO	1	24	77	124	161	175	191	206	223	249	273	297	309
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	0.02	0.1	0.8	1.8	1.7	2.6	4.1	5.4	5.9	5.9	7.0
Emissions (vessels)	kt-CO_2 eq.	NO	NO	1	24	77	124	163	177	193	209	228	255	280	303	316

Reference: IPCC default values, *Report on Maritime Affairs* (Ministry of Land, Infrastructure, Transport and Tourism), etc.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

Same as 4.7.1.2.a Commercial Refrigeration.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

Recalculations occurred due to corrections to the ratio of refrigerant used for the estimation of emissions (vessels) during operation for 2006 to 2020. Updates in the *Railway Statistical Yearbook* for 2020 also contributed to recalculations. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.1.4. Industrial Refrigeration Production, Use and Disposal (2.F.1.-)

1) HFCs

HFCs emissions have been reported as "IE", as they are included in 4.7.1.2. Commercial Refrigeration (2.F.1.-). It is not possible to separate emissions between commercial refrigeration and industrial refrigeration because the industrial association which provides data does not differentiate between the two in its data collection process.

2) PFCs

Emission from this source in the "production" category was reported as "NO" since Japan had no record of their use in the production of the products. The emission was also reported as "NO" in the "use" and "disposal" categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

4.7.1.5. Stationary Air-Conditioning (Household) Production, Use and Disposal (2.F.1.-)

a) Category Description

1) HFCs

HFCs are emitted from the manufacturing, operation, and disposals of household stationary air-conditioning devices.

2) PFCs

Emission from this source in the "production" category was reported as "NO" since Japan had no record of their use in production. The emission was also reported as "NO" in the "use" and "disposal" categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

b) Methodological Issues

- ***Estimation Method***

In accordance with the IPCC Guidelines, emissions of each species of F-gases from 1) manufacturing, 2) operation, 3) disposals are estimated, based on production and shipment amounts and amounts of refrigerants charged. Emission factors are country-specific. The HFC-125 IEF fluctuation between 2009 and 2010 (-9.9%), and 2014 and 2015 (5.6%) is affected by the change in amounts collected at disposal.

- ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma\ (N_{produced} \times m_{manufacturing\text{-}avg} \times x_{manufacturing})$$

$E_{manufacturing}$: Emissions from manufacturing
$N_{produced}$: Number of devices produced
$m_{manufacturing\text{-}avg}$: Average amount of refrigerant contained
$x_{manufacturing}$: Fugitive refrigerant ratio from manufacturing

- ***Emissions from operation***

$$E_{operation} = \Sigma\ (N_{operated} \times m_{operation\text{-}avg} \times x_{operation})$$

$E_{operation}$: Emissions from operation
$N_{operated}$: Number of devices operated
$m_{operation\text{-}avg}$: Average amount of refrigerant contained
$x_{operation}$: Fugitive refrigerant ratio from operation

- ***Emissions from disposal***

$$E_{disposal} = \Sigma\ (N_{disposed} \times m_{disposal\text{-}avg}) - R$$

$E_{disposal}$: Emissions from disposal
$N_{disposed}$: Number of devices disposed
$m_{disposal\text{-}avg}$: Average amount of refrigerant contained
R : Amount collected

Note: In the estimation of emissions from operation, the yearly decrease is reflected in the "average amount of refrigerant contained." The "number of devices for shipment" and "number of devices disposed" are estimated from amount of shipment and lifetime of device.

The associated indices are given in the table below.

Table 4-70 Indices related to emissions of HFCs from stationary air-conditioning (household)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of HFC devices produced	1,000 devices	NO	NO	1,077	3,981	3,460	3,608	3,920	3,507	4,160	4,080	4,193	4,358	3,891	4,078	3,406
Refrigerant charged per device	g	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Fugitive refrigerant ratio at production	%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Number of devices operated	1,000 devices	NO	NO	1,726	26,091	61,540	75,833	83,349	89,020	94,197	99,157	104,067	109,193	113,317	117,693	120,810
Average refrigerant charged during use	g/device	NO	NO	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Fugitive refrigerant ratio during use	%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Number of devices disposed	1,000 devices	NO	NO	2	83	764	1,456	1,907	2,423	2,990	3,567	4,145	4,688	5,220	5,720	6,181
Average refrigerant stock in device disposed	g/device	NO	NO	954	911	841	814	803	796	792	795	796	804	815	825	830
Amount of HFCs collected under law	t/year	-	-	-	10	231	322	466	508	570	700	892	1,181	1,367	1,599	1,622
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	4	17	13	11	11	7	5	3	3	3	2	2	2
Emissions from stocks	kt-CO_2 eq.	NO	NO	72	1,089	2,569	3,165	3,424	3,534	3,549	3,523	3,480	3,425	3,345	3,258	3,146
Emissions from disposal	kt-CO_2 eq.	NO	NO	3	139	916	1,833	2,301	2,984	3,767	4,486	5,059	5,437	5,939	6,336	6,874
Emissions	kt-CO_2 eq.	NO	NO	80	1,245	3,499	5,009	5,736	6,524	7,320	8,012	8,542	8,865	9,287	9,596	10,021

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

For the years 1990 to 1994, it was confirmed that no household stationary air-conditioning with HFCs were used, and therefore emissions for these years are reported as NO. (Ministry of the Environment press release, July 31, 2000, *Projections of disposal etc of refrigerant CFCs, HCFCs, and HFCs (Reference material 1)*)

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

See section 4.7.1.2.a.c).

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

Recalculations occurred due to corrections to the number of HFC devices produced from 2010 and onward. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.1.6. Mobile Air-Conditioning Production, Use and Disposal (2.F.1.-)

a) Category Description

1) HFCs

HFCs are emitted from manufacturing, operation, breakdowns, accidents, and disposals of mobile air-conditioning devices (car air conditioners, and railway and vessel air conditioners).

2) PFCs

Emission from this source in the "production" category was reported as "NO" since Japan had no record of their use in production. The emission was also reported as "NO" in the "use" and "disposal" categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

b) Methodological Issues

- ***Estimation Method***

In accordance with the IPCC Guidelines, emissions of each species of F-gases from 1) manufacturing, 2) operation, 3) breakdowns, 4) accidents and 5) disposals are estimated. Emission factors are country-specific. The below thinking is applied for each type of car.

➢ ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma\ (N_{produced} \times m_{manufacturing} \times x_{manufacturing})$$

$E_{manufacturing}$	: Emissions from manufacturing
$N_{produced}$	: Number of devices produced
$m_{manufacturing}$	: Amount of refrigerant contained
$x_{manufacturing}$	: Fugitive refrigerant ratio from manufacturing

➢ ***Emissions from operation***

$$E_{operation} = \Sigma\ (N_{operated} \times m_{operation} \times x_{operation})$$

$E_{operation}$	: Emissions from operation
$N_{operated}$	: Number of cars operated
$m_{operation}$	: Amount of refrigerant contained
$x_{operation}$	: Fugitive refrigerant ratio from operation

Note: In the estimation of emissions from operation, the yearly decrease is reflected in the "amount of refrigerant contained."

➢ ***Emissions from breakdowns***

$$E_{breakdowns} = \Sigma\ (N_{operated} \times m_{operation} \times A \times x_{accident})$$

$E_{breakdowns}$	: Emissions from maintenance
$N_{operated}$	: number of cars operated
$m_{operation}$	: amount of refrigerant contained
A	: rate of breakdowns
$x_{accident}$	: fugitive refrigerant ratio from breakdowns

➢ ***Emissions from accident***

$$E_{accident} = \Sigma\ (N_{destroyed} \times m_{operation})$$

$E_{accident}$	: Emissions from accident
$N_{destroyed}$	: number of cars in completely destroyed
$m_{operation}$	: amount of refrigerant contained at time of accident

➢ ***Emissions from disposal***

(a) until 2001 $E_{disposal} = \Sigma\ \{N_{disposed} \times m_{disposal} \times (1 - \eta)\}$

(b) from 2002 onward $E_{disposal} = \Sigma\ (N_{disposed} \times m_{disposal\text{-}avg}) - R$

$E_{disposal}$	: Emissions from disposal
$N_{disposed}$	: number of cars disposed
$m_{disposal}$	: amount of refrigerant contained
η	: collection rate

$m_{disposal\text{-}avg}$: average amount of refrigerant contained
R : amount collected

Relevant indices are shown in Table below.

Table 4-71 Indices related to emissions of HFC-134a from car air conditioners

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of cars produced	1,000 devices	0	9,745	9,761	10,407	9,292	9,856	9,613	9,753	9,273	9,205	9,639	9,362	8,140	4,600	3,884
Fugitive refrigerant during production	g	4	4	4	3	1	1	1	1	1	1	1	1	1	1	1
Number of cars operated with HFC air conditioners	1,000 devices	0	15,655	42,374	60,364	66,043	70,406	72,054	72,813	73,272	73,856	74,236	74,087	72,697	70,274	66,966
Average refrigerant charged per device	g	700	700	615	548	497	497	497	497	497	497	497	497	497	497	497
Fugitive refrigerant ratio during use per year per device (normal car)	g	15	15	15	10	10	10	10	10	10	10	10	10	10	10	10
Rate of breakdown incidences	%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Fugitive refrigerant ratio from breakdown cars	%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Number of cars completely destroyed	1,000 devices	0	50	136	193	211	225	231	233	234	236	238	237	233	225	214
Average refrigerant charged in completely destroyed cars	g	681	681	610	522	448	426	417	409	404	400	394	388	383	377	371
Number of cars disposed	1,000 devices	0	116	789	2,058	2,895	2,709	2,835	2,839	2,694	2,666	2,927	2,941	2,920	2,763	2,667
Average refrigerant charged at time of disposal	g	676	676	593	522	444	404	412	393	380	370	360	349	347	339	336
Amount of HFC collected (under law from FY2002)	t/year	-	-	-	531	898	786	785	773	710	682	720	718	694	625	579
Emissions from manufacturing	kt-CO_2 eq.	NO	49	49	45	13	11	11	10	10	10	10	10	8	5	4
Emissions from stocks	kt-CO_2 eq.	NO	704	1,798	2,331	2,222	2,274	2,276	2,255	2,230	2,215	2,189	2,151	2,086	1,994	1,881
Emissions from disposal	kt-CO_2 eq.	NO	112	669	778	555	442	548	492	449	436	477	443	458	446	455
Emissions	kt-CO_2 eq.	NO	865	2,516	3,153	2,791	2,728	2,835	2,757	2,690	2,661	2,676	2,604	2,553	2,444	2,340

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-72 Indices related to emissions of HFCs from air conditioners (railways)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fugitive refrigerant ratio at production	%	0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Emissions from manufacturing	kt-CO_2 eq.	NO	0.003	0.03	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.1	0.1	0.1	0.1	0.1
Emissions from stocks	kt-CO_2 eq.	NO	0.4	1.6	6.9	15.5	18.4	19.8	21.3	22.7	24.1	25.5	27.2	28.8	30.3	32.0
Emissions from disposal	kt-CO_2 eq.	NO	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.05	0.05	0.1	0.1	0.1	0.1
Emissions (railways)	kt-CO_2 eq.	NO	0.4	2	7	16	19	20	21	23	24	26	27	29	30	32

Reference: *Railway Statistical Yearbook*, *Yearbook of Railway Car Production Statistics* (Ministry of Land, Infrastructure, Transport and Tourism), IPCC default values, etc.

Table 4-73 Indices related to emissions of HFCs from air conditioners (vessels)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fugitive refrigerant ratio at production	%	0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Collection rate	%	0%	0%	0%	0%	31%	34%	34%	32%	38%	39%	38%	39%	38%	41%	40%
Emissions from manufacturing	kt-CO_2 eq.	NO	0.0003	0.004	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Emissions from stocks	kt-CO_2 eq.	NO	0.1	1.0	25.8	107.9	137.5	146.8	155.9	161.9	170.1	175.8	180.9	186.5	190.0	188.8
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	0.01	0.01	0.1	0.3	0.2	0.4	0.6	0.8	1.2	1.6	2.6
Emissions (vessels)	kt-CO_2 eq.	NO	0.1	1	26	108	138	147	156	162	171	176	182	188	192	192

Reference: IPCC default values, *Report on Maritime Affairs,etc*.

For car air conditioners, due to the lack of data necessary to estimate emissions for the years 1992 to 1994 in which HFCs were used, estimates have been done by using HFC shipment amounts which is thought to be proportional to the number of car produced, and the fugitive refrigerant during production from 1995, average refrigerant charged per device from 1995, fugitive refrigerant ratio during use per year per device (normal car) from 1995, rate of breakdown incidences from 1995, fugitive refrigerant ratio from breakdown cars from 1995, number of cars completely destroyed in 1995, the number of cars operated with HFC air conditioners from 1995, average refrigerant charged in completely destroyed cars from 1995, number of cars disposed from 1995, average refrigerant charged at the time of disposal from 1995, and extrapolating, etc for these years.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

See section 4.7.1.2.b.c).

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

Recalculations of emission from car air conditioners occurred for 2020, due to corrections to the number of cars produced and completely destroyed. For 2020, updates in the *Railway Statistical Yearbook* also contributed to recalculations. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.2. Foam Blowing Agents (2.F.2.)

4.7.2.1. Closed Cells (2.F.2.-)

4.7.2.1.a. Urethane Foam (2.F.2.-)

a) Category Description

HFC-134a, HFC-245fa, and HFC-365mfc are emitted as a result of foam blowing agent use.

b) Methodological Issues

- ***Estimation Method***

In accordance with the IPCC Guidelines (closed-cell foams), emissions were calculated assuming that 10% of the emission from foam blowing agents used each year occurred within the first year after production, with the remainder emitted over 20 years at the rate of 4.5% per year. The data on the amount of foam blowing agents used each year was provided by the Japan Urethane Foam Association, Japan Urethane Raw Materials Association.

It is difficult to separate the "use" emission from that at the time of "disposal" because urethane foams were disposed of at various times. Accordingly, the emissions in the "use" and "disposal" categories were combined and reported under the "use" category, while the emission in the "disposal" category was reported as "IE".

$$E = E_{manufacturing} + E_{use}$$
$$= (M \times EF_{FYL}) + (Bank \times EF_{AL})$$

E : HFC emissions [t]
$E_{manufacturing}$: Emissions during production [t]
E_{use} : Emissions during use [t]
M : Amount of HFC used [t]

EF_{FYL}	:	Leakage during foam blowing [%]
Bank	:	Total amount used up to the previous year [t]
EF_{AL}	:	Percentage of annual emissions during use [%]

Table 4-74 Indices related to emissions of HFCs from urethane foam

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFC-134a use	t	NO	NO	167	224	66	34	28	14	12	NO	NO	NO	NO	NO	NO
HFC-245fa use	t	NO	NO	NO	3,893	2,365	2,613	2,570	2,533	2,230	2,577	2,596	2,365	1,626	618	551
HFC-365mfc use	t	NO	NO	NO	1311	900	977	921	866	779	794	802	744	702	203	186
Leakage during foam blowing	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Annual emissions rate during use	%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
HFC-134a emissions	kt-CO_2 eq.	NO	NO	24	112	133	137	138	138	139	138	138	138	138	127	116
HFC-245fa emissions	kt-CO_2 eq.	NO	NO	NO	490	1,144	1,399	1,516	1,631	1,718	1,857	1,978	2,075	2,108	2,080	2,101
HFC-365mfc emissions	kt-CO_2 eq.	NO	NO	NO	130	318	391	421	450	474	503	532	556	579	565	571

Reference: *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: As regards HFC-245fa and HFC-365mfc, their use increased because they replaced HCFC-141b whose production ended in January 2004.

For the years 1990 to 1994, it was confirmed that no urethane foam with HFCs was used, and therefore emissions for these years are reported as NO. (*FY2011 PRTR (Pollutant Release and Transfer Register) Estimation methods for releases from sources not required to report* (MOE)

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emissions for both manufacturing and use, *the 2006 IPCC Guidelines* value of 50% was used.

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.2.1.b. Extruded Polystyrene Foam (2.F.2.-)

a) Category Description

HFC-134a is emitted as a result of foam blowing agent use.

b) Methodological Issues

- ***Estimation Method***

Emissions were calculated assuming that 25% of the emission of foam blowing agents occurs within the first year after production, with the remainder emitted at the rate of 0.75% per year. The amount of foam blowing agents used each year was provided by the Extruded Polystyrene Foam Industry Association. This assumption is consistent with the *2006 IPCC Guidelines* and the estimation method under PRTR for the amount of transferred HCFC at polystyrene foam production sites.

It is difficult to separate the “use” emission from that at the time of “disposal” because heat insulation material is disposed of at various times such as the renovation and dismantling of buildings, and in times of disaster. Since disposed polystyrene foam is considered to be emitting HFCs as same as that in use, these emissions are combined and reported under “use”, while the emissions from “disposal” were reported as “IE”.

$$E = E_{manufacturing} + E_{use}$$
$$= (M \times EF_{FYL}) + (Bank \times EF_{AL})$$

E : HFC-134a emissions [t]
$E_{manufacturing}$: Emissions during production [t]
E_{use} : Emissions during use [t]
M : Amount of HFC-134a used in particular year [t]
EF_{FYL} : Leakage during foam blowing (25%)
$Bank$: Total amount used in the past up to the previous year [t]
EF_{AL} : Annual emission rate during use [%]

Table 4-75 Indices related to emissions of HFC-134a from extruded polystyrene foam

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFC-134a use	t	NO	NO	NO	26	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Foam productization rate	%	-	-	-	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%
Annual emission rate during use	%	-	-	-	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
Emissions during production	t	NO	NO	NO	6.50	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions during use	t	NO	NO	NO	9.00	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23
Emissions	t	NO	NO	NO	15.50	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23
Emissions during production	kt-CO_2 eq.	NO	NO	NO	9	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emission during use	kt-CO_2 eq.	NO	NO	NO	13	13	13	13	13	13	13	13	13	13	13	13
Emissions	kt-CO_2 eq.	NO	NO	NO	22	13	13	13	13	13	13	13	13	13	13	13

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc*

For the years 1990 to 1994, it was confirmed that no extruded polystyrene foam with HFCs was used, and therefore emissions for these years are reported as NO. (*FY2011 PRTR (Pollutant Release and Transfer Register) Estimation methods for releases from sources not required to report*)

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

See section 4.7.2.1.a. c).

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.2.2. Open Cells (2.F.2.-)

4.7.2.2.a. High Expanded Polyethylene Foam (2.F.2.-)

a) Category Description

HFC-134a and HFC-152a is emitted as a result of foam blowing agent use.

b) Methodological Issues

- ***Estimation Method***

In accordance with the IPCC Guidelines (open-cell foams), emissions were calculated assuming that all of the emissions from foam blowing agents used occurred at the time of production. The amount of blowing agents used each year was provided by the High Expanded Polyethylene Foam Industry Association.

Table 4-76 Indices related to emissions of HFC-134a from high expanded polyethylene foam

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFC-134a use	t	1	346.00	322.00	128.00	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11
Emissions	t	1	346.00	322.00	128.00	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11	98.11
	kt-CO_2 eq.	1	495	460	183	140	140	140	140	140	140	140	140	140	140	140

Reference: *Documents of Fluorocarbons etc Measures Working Group,* and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-77 Indices related to emissions of HFC-152a from high expanded polyethylene foam

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFC-152a use	t	0.04	14.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions	t	0.04	14.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	kt-CO_2 eq.	0.005	2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic HFC shipment amounts which is thought to be proportional to use amounts of foam blowing agents, and extrapolating for these years.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

See section 4.7.2.1.a. c).

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.3. Fire Protection (2.F.3.)

a) Category Description

HFCs are emitted by the use of halogen fire extinguishers.

b) Methodological Issues

- ***Estimation Method***

HFC-23 and HFC-227ea are used for the production of fire extinguishers. However, as of 2004, only HFC-227ea is filled in the bottles for fire extinguishing equipment, and for HFC-23, each company purchases pre-filled HFC-23 fire extinguisher bottles, and therefore no emissions occur at production. HFCs emissions from this category was reported as “NO” by expert judgment since HFC-227ea was a very small amount, 0.0007 [t] when emission from production in FY2004 was estimated.

For use, in 1995, almost no HFC filled fire extinguishers existed on the market, and therefore it is assumed that there was no use, resulting in NO for 1995 and earlier years. For 1996 and following years, calculations were performed using the following equation and based on the HFC extinguishing agent stocks.

$$E = Bank \times EF$$

E : HFC emissions [t]
$Bank$: HFC extinguishing agent stocks [t]
EF : Emission factor during use

Concerning the emission at the time of disposal of fire extinguishers, it is reported as “NO” because the use of HFC for fire extinguishers has just started, and also the expected lifetime of buildings is 30-40 years, and therefore they are unlikely to be disposed of as of present.

- ***Emission Factors***

There are still no findings on the emission factor of HFC extinguishing agents when using them. The emission rate (0.00088) determined from refills of halons (provided by the Fire and Disaster Management Agency), which are similar extinguishing agents, was adopted as the emission factor for this category.

Table 4-78 References for the Emission factor of fire extinguishers
(The emission ratio of halon fire extinguishers)

	Unit	2002	2003	2004	2005	2006	2007	Average
Installations of halon 1301 (A)	t	17,094	17,090	17,060	16,994	17,075	16,889	17,034
Refills of halon 1301 (B)	t	13	13	22	13	14	15	15
(B) / (A)	-	0.00076	0.00076	0.00129	0.00076	0.00082	0.00089	0.00088

- ***Activity Data***

HFC stock amounts provided by the Fire Defense Agency were used as activity data for HFC emissions from fire extinguishing agents use.

Table 4-79 The amounts of the HFC extinguishing agent stocks

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Stocks of HFC-23	t	NO	NO	306.38	478.27	523.12	532.64	536.67	546.25	559.43	566.54	572.59	579.21	579.97	580.09	581.88
HFC-23 emissions	t	NO	NO	0.27	0.42	0.46	0.47	0.47	0.48	0.49	0.50	0.50	0.51	0.51	0.51	0.51
	kt-CO_2 eq.	NO	NO	4	6	7	7	7	7	7	7	7	8	8	8	8
Stocks of HFC-227ea	t	NO	NO	225.28	391.73	522.44	596.44	639.97	685.75	738.32	753.66	800.21	809.63	845.84	862.29	873.68
HFC-227ea emissions	t	NO	NO	0.20	0.34	0.46	0.52	0.56	0.60	0.65	0.66	0.70	0.71	0.74	0.76	0.77
	kt-CO_2 eq.	NO	NO	1	1	1	2	2	2	2	2	2	2	2	2	2
Total emissions	kt-CO_2 eq.	NO	NO	5	7	8	9	9	9	9	10	10	10	10	10	10

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emissions, *the 2006 IPCC Guidelines* value of 16% was used.

- ***Time-series Consistency***

Calculations are performed with a method consistently used from FY1995, based on an emission factor and activity data received from the Fire Defense Agency. For years 1990 to 1994, emissions are reported as NO, in light of the fact that HFC filled fire extinguishers were not in use in 1995.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.4. Aerosols (2.F.4.)

4.7.4.1. Metered Dose Inhalers (2.F.4.-)

a) Category Description

HFCs are emitted from the manufacturing and use of metered dose inhalers (MDIs).

b) Methodological Issues

- ***Estimation Method***

In accordance with the IPCC Guidelines, emissions were calculated on the assumption that from the amount used each year, 50% of the emission occurred in the year of production, with the remaining 50% emitted in the following year.

The amount of purchased gas, the amount of the use of domestically manufactured MDI and the use of imported MDI, and the amount of disposal of MDI were provided by the Federation of Pharmaceutical Manufacturers' Associations of Japan (FPMAJ). FPMAJ estimates the amount of HFC disposal by mainly including destructed MDI that were defective products.

$$E_n = E_{manufacturing} + E_{potential\ (n-1)} \times EF_{first} + E_{potential\ (n)} \times (1 - EF_{first}) - R_{(n)}$$

E_n	: F-gas (HFC-134a, HFC-227ea) emissions in year n [t]
$E_{manufacturing}$	: Fugitive emissions during manufacturing [t]
$E_{potential\ (n-1)}$, $E_{potential\ (n)}$	: F-gas potential emissions in year n - 1 or in year n [t]
EF_{first}	: 50[%]
$R_{(n)}$	: Amount of disposal of F-gas contained in MDI [t]

$$E_{potential} = U_{domestic} + U_{import}$$

$U_{domestic}$	: Use amount of domestically manufactured MDI [t]
U_{import}	: Use amount of imported MDI [t]

The associated indices are given in the table below.

Table 4-80 Indices related to emissions of HFC-134a from MDI

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Usage of domestic MDI	t	NO	NO	1.40	0.90	1.07	0.77	0.60	0.90	0.59	0.91	0.60	0.75	0.74	0.75	0.60
Usage of imported MDI	t	NO	NO	42.00	70.70	57.05	48.30	46.04	42.36	41.34	39.16	34.17	35.03	32.73	34.55	30.47
Amount collected and destroyed	t	NO	NO	0.10	1.90	2.52	0.76	0.72	0.23	3.56	0.42	0.13	0.03	0.07	0.04	0.34
HFC-134a emissions	t	NO	NO	37.20	62.75	55.52	51.26	47.23	44.91	39.35	40.72	37.38	35.35	34.66	34.48	32.94
	kt-CO_2 eq.	NO	NO	53	90	79	73	68	64	56	58	53	51	50	49	47

Reference: *Documents of Fluorocarbons etc Measures Working Group*, and data provided by METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-81 Indices related to emissions of HFC-227ea from MDI

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Usage of domestic MDI	t	NO	NO	NO	41.00	35.96	25.77	25.11	21.02	22.96	21.41	17.84	18.43	19.63	20.06	19.76
Usage of imported MDI	t	NO	NO	3.60	2.10	0.42	0.73	0.73	0.38	18.75	20.16	27.48	26.17	37.86	39.85	30.51
Amount collected and destroyed	t	NO	NO	NO	1.20	0.80	0.80	0.77	0.54	0.70	0.23	0.33	0.32	0.09	0.02	0.05
HFC-227ea emissions	t	NO	NO	1.80	48.05	33.14	29.83	26.93	23.93	31.70	32.05	43.95	45.41	51.54	59.16	55.15
	kt-CO_2 eq.	NO	NO	6	155	107	96	87	77	102	135	142	146	166	190	178

Reference: *Documents of Fluorocarbons etc Measures Working Group,* and data provided by METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: The production of MDIs using HFC-134a started in 1997, and those using HFC-227ea started in 2001 (with production using imported HFC-227ea starting in 2000).

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, emissions have been estimated to be NO for these years, since for HFC-134a, 1995 and 1996 amounts of usage of domestic MDI and usage of imported MDI are each zero, and for HFC-227ea, 1995 to 1999 amounts of usage of domestic MDI and usage of imported MDI are each zero.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emission factors, 0% was applied for all production, use and disposal, due to the fact that the amount of emissions is equal to the amount of MDI used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all production, use and disposal. As a result, the uncertainties of the emissions for all production, use and disposal were determined to be 10%.

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.4.2. Aerosols (2.F.4.-)

a) Category Description

HFCs are emitted from the manufacturing and use of aerosols.

b) Methodological Issues

- ***Estimation Method***

In accordance with the *2006 IPCC Guidelines*, emissions were calculated on the assumption that 50% of the emission from the amount of aerosol filled in the products (potential emissions) occurred in the year of production, with the remaining 50% emitted in the following year. Fugitive emissions from manufacturing is considered as the balance between the amount used for production and the actual measurement amount filled in the products, and it is included in the emissions. The data on the amount used for production and the amount filled in the products were provided by the Aerosol Industry Association of Japan.

HFC is considered to be actually remaining in disposed aerosols at some level. However, all potential emissions including that for “disposal” are allocated under “use” in accordance with the *2006 IPCC Guidelines*.

$$E_n = E_{manufacturing} + E_{potential\,(n-1)} \times EF_{first} + E_{potential\,(n)} \times (1 - EF_{first})$$

E_n	: HFC emissions in year n [t]
$E_{manufacturing}$	: Fugitive emissions during manufacturing [t]
$E_{potential\,(n-1)}$, $E_{potential\,(n)}$	: HFC potential emissions in year n-1 or in year n [t]
EF_{first}	: 50 [%]

$$E_{manufacturing\ (n)} = M_{(n)} - E_{potential\ (n)}$$

$E_{manufacturing\ (n)}$: Fugitive emissions during manufacturing [t]
$M_{(n)}$: HFC consumed during manufacturing in year n [t]
$E_{potential\ (n)}$: HFC potential emissions [t]

The associated indices are given in the table below.

Table 4-82 Indices related to emissions of HFC-134a from aerosols

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Potential emissions	t	NO	1,300.00	2,044.10	604.40	199.92	167.70	168.00	223.00	206.00	236.00	193.00	159.00	226.00	246.00	183.00
Fugitive emissions during production	t	NO	NO	80.20	24.90	8.08	8.30	7.00	12.00	15.00	22.00	35.00	38.50	37.00	48.00	44.50
Emissions in the year produced, during use	t	NO	650.00	1,022.05	302.20	99.96	83.85	84.00	111.50	103.00	118.00	96.50	79.50	113.00	123.00	91.50
Remaining (emissions in the next year)	t	NO	650.00	1,022.05	302.20	99.96	83.85	84.00	111.50	103.00	118.00	96.50	79.50	113.00	123.00	91.50
HFC-134a emissions	t	NO	1,050.00	2,137.10	908.15	223.04	187.15	174.85	207.50	229.50	243.00	249.50	214.50	229.50	284.00	259.00
	kt-CO_2 eq.	NO	1,502	3,056	1,299	319	268	250	297	328	347	357	307	328	406	370

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc*

Note: Fugitive emissions from 1992 to 1997 are included in potential emissions.

Table 4-83 Indices related to emissions of HFC-152a from aerosols

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Potential emissions	t	NO	NO	34.10	1,299.50	558.00	542.00	320.00	353.00	279.00	328.00	276.00	226.00	142.00	27.00	30.00
Fugitive emissions during production	t	NO	NO	1.10	28.90	638.00	464.00	249.00	185.00	108.50	68.00	89.00	75.00	45.50	17.00	1.00
Emissions in the year produced, during use	t	NO	NO	17.05	649.75	279.00	271.00	160.00	176.50	139.50	164.00	138.00	113.00	71.00	13.50	15.00
Remaining (emissions in the next year)	t	NO	NO	17.05	649.75	279.00	271.00	160.00	176.50	139.50	164.00	138.00	113.00	71.00	13.50	15.00
HFC-152a emissions	t	NO	NO	18.15	1,216.95	1,299.00	986.00	680.00	521.50	424.50	371.50	391.00	326.00	229.50	101.50	29.50
	kt-CO_2 eq.	NO	NO	2	151	161	122	84	65	53	46	48	40	28	13	4

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc*

Note: The production of aerosols using HFC-152a started in 2000.

Table 4-84 Indices related to emissions of HFC-245fa from aerosols

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Potential emissions	t	NO	NO	NO	0.80	0.39	1.09	0.17	1.10	0.28	NO	NO	NO	NO	NO	NO
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions in the year produced, during use	t	NO	NO	NO	0.40	0.19	0.55	0.09	0.55	0.14	NO	NO	NO	NO	NO	NO
Remaining (emissions in the next year)	t	NO	NO	NO	0.40	0.19	0.55	0.09	0.55	0.14	NO	NO	NO	NO	NO	NO
HFC-245fa emissions	t	NO	NO	NO	0.55	0.35	1.56	0.63	0.64	0.69	0.14	NO	NO	NO	NO	NO
	kt-CO_2 eq.	NO	NO	NO	1	0.4	2	1	1	1	0.1	NO	NO	NO	NO	NO

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the second meeting of the Breakout Group on F-gases, FY2014 Committee for the Greenhouse Gas Emissions Estimation Methods etc*

Table 4-85 Indices related to emissions of HFC-365mfc from aerosols

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Potential emissions	t	NO	NO	NO	1.12	NO	0.27	NO	0.24	0.24	NO	NO	NO	NO	NO	NO
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions in the year produced, during use	t	NO	NO	NO	0.56	NO	0.14	NO	0.12	0.12	NO	NO	NO	NO	NO	NO
Remaining (emissions in the next year)	t	NO	NO	NO	0.56	NO	0.14	NO	0.12	0.12	NO	NO	NO	NO	NO	NO
HFC-365mfc emissions	t	NO	NO	NO	0.74	NO	0.14	0.14	0.12	0.24	0.12	NO	NO	NO	NO	NO
	kt-CO_2 eq.	NO	NO	NO	1	NO	0.1	0.1	0.1	0.2	0.1	NO	NO	NO	NO	NO

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the second meeting of the Breakout Group on F-gases, FY2014 Committee for the Greenhouse Gas Emissions Estimation Methods etc*

The *2006 IPCC Guidelines* specifies estimation methods for HFC-43-10mee emissions from this sub-category, however, emissions do not exceed the 3,000 t-CO_2 eq threshold for estimation, determined by the Committee for Greenhouse Gas Emissions Estimation Methods, and therefore is reported as NE (considered insignificant). (See Annex 5)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by domestic HFC shipment amounts which are thought to be proportional to potential emissions, and extrapolating, etc for these years.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emission factors, 0% was applied for all production, use and disposal, due to the fact that the amount of emissions is equal to the amount of aerosols used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all production, use, and disposal. As a result, the uncertainties of the emissions for all production, use and disposal were determined to be 10%.

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.5. Solvents (2.F.5.)

a) Category Description

Liquid HFC-365mfc is used as an industrial dry cleaning solvent by the name of Solkane Dry, and is released into the atmosphere through volatilization, etc. HFCs and PFCs are also emitted from the use of solvents for the cleaning of general electronic parts, and semiconductor/liquid crystal manufacturing. The liquid PFCs used were C_5F_{12} (PFC-41-12) and C_6F_{14} (PFC-51-14). Data on HFCs used as solvents in the cleaning of general electronic parts, and semiconductor/liquid crystal manufacturing are confidential; therefore, these are reported as included under the total of PFCs.

b) Methodological Issues

- ***Estimation Method***

  - ***HFCs***

The annual use amount of Solkane Dry is estimated by multiplying the aggregate number of dry cleaning machines using Solkane Dry (from the domestic manufacturers, and subtracting out the number of machines disposed), by the average solvent amount used. All that is used (=solvent amount replenished) is assumed to have been emitted.

$$E = (N_{special} - D_{special}) \times U_{special} + (N_{partial} - D_{partial}) \times U_{partial}$$

E : HFC-365mfc emissions

$N_{special}$: Aggregate number of dry cleaning machines specialized for Solkane Dry use
$D_{special}$: Aggregate number of specialized machines disposed
$U_{special}$: Average solvent amount used in specialized machines
$N_{partial}$: Aggregate number of dry cleaning machines partially using Solkane Dry
$D_{partial}$: Aggregate number of partial-use machines disposed
$U_{partial}$: Average solvent amount used in partial-use machines

The average solvent amount used in dry cleaning machines using Solkane Dry is set based on the actual amounts of Solkane Dry sold and actual number of operating machines at a large manufacturer. (See the Table below) For the average solvent amount used in Solkane Dry-specialized dry cleaning machines in years 2011 and before, the average value for 2012 to 2017 is used. For the dry cleaning machines partially using Solkane Dry, the average solvent amount used is set by multiplying the amount for specialized machines by a ratio.

Since there is no shipment of dry cleaning machines using Solkane Dry for 2002 and before, emissions only start occurring in 2003.

Table 4-86 Number of dry cleaning machines using Solkane Dry and average solvent amount used

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cumulative number of specialized and mixed-use machines	units	0	0	0	12	121	192	216	234	246	259	268	272	283	292	297
Average solvent use per year (specialized)	kg/unit	0	0	0	673	673	653	678	713	699	692	602	602	602	602	602

➢ ***PFCs***

Assuming that almost all of the total amount of liquid PFC shipment was used in cleaners and for cleaning purposes each year, the entire amount was reported in the ”use” category as the amount of emissions. (Emissions are calculated by gas but are reported as an unspecified mix due to confidentiality reasons. Average GWP for 2021 is 9,300.) Emission from manufacturing was reported as ”NO” since there is no practice to blend before use. Emission at the time of disposal was reported as “IE” on the assumption, from the point of view of conservativeness, that the entire amount including that was disposed of, was emitted during use, because of the difficulty in determining the status of the disposal of PFCs. It is confirmed that no disposals were identified in 1995.

Emissions from PFCs contained in railway rectifiers (Refer to 2.G.2. for details) are subtracted from liquid PFC emissions to yield the total PFC emissions.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic PFC shipment amounts which is thought to be proportional to PFC emissions and extrapolating for these years.

c) Uncertainties and Time-series Consistency

● ***Uncertainty***

For the uncertainties of the HFC emission factors, -5% to +5% was applied. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be -11% to +11%.

For the uncertainties of the PFC emission factors, 0% was applied, due to the fact that the amount of emissions is equal to the amount of solvent used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be 10%.

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.6. Other Applications (2.F.6.)

Refrigerants filled in research and medical equipment are captured and included in other refrigerant categories.

4.8. Other Product Manufacture and Use (2.G.)

This category covers N_2O, HFCs, PFC, and SF_6 emissions from other product manufacture and use. This section includes the following sources: Electrical equipment (2.G.1.), Military applications (2.G.2.), Accelerators (2.G.2.), Other - Railway silicon rectifiers (2.G.2.), Medical applications (2.G.3.), Use during Semiconductor/Liquid Crystal Manufacturing (2.G.3.), and Waterproofing electronic circuits (2.G.4).

In FY2021, emissions from this category were 2,055 kt-CO_2 eq. and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The total emissions of N_2O from this category had increased by 100.4% compared to FY1990. The total of HFCs, PFCs and SF_6 had decreased by 83.3% compared to 1990.

Table 4-87 Emissions from 2.G. other product manufacture and use

Gas			Units	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N_2O	2.G.3	Medical applications	kt-N_2O	0.93	1.41	1.10	0.86	0.32	0.29	0.25	1.11	0.22	0.22	0.23	0.21	0.27	0.28	0.33
		Use during semiconductor/ liquid crystal manufacturing	kt-N_2O	0.05	0.10	0.15	0.38	0.60	0.74	0.95	0.99	1.13	1.22	1.18	1.03	1.04	1.14	1.63
	Total		kt-N_2O	0.98	1.51	1.25	1.23	0.92	1.03	1.20	2.10	1.35	1.44	1.41	1.24	1.31	1.42	1.96
	Total		kt-CO_2 eq.	291	449	371	368	275	308	359	627	402	429	420	370	390	424	583
Gas			Units	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
HFCs	2.G.4	Waterproofing electronic circuits	kt-CO2 eq.	8	6	8	5	4	4	3	3	3	3	3	3	6	6	7
PFCs	2.G.2	Other-Railway silicon rectifiers	kt-CO2 eq.	NO	NO	NO	0	4	NO	10	9	8	21	20	39	49	56	69
	2.G.4	Waterproofing electronic circuits	kt-CO2 eq.	16	14	16	11	8	7	6	6	6	6	6	6	12	13	14
SF_6	2.G.1	Electrical equipment	t	355.81	460.46	127.62	39.45	27.29	31.53	28.19	26.39	26.76	28.74	27.19	25.09	25.12	25.06	26.20
	2.G.2	Military applications	t	NO	NO	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
		Accelerators	t	30.77	35.16	34.49	35.69	33.83	35.05	35.12	35.06	34.27	33.39	33.91	34.50	34.58	33.17	33.23
	Total		t	386.58	495.62	163.34	76.36	62.35	67.81	64.54	62.68	62.26	63.36	62.33	60.82	60.93	59.46	60.66
	Total		kt-CO2 eq.	8,814	11,300	3,724	1,741	1,422	1,546	1,472	1,429	1,419	1,445	1,421	1,387	1,389	1,356	1,383
Total of F-gases			kt-CO_2 eq.	8,838	11,320	3,748	1,758	1,438	1,557	1,490	1,447	1,436	1,475	1,449	1,435	1,456	1,432	1,472

4.8.1. Electrical Equipment (2.G.1.)

a) Category Description

SF_6 are emitted during the manufacturing and use of electrical equipment.

b) Methodological Issues

- ***Estimation Method***

Emissions from producing electrical equipment were calculated by multiplying the amount of SF_6 purchased by assembly fugitive rate. Emissions from the use of electrical equipment were calculated based on the fugitive rate during the use of electrical equipment. Emission factors are country-specific. Emissions from the inspection and disposal of electrical equipment were obtained by actual measurements of SF_6.

In CRF, the emission was reported as “IE” after including the emission from disposal into the use of electrical equipment.

➢ ***Emissions from the production***

$$E_{manufacturing} = AD \times EF_{manufacturing}$$

$E_{manufacturing}$: SF_6 emissions from the production
AD : SF_6 purchased
$EF_{manufacturing}$: Assembly fugitive rate [%]

➢ ***Emission from the use***

$$E_{use} = Stock \times EF_{use}$$

E_{use} : SF_6 emission from the use
$Stock$: Stocks of SF_6
EF_{use} : Rate of emitted SF_6 into the environment during the use of electrical equipment (0.1%)

➢ ***Emission from the inspection***

$$E_{inspection} = E_{measured}$$

$E_{inspection}$: SF_6 emission from the inspection
$E_{measured}$: Actual measurements of SF_6

➢ ***Emission from the disposal***

$$E_{disposed} = E_{measured}$$

$E_{disposed}$: SF_6 emission from the disposal
$E_{measured}$: Actual measurements of SF_6

The associated indices are given in the table below.

Table 4-88 Indices related to emissions of SF_6 from electrical equipment

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Emissions during manufacturing	kt-CO_2 eq.	7,047	9,120	2,291	523	157	146	125	137	163	179	141	119	112	100	89
SF_6 emissions during use, maintenance, and disposal	kt-CO_2 eq.	1,065	1,378	619	376	465	573	517	465	447	476	479	454	460	472	508

Reference: the *Documents of Fluorocarbons etc Measures Working Group*, and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic SF_6 shipment amounts which is thought to be proportional to amounts of SF_6 purchased and stocks of SF_6, amounts of SF_6 charged to electrical equipment from 1995, the assembly fugitive rate from 1995, and the operational fugitive rate from 1995, and extrapolating for these years.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emission factors, -30 to +30% was applied for manufacturing and use, and -20 to +40% was applied for disposal, in accordance with the *2006 IPCC Guidelines*' default value. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. As a result, the uncertainty of the emissions for manufacturing and use was determined to be -32 to +32%, and -22 to +41% for disposal.

- ***Time-series Consistency***

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions: Production of HCFC-22 (2.B.9.-). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.8.2. SF_6 and PFCs from Other Product Use (2.G.2.)

4.8.2.1. Military Applications (2.G.2.-)

a) Category Description

SF_6 is used as an insulating medium in the radar systems of AWACS (Airborne Warning and Control System). When the plane ascends, SF_6 is automatically released from the system and into the atmosphere to maintain the appropriate pressure difference between the system and the outside air. When the plane descends, SF_6 is automatically charged into the system from an SF_6 container on board.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated using a method corresponding to the Tier 2 method (user mass-balance method) in the *2006 IPCC Guidelines*.

$$E = D + M - R - I$$

E : SF_6 Emissions
D : Decrease of SF_6 in the container on board the AWACS

M : SF_6 leakage during acquisition/replacement of SF_6 container on AWACS
R : SF_6 collected/destroyed
I : Net increase in AWACS fleet charge

The four-fleet AWACS was officially authorized for use on March 24, 1999, and therefore SF_6 emissions are considered to have started in 1999.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

No emission factor is set, and therefore the uncertainty of emissions is assessed by assessing the uncertainty of activity data. A 10% uncertainty of metal production is taken for the uncertainty of activity data. As a result, the uncertainty of emissions is 10%.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.8.2.2. Accelerators (2.G.2.-)

a) Category Description

SF_6 is used in university and research facility-operated particle accelerators, and in industrial/medical accelerators (for cancer therapy) as an insulating gas. When the equipment requires maintenance, the SF_6 is transferred into storage tanks, and therefore losses occur primarily during gas transfer.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated using the Tier 1 method in the *2006 IPCC Guidelines*.

$$E = N \times U \times C \times EF$$

E : SF_6 Emissions
N : Number of accelerators
U : SF_6 use factor
C : SF_6 charge factor
EF : SF_6 emission factor

The SF_6 use factor, SF_6 charge factor, SF_6 emission factor, and number of accelerators used for estimating emissions are shown below by type of accelerator.

Table 4-89 SF_6 use factor, SF_6 charge factor, SF_6 emission factor by type of accelerator

Item	University and research operated particle accelerators	Industrial particle accelerators	Medical particle accelerators [1]	Small-scale electron accelerators
SF_6 use factor	33%	100%	100%	100%
SF_6 charge factor [kg]	2,400	1,300	0.5	400 [2]
SF_6 emission factor [kg/kg]	See below Table	0.07	2.0	0.07

Note: 1) Among the medical particle accelerators, cyclotrons and synchrotrons are not considered to use SF_6, and therefore are not estimated for.

Reference: *2006 IPCC Guidelines* default values excluding the 2) value are from results of interviews with main accelerator manufacturers.

Table 4-90 SF_6 emission factor for particle accelerators at university/research facilities

Item	1990-2004	2005-2009	2010-2014	2015-2019	2019-2021
SF_6 emission factor [kg/kg]	0.070	0.063	0.063	0.052	0.045

Reference: Calculated based on JAEA-Technology 2010-023: Operation and Management of the High-pressure Gas Facility for the Tandem Accelerator, and 2011-2018 Environmental Reports (Japan Atomic Energy Agency).

Table 4-91 Number of accelerators by type

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of particle accelerators (University/Research facilities)	188	214	212	209	218	231	225	222	241	245	242	239	239	239	239
Number of particle accelerators (Industrial use)	143	164	145	181	174	184	188	190	193	183	191	198	198	198	198
Number of particle accelerators (Medical use)	531	641	754	857	926	1,028	1,068	1,081	1,108	1,114	1,146	1,132	1,132	1,132	1,132
Number of small-scale (below 1MeV) electron accelerators	243	276	314	282	218	203	201	197	201	196	192	196	198	200	202

Reference: *Statistics on the Use of Radiation in Japan* (Japan Radioisotope Association), except for the *Nuclear Yearbook* (The Japan Atomic Industrial Forum), etc for small-scale electron accelerators

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the EF, a -50 to +400% uncertainty from the *2006 IPCC Guidelines* (particle accelerators - medical use) was applied. A -10 to +10% uncertainty of metal production is taken for the uncertainty of activity data. As a result, the uncertainty of emissions is -51 to +400%.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.8.2.3. Soundproof windows (2.G.2.-)

The *2006 IPCC Guidelines* specifies estimation methods for this this sub-category, however, emissions do not exceed the 3,000 t-CO_2 eq threshold for estimation, determined by the Committee for Greenhouse Gas Emissions Estimation Methods, and therefore is reported as NE (considered insignificant). (See Annex 5)

4.8.2.4. Adiabatic properties: shoes and tyres (2.G.2.-)

PFC and SF_6 use for rubber with adiabatic properties are not found in Japan, and therefore emissions are reported as NO.

4.8.2.5. Other - Railway Silicon Rectifiers (2.G.2.-)

a) Category Description

PFCs are emitted at disposal of railway silicon rectifiers.

b) Methodological Issues

- ***Estimation Method***

Based on the number of devices containing PFC-51-14, the amount of PFC-51-14 contained, and lifetime of the devices installed on ground and on car respectively, given in the *Survey on Management Methods of Halons/Liquid PFCs etc* (2006), and the *Survey on Destruction of Halons/PFCs etc* (2010), the amount of PFC-51-14 disposed after use in railway silicon rectifiers in each fiscal year was estimated. This was done by multiplying the number of railway silicon rectifiers disposed per year, by the amount of PFC contained in each device. PFC emissions are calculated by subtracting the amount of PFC-51-14 destroyed in a specific fiscal year from the PFC disposed after use in railway silicon rectifiers in the same fiscal year.

$$E = M_{disposal} - R$$

E : PFC emissions at disposal of railway silicon rectifiers
$M_{disposal}$: PFC disposed after use in railway silicon rectifiers
R : PFC destroyed

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor from railway silicon rectifiers, the 0% value for solvents was applied since it is a similar source category. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be 10%.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.8.3. N_2O from Product Uses (2.G.3.)

4.8.3.1. Medical Applications (2.G.3.a)

a) Category Description

Nitrous oxide is emitted during anesthetics (laughing gas) use. Since 2006, some hospitals have installed N_2O destruction units, and the reductions achieved are reflected in the total emissions. CO_2 is not used as an anesthetic in Japan.

a) Methodological Issues

- ***Estimation Method***

In relation to emissions of N_2O from use of anesthetics, the actual amount of N_2O shipped as an anesthetic by pharmaceutical manufacturers or importers has been reported for 2005 and preceding years. For 2006 and beyond, the amount of N_2O collected is calculated using the amount of laughing gas used in domestic hospitals equipped with N_2O destruction units for anesthesia, and a destruction rate of 99.9 %. This is subtracted from the N_2O shipped for medical use to yield the amount of N_2O emitted.

$$E = S - (U \times DR)$$

E : Amount of N_2O emitted during the use of laughing gas
S : N_2O shipped for medical use
U : Amount of laughing gas used in hospitals equipped with N_2O destruction units
DR : Destruction rate

- ***Emission Factors***

It is assumed that all of the N_2O used as medical gas escapes into the atmosphere, unless collected. Therefore, no emission factor has been established.

- ***Activity Data***

The amount of shipments of N_2O for anesthetics (calendar year basis) is given in the *Statistics of Production by Pharmaceutical Industry* (Ministry of Health, Labour and Welfare). This is used for 2005 and preceding years, and for 2006 to 2009, the amount of N_2O collected in three, and from 2010 and onward collected in four domestic hospitals equipped with N_2O destruction units is subtracted from the above-mentioned shipment.

Table 4-92 Laughing gas shipment amount and N_2O collected in domestic hospitals

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Laughing gas shipment amount	kg-N_2O	926,030	1,411,534	1,099,979	859,389	320,110	292,971	253,218	1,111,265	219,011	219,011	234,691	211,842	265,728	283,333	330,111
N_2O collected in domestic hospitals	kg-N_2O	NO	NO	NO	NO	914	450	509	NO	NO	NO	NO	NO	NO	NO	NO

b) Uncertainties and Time-series Consistency

- ***Uncertainty***

Because all N_2O used for anesthetics are assumed to escape into the atmosphere, no emission factor has been set. Therefore, the uncertainty for activity data is also the uncertainty for emissions. As *Statistics of Production by Pharmaceutical Industry* is a fundamental statistic based on statistical law, a 5% uncertainty was given for this emission source.

- ***Time-series Consistency***

The amount of shipments are taken from the *Statistics of Production by Pharmaceutical Industry* in a consistent manner throughout the time series.

c) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

d) Category-specific Recalculations

e) There have been no source-specific recalculations. Category-specific Planned Improvements

No improvements are planned.

4.8.3.2. Other (2.G.3.b)

4.8.3.2.a. Use during Semiconductor/Liquid Crystal Manufacturing (2.G.3.b.-)

a) Category Description

N_2O is used as an oxidizing agent to form an insulative oxide film during semiconductor/liquid crystal manufacturing, and the remaining is considered to be released into the atmosphere.

b) Methodological Issues

● ***Estimation Method***

Emissions equal all N_2O shipment amounts for semiconductor/liquid crystal manufacturing.

$$E = AD$$

E : N_2O emissions during semiconductor/liquid crystal manufacturing
AD : N_2O shipped for semiconductor/liquid crystal manufacturing use

● ***Emission Factors***

Emissions equal activity data, and therefore no emission factor has been established.

● ***Activity Data***

The N_2O shipment amounts for semiconductor/liquid crystal manufacturing given in the website of Japan Industrial and Medical Gases Association is used as activity data.

c) Uncertainties and Time-series Consistency

● ***Uncertainty***

Because all N_2O used during semiconductor/liquid crystal manufacturing are assumed to escape into the atmosphere, no emission factor has been set. Therefore, the uncertainty for activity data is also the uncertainty for emissions. For the uncertainty of activity data, a 5% default value in the *2006 IPCC Guidelines* were used.

● ***Time-series Consistency***

The shipment amounts are taken from what is reported by Japan Industrial and Medical Gases Association in a consistent manner throughout the time series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

There is a possibility of over-estimation, since emissions are equal to all N_2O shipment amounts for semiconductor/liquid crystal manufacturing.

4.8.4. Waterproofing electronic circuits (2.G.4.-)

a) Category Description

In the process of adding waterproofing layers onto assembled electronic circuit boards, there is a method of forming fluorocarbon polymers using gas-phase reaction in a plasma. This process can result in emissions of PFCs (CF_4 (PFC-14), C_2F_6 (PFC-116) and CHF_3 (HFC-23).

b) Methodological Issues

- ***Estimation Method***

Following the Tier 1 method in the *2019 Refinement*, emissions were estimated.

$$E_i = EF_i \times n \times I$$

E_i : Emissions of gas i
EF_i : Emission factor for gas i [g/number of assembled electronic circuit boards]
n : Number of assembled electronic circuit boards manufactured [a)]
I : Waterproofing rate by a plasma processing (1%[b)])

Note: The number of assembled electronic circuit boards manufactured (hereafter, assembled boards manufactured) for 1990 to 2011 are not available. Therefore, the number of assembled boards manufactured for 1990 to 2011 are estimated based on the assumption that they are proportional to the number of electronic circuit boards manufactured (before assembly), and by using the number of assembled boards manufactured for 2012.
Reference:
a) *Yearbook of Current Production Statistics – Machinery*
b) *Japan Electronics Packaging and Circuits Association*

The emission factor for each gas used for the estimation are as shown in the following table.

Table 4-93 Emission factors for estimation of emissions from waterproofing assembled electronic circuit boards

Item	CF_4 (PFC-14)	C_2F_6 (PFC-116)	CHF_3 (HFC-23)
Emission factor [g/number of assembled electronic circuit boards]	0.006	0.004	0.003

Reference: Default values given in the *2019 Refinement.*

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emission factors for PFCs and HFCs, 200%, the upper limit value of the Tier 1 method for semiconductors in the *2006 IPCC Guidelines* was applied. For the uncertainties of the activity data, since the *Yearbook of Current Production Statistics* is a fundamental statistics based on statistical law, a 5% value was applied. As a result, the uncertainties of the emissions were determined to be -200 to +200%.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the viewpoint of data source.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

PFCs and HFCs emissions were newly estimated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.9. Other (2.H.)

This category covers CO_2 emissions from other sources. This section includes the following sources: Food and beverages industry (2.H.2.) and Imported carbonated gas (2.H.3.).

In FY2021, emissions from this category were 81 kt-CO_2 and represented 0.01% of Japan's total GHG emissions (excluding LULUCF). The emissions had increased by 25.3% compared to FY1990.

Table 4-94 Emissions from 2.H. Other

Gas			Units	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	2.H.2	Food and beverages industry	kt-CO_2	64	72	87	90	76	76	82	80	83	79	85	80	79	71	74
	2.H.3	Emissions from imported carbonated gas	kt-CO_2	0.3	0.3	0.2	0.2	0.9	23	11	10	14	28	26	25	21	16	7
	Total		kt-CO_2	65	72	87	90	77	100	94	91	97	107	111	105	100	87	81

4.9.1. Food and Beverages Industry (2.H.2.)

The CO_2 recovered, estimated together with the emissions from ethylene oxide production (2.B.8.d) is reported here.

Petroleum refining plants, ammonia production plants, and iron production plants are other sources of supply CO_2 for the production of carbonated gas and dry ice in Japan, however those emissions occurring from petroleum refining plants are reported under the Fuel combustion category (1.A.), and those emissions occurring from ammonia production plants are reported under ammonia production (2.B.1.), and those emissions occurring from iron production plants are reported under the Fuel combustion category (1.A.).

4.9.2. Emissions from Imported Carbonated Gas (2.H.3.)

a) Category Description

CO_2 are emitted from the use of imported carbonated gas.

b) Methodological Issues

The total amount of imported carbonated gas was used for estimating emissions.

- ***Estimation Method***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The import quantities of carbon dioxide in the *Trade Statistics of Japan* was used for estimating emissions.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

No emission factor has been set because all CO_2 are emitted from the use of imported carbonated gas and are assumed to escape into the atmosphere. Therefore, the uncertainty for activity data is also the uncertainty for emissions. For the uncertainty of activity data, a 5% value, which is the uncertainty for the use of electric arc furnaces in steel production referred to in the *Trade Statistics of Japan,* was used.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

References

1. IPCC, *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, 1997.
2. IPCC, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, 2000.
3. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
4. IPCC, *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2019.
5. IUPAC website, *Atomic Weights of the Elements 1999* (http://www.ciaaw.org/pubs/TSAW-1999.pdf), 2001.
6. Ministry of the Environment press release, *Projections of disposal etc of refrigerant CFCs, HCFCs, and HFCs (Reference material 1)*, July 31, 2000.
7. Ministry of the Environment Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 2*, August 2002.
8. Ministry of the Environment Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 1*, August 2006.
9. Ministry of the Environment, *Report of Volatile Organic Compound (VOC) Inventories*, March 2007.
10. Ministry of the Environment, *Survey on Management Methods of Halons/Liquid PFCs etc*, 2006.
11. Ministry of the Environment, *Survey on Destruction of Halons/PFCs etc*, 2010.
12. Ministry of the Environment, *FY2011 PRTR (Pollutant Release and Transfer Register) Estimation methods for releases from sources not required to report*.
13. Ministry of the Environment Committee for the Greenhouse Gas Emissions Estimation Methods, *Documents of the first meeting of the Breakout Group on F-gases*, FY2013 (January, 2014).
14. Ministry of the Environment Committee for the Greenhouse Gas Emissions Estimation Methods, *Documents of the first meeting of the Breakout Group on F-gases*, FY2014 (January, 2015).
15. Ministry of the Environment, *Details of the Compilation Results of CFC, HCFC, and HFC Charge and Recovery Amounts for Commercial Refrigeration and Air Conditioning Equipment*.
16. Ministry of Economy, Trade and Industry, *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*.
17. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics - Chemical Industry*.
18. Ministry of Economy, Trade and Industry, *Documents of Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council*.
19. Ministry of Economy, Trade and Industry, *Documents of the 21st meeting of the Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry*, 2009.
20. Ministry of Economy, Trade and Industry, *Documents of the 2nd Refrigerant Policy Working Group, Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council*, 2010.
21. Agency for Natural Resources and Energy, *General Energy Statistics*.
22. Ministry of Economy, Trade and Industry, *Yearbook of Mineral Resources and Petroleum Products Statistics*.
23. Ministry of Economy, Trade and Industry, *Yearbook of Minerals and Non-Ferrous Metals Statistics*.

24. Ministry of Economy, Trade and Industry, *Yearbook of the Current Survey of Energy Consumption*.
25. Ministry of Economy, Trade and Industry, *Yearbook of Ceramics and Building Materials Statistics*.
26. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials*.
27. Ministry of International Trade and Industry, *Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council*, 1997.
28. Ministry of Finance, *Trade Statistics of Japan*.
29. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Motor Vehicle Transport*.
30. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Motor Vehicle Fuel Consumption*.
31. Ministry of Land, Infrastructure, Transport and Tourism, *Railway Statistical Yearbook*.
32. Ministry of Land, Infrastructure, Transport and Tourism, *Yearbook of Railway Car Production Statistics*.
33. Ministry of Land, Infrastructure, Transport and Tourism, *Report on Maritime Affairs*.
34. Ministry of Health, Labour and Welfare, *Statistics of Production by Pharmaceutical Industry*.
35. Ministry of Agriculture, Forestry and Fisheries, *Yearbook of Fertilizer Statistics (Pocket Edition)*.
36. Japan Solvent Recycling Industry Association, *Survey on Organic Solvents Use and Emission Treatment* (May, 2012).
37. Japan Solvent Recycling Industry Association, *Survey on Solvent Recycle Amounts*.
38. Kainou Kazunari, *Evaluation and Verification of Limestone and Dolomite origin CO_2 emissions using I/O table and Industrial Statistics data in Japan*, RIETI Discussion Paper Series 10-J-026 (April, 2010).
39. Japan Lime Association, *The Story of Lime*, 2005.
40. Carbon Black Association, *Carbon Black Handbook*.
41. The Japan Petroleum Institute, *Petrochemical Processes*, 2001.
42. The Heavy and Chemical Industries News Agency, *Chemicals Handbook*.
43. The Heavy and Chemical Industries News Agency, *Petrochemical Industry of Japan*.
44. Japan Radioisotope Association, *Statistics on the Radiation in Japan*.
45. Japan Atomic Industrial Forum, *The Nuclear Almanac*.
46. Radiation Application Development Association, *Radiation and Industries No.69,* 1996.
47. Fishing Boat and System Engineering Association of Japan, *Journal of Fishing Boat and System Engineering Association of Japan*.
48. Japan Oil, Gas and Metals National Corporation, *Mineral Resources Material Flow*.
49. Japan Paint Manufacturers Association, *Compilation of Estimation Results of VOC Emissions from Paint*.
50. Japan Paint Manufacturers Association, *Survey on the Actual Conditions of the Paint Manufacturing Industry.*
51. Japan Industrial and Medical Gases Association Website (http://www.jimga.or.jp).
52. Tayama, H., Nakanoya, T., Otokawa, Y., Tsukihashi, Y., Seki, N., Onodera, T., Nisugi, H., *Operation and Management of the High-pressure Gas Facility for the Tandem Accelerator,* JAEA-Technology 2010-023.
53. Japan Atomic Energy Agency, *Environmental Report.*

Chapter 5. Agriculture (CRF sector 3)

5.1. Overview of Sector

Greenhouse gas emissions from the agricultural sector are calculated in seven categories: 3.A., 3.B., 3.C., 3.D., 3.F., 3.G., and 3.H. In 3.A.: Enteric Fermentation, CH_4 gas generated and emitted by cattle, buffalo, sheep, goats, horses, and swine as the result of enteric fermentation is reported. In 3.B.: Manure Management, CH_4 and N_2O generated by treatment of manure excreted by cattle, buffalo, sheep, goats, horses, swine, poultry (hen and broiler), rabbits, and mink are reported. In 3.C.: Rice Cultivation, CH_4 emissions from paddy fields (continuously flooded and intermittently flooded) cultivated for rice production are reported. In 3.D.: Agricultural Soils, N_2O emitted directly and indirectly from agricultural soil are reported. Emissions for 3.E.: Prescribed Burning of Savannas are reported as "NO", since Japan has no emission source in this category, while CH_4 and N_2O (as well as CO and NO_X, which is described in Annex 3) emissions from field burning of grains, legumes, root crops, and sugar cane during agricultural activities are reported in 3.F.: Field Burning of Agricultural Residues. 3.G.: Liming and 3.H.: Urea Application, CO_2 emissions by application of limestone and urea to soil are reported.

GHG emissions in the agricultural sector in FY2021 were 32,174 kt-CO_2 eq., comprising 2.8% of total emissions (excluding LULUCF). The value represents a 14.2% decrease from FY1990.

Tier of methodology used in Agriculture sector are showed in Table 5-1.

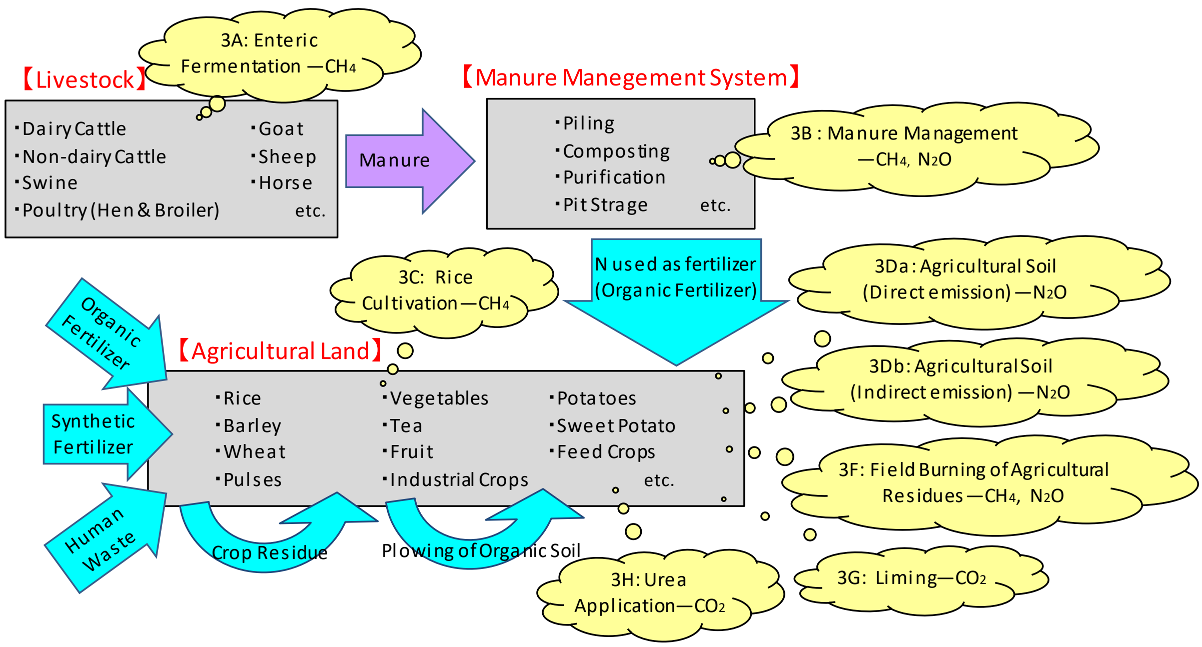


Figure 5-1 Relationships among the categories in the agricultural sector

Table 5-1 Tier of methodology used in Agriculture sector

GREENHOUSE GAS CATEGORIES	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
3.A. Enteric fermentation			CS,T1	CS,D		
3.B. Manure management			CS,T1	CS,D	CS,T1	CS,D
3.C. Rice cultivation			T3	CS		
3.D. Agricultural soils					CS,T2	CS,D
3.F. Field burning of agricultural residues			T1	D	T1	D
3.G. Liming	T1	D				
3.H. Urea application	T1	D				

Note: D: IPCC default, T1: IPCC Tier 1, T2: IPCC Tier 2, T3: IPCC Tier 3, CS: country-specific method or emission factor

5.2. Enteric Fermentation (3.A.)

Ruminants such as cattle, buffalo, sheep, and goats have multi-chamber stomachs. The rumen carries out anaerobic fermentation to decompose cellulose and other substances, thereby releasing CH_4. Horses and swine are not ruminants and have monogastric stomachs, but fermentations in their digestive tracts produce a small amount of CH_4, which is released into the atmosphere. These CH_4 emissions are calculated and reported in the Enteric Fermentation (3.A.) section.

GHG emissions from enteric fermentation in FY2021 were 7,718 kt-CO_2 eq., comprising 0.7% of total emissions (excluding LULUCF). The value represents a decrease by 18.1% from FY1990. The main driver of the emission reduction from FY1990 is a reduction of cattle population (particularly for dairy cattle). The main reason for the decreasing dairy cattle population is the decreasing number of dairy farmers, which is caused by the aging population of dairy farm owners and the lack of successors. In recent years, however, owing to the implementation of production infrastructure measures (MAFF, 2015), the number of dairy cattle reared per farmer have been increasing.

Table 5-2 CH_4 emissions from enteric fermentation (3.A.)

Gas	Livestock species	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CH_4	3.A.1.- Dairy cattle	kt-CH_4	192.1	184.4	171.2	162.9	146.3	143.4	139.7	137.0	136.4	133.5	133.5	133.4	134.9	135.5	137.6
	3.A.1.- Non-dairy cattle		166.5	172.2	171.7	168.0	166.5	159.6	154.8	150.0	150.3	151.1	151.7	150.7	153.0	155.2	157.0
	3.A.2. Sheep		0.167	0.115	0.097	0.071	0.159	0.129	0.138	0.140	0.140	0.143	0.158	0.162	0.170	0.160	0.160
	3.A.3. Swine		15.9	13.9	13.7	13.5	13.7	13.6	13.4	13.2	13.0	13.1	12.9	12.8	12.9	13.0	12.5
	3.A.4.- Buffalo		0.011	0.007	0.006	0.005	0.004	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
	3.A.4.- Goats		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	3.A.4.- Horses		2.1	2.1	1.9	1.6	1.3	1.3	1.3	1.2	1.3	1.3	1.4	1.4	1.4	1.3	1.3
	Total	kt-CH_4	376.9	372.7	358.7	346.0	328.1	318.1	309.5	301.7	301.4	299.2	299.8	298.6	302.5	305.3	308.7
		kt-CO_2eq.	9,423	9,318	8,966	8,651	8,202	7,953	7,737	7,543	7,534	7,481	7,494	7,465	7,563	7,631	7,718

5.2.1. Cattle (3.A.1.)

a) Category Description

This section provides the estimation methods for CH_4 emissions from enteric fermentation in Cattle.

b) Methodological Issues

- ***Estimation Method***

In accordance with decision tree of the *2006 IPCC Guidelines* (Vol. 4, Page 10.25, Figure 10.2), calculations for dairy and non-dairy cattle should be performed using the Tier 2 method. In the Tier 2 method, emission factors are calculated by multiplying the total energy intake of livestock by the CH_4 conversion factor. However, estimation using amount of dry matter intake (DMI) has been practiced in Japan on livestock-related research. It is considered that applying the results of research using amount of DMI for the estimation provides more accurate results which is in accordance with the actual situation of emissions. For that reason, a technique similar to the Tier 2 method but specific to Japan was used for the calculation of CH_4 emissions associated with enteric fermentation by cattle. The emissions were calculated by multiplying the cattle population (dairy and non-dairy) by the emission factors established based on their dry matter intake.

$$E = \sum (EF_i \times A_i)$$

E : CH_4 emissions from enteric fermentation for cattle [kg-CH_4]

EF_i : CH_4 emission factor of enteric fermentation of cattle type i [kg-CH_4 /head/yr]

A_i : Population of each cattle type i [head]

i : Cattle type

As cattle begin to eat coarse feed in real at the age about three months, the calculation of the CH_4 emissions associated with enteric fermentation includes cattle aged three months or older (cattle under three months are excluded from the calculation). To reflect the actual situation in Japan, categorization of cattle is defined as shown in the Table 5-3, and CH_4 emissions from enteric fermentation in cattle are estimated by types and ages.

Table 5-3 Categorization and assumptions underlying calculation of CH_4 emissions associated with enteric fermentation in cattle

Type of cattle					Assumptions for calculation of emissions	Additional information for each animal type
Dairy cattle	Lactating			Primipara	Population by calving time: calculated by multiplying the ratio of population by calving in *Record of Dairy Herd Performance Test* by the population in *Livestock Statistics*.	Lactating cattle. Population of 2 years old and over are written in *the Livestock Statistics*.
				Secondipara		
				Multipara (3 and more)		
	Non-lactating				—	Cattle in non-lactating period at present.
	Heifers			Under 2 years old and over 6 months old	Calculation excludes 6/24 of the population which was assumed to be 6 months old or younger; therefore covering 18/24 of the population under 2 years old.	Dairy cattle which are under 2 years old. Population of under 2 years old are described in *the Livestock Statistics*.
				3 to 6 months old	Comprising 4/24 of the population under 2 years old.	
				Under 3 months old	Covering 2/24 of the population under 2 years old. Excluded from CH_4 emission estimation.	
Non-dairy cattle	Breeding cows			2 years old and over	—	Breeding cow excluding dairy breeds. Population of under 1 year old, 1 year old, 2 years old, and 3 years old and over are described in *the Livestock Statistics*.
				Under 2 years old and over 6 months old	Calculation excludes 6/12 of the population which was assumed to be 6 months to 1 year old for under 1 year old and addition of the population under 1 year old.	
				3 to 6 months old	Comprising 4/12 of the population under 1 year old.	
				Under 3 months old	Covering 2/12 of the population under 1 year old. Excluded from CH_4 emission estimation.	
	Fattening cattle	Wagyu (Male)		1 year old and over	—	Cattle of native breeds in Japan called "Wagyu", which breeds for meat only. Population of under 1 year, 1 year and 2 years old and over are described as beef cattle (Male) in *the Livestock Statistics*.
				Under 1 year old and over 6 months old	Calculation excludes 6/12 of the population which was assumed to be 6 months old or younger; therefore covering 6/12 of the population under 1 year old.	
				3 to 6 months old	Comprising 4/12 of the population under 1 year old.	
				Under 3 months old	Covering 2/12 of the population under 1 year old. Excluded from CH_4 emission estimation.	
		Wagyu (Female)		1 year old and over	—	Cattle of native breeds in Japan called "Wagyu", which breeds for meat only. Population of under 1 year, 1 year and 2 years old (more than 7 categories) are described as beef cattle (Female) in *the Livestock Statistics*.
				Under 1 year old and over 6 months old	Same as same month age of Wagyu (Male)	
				3 to 6 months old	Same as same month age of Wagyu (Male)	
				Under 3 months old	Same as same month age of Wagyu (Male). Excluded from CH_4 emission estimation.	
		Dairy breeds	Dairy breeds	Over 6 months old	Calculation excludes 6/24 of the population which was assumed to be 6 months old or younger; therefore covering 18/24 of the population under 2 years old.	Cattle of dairy breeds for meat such as Holsteins.
				3 to 6 months old	Comprising 4/24 of the population under 2 years old.	
				Under 3 months old	Covering 2/24 of the population under 2 years old. Excluded from CH_4 emission estimation.	
			Hybrid	Over 6 months old	Same as same month age of Dairy breeds	F1 hybrid for beef which female dairy breeds are delivered with crossing with male beef breed cattle.
				3 to 6 months old	Same as same month age of Dairy breeds	
				Under 3 months old	Same as same month age of Dairy breeds. Excluded from CH_4 emission estimation.	

- ***Emission Factors***

The emission factor for CH_4 associated with enteric fermentation in cattle has been established on the basis of the result of breath testing of ruminant livestock in Japan: the measured data for volume of CH_4

per dry matter intake. Results of measurements have made clear that it is possible to estimate CH_4 from enteric fermentation in ruminant livestock using the equation given below, which uses dry matter intake as the explanatory variable (Shibata et al., 1993).

$$EF = Y / L_{CH4} \times Mol_{CH4} \times Day$$

$$Y = -17.766 + 42.793 \times DMI - 0.849 \times (DMI)^2$$

EF	: CH_4 emission factor associated with enteric fermentation for cattle [kg-CH_4/head/yr]
Y	: Volume of CH_4 generated per head per day [l /head/day]
L_{CH4}	: Volume of 1 mol CH_4 [l/mol] (=22.4)
Mol_{CH4}	: Molecular weight of CH_4 [kg/mol] (=0.016)
Day	: Days in a year [day] (=365 or 366)
DMI	: Dry matter intake [kg/day]

Annual emission factors by cattle types were established by applying the DMI to the above equation. The DMI was calculated by substituting body weight, and daily weight gain by growth into the equation established for each type of cattle in *Japanese Feeding Standard* compiled by National Agriculture and Food Research Organization (NARO). Fat corrected milk amount (FCM) is also used for DMI calculation for dairy cattle. The equations to estimate DMI were revised in 2006 for dairy cattle (lactating and non-lactating) and in 2008 for non-dairy cattle (Wagyu (M)).

The amount of fat corrected milk was calculated by estimated milk yield from data in the *Statistics on Milk and Dairy Products* (Ministry of Agriculture, Fisheries and Forestry; MAFF) and the *Livestock Statistics* (MAFF), and from the fat content in milk data in the *Statistics of Livestock Production Costs* (MAFF). Both sets of the data are updated on a yearly basis.

The average body weights of cattle by each calving time which were firstly calculated by applying the average ages in month by calving time described in the *Record of dairy herd performance test* (Livestock Improvement Association of Japan) into the growth curve of cattle described in *Japanese Feeding Standard* was adopted to the body weight for lactating and non-lactating dairy cattle. Average ages in month for primipara for all years were described in the *Record of dairy herd performance test*, however, the record of average ages in month for second calving and more has started since 2015. Therefore, the values of average ages for second calving and more for FY2015 were substituted for before 2015. The regression equation expressing growth curve of dairy cattle have been revised in 1994, 1999, 2006 and each revised regression equation was applied after the revision. Data for body weight and weight gain by daily growth for heifer and non-dairy cattle were obtained from the table of weight by age in month for each type of cattle included in the *Japanese Feeding Standard*.

Table 5-4 Equation to estimate dry matter intake (*DMI*) by cattle

Type of cattle		Equation
Dairy cattle	Lactating	Since 2006: $DMI = 1.3922 + 0.05839 \times W^{0.75} + 0.40497 \times FCM$ $DMI = 1.9120 + 0.07031 \times W^{0.75} + 0.34923 \times FCM$ (Primipara) $FCM = (15 \times FAT / 100 + 0.4) \times MILK$ Before 2006: $DMI = 2.98120 + 0.00905 \times W + 0.41055 \times FCM$ $FCM = (15 \times FAT / 100 + 0.4) \times MILK$
	Non-lactating	$DMI = 0.017 \times W$
	Heifers	$DMI = 0.49137 + 0.01768 \times W + 0.91754 \times DG$
Non-dairy cattle	Breeding cows	For under 49mths old: $DMI = [0.1067 \times W^{0.75} +(0.0639 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = 0.4213 + 0.1491 \times DG$ For 49mths old and over: $DMI = [0.1119 \times W^{0.75} + (0.0639 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / 1.81$ Additional daily nutrient requirements for pregnant cows during last 2 months of pregnant: + 1.0 kg / day on calculated DMI Additional daily nutrient requirements for lactating cows during 5 months of lactation: + 0.5 kg / day to calculated DMI * Target ages are till 120 months old
	Wagyu (M)	Since 2008: $DMI = -3.481 + 2.668 \times DG + 4.548 \times 10^{-2} \times W - 7.207 \times 10^{-5} \times W^2 + 3.867 \times 10^{-8} \times W^3$ Before 2008: $DMI = [0.1124 \times W^{0.75} + (0.0546 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / \{q \times (1.653 - 0.00123 \times W)\} / (q \times 4.4)$ $q = 0.5304 + 0.0748 \times DG$
	Wagyu (F)	$DMI = [0.1108 \times W^{0.75} + (0.0609 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = 0.5018 + 0.0956 \times DG$
	Dairy breeds (over 6 months old)	$DMI = [0.1291 \times W^{0.75} + (0.0510 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = (0.933 + 0.00033 \times W) \times (0.498 + 0.0642 \times DG)$
	Dairy breeds (3 to 6 months old)	$DMI = [0.1291 \times W^{0.75} + \{(1.00 + 0.030 \times W^{0.75}) \times DG\} / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = (0.859 - 0.00092 \times W) \times (0.790 + 0.0411 \times DG)$
	Hybrid	$DMI = [0.1208 \times W^{0.75} + (0.0531 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = (0.933 + 0.00033 \times W) \times (0.498 + 0.0642 \times DG)$

Note: *W*: Weight, *FCM*: Fat Corrected Milk, *FAT*: Fat content in milk, *MILK*: Milk Yield,
DG: Daily Gain, *q*: Energy metabolic rate

Reference: *Japanese Feeding Standard (for dairy cattle and non-dairy cattle)*

Table 5-5 Milk yield (*MILK*) of cattle and fat content in milk (*FAT*)

Item		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Milk yield	Multipara (3 and more)	kg/head/day	21.9	23.6	24.7	26.6	26.9	27.3	27.4	28.0	28.6	28.7	28.8	28.8	29.7	30.0	30.5
	Secundipara	kg/head/day	21.4	23.1	24.2	26.0	26.4	26.8	26.9	27.3	27.9	28.0	28.1	28.1	29.0	29.2	29.7
	Primipara	kg/head/day	18.5	19.9	20.9	22.4	22.7	23.0	23.1	23.5	24.0	24.2	24.5	24.3	25.2	25.2	25.7
Fat content in milk		%	3.7	3.8	3.9	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	4.0

Table 5-6 Weight by cattle (*W*) [kg $head^{-1}$]

Type of cattle			1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dairy cattle		Lactating (Multipara (3 and more))	653.8	653.5	673.7	673.4	685.6	685.7	685.2	684.7	684.7	684.3	683.9	683.9	683.6	683.3	683.2
		Lactating (Secundipara)	598.4	601.6	622.6	622.6	623.9	623.9	623.9	623.9	623.9	623.4	622.5	623.0	622.0	622.0	621.1
		Lactating (Primipara)	517.2	528.0	551.1	538.3	523.6	524.6	524.6	523.6	523.6	522.6	521.6	520.5	520.5	519.5	518.5
		Non-lactating	601.0	602.4	625.3	618.5	623.3	619.9	620.1	618.7	617.4	616.8	616.9	616.3	614.4	612.7	612.0
		Heifer: under 2 yr, over 6 mth	342.4	349.3	364.9	374.2	376.1	376.1	376.1	376.1	376.1	376.1	376.1	376.1	376.1	376.1	376.1
		Heifer: 3 to 6 mth	118.9	119.2	123.0	135.3	137.8	137.8	137.8	137.8	137.8	137.8	137.8	137.8	137.8	137.8	137.8
Non-dairy cattle	Breeding	2 yr and over	471.1	471.1	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8
		Under 2 yr, over 6 mth	314.9	314.9	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0
		3 to 6 mth	118.4	118.4	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2
	Fattening cattle	Wagyu (M): 1 yr and over	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8
		under 1 yr, over 6 mth	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0
		3 to 6 mth	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5
		Wagyu (F): 1 yr and over	382.4	382.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4
		under 1 yr, over 6 mth	219.8	219.8	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0
		3 to 6 mth	118.4	118.4	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2
		Dairy breed: over 6 mth	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8
		3 to 6 mth	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4
		Hybrid: over 6 mth	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8
		3 to 6 mth	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4

Table 5-7 Daily Gain by cattle (*DG*) [kg head^{-1} day^{-1}]

Type of cattle			1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dairy cattle		Lactating	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Non-lactating	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Heifer: under 2 yr, over 6 mth	0.60	0.63	0.65	0.59	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
		Heifer: 3 to 6 mth	0.70	0.71	0.76	0.91	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Non-dairy cattle	Breeding	2 yr and over	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		Under 2 yr, over 6 mth	0.50	0.50	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
		3 to 6 mth	0.74	0.74	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	Fattening cattle	Wagyu (M): 1 yr and over	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
		under 1 yr, over 6 mth	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
		3 to 6 mth	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
		Wagyu (F): 1 yr and over	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
		under 1 yr, over 6 mth	0.71	0.71	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
		3 to 6 mth	0.74	0.74	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
		Dairy breed: over 6 mth	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
		3 to 6 mth	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
		Hybrid: over 6 mth	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
		3 to 6 mth	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14

Table 5-8 Dry matter intake by cattle (*DMI*) [kg day^{-1}]

Type of cattle			1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dairy cattle		Lactating (Multipara (3 and more))	17.5	18.3	19.1	19.9	20.0	20.1	20.1	20.3	20.6	20.7	20.7	20.7	21.1	21.2	21.4
		Lactating (Secundipara)	16.9	17.7	18.4	19.3	19.2	19.4	19.4	19.6	19.8	19.8	19.9	19.9	20.3	20.4	20.6
		Lactating (Primipara)	14.9	15.7	16.4	17.0	17.4	17.6	17.6	17.7	17.9	17.9	18.0	18.0	18.3	18.3	18.5
		Non-lactating	10.2	10.2	10.6	10.5	10.6	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.4	10.4	10.4
		Heifer: under 2 yr, over 6 mth	7.1	7.2	7.5	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
		Heifer: 3 to 6 mth	3.2	3.2	3.4	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Non-dairy cattle	Breeding	2 yr and over	7.7	7.7	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
		Under 2 yr, over 6 mth	6.3	6.3	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
		3 to 6 mth	3.4	3.4	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
	Fattening cattle	Wagyu (M): 1 yr and over	8.2	8.2	8.2	8.2	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
		under 1 yr, over 6 mth	6.5	6.5	6.5	6.5	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
		3 to 6 mth	3.6	3.6	3.6	3.6	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
		Wagyu (F): 1 yr and over	5.6	5.6	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
		under 1 yr, over 6 mth	4.7	4.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
		3 to 6 mth	3.0	3.0	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
		Dairy breed: over 6 mth	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
		3 to 6 mth	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
		Hybrid: over 6 mth	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
		3 to 6 mth	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6

Table 5-9 Emission factors associated with enteric fermentation by cattle [kg-CH_4 head^{-1} yr^{-1}]

Type of cattle			1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dairy cattle		Lactating (Multipara (3 and more))	122.9	125.9	127.7	129.8	129.9	130.3	130.3	130.7	131.6	131.4	131.5	131.5	132.6	132.4	132.8
		Lactating (Secundipara)	120.5	123.8	125.8	128.1	128.0	128.4	128.5	128.9	129.9	129.6	129.7	129.7	131.0	130.8	131.3
		Lactating (Primipara)	112.7	116.4	118.9	121.1	122.6	123.0	123.0	123.4	124.4	124.3	124.5	124.3	125.7	125.3	125.9
		Non-lactating	86.3	86.6	89.0	88.2	88.7	88.4	88.4	88.2	88.3	88.0	88.0	88.0	88.0	87.6	87.5
		Heifer: under 2 yr, over 6 mth	63.4	64.7	66.9	67.8	68.0	68.0	68.0	68.0	68.1	68.0	68.0	68.0	68.1	68.0	68.0
		Heifer: 3 to 6 mth	29.1	29.3	30.4	33.8	34.4	34.4	34.4	34.4	34.5	34.4	34.4	34.4	34.5	34.4	34.4
Non-dairy cattle	Breeding	2 yr and over	68.3	68.5	70.7	70.7	70.7	70.7	70.7	70.7	70.9	70.7	70.7	70.7	70.9	70.7	70.7
		Under 2 yr, over 6 mth	56.9	57.0	66.0	66.0	66.0	66.0	66.0	66.0	66.1	66.0	66.0	66.0	66.1	66.0	66.0
		3 to 6 mth	30.3	30.3	33.7	33.7	33.7	33.7	33.7	33.7	33.8	33.7	33.7	33.7	33.8	33.7	33.7
	Fattening cattle	Wagyu (M): 1 yr and over	72.1	72.3	72.1	72.1	68.5	68.5	68.5	68.5	68.7	68.5	68.5	68.5	68.7	68.5	68.5
		under 1 yr, over 6 mth	58.8	59.0	58.8	58.8	61.7	61.7	61.7	61.7	61.8	61.7	61.7	61.7	61.8	61.7	61.7
		3 to 6 mth	33.0	33.1	33.0	33.0	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4
		Wagyu (F): 1 yr and over	51.0	51.2	57.2	57.2	57.2	57.2	57.2	57.2	57.3	57.2	57.2	57.2	57.3	57.2	57.2
		under 1 yr, over 6 mth	43.1	43.2	53.7	53.7	53.7	53.7	53.7	53.7	53.8	53.7	53.7	53.7	53.8	53.7	53.7
		3 to 6 mth	26.7	26.8	30.9	30.9	30.9	30.9	30.9	30.9	31.0	30.9	30.9	30.9	31.0	30.9	30.9
		Dairy breed: over 6 mth	74.2	74.4	74.2	74.2	74.2	74.2	74.2	74.2	74.4	74.2	74.2	74.2	74.4	74.2	74.2
		3 to 6 mth	40.2	40.3	40.2	40.2	40.2	40.2	40.2	40.2	40.3	40.2	40.2	40.2	40.3	40.2	40.2
		Hybrid: over 6 mth	73.0	73.2	73.0	73.0	73.0	73.0	73.0	73.0	73.2	73.0	73.0	73.0	73.2	73.0	73.0
		3 to 6 mth	42.1	42.2	42.1	42.1	42.1	42.1	42.1	42.1	42.2	42.1	42.1	42.1	42.2	42.1	42.1

- ***Activity Data***

For activity data of this source, the population of each type of cattle on 1st February in each year, recorded by the MAFF in its *Livestock Statistics* is used.

Table 5-10 Livestock population for cattle [1000 head]

		Type of cattle	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dairy cattle		Lactating (Multipara (3 and more))	510	467	447	391	374	347	334	324	317	308	309	309	296	293	297
		Lactating (Secundipara)	260	250	241	229	196	203	202	191	194	193	194	190	186	192	194
		Lactating (Primipara)	313	318	283	280	235	248	236	235	241	234	228	231	233	241	245
		Non-lactating	332	299	249	231	195	194	185	184	185	179	176	171	185	184	188
		Heifer: under 2 yr, over 6 mth	491	445	379	379	351	323	328	328	306	307	316	323	339	334	335
		Heifer: 3 to 6 mth	109	99	84	84	78	72	73	73	68	68	70	72	75	74	75
		Heifer: under 3 mth	55	49	42	42	39	36	36	36	34	34	35	36	38	37	37
Dairy cattle total			**2,068**	**1,927**	**1,725**	**1,636**	**1,467**	**1,423**	**1,395**	**1,371**	**1,345**	**1,323**	**1,328**	**1,332**	**1,352**	**1,356**	**1,371**
Non-dairy cattle	Breeding	2 yr and over	612	591	555	536	575	541	520	505	511	511	517	528	528	528	528
		Under 2 yr, over 6 mth	84	69	68	71	78	64	62	61	64	69	75	79	79	79	79
		3 to 6 mth	12	9	8	9	11	9	9	9	9	12	12	13	13	13	13
		Under 3 mth	6	4	4	5	5	4	5	4	5	6	6	6	6	6	6
	Fattening cattle	Wagyu (M): 1 yr and over	368	412	385	374	409	396	381	368	371	374	379	380	384	389	403
		under 1 yr, over 6 mth	125	133	114	119	127	116	115	112	109	110	116	120	135	139	126
		3 to 6 mth	83	89	76	80	85	77	77	75	72	73	77	80	90	93	84
		under 3 mth	42	44	38	40	42	39	38	37	36	37	39	40	45	46	42
		Wagyu (F): 1 yr and over	197	265	246	290	336	337	328	313	293	310	312	310	306	319	343
		under 1 yr, over 6 mth	102	105	93	89	101	93	91	89	86	81	84	89	103	109	95
		3 to 6 mth	68	70	62	59	67	62	60	59	57	54	56	60	69	72	63
		under 3 mth	34	35	31	30	34	31	30	30	29	27	28	30	34	36	32
		Dairy breed: over 6 mth	665	541	333	351	309	282	276	259	249	235	221	206	201	188	185
		3 to 6 mth	148	120	74	78	69	63	61	58	55	52	49	46	45	42	41
		under 3 mth	74	60	37	39	34	31	31	29	28	26	25	23	22	21	21
		Hybrid: over 6 mth	140	267	511	438	362	373	363	362	379	391	388	371	372	394	416
		3 to 6 mth	31	59	114	97	81	83	81	80	84	87	86	82	83	88	93
		under 3 mth	16	30	57	49	40	41	40	40	42	43	43	41	41	44	46
Non-dairy cattle total			**2,805**	**2,901**	**2,806**	**2,755**	**2,763**	**2,642**	**2,567**	**2,489**	**2,479**	**2,499**	**2,514**	**2,503**	**2,555**	**2,605**	**2,614**

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties for emission factors were calculated by finding the 95% confidence interval in accordance with the equation indicated in the section Emission Factors (Dairy cattle: -26% to +32%, non-dairy cattle: -40% to +49%). Populations of cattle (activity data) are decided by survey of total population in the *Livestock Statistics*, thus standard error for cattle is not described. Therefore, the uncertainties for activity data were substituted by 1% of swine in the *Livestock Statistics.* As a result, the uncertainties of the emissions were determined to be -26% to +32% for dairy cattle and -40% to +49% for non-dairy cattle.

- ***Time-series Consistency***

Emission factors were calculated consistently from FY1990 onward by the method mentioned in the section on Emission Factors. Activity data were used consistently from FY1990 onward from the data in the *Livestock Statistics*.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

It was pointed out by implementation of QA activity (QAWG) in FY2016 that ablactation of dairy cattle is at the age about three months, and CH_4 was actively generated from them. By taking this into account and discussions within the Committee for Greenhouse Gas Emission Estimation Methods, improvement to estimate the emission from cattle at the age three and four months was conducted in 2017 submission inventory.

Comparison between results of Japan's estimation method and IPCC Tier 2 method was conducted. For Tier2 method, equations indicated in the *2006 IPCC Guidelines* (Vol.4, Chapter 10, Equation 10.3~10.16) are used, and estimation is conducted by classification described in Table 5-3 above. If data is available, Japan's data are used (e.g. values of Table 5-4 to Table 5-8 above and values of DE calculated from data described in the *Japanese Feeding Standards*). If not available, default data described in the *2006 IPCC Guidelines* are used (e.g. Y_m, Cf_i and $C_{pregnancy}$).

As a result, for both dairy cattle and non-dairy cattle, considering the error of CH_4 conversion factor (Y_m = 6.5%±1.0%), the emissions based on Japan's method were in the range calculated by IPCC Tier 2 method. Therefore, it is considered that there were no significant differences between emissions of Japan's method and IPCC Tier 2 method.

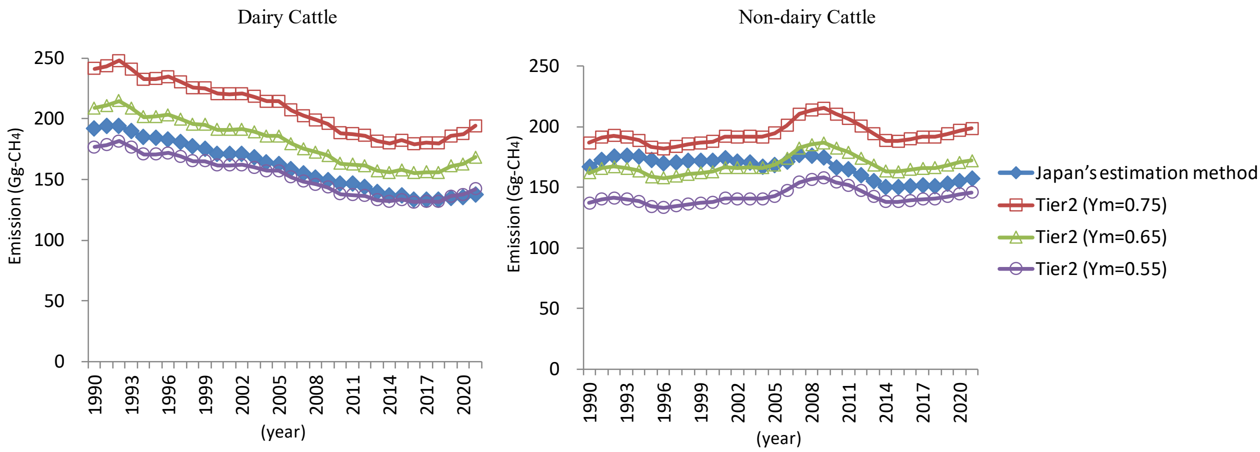


Figure 5-2 Comparison between results of Japan's estimation method and IPCC Tier 2 method

e) Category-specific Recalculations

Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test* was updated, the emissions from dairy cattle for FY2020 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

It is planned to discuss the development of the estimation method, which reflects the emissions reduction with technologies that suppress methane emission by controlling the rumen fermentation (such as by the addition of fatty acid calcium to feed) and by improving the feed efficiency with the total mixed ration (TMR) feeding.

5.2.2. Buffalo, Sheep, Goats, Horses & Swine (3.A.2., 3.A.3., 3.A.4.-)

a) Category Description

This section provides the estimation methods for CH_4 emissions from enteric fermentation in buffalo, sheep, goats, horses and swine.

b) Methodological Issues

- ***Estimation Method***

CH_4 emissions were calculated using the Tier 1 method in accordance with the decision tree of the *2006*

IPCC Guidelines.

$$E = EF \times A$$

E	: CH_4 emissions from enteric fermentation for each livestock [kg-CH_4]
EF	: CH_4 emission factor for enteric fermentation of each livestock [kg-CH_4/head/yr]
A	: Population of each livestock [head]

- ***Emission Factors***

The emission factors for swine have been established on the basis of results of research conducted in Japan. The emission factor for sheep, goats, horses and buffalo are the default values given in the *2006 IPCC Guidelines*.

Table 5-11 Emission factors for CH_4 associated with enteric fermentation in swine, sheep, goats, horses and buffalo

Livestock species	CH_4 emission factor [kg-CH_4/head/yr]	Reference
Swine	1.4	Estimated from Saito (1988)
Sheep	8	*2006 IPCC Guidelines*
Goats	5	
Horses	18.0	
Buffalo	55.0	

- ***Activity Data***

For activity data of sheep and goats, livestock population data given in the *Statistical Document of Livestock Breeding* offered by the Japan Livestock Industry Association until FY2009 and the *Status Report regarding Health Management for Livestock Feeding* by the MAFF from FY2010 onward are used. For swine, population on 1st February in each year recorded in the *Livestock Statistics* by the MAFF are used. The data in 2004, 2009 and 2014 were interpolated. For horses, livestock population given in the *Statistical Document of Horse* offered by the MAFF until FY2009 and the *Status Report regarding Health Management for Livestock Feeding* by the MAFF from FY2010 onward are used. For buffalo, livestock population given in the *Survey Result of Feeding Livestock and Poultry* by Okinawa Prefecture are used.

Table 5-12 Livestock population for buffalo, sheep, goats, swine, and horses [1000 heads]

Livestock species	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Sheep	21	14	12	9	20	16	17	17	18	18	20	20	21	20	20
Goats	26	19	22	16	19	19	20	20	17	16	19	20	20	20	20
Swine	11,335	9,900	9,788	9,620	9,768	9,685	9,537	9,424	9,313	9,346	9,189	9,156	9,223	9,290	8,950
Horses	116	118	105	87	75	74	74	69	74	75	76	78	78	73	73
Buffalo	0.21	0.12	0.10	0.08	0.08	0.09	0.10	0.11	0.11	0.12	0.11	0.11	0.12	0.12	0.11

Note: For swine, data in FY2009 and FY2014 were interpolated.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

An uncertainty assessment was conducted by each livestock category. The uncertainties for emission factors for swine were decided by the Committee of GHG Emissions Estimation Methods. The uncertainties for emission factors of livestock other than swine were applied 50% of default data given in the *2006 IPCC Guidelines*. As the uncertainty for activity data of swine, 1% of standard error for swine given in the *Livestock Statistic* was applied. For activity data of livestock other than swine, uncertainty was substituted by the value of broiler (9%) described in the *Livestock Statistics*. As a result, the uncertainties of the emissions were determined to be -72% to +157% for swine and 51% for buffalo, sheep and goats and horses.

- ***Time-series Consistency***

For emission factors, same values were used consistently. For activity data, the data given in the *Statistical Document of Livestock Breeding*, the *Livestock Statistics*, the *Statistical Document of Horse*, the *Survey Result of feeding Livestock and Poultry* by Okinawa, and the *Status Report regarding Health Management for Livestock Feeding* are used, and consistent estimation method by each livestock are used since FY1990.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

No recalculations are conducted.

f) Category-specific Planned Improvements

There are no improvement plans.

5.2.3. Other Livestock (3.A.4.-)

Deer, alpaca, which are not reported above, but default emission factors are reported in the *2006 IPCC Guidelines*, are farmed as livestock in Japan. However, their population size is small, and the emissions from each of them are lower than 3,000t-CO_2 equivalent, which is the threshold to estimate in this GHG inventory decided by the Committee for GHG Emissions Estimation Methods. Therefore, it was reported as "NE" as considered insignificant (See Annex 5).

5.3. Manure Management (3.B.)

In livestock manure management process, CH_4 is generated by decomposing organic content in livestock manure with CH_4 fermentation. In addition, CH_4 generated by enteric fermentation dissolved in manure is released by aeration or agitation. In manure management, N_2O is produced mainly by microorganism via nitrification and denitrification processes.

CH_4 and N_2O emissions from manure management in FY2021 are 2,458 kt-CO_2 eq. and 3,911 kt-CO_2 eq., comprising 0.2% and 0.3% of total emissions (excluding LULUCF), respectively. The value represents a decrease by 27.3% for CH_4 and a decrease by 10.0% for N_2O from FY1990. Main driver of the CH_4 emission decrease from FY1990 is a reduction of dairy cattle population, and of the N_2O emission decrease from FY1990 is a reduction for indirect N_2O emission by atmospheric deposition because of a reduction of livestock population.

For amount of nitrogen in excretion of swine, decrease was seen in trend since 1990. The reason is that amount of crude protein in feeds has been decreased with the decrease of proportion of soybean meal in feeds year by year.

Table 5-13 CH_4 and N_2O emissions from livestock manure management (3.B.)

Gas	Livestock species	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CH_4	3.B.1.- Dairy cattle	kt-CH_4	107.0	103.1	96.5	94.5	86.8	84.9	82.7	81.1	81.0	79.3	79.4	79.4	80.7	81.1	82.6
	3.B.1.- Non-dairy cattle		3.7	3.8	3.9	4.3	4.9	5.1	5.2	5.3	5.5	5.8	6.1	6.2	6.3	6.3	6.4
	3.B.2. Sheep		0.006	0.004	0.003	0.002	0.006	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006
	3.B.3. Swine		22.2	19.3	17.7	12.5	8.7	8.4	8.0	7.8	7.6	7.4	7.5	7.3	6.8	6.8	6.5
	3.B.4.- Buffalo		0.0004	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
	3.B.4.- Goats		0.005	0.004	0.004	0.003	0.004	0.004	0.004	0.004	0.003	0.003	0.004	0.004	0.004	0.004	0.004
	3.B.4.- Horses		0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	3.B.4.- Poultry		2.1	2.0	2.0	2.3	2.5	2.6	2.6	2.6	2.5	2.6	2.7	2.7	2.6	2.6	2.6
	3.B.4.- Rabbit		0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	3.B.4.- Mink		0.1053	0.0073	0.0038	0.0004	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Total	kt-CH_4	135.3	128.5	120.3	113.7	103.0	101.2	98.7	96.9	96.8	95.3	95.8	95.8	96.6	96.9	98.3
		kt-CO_2 eq.	3,383	3,213	3,007	2,843	2,576	2,530	2,467	2,424	2,420	2,382	2,395	2,396	2,414	2,424	2,458
N_2O	3.B.1.- Dairy cattle	kt-N_2O	2.1	2.1	2.1	2.3	2.4	2.3	2.3	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.1
	3.B.1.- Non-dairy cattle		2.4	2.5	2.5	2.6	2.7	2.5	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
	3.B.2. Sheep		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	3.B.3. Swine		3.7	3.2	3.2	3.8	4.5	4.4	4.3	4.2	4.1	4.1	4.2	4.2	4.2	4.2	4.1
	3.B.4.- Buffalo		0.00012	0.00007	0.00006	0.00005	0.00004	0.00005	0.00005	0.00006	0.00006	0.00007	0.00006	0.00006	0.00007	0.00007	0.00006
	3.B.4.- Goats		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	3.B.4.- Horses		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	3.B.4.- Poultry		1.1	1.1	1.1	1.1	1.2	1.1	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9
	3.B.4.- Rabbit		0.004	0.004	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
	3.B.4.- Mink		0.0223	0.0016	0.0008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	3.B.5. Indirect emissions		5.2	4.8	4.5	4.1	3.9	3.8	3.7	3.6	3.6	3.6	3.7	3.7	3.7	3.7	3.7
	Total	kt-N_2O	14.6	13.7	13.3	14.0	14.7	14.2	13.7	13.3	13.2	13.1	13.3	13.1	13.2	13.2	13.1
		kt-CO_2 eq.	4,346	4,091	3,968	4,163	4,376	4,235	4,070	3,968	3,932	3,907	3,958	3,912	3,926	3,939	3,911
Total of all gases		kt-CO_2 eq.	7,729	7,304	6,975	7,005	6,951	6,764	6,537	6,391	6,352	6,289	6,353	6,308	6,340	6,362	6,369

5.3.1. Cattle, Swine and Poultry (Hen and Broiler) (3.B.1., 3.B.3., 3.B.4.-)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions for manure management from cattle (dairy cattle and non-dairy cattle), swine and poultry (hen and broiler). For grazing animal, CH_4 emissions were reported in this category and N_2O emissions were reported in “3.D.a.3. Urine and dung deposited by grazing animals”.

b) Methodological Issues

- ***Estimation Method***

CH_4 emissions associated with the manure management were calculated by multiplying the amount of organic matter contained in manure from each type of livestock by the emission factor for each type of management system.

$$E_{CH4} = \sum \left(EF_{CH4-n} \times A_{CH4-n} \right)$$

E_{CH4-n}	: CH_4 emissions associated with the management of manure excreted by cattle, swine and poultry [kt-CH_4/yr]
EF_{CH4-n}	: Emission factor for management system n [kg-CH_4/kg-organic matter]
A_{CH4-n}	: Amount of organic matter contained in manure managed by system n [kt-organic matter/yr]
n	: Manure management system

N_2O emissions were calculated by multiplying the amount of nitrogen contained in manure of each type of animal by the emission factor for each type of management system.

$$E_{N2O} = \sum \left(EF_{N2O-n} \times A_{N2O-n} \right) \times 44/28$$

E_{N2O} : N_2O emission associated with management of manure excreted by cattle, swine and poultry

[$kt\text{-}N_2O/yr$]

$EF_{N2O\text{-}n}$	: Emission factor for management system *n* [$g\text{-}N_2O\text{-}N/g\text{-}N$]
$A_{N2O\text{-}n}$	: Amount of nitrogen contained in manure managed by system *n* [kt-N/yr]
n	: Manure management system

- ***Emission Factors***

CH_4 and N_2O Emission factors for each manure management system (hereafter, MMS) associated with Manure Management have been established for each treating method in Japan of for each type of livestock on the basis of the results of research by actual measurements carried out in Japan after reviewing its validity in accordance with the decision tree shown in Figure 5-3. Table 5-16 and Table 5-17 show these emission factors.

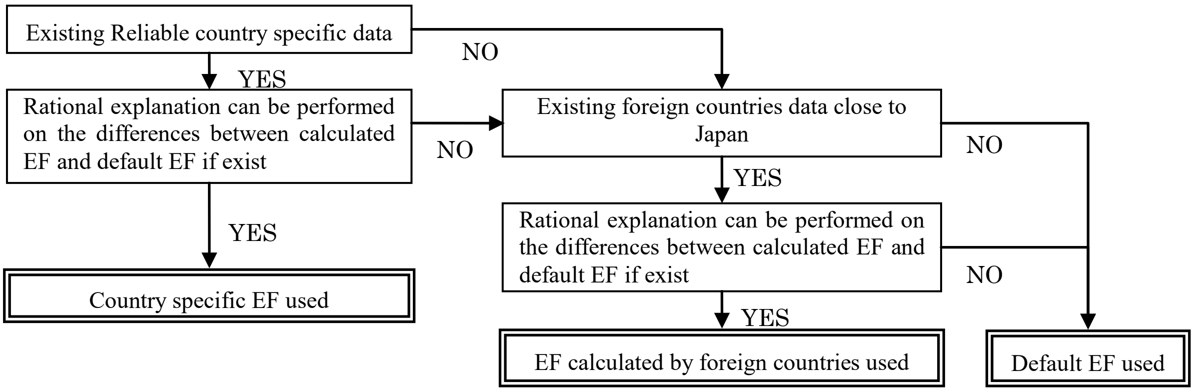


Figure 5-3 Decision tree for determination of EF

Emission factors indicated by "D (default value)" in Table 5-16 and Table 5-17 are based on the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (the *2019 Refinement*). CH_4 emission factors among them were calculated by following equation with *Bo* (maximum methane producing capacity) (Dairy cattle: 0.24, Non-dairy cattle: 0.18, Swine: 0.45) and MCF (methane conversion factor, Table 5-14) in "Other Regions – High productivity systems" indicated in the *2019 Refinement*. Since MCF for composting and pit storage are described by each climate zone in the *2019 Refinement*, MCF values are calculated with regional MCF decided by the average temperature in each region, which are weighted average by regional livestock population. Average temperature by region used for development of MCF values is shown in the following Table 5-15. These temperatures were established by using the average temperatures in each municipality where livestock are mainly housed.

For country-specific emission factors, MCF values are not established because emission factors are estimated directly from results of actual measurement data.

$$EF_{CH4\text{-}n} = Bo \times 0.67 \times MCF$$

$EF_{CH4\text{-}n}$	: Emission factor for management system *n* [$kg\text{-}CH_4/kg$-organic matter]
Bo	: Maximum methane producing capacity [$m^3\text{-}CH_4/kg$-organic matter]
0.67	: Conversion factor from volume to weight [$kg\text{-}CH_4/m^3\text{-}CH_4$]
MCF	: Methane conversion factor [%]

Table 5-14 MCFs (methane conversion factor) used for calculation of default emission factors

Treating method	MCF	System classification in the *2019 Refinement*
Composting - Intensive windrow (dairy cattle)	0.7%	Estimated on the basis of Composting - Intensive windrow
Composting - Intensive windrow (non-dairy cattle)	0.9%	Estimated on the basis of Composting - Intensive windrow
Composting - Intensive windrow (swine)	1.0%	Estimated on the basis of Composting - Intensive windrow
Composting - Intensive windrow (urine)	0.0 %	Estimated on the basis of Aerobic treatment
Composting - In-Vessel	0.5 %	Estimated on the basis of Composting - In-Vessel
Pit storage (non-dairy cattle)	28.6%	Estimated on the basis of Liquid/Slurry and Pit storage
Pit storage (non-dairy cattle), (within a month)	11.6%	Estimated on the basis of Liquid/Slurry and Pit storage – 1 Month
Pit storage (non-dairy cattle), (over a month)	32.9%	Estimated on the basis of Liquid/Slurry and Pit storage – 3, 4, 6, 12 Month
Pit storage (swine)	30.6%	Estimated on the basis of Liquid/Slurry and Pit storage
Pit storage (swine), (within a month)	12.5%	Estimated on the basis of Liquid/Slurry and Pit storage – 1 Month
Pit storage (swine), (over a month)	35.1%	Estimated on the basis of Liquid/Slurry and Pit storage – 3, 4, 6, 12 Month

Note: For other treating method than the above, MCF values are not established because country-specific emission factors are used.
Reference: the *2019 Refinement*, Vol.4 Table10.17

Table 5-15 Average temperature by region used for development of MCF values [°C]

Region	Dairy cattle	Non-dairy cattle	Swine
Hokkaido	6.2	6.2	7.4
Tohoku	9.9	11.0	10.1
Kanto	13.0	12.1	14.4
Hokuriku	15.1	14.0	12.7
Tokai	17.1	14.3	15.0
Kinki	16.9	16.0	13.5
Chugoku	15.3	15.0	14.4
Shikoku	16.5	16.1	15.5
Kyusyu and Okinawa	16.7	16.5	16.3

For “Sun drying” for dairy cattle, non-dairy cattle and swine, CH_4 emission factors in Ishibashi et al. (2003) were adopted.

For “Sun drying” for hen and broiler, emission factors were established based on actual measurement data at poultry manure management facility with drying system (Poultry manure is dried out with agitation on conveyer belt machinery in tunnel ventilation barn) (Tsuchiya et al., 2014).

For “Thermal drying”, emission factor was set as 0 % by assuming that CH_4 emission from this manure management system theoretically does not occur.

For “Carbonization”, emission factor for “Thermal drying” is adopted.

For “Composting - In-Vessel (feces)” and “Composting - In-Vessel (feces and urine mixed)” for swine, emission factor is referred to *Project Report of Survey on Prevention of Global Warming in the Agriculture, Forest and Fisheries Sector within the Environment and Biomass Comprehensive Strategy Promotion Project in FY2008* (Nationwide Survey) (Hereinafter called “*Report of Survey Project in FY2008* (Nationwide Survey)”).

For emission factors of “Composting - Intensive windrow (feces)” and “Composting - In-Vessel (feces)” for hen and broiler, emission factor of these treating methods for swine is applied on the bases of expert judgment that characteristics of feces such as percentage of moisture and the condition of feces are close to that of swine. Because emission factors by treating methods by livestock are much different by treating methods rather than by livestock.

For “Piling”, the most major manure management practice in Japan, Osada et al. (2005) measured actual CH_4 and N_2O emissions by using chamber system covering compost heap, and Japan’s emission factors for dairy cattle, non- dairy cattle and swine were set from these data.

For “Piling” of hen and broiler, emission factors were established on the basis of actual GHG measurement data using chamber, which covers piled up manure, at piling composting management facility in three areas of Japan. Detail method is described in the report by MAFF (2014).

For “Incineration”, emission factor written in *GHGs emissions control in livestock industry Summary* (Japan Livestock Technology Association, 2002) is used.

For “Purification” for cattle, Shiraishi et al. (2017) measured actual CH_4 and N_2O emissions for urine and the mixture of feces and urine of dairy cattle from a purification plant. Emission factors based on the result of this study were applied to the purification of urine and the mixture of feces and urine from dairy and non-dairy cattle.

For “Purification” for swine, emission factor is from the *Project on Survey and Investigation for Elaboration of GHG Emissions from Agriculture, Forest and Fisheries Sector, within the Project on Development for Method of Promotion for Countermeasures of Global Environment in the Agriculture, Forest and Fisheries Sector in FY2012* (MAFF 2013) (Hereinafter called "*the Report of Project* (MAFF 2013)").

For CH_4 emission factors of “Pit storage” and “Methane fermentation” for dairy cattle, regional emission factors of 9 regions in Japan were established by using air temperature as a parameter, and based on actual measurement data on pit storage system and methane fermentation system by using measurement technique such as floating chamber method (*The Report of Project on Survey and Investigation for Elaboration of GHG Emissions from Agriculture, Forest and Fisheries Sector, within the Project on Development for Method of Promotion for Countermeasures of Global Environment in the Agriculture, Forest and Fisheries Sector in FY2011*, 2012). Therefore, integrated emission factors for all Japan, which are weighted averages of the regional emission factors with dairy cattle population in each region (described in the *Livestock Statistics*), are used (see Table 5-18). Emission factors in latest year are lower than 1990 because ratio of livestock population in Hokkaido region, where temperature is low and emission factor is low, has gradually increased (FY1990: 42% and FY2021: 62%).

For “Pasture, range and paddock” of dairy cattle and non-dairy cattle, emission factors were established by actual measurement data of collected manure set in chamber in grazing area (Mori and Hojito, 2015).

For “Industrial waste treatment”, emission factors for “Pit storage” is adopted. For “Other”, emission factors were established based on the maximum value in each state of manure (feces, urine, and feces and urine mixed).

Table 5-16 CH_4 Emission factors for each method of treating manure from cattle, swine, and poultry

[%: kg-CH_4/kg-organic matter]

Treating method	Dairy cattle		Non-dairy cattle		Swine		Hen		Broiler	
Sun drying	0.20 %	J2)	0.20 %	J2)	0.20 %	J2)	0.14 %			J10)
Thermal drying	0 %									Z3)
Carbonization	-		-		-		0%			TD
Composting – Intensive windrow (feces)	0.113 %	D1)	0.109 %	D1)	0.302 %	D1)	0.302 %			Sw
Composting – Intensive windrow (urine)	0.000%	D1)	0.000 %	D1)	0.000 %	D1)	—			
Composting – Intensive windrow (feces and urine mixed)	0.113%	D1)	0.109%	D1)	0.302 %	D1)	—			
Composting – In-Vessel (feces)	0.08 %	D1)	0.06 %	D1)	0.08 %	J7)	0.08 %			Sw
Composting – In-Vessel (urine)					0.151 %	D1)	-			
Composting – In-Vessel (feces and urine mixed)					0.08 %	J7)	-			
Piling	3.8 %	J4)	0.13 %	J4)	0.16 %	J4)	0.13 %	J12)	0.02 %	J12)
Incineration	0.4 %									O3)
Purification	0.3%			J13)	0.91 %	J11)	-			
Pit storage	Table 5-18	JR8)	3.4 %	D1)	9.2 %	D1)	0.13 %	Pl	0.02 %	Pl
Pit storage (within a month)			1.4 %	D1)	3.8 %	D1)				
Pit storage (over a month)			4.0 %	D1)	10.6 %	D1)				
Methane fermentation (feces)	3.8%	Pl	0.13%	Pl	0.16%	Pl	0.13 %	Pl	0.02 %	Pl
Methane fermentation (urine, feces and urine mixed)	Table 5-18	JR8)	3.5%	JR8)	3.6%	JR8)	-			
Industrial waste treatment	Table 5-18	JR8)	3.4 %	PS	9.2 %	PS	0.13 %	PS	0.02 %	PS
Pasture, range and paddock	0.076%			J9)	-		0.14%			SD
Other (feces)	3.8%	M	0.4%	M	0.4%	M	0.4%			M
Other (urine, feces and urine mixed)	3.8%	M	4.0%	M	10.60%	M	-			

Note: See notation and references of Table 5-17 below.

Table 5-17 N_2O Emission factors for each method of treating manure from cattle, swine and poultry

[%: kg-N_2O-N/kg-N]

Treating method	Dairy cattle		Non-dairy cattle		Swine		Hen		Broiler	
Sun drying	2.0 %					D1)	0.33%			J10)
Thermal drying	2.0 %									D1)
Carbonization	-						2.0%			TD
Composting – Intensive windrow (feces)	0.5 %					D1)	0.5 %			Sw
Composting – Intensive windrow (urine)	1.0 %						—			
Composting – Intensive windrow (feces and urine mixed)	0.5 %						—			
Composting – In-Vessel (feces)	0.25 %			J5)	0.16 %	J7)	0.16 %			Sw
Composting – In-Vessel (urine)	0.6%					D1)	-			
Composting – In-Vessel (feces and urine mixed)	0.25%			J5)	0.16%	J7)	-			
Piling	2.4 %	J4)	1.6 %	J4)	2.5 %	J4)	0.54%	J12)	0.08%	J12)
Incineration	0.1 %									O3)
Purification	2.88 %			J13)	2.87%	J11)	-			
Pit storage	0.02%	J8)	0 %			D1)	0.54%	PI	0.08%	PI
Methane fermentation (feces)	2.4 %	Pl	1.6 %	Pl	2.5 %	Pl	0.54%	Pl	0.08%	Pl
Methane fermentation (urine, feces and urine mixed)	0.15%	J8)	0.15%			Dc	-			
Industrial waste treatment	0.02%	PS	0 %			PS	0.54%	PS	0.08%	PS
Pasture, range and paddock	0.684%			J9)	-		0.33%			SD
Other (feces)	2.4%	M	2.0%	M	2.5%	M	2.0%			M
Other (urine, feces and urine mixed)	2.88%	M	2.88%	M	2.87%	M	-			

Note: 1) Manure excreted by hen and broiler was categorized as feces since it contains a very small amount of urine.

2) For the emission factors of "Composting" for 2018 and before, which were not separated by its aeration system, the weighted average of EFs for "Intensive windrow" and "In-Vessel" by the proportion for each

of system are used.

D: Default value of the *2019 Refinement*
J: Established by actual data of Japan
JR: Established using regional emission factors for dairy cattle and regional population of each livestock in Japan
O: Established by data of other countries
Z: No emission occurrence because of the mechanism
Pl: Application for the value of "Piling"
SD: Application for the value of "Sun drying"
TD: Application for the value of "Thermal draying"
PS: Application for the value of "Pit storage"
Sw: Application for the value of "Swine"
Dc: Application for the value of "Dairy cattle"
M: Application of the maximum values of the treating methods for "feces" or "feces and urine mixed"

References for Table 5-16 and Table 5-17:
1) the *2019 Refinement*
2) Ishibashi et al. (2003)
3) Japan Livestock Technology Association, (2002)
4) Osada et al. (2005)
5) Osada et al. (2000)
6) Osada (2003)
7) Report of Survey Project in FY2008 (Nationwide Survey), (2009)
8) MAFF, *the Report of Project on Survey and Investigation in FY2011*, (2012)
9) Mori and Hojito (2015)
10) Tsuchiya et al. (2014)
11) MAFF, *the Report of Project on Survey and Investigation in FY2012*, (2013)
12) MAFF, *the Report of Project on Survey and Investigation in FY2013*, (2014)
13) Shiraishi et al. (2017)

Table 5-18 Annual CH_4 Emission factors for "Pit storage" and "Methane fermentation" for dairy cattle
[%: kg-CH_4/kg-organic matter]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Pit storage	2.47%	2.44%	2.42%	2.40%	2.37%	2.37%	2.37%	2.37%	2.36%	2.36%	2.36%	2.35%	2.35%	2.34%	2.34%
Methane fermentation	3.22%	3.17%	3.14%	3.11%	3.06%	3.06%	3.06%	3.05%	3.05%	3.04%	3.03%	3.03%	3.02%	3.02%	3.01%

Note: These figures are weighted averages of regional emission factors for dairy cattle from *the Report of Project in FY2011*, (MAFF 2012) by annual dairy cattle population in each region.

- ***Activity Data***

The values used for the activity data are estimates of the amount of organic matter and the amount of nitrogen excreted annually by various type of livestock by management system, respectively.

$$A_{CH4\text{-}n} = P \times Ex \times Day \times Org \times Mix_n \times MS_n / 1000$$

$$A_{N2O\text{-}n} = P \times Nex \times Day \times Mix_n \times MS_n / 1000$$

$A_{CH4\text{-}n}$: Amount of organic matter contained in manure by management system *n* by livestock [kt-organic matter/yr]
$A_{N2O\text{-}n}$: Amount of nitrogen contained in manure by management system *n* by livestock [kt-N/yr]
P : Population of each livestock [1000 heads]
Ex : Amount of feces and urine excreted per head per day from each livestock [kg/head/day]
Org : Organic matter content in feces and urine from each livestock [%]
Nex : Nitrogen content of feces and excreted per head per day from each livestock [kg-N/head/day]
Day : Days in a year [day]
Mix_n : Proportion of separated and mixed treatment of manure by type of livestock [%]
MS_n : Proportion of each manure management system by animal [%]
n : Manure management system

Total amount of organic matter by livestock was calculated by multiplying the population of each type of animal by the amount of manure per head by the organic matter content in feces or urine. Total nitrogen amount was calculated by multiplying the population of each type of animal by the nitrogen content of feces or urine excreted per head (Table 5-19). The amount of organic matter and nitrogen were allocated to each manure management system by multiplying the total amount by the proportion of separated and mixed treatment of manure and the proportion of manure management system by type of animal (Table 5-32, Table 5-33, Table 5-34).

Table 5-19 Amount of excretion (*Ex*) and amount of nitrogen in excretion (*Nex*) from dairy cattle

Item				1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dairy Cattle	Amount of excretion [kg/head/day]	Feces	Lactating (Multipara (3 and more))	41.5	43.1	44.5	46.0	46.1	46.4	46.4	46.8	47.3	47.4	47.5	47.5	48.2	48.4	48.8
			Lactating (Secundipara)	40.3	41.8	43.3	44.8	44.7	45.0	45.0	45.3	45.8	45.9	46.0	46.0	46.7	46.8	47.3
			Lactating (Primipara)	36.7	38.2	39.5	40.6	41.4	41.6	41.6	41.8	42.2	42.3	42.5	42.4	42.9	42.9	43.3
			Non-lactating	27.9	27.9	28.7	28.5	28.6	28.5	28.5	28.5	28.4	28.4	28.4	28.4	28.3	28.3	28.3
			Heifer: under 2 yr, over 6 mth	22.1	22.4	22.9	23.1	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2
			Heifer: 3 to 6 mth	14.9	14.9	15.1	15.8	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9
		Urine	Lactating (Multipara (3 and more))	16.9	16.9	17.0	17.0	17.0	17.0	17.0	16.9	16.9	16.9	16.9	16.9	16.9	16.9	17.0
			Lactating (Secundipara)	17.1	17.1	17.2	17.2	17.2	17.2	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1
			Lactating (Primipara)	18.8	18.8	18.9	18.9	18.8	18.8	18.8	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7
			Non-lactating	15.2	15.2	15.4	15.3	15.4	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3
			Heifer: under 2 yr, over 6 mth	12.3	12.3	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
			Heifer: 3 to 6 mth	4.4	4.4	4.8	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
	Amount of N in excretion [g-N/head/day]	Feces	Lactating (Multipara (3 and more))	155.7	164.4	172.7	181.7	182.1	183.8	184.0	186.0	189.1	189.6	190.1	190.4	194.7	195.5	198.2
			Lactating (Secundipara)	148.5	157.4	165.5	174.3	173.9	175.6	175.7	177.6	180.5	180.8	181.3	181.3	185.5	186.3	188.9
			Lactating (Primipara)	128.6	136.7	144.1	150.2	154.7	156.0	156.1	157.4	159.5	160.1	160.9	160.3	163.6	163.7	165.8
			Non-lactating	82.7	83.0	86.8	85.6	86.4	85.9	85.9	85.7	85.5	85.4	85.4	85.3	85.0	84.7	84.6
			Heifer: under 2 yr, over 6 mth	53.3	54.5	57.2	58.3	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5
			Heifer: 3 to 6 mth	20.6	20.7	21.6	24.3	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9
		Urine	Lactating (Multipara (3 and more))	76.1	81.0	83.2	87.9	89.5	90.5	90.8	92.1	93.5	93.9	94.2	94.2	96.4	96.9	98.0
			Lactating (Secundipara)	85.8	90.2	92.2	96.6	98.4	99.3	99.6	100.7	102.1	102.3	102.6	102.5	104.5	105.0	106.1
			Lactating (Primipara)	88.8	92.5	94.4	98.7	92.8	93.9	94.2	95.5	97.2	97.9	98.8	98.4	101.0	101.3	103.0
			Non-lactating	98.6	98.8	103.1	101.9	102.8	102.1	102.2	101.9	101.7	101.5	101.6	101.5	101.1	100.8	100.6
			Heifer: under 2 yr, over 6 mth	65.1	66.6	69.7	70.9	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1
			Heifer: 3 to 6 mth	27.4	27.6	37.4	43.1	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2

Table 5-20 Amount of excretion (*Ex*) and amount of nitrogen in excretion (*Nex*) from non-dairy cattle

Item				1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Non-dairy cattle	Amount of excretion [kg/head/day]	Feces	Breeding: 2 yr and over	17.4	17.4	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2
			under 2 yr, over 6 mth	12.6	12.6	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
			3 to 6 mth	5.9	5.9	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
			Wagyu (M): 1 yr and over	12.3	12.3	12.3	12.3	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8
			under 1 yr, over 6 mth	8.4	8.4	8.4	8.4	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
			3 to 6 mth	5.0	5.0	5.0	5.0	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
			Wagyu (F): 1 yr and over	10.0	10.0	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
			under 1 yr, over 6 mth	7.2	7.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
			3 to 6 mth	4.5	4.5	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
			Dairy breed: over 6 mth	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
			3 to 6 mth	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
			Hybrid: over 6 mth	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
			3 to 6 mth	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
		Urine	Breeding: 2 yr and over	7.1	7.1	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
			under 2 yr, over 6 mth	5.8	5.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
			3 to 6 mth	3.1	3.1	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
			Wagyu (M): 1 yr and over	7.6	7.6	7.6	7.6	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
			under 1 yr, over 6 mth	6.0	6.0	6.0	6.0	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
			3 to 6 mth	3.3	3.3	3.3	3.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
			Wagyu (F): 1 yr and over	5.2	5.2	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
			under 1 yr, over 6 mth	4.3	4.3	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
			3 to 6 mth	2.7	2.7	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
			Dairy breed: over 6 mth	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
			3 to 6 mth	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
			Hybrid: over 6 mth	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
			3 to 6 mth	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
	Amount of nitrogen in excretion [g-N/head/day]	Feces	Breeding: 2 yr and over	58.9	58.9	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8
			under 2 yr, over 6 mth	46.1	46.1	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2
			3 to 6 mth	21.5	21.5	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3
			Wagyu (M): 1 yr and over	63.5	63.5	63.5	63.5	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1
			under 1 yr, over 6 mth	48.1	48.1	48.1	48.1	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3
			3 to 6 mth	23.7	23.7	23.7	23.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7
			Wagyu (F): 1 yr and over	40.1	40.1	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4
			under 1 yr, over 6 mth	32.5	32.5	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7
			3 to 6 mth	18.7	18.7	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
			Dairy breed: over 6 mth	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3
			3 to 6 mth	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8
			Hybrid: over 6 mth	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2
			3 to 6 mth	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2
		Urine	Breeding: 2 yr and over	73.9	73.9	76.7	76.7	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9
			under 2 yr, over 6 mth	57.5	57.5	69.4	69.4	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6
			3 to 6 mth	35.5	35.5	43.6	43.6	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3
			Wagyu (M): 1 yr and over	76.9	76.9	76.9	76.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9
			under 1 yr, over 6 mth	65.1	65.1	65.1	65.1	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6
			3 to 6 mth	41.0	41.0	41.0	41.0	48.2	48.2	48.2	48.2	48.2	48.2	48.2	48.2	48.2	48.2	48.2
			Wagyu (F): 1 yr and over	49.8	49.8	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2
			under 1 yr, over 6 mth	44.8	44.8	57.5	57.5	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4
			3 to 6 mth	33.9	33.9	42.3	42.3	51.6	51.6	51.6	51.6	51.6	51.6	51.6	51.6	51.6	51.6	51.6
			Dairy breed: over 6 mth	84.2	84.2	84.2	84.2	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5
			3 to 6 mth	57.2	57.2	57.2	57.2	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8
			Hybrid: over 6 mth	82.0	82.0	82.0	82.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0
			3 to 6 mth	57.0	57.0	57.0	57.0	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8

Table 5-21 Amount of excretion (*Ex*) and amount of nitrogen in excretion (*Nex*) from swine

Item				Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Swine	Excretion	Feces	Growing-finishing	kg/head/day	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.9	1.9	1.9
			Breeding	kg/head/day	2.2	2.2	2.3	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
		Urine	Growing-finishing	kg/head/day	4.3	4.2	4.1	4.0	3.9	3.9	3.8	3.7	3.7	3.7	3.9	3.9	3.9	3.9	3.9
			Breeding	kg/head/day	5.5	5.5	5.5	5.2	5.1	5.1	4.9	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7
	Nitrogen	Feces	Growing-finishing	g-N/head/day	14.0	14.0	13.3	13.3	13.6	13.7	13.7	13.7	13.6	13.5	14.1	14.1	14.3	14.2	14.2
			Breeding	g-N/head/day	20.2	20.2	20.2	19.4	19.7	19.8	19.8	19.8	19.7	19.7	19.7	19.7	19.8	19.7	19.7
		Urine	Growing-finishing	g-N/head/day	27.9	27.6	26.8	25.9	25.3	25.2	24.5	24.1	24.0	23.9	25.3	25.2	25.3	25.2	25.2
			Breeding	g-N/head/day	36.0	35.6	35.7	33.8	33.0	33.0	31.8	31.3	31.1	31.1	31.1	30.9	30.7	30.7	30.7

Table 5-22 Nitrogen content in feces excreted for Hen and Broiler (*Nex*)

Item				Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Poultry	Excretion	Hen	Adult	kg/head/day	0.086	0.087	0.088	0.088	0.087	0.094	0.095	0.094	0.091	0.092	0.094	0.092	0.090	0.087	0.088
			Poult	kg/head/day	0.041	0.041	0.039	0.040	0.040	0.042	0.042	0.042	0.041	0.041	0.042	0.042	0.041	0.040	0.040
		Broiler		kg/head/day	0.097	0.098	0.098	0.096	0.101	0.098	0.094	0.092	0.089	0.088	0.087	0.085	0.084	0.083	0.083
	Nitrogen	Hen	Adult	g-N/head/day	2.18	2.16	2.06	1.93	1.86	1.88	1.82	1.79	1.78	1.79	1.80	1.77	1.73	1.71	1.71
			Poult	g-N/head/day	1.04	1.03	0.97	0.98	1.01	0.99	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98
		Broiler		g-N/head/day	2.06	2.04	1.95	1.75	1.86	1.69	1.56	1.54	1.53	1.52	1.54	1.47	1.45	1.45	1.47

Table 5-23 Organic matter content in feces and urine, by type of livestock (wet base) (*Org*) [1)]

Livestock species	Organic matter content	
	Feces	Urine
Dairy cattle	16%	0.5%
Non-dairy cattle	18%	2.0%[2)]
Swine	20%	1.4%[3)]
Hen	15%	―
Broiler	15%	―

Reference: 1) Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*. (2002)
2) Expert judgement
3) Estimated value based on *Guide for processing and using livestock manure*, Livestock Industry's Environmental Improvement Organization, 1998

For livestock population, same references indicated in '3.A. Enteric Fermentation' for dairy cattle non-dairy cattle and swine are used.

Livestock population for hen described in the *Livestock Statistics* are used (see the following Table 5-24) but the data in FY2004, FY2009, FY2014 and FY2019 are interpolated. For broiler from 1990 to 2008, livestock population described in the *Statistics on Livestock Products Marketing* are used. For 2009 onwards, as livestock population are not surveyed in the statistics, livestock population are estimated by using the number of shipments of broiler in the same statistics (see the following Table 5-25). 5-year average (0.170) from FY2004 to FY2008 of "livestock population" / "annual number of shipments", is multiplied by the number of shipments of each year. In addition, days of feeding to shipment are shorter than the past. Therefore, 0.919 (= 49 days/ 53.3 days), ratio of feeding days until shipment of present (*Planning for Breeding Improvement of Poultry*, 2015) and past (*Questionnaire Survey on Current Feeding Status for Broiler*, 2008) is multiplied.

Table 5-24 Livestock population for hen [1000 heads]

Livestock species	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Hen	188,786	190,634	186,202	180,697	178,546	174,784	174,806	175,270	175,733	178,900	184,350	184,917	184,145	183,373	182,661

Note: Data of non-surveyed year (in 2009, 2014 and 2019) were interpolated.
Reference: *The Livestock Statistics*

Table 5-25 Livestock population for broiler [1000 heads]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Livestock Population in statistics (broiler)	142,740	118,123	106,311	103,687											
Number of Shipment (broiler)				606,898	633,799	649,629	653,999	661,030	666,859	677,332	685,105	700,571	712,493	725,190	732,901
Livestock Population used in this inventory (broiler)	142,740	118,123	106,311	103,687	98,913	101,384	102,066	103,163	104,073	105,707	106,920	109,334	111,195	113,176	114,380

Note: From 1990 to 2008, livestock population data in the statistics are used. For 2009 onwards, estimated data by using the number of shipments are used.
Reference: MAFF, *Statistics on Livestock Products Marketing*

Amount of feces per head per day for dairy cattle is calculated by using the multiple regression equation which is written in *Japanese Feeding Standard for dairy cattle* and has two explanatory variables, DMI and Natural Detergent Fiber of organic matter (%) (NDFom). Amount of urine excreted per head per day for dairy cattle is calculated by the multiple regression equation which is written in Otani et al. (2010) and has three explanatory variables, Nitrogen Intake (NI), potassium Intake (KI) and milk yield. DMI and milk yield are used same data described in '3.A. Enteric Fermentation'. NDFom was set at 35% referred to *Japanese Feeding Standard for dairy cattle*. NI was calculated by dividing Crude Protein (CP) by 6.25. CP were calculated following with formulas in *Japanese Feeding Standard* with DMI, milk yield, weight, fat content in milk and daily gain which are same data in '3.A. Enteric Fermentation' (Table 5-28). The preferable CP content in feed dry matter is 12% and over for the most effective digestion of feed and fermentation by microorganism in rumen, described in *Japanese Feeding Standard*. Therefore, CP values are adjusted to be 12% of DMI when the calculated CP was lower than 12% of DMI. KI was set with referring to Kume et al. (2010) (Table 5-26).

Nitrogen contents in excretion per head per day for dairy cattle, for both in feces and urine, were calculated with the regression equation in Choumei et al. (2006) (Table 5-26). DMI and CP used in calculation for nitrogen contents are common to feces and urine.

Table 5-26 Equation to estimate amount of excretion and nitrogen content in excretion for dairy cattle

	Equation
Amount of feces[1)]	F = -8.4753 + 1.8657 × DMI + 0.4948 × $NDFom$ ($NDFom$: 35%)
Amount of urine[2)]	U = -2.2870 + 0.0231 × NI + 0.0581 × KI -0.3350 × $MILK$ ($NI = CP$ / 6.25)
Potassium Intake[3)]	KI = : 380g/day (Primipara) : 350g/day (2nd calving and over) : 250g/day (Non-lactating) : 220g/day (Heifer: 7 to 24 months) : 100g/day (Heifer: 3 to 6 months)
Nitrogen content in feces[4)]	$N_f = 5.01 \times DMI^{1.2}$ (Lactating) $N_f = 4.97 \times DMI^{1.21}$ (Non-lactating and Heifer)
Nitrogen content in urine[4)]	$N_u = 16.57 \times (CP / 1000 / DMI) \times 100 - 138.6$ (Lactating) $N_u = 0.24 \times (CP / 6.25)^{1.14}$ (Non-lactating and Heifer)

Note: See notation and references of Table 5-28 below.

For amount of excretion per head per day for non-dairy cattle, amount of feces and urine each are separately calculated by using DMI and TDN% provided in *Japanese Feeding Standard* for variables instead of GE and DE%, based on the equation 10.24 in the *2006 IPCC Guidelines* (Vol 4, page 10.42) which is for the dry-organic matter in excretion. The conversion factor for dietary GE per kg of dry matter (1/18.45) for converting energy unit into weight unit provided in *2006 IPCC Guidelines* was not used because DMI itself stands for weight. TDN% is the most used evaluation value of dietary energy in Japan and could be converted into DE% using the following equation:

TDN 1kg = 4.41 Mcal DE (*Japanese Feeding Standard for non-dairy cattle*)

For non-dairy cattle, percentage of moisture contents in feces for Wagyu (Male), Wagyu (Female) and Breeding cows had been decided as 80%, and that for Dairy breeds and Hybrid had been decided as 85% based on the expert judgement in the Committee for GHG Emissions Estimation Methods (FY2020). Organic matter content in urine had also been decided to be 2.0% in the Committee. Nitrogen contents in excretion per head per day for non-dairy cattle were calculated with the regression equation in Choumei et al. (2006) for both feces and urine (Table 5-27). Nitrogen content in feces is calculated in formula with a variable of DMI and nitrogen content in urine is calculated with formula with a variable CP. DMI is from Table 5-8 described above. CP is calculated with formula in Table 5-28. CP is adjusted to be 12% of DMI as same as in case of dairy cattle.

Table 5-27 Equation to estimate amount of excretion and nitrogen content in excretion for non-dairy cattle

	Equation
Amount of feces	$F = F_{dry} / (1\text{-}MC)$ $F_{dry} = DMI \times (1 - TDN\%)$ MC: 80% (Wagyu (M), Wagyu (F), Breeding) 5), 85% (Dairy breed, Hybrid) 5)
Amount of urine	$U = VSU / OC$ $VSU = DMI \times UE \times (1 - ASH)$ OC = 2.0% 5), UE = 2.0% 5), ASH = 8.0% 6)
Nitrogen content in feces4)	$N_f = 7.22 \times DMI^{1.00}$ (for dairy breeds) $N_f = 4.97 \times DMI^{1.21}$ (for other non-dairy cattle)
Nitrogen content in urine4)	$N_u = -14.96 + 0.60 \times NI$ (for dairy breeds) $N_u + N_m = 0.24 \times NI^{1.14}$ (for other non-dairy cattle) ($N_m = 0$, $NI = CP / 6.25$)

Note: See notation and references of Table 5-28 below.

Table 5-28 Equation to estimate crude protein (CP)1)

		Equation
Dairy cattle	Lactating	$CP = (CP1 + CP2) \times CFA$ $CP1 = 2.71 \times W^{0.75} / 0.6 \times$ Correction factor by calving Correction factor by calving: primipara: 1.3, 2nd calving: 1.15, 3rd calving and more: 1 $CP2 = (26.6 + 5.3 \times \text{FAT}) \times MILK / 0.65$ $CFA = 1 + MILK / 15 \times 0.04$
	Non-lactating	$CP = 2.71 \times W^{0.75} / 0.6$
	Heifer	$CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ $FN = 30 \times DMI / 6.25$ $UN = 2.75 \times W^{0.5} / 6.25$ $SP = 0.2 \times W^{0.6}$ $RP = 10 \times DG \times 23.5505 \times W^{-0.0645}$ EP = 0.51 (for body weight 120kg and over) 0.63 (for body weight 67−119kg)
Non-dairy cattle	Before 2008	$CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ $FN = 4.80 \times DMI$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$ $RP = DG \times (235 - 0.195 \times W)$ (Dairy breeds) $RP = DG \times (235 - 0.234 \times W)$ (Hybrid and Wagyu (male)) $RP = DG \times (235 - 0.293 \times W)$ (Wagyu (female) and Breeding cows (before 49 months old)) $RP = 0$ (Breeding cows (49 months old and over)) EP: 0.51 (for body weight 150kg and over) : 0.56 (for body weight 101−149kg) : 0.66 (for body weight 51−100kg) (Breeding cows, additional CP for the last 2 months of pregnancy period) $CP = DCPR / 0.75$ $DCPR = TP / 38.5 \times 30.0 / 63 / 0.6 \times 1000 + FN \times 6.25$ $TP = TP(t) - TP(t - 63)$ $TP(t) = (1.486 \times 10^{-4} \times t^3 - 4.247 \times 10^{-2} \times t^2 + 3.173 \times t - 0.328) \times$ $(-0.323 \times 10^{-6} \times t^3 + 3.000 \times 10^{-4} \times t^2 - 9.430 \times 10^{-2} \times t + 11.263) \times 6.25$ $FN = 4.80 \times 3.21 / 2.7$ (Breeding cows, additional CP for 5 months of lactation period) $CP = DCPR / 0.65$ $DCPR = 53 \times MILK$
	Since 2008	$CP = (MCP / 0.85 + MPu / 0.80) / 1.15$ $MCP = 100 \times TDN$ (except Breeding cows) $MCP = 130 \times TDN$ (Breeding cows) $MPu = MPR - MPd$ $MPR = MPm + MPg$ $MPd = 0.8 \times 0.8 \times MCP$ $MPm = (FN \times 6.25 + UN \times 6.25 + SP) / 0.67$ $FN = 4.80 \times DMI - Adj$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$ $MPg = RP / 0.492$ $RP = DG \times (235 - 0.195 \times W)$ (Dairy breeds) $RP = DG \times (235 - 0.234 \times W)$ (Hybrid and Wagyu (male)) $RP = DG \times (235 - 0.293 \times W)$ (Wagyu (female) and Breeding cows (before 49 months old) $RP = 0$ (Breeding cows (49 months old and over)) $Adj = (100 \times TDN \times 0.64 \times 0.25 \times 0.5) / 6.25$ (Other than breeding cows)

		Equation
		$Adj = (130 \times TDN \times 0.64 \times 0.25 \times 0.5) / 6.25$ (Breeding cows) (Dairy breeds under 200kg of body weight) $CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ $FN = 4.80 \times DMI$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$ $RP = DG \times (235 - 0.234 \times W)$ EP: 0.51 (Breeding cows, additional CP for the last 2 months of pregnancy period) $MPc = PP(t) / 0.65$ $PP(t) = BW / 40 \times TP(t) \times 34.37e^{-0.00262t}$ $TP(t) = 10^{3.707-5.698e\wedge 0.0022t}$ (Breeding cows, additional CP for 5 months of lactation period) $MP\ell = (38 \times MILK) / 0.65$

Note: for Table 5-26, Table 5-27 and Table 5-28

F: Feces wet weight (kg/day)
DMI: Dry matter intake (kg/day)
NDFom: Natural detergent fiber of organic matter (%)
U: Urine weight (kg/day)
NI: Nitrogen intake (kg/day)
KI: Potassium intake (kg/day)
MILK: Milk yield (kg/day)
N_f: Nitrogen content in feces (kg/day)
Nu: Nitrogen content in urine (kg/day)
CP: Crude protein (g)
F_{dry} : Feces dry weight (kg/day)
MC: Percentage of moisture contents in feces (%)
TDN%: Percentage of total digestible nutrients
VSU: Volatile solid excretion rate in urine (kg/day)
OC: Organic matter content in urine (%)
UE: Urinary energy (%)
ASH: Ash content (%)
CFA: Correction factor
W: Body weight (kg)
FAT: Fat content in milk (%)
NP: Net protein for preservation and gain for growth
EP: Conversion efficiency of crude protein to net protein on growth
FN: Metabolic fecal nitrogen for growth after ablactation (for heifers which body weight is 66kg and over) (g/day)
UN: Endogenous urinary nitrogen (g/day)
SP: Shedding skin protein (g/day)
RP: Protein accumulation associate with gain (g/day)
DG: Daily gain (kg/day)
DCPR: Digestible crude protein requirement (g/day)
TP(t): Total protein accumulation in pregnant uterus until (t) days after conception (g)
t: Days after conception (day)
MCP: Microbial crude protein (g/day)
MPu: Undigestible crude protein from feed (g/day)
TDN: Total digestible nutrients (kg/day)
MPR: Metabolic protein requirement (g/day)
MPd: Metabolic protein delivered by microbial (g/day)
MPm: Metabolic protein requirement for maintenance (g/day)
MPg: Metabolic protein requirement for growth (g/day)
Adj: Adjustment value
MPc: Metabolic protein requirement for conception (g/day)
PP(t): Protein accumulation in pregnant uterus at (t) days after conception (g/day)
BW: Birth weight (kg)
MPℓ: Metabolic protein for lactation (g/day)

Reference: 1) *Japanese Feeding Standard (for dairy cattle and non-dairy cattle)*
2) Otani et al. (2010)
3) Kume et al. (2010)
4) Chomei et al. (2006)
5) Expert judgement
6) *2006 IPCC Guidelines*, Vol.4

The amount of feces for swine was calculated by using DMI and Digestion Rate for feed (DR (%)) instead of GE and DE%, on the basis of equation 10.24 in the *2006 IPCC Guidelines*. The amount of urine was calculated on the basis of amount of nitrogen in excretion per head per day explained in below. Categorization for calculation is for 2 types as growing-finishing pig and breeding pig.

Nitrogen contents in excretion per head per day from swine are calculated by dividing the total nitrogen in excretion per head of every class by total days of raising (Estimated on the basis of *The report of the fact-finding survey for pig farming (The result of National tabulation results)*, Japan Pork Producers Association). Nitrogen contents in excretion per head is calculated by subtracting amount of nitrogen accumulated in body from amount of nitrogen intake for each body weight class written in *Japanese Feeding Standard for Swine*. Nitrogen intake was calculated by using the CP content in feeds and the amount of feed intake. The CP content in feeds is established as the average CP content in feed calculated by using the CP content in each feedstuff and the proportion of feedstuffs to feed (Estimated on the basis of *Feed bulletin*, MAFF). Nitrogen contents in feces and urine per day is calculated by multiplying the ratio between feces and urine to nitrogen contents in excretion per day (Table 5-29). Ratio of feces is calculated by dividing the nitrogen amount converted from the sum of the amount of undigested crude protein in feed, amount of excretion of endogenous crude protein and the amount of crude protein to be lost as fallen hair or skin by the nitrogen contents in excretion on the basis of Ogino et al. (2020). All remains are assumed to be allocated to urine, and therefore the proportion allocated to urine is estimated. For "CP content in milk" and "Amount of milk" of lactating sows, the values in Niwa (1994) were adopted.

Table 5-29 Equation to estimate amount of nitrogen content in excretion for swine

	Equation
Amount of feces	$F = F_{dry} / (1 - MC)$ MC: 72% [1)] $F_{dry} = DMI \times (1 - DR\%)$
Amount of urine	$U = N_u / (OC \times 0.469)$ $OC = 1.4\%$ [1)]
Nitrogen content in feces [2)]	$N_f = N_{out} \times f$ $f = (UDCP + ECP + CP_{loss}) / 6.25 / N_{out}$ $UDCP = UD \times F_{intake}$ $UD = 1 - \Sigma n\ (CPFS\text{-}n \times DCP\text{-}n)$ $ECP = 14.05 \times \Sigma i\ DMIi$ [4)] $CP_{loss} = \Sigma i\ 104.7 \times Day \times AVW^{0.75}$ [4)]
Nitrogen content in urine	$N_u = N_{out} \times u$ $u = (1 - f)$
Nitrogen content in excretion	$N_{out} = N_{in} - N_{PR}$ $N_{out} = N_{in} - N_M$ (Lactating sow) $N_{in} = (CP \times F_{intake}) / 6.25$ $F_{intake} = F_{demand} \times Day$ $N_{PR} = (149.2 \times W^{-0.0154} \times WG) / 6.25$ (Growing-finishing pigs before 2005) $N_{PR} = (-0.121 \times W + 119.2 \times WG + 25.5) / 6.25$ (Growing-finishing pigs since 2005) $N_{PR} = ((5.78 \times NWG + 103.87) / 5.56) / 6.25$ (Pregnant sows) $N_M = \Sigma (CP_M \times MILK) / 6.25$ (Lactating sows)

Note:

F: Feces wet weight (kg/day)	F_{dry}: Feces dry weight (kg/day)	MC: Percentage of moisture contents in feces (%)
DMI: Dry matter intake (kg/day)	$DR\%$: Digestion Rate for feed (%)	U: Urine weight (kg/day)
Nu: Nitrogen content in urine (kg/day)	OC: Organic matter content in urine (%)	N_f: Nitrogen content in feces (kg/day)
N_{out}: Nitrogen content in excretion (g)	f: Proportion of feces to excretion	$UDCP$: Undigested crude protein in feed (g)
ECP: Excretion of endogenous crude protein (g)	CP_{loss}: Amount of crude protein to be lost as fallen hair or skin (g)	UD: Undigestibility (%)
F_{intake}: Feed intake (kg)	n: Varieties of feedstuffs	$CPFS$: Crude protein content in feedstuffs (%)
DCP: Percentage of digestible crude protein in feedstuffs (%)	i: Body weight class for growing-finishing pigs	Day: Total days of raising (day)
AVW: Averaged body weight (kg)	u: Proportion of urine to excretion	N_{in}: Nitrogen content in feed intake (g)
N_{PR}: Nitrogen amount in accumulated protein in body (g)	N_M: Nitrogen amount in milk (g)	CP: Crude protein contents in feed intake (%)
F_{demand}: Daily demand of feed intake (kg/day)	W: Body weight (kg)	WG: Daily weight gain (kg/day)
NWG: Weight gain by pregnant sow in gestational period without conceptus (kg)	CP_M: Crude protein content in milk (%)	$MILK$: Amount of milk (g)

Reference: 1) Guide for processing and using livestock manure
2) Ogino et al. (2020)

3) *Japanese Feed Standard for Swine*
4) *NRC (2012)*

Table 5-30 CP content in feedstuffs (%) and proportion of feedstuffs in feed material

	CP content (%)[1]			Proportion of feedstuffs in feed material[2]								
				Swine			Hen			Broiler		
Name of feed material	1995	2001	2009	1995	2001	2009	1995	2001	2009	1995	2001	2009
Corn	8.8	8.0	7.6	0.471	0.503	0.541	0.589	0.606	0.581	0.485	0.444	0.427
Grain sorghum (Milo)	9.0	8.8	8.8	0.161	0.136	0.104	0.059	0.034	0.046	0.151	0.189	0.183
Wheat	12.1	12.1	12.1	0.005	0.005	0.011	0.000	0.000	0.000	0.000	0.000	0.000
Barley (Naked variety)	10.5	10.5	10.5	0.006	0.006	0.013	0.000	0.000	-	0.000	0.000	0.000
Rice	7.9	7.9	7.5	0.011	0.008	0.010	0.010	0.006	0.010	0.017	0.013	0.026
Wheat feed flour	15.5	15.5	15.5	0.010	0.008	0.008	0.000	0.000	0.001	0.001	0.001	0.003
Rye	10.9	10.4	10.0	0.029	0.024	0.004	0.000	0.000	-	0.000	0.000	0.000
Oats	9.8	9.8	9.8	0.000	0.000	0.000	-	-	-	-	-	-
Other grains	10.1	10.1	10.1	0.008	0.010	0.012	0.001	0.001	0.001	0.001	0.001	0.002
Soybean, Soybean meal	36.7	36.7	36.7	-	0.004	0.004	-	0.001	0.001	-	0.001	0.001
Other beans	25.7	25.7	25.7	-	0.000	0.000	-	0.000	-	-	0.000	-
Wheat bran / Barley bran	15.4	15.7	15.7	0.012	0.009	0.009	0.008	0.006	0.005	0.001	0.001	0.000
Rice bran	14.8	14.8	14.8	0.004	0.003	0.001	0.009	0.006	0.004	0.002	0.001	0.001
Defatted rice bran	17.7	17.5	18.6	0.006	0.007	0.007	0.009	0.008	0.008	0.001	0.001	0.001
Gluten feed	19.8	19.8	20.9	0.009	0.008	0.008	0.017	0.019	0.015	0.001	0.001	0.001
Gluten meal	51.5	51.5	51.3	0.000	0.000	0.000	0.035	0.033	0.031	0.004	0.002	0.003
Hominy feed	9.6	9.6	9.0	0.000	0.000	-	0.000	0.000	-	0.000	0.000	-
Screening pellet	12.3	12.3	12.3	0.000	0.000	-	0.000	0.000	-	-	-	-
Beat pulp	10.9	10.9	8.5	0.000	0.000	0.000	-	0.000	-	-	-	0.000
DDGS	30.8	30.8	30.8	-	-	-	-	-	-	-	-	-
Other chaff and bran	12.2	12.2	12.2	0.002	0.002	0.009	0.005	0.004	0.020	0.001	0.001	0.007
Alfalfa meal pellet cube	16.7	16.7	16.2	0.004	0.003	0.003	0.003	0.003	0.001	0.000	0.000	0.000
Soyabean meal	46.1	46.1	45.0	0.143	0.148	0.142	0.127	0.162	0.162	0.199	0.231	0.221
Rapeseed meal	37.1	37.1	37.3	0.032	0.035	0.041	0.035	0.039	0.050	0.023	0.025	0.027
Cotton seed meal	35.4	35.4	35.4	0.000	0.000	0.000	0.000	-	0.000	0.000	-	-
Other plant seed meals	32.7	32.7	32.7	0.004	0.006	0.005	0.008	0.011	0.011	0.002	0.002	0.002
Fish meal	59.8	59.8	59.6	0.014	0.010	0.008	0.023	0.014	0.010	0.021	0.011	0.009
Fish Soluble Powder	56.1	56.1	56.1	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Dried skim milk	35.8	35.8	34.6	0.005	0.004	0.002	0.000	-	-	0.000	0.000	0.000
Dried whey	12.0	12.0	12.0	0.003	0.004	0.004	0.000	0.000	0.000	-	-	0.000
Meat meal / Meat and bone meal	60.8	60.8	59.6	0.015	0.005	0.001	0.035	0.015	0.007	0.034	0.018	0.016
Feather meal	84.5	84.5	83.1	0.000	0.000	0.000	0.002	0.001	0.000	0.004	0.002	0.004
Other animal origin feed	43.5	43.5	43.3	0.001	0.000	0.001	0.001	0.001	0.002	0.004	0.004	0.008
Animal fat	0.0	0.0	0.0	0.013	0.013	0.011	0.018	0.024	0.027	0.042	0.046	0.048
Vegetable cooking oil	0.0	0.0	0.0	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.001
Molasses	9.4	9.4	9.4	0.005	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000
Feed additives	0.0	0.0	0.0	0.004	0.004	0.005	0.003	0.003	0.004	0.004	0.004	0.006
Special feed	0.0	0.0	0.0	0.016	0.019	0.018	-	-	-	-	-	-
Other feed	13.1	13.1	13.0	0.005	0.009	0.013	0.001	0.002	0.004	0.001	0.001	0.003
Amino acid	100.0	100.0	100.0	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003
Total				1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: Estimated based on references below. The values for 1995, 2001 and 2009 are extracted and shown.

Reference: 1) National Agriculture and Food Research Organization compiled, *Tables of Feed Composition in Japan*, Japan Livestock Industry Association.

2) Ministry of Agriculture, Forestry and Fisheries of Japan, *Feed bulletin*.

The amount of excretion of poultry was calculated from the feed intake per head per day, based on Equation 10.24 of the *2006 IPCC Guidelines*. Since the amount of feed intake at each growing stage of chicks is different, the amount of excretion per chick was calculated as the weighted average of the amount of excretion by the proportion of the number of chicks at each growing stage (Table 5-31).

The amount of nitrogen in the excretion of poultry per head per day, based on the method for calculating nitrogen excretion in Ogino et al. (2017), was calculated by subtracting the amount of nitrogen in the laid eggs and in the gaining body from the total amount of ingested nitrogen, assuming the remaining amount of nitrogen was excreted. Nitrogen intake was calculated by using the CP content in feed and the amount of feed intake, same with swine. Since broilers and chicks of layers do not lay eggs, only the amount of nitrogen in the gaining body was subtracted from the amount of ingested nitrogen, and the remaining amount of nitrogen was assumed to be excreted. Since the amount and composition of feed intake at each growing stage of chicks of layers were different, the amount of excretion for a chick was calculated as the weighted average of the amount of excretion by the proportion of the number of chicks at each growing stage. Feed intake, daily weight gain, CP content in daily weight gain, and body weight were drawn from the *Breeding Management Guidelines for Commercial Chicken* (GHEN Corporation CO., Ltd.).

Table 5-31 Equation to estimate amount of nitrogen content in excretion for poultry

	Equation [1]
Amount of feces	$F_{dry} = Intake \times Dry \times (1\text{-}DR\%)$ Dry : 87% [2] $F_{wet} = F_{dry} / (1 - MC)$ MC : hen 78%、broiler 80% [3]
Nitrogen content in excretion	$N_{out} = N_{in} - N_{egg} - N_{wg}$ (hen) $N_{in} = F_{intake} \times W_{egg} \times CP_{feed} / 6.25$ $N_{egg} = W_{egg} \times CP_{egg} / 6.25$ CP_{egg} : 12% [2] $N_{wg} = WG \times CP_{wg} / 6.25$ CP_{wg} : 19.2% $N_{out} = N_{in} - N_{wg}$ (chicks of layer) $N_{in} = Intake \times CP_{feed} / 6.25$ $N_{wg} = WG \times CP_{wg} / 6.25$ CP_{wg} : 19.2% $N_{out} = N_{in} - N_{pr}$ (broiler) $N_{in} = F_{intake} \times WG \times CP_{feed} / 6.25$ $N_{pr} = WG \times CP_{chiken} / 6.25$ $CP_{chicken}$: 19.2% $WG = W / 47$

Note:

F_{dry}: Feces dry weight (kg/day)	*Intake*: Amount of feed intake (g/day)	*Dry*: Dry matter fraction of feed (%)
DR%: Digestion Rate for feed (%)	F_{wet}: Feces wet weight (kg/day)	*MC*: Percentage of moisture contents in feces (%)
N_{out}: Nitrogen content in excretion (gN/day)	N_{in}: Nitrogen content in feed intake (gN/day)	N_{egg}: Nitrogen content in egg (gN/day)
N_{wg}: Nitrogen content in daily weight gain (gN/day)	F_{intake}: Feed intake (Hen: g/g-egg weight/day, broiler: g/g-body weight (47days old))	W_{egg}: Daily egg production weight (g/day)
CP_{feed}: Crude protein content in feed (%)	CP_{egg}: Crude protein content in egg (%)	*WG*: Daily weight gain (g/day)
CP_{wg}: Crude protein content in daily weight gain (%)	N_{PR}: Nitrogen amount in accumulated protein in body (g)	*W*: Body weight (47days old) (g)
$CP_{chicken}$: Crude protein content in chicken (%)		

Reference: 1) Ogino et al. (2017)
2) *Japanese Feeding Standard for Poultry*
3) Tsuiki and Harada (1997)

The "Proportion of separated and mixed treatment of manure" and "Proportion of manure management system by type of livestock" were set from percentage of treating method of manure and proportion of separated and mixed treatment of manure for 1997 in *GHGs emissions control in livestock industry Summary* (Japan Livestock Technology Association, March 2002), and *GHGs emissions control in livestock Part4*. (Japan Livestock Technology Association,1999) and percentage of treating method of manure and proportion of separated and mixed treatment of manure in the *Survey of current status for livestock manure management system 2009*, (MAFF, 2011) and in the *Survey of current status for livestock manure management system and others 2019*, (MAFF, 2021). The 1997 survey is data before enforcement of the "Act on the Appropriate Treatment and Promotion of Utilization of Livestock

Manure” which has been in force since 1999 and prohibits inappropriate manure management and induced changes of percentage of manure management. Therefore, the 1997 survey results were applied until FY1999, the 2009 survey results were applied for FY2009 and the 2019 survey results were applied since FY2019 (Table 5-32, Table 5-33 and Table 5-34). For FY2000 to FY2008 and FY2010 to FY2018, data is estimated by interpolation using the result from 1997, 2009 and 2019 survey.

Table 5-32 Proportion of separated and mixed treatment of manure, by type of livestock (Mix_n)

Livestock species	Separated			Mixed		
	~1999	2009	2019	~1999	2009	2019
Dairy cattle	60.0%	45.5%	30.9%	40.0%	54.5%	69.1%
Non-dairy cattle	7.0%	4.8%	2.5%	93.0%	95.2%	97.5%
Swine	70.0%	73.9%	76.3%	30.0%	26.1%	23.7%
Hen	100.0%	100.0%	100.0%	—	—	—
Broiler	100.0%	100.0%	100.0%	—	—	—

Note: For Hen and Broiler, the proportion is reported at the mixed in the report of survey in 2019 but the proportion is reported at the separated in the NIR due to maintaining consistency in the inventory.
Reference: Until 1999: Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*
At 2009: *Survey of current status for livestock manure management system, 2009*
At 2019: *Survey of current status for livestock manure management system and others, 2019*

Table 5-33 Proportion of manure management system by type of livestock (dairy cattle, non-dairy cattle and swine) (MS_n)

State of Manure (Separated or Mixed)		Treating method	Dairy cattle			Non-dairy cattle			Swine		
			~1999	2009	2019	~1999	2009	2019	~1999	2009	2019
Separated	Feces	Sun drying	2.8%	2.0%	2.7%	1.5%	0.9%	2.1%	7.0%	0.7%	0.8%
		Thermal drying	0%	0%	0.0%[3)]	0%	0%	0.0%	0.7%	0.1%	0.0%
		Carbonization			—			—			—
		Composting	9.0%	6.6%	9.0%	11.0%	8.1%	4.7%	62.0%	48.2%	57.9%
		Open Composting			7.9%			4.5%			26.3%
		Closed Composting			1.0%			0.2%			31.6%
		Piling	88.0%	90.1%	87.3%	87.0%	89.8%	92.9%	29.6%	49.3%	39.9%
		Pit storage (within a month)			0.5%			0.1%			0.1%
		Pit storage (over a month)			0.0%			0.1%			—
		Incineration	0.2%	0%	0.1%	0.5%	—	—	0.7%	0.6%	0.9%
		Methane fermentation		—[2)]	0.3%		—	—		0.1%	0.1%
		public sewage		0%	0.0%		—	—		—	—
		Industrial waste treatment			0.0%			0.0%			0.1%
		Pasturage		0%			—			—	
		Other		1.3%			1.2%			1.0%	0.01%
	Urine	Sun drying		0%			0%			0%	
		Composting (urine)	1.5%	1.7%	8.6%	9.0%	1.2%	19.3%	10.0%	5.4%	7.9%
		Open Composting			6.2%			17.8%			7.1%
		Closed Composting			2.5%			1.5%			0.9%
		Purification	2.5%	5.1%	5.4%	2.0%	4.4%	7.8%	45.0%	76.3%	84.3%
		Discharge			3.2%			7.2%			71.1%
		Reuse			2.1%			0.5%			13.2%
		Pit storage	96.0%	89.6%	82.1%	89.0%	91.4%	68.2%	45.0%	15.3%	6.0%
		PS (within a month)			12.4%			10.3%			2.0%
		PS (over a month)			69.7%			58.0%			4.0%
		Methane fermentation		1.9%	2.7%		0%	4.5%		0.5%	1.0%
		Public sewage		0.8%	1.1%		0.6%	0.2%		0.4%	0.6%
		Industrial waste treat.			0.0%			—			0.0%
		Other		0.9%	0.1%		2.4%	0.0%		2.1%	0.0%

State of Manure (Separated or Mixed)	Treating method	Dairy cattle			Non-dairy cattle			Swine		
		~1999	2009	2019	~1999	2009	2019	~1999	2009	2019
Mixed	Sun drying	4.4% [1)]	1.1%	1.9%	3.4% [1)]	0.7%	1.3%	6.0%	0.2%	0.2%
	Thermal drying	0%	0%	0.0%	0%	0%	―	0%	0%	―
	Carbonization			―			0.0%			―
	Composting (urine)	18.7% [1)]	22.9%	12.0%	21.8% [1)]	10.8%	14.5%	29.0%	21.3%	23.2%
	Open Composting			11.2%			13.6%			13.7%
	Closed Composting			0.7%			0.9%			9.5%
	Piling	13.1% [1)]	50.8%	45.1%	73.2% [1)]	85.7%	77.4%	20.0%	51.4%	52.1%
	Purification	0.3% [1)]	0.2%	0.2%	0%	0%	0.0%	22.0%	18.5%	12.9%
	Discharge			0.0%			0.0%			11.7%
	Reuse			0.2%			―			1.1%
	Pit storage	57.0% [1)]	15.4%	32.2%	0.6% [1)]	0.1%	5.4%	23.0%	4.0%	5.9%
	PS (within a month)			6.5%			1.8%			3.2%
	PS (over a month)			25.7%			3.6%			2.8%
	Incineration		0.1%	0.0%		0%	0.0%		0%	0.1%
	Methane fermentation		1.7%	5.9%		0%	0.1%		2.0%	4.4%
	Public sewage		0.1%	0.0%		0%	0.0%		0.7%	0.8%
	Industrial waste treat.			0.1%			0.1%			0.4%
	Pasturage	6.5% [1)]	6.5%	2.5%	1.1% [1)]	1.1%	1.2%		0%	0.0%
	Other		1.2%	0.0%		1.6%	0.0%		1.9%	0.0%

Reference: ~1999: Japan Livestock Technology Association, *GHGs emissions control in livestock Part4*.
2009: *Survey of current status for livestock manure management system, 2009*
2019: *Survey of current status for livestock manure management system and others, 2019*

Note: 1) For dairy cattle and non-dairy cattle, percentage of "Pasturage" are not indicated in Japan Livestock Association data (1999) but are indicated in the result of survey for 2009 (MAFF, 2011). Therefore, the percentages of "Pasturage" indicated in MAFF (2011) are applied to the years before 2009 consistently. In addition, each percentage of the mixed management of dairy cattle and non-dairy cattle is adjusted so that the sum of the percentages can be 100%.
2) The symbol '―' is applied to for no-existing management.
3) '0.0%' is used for the value less than a unit.
4) Blank is for non-listed item on the survey.

Table 5-34 Percentage of manure management system by type of livestock (hen and broiler) (*MSn*)

State of Manure (Separated or Mixed)		Treating method	Hen			Broiler		
			~1999	2009	2019	~1999	2009	2019
Separated	Feces	Sun drying	30.0%	8.2%	4.1%	15.0%	2.5%	0.8%
		Thermal drying	3.0%	2.2%	0.9%	0.0%	1.1%	0.3%
		Carbonization			0.2%			0.9%
		Composting	42.0%	49.6%	52.0%	5.1%	19.3%	10.8%
		Open Composting			29.0%			9.4%
		Closed Composting			23.0%			1.4%
		Piling	23.0%	36.8%	35.3%	66.9%	36.6%	27.3%
		Pit storage (within a month)			1.1%			2.3%
		Pit storage (over a month)			1.1%			1.3%
		Incineration	2.0%	1.6%	2.9%	13.0%	30.4%	46.8%
		Methane fermentation		―	0.1%		0.1%	0.3%
		Public sewage		―	―		―	―
		Industrial waste treatment			2.0%			5.8%
		Pasturage		0%	0.0%		0.1%	―
		Other		1.6%	0.2%		9.9%	3.5%

Reference: See Table 5-33 above

- ***Background information for livestock manure management in Japan***

In Europe, slurry spreading (liquid system) is major manure management system. On the other hand, in Japan, composting system ("Composting" and "Piling") are major management system. Osada et al.

(2005), which investigated emission factors by actual measurement for "Piling", described that "Proper recycling of nutritive salts from livestock compost cannot be completed only by circulation in an area where the livestock density per unit area is especially high. Thus, livestock excrement can be made more manageable through the composting process, and the resulting product can be distributed over a wide area". Composting ("Composting" and "Piling") is widely practiced in Japan because, among other things: (1) it is essential for Japanese livestock farmers to facilitate transportation and handling, because the lack of space required for the on-site reduction of manure makes it necessary to direct the manure for uses outside their farms; and (2) compost is in considerably higher demand as a fertilizer for various crops than slurry or liquid manure in Japan where fertilizers tend to be lost by heavy rain and the expectations of the protection of water quality, prevention of odor, and sanitary management are high.

- ***Reporting in Common Reporting Format (CRF)***

In the CRF, it is required to report allocation and amount of nitrogen excretion by MMS ("Anaerobic lagoons", "Liquid systems", "Daily spread", "Solid storage and dry lot", "Pasture, range and paddock", "Composting", "Digesters", "Burned for fuel or as waste", and "Other").

For cattle, swine, and poultry, Japan's country-specific manure treatment method and the implementation rates of the treatment method have been established for each type of animal. For details and correspondence of the Japanese manure treatment method to Manure management system (MMS) in CRF, see Table 5-35.

"Anaerobic Lagoons" have been reported as "NO". Because there are quite small number of livestock farmers who has enough area of field to spread manure, and it is assumed that there are no livestock farmers who use anaerobic lagoons. There are cases when manure is spread to fields in Japan, but even in these cases, stirring is conducted before the spreading. Therefore, there are no anaerobic manure management systems.

Table 5-35 Correspondence of the Japanese manure treatment method to CRF classification (Manure management system)

Classification in Japan			Classification in CRF (MMS)	Description of manure treatment method
State of Manure		Manure treatment method		
Separated	Feces	Sun drying	Solid storage and dry lot	Dried under sunlight to facilitate handling (for storage and odor prevention).
		Thermal drying	Other	Dried by heat to facilitate handling.
		Carbonization	Other	Produced carbide by pyrolyzing organic matter under high temperature in the no oxygen or the absence of oxygen.
		Composting	Composting	Fermented for several days to several weeks with forced aeration and agitation in lidded or closed tanks.
		Open composting	Composting	Fermented for several days to several weeks with forced aeration and/or agitation in open systems as scoop type composting facilities.
		Closed composting	Composting	Fermented for several days to several weeks with forced aeration and/or agitation in closed systems as closed vertical tank type composting facilities.
		Piling	Composting	Piling system is a method of composting. Piled about 1.5-2m height on compost bed or in shed to ferment for several months with occasional turning.
		Pit storage (within a month)	Liquid system	Stored in the storage tank (Slurry store etc.) within a month and utilize in agriculture by spreading to farm field or other way after storage.
		Pit storage (over a month)	Liquid system	Stored in the storage tank (Slurry store etc.) for over a month and utilize in agriculture by spreading to farm field or other way after storage.
		Incineration	Burned for fuel or as waste	For amount reduction, disposal, or use as an energy source (e.g. chicken manure boiler).
		Methane fermentation	Digesters	Slurry livestock manure is fermented under anaerobic conditions. Generated methane gas is used as an energy source.
		Public sewage	—	Released into public sewage without purification or aeration management. Emissions are included in the Waste sector.
		Industrial waste treatment	Other	Disposed as industrial waste.
		Pasture/Range/Paddock	Pasture, range and paddock	Livestock are fed on a land with vegetation to eat. N_2O Emissions are reported in the 'Urine and dung deposited by grazing animals (3.D.a.3.)'.
		Other	Other	Treated with the method not mentioned above.
	Urine	Liquid composting	Composting	Treated in an aeration storage tank.
		Open composting (aeration treatment)	Composting	Aerated in open systems.
		Closed composting (aeration treatment)	Composting	Aerated in closed systems.
		Purification	Other	Separate pollutants using aerobic microorganisms, such as activated sludge.
		Purification - discharge	Other	Discharged after removing substance causing water pollution by microorganisms in activated sludge.
		Purification - agricultural use	Other	Utilized in agriculture by spreading to farm filed or other way after removing substance causing water pollution by microorganisms in activated sludge.
		Pit storage	Liquid systems	Stored in a storage tank.
		Pit storage (within a month)	Liquid system	Same as above (Pit storage (within a month) for feces).
		Pit storage (over a month)	Liquid system	Same as above (Pit storage (over a month) for feces).
		Methane fermentation	Digesters	Same as above (Methane fermentation for feces).
		Public sewage	—	Same as above (Public sewage for feces).
		Industrial waste treatment	Other	Same as above (Industrial waste treatment for feces).
		Other	Other	Treated with the method not mentioned above.

Table 5-35 Correspondence of the Japanese manure treatment method to CRF classification (Manure management system) (Continued)

Classification in Japan		Classification in CRF (MMS)	Description of manure treatment method
State of Manure	Manure treatment method		
Mixed	Sun drying	Solid storage and dry lot	Dried under sunlight to facilitate handling.
	Thermal drying	Other	Same as above (Thermal drying).
	Carbonization	Other	Same as above (Carbonization).
	Liquid composting	Composting	Treated in an aeration storage tank.
	Open composting	Composting	Same as above (Open composting for feces).
	Closed composting	Composting	Same as above (Closed composting for feces).
	Piling	Composting	Same as above (Piling).
	Purification	Other	Same as above (Purification).
	Purification - discharge	Other	Same as above (Purification - discharge).
	Purification - agricultural use	Other	Same as above (Purification - agricultural use).
	Pit storage	Liquid systems	Stored in a storage tank (e.g. slurry storage).
	Pit storage (within a month)	Liquid system	Same as above (Pit storage (within a month)).
	Pit storage (over a month)	Liquid system	Same as above (Pit storage (over a month)).
	Methane fermentation	Digesters	Same as above (Methane fermentation).
	Public sewage	—	Same as above (Public sewage).
	Industrial waste treatment	Other	Same as above (Industrial waste treatment).
	Pasture/Range/Paddock	Pasture, range and paddock	Same as above (Pasture/Range and paddock).
	Other	Other	Treated with method not mentioned above.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the uncertainties of the CH_4 emission factors, Tier 2 values (20%) described in the *2006 IPCC Guidelines* were applied. For N_2O emission factors, uncertainty was calculated by synthesis of default uncertainties of each parameter described in the *2006 IPCC Guidelines* uncertainty.

For the uncertainties of the activity data, 1% (the standard error for swine given in the *Livestock Statistics*) was applied to swine, and 9% (the standard error for broiler given in the *Livestock Statistics*) was applied to poultry. For cattle, 1% is adopted, same as “Enteric Fermentation, Cattle”.

As a result, the uncertainties of the emissions for dairy cattle, non-dairy cattle and swine were determined to be -20% to +20% for CH_4 and -71% to +112% for N_2O, and emissions for poultry were determined to be -22% to +22% for CH_4 and -72% to +112% for N_2O.

- ***Time-series Consistency***

Emission factors were used consistently from FY1990 onward by the method. Activity data were calculated consistently from FY1990 onward from the data in the *Livestock Statistics*.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

Country-specific emission factors are used for CH_4 and N_2O emission factors for grazing cattle, and these values are lower than the value calculated from the default data described in the *2006 IPCC Guidelines*. It is guessed that andosol and brown forest soil, which drainage is well, are dominant for grazing land in Japan. Therefore, CH_4 and N_2O emission factors are low in Japan.

Country-specific emission factors are used for CH_4 and N_2O emission factors by pit storage for dairy cattle, and these values are lower than the value calculated from the default data described in *2006 IPCC Guidelines*. For CH_4, the reasons are assumed that pit storage period of slurry in Japan is comparatively shorter than other countries and the short period stored slurry is spread to agriculture and grazed meadow soil before further activation of CH_4 emissions. For N_2O, the inferred reason of lower value of the emission factor is the same as CH_4, the Japanese shorter period pit storage doesn't reach to occurrence of scum which is guessed as N_2O source.

In the inventory review, the ERT pointed out that Japan's IEFs for dairy cattle are very higher than other Annex I Parties. This reason is that "Piling" is major manure management system in Japan, and EF for "Piling" is very high. Moisture for dairy cattle feces is high, and they easily make anaerobic condition. It is considered to be the reason for high CH_4 emission factor of piling.

For emission factors by piling for poultry, hen's EF is higher than broiler's one. For CH_4, the reason is guessed to be that moisture content of manure for hen is higher than for broiler. Country-specific emission factors of N_2O by pilling for poultry is lower than the default emission factors. The reason is guessed to be that the default emission factors include not only poultry but also other animals (such as cattle and swine) (Nitrification is less likely to occur in poultry manure than cattle or swine manure).

Country-specific emission factors of N_2O for sun drying of poultry is lower than the default emission factors. The reason is guessed to be that the default emission factors include not only poultry but also other animals, which are the same reason for emission factors by piling for poultry.

e) Category-specific Recalculations

Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test*, averaged age in days of shipment in *The report of the fact-finding survey for pig farming*, and egg production and feed intake per day for hen for FY2020 were updated, the emissions from dairy cattle, swine and hen for FY2020 were recalculated. Since the equation used for the estimation of the amount of excretion for swine was revised, CH_4 emissions from swine for the whole time series were recalculated. Emission factors for "Composting – Intensive windrow" and "Composting – In Vessel" were separately established using country specific values and default values in the *2019 Refinement*, therefore, the emissions for the whole time-series were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

As research on actual emissions and information collection for emission reduction method has been continuously conducted by the organizations and agencies concerned, a review of emission factors and parameters will be implemented when the new data are obtained.

5.3.2. Buffalo, Sheep, Goats, Horses, Rabbits and Mink (3.B.2., 3.B.4.-)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions for manure management from buffalo, sheep, goats, horses, rabbits and mink.

b) Methodological Issues

- ***Estimation Method***

CH_4 and N_2O emissions were calculated by using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 4, Page 10.36, Fig 10.3 and Page 10.55, Fig. 10.4).

$$E_{CH_4} = EF_{CH_4} \times P$$

$$E_{N_2O} = \sum(EF_{N_2O\text{-}n} \times P \times Nex \times MS_n)$$

E_{CH_4} : CH_4 emissions associated with manure management [kg-CH_4/yr]

E_{N_2O} : N_2O emissions associated with manure management [kg-N_2O/yr]

EF_{CH_4} : CH_4 emission factor [kg-CH_4/head/yr]

$EF_{N_2O\text{-}n}$: N_2O emission factor of manure management *n* [kg-N_2O/kg-N]

P : Population of each livestock [head]

Nex : Nitrogen content in manure [kg-N/head/yr]

MS_n : Percentage of manure management system *n* [%]

- ***Emission Factors***

For the emission factors for CH_4, the default values for temperate zones in industrialized nations, given in the *2006 IPCC Guidelines* were used. For buffalo, the default value given for the temperate zone in Asia was used (Table 5-36).

For the emission factors for N_2O, the default values given in the *2006 IPCC Guidelines* and the *2019 Refinement* were used (Table 5-37).

Table 5-36 CH_4 emission factors for sheep, goats, horses, rabbits and mink

Livestock species	CH_4 Emission factors [kg-CH_4/head/yr]	Reference
Sheep	0.28	*2006 IPCC Guidelines*, Vol. 4, p. 10.40, Table 10.15
Goats	0.20	
Horses	2.34	
Buffalo	2	*2006 IPCC Guidelines*, Vol. 4, p. 10.39, Table 10.14
Rabbits	0.08	*2006 IPCC Guidelines*, Vol. 4, p. 10.41, Table 10.16
Mink	0.68	

Table 5-37 N_2O Emission factors for buffalo, sheep, goats, horses, rabbits and mink

Manure management system	N_2O Emission factors [%: kg-N_2O-N/kg-N]
Dry lot	2.0%
Pasture/Range/Paddock (buffalo)	0.6%
Pasture/Range/Paddock (sheep, goats, horses)	0.3%
Daily spread	0%
Burned for fuel	0%

Reference: Dry lot, Daily Spread: *2006 IPCC Guidelines*, Vol.4, page 10.62, Table 10.21,
Pasture Range and Paddock: the *2019 Refinement*, Vol.4, page 11.11, Table 11.1

- ***Activity Data***

For livestock population for sheep, goats, horses and buffalo, same data described in '3.A. Enteric Fermentation' are used (See Table 5-12). For rabbits and mink, population data in the *Statistical*

Document for small animals and laboratory animals by MAFF are used (See Table 5-38 below).

For N_2O, in order to determine the total nitrogen amount for each livestock, first, it was calculated by multiplying the population of each type of animal by the nitrogen content of manure per head of animal (or by the nitrogen amount in manure per weight and livestock weight). Then, the amount of nitrogen per manure management category was calculated by multiplying the total nitrogen by the percentage of each manure management system (Table 5-39). For the percentage of manure management system for buffalo, the default values given in the *2006 IPCC Guidelines* were used (classification is "Asia") (Table 5-40).

For rabbits and mink, percentage of manure management system usage (MS_n) is considered by expert judgment that all manure are managed by "Dry lot" because default values are not described in the *2006 IPCC Guidelines*. For the percentage of manure management system usage (MS_n) for sheep, goats and horses, the *2006 IPCC Guidelines* (Vol.4, p.10.61) described that "Manure from other animal categories is typically managed in pasture and grazing operations". Therefore, it is assumed that their livestock manures are managed by grazing system.

Table 5-38 Livestock population for rabbits and mink [1000 heads]

Livestock Species	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Rabbit	15	16	21	19	18	18	18	18	18	18	18	18	18	18	18
Mink	155	11	6	1	1	1	1	1	1	1	1	1	1	1	1

Reference: *Statistical Document for small animals and laboratory animals* (MAFF)

Table 5-39 Body weight and N excretion rate for buffalo, sheep, goats, horses, rabbits and mink (*Nex*)

Livestock species	Body weight [kg]	N excretion rate per weight [kg-N/1000kg-body weight/day]	N excretion rate [kg-N/head/yr]
Buffalo	380	0.32	(44.4)
Sheep	48.5	1.17	(20.7)
Goats	38.5	1.37	(19.3)
Horses	377	0.46	(63.3)
Rabbits	-	-	8.10
Mink	-	-	4.59

Note: Values in parentheses are calculated values using body weight and N excretion rate per weight.
Reference: *2006 IPCC Guidelines*, Vol.4, page 10.79, Table 10A-6, page 10.82, Table 10A-9, page 10.59, Table 10.19

Table 5-40 Percentage of manure management system for buffalo (MS_n)

Manure management system	Percentage
Lagoons	0%
Liquid/Slurry	0%
Solid storage	0%
Dry lot	41%
Pasture/Range/Paddock	50%
Daily spread	4%
Digester	0%
Burned for fuel	5%
Other	0%

Reference: *2006 IPCC Guidelines*, Vol.4, page 10.79, Table 10A-6

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

An uncertainty assessment was conducted for individual livestock categories. With respect to the uncertainties for emission factors for CH_4, Tier 1 default value (30%) described in the *2006 IPCC Guidelines* was applied. For N_2O, the uncertainty was calculated by synthesis of default values of each parameter described in the *2006 IPCC Guidelines*. For the activity data, uncertainty was substituted by the value of broiler (9%) described in the *Livestock Statistics*. As a result, the uncertainties of the emissions were determined to be -31% to +31% for CH_4, and -72% to +112% for N_2O for each livestock.

- ***Time-series Consistency***

For emission factors, same values were used consistently for all the years. For Activity data were calculated consistently for all the years from the data in the *Statistical Document of Livestock Breeding,* the *Statistical Document of Horse,* the *Survey Result of Feeding Livestock and Poultry* by Okinawa and the *Status Report regarding Health Management for Livestock Feeding*.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

Since N_2O emission factors for sheep, goats, horses and buffalo grazed in Pasture/Range/Paddock were revised to that in the *2019 Refinement*, the emissions for the whole time series were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no improvement plans.

5.3.3. Other Livestock (3.B.4.-)

Deer, reindeer, fox, and other poultries (duck, turkey, etc.), which are other livestock than those listed above, are reported in the *Statistical Document for Small Animals and Laboratory Animals* (MAFF). However, their population size is small, and each emission was lower than 3000t-CO_2 equivalent, which is the threshold to estimate in this GHG inventory decided by the Committee for GHG Emissions Estimation Methods. Therefore, it was not reported (See Annex 5).

5.3.4. Indirect N_2O emissions (3.B.5.)

5.3.4.1. Atmospheric Deposition (3.B.5.-)

a) Category Description

This section provides the estimation methods for N_2O indirect emissions caused by atmospheric deposition of nitrogen volatilized as NH_3 and NOx from livestock manure management.

b) Methodological Issues

- ***Estimation Method***

N_2O emissions have been calculated by Tier 2 method in accordance with decision tree of the *2019 Refinement* (Vol.4, Page 10.79, Fig. 10.4).

$$E = N_{Volatilization\text{-}MMS} \times EF \times 44 / 28$$

E	: N_2O emissions by atmospheric deposition in the process of livestock manure management [kg-N_2O/yr]
$N_{Volatilization\text{-}MMS}$	: Nitrogen amount volatilized as NH_3 and NOx in the process of livestock manure management [kg (NH_3-N+NO_X-N)/yr]
EF	: Emission factor [kg-N_2O-N/kg (NH_3-N+NO_X-N)]

- ***Emission Factors***

0.014 [kg-N_2O-N/kg-NH_3-N & NO_X-N deposited] (default value, the *2019 Refinement,* Vol.4, Page 11.26, Table11.3, Wet climate).

- ***Activity Data***

For cattle, swine, and poultry (hen and broiler), as described in the following equation, amount of nitrogen that volatilized as ammonia and nitrogen oxides from livestock manure management ($N_{Volatilizaiton\text{-}MMS}$) is calculated using the nitrogen amount included in each treatment method ($A_{N2O\text{-}i}$) which calculated in the above 5.3.1., and volatilization rate as NH_3 and NOx from manure in each livestock barn ($Frac_{GASM1i}$) and in each process of treatment ($Frac_{GASM2i}$). The volatilization rate as NH_3 and NOx from manure are estimated from data described in Hojito et al. (2003) (See Table 5-41). For "Purification", it is considered that there are not volatilized in treatment process. Indirect N_2O emissions form grazing animal are reported in 3.D.b.1.

$$N_{Volatilization\text{-}MMS} = \sum\{ A_{N2O\text{-}i} \times Frac_{GASM1i} + (A_{N2O\text{-}i} - A_{N2O\text{-}i} \times Frac_{GASM1i}) \times Frac_{GASM2i} \}$$

$N_{Volatilization\text{-}MMS}$: Nitrogen amount volatilized as NH_3 and NOx in the process of livestock manure management [kg (NH_3-N+NO_X-N)/yr]

$A_{N2O\text{-}i}$: Nitrogen amount in livestock manure by treatment method *i* [kg-N]

$Frac_{GASM1i}$: Volatilization rate as NH_3 and NO_X in livestock barn by treatment method *i* [kg-NH_3-N + NO_X-N/kg-N]

$Frac_{GASM2i}$: Volatilization rate as NH_3 and NO_X in process of treatment by treatment method *i* [kg-NH_3-N + NO_X-N/kg-N]

Table 5-41 Volatilization rate as NH_3 and NOx from manure (in livestock barn and in process of treatment)

Livestock species	Treatment method		Volatilization rate in livestock barn ($Frac_{GASM1}$)	Volatilization rate in process of treatment ($Frac_{GASM2}$)
Dairy cattle	Feces	Other than Composting	10.3%	13.7%
		Composting	10.3%	1.9%
	Urine	Other than Purification	10.3%	11.0%
		Purification	10.3%	0%
	Mixed	Other than Purification, Pit storage, Methane fermentation	4.5%	13.7%
		Purification	10.3%	0%
		Pit storage, Methane fermentation	10.3%	10.8%
Non-dairy cattle	Feces	Other than Composting	6.38%	13.7%
		Composting	6.38%	1.9%
	Urine	Other than Purification	6.38%	11%
		Purification	6.38%	0%
	Mixed	Other than Purification, Pit storage, Methane fermentation	6.38%	13.7%
		Purification	6.38%	0%
		Pit storage, Methane fermentation	6.38%	10.8%
Swine	Feces	All management	14.7%	19.7%
	Urine	Other than Purification	14.7%	27.0%
		Purification	14.7%	0%
	Mixed	Other than Purification, Pit storage, Methane fermentation	15.8%	24.2%
		Purification	14.7%	0%
		Pit storage, Methane fermentation	14.7%	25.0%
Hen and Broiler	Feces	All management	8.4%	51.5%

Reference: Hojito et al. (2003)

For buffalo, rabbits, and mink, nitrogen amount volatilized as NH_3 and NOx from manure were estimated by multiplying total nitrogen amount of manure of each livestock by default volatilization rate described in the *2006 IPCC Guidelines* (Vol.4, Page10.65, Table10.22, Other-Solid storage: 12%).

$$N_{Volatilization\text{-}MMS} = (P \times N_{ex} \times MS_n) \times Frac_{GASM}$$

$N_{Volatilization\text{-}MMS}$	: Nitrogen amount volatilized as NH_3 and NOx in the process of livestock manure management [kg (NH_3-N+NO_X-N)/yr]
P	: Population of each livestock [head]
N_{ex}	: Nitrogen content in manure per head [kg-N/head/yr]
MS_n	: Percentage of manure management *n* [%]
$Frac_{GASM}$	: Volatilization rate as NH_3 and NO_X in process of treatment for management system [%]

Table 5-42 Nitrogen amount volatilized as NH_3 and NOx in the process of livestock manure management [kt (NH_3-N+NO_X-N)]

Livestock Species	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dairy cattle	26.6	26.1	24.6	23.4	20.5	20.2	19.7	19.5	19.6	19.2	19.3	19.3	19.7	19.8	20.3
Non-dairy cattle	22.3	23.0	23.0	22.5	22.5	21.5	20.8	20.2	20.2	20.3	20.4	20.2	20.5	20.8	21.0
Swine	53.1	46.1	43.5	39.2	37.3	36.9	35.6	34.8	34.1	33.9	34.6	34.4	34.8	34.8	33.6
Poultry (Hen, Broiler)	134.0	124.4	111.5	99.7	98.1	94.4	90.4	89.4	89.7	91.0	93.6	92.5	91.3	91.0	91.1
Other livestocks (Buffalo, Mink, Rabbit)	0.10	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	236.1	219.5	202.7	184.8	178.4	173.0	166.5	163.8	163.6	164.4	167.9	166.4	166.4	166.5	166.0

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

Uncertainty (-106% to +447%) described in "Agricultural Soils (Atmospheric Deposition)" below was applied.

- ***Time-series Consistency***

For emission factors, consistent values (default values) were used in all time-series. For activity data, constant value for volatilized factor and constant estimation method for manure amount calculated in 5.3.1. were used.

d) Category-specific QA/QC and Verification

Country specific values for volatilization rate as NH_3 from manure management (Hojito et al., 2003) exclude volatilization when the manure is applied to soil to avoid double counting of the NH_3 emissions from agricultural soil in the category of atmospheric deposition (3.D.b.1), though the default values of $Frac_{GasMS}$ from *2006 IPCC Guidelines* account for N volatilization during the manure management and when the manure is applied to soil. There is a possibility that the differences between the country specific values and the default values come from differences in the boundaries between them. Furthermore, for "feces and urine mixed – Composting", in which the largest amount of excretion for dairy cattle and non-dairy cattle is treated, the low moisture content in feces due to the mixture of sub materials lead to low NH_3 volatilization during composting. Volatilization rate as NH_3 from manure for non-dairy cattle particularly tend to be lower than the default values because of the lower moisture content in feces. Thus these country specific values are considered to have high accuracy.

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

The amount of nitrogen content in excretion for dairy cattle, swine and hen were revised due to updates in the population of dairy cattle by calving in *Record of Dairy Herd Performance Test*, averaged age in days of shipment in *The report of the fact-finding survey for pig farming*, and egg production and feed intake per day for hen, resulting in the recalculation in emissions for FY2020. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Refer to the section" 5.3.1. Cattle, Swine and Poultry (Hen and Broiler)".

5.3.4.2. Nitrogen Leaching and Run-off (3.B.5.-)

In Japan, under the "*Act on the Appropriate Treatment and Promotion of Utilization of Livestock Manure*", taking some measures to prevent flowing wastewater out of manure management, such as introducing concrete-clad floor, or using waterproof sheet, is required; so, the possibility of nitrogen leaching and run-off to subsurface water is very low. Therefore, this source is reported as "NO".

5.4. Rice Cultivation (3.C.)

CH_4 is generated under anaerobic conditions by microbes' activity. Therefore, paddy fields provide favorable conditions for CH_4 generation. In Japan, all paddy fields are irrigated, and intermittently and continuously flooded paddy fields are targeted in this category. In Japan, rice cultivation is practiced mainly on intermittently flooded paddy field.

CH_4 emissions from rice cultivation in FY2021 are 11,942 kt-CO_2 eq., comprising 1.0% of total emissions (excluding LULUCF). The value represents a decrease by 1.5% from FY1990.

Table 5-43 CH_4 emissions from rice cultivation (3.C.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CH_4	3.C.1.- Continuously flooded	kt-CH_4	68.5	74.9	69.1	67.6	68.3	65.0	67.6	67.8	67.0	67.6	67.0	66.3	65.7	65.8	65.5
	3.C.1.- Intermittently flooded		416.6	448.8	418.0	421.1	419.1	395.5	415.5	416.3	410.6	417.6	416.0	413.7	411.5	412.5	412.2
	Total	kt-CH_4	485.2	523.7	487.0	488.6	487.4	460.4	483.1	484.1	477.6	485.1	483.0	480.0	477.2	478.3	477.7
		kt-CO_2 eq.	12,129	13,092	12,175	12,216	12,185	11,511	12,078	12,101	11,941	12,128	12,075	12,000	11,931	11,958	11,942

5.4.1. Irrigated (Intermittently Flooded (Single Aeration) and Continuously Flooded) (3.C.1.)

a) Category Description

This section provides the estimation methods for CH_4 emissions from intermittently flooded and continuously flooded rice cultivation.

- ***Water management regime in Japanese paddy fields***

The general practice of mid-season drainage and subsequent intermittent flooding by paddy farmers in Japan is different in nature from the intermittently flooded paddy field (multi aeration) concept in the *2006 IPCC Guidelines*. Therefore, Japan reports its practice as "Intermittent flooding (Single aeration)" in the CRF (Figure 5-4 presents the outline). Intermittently flooded paddy fields with prolonged mid-season drainage for the mitigation of CH_4 emissions is included in this sub-category.

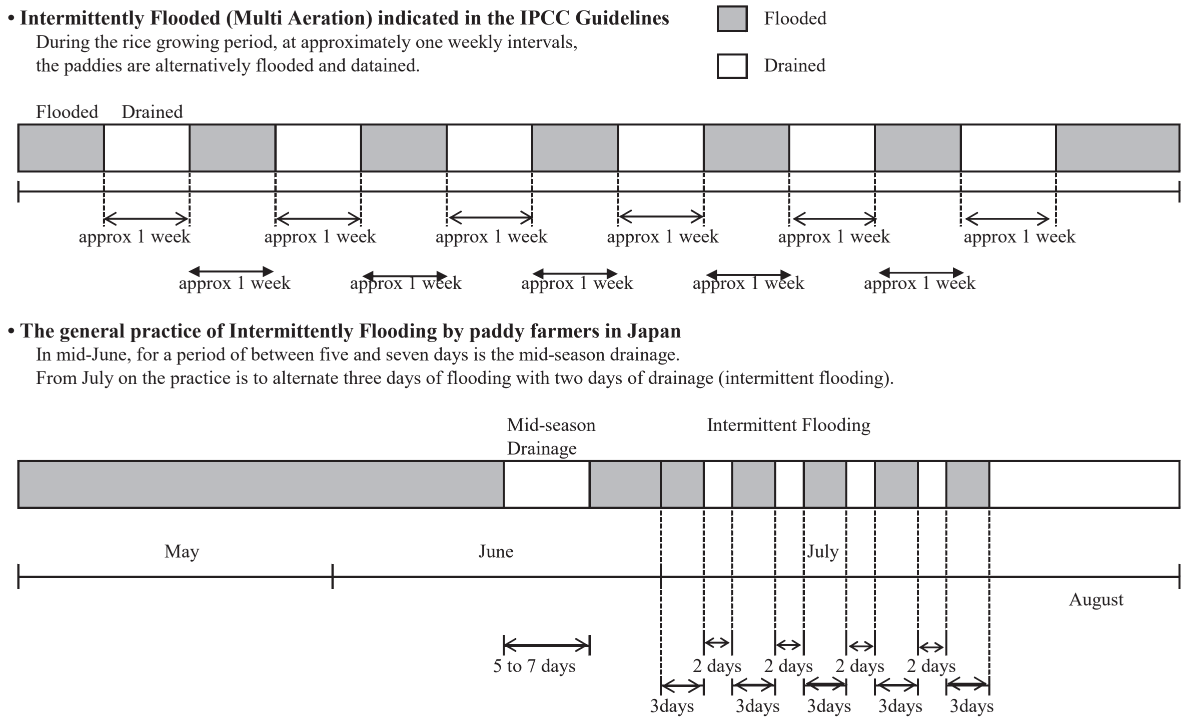


Figure 5-4 Comparison of water management regime in Japan and intermittent flooding (multi aeration) indicated in the *2006 IPCC Guidelines*

b) Methodological Issues

● *Estimation Method*

Based on the calculation method in the *2006 IPCC Guidelines*, the emissions were estimated using emission factors calculated by the regression formula of CH_4 emission flux estimated by DeNitrification-DeComposition-Rice model (DNDC-Rice model, Fumoto et al. (2010)), which is the mathematical model to estimate change of CH_4 emissions with methods of organic matter application and/or water regime on paddy field, and the following formula established on the basis of the model. The DNDC-Rice model, the improved model, is based on the DNDC model and has developed in Japan so as to estimate CH_4 emissions from paddy field in Japan. Figure 5-5 is a conceptual scheme of the DNDC-Rice model.

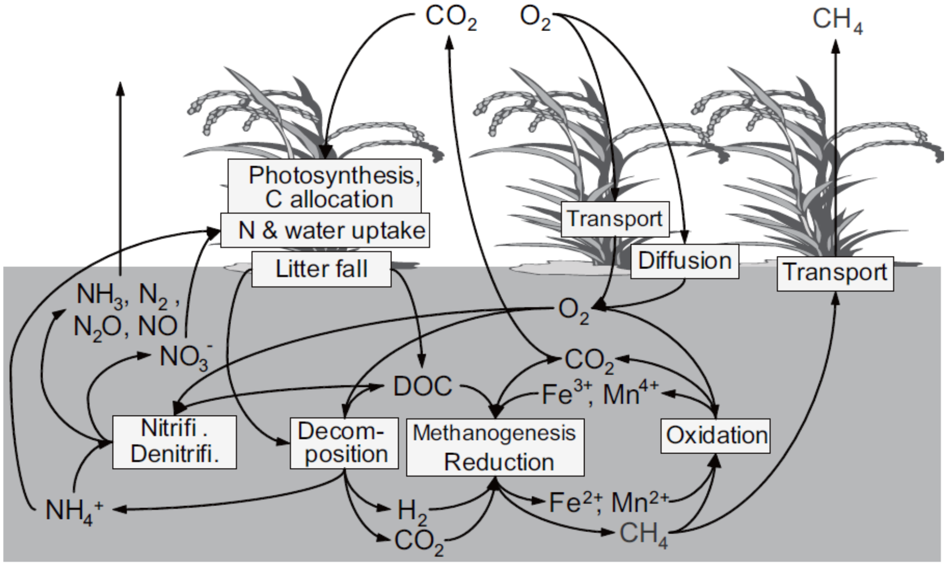


Figure 5-5 Conceptual scheme of the DNDC-Rice model

Reference: Fumoto et al. (2010)

Tier3 method (DNDC-Rice model) was used to establish emission factor, and modified Tier2 method was used to estimate emissions. The area for paddy fields with prolonged mid-season drainage were extracted, and percentage of CH_4 emission reduction (30%) was used as a parameter of the emission factor for it.

Estimation method used in this section was developed through discussion in the Committee for Greenhouse Gas Emissions Estimation Methods on the basis of a paper of Katayanagi et al. (2016), Katayanagi et al. (2017) and relevant paper.

$$E = \sum_{i,j,k,l,m} \{(A_{i,m} \times f_{Di,j} \times f_{Wi,k} \times f_{Ol}) \times EF_{i,j,k,l,m}\} \times 16 / 12$$

$$EF = aX + b$$

E	: CH_4 emissions from paddy field [kgCH_4/yr]
i	: Region (7 regions in Japan)
j	: Type of drainage (Poorly drained, one day drained, 4 hours drained)
k	: Type of water regime (Intermittently flooded, continuously flooded)
l	: Type of organic matter application (rice straw, compost, non-amendment)
m	: Type of mid-season drainage (prolonged, conventional)
A	: Crop area of rice paddy field by region [ha]
f_D	: Proportion of drainage
f_W	: Proportion of water regime
f_O	: Proportion of organic matter application
EF	: EFs by region, drainage, water regime, organic matter application, prolonged mid-season drainage [kgCH_4-C/ha/yr]
X	: Amount of organic matter [t-C/ha/yr]
a	: Slope (from the regression formula for CH_4 emissions calculated by the DNDC-Rice model and amount of organic matter)
b	: Intercept (from the regression formula for CH_4 emissions calculated by the DNDC-Rice model and amount of organic matter)

- ***Emission Factors***

The DNDC-Rice model was used to calculate the emission factor.

EFs were established on the basis of the information on nationwide 986 points of paddy field. The input data are soil (soil organic carbon content, pH, clay content, dry density, etc.), field drainage (maximum drainage rate), meteorological data (temperature, precipitation), and field management information (the day of transplantation, harvest date, plowing date, tillage method, fertilization date, fertilizer amount, organic matter application date, amount of organic matter application, organic C/N ratio, flooded date, drained date). The following are input data and references.

- Soil physical and chemical properties: data in 986 points described in the *Basic Survey of Soil Environment* (MAFF), which includes all data needed to be input in the DNDC-Rice model
- Field drainage: Maximum drainage rate of survey sites were set as 15 mm day^{-1}, 10 mm day^{-1} and 5 mm day^{-1} based on the data provided in "Flooded Situation" (4 hours drained, one day drained, poor drainage) in *Fourth Basic Survey on Infrastructure Development of Land Use* (MAFF)
- Meteorological data: Daily lowest temperature, daily highest temperature, and precipitation of the nearest AMeDAS point from each survey site were used.
- Field management information: data set created by Hayano et al. (2013) which were divided the whole Japan to 136 regions in accordance with the primary subdivision area by Japan Meteorological Agency and included cultivated history on the basis of the data published by Japan Agricultural Cooperatives or similar organization in each region were used.
- Amount of organic matter application: By using the method described by Yagasaki and Shirato (2014), application amount of compost and rice straw plowed into soil by each prefecture in 1981 to 2019 were estimated. In other words, the amount of rice straw plowed into soil were estimated by multiplying rice straw yield estimated from the yield of paddy rice in normal years by the percentage plowed into the soil, then, by dividing the value by the rice cropping area. For amount of compost application, the average application amount per 10a in Production Cost of Rice in the *Statistics on Farm Management* (MAFF) is used.

Using the DNDC-Rice model and the above input data, CH_4 flux of each 986 points from 1981 to 2010 (30 years) were estimated by total 8 scenarios (water management 2 scenarios (intermittently flooded and continuously flooded) and organic matter applied 4 scenarios (straw and compost[1], rice straw only, compost only, non-organic matter). Taking into account statistical significant difference of their results, CH_4 flux were sorted out by seven regions, drainage (3 levels), water regime, and organic matter application, and estimated averages of each year by each classification. In addition, the regression equation (linear function) to predict CH_4 flux (mean values for each year of each category) were determined by amount of organic matter application. Intercept "b" of the regression equation were fixed to the CH_4 emissions flux estimated non-organic application scenario.

Total amount of organic matter application by prefecture which was estimated by the method described in Yagasaki and Shirato (2014) were aggregated to region level. In addition, to induce amount of organic

1 The application scenario "straw and compost" was constructed in the model. However, since proportion of organic matter management to input both straw and compost in Japan (f_O) is not available, its scenario is not used for inventory emission estimation.

matter application by region and application type (*X*) which are used in estimation for the inventory, their data of total amount of organic matter by region and proportion of organic matter management (Table 5-49) were used. The proportion of organic matter management is based on the survey result of *Basic Survey of Soil Environment*, *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*, *The Project of Basic Survey on Greenhouse Gas Emission Estimation from Agricultural Land Soil*, and *The Project of Basic Survey for Carbon Stock on Agricultural Land Soil*. Amount of organic matter application in each input segment by region and the emission factor of each segment calculated these input, and they are shown in Table 5-44, and Table 5-45 below, respectively.

For "Intermittently flooded paddy fields with prolonged mid-season drainage", the emission factors were established by multiplying the emission factor of "Intermittently flooded paddy fields with conventional mid-season drainage" by (1-0.3), using percentage of CH_4 emission reduction (30%) derived from Itoh et al. (2011).

Table 5-44 Amount of organic matter application by region and type (*X*) [t-C/ha/yr]

Item		1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Rice straw	Hokkaido	1.73	1.74	1.92	2.03	2.12	1.95	1.96	1.98	2.06	2.09	2.09	2.06	2.04	2.07	2.08
	Tohoku	1.49	1.73	2.02	2.11	2.07	1.88	1.95	1.96	2.05	2.11	2.12	2.13	2.11	2.15	2.15
	Hokuriku	2.69	2.62	2.74	2.82	2.75	2.46	2.45	2.43	2.49	2.53	2.54	2.55	2.53	2.56	2.57
	Kanto	1.32	1.49	1.77	1.96	1.96	1.76	1.80	1.79	1.85	1.88	1.89	1.90	1.88	1.91	1.91
	Tokai and Kinki	2.01	1.98	2.22	2.33	2.23	1.96	2.01	2.04	2.13	2.23	2.24	2.22	2.19	2.22	2.22
	Chugoku and Shikoku	1.74	1.83	2.10	2.13	2.15	1.92	1.93	1.91	1.98	2.01	2.02	1.94	1.92	1.94	1.94
	Kyusyu and Okinawa	1.17	1.14	1.26	1.36	1.40	1.18	1.24	1.25	1.30	1.32	1.32	1.32	1.31	1.32	1.32
Compost	Hokkaido	1.69	1.86	2.10	2.05	2.18	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04
	Tohoku	1.69	1.86	2.10	2.05	2.18	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04
	Hokuriku	1.69	1.86	2.10	2.05	2.18	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04
	Kanto	1.69	1.86	2.10	2.05	2.18	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04
	Tokai and Kinki	1.69	1.86	2.10	2.05	2.18	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04
	Chugoku and Shikoku	1.69	1.86	2.10	2.05	2.18	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04
	Kyusyu and Okinawa	1.69	1.86	2.10	2.05	2.18	1.96	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04

Table 5-45 CH_4 emission factors in each segment (conventional mid-season drainage) [kg-CH_4-C/ha/yr]

Item			1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Poorly drained field, Continuously flooded	Rice straw	Hokkaido	585	588	636	665	690	646	647	652	676	682	682	675	669	677	679
		Tohoku	573	636	714	739	727	678	696	699	722	739	742	745	739	749	751
		Hokuriku	741	725	753	772	754	687	684	679	694	702	705	708	702	710	712
		Kanto	181	202	237	260	259	235	240	238	246	250	251	252	250	253	253
		Tokai and Kinki	436	429	477	499	478	426	435	441	459	479	482	477	472	477	477
		Chugoku and Shikoku	422	439	491	499	501	455	458	455	468	474	476	460	456	460	460
		Kyusyu and Okinawa	158	155	169	181	186	159	167	168	174	176	177	177	175	177	177
	Compost	Hokkaido	574	621	686	670	708	646	621	654	624	657	638	618	678	634	669
		Tohoku	627	673	736	721	758	698	673	705	676	708	689	670	729	686	720
		Hokuriku	507	548	603	590	622	569	548	576	550	579	562	545	596	559	589
		Kanto	226	248	277	270	287	259	248	263	249	264	255	246	273	254	269
		Tokai and Kinki	372	406	454	443	470	425	407	430	409	433	419	404	448	416	441
		Chugoku and Shikoku	411	445	492	481	508	464	446	469	448	471	457	443	486	455	480
		Kyusyu and Okinawa	221	242	271	264	281	254	243	257	244	258	250	241	268	248	264
	No-amendment	Hokkaido	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114
		Tohoku	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175
		Hokuriku	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113
		Kanto	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
		Tokai and Kinki	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
		Chugoku and Shikoku	77	77	77	77	77	77	77	77	77	77	77	77	77	77	77
		Kyusyu and Okinawa	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Poorly drained field, Intermittently flooded	Rice straw	Hokkaido	585	588	636	665	690	646	647	652	676	682	682	675	669	677	679
		Tohoku	547	610	687	711	700	651	669	672	694	711	715	717	711	721	723
		Hokuriku	552	539	562	578	563	507	505	501	513	520	522	525	520	526	528
		Kanto	164	182	213	234	233	212	216	215	221	226	226	227	225	228	228
		Tokai and Kinki	352	346	386	405	388	344	352	357	371	388	391	387	382	387	386
		Chugoku and Shikoku	377	393	441	448	450	408	411	407	419	426	427	412	408	413	413
		Kyusyu and Okinawa	139	136	148	159	162	139	146	147	152	154	154	155	153	155	155
	Compost	Hokkaido	574	621	686	670	708	646	621	654	624	657	638	618	678	634	669
		Tohoku	600	646	709	694	730	670	646	678	649	681	662	643	701	659	693
		Hokuriku	359	392	438	427	454	410	393	416	395	418	404	390	433	402	426
		Kanto	204	223	250	243	259	234	223	237	225	238	230	222	246	229	243
		Tokai and Kinki	300	328	367	358	381	343	328	348	330	350	338	326	362	336	357
		Chugoku and Shikoku	367	399	442	432	457	416	399	421	401	423	410	397	437	408	431
		Kyusyu and Okinawa	192	210	235	229	243	220	210	223	211	224	216	209	232	215	228
	No-amendment	Hokkaido	114	114	114	114	114	114	114	114	114	114	114	114	114	114	114
		Tohoku	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153
		Hokuriku	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
		Kanto	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
		Tokai and Kinki	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		Chugoku and Shikoku	57	57	57	57	57	57	57	57	57	57	57	57	57	57	57
		Kyusyu and Okinawa	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
One day drained field, Continuously flooded	Rice straw	Hokkaido	342	344	375	394	410	381	382	385	400	405	405	400	396	402	403
		Tohoku	423	471	530	549	540	503	516	519	536	549	552	553	549	557	558
		Hokuriku	556	543	566	581	566	512	510	506	517	525	526	529	524	531	532
		Kanto	122	135	157	172	171	156	159	158	163	166	166	167	165	167	167
		Tokai and Kinki	198	194	217	228	218	193	197	200	209	218	220	218	215	217	217
		Chugoku and Shikoku	166	174	196	199	201	181	182	180	186	189	190	183	181	183	183
		Kyusyu and Okinawa	131	129	141	151	155	132	139	140	145	147	147	147	146	147	147
	Compost	Hokkaido	335	365	407	397	421	381	366	386	367	389	376	364	402	374	396
		Tohoku	463	499	547	536	564	517	499	523	501	526	511	497	541	509	535
		Hokuriku	366	399	444	433	459	416	399	422	401	424	411	397	438	408	432
		Kanto	151	164	183	179	189	171	164	174	165	175	169	163	181	168	178
		Tokai and Kinki	167	184	206	201	214	192	184	195	185	196	189	183	203	188	200
		Chugoku and Shikoku	162	176	197	192	204	184	176	187	177	188	182	176	194	181	191
		Kyusyu and Okinawa	185	202	227	221	235	212	203	215	204	216	209	202	224	208	221
	No-amendment	Hokkaido	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
		Tohoku	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
		Hokuriku	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
		Kanto	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
		Tokai and Kinki	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
		Chugoku and Shikoku	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
		Kyusyu and Okinawa	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
One day drained field, Intermittently flooded	Rice straw	Hokkaido	236	237	259	272	284	263	264	266	277	280	280	277	274	278	279
		Tohoku	297	333	378	392	385	357	367	369	382	392	394	395	392	397	398
		Hokuriku	403	393	410	421	410	371	369	366	375	380	381	383	380	384	385
		Kanto	90	100	116	127	126	115	117	117	120	122	123	123	122	123	123
		Tokai and Kinki	89	87	98	103	98	87	89	90	94	98	99	98	97	98	98
		Chugoku and Shikoku	88	92	105	107	107	96	97	96	99	101	101	98	96	98	98
		Kyusyu and Okinawa	75	73	80	86	88	75	79	80	82	84	84	84	83	84	84
	Compost	Hokkaido	231	252	281	275	292	264	252	267	254	269	260	251	278	258	274
		Tohoku	328	354	390	382	403	368	354	372	356	374	363	353	386	362	381
		Hokuriku	264	288	321	313	332	301	289	305	290	307	297	287	317	295	313
		Kanto	111	121	135	131	139	126	121	128	122	129	125	120	133	124	131
		Tokai and Kinki	75	83	93	90	96	87	83	88	83	88	85	82	92	85	90
		Chugoku and Shikoku	86	94	105	103	109	98	94	100	95	100	97	94	104	96	102
		Kyusyu and Okinawa	105	115	129	126	134	121	116	123	116	123	119	115	128	118	126
	No-amendment	Hokkaido	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		Tohoku	71	71	71	71	71	71	71	71	71	71	71	71	71	71	71
		Hokuriku	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
		Kanto	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		Tokai and Kinki	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
		Chugoku and Shikoku	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
		Kyusyu and Okinawa	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7

Table 5-45 CH_4 emission factors in each segment (conventional mid-season drainage) [kgCH4-C/ha/yr] (Continued)

Item			1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
4 hour drained field, Continuously flooded	Rice straw	Hokkaido	308	310	338	355	369	343	344	347	361	365	365	361	357	362	363
		Tohoku	385	431	488	506	497	462	475	477	493	506	508	510	506	513	514
		Hokuriku	529	516	538	553	539	487	485	481	492	499	501	503	499	505	506
		Kanto	163	180	209	228	228	207	211	210	216	220	221	222	220	222	223
		Tokai and Kinki	212	208	232	243	233	207	212	215	224	233	235	233	230	233	232
		Chugoku and Shikoku	225	235	266	270	271	245	247	245	252	256	257	248	245	248	248
		Kyusyu and Okinawa	157	154	169	181	185	158	166	167	173	176	176	176	174	176	176
	Compost	Hokkaido	302	329	367	358	380	344	329	348	331	350	339	328	362	337	357
		Tohoku	424	458	504	493	520	476	458	481	460	484	470	456	498	467	492
		Hokuriku	348	379	422	412	437	396	380	401	382	403	390	378	417	388	411
		Kanto	201	218	243	237	251	228	218	231	219	232	225	217	240	223	236
		Tokai and Kinki	180	197	221	215	229	207	198	209	199	211	203	196	218	202	215
		Chugoku and Shikoku	220	239	266	260	275	250	239	253	240	254	246	238	263	245	259
		Kyusyu and Okinawa	222	243	272	265	282	254	243	258	244	259	250	242	269	249	264
	No-amendment	Hokkaido	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
		Tohoku	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
		Hokuriku	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
		Kanto	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
		Tokai and Kinki	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
		Chugoku and Shikoku	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
		Kyusyu and Okinawa	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
4 hour drained field, Intermittently flooded	Rice straw	Hokkaido	171	172	188	198	206	191	192	193	201	203	203	201	199	202	203
		Tohoku	268	301	342	355	349	323	333	334	346	355	357	358	355	360	361
		Hokuriku	356	347	362	372	362	327	326	323	331	335	336	338	335	339	340
		Kanto	111	123	144	157	157	142	145	145	149	151	152	153	151	153	153
		Tokai and Kinki	119	117	130	137	131	116	119	120	125	131	132	131	129	131	130
		Chugoku and Shikoku	156	163	184	187	188	169	170	169	174	177	178	171	169	171	171
		Kyusyu and Okinawa	93	91	100	107	109	93	98	99	102	104	104	104	103	104	104
	Compost	Hokkaido	167	183	205	200	212	191	183	194	184	195	189	182	202	188	199
		Tohoku	296	320	354	346	365	333	321	337	322	339	329	319	350	327	345
		Hokuriku	232	253	282	276	293	264	253	268	255	269	261	252	279	259	275
		Kanto	138	150	167	163	173	157	150	159	151	160	154	149	165	154	163
		Tokai and Kinki	101	111	124	121	129	116	111	117	111	118	114	110	122	113	120
		Chugoku and Shikoku	152	165	184	180	191	173	165	175	166	176	170	164	182	169	179
		Kyusyu and Okinawa	131	144	161	157	167	151	144	153	145	154	148	143	159	147	157
	No-amendment	Hokkaido	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
		Tohoku	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59
		Hokuriku	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
		Kanto	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
		Tokai and Kinki	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
		Chugoku and Shikoku	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
		Kyusyu and Okinawa	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7

- ***Activity Data***

For area of paddy rice field by region (*A*), data described in the *"Statistics of Cultivated and Planted Area"* by MAFF were used. For drainage (f_D), proportion of water regime (f_w), proportion of organic matter (f_O), survey data by MAFF etc. described in Table 5-46 to Table 5-49 were used respectively.

Area of paddy fields with "prolonged mid-season drainage" in the status report of *"the Direct Payments for Environmentally Friendly Agriculture* (MAFF)", with mid-season drainage of more than 14 consecutive days, were determined as area of "Intermittently flooded paddy fields with prolonged mid-season drainage". Prolonging mid-season drainage is assumed to have been started since FY2015 based on the available data indicating that the direct payment for "prolonged mid-season drainage" had been started from FY2015.

Table 5-46 Area of paddy fields by region (*A*) [kha]

Item		1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Conventional midseason drainage	Hokkaido	146	163	135	119	115	113	113	112	111	108	107	106	106	105	103
	Tohoku	525	539	456	444	429	414	419	419	414	413	412	412	412	408	407
	Hokuriku	258	260	221	218	213	213	215	216	214	213	212	213	213	212	211
	Kanto	386	390	336	331	322	324	324	323	322	320	318	316	314	312	310
	Tokai and Kinki	261	264	217	208	199	198	198	196	182	179	177	178	177	176	174
	Chugoku and Shikoku	236	232	187	182	178	175	175	173	170	167	165	162	159	157	155
	Kyusyu and Okinawa	246	251	207	206	201	203	203	201	199	196	195	192	192	190	188
	Total	2,058	2,098	1,758	1,708	1,657	1,640	1,647	1,639	1,609	1,597	1,586	1,579	1,572	1,560	1,549
Prolonged midseason drainage	Hokkaido	—	—	—	—	—	—	—	—	0	0	0	0	0	0	0
	Tohoku	—	—	—	—	—	—	—	—	2	1	1	1	1	3	3
	Hokuriku	—	—	—	—	—	—	—	—	0	0	0	0	0	0	0
	Kanto	—	—	—	—	—	—	—	—	0	0	0	0	0	0	1
	Tokai and Kinki	—	—	—	—	—	—	—	—	11	12	13	11	12	11	11
	Chugoku and Shikoku	—	—	—	—	—	—	—	—	0	0	0	0	0	0	0
	Kyusyu and Okinawa	—	—	—	—	—	—	—	—	0	0	0	0	0	0	0
	Total	—	—	—	—	—	—	—	—	13	14	14	12	13	15	15

Note: Upon the estimation, Tokai and Kinki regions are aggregated as one region
Reference: *Statistics of Cultivated and Planted Area* (MAFF) and *the Direct Payments for Environmentally Friendly Agriculture* (MAFF)

Table 5-47 Proportion of drainage (f_D)

Region	4 hours drained	One day drained	Poorly drained
Hokkaido	51%	42%	7%
Tohoku	63%	31%	6%
Hokuriku	69%	26%	4%
Kanto	59%	32%	9%
Tokai and Kinki	69%	23%	8%
Chugoku and Shikoku	65%	27%	8%
Kyusyu and Okinawa	74%	21%	5%

Reference: *Fourth Basic Survey on Infrastructure Development of Land Use*

Table 5-48 Proportion of water regime (f_w)

Region	Continuously flooded	Intermittently flooded
Hokkaido	48%	52%
Tohoku	5%	95%
Hokuriku	4%	96%
Kanto	14%	86%
Tokai and Kinki	11%	89%
Chugoku and Shikoku	8%	92%
Kyusyu and Okinawa	7%	93%

Reference: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*

Table 5-49 Proportion of organic matter management in Japan (f_O)

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Straw amendment	63%	70%	71%	72%	74%	82%	84%	85%	83%	82%	82%	82%	83%	82%	82%
Various compost amendment	17%	10%	9%	8%	9%	6%	7%	6%	5%	6%	6%	6%	5%	6%	6%
No-amendment	20%	20%	20%	20%	17%	12%	9%	9%	12%	12%	12%	12%	12%	12%	12%

Reference: 1990-2007: *Basic Survey of Soil Environment*
2008-2012: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*
2013-2014: *The Project of Basic Survey on Greenhouse Gas Emissions from Agricultural Land Soils*
Since 2015: *The Project of Basic Survey for Carbon Stock on Agricultural Land Soil*

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the emission factors, uncertainty (6%) was calculated by the DNDC-Rice model. For the uncertainty of the activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied. As a result, the uncertainties of the emissions were determined to be 6%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

Comparison of CH_4 emissions calculated by the DNDC-Rice model and emissions of actually measured data in the field was discussed and reported in the paper by Minamikawa et al. (2014), Fumoto et al. (2010), and Katayanagi et al. (2016). Figure 5-6 is comparison of annual methane emission between values observed and values simulated by the DNDC-Rice model described in Katayanagi et al. (2016). The Paper reports that simulated CH_4 emission was strongly and significantly correlated with the observations (r=0.861), reflecting the variations caused by differences among the sites and the treatments.

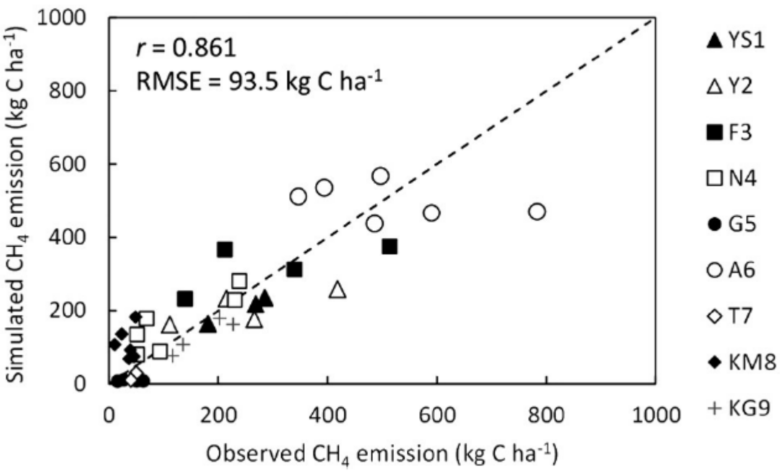


Figure 5-6 Comparison of annual methane emission between values obserbed and values simulated by the DNDC-Rice model

Reference: Quoted from Figure 3 in Katayanagi et al. (2016)

In addition, validation of application of the emission factors calculated by the DNDC-Rice model, into Japan's inventory has been conducted in Katayanagi et al. (2016) and also has been discussed in the Agriculture Breakout Group on the Committee of GHG Emission Estimation Methods.

e) Category-specific Recalculations

The calculation method for emissions from Intermittently flooded paddy fields with prolonged mid-season drainage was revised to that using percentages of emission reduction in CH_4, therefore, emissions since FY2015 were recalculated. Emissions since FY2018 were recalculated due to the revisions in the amount of organic matter application for DNDC-Rice model since FY2018. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

In the future, if the research on the DNDC-Rice model progress and the model are improved and updated, application of the improved version will be considered.

5.4.2. Rainfed, Deep Water and Other (3.C.2., 3.C.3., 3.C.4.)

As indicated in the *World Rice Statistics 1993–94*, International Rice Research Institute (IRRI) (1995), rainfed and deep water paddy fields do not exist in Japan. Therefore, this category has been reported as "NO".

Just as indicated in IRRI (1995), a possible source of emissions for other rice cultivation system is upland rice, but since upland rice field are not flooded, the soil condition is aerobic. The bacteria that generate CH_4 are obligatory anaerobic bacterium, and unless the soil is maintained in an anaerobic state, CH_4 will not be emitted. As generation of CH_4 is not feasible, this category was reported as "NA".

5.5. Agricultural Soils (3.D.)

This section provides the estimation methods for N_2O direct emissions from soils (by applied inorganic N fertilizers, organic fertilizers, grazing livestock manure, crop residue, mineralization by soil carbon loss, and plowing of organic soil), and for N_2O indirect emissions (by atmospheric deposition, and nitrogen leaching and run-off).

N_2O emissions from agricultural soils in FY2021 are 5,628 kt-CO_2 eq., comprising 0.5% of total emissions (excluding LULUCF). The value represents a decrease by 23.3% from FY1990. Main drivers of the emission reduction from FY1990 are decreases of nitrogen amount applied to soil of inorganic fertilizer and organic fertilizer from livestock manure. The main reasons of their decrease of fertilizer are that the area of cropping has been decreasing (Table 5-56) and reducing the usage of fertilizer has been recommended to mitigate nitrogen pollution in groundwater in some areas.

Table 5-50 N_2O emissions from agricultural soils (3.D.)

Gas	Item		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N_2O	3.D.a. Direct emission	1. Inorganic N fertilizers	kt-N_2O	6.2	5.3	5.0	4.8	4.2	4.1	4.2	4.1	3.9	3.9	3.9	3.9	3.8	3.8	3.8
		2. Organic N fertilizers		4.9	4.7	4.5	4.0	4.2	4.1	4.1	4.1	4.4	4.4	4.5	4.5	4.3	4.3	4.3
		3. Manure by grazing animal		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		4. Crop residues		1.4	1.4	1.5	1.4	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1
		5. Mineralization		1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3
		6. Cultivation of organic soil		0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	3.D.b. Indirect emission	1. Atmospheric deposition		3.6	3.4	3.2	3.0	2.9	2.9	2.9	2.9	3.0	3.0	3.0	3.0	2.9	3.0	3.0
		2. N leaching and run-off		6.4	6.0	5.7	5.4	5.1	5.0	5.0	5.0	5.0	4.9	5.0	5.0	4.9	4.9	4.9
	Total		kt-N_2O	24.6	22.7	21.8	20.5	19.5	19.1	19.3	19.1	19.2	19.1	19.3	19.2	18.9	18.9	18.9
			kt-CO_2 eq.	7,336	6,763	6,496	6,115	5,806	5,692	5,742	5,679	5,730	5,695	5,749	5,715	5,622	5,626	5,628

5.5.1. Direct N_2O Emissions from Managed Soils (3.D.a.)

Application of inorganic fertilizers and organic fertilizers, and grazing livestock manure, or plowing of crop residues into soil generates ammonium ions in the soil. The soil emits N_2O in the process of oxidizing the ammonium ions into nitrate-nitrogen under aerobic conditions. N_2O is also emitted via denitrification of nitrate. In addition, N_2O is generated by decomposition of organic matter in mineral soil and plowing of organic soil because of nitrification and denitrification of nitrogen. N_2O emissions by the application of synthetic fertilizers and organic fertilizers to pastureland (included in the planted area for feed crops, see Table 5-56) are estimated in this category.

5.5.1.1. Inorganic N Fertilizers (3.D.a.1.)

a) Category Description

This section provides the estimation methods for N_2O emissions by the application of inorganic N fertilizers (synthetic fertilizers).

b) Methodological Issues

- ***Methodology for Estimating Emissions/Removals of GHGs***

N_2O emissions were calculated by Tier2 method, using country-specific emission factors in accordance with decision tree of the *2006 IPCC Guidelines* (Vol. 4, p.11.9, Fig.11.2).

In addition, estimation method for N_2O emission reduction from agricultural soil using synthetic N fertilizer with nitrification inhibitor is also established.

$$E = \sum_{i,j} (F_{SNi,j} \times EF_{1i,j}) \times 44/28$$

E	: N_2O emissions associated with the application of synthetic fertilizer in agricultural soil (crop field) [kg-N_2O/yr]
$F_{SNi,j}$	: Nitrogen amount of synthetic fertilizer j applied to agricultural soil for crop type i [kg-N/yr]
$EF_{1i,j}$	: N_2O emission factor of synthetic fertilizer j for crop type i [kg-N_2O-N/kg-N]
i	: Crop type
j	: Fertilizer type (with or without nitrification inhibitor)

- ***Emission Factors***

Emission factors were established by analyzing measured data in Japan, based on the amount of application of synthetic fertilizer and N_2O emissions. Emission factors of the application of synthetic fertilizer with nitrification inhibitor were established by multiplying their country-specific emission factor by N_2O reduction rate.

Comparing emission factors among various crops, it was identified that emission factor of tea was significantly higher and emission factor of rice was significantly lower than those of other crops. As there were not significant differences among the other crops, emission factors associated with the application of synthetic fertilizer in agricultural soil were defined three categories for rice, tea and other crops. Emission factor of Japan is lower than that of default value in the *2006 IPCC Guidelines*. It is the reason that the volcanic ash soil that is well-drained soil and widely distributed in Japan releases little N_2O emissions. The emission factor of rice is adopted as a default value within the *2006 IPCC Guidelines* and its validity has been internationally confirmed.

N_2O emission reduction rate using synthetic fertilizer with nitrification inhibitor was decided as 26%, the lower limit of N_2O reduction rate using fertilizer with dicyandiamide (26-36%) described in Akiyama et al. (2010). Although dicyandiamide is dominantly added as nitrification inhibitor in Japan, other chemical materials as inhibitor are used in a few products. Therefore, the lower limit of the rate of dicyandiamide was used to avoid overestimation of emission reduction. In addition, since nitrification seldom occur on flooded situation for paddy rice, synthetic fertilizer with nitrification inhibitor is never used. Therefore, EF with nitrification inhibitor for paddy rice was not developed.

Table 5-51 N_2O emission factor for synthetic fertilizer to agricultural soil

Crop type	Emission Factor without nitrogen inhibitor [%: kg-N_2O-N/kg-N]	Emission Factor with nitrogen inhibitor [%: kg-N_2O-N/kg-N]
Paddy rice	0.31%	-
Tea	2.9%	2.1% [=2.9%×(1-0.26)]
Other crops	0.62%	0.46% [=0.62%×(1-0.26)]

Reference: Akiyama et al. (2006 a)
Akiyama et al. (2006 b)
Akiyama et al. (2010)

- ***Activity Data***

For total nitrogen amount of synthetic fertilizer, demand for nitrogenous fertilizer described in *Yearbook of Fertilizer Statistics (Pocket Edition)* by Association of Agriculture and Forestry Statistics are used for estimation. To estimate amount of synthetic fertilizer applied to the agricultural soil, amount of synthetic fertilizer applied to forest are subtracted from this total amount (Table 5-52).

In addition, to estimate the amount of synthetic fertilizer applied by crop type, values corresponding to the amounts of nitrogen applied for each crop type are calculated by multiplying area of each crop field (Table 5-56) by the amounts of synthetic fertilizers applied per unit area for each crop type based on the results of studies (Tsuruta 2001) in Japan. Total synthetic fertilizer is apportioned to each crop type in accordance with the corresponding application amount for each crop type.

$$F_{SNi} = (F_T - F_{FRST}) \times \frac{(RA_i \times RF_i \times 10)}{\sum(RA_n \times RF_n \times 10)}$$

F_{SNi}	: Nitrogen amount of synthetic fertilizer applied to agricultural soil for crop type *i* [t-N/yr]
F_T	: Total nitrogen amount of synthetic fertilizer [t-N/yr]
F_{FRST}	: Nitrogen amount of synthetic fertilizer applied to forest [t-N/yr]
RA_i	: Area planted of crop type *i* [ha]
RF_i	: Nitrogen amount of synthetic fertilizer per area planted of crop type *i* [kg-N/10a]
RA_n	: Area planted by each crop type [ha]
RF_n	: Nitrogen amount of synthetic fertilizer per area planted by each crop type [kg-N/10a]

The amounts of fertilizer applied by crop type are known because the amounts of synthetic and organic fertilizers applied for each crop type were determined by a farming study conducted in 2000 (Tsuruta 2001). Based on expert judgement, there is likely little year-on-year change in application amounts to crops except for paddy rice and tea, data on the amounts of synthetic fertilizer applied per unit area according to Tsuruta (2001) were applied uniformly for these crops in all the years (Table 5-54).

Fertilizer application amounts for tea change from year to year because of the influence of the transition of recommended rate of fertilizer application by local governments and other factors. The amounts of nitrogen applied to tea fields (the total amount of nitrogen from synthetic and organic fertilizer) in 1993, 1998, and 2002 investigated and summarized by Nonaka (2005) and the ratio of synthetic fertilizer and organic fertilizer applied to tea according to Tsuruta (2001) were used to estimate the amounts of synthetic and organic fertilizer applied in 1993, 1998 and 2002. Time-series data were prepared by interpolating calculated values by estimated fertilizer amount data of three years into from 1993 to 2002 and deferring the 1993 data for previous years and the 2002 data for subsequent years (see Table 5-55).

For paddy rice, the data of synthetic fertilizer application amount for unit area for each year in *Yearbook of Fertilizer Statistics* was used. The values of paddy rice were substituted for upland rice.

Shipping amount of synthetic fertilizer with nitrification inhibitor which is included in “N amount of synthetic fertilizer applied (agricultural soil)" is from surveyed data by MAFF since 1996, and 13% which is an average nitrogen content in production from major manufacturers was applied for emission estimation. It assumes little nitrification inhibitor was used prior to 1996, while there is no data available because this survey started from 1996. In addition, since synthetic fertilizer with nitrification inhibitor was not used for paddy rice nor feed crops, they were excluded from estimation.

Table 5-52 Nitrogen amount of synthetic fertilizer applied to soil [t-N/yr]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total N amount in synthetic fertilizer	611,955	527,517	487,406	471,190	409,590	396,783	409,918	394,629	372,339	374,879	374,879	374,879	374,879	374,879	374,879
N amounut in synthetic fertilizer applied (forest soil)	288	248	229	222	193	187	193	186	175	176	176	176	176	176	176
N amounut in synthetic fertilizer applied (agricultural soil)	611,667	527,269	487,177	470,968	409,397	396,596	409,725	394,443	372,164	374,703	374,703	374,703	374,703	374,703	374,703

Note: This amount includes synthetic fertilizer with nitrification inhibitor.
Reference: Total N amount: *Yearbook of Fertilizer Statistics (Pocket Edition)*
N amount to forest soil: Estimated on the basis of Forestry Agency Survey

Table 5-53 Nitrogen amount of synthetic fertilizer with nitrification inhibitor [t-N]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N amount in synthetic fertilizer with nitrification inhibitor	NE	NE	4,030	4,290	4,940	5,070	7,800	4,550	5,070	5,330	5,070	5,590	6,045	5,785	6,084

Note: The value is estimated based on the assumption that products have 13% of nitrogen contents.
Reference: Survey by MAFF

Table 5-54 Amount of synthetic fertilizers application per area by each crop type (other than rice and tea)

Crop type	Amount of application [kg-N/10a]
Vegetables	21.27
Fruit	14.70
Potatoes	12.70
Pulse	3.10
Feed crops	10.00
Sweet potato	6.20
Wheat	10.00
Coarse cereal (including Buckwheat)	4.12
Mulberries	16.20
Industrial crops	22.90
Tobacco	15.40

Reference: Tsuruta (2001)

Table 5-55 Amount of synthetic fertilizers application per area (rice and tea) [kg-N/10a]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N amount in synthetic fertilizers application per area (rice)	9.65	8.71	7.34	6.62	5.95	6.04	6.10	5.97	5.85	5.85	5.85	5.85	5.85	5.85	5.85
N amount in synthetic fertilizers application per area (tea)	57.23	54.88	48.06	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76

Reference: Rice: *Yearbook of Fertilizer Statistics (Pocket Edition)*, Tea: Nonaka (2005) and Tsuruta (2001)

Table 5-56 Planted area by each crop type [kha]

Crop type	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Vegetables	620.1	564.4	524.9	476.3	465.4	457.9	453.4	452.1	448.9	444.1	441.7	437.3	432.5	424.9	419.8
Paddy rice (for grain)	2,055.0	2,106.0	1,763.0	1,702.0	1,625.0	1,579.0	1,597.0	1,573.0	1,505.0	1,478.0	1,465.0	1,470.0	1,469.0	1,462.0	1,403.0
Fruit	346.3	314.9	286.2	265.4	246.9	240.3	237.0	233.8	230.2	226.7	222.7	218.4	214.9	211.2	207.8
Tea	58.5	53.7	50.4	48.7	46.8	45.9	45.4	44.8	44.0	43.1	42.4	41.5	40.6	39.1	38.0
Potatoes	115.8	104.4	94.6	86.9	82.5	81.2	79.7	78.3	77.4	77.2	77.2	76.5	74.4	71.9	70.9
Pulse	256.6	155.5	191.8	193.9	189.0	180.2	178.5	181.0	187.6	187.7	187.9	185.4	183.6	183.3	184.0
Feed crops	1,096.0	1,013.0	1,026.0	1,030.0	1,012.0	1,029.0	1,012.0	1,019.0	1,072.0	1,082.0	1,084.9	1,068.6	1,059.1	1,052.6	1,102.5
for Pasture land	646.7	660.7	644.7	630.6	616.7	613.4	611.1	607.7	606.5	603.4	601.1	598.8	596.9	595.2	593.5
Sweet potato	60.6	49.4	43.4	40.8	39.7	38.8	38.6	38.0	36.6	36.0	35.6	35.7	34.3	33.1	32.4
Wheat	366.4	210.2	236.6	268.3	265.7	269.5	269.5	272.7	274.4	275.9	273.7	272.9	273.0	276.2	283.0
Coarse cereal (incl. buckwheat)	29.6	23.4	38.4	45.9	49.7	62.6	62.9	61.4	59.7	62.2	64.5	65.5	67.1	68.3	67.2
Mulberries	59.5	26.3	5.9	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Industrial crops	142.9	124.5	116.3	110.3	104.8	100.2	98.5	97.8	98.8	99.3	100.3	98.2	97.3	97.9	106.0
Tobacco	30.0	26.4	24.0	19.1	15.0	9.0	8.9	8.6	8.3	8.0	7.6	7.1	6.5	6.1	5.7
Upland rice	18.9	11.6	7.1	4.5	2.9	2.1	1.7	1.4	1.2	0.9	0.8	0.8	0.7	0.6	0.6
Total	5,256.2	4,783.7	4,408.5	4,295.1	4,147.4	4,097.7	4,085.0	4,063.9	4,046.1	4,023.2	4,006.3	3,979.9	3,954.9	3,929.1	3,922.7

Reference: Potatoes: *Vegetable Production and Shipment Statistics*, Tobacco: Survey of Japan Tobacco Inc., Mulberries: MAFF Survey, Other crops: *Statistics of Cultivated and Planted Area*

(Note: "Industrial crops" is subtracted the area of "Tobacco" from estimated value from total area of tea, rape, sugar beet and sugarcane. The values of "Vegetable" before 2017 excluded the value of "Potatoes". The values of "Vegetable", "Fruit", "Pulse", "Feed crops" and "Coarse cereal" in 2017 are estimated by using the last five years average proportion of sum of planted areas for object crops in each crop group to the statistic because of the abolition of statistical survey for planted area of these crop groups.)

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the emission factors, uncertainty (31%) described in the reference of EFs, Akiyama et al. (2006), was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 31%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1. Comparison with Japan's EF and the default EF in the IPCC Guidelines is described in the section 'Emission factors' above.

e) Category-specific Recalculations

The total area for orchards since FY2018 associated with land use conversion in LULUCF sector was changed, therefore, emissions since FY2018 was recalculated. Since the amount of synthetic fertilizer with nitrification inhibitor applied to cropland for FY2020 was revised, emissions for FY2020 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no improvement plans.

5.5.1.2. Organic N Fertilizers (3.D.a.2.)

a) Category Description

This section provides the estimation methods for N_2O emissions by application of organic fertilizer (manure from livestock and other, and compost).

b) Methodological Issues

- ***Estimation Method***

Emissions of N_2O have been calculated by Tier2 method in accordance with decision tree of the *2006 IPCC Guidelines* (Vol.4, p.11.9, Fig.11.2).

$$E = \sum_i (F_{ONi} \times EF_{1i}) \times 44/28$$

E	: N_2O emissions from the organic fertilizers applied to agricultural soils [kg-N_2O/yr]
F_{ONi}	: Nitrogen amount of organic fertilizer applied to agricultural soil for crop type *i* [kg-N/yr]
EF_{1i}	: N_2O emission factor of organic fertilizer for crop type *i* [kg-N_2O-N/kg-N]
i	: Crop types

- ***Emission Factors***

Emission factors for N_2O associated with the application of synthetic fertilizers without nitrification inhibitor and organic fertilizers were defined as the same value, because there was no significant difference between emission factors of synthetic fertilizers and organic fertilizers.

- ***Activity Data***

For activity data (total amount of nitrogen contained in the organic fertilizers), the following nitrogen was calculated on the basis of formula described in the *2006 IPCC Guidelines* (Vol.4, p11.12, Equation 11.3).

$$F_{ON} = F_{AM} + F_{SEW} + F_{FU} + F_{COMPsub} + F_{OOA}$$

F_{ON}	: Nitrogen amount in organic fertilizers applied to soil [kg-N/yr]
F_{AM}	: Nitrogen amount in livestock manure applied to soil [kg-N/yr]
F_{SEW}	: Nitrogen amount in sewage sludge applied to soil [kg-N/yr]
F_{FU}	: Nitrogen amount in human waste applied to soil [kg-N/yr]
$F_{COMPsub}$	: Nitrogen amount in composting sub-material applied to soil (rice straw, rice husk, wheat straw) [kg-N/yr]
F_{OOA}	: Nitrogen amount in other organic fertilizers applied to soil (fish residue, soybean oil residue, canola oil residue, etc.) [kg-N/yr]

➢ ***Nitrogen amount in livestock manure applied to soil (F_{AM})***

Amount of nitrogen in livestock manure applied to agricultural soil (F_{AM}) was calculated by subtracting the amount of nitrogen included in grazing livestock excretion(F_{PRP}), nitrogen discharged into public sewage (F_{PSW}) nitrogen in livestock manure volatilized as N_2O (excluding grazing livestock) (F_{N2O}), nitrogen in manure volatilized as NH_3 and NO_X (excluding grazing livestock) ($F_{NH3+NOx}$), nitrogen not applied to soil due to disposal as industrial waste, discharge to river after purification and other reasons ($F_{disposal}$) from the total nitrogen in livestock manure ($F_{Total\text{-}AW}$).

$$F_{AM} = F_{Total\text{-}AW} - F_{PRP} - F_{PSW} - F_{N_2O} - F_{NH_3+NOx} - F_{disposal}$$

F_{AM}	: Nitrogen amount in livestock manure applied to soil [kg-N/yr]

$F_{Total\text{-}AW}$	: Total amount of nitrogen excreted by livestock [kg-N/yr]
F_{PRP}	: Amount of nitrogen included in grazing livestock excretion [kg-N/yr]
F_{PSW}	: Amount of nitrogen discharged into public sewage [kg-N/yr]
F_{N2O}	: Nitrogen in livestock manure volatilized as N_2O (excluding N from grazing livestock) [kg-N/yr]
$F_{NH3+NOx}$	: Nitrogen in manure volatilized as NH_3 and NO_X (excluding N from grazing) [kg-NH_3-N + NO_X-N/yr]
$F_{disposal}$	: Nitrogen not applied to farm field due to disposal as industrial waste, discharge to river after purification and other reasons [kg-N/yr]

For the amount of nitrogen included in grazing livestock excretion (F_{PRP}) amount of nitrogen discharged into public sewage (F_{PSW}) and nitrogen in livestock manure volatilized as N_2O (excluding N from grazing livestock excretion) (F_{N2O}), the amount calculated in 3.B. Manure management were used.

Nitrogen not to applied to farm field ($F_{disposal}$) was calculated by using the percentage of non-agricultural utilization in the *survey of current status for livestock manure management system and others 2019* (MAFF, 2021).

Table 5-57 Nitrogen amount in livestock manure applied to agricultural soil (F_{AM}) [t-N]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total nitrogen amount in animal waste ($F_{Total\text{-}AW}$)	683,190	642,484	604,830	569,646	554,199	540,003	521,676	511,887	511,179	511,532	520,651	517,390	521,113	522,494	521,246
Nigrtogen amount in excretion from grazing livestock and for public swedge ($F_{PRPt}+F_{PRP}$)	12,987	12,836	12,024	11,653	11,365	10,881	10,592	10,025	10,118	9,907	9,890	9,851	9,693	9,425	9,459
Amount of N_2O-N released from manure (excluing excretion from grazing livestock and for public sweage) (F_{N2O})	5,977	5,663	5,636	6,302	6,847	6,621	6,360	6,179	6,106	6,042	6,101	6,024	6,054	6,080	6,028
Amount of NH_3-N and NOx-N released from manure (excluing excretion from grazing livestock and for public sweage) ($F_{NH3}+F_{Nox}$)	236,054	219,528	202,664	184,778	178,364	173,008	166,498	163,830	163,571	164,382	167,874	166,418	166,375	166,491	165,967
Nitrogen amount not to applied to farm field ($F_{disposal}$)	40,698	35,271	36,112	46,106	55,675	54,876	52,428	51,253	50,666	50,658	52,275	51,904	52,532	52,666	51,176
Nitrogen amount in livestock manure applied to agricultural soil (F_{AM})	387,474	369,185	348,394	320,806	301,948	294,616	285,798	280,600	280,717	280,543	284,510	283,193	286,459	287,833	288,616

- ***Nitrogen amount in sewage sludge applied to soil (F_{SEW})***

Nitrogen amount in sewage sludge applied to soil (F_{SEW}) was calculated by multiplying amount of sludge described in the *Yearbook of Fertilizer Statistics (Pocket Edition)* by nitrogen contents established using data provided by Japan Sewage Works Association.

- ***Nitrogen amount in human wastes applied to soil (F_{FU})***

Nitrogen amount of human waste (F_{FU}) was calculated from the amount of human waste-derived nitrogen calculated with the data of *Waste Treatment in Japan*.

- ***Nitrogen amount in composting sub-material applied to soil ($F_{COMPsub}$)***

For composting sub-material, data of "composting" and "barn bedding" of rice straw, rice chaff and wheat straw calculated from each prefecture data were used. For nitrogen content rate of rice straw, rice chaff and wheat straw, values described in 5.5.1.4. “Crop Residue” below were used (Table 5-65).

- ***Nitrogen amount in other organic fertilizers applied to soil (F_{OOA})***

Nitrogen amount in other organic fertilizers (fish residue, soybean oil residue, canola oil residue, etc.) applied to soil (F_{OOA}) was calculated by multiplying amount of other organic fertilizer described in the *Yearbook of Fertilizer Statistics (Pocket Edition)* by nitrogen contents established using data provided in the *Yearbook of Fertilizer Statistics (Pocket Edition)*.

Table 5-58 Amount of sludge and other organic fertilizer [kt]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Animal derived fertilizers	384.1	389.4	341.0	262.7	268.3	302.6	298.3	268.2	300.6	310.0	285.4	287.5	277.2	268.2	220.7
Fish residue	111.5	88.6	89.0	73.9	62.2	55.4	60.0	51.7	52.9	54.7	53.3	61.8	53.2	51.4	37.1
Bone meal	113.1	134.2	112.8	11.4	16.7	19.4	16.2	18.5	20.0	22.3	20.0	18.4	22.5	15.5	13.7
Other animal derived	159.5	166.6	139.2	177.5	189.4	227.7	222.1	198.1	227.7	233.0	212.1	207.4	201.6	201.3	169.9
Plant derived fertilizers	635.9	725.7	982.4	494.8	1,064.3	1,079.2	1,203.7	1,455.4	1,852.7	1,810.9	2,012.0	1,981.9	1,569.6	1,712.6	1,753.2
Soybean oil residue	3.5	4.7	28.9	1.1	209.5	134.4	167.7	265.0	477.0	494.5	491.3	484.8	494.6	488.4	492.4
Canola oil residue	451.0	437.2	620.7	241.0	221.4	347.9	288.4	399.5	474.8	486.8	449.3	420.1	414.6	403.4	440.1
Other plant derived	181.4	283.8	332.8	252.7	633.5	596.9	747.6	790.9	900.9	829.6	1,071.4	1,077.0	660.4	820.7	820.8
Sludge	787.3	935.2	817.7	1,287.4	1,395.6	1,329.3	1,355.5	1,292.9	1,395.7	1,351.7	1,377.8	1,358.0	1,345.9	1,261.5	1,259.8

Reference: *Yearbook of Fertilizer Statistics (Pocket Edition)*

Table 5-59 Nitrogen content rate of each organic fertilizer

Organic fertilizer	Nitrogen content
Fish residue	8.0%
Bone meal	4.1%
Other animal matters	7.5%
Soybean oil residue	7.5%
Canola oil residue	5.1%
Other vegetable matter	4.6%
Sludge	2.7%

Reference: Other than sludge: Yearbook of Fertilizer Statistics (Pocket Edition)
Sludge: Established from Japan Sewage Works Association data

Table 5-60 Nitrogen amount in organic fertilizers applied to agricultural soil [t-N]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
From livestock manure (F_{AM})	387,474	369,185	348,394	320,806	301,948	294,616	285,798	280,600	280,717	280,543	284,510	283,193	286,459	287,833	288,616
From sewage sludge (F_{SEW})	21,257	25,250	22,078	34,760	37,682	35,892	36,599	34,907	37,685	36,497	37,202	36,666	36,339	34,059	34,016
From human waste (F_{FU})	10,394	4,747	2,116	874	427	351	286	273	231	204	223	260	234	197	200
From composting sub-material ($F_{COMPsub}$)	18,316	15,514	11,485	11,217	8,864	8,803	8,879	7,700	6,816	6,774	6,480	6,578	6,471	6,589	7,974
From other organic fertilizers (F_{OOA})	57,128	60,790	71,314	43,685	76,006	77,593	83,796	96,378	123,560	122,844	130,034	128,575	108,916	114,802	113,401
Total (Nitrogen amount applied to agricultural soil as organic N fertilizer) (F_{ON})	494,569	475,485	455,387	411,343	424,928	417,256	415,358	419,857	449,009	446,861	458,449	455,272	438,418	443,480	444,207

- ***Estimation for nitrogen amount of organic fertilizer applied to agricultural soil for crop type i***

Nitrogen amount of organic fertilizer applied to agricultural soil for crop type *i* ($F_{ON\,i}$) is calculated by multiplying the total nitrogen amount in organic fertilizers applied to agricultural soil above (F_{ON}) by the proportion of nitrogen amount to be applied to crop type *i* for the total nitrogen (F_{ON}) (proportion of fertilizer application). The proportion of fertilizer application was calculated by dividing the product of nitrogen amount of organic fertilizer application per unit area of crop field for crop type *i* and the cultivation area for crop type *i* by the grand total of all products for all crop types.

$$F_{ONi} = F_{ON} \times \frac{(RA_i \times RF_i / 10)}{\sum (RA_n \times RF_n / 10)}$$

F_{ONi}	: Nitrogen amount of organic fertilizer applied to agricultural soil for crop type *i* [t-N/yr]
F_{ON}	: Total nitrogen amount in organic fertilizers applied to agricultural soil [t-N/yr]
RA_i	: Area planted of crop type *i* [ha]
RF_i	: Nitrogen amount of organic fertilizer per area of crop field for crop type *i* [kg-N/10a]
RA_n	: Area planted by each crop type [ha]
RF_n	: Nitrogen amount of organic fertilizer per area of crop field by each crop type [kg-N/10a]

For nitrogen amount in organic fertilizer applied per unit area for tea, as same as the synthetic fertilizers, the amounts of nitrogen applied to tea fields (the total of synthetic and organic) in 1993, 1998, and 2002 investigated and summarized by Nonaka (2005) and the ratio of synthetic fertilizer and organic fertilizer applied to tea according to Tsuruta (2001) were used to estimate the amounts of organic fertilizer applied and time-series data were prepared (see Table 5-55). Organic fertilizer application amount per unit area by each crop type except tea is based on the data on the survey in 2000 as same as synthetic fertilizer. The value of upland rice was substituted by the value of paddy rice. Cultivated area by each crop type is same as synthetic fertilizers.

Table 5-61 Amount of nitrogen applied as organic fertilizers per area for tea [kg-N/10a]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N amount in organic fertilizers application per area (tea)	20.77	19.92	17.44	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24

Reference: Nonaka (2005), Tsuruta (2001)

Table 5-62 Amount of nitrogen applied as organic fertilizers per area by each crop type (except tea)

Crop type	Amount of application [kg-N/10a]
Vegetables	23.62
Paddy rice	3.2
Fruit	10.90
Potatoes	7.94
Pulse	6.24
Feed crops	10.00
Sweet potato	8.85
Wheat	5.70
Coarse cereal (including Buckwheat)	1.81
Mulberries	0.00
Industrial crops	3.96
Tobacco	11.41

Reference: Tsuruta (2001)

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the emission factors, uncertainty (31%) described in the reference of EFs, Akiyama et al. (2006), was applied. For activity data for livestock manure, 9% for population of broiler given in the *Livestock Statistics* was applied as substitution. For activity data for others, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 23%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

The total area for orchards since FY2018 associated with land use conversion in LULUCF sector was changed, therefore, emissions since FY2018 was recalculated. Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test*, averaged age in days of shipment in *The report of the fact-finding survey for pig farming*, egg production and feed intake per day for hen, crop residues for composting sub-materials, and the distribution amount of other organic fertilizer for FY2020 were updated/revised, the emissions from livestock manure, composting sub-materials, and other organic fertilizers for FY2020 were recalculated. The emissions from livestock manure for the whole time-series were recalculated, due to the revision in emission factors for "Composting" out of the manure treating methods (3.B.). See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

The same emission factor has been used for synthetic and organic fertilizers. Thus, the possibility to establish separate emission factors for these two types of fertilizer is under consideration.

5.5.1.3. Urine and Dung Deposited by Grazing Animals (3.D.a.3.)

a) Category Description

This section provides the estimation methods for N_2O emissions from urine and dung deposited by grazing animals.

b) Methodological Issues

The method for calculating CH_4 and N_2O emissions from urine and dung deposited by grazing animals is described in 5.3.1 "Livestock Waste Management: Cattle, Swine and Poultry (Hen and Broiler) (3.B.1., 3.B.3., 3.B.4.)" and 5.3.2. "Buffalo, Sheep, Goats, Horses, Rabbits and Mink (3.B.2., 3.B.4.)".

5.5.1.4. Crop Residues (3.D.a.4.)

a) Category Description

This section provides the estimation methods for N_2O emissions by crop residue plowed into soil.

b) Methodological Issues

- ***Estimation Method***

Basically, the N_2O emissions were calculated by using the *2006 IPCC Guidelines*. For emission factors, default EF described in the *2019 Refinement* were used. However, activity data for some crops (rice, tea, vegetables, sugarcane and sugar beet) were estimated by country-specific method which is considered to be capable for estimating emissions more accurately than the method provided in the *2006 IPCC Guidelines*.

$$E = EF \times A \times 44 / 28$$

E	: N_2O emissions from crop residue [kg-N_2O/yr]
EF	: N_2O emission factor for crop residue [kg-N_2O-N/kg-N]
A	: Nitrogen amount in crop residue plowed into soils [kg-N/yr]

- ***Emission Factors***

0.006 [kg-N_2O-N/kg-N] (Disaggregated (Wet climates), the *2019 Refinement*)

- ***Activity Data***

➢ ***Rice***

For the amount of rice crop residue of above-ground biomass plowed into soil, the data for rice straw and rice chaff plowed into soil calculated from each prefecture data was used. The nitrogen content of rice was calculated by multiplying the aforementioned data by nitrogen content in crop residue (kg-N/t) calculated from Date (1988). In addition, below-ground was calculated from yield, dry matter fraction of harvested crop, ratio of below-ground residues to yield, N content of below-ground residues. For the ratio of below-ground residues to yield ($Frac_{BGR\text{-}Y}$), 27% indicated by Ogawa et al. (1988) was used.

For dry matter fraction of harvested product (*DRY*), 0.89 of default value indicated in the *2019 Refinement* was used.

$$A_{Rice} = Residue \times N_{AG} + Y \times DRY \times Frac_{BGR\text{-}Y} \times N_{BG}$$

A_{Rice}	: Nitrogen amount in crop residue plowed into soils [t-N] (Rice)
$Residue$	: Amount of crop residue plowed into soils (rice straw and chaff) [t]
N_{AG}	: N contents of above-ground residues (rice straw and chaff) [%: kg-N/kg]
Y	: Yield of rice [t]
DRY	: Dry matter fraction of harvested product
$Frac_{BGR\text{-}Y}$	: Ratio of below-ground residues to yield of crop T [%]
N_{BG}	: N contents of below-ground residues [%: kg-N/kg]

➢ ***Tea***

For tea, "Leaf fall" and "Autumn pruning" were targeted as the residues which return into soils annually. In addition, as residues return into soil once in several years, "Medium pruning", which prunes the part of 30-50 cm from the ground and carried out once in about five years, was targeted. For the "Medium pruning", it assumed that it carried out by one fifth in every year in all area of tea field, and all of tea field will be renewal in five years. The residues' nitrogen contents were calculated by multiplying by nitrogen contents per unit area of "Leaf fall", "Autumn pruning" and "Medium pruning" by crop field areas. The crop field areas used for this were the data indicated in the *Statistics of Cultivated and Planted Area* by MAFF.

$$A_{Tea} = (A_{AP} + A_{LF} + A_{MP}/5) \times 10 \times Area$$

A_{Tea}	: Nitrogen amount in crop residue plowed into soils [kg-N] (Tea)
A_{AP}	: Nitrogen amount included in residue by autumn pruning [kg-N/10a]
A_{LF}	: Nitrogen amount included in residue by leaf fall [kg-N/10a]
A_{MP}	: Nitrogen amount included in the residue by medium pruning [kg-N/10a]
$Area$	: Area planted of tea [ha]

Table 5-63 Amount of nitrogen content included in tea residue of branch pruning

Kind of branch pruning		Amount of Nitrogen content [kg-N/10a]	Reference
Autumn pruning	Annual	7.7	Hoshina et al. (1982), Kinoshita and Tsuji (2005), Tachibana et al. (1996)
Medium pruning	Once in five years	19.4	Ohta et al. (1996)
Leaf fall	Annual	11.5	Hoshina et al. (1982)

➢ ***Vegetables, sugarcane and sugar beet***

The amount of nitrogen in each crop residue plowed into soil were calculated by multiplying nitrogen content in residue per crop yield calculated from Matsumoto (2000) by annual crop yield (by *Statistics of Cultivated and Planted Area* or *Vegetable Production and Shipment Statistics*) by the fraction of above-ground residue removed and fraction burnt on field (after consideration of Combustion Factor).

For the amount of nitrogen in crop residue plowed into soil, the data of the *Document of Kagoshima prefectural Institute for Agricultural Development* was used for sugarcane, and the data of *Hokkaido Fertiliser Recommendations 2010* was used for sugar beets, potato, Japanese radish and onion, and the data of Owa (1996) was used for Chinese cabbage and lettuce.

When any crop has no available data with respect to nitrogen content included in crop residue per crop yield, the value for a similar type of crop was used. The same values were adopted for all fiscal years.

$$A_{Vegetable} = Y \times (1 - Frac_{Remove} - Frac_{burnt} \times CF) \times N_R$$

$A_{Vegetable}$	: Nitrogen amount in crop residue plowed into soils (Vegetables, Sugarcane, Sugarbeet) [t-N]
Y	: Yield [t]
$Frac_{Remove}$	: Fraction of above-ground residue removed [%]
$Frac_{burnt}$	: Fraction burnt on field [%]
CF	: Combustion factor
N_R	: Nitrogen contents in crop residue [%: kg-N/kg]

Table 5-64 Fraction of above-ground residue removed ($Frac_{Remove}$), Fraction burnt on field ($Frac_{burnt}$), Combustion factor (*CF*), and Ratio of below-ground residues to above-ground biomass ($RS_{(T)}$) for main crops

Crop type	Fraction of above-ground residue removed ($Frac_{Remove}$)	Fraction burnt on field ($Frac_{burnt}$)	Combustion factor (*CF*)	Raito of above-ground residues ($RS_{(T)}$)
Vegetables	47%	7%	0.80 4)	-
Sugarbeet	47% 1)	7% 1)	0.80 4)	-
Sugarcane	47% 1)	7% 1)	0.80 4)	-
Green manure crops	0% 2)	0% 2)	-	Perennial grasses:0.80 Sorghum: 0.24 8)
Feed crops	100% 3)	0% 3)	-	
Wheat, barley, rye and oats	See Table 5-66	See Table 5-66	0.90 5)	Wheat: 0.24 5) Barley: 0.22 Rye: 0.25 9) Oats: 0.25
Pulse	13%	12%	0.80 4)	0.19 6)
Maize, tubers and roots, other crops	47% 1)	7% 1)	0.80 4)	Maize: 0.22 Tubers and roots: 0.20 Other crops: 0.22 7)

Reference: $Frac_{Remove}$, $Frac_{burnt}$: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*
CF, $RS_{(T)}$: The *2019 Refinement*

Note:1) Value of vegetables, 2) All residues are plowed into soil, 3) All above-ground biomass removed as for feed, 4) Value of maize and/or sugarcane, 5) Value of wheat in *2006 IPCC Guidelines*, 6) Value of Soybean, 7) Value of generic grains, 8) Average value between maize and oats, 9) Substituted by oats

Table 5-65 N contents of above- and below-ground residues (N_{AG}, N_{BG}) for main crops

Crop type	N contents of above-ground residues (N_{AG})	N contents of below-ground residues (N_{BG})	Note
Rice (above ground)	Straw: 0.541% [a)] Chaff: 0.423% [a)]	-	Wet weight
Rice (below ground)	-	0.9% [1)]	Dry weight
Vegetables	Japanese radish: 0.093% [b), c)] Chinese cabbage: 0.071% [c)] Cabbage: 0.183% [e)] Lettuce: 0.164% [c)] Onion: 0.019% [b), c)]		Wet weight
Sugar beet	0.095% [b), c)]		
Sugarcane	0.548% [d)]		Dry weight
Green manure crops and Feed crops	Perennial grasses: 1.5% [z)] Sorghum: 0.7% [z)]	Perennial grasses:1.2% [z)] Sorghum: 0.6% [z)]	
Wheat	0.43% [e)]	0.9% [2)]	
Barley	Two-row: 2.14% [e)] Six-row: 0.31% [e)]	1.4% [z)]	
Rye	0.50% [z)]	1.1% [z)]	
Oats	0.70% [z)]	0.8% [z)]	
Maize	1.64% [e)]	0.7% [z)]	
Soybean	0.65% [e)]	0.8% [z)]	
Adzuki beans	0.84% [e)]	1.0% [3)]	
Potatoes	2.42% [e)]	1.4% [z)]	

Reference: a) Date (1988)
b) Hokkaido Government, Department of Agriculture (2010)
c) Owa (1996)
d) Document of Kagoshima prefectural Institute for Agricultural Development
e) Matsumoto (2000)
z) The *2019 Refinement*

Note:1) Substituted by wheat in the *2006 IPCC Guidelines*
2) Value of wheat in the *2006 IPCC Guidelines*
3) Substituted by value of dry bean in the *2006 IPCC Guidelines*

➢ ***Feed and green manure crops, wheat, barley, orts, rye, maize, pulse, tubers and roots (e.g. potato, sweet potato), and other crops (e.g. buckwheat, tobacco)***

Activity data were calculated by the method shown in the following equation in accordance with the *2006 IPCC Guidelines*. For parameters, values in

Table 5-64 and Table 5-65 were used. The proportion removed from field and burned in field for wheat, barley, rye and oats were determined on the basis of data of crop area by treating method for wheat straw surveyed by MAFF as shown in the Table 5-66. Since the survey data are not available in and before FY2006, the values for FY2007 were applied to these years. Fraction renewed of field ($Frac_{Renew}$) was determined for feed crops as 3% by expert judgment, taking into account variable survey results. For other crops, it was calculated as 100% renewed.

$$A = \sum_T \left\{ \begin{array}{c} \left(Area_{(T)} - Area_{burnt(T)} \times CF\right) \times Frac_{Renew(T)} \times \\ \left[AG_{DM(T)} \times N_{AG(T)} \times \left(1 - Frac_{Remove(T)}\right) + \left(AG_{DM(T)} \times 1000 + Crop_{(T)}\right) \times R_{BG-BIO(T)} \times N_{BG(T)}\right] \end{array} \right\}$$

$$Area_{burnt(T)} = Area_{(T)} \times Frac_{burnt(T)}$$

A	: Nitrogen amount in crop residue plowed into soils [t-N]
$Area_{(T)}$	: Area planted of crop T [ha]
$Area_{burnt(T)}$	: Area burnt of crop T [ha]
CF	: Combustion factor
$Frac_{Renew(T)}$	: Fraction renewed of field of crop T [%]
$AG_{DM(T)}$	: Dry matter of above-ground residues of crop T [Mg/ha]
$N_{AG(T)}$	: N contents of above-ground residues of crop T [%]

$Frac_{Remove(T)}$	: Fraction removed from field of crop T [%]
$Crop_{(T)}$	: Dry matter in yield of crop T [kg/ha]
$R_{BG\text{-}BIO(T)}$	: Ratio of below-ground residues to above-ground biomass of crop T
$N_{BG(T)}$	: N contents of below-ground residues of crop T [%]
$Frac_{burnt(T)}$	: Fraction burnt on field of crop T [%]

Table 5-66 Proportion removed from field and burned in field for wheat, barley, rye and oats [%]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Proportion removed from field	32.1	32.1	32.1	32.1	37.8	40.2	41.0	41.0	37.9	40.2	38.5	39.5	37.2	37.2	37.0
Proportion burned in field	13.5	13.5	13.5	13.5	10.6	9.2	8.8	8.3	8.0	7.7	7.7	6.9	7.5	7.6	8.4

Note: Calculated from each prefecture data

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For uncertainty of the emission factor, default values (-70% to +200%) described in the *2006 IPCC Guidelines* were applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -70% to +200%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

At the Breakout Group on Agriculture of the Committee for GHG Emissions Estimation Method in 2012, nitrogen content for rice were checked in detail. As a result, the group decided to use data by Date (1988), which were separated into rice straw and chaff and were considered as the most appropriate to represent Japan's actual circumstances because the data are intermediate among the various regional data in Japan.

e) Category-specific Recalculations

Since the amount of rice straw and rice chaff plowed into soil for FY2020 were updated, the emissions for FY2020 were recalculated. Since the emission factor was revised to that in the *2019 Refinement*, emissions for the whole time series were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Discussion whether it will be possible to establish country-specific emission factors for Japan has been conducted.

5.5.1.5. Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter (3.D.a.5.)

a) Category Description

This section estimates N_2O emissions by nitrogen mineralization in loss of carbon oxidized by organic matter in mineral soil. N_2O emissions from nitrogen mineralization in pastureland are estimated and reported in the LULUCF sector. See section 6.14 in this NIR.

b) Methodological Issues

- ***Estimation Method***

Based on Equation 11.1 and Equation 11.8 described in section 11.2.1. in Vol.4 of the *2006 IPCC Guidelines*, N_2O emission factor per unit area (EF_{N2O}-$N_{i,j}$) [kg-N_2O-N] is set for calculation. The N_2O emission factors are country-specific values by region by soil type. Activity data are the area of cropland remaining cropland in mineral soil.

$$N_2O - N_{direct\_N_{Minerarl_i}} = F_{SOM_i} \times EF_i$$ (eq.11.1, the *2006 IPCC Guidelines*)

$$F_{SOM_i} = \sum_k \left(\Delta C_{Mineral_{i,k}} \times \frac{1}{R_{i,k}} \right)$$ (eq.11.8, the *2006 IPCC Guidelines*)

$$N_2 - N_{direct\text{-}N_{Minerarl_{i,j}}} = EF_{N2O\text{-}N_{i,j}} \times A_{i,j}$$

N_2O-N_{direct}-$_{NMineral}$	: Direct N_2O emissions from N mineralization as a result of loss of organic matter in mineral soil [kg-N_2O-N]
EF	: N_2O emission factor per amount of N mineralization [kg-N_2O-N/kg-N]
A	: Mineral soil area with soil carbon loss as a result of loss of soil organic matter [ha]
i	: Land use/type of land (paddy fields, upland fields, orchard and tea plantations)
j	: Regions (Hokkaido, Tohoku, Kanto, Hokuriku, Tokai/Kinki, Chugoku/Shikoku, Kyushu/Okinawa)
k	: Soil type (soil type based on the classification of Yagasaki and Shirato (2014))

- ***Emission Factors***

The emission factor is established by Shirato et al. (2021). The detail of the estimation are shown in LULUCF sector (6.14.b)).

Table 5-67 N_2O emission factor by mineralization for paddy field and upland field by each region [kg N_2O-N/ha/yr]

Region	Paddy field	Upland field
Hokkaido	0.244	0.210
Tohoku	0.269	0.189
Kanto	0.291	0.166
Hokuriku	0.265	0.167
Tokai and Kinki	0.284	0.172
Chugoku and Shikoku	0.307	0.200
Kyusyu and Okinawa	0.310	0.197

Reference: Shirato et al. (2021)

- ***Activity Data***

The area of plowed mineral soil was established by subtracting the area of organic soils (peat soil and muck soil) in paddy fields and common upland fields by region in Japan from the cultivated areas of paddy fields and common upland fields, obtained from the *Statistics of Cultivated and Planted Area* (MAFF). Lands of mineral soil converted to paddy field and upland field are estimated in LULUCF sector. For detail, see estimation method described in LULUCF sector (6.6.1 b) 2) "Activity Data" below).

Table 5-68 Intended areas of mineral soil in Agriculture sector [kha]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Intended paddy field	2,638	2,577	2,498	2,418	2,360	2,331	2,324	2,315	2,304	2,288	2,272	2,256	2,242	2,226	2,209
Hokkaido	191	190	187	180	179	178	178	178	178	178	177	177	177	176	176
Tohoku	578	582	577	564	557	542	541	540	537	534	530	527	525	522	519
Kanto	488	477	464	445	429	424	422	420	418	415	413	410	407	403	399
Hokuriku	318	305	296	288	282	280	280	279	278	277	276	275	274	273	272
Tokaiand Kinki	365	351	336	325	313	311	309	307	305	303	301	298	295	293	291
Chugoku and Shikoku	338	323	303	291	282	279	277	276	274	272	270	267	266	263	259
Kyusyu and Okinawa	360	349	335	325	318	316	315	315	313	309	306	302	299	296	293
Intended upland field	1,171	1,126	1,104	1,119	1,138	1,136	1,134	1,129	1,125	1,122	1,115	1,109	1,103	1,096	1,091
Hokkaido	389	368	369	382	396	398	398	398	399	401	401	402	402	403	403
Tohoku	135	132	128	129	132	130	130	129	129	128	127	126	125	125	124
Kanto	293	287	287	288	285	283	281	279	276	274	271	268	265	262	261
Hokuriku	24	23	22	23	25	25	25	25	25	25	25	25	25	25	25
Tokaiand Kinki	58	57	57	60	61	62	62	62	61	61	61	60	60	60	59
Chugoku and Shikoku	60	57	51	51	54	54	54	54	53	53	52	52	51	50	49
Kyusyu and Okinawa	212	202	191	187	184	184	182	182	180	180	178	176	174	172	171

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the emission factors, uncertainty (paddy field 2.4%, upland field 2.9%) was estimated from standard deviation described in the reference of EFs, Shirato et al. (2021) was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 2.4%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

Since the mineral soil area associated with land use conversion in LULUCF sector was changed, the emissions for the whole time series were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no improvement plans.

5.5.1.6. Plowing of Organic Soils (3.D.a.6.)

a) Category Description

In Japan, organic soil mainly occurs in Hokkaido. In Japanese GHG inventory, two categories of soil type, “muck soil” and “peat soil”, are treated as organic soils. In Japan, the creation of farmland on organic soils was mostly completed by the 1970s, and in general farmers till land that has had soil dressing.

b) Methodological Issues

- ***Estimation Method***

Emissions of N_2O from the plowing of organic soil were calculated by multiplying the area of the plowed organic soil of paddy field, upland field, and grassland by the emission factor in accordance with the *2006 IPCC Guidelines*.

$$E = EF \times A \times 44 / 28$$

E	: N_2O emission associated with the plowing of organic soils [kg-N_2O/yr]
EF	: N_2O emission factor for plowing of organic soils [kg-N_2O-N/ha/yr]
A	: Area of plowed organic soils [ha]

- ***Emission Factors***

For paddy field cultivation in organic soils, it is known that N_2O emission in paddy field is lower than the one in upland field. In Japan, Nagata and Sameshima (2006) observed N_2O emissions for paddy field of organic soil in Hokkaido, but the observations included emissions from applied nitrogen. Therefore, country-specific emission factor is determined to be 0.30 [kg-N_2O-N/ha/year] by deducting emission for applied fertilizer (estimated from country-specific emission factor of fertilizers (0.31% [% : kg-N_2O-N/kg-N]) indicated in Table 5-51 above).

For upland field and grassland (pastureland) cultivation, default values of 13 [kg-N_2O-N/kg-N] and 8.2 [kg-N_2O-N/kg-N] indicated in the *2019 Refinement* were used respectively.

- ***Activity Data***

The area of organic soil was obtained from the value calculated in LULUCF sector. For 1992, 2001 and 2010 when area data by soil type is available, the proportion of soil categorized in organic soil was estimated from area data by soil types, land categories and prefectures, and the proportion was multiplied by area by land categories and prefectures to obtain organic soil area. For other years, organic soil area was estimated by adjusting constant rate of converted land area to the area in 1992, 2001 and 2010.

Plowed area of organic soil includes all areas of organic soil for rice field and upland field and the renewed pasture lands, while organic soils for orchard, grazed meadow and wild land are not included. This is because orchard, grazed meadow and wild land are not plowed. (see 6.7.1. Grassland remaining Grassland)

The renewal of grassland is the maintenance work with re-sowing and re-plowing which is done once in several years. Annual plowed grassland area of organic soil is calculated by multiplying the annual renewal ratios by organic soil areas of grassland. For annual renewal ratio of grassland, a report of a study result by Hatano (2017) was utilized. The result by Hatano mentioned annual renewal ratios of grassland for categorized two areas, "Hokkaido" and "other areas" from 2006 to 2015. Averaged annual renewal ratios from 2006 to 2010 for each area (Hokkaido: 3.0%, other area: 1.3%) were substituted for the ratios before 2006 and since 2016.

Table 5-69 Annual renewal ratio of grassland

Fiscal year	Before 2006	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Since 2016
Hokkaido	3.0%	2.5%	2.8%	3.0%	3.7%	2.9%	3.5%	3.6%	3.3%	3.9%	4.1%	3.0%
Other area	1.3%	1.0%	1.2%	1.0%	1.4%	2.1%	3.8%	15.7%	9.6%	5.2%	3.5%	1.3%

Reference: Hatano (2017)

Table 5-70 Intended areas of organic soil in the agriculture sector [kha]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Intended paddy field	131.6	129.8	129.1	127.3	125.3	124.9	125.0	125.1	125.0	124.8	124.9	124.9	124.9	124.9	124.8
Intended upland field	16.7	16.7	17.0	16.9	16.8	16.5	16.4	16.3	16.2	16.1	16.0	16.0	16.0	16.0	15.9
Intended grassland (Hokkaido)	1.2	1.2	1.2	1.2	1.1	1.4	1.3	1.5	1.6	1.2	1.2	1.2	1.2	1.2	1.2
Intended grassland (other area)	0.005	0.004	0.003	0.003	0.004	0.029	0.018	0.010	0.006	0.002	0.002	0.002	0.002	0.002	0.002

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For uncertainty of the emission factor, default values (-75% to +200%) described in the *2006 IPCC Guidelines* were applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -75% to +200%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

The country-specific emission factor, 0.30 [kg-N_2O-N/ha/yr], from paddy fields with organic soil is set based on the actual measurement values of N_2O emissions from the paddy fields with peat soil in Hokkaido (Nagata and Sameshima, 2006). N_2O emissions from the paddy fields with peat soil were measured on 8 observation points and the range of emission measurement values were -0.28 to 1.27 [kgN_2O-N/ha/yr]. For setting the CSEF, emissions from fertilization were deducted because fertilizers were applied on those observation points. Emission estimation values of N_2O from fertilization to the paddy fields were in the range between 0.11 to 0.29 [kgN_2O-N/ha/yr]. The N_2O emission factor from the paddy fields with peat soil, therefore, is calculated as 0.30 [kg-N_2O-N/ha/yr].

The default emission factor for upland fields 13 [kg-N_2O-N/ha/yr] (the *2019 Refinement*, Vol.11, page 11.11) is in the range between 2.87 to 13.60 [kg-N_2O-N/ha/yr] which were the values from the measurements conducted in 9 observation points of upland fields with peat soil (Nagata and Sameshima, 2006).

e) Category-specific Recalculations

Since the organic soil area associated with land use conversion in LULUCF sector was changed, the emissions of FY1990, FY1991, and from FY2011 were recalculated. Since the emission factors for intended upland field and intended grassland were revised to that in the *2019 Refinement*, emissions for the whole time series were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvement plans.

5.5.2. Indirect N_2O Emissions from Managed Soils (3.D.b.)

Nitrogen compounds such as ammonia, that volatilize and are released into the atmosphere from synthetic fertilizers applied to agricultural soils, organic fertilizers applied to agricultural soils and the grazing livestock manure applied to soil are deposited on soil as the results of various actions, including turbulent diffusion, molecular diffusion, effect of electrostatic forces, chemical reactions, plant respiration, and being washed out of the air by rain. In this section, the amount of N_2O generated by microbe activity on the deposited nitrogen compounds was calculated.

N_2O is generated by the action of microbes on nitrogen that leaches or runs off as nitrate from synthetic fertilizers, organic fertilizers, etc.

5.5.2.1. Atmospheric Deposition (3.D.b.1.)

a) Category Description

This section provides the estimation methods for N_2O indirect emissions caused by atmospheric deposition of nitrogen compounds volatilized as NH_3 and NOx from synthetic fertilizers applied to soil, organic fertilizers applied to soil, and the grazing livestock manure applied to soil.

b) Methodological Issues

- ***Estimation Method***

N_2O emissions have been calculated in accordance with decision tree of the *2019 Refinement* (Vol. 4, Page 11.23, Fig11.3).

$$E = EF \times A \times 44 / 28$$

E	: N_2O emissions from atmospheric deposition [kg-N_2O/yr]
EF	: N_2O emission factor for atmospheric deposition [kg-N_2O-N/ kg-NH_3-N+NO_X-N volatilized]
A	: Total nitrogen amount volatilized as NH_3 and NOx from synthetic fertilizers, organic fertilizers, and deposition by grazing livestock [kg-NH_3-N+NO_x-N/yr]

- ***Emission Factors***

0.014 [kg-N_2O-N/kg-NH_3-N & NO_X-N volatilized] (the *2019 Refinement,* Vol.4 Table11.3).

- ***Activity Data***

As described in the following equation, the activity data are composed of the “nitrogen amount volatilized as NH_3 and NOx from synthetic fertilizers applied to soil by type of fertilizer, organic fertilizers applied to soil, and the excretion deposited by grazing livestock. The “nitrogen amount volatilized NH_3 and NOx in process of livestock manure management” are reported in 3.B.5.

$$A = \sum_t (F_{SNt} \times Frac_{GASFt}) + [\,(F_{ON} + F_{PRP}) \times Frac_{GASM3}\,]$$

A	: Total N amount volatilized as NH_3 and NOx from synthetic fertilizers, organic fertilizers, and excretion by grazing livestock [kg-NH_3-N+NO_x-N]
F_{SNt}	: N amount for synthetic fertilizers *t* applied to agricultural soil [kg-N/yr]
$Frac_{GASFt}$	: Fraction of volatilization as NH_3 and NOx from synthetic fertilizer applied to agricultural soil [(kg-NH_3-N + NO_X-N)/kg-N]
F_{ON}	: N amount for organic N fertilizers applied to agricultural soil [kg-N/yr]
F_{PRP}	: N amount in urine and dung deposited by grazing livestock [kg-N/yr]
$Frac_{GASM3}$	: Fraction of volatilization as NH_3 and NOx from applied organic N fertilizer (F_{ON}) and of urine and dung N deposited by grazing animals (F_{PRP}) [(kg-NH_3-N + NO_X-N)/kg-N]

➢ ***N amount volatilized as NH_3 and NOx from synthetic fertilizers applied to soil ($F_{SN} \times Frac_{GASF}$)***

For N amount of synthetic fertilizer applied to agricultural soil (F_{SNt}), the demand for nitrogenous fertilizer described in *Yearbook of Fertilizer Statistics (Pocket Edition)* was used for estimation. To estimate the value of synthetic fertilizer applied to agricultural soil (F_{SNt}), amount of synthetic fertilizer applied to forest were subtracted from this demand for nitrogenous fertilizer. The default values, indicated in Table 5-72, given in the *2019 Refinement* were used for the fraction of volatilization ($Frac_{GASFt}$). Fractions of N volatilized from each type of fertilizer are provided in the *2019 Refinement*, although they are not disaggregated in the *2006 IPCC Guidelines*. Using the default EFs from the *2019 Refinement* leads to estimates that reflect the circumstances of Japan more accurately because those EFs reflect the types of fertilizer used.

Table 5-71 Amount of synthetic fertilizer applied to agricultural soil by type (excluding forest application) [t-N]

Type	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Urea-based	115,620	107,917	106,712	125,170	117,267	109,403	136,391	129,924	136,622	132,424	132,424	132,424	132,424	132,424	132,424
Ammonium-based	465,738	393,888	363,180	286,181	245,364	249,294	239,123	228,585	208,505	224,393	224,393	224,393	224,393	224,393	224,393
Ammonium-nitrate-based	8,010	7,090	3,947	2,207	989	877	1,105	889	713	3,160	3,160	3,160	3,160	3,160	3,160
Other	22,300	18,374	13,338	57,410	45,778	37,022	33,105	35,045	26,325	14,726	14,726	14,726	14,726	14,726	14,726

Reference: Yearbook of Fertilizer Statistics (Pocket Edition)

Table 5-72 Fraction of nitrogen volatilized from synthetic fertilizers and organic fertilizers as ammonia or nitrogen oxides [kg-NH_3-N + NO_X-N/kg-N]

	Type	Value
$Frac_{GASF}$	Urea	0.15
	Ammonium-based	0.08
	Ammonium-nitrate-based	0.05
	For other type of N fertilizer	0.11
$Frac_{GASM}$	All organic N fertilizer	0.21

Reference: the *2019 Refinement*, Vol. 4, Table 11.3

➢ ***N amount volatilized as NH_3 and NOx from organic fertilizers applied to agricultural soil and from excretion by grazing livestock (($F_{ON} + F_{PRP}$) × $Frac_{GASM3}$)***

For nitrogen amount in organic N fertilizers applied to agricultural soil (F_{ON}), the data described in the "Organic N Fertilizers (3.D.a.2.)" were used. For the nitrogen amount in excretion from grazing livestock (F_{PRP}), the calculated data in 3.B. were used. For fraction of nitrogen volatilized as NH_3 and NOx ($Frac_{GASM3}$), default value ($Frac_{GASM} = 0.21$) of the *2019 Refinement* indicated in Table 5-72 above was used.

Table 5-73 Amount of nitrogen that volatilizes as ammonia and nitrogen oxides from synthetic fertilizers, livestock manure, and human waste [t (NH_3-N+NOx-N)]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
From synthetic N fertilizers applied to soil ($F_{SN} \times Frac_{GASF}$)	57,455	50,074	46,726	48,095	42,304	40,470	43,285	41,675	40,105	39,593	39,593	39,593	39,593	39,593	39,593
From organaic N fertilizers ($F_{ON} \times Frac_{GASM3}$)	103,859	99,852	95,631	86,382	89,235	87,624	87,225	88,170	94,292	93,841	96,274	95,607	92,068	93,131	93,283
From excretion from grazing livestock ($F_{PRP} \times Frac_{GASM4}$)	2,727	2,696	2,506	2,342	2,220	2,115	2,058	1,940	1,959	1,913	1,904	1,894	1,856	1,800	1,811
Total (nitrogen amount volatilized as ammonia and nitrogen oxides (A)	164,042	152,622	144,863	136,819	133,759	130,208	132,568	131,784	136,356	135,347	137,771	137,094	133,517	134,523	134,687

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For uncertainty of the emission factor, uncertainty (-106% to +447%) was calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 9% for population of broiler given in the *Livestock Statistics* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -106% to +447%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test*, averaged age in days of shipment in *The report of the fact-finding survey for pig farming*, egg production and feed intake per day for hen, crop residues for composting sub-materials, and the distribution amount of other organic fertilizer for FY2020 were updated/revised, the emissions from organic N fertilizers and that from excretion from grazing livestock for FY2020 were recalculated. The emissions from organic N fertilizers for the whole time-series were recalculated, due to the revision in emission factors for "Composting" out of the manure treating methods (3.B.). See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Discussion for the establishment of country-specific emission factors and the ratios of volatile nitrogen compounds has been conducted.

5.5.2.2. Nitrogen Leaching and Run-off (3.D.b.2.)

a) Category Description

This section provides the estimation methods for N_2O emissions from Nitrogen Leaching and Run-off.

b) Methodological Issues

- ***Estimation Method***

N_2O emissions were calculated according to the decision tree in the *2019 Refinement* (Vol. 4, Page 11.23, Fig11.3), by multiplying default emission factors by the amount of nitrogen that leached and run-off.

$$E = EF \times A \times 44 / 28$$

E	: N_2O emissions from N leaching and run-off [kg-N_2O]
EF	: N_2O emission factor for N leaching and run-off [kg-N_2O-N/kg-N]
A	: Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [kg-N]

- ***Emission Factors***

0.011 [kg-N_2O-N/kg-N] (default value, the *2019 Refinement*, Vol. 4, Table11.3).

- ***Activity Data***

As described in the formula below, activity data was composed of each nitrogen amount of leaching and run-off by synthetic fertilizers, organic fertilizers, excretion deposited by grazing livestock, crop residue, and carbon loss by mineralization. Each AD was calculated by multiplying the default value of fraction of leaching and run-off ($Frac_{LEACH}$, 0.24 [kg-N/kg-N]) given in the *2019 Refinement* by the amount of nitrogen calculated in 3.D.a.1. to 3.D.a.5. above. For $Frac_{LEACH}$, the *2019 Refinement* value was used because it was established from a larger data set provided by researches covering wide ranges of climate zone, crop types, livestock species and types of fertilizers, thus it is more accurate than that from the *2006 IPCC Guidelines*.

$$A = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times Frac_{LEACH}$$

A	: Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [kg-N/yr]
F_{SN}	: Nitrogen amount in synthetic fertilizers applied to agricultural soil [kg-N/yr]
F_{ON}	: Nitrogen amount in organic N fertilizers applied to agricultural soil [kg-N/yr]
F_{PRP}	: Nitrogen amount in urine and dung deposited by grazing livestock [kg-N/yr]
F_{CR}	: Nitrogen amount in crop residue plowed into soil [kg-N/yr]
F_{SOM}	: Nitrogen amount in mineralization in loss of carbon oxidized by organic matter in mineral soil [kg-N/yr]
$Frac_{LEACH}$	: Fraction of nitrogen leaching and run-off in each activity [kg-N/kg-N]

Table 5-74 Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [t (NH_3-N+NO_X-N)]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
From synthetic N fertilizers applied to soil (F_{SN}×$Frac_{LEACH}$)	146,800	126,545	116,922	113,032	98,255	95,183	98,334	94,666	89,319	89,929	89,929	89,929	89,929	89,929	89,929
From organaic N fertilizers (F_{ON}×$Frac_{LEACH}$)	118,697	114,116	109,293	98,722	101,983	100,141	99,686	100,766	107,762	107,247	110,028	109,265	105,220	106,435	106,610
From excretion from grazing livestock (F_{PRP}×$Frac_{LEACH}$)	3,117	3,081	2,864	2,676	2,537	2,417	2,351	2,217	2,239	2,187	2,175	2,165	2,121	2,057	2,070
From crop residue (F_{CR}×$Frac_{LEACH}$)	36,239	35,824	38,175	35,164	30,200	30,631	30,620	29,862	29,533	28,265	28,125	27,916	28,518	27,955	28,125
From mineralization (F_{SOM}×$Frac_{LEACH}$)	66,516	64,788	62,844	61,213	60,057	59,412	59,236	59,023	58,742	58,375	57,963	57,556	57,204	56,810	56,383
Total (nitrogen amount by leaching and run-off) (A)	371,369	344,353	330,098	310,808	293,033	287,785	290,228	286,534	287,595	286,002	288,220	286,831	282,992	283,185	283,116

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For uncertainty of the emission factor, uncertainty (-115% to +287%) was calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 9% was applied as same as "Atmospheric Deposition" above. As a result, the uncertainties of the emissions were determined to be -115% to +287%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test*, averaged age in days of shipment in *The report of the fact-finding survey for pig farming*, egg production and feed intake per day for hen, crop residues for composting sub-materials, the amount of rice straw and rice chaff plowed into soil, and the distribution amount of other organic fertilizers for FY2020 were updated/revised, the emissions from organic N fertilizers, excretion from grazing livestock, and crop residue for FY2020 were recalculated. The emissions from organic N fertilizers for the whole time-series were recalculated, due to the revision in emission factors for "Composting" out of the manure treating methods (3.B.). See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Discussion for the establishment of country-specific emission factors and the fraction of nitrogen leaching and run-off has been conducted.

5.6. Prescribed Burning of Savannas (3.E.)

This source is given in the *2006 IPCC Guidelines* as "being for the purpose of managing pastureland in sub-tropical zones". There is no equivalent activity in Japan, and this source has been reported as "NO".

5.7. Field Burning of Agricultural Residues (3.F.)

a) Category Description

Incomplete burning of crop residues in field releases CH_4 and N_2O into the atmosphere. CH_4 and N_2O emissions from this source are calculated and reported in this category.

CH_4 and N_2O emissions from Field Burning of Agricultural Residues in FY2021 are 64 kt-CO_2 eq. and 20 kt-CO_2 eq., comprising 0.005% and 0.002% of total emissions (excluding LULUCF), respectively. The value represents a decrease by 49.7% and 49.7% for CH_4 and N_2O from FY1990, respectively.

Table 5-75 CH_4 and N_2O emissions from field burning of agriculture residues (3.F.)

Gas	Item		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CH_4	3.F.1. Cereals	Wheat	kt-CH_4	0.38	0.22	0.27	0.31	0.24	0.21	0.20	0.19	0.18	0.18	0.18	0.16	0.17	0.18	0.20
		Barley		0.15	0.09	0.08	0.08	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06
		Maize		0.08	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.04	0.04
		Rice		1.96	2.05	1.38	1.03	0.70	0.66	0.75	0.68	0.56	0.57	0.47	0.53	0.51	0.50	0.48
		Other cereals		0.06	0.05	0.08	0.09	0.09	0.12	0.12	0.12	0.11	0.12	0.12	0.13	0.13	0.13	0.13
	3.F.2. Pulses	Soybeans		0.47	0.22	0.40	0.43	0.45	0.42	0.42	0.43	0.46	0.49	0.49	0.47	0.46	0.46	0.47
		Other pulses		0.35	0.27	0.22	0.19	0.16	0.15	0.16	0.16	0.14	0.12	0.12	0.12	0.13	0.13	0.12
	3.F.3. Tubers and roots	Potatoes		0.23	0.20	0.18	0.17	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14
		Sugarbeet		0.14	0.14	0.14	0.13	0.12	0.12	0.11	0.11	0.11	0.12	0.11	0.11	0.11	0.11	0.11
		Other tubers and roots		0.20	0.17	0.15	0.13	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.10	0.10
	3.F.4.	Sugarcane		0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04
	3.F.5. Other	Vegetables		0.95	0.87	0.81	0.74	0.72	0.71	0.70	0.69	0.69	0.69	0.68	0.68	0.67	0.66	0.65
		Other crops		0.08	0.06	0.05	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Total		kt-CH_4	5.1	4.4	3.8	3.4	2.9	2.8	2.9	2.8	2.7	2.7	2.6	2.6	2.6	2.6	2.6
			kt-CO_2 eq.	127	111	96	86	74	71	72	70	67	67	64	65	64	64	64
N_2O	3.F.1. Cereals	Wheat	kt-N_2O	0.010	0.006	0.007	0.008	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.004	0.004	0.005	0.005
		Barley		0.004	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
		Maize		0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
		Rice		0.051	0.053	0.036	0.027	0.018	0.017	0.019	0.018	0.015	0.015	0.012	0.014	0.013	0.013	0.012
		Other cereals		0.002	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	3.F.2. Pulses	Soybeans		0.012	0.006	0.010	0.011	0.012	0.011	0.011	0.011	0.012	0.013	0.013	0.012	0.012	0.012	0.012
		Other pulses		0.009	0.007	0.006	0.005	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003
	3.F.3. Tubers and roots	Potatoes		0.006	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
		Sugarbeet		0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
		Other tubers and roots		0.005	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	3.F.4.	Sugarcane		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	3.F.5. Other	Vegetables		0.025	0.023	0.021	0.019	0.019	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.017	0.017	0.017
		Other crops		0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0005	0.0004	0.0004	0.0004
	Total		kt-N_2O	0.13	0.12	0.10	0.09	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
			kt-CO_2 eq.	39	34	30	26	23	22	22	22	21	21	20	20	20	20	20
Total of all gases			kt-CO_2 eq.	166	145	126	112	96	93	94	92	88	88	84	85	84	84	84

b) Methodological Issues

- ***Estimation Method***

CH_4 and N_2O emissions were calculated by using the method indicated in the *2006 IPCC Guidelines.*

$$E = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

E	: CH_4 and N_2O emissions from field burning of agriculture residues [t-CH_4 or t-N_2O]
A	: Area burnt [ha]
M_B	: Mass of fuel available for combustion [t/ha]
C_f	: Combustion factor
G_{ef}	: Emission factor [g-CH_4/kg or g-N_2O/kg]

- ***Emission Factors***

CH_4: 2.7 [g-CH_4/kg (dry matter)] (default value in the *2006 IPCC Guidelines*, Table 2.5)

N_2O: 0.07 [g-N_2O/kg (dry matter)] (default value in the *2006 IPCC Guidelines*, Table 2.5)

- ***Activity Data***

Parameters used in estimation are indicated in the Table 5-76 below. For proportion of burned residue and combustion factor, same values in Crop Residues (3.D.a.4.) were used. For rice, since data of the amount of burning rice straw and rice chaff on crop field (Table 5-77) is available, mass of fuel available for combustion (M_B) was not multiplied in estimation. The proportion burned in field for wheat, barley, rye and oats were the same values as shown in Table 5-66.

Table 5-76 Proportion of burned residue on agricultural field, $M_B \times C_f$ and Combustion factor

Crop	Proportion of burned residue	$M_B \times C_f$	Combustion Factor (C_f)
Rice	---	---	0.80
Pulse	12% 1)	10 3)	---
Vegetable, Sugarbeet, Maize, Tuber crops (e.g. potato), Buckwheat, Canola seed, Konjac, Rush grass, Tabaco	7% 2)	10 3)	---
Sugarcane	7% 2)	6.5	---
Wheat, Barley, Ray, Oats	See Table 5-66	4 4)	---

Reference: Proportion burned: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*
$M_B \times C_f$: *2006 IPCC Guidelines*
Note: 1) value of pulse, 2) value of vegetable, 3) value of maize, 4) value of wheat

For rice, amount of rice straw and rice chaff burned on crop field is surveyed by MAFF (Table 5-77). The amounts of burning residue of other crops were estimated by area data described in the *Crop Statistics* or the *Vegetable Production and Shipment Statistics*. The dry matter fraction (0.89) from the *2006 IPCC Guidelines* was used for converting the amount of residue in wet basis into that in dry basis.

Table 5-77 Amount of rice straw and rice chaff burned in crop field (Wet) [kt]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Rice straw	438.2	536.9	429.1	276.6	149.3	149.4	183.4	161.7	144.2	152.8	129.3	136.1	123.3	129.7	115.6
Rice chaff	581.3	528.3	291.3	260.3	212.9	195.6	206.6	193.9	147.5	142.6	114.2	140.7	140.7	132.8	134.3
Total	1,019.5	1,065.2	720.4	536.9	362.2	345.0	390.0	355.6	291.7	295.4	243.5	276.8	264.0	262.5	249.9

Reference: Calculated from each prefecture data

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For uncertainty of the emission factor, uncertainties (CH_4: 296%, N_2O: 300%) were calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 296% for CH_4 and 300% for N_2O.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

Since the amount of rice straw and rice chaff removed from field and burned in field in FY2020 were updated, the emissions for FY2020 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvement plans.

5.8. Liming (3.G.)

a) Category Description

CO_2 are released into the air by application of limestone ($CaCO_3$) fertilizer and/or dolomite

($CaMg(CO_3)_2$) fertilizer via hydrogen carbonate ions (HCO_3^-) which is released in soil water. This category deals with CO_2 emissions from their agricultural lime application.

CO_2 emissions from this category in FY2021 were 225 kt-CO_2, comprising 0.02% of total emissions (excluding LULUCF). The value represents a decrease by 59.0% from FY1990.

Table 5-78 CO_2 emissions from agricultural lime application (3.G.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	3.G.-Limestone	kt-CO_2	550	303	332	231	242	369	379	362	258	252	293	241	241	232	223
	3.G.-Dolomite		0.3	0.5	0.5	0.6	1.0	0.6	1.1	1.0	0.8	0.8	0.9	0.9	0.9	0.8	2.0
	Total	kt-CO_2	550	304	333	231	243	370	380	363	259	253	294	242	242	233	225

b) Methodological Issues

- ***Estimation Method***

The Tier 1 method is used in accordance with the decision tree described in the *2006 IPCC Guidelines* (Vol.4, 11.27, Figure11.4).

$$E = (M_{Limestone} \times EF_{Limestone} + M_{Dolomite} \times EF_{Dolomite}) \times 44/12$$

E	: Annual CO_2 emissions from agricultural lime application [t-CO_2]
$M_{Limestone}$	: Annual amount of calcic limestone [t]
$EF_{Limestone}$	: Emission factor of calcic limestone [t-C/t]
$M_{Dolomite}$	: Annual amount of dolomite [t]
$EF_{Dolomite}$	: Emission factor of dolomite [t-C/t]

- ***Emission Factors***

Limestone ($CaCO_3$): 0.12 [t-C/t] (default value, *2006 IPCC Guideline*s, Vol.4, page 11.29).

Dolomite ($CaMg(CO_3)_2$): 0.13 [t-C/t] (default value, *2006 IPCC Guidelines*, Vol.4, page 11.29).

- ***Activity Data***

The activity data were calculated by adding up lime production and import quantities as listed in *the Yearbook of Fertilizer Statistics* published by the Association of Agriculture and Forestry Statistics. Based on expert judgment, all of the "Calcium carbonate fertilizer" and 70% of each of "Fossil seashell fertilizer", "Crushed limestone" and "Seashell fertilizer" listed in the Yearbook were classified as calcic limestone ($CaCO_3$), and all of the "Magnesium carbonate fertilizer" and 74% of "Mixed magnesium fertilizer" as dolomite ($CaMg(CO_3)_2$).

Table 5-79 Amount of limestone and dolomite applied to agricultural soils [kt]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Applied Limestone	1,250	689	755	524	550	839	860	822	586	573	665	548	549	527	508
Applied Dolomite	0.7	1.1	1.1	1.4	2.0	1.3	2.2	2.0	1.7	1.7	2.0	1.9	1.9	1.8	4.3

Reference: Estimated from the data described in *Yearbook of Fertilizer Statistics*

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For uncertainty of the emission factor, default values (50%) described in the *2006 IPCC Guidelines* was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 50%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

No recalculations are conducted.

f) Category-specific Planned Improvements

There are no improvement plans.

5.9. Urea application (3.H.)

a) Category Description

CO_2 are released into the air by application of urea ($(NH_3)_2CO$) fertilizer via hydrogen carbonate ions (HCO_3^-) which is released in soil water. This category deals with estimation and reporting for this CO_2 emissions.

CO_2 emissions from this category in FY2021 were 208 kt-CO_2, comprising 0.02% of national total emissions (excluding LULUCF). The value represents an increase by 14.5% from FY1990.

Table 5-80 CO_2 emissions from urea fertilizer (3.H.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	3.H. Urea fertilization	kt-CO_2	182	170	168	197	184	172	214	204	215	208	208	208	208	208	208

b) Methodological Issues

- ***Estimation Method***

The Tier 1 method is used in accordance with the decision tree described in the *2006 IPCC Guidelines* (Vol.4, p.11.33, Fig.11.5).

$$E = (M \times EF) \times 44/12$$

E : Annual CO_2 emissions from urea application [t-CO_2]
M : Annual amount of urea application [t]
EF : Emission factor for urea application [t-C/t]

- ***Emission Factors***

0.20 [t-C/t] (default value, *2006 IPCC Guidelines*, p.11.34).

- ***Activity Data***

For the amount of urea applied, “total demand of urea fertilizer” in Japan described in *the Yearbook of Fertilizer Statistics (Pocket Edition)* published by the Association of Agriculture and Forestry Statistics is used.

Table 5-81 Total demand for urea fertilizer in Japan [kt]

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total demand for urea fertilizer	248	231	229	268	251	235	292	279	293	284	284	284	284	284	284

Reference: Estimated from the data described in *Yearbook of Fertilizer Statistics (Pocket Edition)*

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

For uncertainty of the emission factor, default value (50%) described in the *2006 IPCC Guidelines* was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 50%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

Emissions for the whole time series were recalculated due to changes in activity data from imported urea fertilizer to the total demand for urea fertilizer in Japan including domestically produced urea in accordance with the *2006 IPCC Guidelines*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no improvement plans.

5.10. Other Carbon-containing Fertilizers (3.I.)

Since there are no other sources to be reported in this category, this category is reported as “NO”.

5.11. Other (3.J.)

Since there are no other sources as “Other”, this category is reported as “NO”.

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
2. IPCC, *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2019.
3. International Rice Research Institute, *World Rice Statistics 1993-94*, 1995.
4. Environmental Agency, Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 1*, September 2000.
5. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 3*, August 2002.
6. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods,* February 2006.
7. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Report of the research on the state of wide-range movement and cyclical use of wastes* (the volume on cyclical use).
8. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Waste Treatment in Japan.*
9. Japan Meteorological Agency, *Climate Charts of Japan.*
10. Ministry of Agriculture, Forestry and Fisheries of Japan, Agricultural Production Bureau, Livestock Industry Department, *Survey of current status for livestock manure management system 2009*, 2011.
11. Ministry of Agriculture, Forestry and Fisheries of Japan, Agricultural Production Bureau, Livestock Industry Department, *Survey of current status for livestock manure management system and others 2019*, 2021.
12. Ministry of Agriculture, Forestry and Fisheries of Japan, *the Report of Project on Survey and Investigation for Elaboration of GHG Emissions from Agriculture, Forest and Fisheries Sector, within the Project on Development for Method of Promotion for Countermeasures of Global Environment in the Agriculture, Forest and Fisheries Sector in FY2011*, 2012.
13. Ministry of Agriculture, Forestry and Fisheries of Japan, *the Report of Project on Survey and Investigation for Elaboration of GHG Emissions from Agriculture, Forest and Fisheries Sector, within the Project on Development for Method of Promotion for Countermeasures of Global Environment in the Agriculture, Forest and Fisheries Sector in FY2012*, 2013.
14. Ministry of Agriculture, Forestry and Fisheries of Japan, *the Report of Project on Survey and Investigation for Elaboration of GHG Emissions from Agriculture, Forest and Fisheries Sector, within the Project on Development for Method of Promotion for Countermeasures of Global Environment in the Agriculture, Forest and Fisheries Sector in FY2013*, 2014.
15. Ministry of Agriculture, Forestry and Fisheries of Japan, *Basic Survey of Soil Environment*, 1990.
16. Ministry of Agriculture, Forestry and Fisheries of Japan, *The Entry Guideline for fourth Fundamental Research of Land Use Infrastructure*, 2006.
17. Ministry of Agriculture, Forestry and Fisheries of Japan, *Planning for Breeding Improvement of Poultry*, 2015.
18. Ministry of Agriculture, Forestry and Fisheries of Japan, *Summary of the Basic Plan for Food, Agriculture and Rural Areas*, April 2015.
19. Ministry of Agriculture, Forestry and Fisheries of Japan, *the Project of Basic Survey on Greenhouse Gas Emission Estimation from Agricultural Land Soil*, 2014.

20. Ministry of Agriculture, Forestry and Fisheries of Japan, *the Project of Basic Survey for Carbone Stock on Agricultural Land Soil*, 2018.
21. Ministry of Agriculture, Forestry and Fisheries of Japan, *Crop Statistics.*
22. Ministry of Agriculture, Forestry and Fisheries of Japan, *Livestock Statistics.*
23. Ministry of Agriculture, Forestry and Fisheries of Japan, *Statistical Document for small animals and laboratory animals*.
24. Ministry of Agriculture, Forestry and Fisheries of Japan, *Statistics of Cultivated and Planted Area.*
25. Ministry of Agriculture, Forestry and Fisheries of Japan, *Statistics on Farm Management.*
26. Ministry of Agriculture, Forestry and Fisheries of Japan, *Statistics of Livestock Production Costs.*
27. Ministry of Agriculture, Forestry and Fisheries of Japan, *Statistics on Livestock Products Marketing.*
28. Ministry of Agriculture, Forestry and Fisheries of Japan, *Statistics on Milk and Dairy Products.*
29. Ministry of Agriculture, Forestry and Fisheries of Japan, *Status Report regarding Health Management for Livestock Feeding*.
30. Ministry of Agriculture, Forestry and Fisheries of Japan, *Feed bulletin*.
31. Ministry of Agriculture, Forestry and Fisheries of Japan, *Vegetable Production and Shipment Statistics.*
32. Ministry of Agriculture, Forestry and Fisheries, Agricultural Production Bureau, Livestock Industry Department, Livestock Production and Feed Division, *Statistical Document of Horse.*
33. Ministry of Agriculture, Forestry and Fisheries of Japan, *the Direct Payments for Environmentally Friendly Agriculture*.
34. Report of Survey Project for Prevention of Global Warming in the Agriculture, Forest and Fisheries Sector within the Environment and Biomass Comprehensive Strategy Promotion Project in FY2008 (Nationwide Survey), Project Title: *Discussions on Greenhouse Gas Emissions Estimation Method for Livestock Manure Management by taking Japan's Climate Conditions into account*., 2009.
35. Hokkaido Government, Department of Agriculture, *Hokkaido Fertilizer Recommendations 2010*, 2010.
36. Okinawa prefecture, *Survey Result of Feeding Livestock and Poultry*.
37. GHEN Corporation CO., Ltd., *Breeding Management Guidelines for Commercial Chicken*.
38. Association of Agriculture and Forestry Statistics, *Yearbook of Fertilizer Statistics* (*Pocket Edition*).
39. National Agriculture and Food Research Organization compiled, *Japanese Feeding Standards*, Japan Livestock Industry Association.
40. National Agriculture and Food Research Organization compiled, *Standard Tables of Feed Composition in Japan*, Japan Livestock Industry Association.
41. Japan Livestock Industry Association, *Statistical Document of Livestock Breeding*.
42. Livestock Improvement Association of Japan. INC, *Record of Dairy Herd Performance Test*.
43. Japan Pork Producers Association, *The report of the fact-finding survey for pig farming (The result of National tabulation results.*
44. Livestock Industry's Environmental Improvement Organization compiled, *Guide for processing and using livestock manure*, Livestock Industry's Environmental Improvement Organization, 1998.
45. Japan Livestock Technology Association, *GHGs emissions control in livestock industry Part4*, March 1999.
46. Japan Livestock Technology Association, *GHGs emissions control in livestock industry Summary*,

March 2002.

47. Japan Livestock Technology Association, *Questionnaire Survey on Current Feeding Status for Broiler*, 2008.
48. Japan Sewage Works Association data
49. Japan Tabaco Inc. data
50. Research Council on Soil Function for Global Warming Countermeasures, *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*.
51. Akiyama, H., Yagi, K., and Yan, X., *Direct N_2O emissions and estimate of N_2O emission factors from Japanese agricultural soils*, In program and Abstracts of the International Workshop on Monsoon Asia Agricultural Greenhouse Gas Emissions, March 7-9, 2006, Tsukuba, Japan, pp. 27, 2006 a.
52. Akiyama, H., Yan X. and Yagi, K., *Estimations of emission factors for fertilizer-induced direct N_2O emissions from agricultural soils in Japan: Summary of available data*, Soil Science and Plant Nutrition, 52, 774-787, 2006 b.
53. Akiyama, H., Yan X. and Yagi, K., *Evaluation of effectiveness of enhanced-efficiency fertilizers as mitigation options for N_2O and NO emissions from agricultural soils: meta-analysis*, Global Change Biology, 16(6), 1837-1846, 2010.
54. Choumei, Y., Terada, F. and Hirooka, H., *Prediction and Comparison of Nitrogen Excretions in Dairy and Beef Cattle*, Japanese Journal of Zootechnical Science, 77(4), 485-494, 2006.
55. Date, N., *Handbook for Organic Fertilizers and Microbial Materials*, Rural Culture Association Japan, pp. 116-117, 1988.
56. Fumoto, T., Yanagihara, T., Saito, T. and Yagi, K., *Process-modeling approach toward estimation of greenhouse gas emissions from crop lands*, Journal of the Japanese Society of Soil Physics, 114, 49-52, 2010.
57. Hatano, R., *Report of survey on actual management of grasslands forage cropping areas in Japan*, Project Report of Livestock Industry Promotion by Japan Racing Association in FY2016, 2017.
58. Hayano, M., Fumoto, T., Yagi, K. and Shirato, Y., *National-scale estimation of methane emission from paddy fields in Japan: Database construction and upscaling using a process-based biogeochemistry model*. Soil Science Plant Nutrition, 59(5), 812–823, 2013.
59. Hojito, M., Ikeguchi, A., Kohyama, K., Shimada, K., Ogino, A., Mishima, S. and Kaku, K. *Estimation of Nitrogen Loading in Japanese Prefectures and Scenario Testing of Abatement Strategies*, Japanese Journal of Soil Science and Plant Nutrition, 74(4) 467-474, 2003.
60. Hoshina, T., Kozai, S. and Honjo, Y., *Decomposition of Tea Organic Residues in Soil and Re-absorption of the Nitrogen by Tea Plant*, Tea Research Journal, 55, 30-36, 1982.
61. Ishibashi, M., Hashiguchi, J. and Koga, M., *Development of technology of reducing GHG on the livestock industry* (*second report*), the experiment and study of environmental safeguards on the livestock industry, Annual Report of the Kumamoto Prefectural Agricultural Research Center Animal Husbandry Research Institute, 2003.
62. Katayanagi, N., Fumoto, T., Hayano, M., Takata, Y., Kuwagata, T., Shirato, Y., Sawano, S., Kajiura, M., Sudo, S., Ishigooka, Y. and Yagi, K., *Development of a method for estimating total CH_4 emission from rice paddies in Japan using the DNDC-Rice model*, Science of the Total Environment, 547, 429–440, 2016.
63. Katayanagi, N., Fumoto, T., Hayano, M., Shirato, Y., Takata, Y., Leon, A. and Yagi, K., *Estimation of*

total CH_4 emission from Japanese rice paddies using a new estimation method based on the DNDC-Rice simulation model, Science of the Total Environment, 601–602, 346–355, 2017.

64. Kinoshita, T., and Tsuji, M., *Nitrogen Balance in "Tencha" Tea Field*, Tea Research Journal, 100, 52-54, 2005.

65. Kume, S., Nonaka, K., Oshita, T. and Kozakai, T., *Evaluation of drinking water intake, feed water intake and total water intake in dry and lactating cows fed silages*, Livestock Science, 128(1-3), 46-51, 2010.

66. Matsumoto, N., *Development of Estimation Method and Evaluation of Nitrogen Flow in Regional Areas*, Bulletin of National Institute for Agro-Environmental Sciences, 18, 81-152, 2000.

67. Minamikawa, K., Fumoto, T., Itoh, M., Hayano, M., Sudo, S. and Yagi, K., *Potential of prolonged midseason drainage for reducing methane emission from rice paddies in Japan: a long-term simulation using the DNDC-Rice model*, Biology and Fertility of Soils, 50(6), 879-889, 2014.

68. Mori, A. and Hojito, M., *Methane and nitrous oxide emissions due to excreta returns from grazing cattle in Nasu, Japan*, Grassland Science, 61(2), 109-120, 2015.

69. Niwa, T., *Handbook for Pig raising*, Yokendo 1994.

70. Nonaka, K., *Nitrogenous environmental load in tea fields and fertilizer application technology for the reduction of the environmental load*, Tea Research Journal, 100, 29-41, 2005.

71. Nagata, O. and Sameshima, R., *Effect of land use change in Ishikari peatland on greenhouse gas emission*, New Research Results: Hokkaido Region, 115-121, 2006.

72. Ogawa, K., Takeuchi, Y. and Katayama, M., *Biomass Production and the Amounts of Absorbed Inorganic Elements by Crops in Arable lands in Hokkaido, and its evaluation*, Research Bulletin of the Hokkaido National Agricultural Experiment Station, 149, 57-91, 1988.

73. Ogino, A., Murakami, H., Yamashita, T., Furuya, M., Kawahara, H., Ohkubo, T. and Osada, T., *Estimation of nutrient excretion factors of broiler and layer chickens in Japan*, Animal Science Journal, 88(4), 659-668, 2017.

74. Ogino,A., Ohmori, H., Inoue, H., Yamashita, T. and Osada, T. *Estimation of nitroge, phosphorus, and potassium excretion factors of fattening pigs in Japan*, Nihon Chikusan Gakkaiho 91(3), 281-288, 2020.

75. Ohta, M., Iwahashi, M. and Morita, A., *Decomposition of Organic Matter derived from Pruned Branches and Nitrogen Loss in a Renewal Tea Field after First Crop of Tea*, Tea Research Journal, 84 (supplement), 130-131, 1996.

76. Otani, F., Amari, M., Tagusari, M. and Kume, S., *Urine amount of Lactating dairy cow is able to estimate from Intake of Nitrogen and Potassium, and Milk production*, Result information of Institute of Livestock and Grassland Science, NARO, 2010.

77. Osada, T., Kuroda, K. and Yonaga, M., *Determination of nitrous oxide, methane, and ammonia emissions from a swine waste composting process*, Journal of Material Cycles and Waste Management, 2(1), 51-56. 2000.

78. Osada, T., *Nitrous Oxide Emission from Purification of Liquid Portion of Swine Wastewater*, Greenhouse Gas Control Technologies - 6 International Conference, Volume I, J. Gale and Y. Kaya (Eds.), 1299-1304. 2003.

79. Osada, T., Fukumoto, Y., Tamura, T., Shiraishi, M. and Ishibashi, M., *Greenhouse gas generation from livestock waste composting*, Proceedings of the Fourth International Symposium on Non-CO_2 Greenhouse Gases (NCGG-4), Science, Control, Policy and Implementation, Millpress, Rotterdam, 105-111, 2005.

80. Owa, N., "*New Trends in Technology for Efficient Use of Nutrients – Nutritional Balance of Crops in Japan"* 1996 Sixth Kanto-Tokai Agricultural Study Session on Soil Management Technologies for Agricultural Production in Harmony with Environment; National Agriculture and Bio-oriented Research Organization, 1996.
81. Saito, M., *Methane Excretion in Fattening Pigs and Pregnant sows*, Japanese Journal of Zootechnical Science, 59(9), 779-778, 1988.
82. Shibata, M., Terada, F., Kurihara, M., Nishida, T. and Iwasaki, K., *Estimation of Methane Production in Ruminants*, Japanese Journal of Zootechnical Science, 64(8), 790-796, 1993.
83. Shiraishi, M., Osada, T., Mizuki, T. and Takatori, K., *Greenhouse gas emission from the Facility of Cattle Wastewater Treatment with Activated-Sludge process*, Japanese Journal of Zootechnical Science, 88(4), 479-490, 2017.
84. Tachibana, N., Ikeda T. and Ikeda, K., *Changes in Nitrogen Uptake with Aging and Under Heavy Application of Nitrogen in Tea Plants*, Japanese Journal of Crop Science, 65(1), 8-15, 1996.
85. Tsuchiya, I., Etsue, H., Dougan, H., Sakamoto, T., Ishida, M., Hasegawa, S. and Osada, T. *Measurement of greenhouse effect gas emissions from drying treatment of poultry manure facility*, Japanese Journal of Zootechnical Science, 85(1), 61-69, 2014.
86. Tsuiki, M. and Harada, Y., *A Computer Program for Estimating the Amount of Livestock Wastes*, J. JASS, 13(1), 17-23, 1997.
87. Tsuruta, H., *Model building for greenhouse gas reduction method on agriculture -Nitrous oxide-*, Research Report on Methodologies for Quantification of GHG Emission Reduction in FY 2000, Association for Advancement of Agricultural Science, 2001.
88. Yagasaki, Y. and Shirato, Y., *Assessment on the rates and potentials of soil organic carbon sequestration in agricultural lands in Japan using a process-based model and spatially explicit land-use change inventories – Part 1: Historical trend and validation based on nation-wide soil monitoring*, Biogeosciences, 11(16), 4429–4442, 2014.
89. Shirato, Y., Ayaka W. Kishimoto-Mo, W. A. and Takata, Y., *A modeling approach to estimating N_2O emission derived from loss of soil organic matter for the Japanese greenhouse gas inventory*, Soil Science and Plant Nutrition, 67(3), 347-352, 2021.
90. Itoh, M., Sudo, S., Mori, S., Saito, H., Yoshida, T., Shiratori, Y., Suga, S., Yoshikawa, N., Suzue, Y., Mizukami, H., Mochida, T. and Yagi, K., "*Mitigation of methane emissions from paddy fields by prolonging midseason drainage*", Agriculture, Ecosystems and Environment, 141, 359–372, 2011.
91. National Research Council of the National Academies (NRC), "*Nutrient Requirements of Swine – Animal Nutrition Series–*", 2012.

Chapter 6. Land Use, Land-Use Change and Forestry (CRF sector 4)

6.1. Overview of Sector

The land use, land-use change, and forestry (LULUCF) sector deals with greenhouse gas (GHG) emissions and removals resulting from land use such as forestry activities and its land-use change. GHG emissions and removals in this sector consist of carbon stock changes in five carbon pools (aboveground biomass, belowground biomass, dead wood, litter, and soil) in each land-use category, such as forest land (4.A.), cropland (4.B.), grassland (4.C.), wetlands (4.D.), settlements (4.E.) and other land (4.F.) which are divided in accordance with the *2006 IPCC Guidelines'* land-use classification, and carbon stock changes in harvested wood products (HWP) pool in forest land (4.G.). It also consists of direct N_2O emissions from N fertilization (4.(I)), CH_4 and N_2O emissions from drainage and other management of organic soils (4.(II)), N_2O emissions from nitrogen mineralization resulting from change of land use or management of mineral soils (4.(III)), indirect N_2O emissions from managed soils (4.(IV)), and emissions of CH_4 and N_2O etc. from biomass burning (4.(V)) in each land-use category (except N_2O emissions from 4.(I) and 4.(II) in cropland and grassland as well as from 4.(III) and 4.(IV) in cropland remaining cropland, which are reported in the Agriculture sector). Methodological tiers used in this sector are shown in Table 6-1. In this chapter, above- and below-ground biomass are collectively referred as "living biomass", and dead wood and litter are also referred as "dead organic matter".

This sector includes both sources and sinks; however, it has been continuously a net sink since FY1990 in Japan. Net removals in FY2021 were 51,695 kt-CO_2 eq; which accounts for 4.4% of the total national emissions (excluding LULUCF). The net removals in FY2021 also represent a decrease of 18.3% compared to FY1990 and an increase of 0.2% compared to FY2020. Net removals in Japan had been increasing from FY1990 to FY2003, but have been on a long-term decreasing trend since FY 2004. The key drivers for the rise in removals from FY1990 to FY2003 were increase of removals in forest land, decrease in the amount of carbon loss in mineral soils in cropland, and decrease of emissions due to the decrease in areas of forest land conversion. The decreasing trends in net removals since FY 2004 are mainly caused by the decrease of removals in forest land.

Table 6-1 Methodological tiers used in the LULUCF sector

GHG source and sink category	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
A. Forest land	T1,T2,T3	CS,D	T1	D	T1,T2	CS,D
B. Cropland	T1,T2,T3	CS,D	T1	D	T1,T2	CS,D
C. Grassland	T1,T2,T3	CS,D	T1	D	T1,T2	CS
D. Wetlands	T1,T2	CS,D	-	-	-	-
E. Settlements	T1,T2	CS,D	T1	CS,D	T1	CS,D
F. Other land	T2	CS,D	-	-	T1	D
G. Harvested wood products	T2,T3	CS,D				

Note: D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country-specific method or emission factor

Japan's national land is an archipelago consisting of Hokkaido, Honshu, Shikoku, Kyushu and other islands, and lies off the east coast of the Eurasian Continent. The archipelago is formed into a crescent shape extending from northeast to southwest. Its northernmost point is located at about 45 degrees north latitude, and its southernmost point is located at about 20 degrees north latitude. Most of Japan's national land is located in the temperate humid climate zone. Some islands in the southern part of Japan belong to the subtropical climate zone, and the northern part of Japan is located in the cool-temperate climate zone.

6.2. Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories

6.2.1. Method of determining the area of each land use category

All of the land area of Japan is allocated to one of the 6 land-use categories in accordance with the *2006 IPCC Guidelines.* The allocation is on the basis of the criteria and definitions in existing statistics in Japan as shown in Table 6-2. Land which is not classified into the five land-use categories (forest land, cropland, grassland, wetlands and settlements) is defined as "other land", and its area is determined by deducting the total area of the five land-use categories from the total national land area.

Table 6-2 Criteria for IPCC land-use category allocation and data sources and methods for determing land areas

IPCC land-use category	Criteria for land-use category allocation	Data sources and methods for determining land areas
Forest land	Forests under Forest Law Article 5 and 7.2 (excluding agricultural woodlands and urban forests)	Forests with standing trees (intensively managed forests, semi-natural forests), forests with less standing trees and bamboo in the forests which are included in the regional forests plan according to the *Forestry Status Survey* [-FY2004] and the *National Forest Resources Database* (NFRDB) [FY2005-] (Forestry Agency).[1]
Cropland	Rice fields, upland fields, orchards and dilapidated farmland	Rice fields, upland fields and orchard according to *Statistics of Cultivated and Planted Area* by the MAFF. Dilapidated farmland according to *Census of Agriculture and Forestry* (MAFF) and *Survey on the Occurrence and Resolution of Dilapidated Farmland* (MAFF), etc.
Grassland	Pasture land, grazed meadow land, and wild land[2] (not included in pasture land and grazed meadow land)	Pasture land according to *Statistics of Cultivated and Planted Area* (MAFF), grazed meadow land (excluding when it is included in forest land) according to *Census of Agriculture and Forestry* (MAFF), and wild land according to *Land Use Status Survey* (MLIT).
Wetlands	Lands covered with water (such as dams), rivers, and waterways. (including mangroves not included in forest land)	Lands covered with water, rivers, and waterways according to *Land Use Status Survey, Survey of Forestry regions* (MLIT). Areas of Mangroves are identified with other surveys and statistical data (see section 6.7.1. b)2) for the details). However, since this area is not part of the total land area of the country, it is treated as land area outside of the national land area.
Settlements	Urban areas that do not constitute forest land, cropland, grassland or wetlands. Urban green areas, including urban forests, consist of both green spaces conserved by zoning and urban green facilities.	Settlements are roads, residential land, school reservations, park and green areas, road sites, environmental facility sites, golf courses, ski courses and other recreation sites identified in *Land Use Status Survey* and other surveys by the MLIT. The included figures for urban green areas are taken from the surveys on urban green facilities conducted by the MLIT. (Details are shown in Table 6-49).
Other land	Any land that does not belong to the above land-use categories.	Determined by subtracting the total area belonging to the above five land-use categories from the total area of national land according to *Statistical Reports on the Land Area by Prefectures and Municipalities in Japan* by the Geospatial Information Authority of Japan.

Note: MAFF: Ministry of Agriculture, Forestry and Fisheries; MLIT: Ministry of Land, Infrastructure, Transport and Tourism

[1] The *Forestry Status Survey* and the *National Forest Resources Database* (NFRDB) use the same definitions and survey methods for forests, and these two databases have time-series consistency.

[2] Its present status is mainly wild grassland (including perennial pasture land, degenerated pasture land, and areas abandoned after cultivation and becoming wild). The item of "wild land" was changed to "wild land, etc" including

ERT indicated in the 2022 Review (ARR2022 L.15) that Japan should provide information in NIR on why the approach of reporting total area as the sum of all land use categories was not applied. The reason is that it is difficult to capture all land areas in “other land” through existing data sources because these do not cover the entire range of other land, although there are some statistics that partially capture "other land" elements.

The area of each land-use category in FY2021 obtained by the methods shown in Table 6-2 is as follows; approximately 24.97 million ha for forest land, 4.04 million ha for cropland, 0.9 million ha for grassland, 1.35 million ha for wetlands, 3.90 million ha for settlements, and 2.64 million ha for other land. Note that each land use category has its own subcategories. See the section on each land use category for a description of the subcategories and their definitions. The frequency of statistical surveys used and other information are shown in Table 6-3.

Table 6-3 Statistics used for area estimation

Name of the statistics / census	Survey method	Survey due date	Frequency	Presiding ministry
Forest Status Survey	Complete count survey	March 31st	Every 5 years	Forestry Agency
National Forest Resources Database (NFRDB)[3]	Complete count survey	April 1st	Every year	Forestry Agency
Statistics of Cultivated and Planted Area (Survey of cropland area)	Ground measurement survey (sample)	July 15th	Every year	MAFF
Census of Agriculture	Complete count survey	February 1st	Every 5 years	MAFF
Survey on the status of occurrence and elimination of dilapidated cropland	Complete count survey	December 31st	Every year	MAFF
Land Use Status Survey	Complete count survey	October 1st	Every year	MLIT
Statistical Reports on the Land Area by Prefectures and Municipalities in Japan	Complete count survey	October 1st	Every year	GSI

Note: GSI: Geographical Survey Institute

Japan’s total land area as of FY2021, from the *Statistical Reports on the Land Area by Prefectures and Municipalities in Japan* (GSI), is about 37.8 million ha, an increase of 0.06% (approximately 0.24 million ha) compared to FY1990 due to the reclamation by drainage and landfilling of sea areas. As noted by ERT in the 2022 Review (ARR2022 L.15), it is recommended to “ensure that the national land area is consistent across the inventory time-series “in Section 3.3, Chapter 3, Volume 6 of *the 2006 IPCC Guidelines*.” However, in Japan, the national land area itself fluctuates from year to year and thus keeping the same total land area through the entire time-series would result in reporting inaccurate information. Therefore, Japan reports that the sum of all land use categories for each year is equal to the total national land area for each year which have been identified by the statistical source, thereby accurately reflecting the actual

grazed meadow land, so the areas of wild land from 2011 onward were calculated excluding grazed meadow land of the “*Census of Agriculture and Forestry*”.

[3] The *National Forest Resource Database* maintains and manages administrative information such as forest registers and forest planning maps, and location information such as Orthophoto and satellite information such as Landsat TM and SPOT images.

changes in the total land area of Japan. The Guidelines also state that "Ensure that the national land area is consistent across the inventory time-series; otherwise stock changes will reflect false C increases or decreases due to a change in total land area accounted for when using a stock change emissions estimation method." In practice, the increase in area due to reclamation, etc. in the relevant year is not directly allocated to forest land or other land use areas, but is included in "other land" and the carbon stock is calculated according to the status of conversion from the following year. In addition, in the calculation of "other land" that has been increased including by reclamation, it is assumed that no carbon losses or gains occur in the conversion of sea areas to other land, and no change in carbon stocks is reported. Therefore, even when the time-series consistency of the total land area is not maintained as in Japan, over- or under-estimation of emissions and removals do not occur because the stock change method, which takes land expansion as a direct activity amount, is not used in its calculations.

In addition, emissions and removals from mangrove forests located in intertidal zone are included in the estimation from the 2023 submission and are reported under the wetlands category. However, the area is excluded from both the wetlands category area and land-use transition matrix, because the area is slightly outside the national "land" area which is determined by the high tide line.

6.2.2. Method of estimating the area converted from other land uses

Each land-use category is further classified into "land remaining in a land-use category" and "land converted to a new land-use category" depending on its history of land-use conversion. To classify into these two sub-categories, a default period of 20 years is applied as the threshold to distinguish the occurrences of land-use conversion in accordance with the *2006 IPCC Guidelines*. Since the transition period was set at 40 years for the calculation of carbon stock changes in mineral soils due to the conversion between forest land and grassland/cropland, the land conversion status was estimated for over a 40-year period. For land that has passed 21 years after conversion, emissions and removals are reported under the land remaining in the same land-use categories. Each land-use area is estimated based on existing statistics. Table 6-4 shows the survey methods and due dates of major land area statistics.

Table 6-4 Statistics used for estimating area of land-use conversions

Name of the statistics / survey	Survey contents	Survey due date	Frequency	Presiding ministry
Survey of land use change status by remote sensing image interpretation (survey to determine areas converted between forest land and non-forest land)	Identifying non-forest land converted to forest land and forest land converted to non-forest land by image interpretation	December 31st	Every year (2 years to complete one cycle)	Forestry Agency
Statistics of Cultivated and Planted Area (Survey of Expansion area and Abandoned area of cropland)	Circulation survey (using documents from relevant agencies and aerial photographs, etc.) to ascertain the reason for movement and the area of each land category	July 15th	Every year	MAFF
Movement and Conversion of Cropland	Survey on the area of converted cropland and grassland by means of the notified area	December 31st	Every year	MAFF
Administrative Statistics of Creation of Agricultural Land	Project based area (area of land established of cropland and grassland)	March 31st	Every year	MAFF

6.2.2.1. **Identification of the area of conversion between Forest Land and Non-Forest Land from 1990 to the most recent year**

6.2.2.1.a. **Methodologies and procedures**

a) ***Plot design and interpretation procedure***

1. Plot setting: Approximately 1.5 million plots were set up in a grid pattern at 500m intervals across the country.

2. Image used for interpretation: Orthophoto taken at the end of 1989 (hereinafter referred to as “1989 aerial photo”) and satellite images of SPOT (hereinafter referred to as “satellite image”) (all images taken at approximately two-year intervals since 2005). Details of the images used are shown in Table 6-5.

3. Coverage of interpretation: The entire country is divided into two parts, and half of the total plots are interpreted in turns each year, alternating between the two parts. It takes two years to complete a cycle of image interpretation for the whole country.

4. Interpretation methods:

① Plots where changes of forest cover occurred are detected by comparing 1989 aerial photo and the most recent satellite images. Changes from non-forest land to forest land due to human-induced afforestation practices are categorized as "land converted to forest land (or land subject to AR activities)" and those from forest land to non-forest land are categorized as "land converted from forest land (or land subject to D activities)" (Hayashi et al. 2008). The land units are evaluated in spatial assessment units (0.3 ha in area and 20 m in width) considering the numerical definition of forest (Table 6-16), and the land use status before or after conversion for each plot is also identified.

② The number of points when the changes were occurred was determined by using 1989 aerial photos and satellite images taken at approximately two-year intervals since 2005. Each time this procedure is performed, the results of previous interpretation are corrected.

③ Plots which were difficult to interpret for some reason were excluded from available sample plots.

b) ***Procedures for calculating the occurrence rate of conversion between forest land and non-forest land***

1. For plots identified as having changed between 1990 and 2005, the cumulative occurrence rate from the beginning of 1990 to the end of 2005 was calculated by dividing the number of total occurrence plots by the number of total available sample plots. In the estimation of "land converted to forest land (or land subject to AR activities)," the cumulative occurrence rate was divided by 16 to obtain the occurrence rate for the single year from 1990 to 2005, assuming that those changes occurred linearly from 1990 to 2005. In the estimation of "land converted from forest land (or land subject to D activity)," the cumulative occurrence rate from 1990 to 2005 was allocated for each year according to the conversion rate in the *Area of forest land conversion* statistics. Respective occurrence rates for 2005 are alternatively used for those for 2006.

2. For the occurrence from 2007 onward, the number of occurrences between two images photographed in two-year intervals were divided by two to obtain the number of occurrences for

one year. In addition, since one interpretation cycle is completed in two sets of interpretation work, the number of occurrences is summed up for those two sets and then divided by the total number of available sample plots to obtain occurrence rate in each single year. In years when the second half of the interpretation work is not available yet, the results of the second half of the previous cycle's interpretation work are used to cover the entire land area.

c) ***Calculation of area converted between forest land and non-forest land***

The area converted between forest land and non-forest land was calculated by multiplying the national land area by the occurrence rates of conversions between forest land and non-forest land in each single year. The changes in areas estimated from the above-mentioned procedure was used as the activity data for a single Fiscal year.

As shown in Section 6.2.1. , the land area in Japan has been gradually increasing due to land reclamation, etc. However, the newly expanded land area is not included in this land use change survey because it is considered that afforestation and deforestation activities have hardly occurred on the reclaimed coastal areas. Therefore, the land area in 2005, when the land use change survey started, was used as the fixed land area for the entire time series in the calculation for multiplying the land area by the rate of land use change.

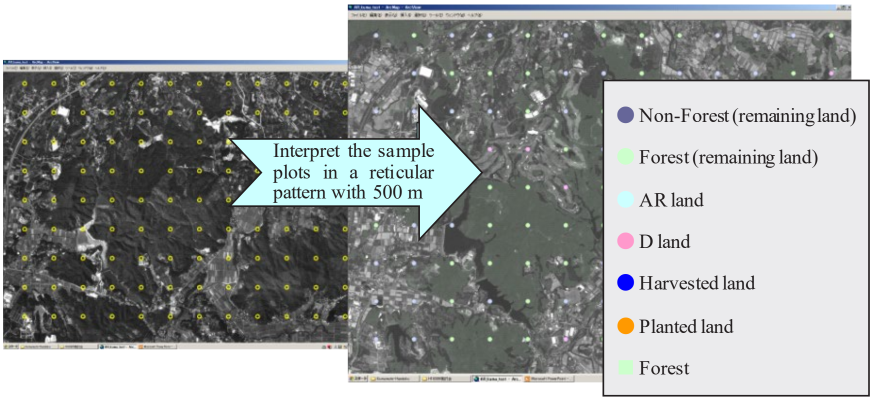


Figure 6-1 Identification of conversion between forest land and non-forest land by interpreting remote sensing images

In Japan, the forest register is used as the basic data for reporting forest land subject to forest planning. The conversion between forest land and non-forest land is not identified by the forest register but by interpreting aerial photo and satellite image, because it is difficult to reproduce the forest status with conversion from FY1990 to FY2005 in the forest register, and also because it is difficult to distinguish whether increases of forest area are caused by human-induced conversion or not in the forest register.

6.2.2.1.b. **Data used**

The data used to identify conversion between forest land and non-forest land are as follows.

Table 6-5 Data used to identify conversion between forest land and non-forest land

Data sources	Resolution [m]	Data format
Orthophoto aerial photograph (1989)	1	Raster
SPOT5/HRV-P (2005, 2007, 2009-2014)	2.5	Raster
SPOT6/7/HRV-P (2015-2021)	1.5	Raster

6.2.3. Land-use transition matrix

Land-use transition matrix to determine land use conversion has been produced annually since the beginning of FY1990 to date, for six land-use categories whose areas are identified in accordance with the description in section 6.2. and in the beginning part of section 6.3. Land use conversion that occurred in FY1990 and in FY2021 are shown in the following Table 6-6 and Table 6-7, respectively. In addition, land use matrix produced by accumulating land conversion between each land-use category, from the beginning of FY1990 to the end of FY2021, is shown in Table 6-8.

Table 6-6 Land-use transition matrix for Japan in FY1990 [kha]

at the end / at the beginning	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest land	24,945.70	3.98	2.02	0.31	14.54	3.60	24,970.16
Cropland	3.14	4,758.92	1.13	0.03	23.33	2.38	4,788.92
Grassland	0.24	0.01	1,028.24	0.00	1.22	0.14	1,029.84
Wetlands	NO	0.31	0.15	1,309.57	IE	IE	1,310.03
Settlements	0.59	IE	NO	0.00	3,160.15	IE	3,160.75
Other land	0.59	0.21	0.01	0.09	0.76	2,512.35	2,514.02
Total	24,950.27	4,763.42	1,031.55	1,310.00	3,200.00	2,518.47	37,773.71

Table 6-7 Land-use transition matrix for Japan in FY2021 [kha]

at the end / at the beginning	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest land	24,971.02	1.34	0.86	0.11	1.79	0.04	24,975.16
Cropland	NO	4,031.20	0.62	0.01	14.53	0.91	4,047.26
Grassland	NO	0.01	901.19	0.00	2.06	0.51	903.77
Wetlands	NO	NO	NO	1,349.85	IE	IE	1,349.85
Settlements	NO	IE	NO	0.00	3,878.51	IE	3,878.51
Other land	NO	4.48	0.74	0.03	0.12	2,637.56	2,642.92
Total	24,971.02	4,037.03	903.40	1,350.00	3,897.00	2,639.01	37,797.46

Table 6-8 Land-use transition matrix of Japan for FY1990-FY2021 [kha]

at the end of FY2021 / at the beginning of FY1990	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest land	24,869.65	25.48	18.42	16.51	219.04	51.63	25,200.73
Cropland	39.99	3,953.59	24.06	1.43	433.96	61.46	4,514.48
Grassland	10.97	1.15	853.78	0.22	44.81	8.63	919.56
Wetlands	0.14	1.05	0.45	1,327.18	IE	IE	1,328.83
Settlements	26.93	IE	NO	0.08	3,173.38	IE	3,200.39
Other land	23.34	55.76	6.69	4.57	25.82	2,517.29	2,633.47
Total	24,971.02	4,037.03	903.40	1,350.00	3,897.00	2,639.01	37,797.46
Net change of each land-use category (FY1990-FY2021)	-229.71	-477.45	-16.16	21.17	696.61	5.54	-

Note: The areas described as "IE" are included in "Other land remaining other land" which could be used for adjustment with total area of national land.

6.3. Parameters for estimating carbon stock changes due to land-use conversions

Prior to the sections describing detailed methods for each land-use category, basic parameters used for estimating carbon stock changes due to land-use conversions are shown here (Table 6-9 to Table 6-14) to avoid repeating these parameters in each subsequent section.

Table 6-9 Biomass stocks or carbon stocks in living biomass before and immediately after land-use conversion

Land-use category			Biomass stocks or carbon stocks	Methodology for setting parameters and data source used
Before conversion	Forest land		146.4 [t-d.m./ha] (FY2021)	The values of biomass stocks in forest land prior to conversion were based on the average carbon stock per unit area of forests with standing trees at the beginning of the period. The values for FY1990-FY2007 are substituted by the average value for FY2008- FY2012. (See Table 6-10 for values for each fiscal year in the time series.)
	Cropland	Cropland (Average)	1.7 [t-C/ha]	Average value of below-listed rice and upland fields from FY 1990 to FY2017 (Weighted average value of area in rice and upland fields is used for the value at each year.) The amount of dry matter of crop residues plowed into rice and upland fields is estimated by utilizing the activity data in the agriculture sector (3.D.a.4.)
		Rice field	2.0 [t-C/ha]	Average carbon content of crop residues plowed into rice fields from FY1990 to FY2017.
		Upland field	1.3 [t-C/ha]	Weighted average carbon content of crop residues plowed into upland fields from FY1990 to FY2017, calculated by crop cultivation area for each type of crop.
		Orchard	-	It is not indicated since carbon stock change after conversion is calculated collectively in the calculation of the "orchard" in cropland remaining cropland. See 6.5.1.b) for the parameter of "orchard remaining orchard".
	Grassland		13.5 [t-d.m./ha]	Default value (Table 6.4: "warm temperate wet", Volume 4 of the *2006 IPCC Guidelines*).
	Wetlands, settlements and other land		0 [t-d.m./ha]	Assumed to be "0".
Immediately after conversion	All land uses		0 [t-d.m./ha]	Assumed to be "0".

Table 6-10 Biomass stocks in forest land before land-use conversion

Land-use category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Forest land (before conversion)	t-d.m./ha	93.1	93.1	93.1	93.1	93.1	93.4	93.9	94.0	94.0	94.0	94.0	93.5	152.7	153.7	154.9

Table 6-11 Annual increments in living biomass after land-use conversion

Land-use category			Annual increments	Methodology for setting parameters and data source used
After conversi-on	Forest land		3.0 [t-C./ha/yr]	To estimate the average annual growth of forests within 20 years after conversion, average growth increments per unit area for 3 years (FY2008-FY2010) including year of FY2009, which is 20 years after the start of AR activity under the Kyoto Protocol, is applied.
	Cropland	Cropland (average)	1.7 [t-C/ha/yr]	Assumed that carbon stock after conversion reaches the value in Table 6-9 in one year.
		Rice field	2.0 [t-C/ha/yr]	Assumed that carbon stock after conversion reaches the value in Table 6-9 in one year.
		Upland field	1.3 [t-C/ha/yr]	Assumed that carbon stock after conversion reaches the value in Table 6-9 in one year.
		Orchard	-	It is not indicated since carbon stock change after conversion is calculated collectively in the calculation of the "orchard" in cropland remaining cropland.
	Grassland		2.7 [t-d.m./ha/yr]	Assumed that carbon stock after conversion reaches the default value (Table 6.4: 13.5 at "warm temperate wet", Volume 4 of the *2006 IPCC Guidelines*) in 5 years.
	Wetlands, Settlements and other land		0 [t-C/ha/yr]	Assumed to be "0".

Table 6-12 Carbon stocks in dead wood before, immediately after and after land-use conversion

Land-use category		Carbon stocks	Methodology for setting parameters and data source used
Before conversion	Forest land	10.0 [t-C/ha]	Average value calculated using the results of the Forest Soil Inventory Survey (Ugawa et al. (2012)). Stocks in dead wood for fallen trees were calculated as 4.2 t-C/ha; fallen trees: stumps: standing dead trees = 42:33:25; thus, total stocks of dead wood were calculated as 4.2 *(100/42) = 10 t-C/ha.
	Cropland, grassland, wetlands, settlements, other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier 1)
Immediately after conversion	All land uses	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier 1)
After conversion	Forest land	6.5 [t-C/ha]	Predicted carbon stocks in 40 years after afforestation, based on the regression equation using the results of a domestic survey of the amount of dead wood in afforested areas after land use conversion, starting from 0 accumulation in year 0. The annual carbon stock change is 0.16 t-C/ha/yr.
	Cropland, grassland, wetlands, other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier 1)
	Settlements	0 [t-C/ha]	Default value (Section 8.3.2 in Volume 4 of the *2006 IPCC Guidelines*, Tier 1) If land is converted to urban green facilities, it is not indicated since it is included in the estimation of stock changes in living biomass.

Table 6-13 Carbon stocks or annual changes in litter before, immediately after and after land-use conversion

Land-use category		Carbon stocks or annual change	Methodology for setting parameters and data source used
Before conversion	Forest land	4.9 [t-C/ha] (FY2020)	Average value calculated using the results of the Forest Soil Inventory Survey (Ugawa et al. (2012)).
	Cropland, grassland, wetlands, settlements, and other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier 1)
Immediately after conversion	All land-uses	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier 1)
After conversion	Forest land	6.67 [t-C/ha]	Average carbon stocks in litter based on a domestic survey of the amounts of litter in afforested areas, starting from 0 accumulation in year 0 after land conversion. The measured data after 21 years from land conversions, which are observed to reach almost stable state of litter stock, are used.
	Cropland, grassland, wetlands, settlements and other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 4 of the *2006 IPCC Guidelines*, Tier 1)

Table 6-14 Carbon stocks in mineral soils before and after land-use conversion

Land-use category			Carbon stocks or annual change	Transition period (years)	Stock change factor	Methodology for setting parameters and data source used
Before conversion	Forest land		76.0 [t-C/ha]			Average soil carbon stocks of all forests in Japan (Yamashita et al. (2022))
	Cropland	Rice field	70.5 [t-C/ha]			Average soil carbon stocks of each land use in Japan. Estimated from the soil group data which is based on soil surveys from 2015 to 2018 used in Matsui et al.(2021). Soil carbon stocks of each land use type is divided by the area of respective land use type. Organic soils are excluded.
		Upland field	90.8 [t-C/ha]			
		Orchard	79.1 [t-C/ha]			
		Cropland (average)	77.2 [t-C/ha]			
	Grassland (pasture land)		120.7 [t-C/ha]			
	Cropland and Grassland (average)		83.0 [t-C/ha]			
After conversion	Forest land (from cropland or grassland)		0.44 [t-C/ha]	40	1.21	County specific transition period (40 years) and country-specific stock change factor of 1.21 were set by a domestic research project as Tier 2 factor for conversion from cropland and grassland to forest land. The annual carbon stock change was calculated as (83 x 1.21-83) / 40 = 0.44 t-C/ha/yr, based on the average soil carbon stocks of the initial cropland and grassland values.
	Forest land (from other than cropland or grassland)		1.5 ［t-C/ha/yr］	40	-	Set by the Committee for the GHG Emissions Estimation Methods in FY2022 based on the results of the above-mentioned research project.
	Rice field		1.33 [t-C/ha/yr]	20	1.35	Default stock change factor of 1.35 for rice field in the *2019 IPCC Refinement* and default transition period (20 years) were used. Annual change is calculated based on the average carbon stocks of the forest land and the default values.
	Upland field and Orchard		-0.44 [t-C/ha/yr]	40	0.77	Country-specific transition period (40 years) and country-specific stock change factor of 0.77 were set by the above-mentioned research project as Tier 2 factor for conversion from forest land to cropland. Annual carbon stock change is calculated using the average carbon stocks of the forest land as the initial value.
	Grassland (pasture land)		-0.54 [t-C/ha/yr]	20	0.858	Country-specific transition period (equivalent to default transition period 20 years) and country-specific stock change factor of 0.858 were set by the above-mentioned research project, as Tier 2 factor for conversion from forest land to grassland, according to Koga et al. (2020). Annual carbon stock change is calculated using the average carbon stocks of the forest land as the initial value.
	Settlements		28.1 [t-C/ha]	20		Average soil carbon stocks of settlements at 20 years after land conversion, as determined by Tonosaki et al. (2022)
	Other land (excluding natural disasters)		20.1 [t-C/ha]	20		Simple average of soil carbon stocks of lands immediately after development obtained by sample survey results, as mentioned in Tonosaki et al. (2022) Determined by the Committee for the GHG Emissions Estimation Methods in FY2022.

Note: Project for the Comprehensive Promotion of Environmental Research
[2-1601] Evaluation Study on the Soil Carbon Changes through the Land Use Changes between Forest Land and Cropland and its Application to GHG Inventory
[2-1909] Assessment of Soil Carbon Stock Changes due to Land Use Changes and Its Application to National Greenhouse Gas Inventories

6.4. Forest land (4.A.)

Forests to be calculated under this category of the Convention inventory are the forests that are subject to forest planning under Articles 5 and 7.2 of the Forest Law as shown in Table 6-2, which is the same scope as the forests subject to reporting in the Global Forest Resources Assessment (FRA) that Japan submits to FAO. Therefore, all forests subject to the calculation are treated as "managed forests", which are divided by the management entity into "National forests" as defined in Article 7.2 and "Private forests (forests other than National forests)" as defined in Article 5 of the Forest Law. Forest category consists of 4 subcategories, which are intensively managed forests, semi-natural forests, bamboo, and forests with less standing trees, as shown in Table 6-15. Intensively managed forests and semi-natural forests are further collectively referred to as "Forests with standing trees". The definition of forests in Japan is based on the *KP Supplements* is specified numerically as shown in Table 6-16, and forests with standing trees meet the minimum values in the Table. Forests with standing trees are further divided into Ikusei-rin forests and Tennensei-rin forests depending on forest management types. Table 6-17 shows the correspondence of these above to the subcategories under this category. However, for the sake of reporting under the Convention, "intensively managed forests in Ikusei-rin forests" are referred to as "intensively managed forests", and "semi-natural forests in Ikusei-rin forests" and "Tennensei-rin forests" are collectively referred to as "semi-natural forests".

Note that there are a small number of forests that are not covered by the forest planning, and these forests are excluded from "managed forests" and are mainly included in the area of "Other land use (4.F.)" for reporting and carbon stock changes are not reported.

Table 6-15 Definitions of forest subcategories

Subcategory		Definition
Forests with standing trees		Forests that do not fall under "forests with less standing trees", where the crown cover of standing trees is 30% or more (including young stands with the degree of stocks of 3 or more even though the tree crown cover is less than 30%). Even if the crown cover of standing trees is less than 30%, forests with a total crown cover of both standing trees and bamboo of 30% or more, while dominated by standing trees, are included in this subcategory.
	Intensively managed forests	Forests established by artificial regeneration such as tree planting and seeding, where the volume (or number) of standing trees of tree species subject to the artificial regeneration account for 50% or more.
	Semi-natural forests	Forests with standing trees which are not classified as "intensively managed forests".
Forests with less standing trees		Forests with a total crown cover of both standing trees and bamboo of less than 30%.
Bamboo		Forests that do not fall under "forests with standing trees", where the crown cover of bamboo (excluding bamboo grasses) is 30% or more. Even if the crown cover of bamboo is less than 30%, forests with a total crown cover of both standing trees and bamboo of 30% or more, while dominated by bamboo, are included in this subcategory.

Reference: *Forest Resources Status Survey* (March 31, 2007) (Forestry Agency), partially modified.

Note: The degree of stocks is the ratio of actual tree volume to expected tree volume in a given forest area, multiplied by 10.

Table 6-16 Numerical definition of Forest in Japan

Elements	Numerical definition of forests in Japan
Minimum area	0.3 [ha]
Minimum tree crown coverage	30 [%]
Minimum tree height	5 [m]
Minimum forest width	20 [m]

Table 6-17 Correspondence and definitions of sub-categories by reporting and by management type

<table>
<tr><th>Sub-categories by reporting</th><th colspan="2">Sub-categories by management type</th></tr>
<tr><td>Intensively managed forest</td><td rowspan="2">Ikusei-rin forest</td><td>Ikusei-tansou-rin forest; Forests where practices for establishment and maintenance of single-storied forests have been carried out after clear-cutting.</td></tr>
<tr><td rowspan="2">Semi-natural forest</td><td>Ikusei-fukusou-rin forest; Forests where practices for establishment and maintenance of multi-storied forests have been carried out after selective cutting.</td></tr>
<tr><td>Tennensei-rin forest</td><td>Forests where practices for establishment and maintenance of forests mainly through the use of natural forces are carried out.</td></tr>
</table>

Japan's forest land area in FY2021 was about 24.97 million ha, representing about 66.1% of the total national land area. The net removal in this category in FY2021 was 58,343 kt-CO_2 (GHG emissions other than changes in carbon stocks are not included). This represents a decrease of 3.3% compared to FY2020, and a decrease of 32.4% compared to the FY1990 value, and it has been on a decreasing trend in the long term.

Table 6-18 Emissions and removals in forest land resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
4.A. Forest land	Total	kt-CO_2	-86,265	-95,436	-97,953	-99,808	-82,608	-84,056	-76,311	-73,363	-66,884	-62,341	-64,398	-62,890	-58,686	-60,357	-58,343
	Living biomass	kt-CO_2	-79,912	-87,199	-90,624	-94,576	-80,325	-82,859	-75,437	-72,667	-66,279	-61,779	-63,797	-62,204	-57,968	-59,579	-57,613
	Dead wood	kt-CO_2	-3,017	-4,026	-2,930	-958	1,123	1,898	2,081	2,131	2,119	2,057	1,935	1,756	1,604	1,460	1,406
	Litter	kt-CO_2	-2,936	-2,570	-1,938	-1,174	-583	-462	-423	-393	-380	-363	-357	-336	-298	-273	-237
	Mineral soil	kt-CO_2	-400	-1,641	-2,461	-3,101	-2,823	-2,633	-2,532	-2,434	-2,343	-2,256	-2,179	-2,106	-2,023	-1,965	-1,899
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.A.1. Forest land remaining Forest land	Total	kt-CO_2	-76,686	-91,253	-95,254	-97,824	-81,192	-82,709	-75,007	-72,120	-65,709	-61,229	-63,351	-61,918	-57,791	-59,540	-57,604
	Living biomass	kt-CO_2	-73,836	-84,529	-88,891	-93,303	-79,394	-81,971	-74,569	-71,838	-65,494	-61,033	-63,088	-61,544	-57,357	-59,018	-57,101
	Dead wood	kt-CO_2	-2,687	-3,881	-2,836	-887	1,175	1,948	2,128	2,177	2,162	2,098	1,973	1,792	1,637	1,490	1,434
	Litter	kt-CO_2	-2,259	-2,272	-1,744	-1,029	-476	-360	-326	-300	-291	-279	-278	-263	-230	-210	-180
	Mineral soil	kt-CO_2	2,096	-571	-1,784	-2,605	-2,497	-2,326	-2,240	-2,159	-2,086	-2,016	-1,958	-1,904	-1,841	-1,802	-1,757
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.A.2. Land converted to Forest land	Total	kt-CO_2	-9,579	-4,183	-2,699	-1,984	-1,416	-1,346	-1,304	-1,243	-1,175	-1,112	-1,048	-972	-894	-817	-739
	Living biomass	kt-CO_2	-6,076	-2,670	-1,733	-1,272	-932	-888	-868	-829	-786	-746	-709	-660	-611	-561	-512
	Dead wood	kt-CO_2	-330	-145	-94	-71	-52	-50	-48	-45	-43	-41	-38	-36	-33	-30	-28
	Litter	kt-CO_2	-677	-298	-194	-145	-106	-102	-98	-93	-89	-84	-79	-74	-68	-63	-57
	Mineral soil	kt-CO_2	-2,496	-1,070	-677	-496	-326	-307	-291	-275	-258	-241	-221	-202	-183	-163	-142
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

6.4.1. Forest land remaining Forest land (4.A.1.)

a) ***Category Description***

This subcategory deals with carbon stock changes in forest land remaining forest land, which has remained forested without conversion for the past 20 years. The net removals in this subcategory in FY2021 were 57,604 kt-CO_2 (GHG emissions other than changes in carbon stocks are not included). This represents a decrease of 24.9% compared to FY1990 and a decrease of 3.3% compared to FY2020. It had been on an increasing trend from FY1990 to FY2004, but has been decreasing since FY2005. The increase in net removals in the first half of the reporting period is mainly due to the growth in intensively managed forests, and the decrease in net removals in the second half of the period is mainly due to progression in the maturation of those intensively managed forests.

As for a factor influencing changes in the forest growth, the rate of increment in growing stocks becomes slow in forests over 50 years old in Japan. Large-scale development of planted forests was carried out in Japan in the 1960s, but since then the area of planted forest development has decreased. These large-scale planted forests had contributed to the increase in removals until around FY2004, but the removals began to decrease from around FY2005 due to progression in the maturation. The distribution of age class structure of the planted forests has since shifted further to the elderly side, with these planted forests over 51 years old accounting for 50% of the total intensively managed forest area in FY2017 (Figure 6-2).

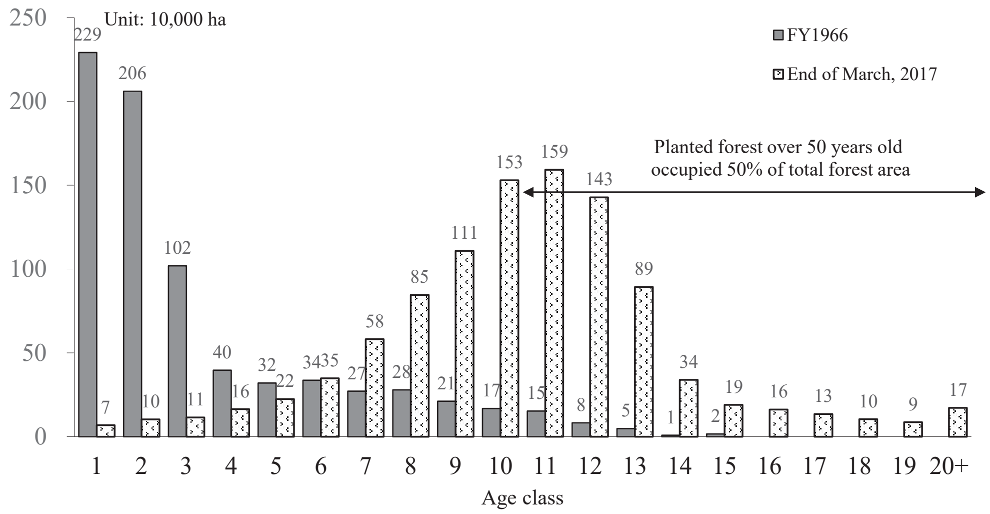


Figure 6-2 Changing forest age class configuration of planted forests

Sources: *State of Forest Resources* (March 31, 2017) (Forestry Agency); *Forest Resources of Japan* (April 1968) (Forestry Agency)

Note: Age-classes are divided by 5 year-period steps. “Age-class 1” includes the 1st to 5th year after plantation with the year of plantation counted as the 1st year.

Recently, domestic wood supply has been on an increasing trend. The changes in the supply of domestically produced wood since 1990 are shown in Figure 6-3. The supply of domestic wood had been declining from FY1990 to FY2002, but since then, it has turned to an increasing trend and has been continuously increasing. As mentioned above on the trend of growing stocks of forests, the forest resources in Japan have become enriched to be able to meet the demand for wood supply since those forests planted in the 1960s have grown enough to be harvested from around 2000, and the use as woody biomass in power generation facilities has increased in recent years, both of which have affected the increase in wood supply from FY2003.

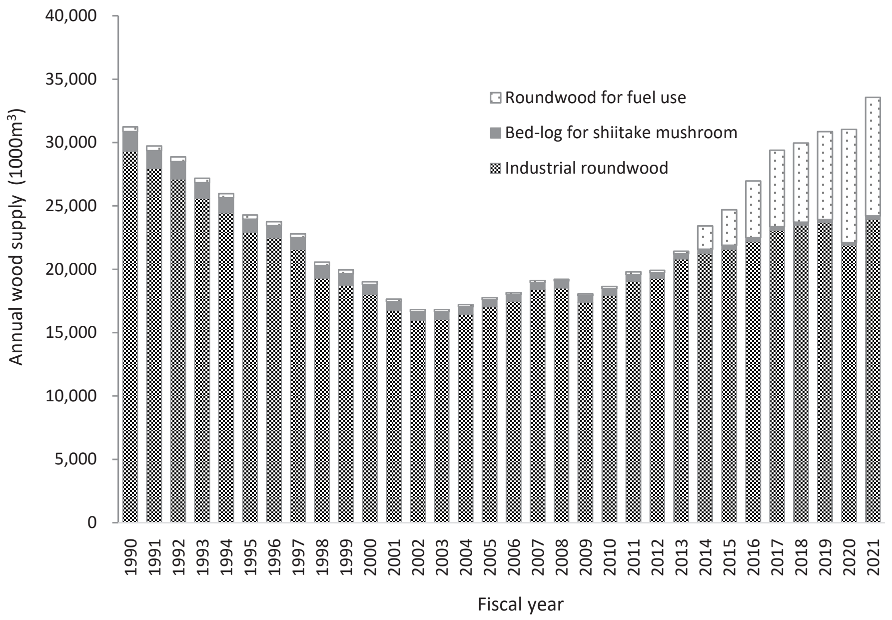


Figure 6-3 Changes in the supply of domestic wood (except logging residue)

Source: *Wood supply and demand chart* (FY2021) (Forestry Agency)

b) ***Methodological Issues***

1) Carbon stock changes in Living Biomass in "Forest land remaining Forest land"

● ***Estimation Method***

➢ ***Carbon stock changes in Living Biomass in intensively managed forests, semi-natural forests and forests with less standing trees***

The Tier 2 stock difference method is used for the estimation in the subcategories. Since the NFRDB collectively deals with carbon stock changes in living biomass in "forest land remaining forest land" and "land converted to forest land", it is difficult to separate those in "forest land remaining forest land" from the total. Therefore, carbon stock changes in "forest land remaining forest land" (ΔC_{FF_LB}) are obtained by subtracting those amount in "land converted to forest land" (ΔC_{LF_LB}) calculated by estimation from the amount of carbon stock change in the entire forest land (ΔC_{F_LB}). See section 6.4.2. b)1) for the method of estimating the amount of carbon stock changes in "land converted to forest land".

$$\Delta C_{FF\_LB} = \Delta C_{F\_LB} - \Delta C_{LF\_LB}$$

$$\Delta C_{F\_LB} = \sum_k \{(C_{t2} - C_{t1})/(t_2 - t_1)\}_k$$

ΔC_{FF_LB}	: Annual change in carbon stocks in living biomass in forest land remaining forest land [t-C/yr]
ΔC_{F_LB}	: Annual change in carbon stocks in living biomass in entire forest land [t-C/yr]
ΔC_{LF_LB}	: Annual change in carbon stocks in living biomass in the land converted to forest land [t-C/yr]
t_1, t_2	: Time points of carbon stock measurement
C_{t1}	: Total carbon stock in biomass calculated at time t_1 [t-C]
C_{t2}	: Total carbon stock in biomass calculated at time t_2 [t-C]
k	: Type of forest management, or forests with less standing trees

$$C_{F\_LB} = \sum_j \{V_j \times D_j \times BEF_j \times (1 + R_j) \times CF\}$$

C_{F_LB}	: Carbon stock in living biomass in entire forest land[t-C]
V	: Merchantable volume [m^3]
D	: Wood density [t-d.m./m^3]
BEF	: Biomass expansion factor for conversion of merchantable volume
R	: Root-to-shoot ratio
CF	: Carbon fraction of dry matter [t-C/t-d.m.]
j	: Tree species (Private forests or National forests in the case of forests with less standing trees)

$$V_j = \sum_m (A_{m,j} \times v_{m,j})$$

V	: Merchantable volume [m^3]
A	: Area [ha]
v	: Merchantable volume per unit area [m^3/ha]
m	: Age class or forest age
j	: Tree species

➢ ***Carbon stock changes in Living Biomass in Bamboo***

Carbon stock changes in living biomass in Bamboo are reported as “NA” because annual growth and death of bamboo trunk in established bamboo forests can be regarded as equivalent. Bamboo does not have a vascular cambium, therefore, it reaches the limit of growth in the first year of the emergence and then do not exhibit secondary growth, and as such, in bamboo forests that have reached a certain density, the amount of emerging bamboo is said to be equal to the amount of those dying. The result of FAO’s survey (2007) of bamboo resource status in 2000 and 2005 in several countries in Asia and Africa also showed that the carbon stock per unit area for the 5 years from 2000 to 2005 remained almost flat.

● ***Parameters***

➢ ***Volume per unit area***

The merchantable volume per unit area is set based on the “Yield tables” developed for each tree species in Private and National forests, as shown in Table 6-19. “Yield tables” provide stand growth under standard forest practices for a given region, tree species and site class, and also provide estimates of the volume per unit area with respect to the forest ages. The "New yield tables" prepared in 2006, which had previously been used to estimate the volume of intensively managed forests in private forests, were reviewed and updated to the "2021 yield tables" (Forestry Agency) to better reflect the current state of the forests, which are used from the current (2023) submission. While the "New yield tables" were based on the results of field survey conducted in FY2003-FY2005, the "2021 yield tables" use data from field survey conducted in FY2014-FY2016 and National Forest Inventory survey in FY2014-FY2018, in addition to the data used to develop the "New yield tables."

“2021 Yield tables” are applied to estimate the volumes per unit area of Japanese cedar, Hinoki cypress and Japanese larch in private forests, which are representative tree species of intensively managed forests in Japan. These three tree species cover 82% of intensively managed forests of private forests in terms of areas. Regional differences were considered in the development of the “2021 yield tables”; the tables were developed for 7 regions for Japanese cedar, 4 regions for Hinoki cypress and 2 regions for Japanese larch.

The total forest removals for the period 2013-2020 was recalculated by applying the “2021 yield tables”, which resulted in an increase of approximately 1.08 times from the values submitted in 2022 when the “2021 yield tables” were not applied.

Table 6-19 Yield tables used to estimate merchantable volume

Tree species			Yield tables in use	
			Private forest	National forest
Intensively managed forests	Conifer	Japanese cedar, Hinoki cypress, Japanese larch	2021 yield tables (From the 2023 submission)	Yield tables developed by Regional Forest Offices
		Other conifer	Yield tables developed by prefectures	
	Broad leaf			
Semi-natural forests				

➢ ***Parameters for estimating Carbon Stock in Living Biomass (Biomass expansion factor and Root-to-shoot ratio, Wood density and Carbon fraction of dry matter)***

The biomass expansion factors (BEF) [above-ground biomass/below-ground biomass], root-to-shoot ratios (R) and wood density (D) were set based on the results of biomass surveys on major tree species, and existing research reports which were developed by the Forestry and Forest Products Research Institute (Table 6-20).

BEFs were set for two age class categories (20 years and below / 21 years and above) and for each tree species, because BEFs were found to differ between young forests and mature forests. On the other hand, R and D values were set by tree species only, because no clear correlation was found between these values and forest ages. For forests with less standing trees, information on tree species and age composition was not available. Therefore, a weighted average of each parameter, weighted by tree species and area composition of all forests with standing trees, was used separately for private and national forests.

Carbon fractions (CF) of dry matter were set separately for conifer trees and broad leaf trees based on Japan’s research results, and the average value of 0.50 was used for the forests with less standing trees.

Table 6-20 Parameters for estimations of Living Biomass for each tree species

		BEF [-]		R	D	CF	Note
		≦20	＞20	[-]	[t-d.m./m³]	[t-C/t-d.m.]	
Forests with standing trees (Conifer trees)	Japanese cedar	1.57	1.23	0.25	0.314	0.51	
	Hinoki cypress	1.55	1.24	0.26	0.407		
	Sawara cypress	1.55	1.24	0.26	0.287		
	Japanese red pine	1.63	1.23	0.26	0.451		
	Japanese black pine	1.39	1.36	0.34	0.464		
	Hiba arborvitae	2.38	1.41	0.20	0.412		
	Japanese larch	1.50	1.15	0.29	0.404		
	Momi fir	1.40	1.40	0.40	0.423		
	Sakhalin fir	1.88	1.38	0.21	0.318		
	Japanese hemlock	1.40	1.40	0.40	0.464		
	Yezo spruce	2.18	1.48	0.23	0.357		
	Sakhalin spruce	2.17	1.67	0.21	0.362		
	Japanese umbrella pine	1.39	1.23	0.20	0.455		
	Japanese yew	1.39	1.23	0.20	0.454		
	Ginkgo	1.50	1.15	0.20	0.450		
	Exotic conifer trees	1.41	1.41	0.17	0.320		
	Other conifer trees	2.55	1.32	0.34	0.352		Applied to Hokkaido, Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima, Tochigi, Gunma, Saitama, Niigata, Toyama, Yamanashi, Nagano, Gifu and Shizuoka prefectures
		1.39	1.36	0.34	0.464		Applied to Okinawa prefecture
		1.40	1.40	0.40	0.423		Applied to prefectures other than above
Forests with standing trees (Broad leaf trees)	Japanese beech	1.58	1.32	0.26	0.573	0.48	
	Oak (evergreen tree)	1.52	1.33	0.26	0.646		
	Japanese chestnut	1.33	1.18	0.26	0.419		
	Japanese chestnut oak	1.36	1.32	0.26	0.668		
	Oak (deciduous tree)	1.40	1.26	0.26	0.624		
	Japanese poplar	1.33	1.18	0.26	0.291		
	Alder	1.33	1.25	0.26	0.454		
	Japanese elm	1.33	1.18	0.26	0.494		
	Japanese zelkova	1.58	1.28	0.26	0.611		
	Cercidiphyllum	1.33	1.18	0.26	0.454		
	Japanese big-leaf magnolia	1.33	1.18	0.26	0.386		
	Maple tree	1.33	1.18	0.26	0.519		
	Amur cork	1.33	1.18	0.26	0.344		
	Linden	1.33	1.18	0.26	0.369		
	Kalopanax	1.33	1.18	0.26	0.398		
	Paulownia	1.33	1.18	0.26	0.234		
	Exotic broad leaf trees	1.41	1.41	0.16	0.660		
	Japanese birch	1.31	1.20	0.26	0.468		
	Other broad leaf trees	1.37	1.37	0.26	0.469		Applied to Chiba, Tokyo, Kochi, Fukuoka, Nagasaki, Kagoshima, and Okinawa prefectures
		1.52	1.33	0.26	0.646		Applied to Mie, Wakayama, Oita, Kumamoto, Miyazaki, and Saga prefectures
		1.40	1.26	0.26	0.624		Applied to prefectures other than above
Forests with less standing trees	Private forests	1.27		0.26	0.48	0.50	
	National forests	1.30		0.26	0.47		

Note: BEF: Biomass expansion factor (20 = forest age); R: Root-to-shoot ratio; D: Wood density; CF: Carbon Fraction

- ***Activity Data***

➢ ***Determining the forest area***

Forest areas by species and forest age in intensively managed forests, semi-natural forests, forests with less standing trees and bamboo under the forest planning system were obtained from the *Forest Status*

Survey until FY2004 and has been obtained from the NFRDB, which was developed and is being maintained by the Forestry Agency based on the forest register information etc., since FY2005 and onward. Data for FY1991-FY1994, FY1996-FY2001, and FY2003-FY2004 were estimated by linear interpolation, as no data was available for those periods. In addition, area data of Sakhalin fir, Yezo spruce, Japanese chestnut oak and Oak (deciduous tree) before FY1990 are not available individually; therefore, these data were estimated from “other conifer” and “other broad leaf” area divided by the area ratio in FY1995. The forest registers are prepared according to the procedure in Figure 6-4 and are updated by prefectures for private forests and by the Regional Forest Offices of the Forestry Agency for national forests. When the forest registers are updated, changes to the forest register information for multiple years may be reflected at once.

Table 6-21 Classifications in Forest Status Survey (before 2004) and NFRDB (after 2005)

Conifer trees		Broad leaf trees	
Before 2004	After 2005	Before 2004	After 2005
Japanese cedar	Japanese cedar	Japanese chestnut oak	Japanese chestnut oak
Hinoki cypress	Hinoki cypress	Oak (deciduous tree)	Oak (deciduous tree)
Pine	Japanese red pine	Other broad leaf	Japanese beech
	Japanese black pine		Oak (evergreen tree)
Japanese larch	Japanese larch		Japanese chestnut
Sakhalin fir	Sakhalin fir		Japanese poplar
Yezo spruce	Yezo spruce		Alder
	Sakhalin spruce		Japanese elm
Other conifer	Sawara cypress		Japanese zelkova
	Hiba arborvitae		Cercidiphyllum
	Momi fir		Japanese big-leaf magnolia
	Japanese hemlock		Maple tree
	Japanese umbrella pine		Amur cork
	Japanese yew		Linden
	Ginkgo		Kalopanax
	Exotic conifer trees		Paulownia
	Other needle leaf		Japanese birch
			Exotic broad leaf trees
			Other broad leaf

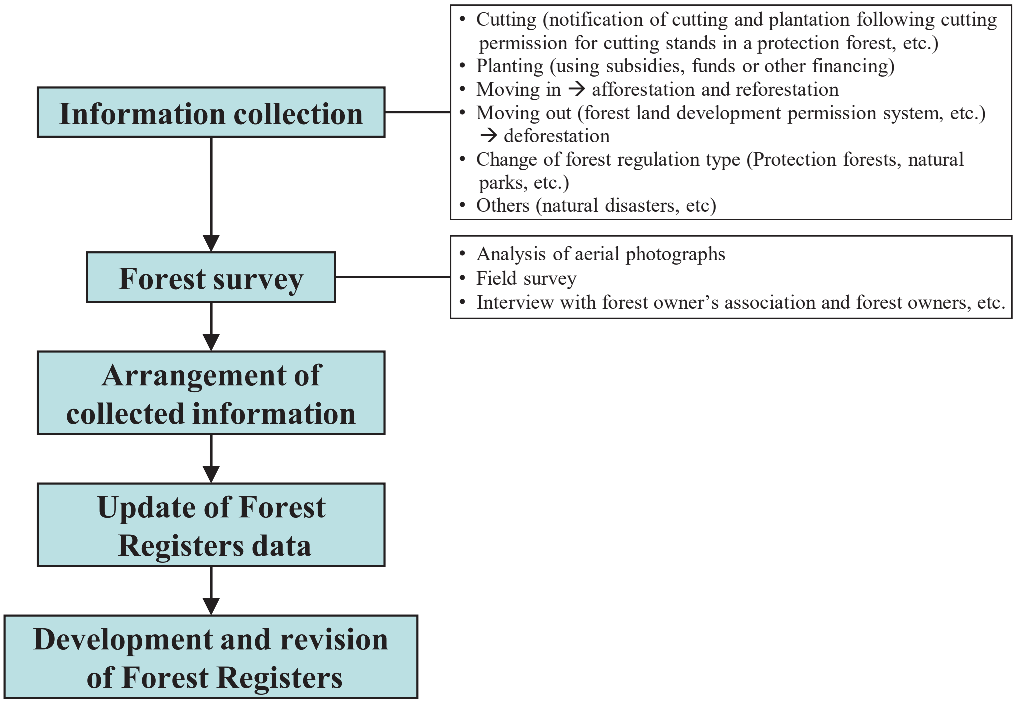


Figure 6-4 Procedures for developing and updating Forest Registers

➢ ***Obtaining the land area of "Forest land remaining Forest land"***

This land area is estimated by subtracting the cumulative total area of land converted to forest land during the past 20 years from the total area of forest land in the year subject to estimation. All areas of land converted to forest land are assumed to be intensively managed forests. For the activity data of land converted to forest land, see section 6.5.2. b)1).

Table 6-22 Area of forest land remaining forest land (within the past 20 years)

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Forest land remaining Forest land	kha	24,396.3	24,653.2	24,717.7	24,873.6	24,879.1	24,876.2	25,093.2	25,037.6	24,833.5	24,739.8	24,811.9	24,854.8	24,870.8	24,933.8	24,924.5
Intensively managed forests	kha	9,733.8	10,111.9	10,172.2	10,217.9	10,198.0	10,188.4	10,161.0	10,149.0	10,129.2	10,056.9	10,075.8	10,079.5	10,059.3	10,048.4	10,029.0
Semi-natural forests	kha	13,354.5	13,220.3	13,195.2	13,315.7	13,360.8	13,355.2	13,369.3	13,380.7	13,401.4	13,389.2	13,426.2	13,441.2	13,457.9	13,465.1	13,473.6
Cut-over forests and lesser stocked forests	kha	1,159.0	1,171.0	1,197.4	1,186.0	1,161.7	1,170.8	1,400.6	1,355.6	1,150.0	1,146.9	1,155.2	1,167.0	1,185.4	1,251.2	1,248.3
Bamboo	kha	149.0	150.0	152.9	154.0	158.6	161.7	162.3	152.4	153.0	146.8	154.8	167.0	168.2	169.1	173.5

Reference: *Forest Status Survey, NFRDB* (Forestry Agency)

2) Carbon Stock Changes in Dead Organic Matter and Soils in "Forest land remaining Forest land"

● ***Estimation Method***

➢ ***Carbon Stock Changes in Dry Organic Matter and Mineral Soils in Forests with Standing Trees***

In accordance with the decision tree provided in the *2006 IPCC Guidelines*, these pools are estimated by the Tier 3 method. Average carbon stock changes per unit area in forests with standing trees for dead wood, litter and mineral soils are calculated by forest type, forest management type and age class or forest age by using the CENTURY-jfos model.

The carbon stock changes in pools of dead wood, litter and mineral soils of all forests with standing trees are summed up for each pool by multiplying each of the calculated average carbon stock changes per unit area by the land area of tree species, forest management type, age class or age of the forest. The carbon stock changes in pools of dead wood, litter and mineral soils in "Forest land remaining Forest land (forests with standing trees)" (ΔC_{FF_dls}) are obtained by subtracting those amounts in "land converted to forest land (forests with standing trees)" (ΔC_{LF_dls}) from the amounts of all forests with standing trees estimated above (ΔC_{F_dls}). See section 6.5.2.b)2) for the method of estimating the amount of carbon stocks in "land converted to forest land"

$$\Delta C_{FF\_dls} = \Delta C_{F\_dls} - \Delta C_{LF\_dls}$$

$$\Delta C_{F\_dls} = \sum_{k,m,j} \{A_{k,m,j} \times (d_{k,m,j} + l_{k,m,j} + S_{k,m,j})\}$$

ΔC_{FF_dls}	: Annual change in carbon stocks in dead wood, litter and mineral soils in forest land remaining forest land (forests with standing trees) [t-C/yr]
ΔC_{F_dls}	: Annual change in carbon stocks in dead wood, litter and mineral soils in entire forest land (forests with standing trees) [t-C/yr]
ΔC_{LF_dls}	: Annual change in carbon stocks in dead wood, litter and mineral soils in the land converted to forest land (forests with standing trees) [t-C/yr]
A	: Area [ha]
d	: Average carbon stock change per unit area in dead wood [t-C/ha/yr]
l	: Average carbon stock change per unit area in litter [t-C/ha/yr]
s	: Average carbon stock change per unit area in mineral soil [t-C/ha/yr]
k	: Type of forest management
m	: Age class or forest age
j	: Tree species

➢ ***Carbon Stock Changes in Dry Organic Matter and Mineral Soils in Forests with Less Standing Trees and Bamboo***

With respect to forests with less standing trees and Bamboo, carbon stock changes in dead organic matter and mineral soils are reported as "NA" because gains and losses of carbon stocks in the dead organic matter and mineral soils are equivalent on a long-term basis (FRA, 2010).

➢ ***CO_2 emissions from organic soils caused by cultivation and drainage***

Since it is unlikely in Japan that the treatment of drainage would be taken and then to plant trees on land with organic soil not suitable for growing forestry tree species, it was assumed that organic soils do not exist in intensively managed forests, "Semi-natural forests in Ikusei-rin forests", forests with less standing trees and bamboo, but exist only in "Tennensei-rin forests". Moreover, when we consulted with forest experts, they said they had never heard of such cases in Japan. In addition, there are many cases where areas with organic soils have a precious natural environment, and the change of the land configuration or characteristics are being regulated in these places by law and regulations. Given the above, it was concluded that drainage in forest land with organic soils is not implemented in Japan[4]; therefore, the emissions for this category are reported as "NO", since emissions from organic soils under the estimation

---

[4] Drainage in organic soils in forest was discussed and concluded by breakout group on LULUCF under the Committee for the GHG Estimation Methods in FY2012 and FY2013.
Issue 6, FY2012：https://www.env.go.jp/content/900444857.pdf
Issue 2, FY2013：https://www.env.go.jp/content/900444882.pdf

methodology of Tier 1 or Tier 2 are estimated only when drainage is implemented in accordance with the *2006 IPCC Guidelines*.

- ***Parameters***

➢ ***Key Assumptions, Modification and Use of Parameters for the CENTURY-jfos Model for estimating Carbon Stock Changes in Dry Organic Matter and Mineral Soils***

CENTURY-jfos model is a soil carbon cycle model based on the CENTURY model, which is an ecosystem carbon cycle model developed by Colorado State University and is one of the most widely used models, with some adjustments to be applicable to forests in Japan.

When adjusting the CENTURY-jfos model, it was assumed that forests have continually existed and been used for a long term without undergoing conversion from/to other land use, and that their soil carbon stocks have reached a nearly steady state. The parameters for the net primary production and tree mortality used in the model were adjusted to predict soil carbon dynamics by prefecture and by forest type as below. Note that the forest biomass growth is defined as net primary production minus mortality.

Forest types were classified into the following eight types: Japanese Cedar, Hinoki Cypress, Pine species, Japanese Larch, Sakhalin Fir, Sakhalin Spruce, broad leaf trees and other conifer trees. Climate condition and average soil carbon stocks were calculated using the following 3 data sets: the NFRDB for the geographical forest distribution of the tree species, the mesh climate data of Japan for average temperature and precipitation from 1970 to 2000 (Japan Meteorological Agency, 2002); and average soil carbon stocks for each soil type (Morisada et al. 2004a, Morisada 2004b).

It should be noted that the yield tables represent the relations between forest age and yield, and include the effects of forest management, such as thinning. The parameter of biomass growth in the model should be adjusted to reflect the condition with no thinning, since the model also runs simulations for intensively managed forests by considering standard thinning scenarios conducted at forest age of 25 (with 20% thinning and 80% residues) and at forest age of 40 (with 20% thinning and 20% residues). Therefore, the biomass growth in the model was not directly taken from the yield tables, but was parameterized by using the forest biomass stock data whose relative yield index value are 0.85 or greater, because these data were thought to be largely unaffected by thinning.

Based on literature information, the average amount of litterfall for forests up to 60 year-old was adjusted to be 2.2 to 2.3 t-C/ha/yr for coniferous forests and 2.5 t-C/ha/yr for broadleaf forests, respectively. Because no reference information was available for the amount of fallen log and root mortality, the default mortality rates (trunk 0.96%/yr and roots 1.2%/yr) of the CENTURY model were used.

Before conducting this simulation, spin-up of 3,000 years was conducted with the assumption of a cutting rotation age of 60 years for broadleaf forests. As a result, the coefficient of the transition rate to passive soil organic matter in the decomposition process were modified so that the soil carbon stocks calculated by the model match the soil carbon stocks in 30cm depth for each prefecture by forest type described above. The parameters were determined in accordance with the CENTURY manual (Metherell et al. 1993).

Using the adjusted model, the average annual carbon stock changes per unit area were calculated for dead wood, litter, and soil pools, for each age class 1-19 (100 years), by forest management type – one in managed forests with thinning and the other in the natural forests with and without thinning.

During the reviews (ARR 2020 L.2 (L.4 2018) (L.11. 2016)), it was pointed out that the carbon stock of dead wood showed relatively higher values compared to the values of carbon stock of the living biomass in Japanese forests. Considering that the ratio of the amount of dead wood to the amount of living biomass currently reported is only slightly higher than the ratio of the below-ground biomass to the above-ground biomass, and that the stumps left at the logged-sites will be transferred to the dead wood pool, and that a large amount of dead wood will be supplied due to thinning and other forest management activities in intensively managed forests, it was concluded that the values do not significantly deviate from the actual situation.

Work is currently underway to revise the model based on the results of forest soil inventory survey, taking into consideration of the amount of dead wood supply.

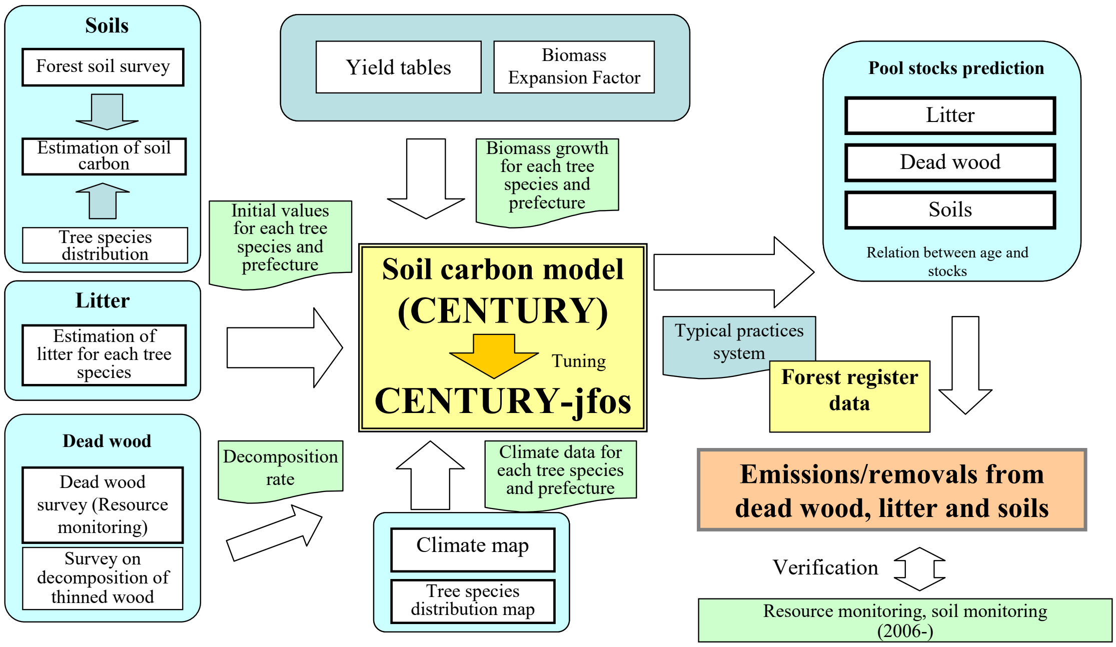


Figure 6-5 Estimation of emissions/removals in dead wood, litter and soils

- ***Activity Data***

➢ ***Area of Mineral Soils***

Forest area data by forest management type, tree species and age provided by the NFRDB were used as activity data to be multiplied by the annual carbon stock changes per unit area calculated by the CENTURY-jfos model.

➢ ***Area of Organic Soils***

Areas of organic soils in forest land were estimated by means of soil maps and status of distribution of organic soils in each prefecture. Furthermore, organic soils exist only in semi-natural forests in Japan; hence, all areas of organic soils are reported in semi-natural forests, and areas of organic soils in intensively managed forests, forests with less standing trees and bamboo are reported as “NO”.

c) *Uncertainties and Time-series Consistency*

● *Uncertainty Assessment*

The uncertainties of the parameters and activity data for living biomass were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty estimates for dead organic matter and soil were assessed by calculating the variance of outputs from the CENTURY-jfos model. As a result, the uncertainty estimate was 9% for the total removals by forest land remaining forest land. Uncertainty estimates regarding the major parameters in this category are shown in Table 6-23.

Table 6-23 Uncertainty estimates regarding major parameters in the forest land category

			Uncertainty estimates [%]	Country specific (CS) or default(D)	Remarks
Forest land area			5.9	CS	Estimated based on uncertainty estimates of land areas in the NFRDB. Used 5.9% without distinguishing tree species.
Volume of timber per area			12.3	CS	Estimated based on analysis of comparison between yield table and measured data.
Biomass Expansion Factor	Japanese cedar	≦20	3.5	CS	Estimated based on measured values.
		＞20	1.1	CS	
	Hinoki cypress	≦20	3.2	CS	
		＞20	1.6	CS	
	Oak (deciduous tree)	≦20	8.6	CS	
		＞20	2.1	CS	
Wood density	Japanese cedar		2.5	CS	
	Hinoki cypress		1.7	CS	
	Oak (deciduous tree)		1.6	CS	
Carbon fraction of dry matter	All tree species		6.0	D	Estimated taking into account the *2006 IPCC Guidelines* default value.
Dead wood	All forests		22.1	CS	Result of uncertainty analysis of CENTURY-jfos model.
Litter			51.0		
Soils			19.9		

● *Time-series Consistency*

There were no data for forest areas from FY1991 to FY1994, from FY1996 to FY2001, and from FY2003 to FY2004. Therefore, the time-series consistency was ensured by estimating these forest areas by means of interpolation.

In the current submission, carbon stock changes in living biomass, dead wood, litter, and mineral soils of the intensively managed forests in the private forests from FY 2008 and onward were recalculated using the "2021 Yield Tables", while the recalculation of values for the preceding years will be addressed in the next submission or later. Therefore, to avoid inconsistency in the time series in the estimation, the 1990-2007 values were adjusted using the average increase rate of total forest removals (1.08) which was calculated by comparing the 2008-2020 values submitted in 2022 and those recalculated using the "2021 Yield Tables". Specifically, the recalculated intensively managed forests in the private forests were multiplied by a factor of 1.12 so that the average rate of increase for the entire forest land becomes equal to 1.08.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

- ***Recalculation due to revision of yield tables***

The carbon stock changes of living biomass, dead wood, litter, and mineral soil for all years have been recalculated due to the revision of the yield tables for the intensively managed forests in the private forests, which are used to estimate volume per unit area.

- ***Correction in accordance with revision of the area of land converted to forest land***

Areas of intensively managed forests in forest land remaining forest land was recalculated to be consistent with the revision of interpretations of the Survey of land use change status by satellite image interpretation which are used as original data for determining areas of forests converted from other land-use. Following the revision, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years. See Chapter 10 for impact on trend.

f) ***Category-specific Planned Improvements***

Currently, we are continuously working refining the input data used for CENTURY-jfos.

6.4.2. Land converted to Forest land (4.A.2.)

a) ***Category Description***

This subcategory deals with the carbon stock changes in forest land converted from other land-use categories within 20 years. The net removals in this subcategory in FY2021 were 739 kt-CO_2 (GHG emissions other than changes in carbon stock are not included). This represents a decrease of 92.3% compared to FY1990 and a decrease of 9.6% compared to FY2020. Removals since 1990 have been on a consistent decreasing trend.

b) ***Methodological Issues***

1) Carbon stock change in Living Biomass in "Land converted to Forest land"

- ***Estimation Method***

The Tier 2 method which is estimated by summing the loss of carbon stock due to conversion ($\Delta C_{LB\_conversion\_to\_F}$) using Equation 2.16 from the *2006 IPCC Guidelines* (Vol. 4, Section 2.3.1.2) and the change of carbon stock accumulated after conversion ($\Delta C_{LF\_LB\_SC}$) was used for the annual carbon stock change in land converted to forest land (ΔC_{LF_LB}). Moreover, it was assumed that all land conversion occurred in intensively managed forests. And the ΔC_{LF_LB} value was reported for each land-use category before conversion and for each subcategory basis in cropland.

$$\Delta C_{LF\_LB} = \Delta C_{LB\_conversion\_to\_F} + \Delta C_{LF\_LB\_SC}$$

$$\Delta C_{LB\_conversion\_to\_F} = \sum_i \{\Delta A_i \times (B_a \times CF_a - B_{b_i} \times CF_{bi})\}$$

$$\Delta C_{LF\_LB\_SC} = \Delta A_{LF} \times IEF_{AR}$$

ΔC_{LF_LB}	: Annual carbon stock change in land converted to forest land [t-C/yr]
$\Delta C_{LB\_conversion\_to\_F}$	: Annual carbon stock change at the land conversion (loss) [t-C/yr]
$\Delta C_{LF\_LB\_SC}$	: Carbon stock gains due to biomass growth in the converted forest land within 20 years from conversion [t-C/yr]
i	: Land-use category before conversion
ΔA_i	: Annual land area that has been converted from land-use type i to forest land[ha/yr]
B_a	: Dry matter weight biomass per unit area immediately after conversion to forest [t-d.m./yr] (default value=0)
$B_{b,i}$	: Dry matter biomass weight per unit area before conversion from land-use type i to forestland [t-d.m./yr]
CF_a	: Carbon fraction of dry matter after conversion (forest land) [t-C/t-d.m.]
CF_{bi}	: Carbon fraction of dry matter in land-use type before conversion [t-C/t-d.m.]
ΔA_{LF}	: Area of converted forest land within 20 years [ha]
IEF_{AR}	: Average carbon stock gain per unit area due to AR activities (equal to the implied removal factor) [t-C/ha/yr]. See Table 6-9.

- ***Parameters***

➢ ***Parameters for estimating Living Biomass Stocks***

- ***Per unit area removals used in the estimation after conversion (IEF_{AR})***

Annual increase in biomass carbon stocks due to biomass growth in "land converted to forest land" uses the value of the carbon stock gain per unit area caused from AR activities (Table 6-9) which is estimated in the forest land subjected to AR activities under Article 3, paragraph 3, of the Kyoto Protocol, since it can be considered that growth in "land converted to forest land" is similar to that in the land subjected to AR activities.

- ***Biomass stock or Carbon stock in each Land-Use Category (B_a)***

The parameter in cropland (rice fields and upland fields) and grassland before conversion, shown in Table 6-9, is used. For conversions from wetlands, settlements and other land, carbon stock losses in living biomass are assumed as 0, the carbon losses are reported as "NA".

- ***Carbon Fraction of Dry Matter (CF)***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. For that of grassland, the default value for herbaceous biomass (0.47 t-C/t-d.m.) was applied in accordance with the *2006 IPCC Guidelines*.

- ***Activity Data***

The areas of land converted to forest land within 20 years were calculated by summing the annually converted areas during the past 20 years. The estimation methods for total converted areas and for annually converted areas from each land-use category are described below. Since the transition period in the calculation of changes in soil carbon stocks is set at 40 years, the area converted to forest land is estimated from the year 1951.

➢ ***Total area of "Land converted to Forest land"***

It is logically presumed that the areas of land converted to forest land include AR areas, forest land restored from degraded land by natural succession, and land whose land-use categories are changed to forest land due to other reasons. However, it is not common in Japan that forest land restored from degraded land by natural succession is determined as "Forests under Forest Law Article 5 and 7.2" as indicated in Table 6-2. Therefore, such areas are classified as remaining land categories. Hence, it is regarded that the areas of land converted to forest land are similar to the AR areas, and that the areas are determined in accordance with the concept of "overlap" described as a time series consistency and recalculation approach on section 5.3.3.1 in Volume 1 of the *2006 IPCC Guidelines*, by using areas of forested cropland reported in the *Statistics of Cultivated and Planted Area* and annual forested areas estimated by using the method described in section 6.2.2.1.

The annual forested areas before FY2005 are not directly obtained from satellite image interpretation. Thus, the area of land converted to forest land before FY2005 are estimated by the following method.

- ***From FY1990 to FY2004***

The annual areas of land converted to forest land from FY1990 to FY2004 are calculated by averaging the total AR area of FY 2005, obtained from interpretating aerial orthophotos taken at the end of FY1989 and satellite images taken in 2005, and allocating it to each year from FY1990 to FY2004.

- ***From FY1971 to FY1989***

The annual areas of land converted to forest land are calculated by using forest area and deforestation area obtained from statistics provided by the *Census of agriculture and Forestry* (MAFF). The procedure of the calculation method is as follows.

1. Changes in forest area in 10 years (A_{t2}-A_{t1}) from FY1970 to FY1980 and FY1980 to FY1990 and deforested area in 10 years (ΔA_{D10}) are calculated by using the forest areas obtained from the statistics in FY1970, FY1980 and FY1990 respectively.
2. Total areas of land converted to forest land in the same 10 years' periods (ΔA_{LF10}) are calculated by summing of those areas calculated in Step 1 ($\Delta A_{LF10}=(A_{t2}+\Delta A_{D10})-A_{t1}=(A_{t2}-A_{t1})+\Delta A_{D10}$).
3. The values from Step 2 are allocated to each year according to the area of afforested land based on the statistical values which are from "the *Statistics of Cultivated and Planted Area* (MAFF)".

- ***From FY1951 to FY1969***

The annual areas of land converted to forest land are calculated to maintain consistency between the change in total forest area and deforestation area, as was done for the period 1971-1989 by using forest area (1951, 1954, 1957, 1965, 1970) obtained from statistics provided by the *Census of Agriculture and Forestry* and *Statistical Tables of the Ministry of Agriculture and Forestry* (MAFF) and the deforested area estimated from the area under cultivation in the *Statistics of Cultivated and Planted Area*.

➢ ***Areas of "Cropland and Grassland converted to Forest Land" among the total areas***

- ***From FY2005 onwards***

The areas of cropland or grassland converted to forest land since FY2005 were respectively estimated by multiplying the percentage of the number of plots interpreted as conversion from cropland or grassland to forest land in the total number of AR plots. As subcategories of cropland, the areas of cropland converted to forest land from FY 2005 to 2016 is further divided into “rice fields converted to forest land”, “upland fields converted to forest land” and “orchards converted to forest land” by using area data obtained by statistics, obtained in the same way as below [from 1951 to 2004]. Since the subcategory of cleared and abandoned land is not available in the *Statistics on Cultivated and Cropland Area* after FY2017, the data is divided into fields based on the percentage of cropland from rice fields and fields in the *Movement and Conversion of Cropland* and proportionally divided into upland fields and orchards based on the current area.

- ***From FY1951 to FY2004***

The areas of cropland converted to forest land were determined by utilizing the areas of forested cropland reported in the Statistics of Cultivated and Planted Area. As its subcategories, the areas of cropland converted to forest land are categorized to rice fields converted to forest land, upland fields converted to forest land and orchards converted to forest land. The areas of rice fields converted to forest land are determined by utilizing the areas of forested by planting on rice fields provided by *the* Statistics of Cultivated and Planted Area. The areas of upland fields and orchards converted to forest land are estimated through dividing the areas of forested by planting on total arable land by using the area ratio of the three agricultural sub-land uses categories (upland field, orchard and pasture). For the period 1971-2002, the area data of annual agricultural land creation in sub-land use category level obtained by *Administrative Statistics of Creation of Agricultural Land* were taken into account to estimate the area ratio of each sub-land use category. For other periods, the estimates were prorated using existing area ratios of upland fields, orchards and pasture land provided in the *Statistics on Cultivated and Cropland Area*.

The areas of grassland converted to forest land are calculated by summing the areas of forested by planting on pasture land estimated from the data in the *Statistics of Cultivated and Planted Area* and those of forested by planting on grazed meadow reported in *A Move and Conversion of Cropland* (MAFF).

➢ ***Areas of “Wetlands, Settlements or Other land converted to Forest land”***

- ***From FY2005 onwards***

The areas of wetlands, settlements or other land converted to forest land since FY2005 were respectively estimated by multiplying the percentage of the number of plots interpreted as conversion from each land-use to forest land in the total number of AR plots.

- ***From FY1951 to FY2004***

Since the areas of wetlands, settlements, and other land converted to forest land cannot be obtained directly from statistics for the years before FY2004, they are estimated by subtracting the summed areas of cropland converted to forest land and grassland converted to forest land from the total area of land converted to forest land, and by multiplying the difference by ratios of areas of wetlands, settlements, and other land converted to forest land, which are estimated based on trend of results of AR identification in 2007. The allocation ratio was fixed at wetlands: settlements: other land = 0: 1: 1.

Table 6-24 Area of land converted to forest land within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Forest land	kha	4.57	4.57	4.57	4.57	3.09	2.69	1.02	1.02	0.96	0.96	0.14	0.14	0.05	0.05	NO
Cropland converted to Forest land	kha	3.14	1.33	1.19	2.75	1.75	1.40	0.59	0.59	0.33	0.33	0.08	0.08	NO	NO	NO
Rice field	kha	0.92	0.47	0.41	0.82	0.75	0.51	0.21	0.20	0.11	0.11	0.03	0.03	NO	NO	NO
Upland field	kha	1.23	0.57	0.34	1.50	0.80	0.71	0.30	0.31	0.18	0.17	0.04	0.04	NO	NO	NO
Orchard	kha	0.99	0.30	0.44	0.42	0.21	0.18	0.08	0.08	0.04	0.04	0.01	0.01	NO	NO	NO
Grassland converted to Forest land	kha	0.24	0.20	0.16	0.82	0.72	0.92	0.27	0.27	0.50	0.50	0.04	0.04	0.05	0.05	NO
Wetlands converted to Forest land	kha	NO	NO	NO	0.00	NO	0.03	0.03	0.03	NO	NO	NO	NO	NO	NO	NO
Settlements converted to Forest land	kha	0.59	1.52	1.61	0.81	0.50	0.28	0.09	0.09	0.10	0.10	0.01	0.01	NO	NO	NO
Other land converted to Forest land	kha	0.59	1.52	1.61	0.18	0.11	0.07	0.05	0.05	0.03	0.03	0.01	0.01	NO	NO	NO

Reference: *Forestry Status Survey, NFRDB* (Forestry Agency)

Table 6-25 Area of Land converted to forest land within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Forest land	kha	554.0	243.7	158.3	118.6	87.1	83.3	79.8	76.2	72.6	69.0	64.6	60.2	55.6	51.1	46.5
Cropland converted to Forest land	kha	123.9	60.6	43.9	35.1	32.1	30.3	29.2	28.3	27.3	26.3	25.2	24.1	22.8	21.6	20.7
Rice field	kha	53.8	23.7	15.9	11.7	11.8	11.2	10.9	10.5	10.2	9.8	9.4	8.9	8.5	8.1	7.8
Upland field	kha	44.3	21.2	14.6	12.5	13.5	13.1	12.7	12.5	12.1	11.8	11.4	11.0	10.7	10.3	10.2
Orchard	kha	25.8	15.7	13.4	10.9	6.8	5.9	5.6	5.3	5.1	4.8	4.4	4.1	3.6	3.2	2.7
Grassland converted to Forest land	kha	17.4	8.7	5.7	5.0	7.2	8.5	8.6	8.7	9.0	9.3	9.1	8.9	8.8	8.7	8.6
Wetlands converted to Forest land	kha	NO	NO	NO	NO	0.03	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Settlements converted to Forest land	kha	206.4	87.2	54.3	39.6	25.4	23.9	22.6	21.3	19.8	18.4	16.9	15.3	13.7	12.1	10.4
Other land converted to Forest land	kha	206.4	87.2	54.3	38.9	22.4	20.6	19.2	17.8	16.3	14.8	13.3	11.7	10.1	8.5	6.8

Reference: *Forestry Status Survey, NFRDB* (Forestry Agency)

2) Carbon Stock Changes in Dead Organic Matter and Soils in "Land converted to Forest land"

- ***Estimation Method***

➢ ***Carbon Stock Changes in Dead Organic Matter in forests with standing trees***

Carbon stock changes in dead wood and litter were calculated under the assumption that these carbon stocks change linearly in each transition period from those in land-use categories other than forest land (0 t-C/ha) to those in forest land, calculating the rate of change per year (t-C/ha/yr), and multiplying it by the area of activity as shown in the following equation. Even if the transition period is 40 years for dead wood, the area of activity should be the area converted in the last 20 years, since under that category, lands up to 20 years after conversion are subject to reporting. Lands that have been converted for more than 21 years up to 40 years are reported under the category of "forest land remaining forest land."

$$\Delta C_{LF\_dl} = \sum_i \{\Delta A_{LF_i} \times (C_{F20_{dl}} - C_{i_{dl}})/T_{dl}\}$$

ΔC_{LF_dl} : Annual change in carbon stocks in dead wood, litter or mineral soils in land-use category i converted to forest land (forests with standing trees) [t-C/yr]

ΔA_{LFi} : Area of land-use category i being converted to forest land (forests with standing trees) within the past 20 years [ha]

C_{F20_dl} : Average carbon stocks in dead wood, litter or mineral soils per unit area in 20-year-old-forests obtained by the CENTURY-jfos model [t-C/ha]

C_{i_dls} : Average carbon stocks in dead wood, litter or mineral soils per unit area in land-use category i before conversion [t-C/ha]

T_{dl} : Transition period (40 years for dead wood, 20 years for litter)

i : Land-use category before conversion

➢ ***Carbon stock changes in mineral soils of forests with standing trees***

Carbon stock changes in mineral soils were calculated by multiplying the annual change, calculated using the method shown in Table 6-14, by the forest area converted from other land uses over the past 20 years. The amount of annual change depends on the land use prior to the conversion.

➢ ***CO_2 emissions from organic soils due to cultivation and drainage***

Emissions from organic soils in this category were reported as "NO" in the same manner as forest land remaining forest land.

- ***Parameters***

➢ ***Parameters for estimating carbon stock changes in dry organic matter and soils***

Parameters for each carbon pool in Table 6-12 (dead wood), Table 6-13 (litter) and Table 6-14 (mineral soils) were used, in particular, for the categories cropland, grassland, wetlands, settlements and other land before conversion and for the category forest land after conversion.

- ***Activity Data***

➢ ***Total areas of "Land converted to Forest land"***

Areas of land converted to forest land used as the same as that used for estimation of living biomass. See Table 6-22.

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

The uncertainties of the parameters and activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. As a result, the uncertainty estimate was 9% for the entire removal from land converted to forest land.

- ***Time-series Consistency***

Time-series consistency for this subcategory is ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

- ***Correction in accordance with revision of the area converted to forest land***

As it was mentioned in 6.4.1. e), areas of land converted to forest land due to the correction of the area were recalculated. Accordingly, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years. See Chapter 10 for impact on trend.

- ***Recalculation of carbon stocks of dead organic matter and mineral soils due to revision of calculation method***

Annual changes in carbon stocks of dead organic matter and mineral soils were updated by revising carbon stocks before and after the conversion, land conversion factor and transition periods. Accordingly, the carbon stock changes in dead organic matter and mineral soils in the relevant categories were recalculated for all years. See Chapter 10 for the extent of the impact of the recalculation.

f) ***Category-specific Planned Improvements***

Nothing in particular.

6.5. Cropland (4.B.)

Cropland is the land that produces annual and perennial crops; it includes temporarily fallow land. Cropland in Japan's inventory consists of rice fields, upland fields, orchards and dilapidated farmland.

In FY2021, Japan's cropland area was about 4.04 million ha, which is equivalent to about 10.7% of the national land. The area of organic soil in cropland is about 0.17 million ha. The emissions from this category in FY2021 were 4,666 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 44.0% compared to FY1990 and an increase of 0.3% compared to FY2020.

Table 6-26 Emissions and removals in cropland resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
4.B. Cropland	Total	kt-CO_2	8,331	3,827	4,002	3,912	5,846	6,508	5,472	6,193	5,698	5,443	4,552	3,968	4,681	4,650	4,666
	Living biomass	kt-CO_2	930	389	198	211	282	226	199	200	251	252	172	201	239	290	541
	Dead wood	kt-CO_2	146	34	11	20	28	28	18	18	18	18	8	8	13	13	49
	Litter	kt-CO_2	72	17	6	10	14	14	9	9	9	9	4	4	7	7	24
	Mineral soil	kt-CO_2	5,933	2,159	2,572	2,473	4,342	5,068	4,073	4,795	4,253	4,001	3,206	2,592	3,260	3,178	2,892
	Organic soil	kt-CO_2	1,250	1,228	1,214	1,197	1,180	1,173	1,172	1,170	1,167	1,163	1,162	1,162	1,163	1,163	1,160
4.B.1. Cropland remaining Cropland	Total	kt-CO_2	7,407	3,591	3,911	3,760	5,646	6,336	5,358	6,073	5,572	5,315	4,508	3,931	4,571	4,532	4,212
	Living biomass	kt-CO_2	280	245	157	121	154	127	144	137	179	175	165	207	182	229	198
	Dead wood	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Litter	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mineral soil	kt-CO_2	5,933	2,159	2,572	2,473	4,342	5,068	4,073	4,795	4,253	4,001	3,206	2,592	3,260	3,178	2,892
	Organic soil	kt-CO_2	1,194	1,187	1,181	1,166	1,149	1,141	1,141	1,141	1,140	1,139	1,136	1,132	1,129	1,126	1,122
4.B.2. Land converted to Cropland	Total	kt-CO_2	924	236	91	152	201	173	114	119	126	128	45	36	110	118	454
	Living biomass	kt-CO_2	651	144	41	90	128	99	55	62	72	77	6	-6	56	61	342
	Dead wood	kt-CO_2	146	34	11	20	28	28	18	18	18	18	8	8	13	13	49
	Litter	kt-CO_2	72	17	6	10	14	14	9	9	9	9	4	4	7	7	24
	Mineral soil	kt-CO_2	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Organic soil	kt-CO_2	56	41	33	32	31	32	31	29	27	25	26	30	34	37	39

6.5.1. Cropland remaining Cropland (4.B.1.)

a) ***Category Description***

This subcategory deals with carbon stock changes in cropland, which has remained as cropland during the past 20 years. The emissions from this subcategory in FY2021 were 4,212 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 43.1% compared to FY1990 and a decrease of 7.1% compared to FY2020. CO_2 emissions from mineral soil pool in FY2021 were 2,892 kt-CO_2; a 51.3% decrease compared to FY1990 and a 9.0% decrease compared to FY2020.

The trend on emissions in time-series data in this category started from a decreasing trend of emissions from FY1990 to FY2003, turned to continuously increasing trend of emissions from FY2004 to FY2008, which is the peak of emissions for whole time series, and shown a declining trend of emissions again since then. It is considered that the time-series variability is mainly caused by annual variability of carbon input amount into mineral soils (especially, carbon input of compost) and annual fluctuation of temperature that affects decomposition of the carbon input. Among the three subcategories of cropland (rice field, upland field and orchard), the annual fluctuations have been largely affected by the trends in upland fields, especially occurred in Hokkaido prefecture, which holds more than 25% of upland field in Japan. This is because that the amount of emissions are calculated by multiplying the carbon stock change factor by the area of prefecture, so even if the fluctuation of the carbon stock change factor is small, it will be amplified when there is a fluctuation in a prefecture with a large area.

In addition, estimation of carbon stock changes in mineral soils by biochar amendments in cropland have been reported since the 2020 submission. The amount of reduction in emission by the effect of carbon storage by biochar amendment in FY2021 is 3.03 kt-CO_2.

The area of cropland remaining croplands within the past 20 years was shown in Table 6-27. Besides, this area contained both land of mineral soils and organic soils.

Table 6-27 Areas of cropland remaining cropland within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cropland remaining Cropland	kha	4,563	4,442	4,340	4,283	4,238	4,179	4,166	4,151	4,140	4,116	4,088	4,057	4,035	4,005	3,977
Rice fields	kha	2,765	2,704	2,626	2,545	2,484	2,454	2,447	2,439	2,427	2,413	2,395	2,378	2,364	2,348	2,332
Upland fields	kha	1,186	1,141	1,120	1,135	1,153	1,152	1,149	1,145	1,141	1,138	1,130	1,124	1,118	1,111	1,106
Orchards	kha	445	393	350	330	309	301	297	293	289	285	280	274	269	263	258
dilapidated farmland	kha	167	204	244	272	292	272	273	273	283	281	283	280	284	282	282

b) ***Methodological Issues***

1) Carbon Stock Changes in Living Biomass in "Cropland remaining Cropland (Orchard)"

- ***Estimation Method***

➢ ***Carbon Stock Changes in Living Biomass in Rice Fields, Upland Fields and Dilapidated farmland***

As for carbon stock changes in living biomass, only perennial woody species are considered for estimation according to the section 5.2.1.1 in Volume 4 of the *2006 IPCC Guidelines*.

In rice fields and upland fields where annual crops are grown, the biomass increased by growth is lost by harvesting and decomposition in a short period of time, so it does not contribute to carbon stock storage over time. Therefore, it is not included in the calculation of carbon stock changes. In addition, the anthropogenic biomass carbon stock change was not considered and reported as zero or "NA" in the dilapidated farmland, since there is no direct human management for changing biomass stock.

➢ ***Carbon Stock Changes in Living Biomass in Orchard***

Carbon stock changes in living biomass in orchard are estimated by applying the Tier 2 estimation method of the stock–difference method described in section 5.2.1.1 in Volume 4 of the *2006 IPCC Guidelines*.

The carbon stocks in living biomass in orchard are calculated by multiplying area of each orchard tree type by dry matter biomass weight per tree taken by existing research reports, standard planting density, and carbon fraction of dry matter. The carbon stocks in above- and below ground biomass were calculated by using the root-to-shoot ratio.

$$\Delta C_{C_{LB}} = C_{t+1} - C_t$$

$$C_t = \sum_j \left(A_{t,j} \times D_j \times W_j\right) \times \frac{10}{1000} \times CF$$

Note: 10/1000 is for unit conversion

ΔC_{C_LB}	: Carbon stock change in living biomass in Orchard [t-C/yr]
C_t	: Total Carbon in living biomass at time *t* [t-C]
A_t	: Cultivation area of orchard at time *t* [ha]
D	: Planting density [tree/10a]
W	: Dry matter weight of above-ground biomass per tree [kg/tree]
CF	: Carbon fraction of dry matter [t-C/t-d.m.]
j	: Type of orchard tree

- ***Parameters***

➢ ***Parameters for Living Biomass Estimation in Orchard tree***

Country specific parameters of the planting density, dry matter biomass weight per tree, and root-to- shoot ratio were set for major orchard trees based on existing research reports.

Dry matter biomass weight for tea tree are 48 t-d.m./ha; the dry matter biomass weight for fruit orchard tree are 8 - 24 t-d.m./ha, the root-shoot ratio is 7:3 - 5:4. The country specific carbon fraction of dry matter of forest (broad leaf: 0.48 t-C/t-d.m.) was applied as the carbon fraction of dry matter of orchard trees.

- ***Activity Data***

➢ ***Area for Orchard***

The cultivation areas for 15 major orchard trees were identified by *the Statistics of Cultivated and Planted Area* and for fruit trees other than 15 major orchard trees ware identified by *Survey on Productive Movement of Local Fruits*. Even when the survey is conducted only in the main producing prefectures for major orchard trees, all the area of the orchard trees at each prefecture are estimated in line with the method to assume the national total area in the statistics or using interpolation. As the area of "newly-established" and "deserted" is not identified by orchard type in this statistic, only the apparent amount of change after land conversion is used as activity data. Therefore, this value includes area of orchard land converted from other land-use.

2) Carbon Stock Changes in Dead Organic Matter in "Cropland remaining Cropland"

- ***Estimation Method***

Carbon stock changes in dead organic matter are estimated as zero by applying the Tier 1 method, assuming that the carbon stocks are not changed, according to section 5.2.2.1 in Volume 4 of the 2006 IPCC Guidelines. Thus, the carbon stock changes are reported as "NA".

3) Carbon Stock Changes in Soils in "Cropland remaining Cropland"

For mineral soils, the estimations are conducted separately to agricultural land and dilapidated farmland. Carbon stock changes in agricultural land consist on carbon stock changes due to normal practices in farming as well as carbon accumulation by biochar amendment. For organic soils, the emission associated with cultivation of organic soils (on-site) and the emission due to water-soluble carbon loss from drained organic soils (off-site) in rice fields and upland fields in agricultural land were estimated.

- ***Estimation Method***

➢ ***Carbon Stock Changes in Mineral soils***

- ***Carbon Stock Changes in Mineral soils in agricultural land (rice fields, upland fields and orchard)***

Japan uses a Tier 3 method, the Rothamsted Carbon Model (Roth C), to estimate soil organic carbon stock changes in agriculture land (cropland and managed grassland) over time.

As shown in Figure 6-6, amounts of soil carbon [t C/ha (for each 100m x 100m mesh)] by each of the five compartments with different rates of carbon decomposition are calculated monthly, using inputs from weather data (monthly average temperature, precipitation, and open-pan evaporation), soil property data (soil clay content, depth of surface soil, carbon content at the starting year, and bulk density), land-use data, and carbon input from crop residue and organic manure. The annual soil carbon stock changes [t-C/ha/yr] for each mesh were calculated by taking the difference between the annual total carbon of all compartment for all months in this year and those in the previous year. In order to classify the report category of the GHG inventory, the average amount of soil carbon stock changes per unit area by each subcategory and by each prefecture [t-C/ha/yr] were estimated by identifying the land use in subcategory for each mesh and by superimposing the map with the prefectural administrative boundaries on the mesh data. The total carbon stock changes in agriculture land [t-C/year] were calculated by multiplying the carbon stock change parameter obtained from the model by the mineral soil area of each prefecture level obtained from statistics.

$$\Delta C_{C\_ms} = \sum_{i,j} \left(\Delta SOC_{i,j} \times A_{i,j} \right)$$

ΔC_{C_ms}	: Carbon stock changes in mineral soils in agricultural land [t-C/yr]
$\Delta SOC_{i,j}$	: Carbon stock changes in mineral soils per unit area [t-C/ha/yr] by subcategory *j* and by prefecture *i*, estimated from the Roth C model
A	: Area of cropland with mineral soil obtained from statistics [ha]
i	: Prefecture
j	: Type of land-use subcategory in cropland (rice fields, upland fields and orchard)

In the model calculation, land unit which was recorded once as cropland since FY1970 was regarded as cropland and used for calculation; the result of the calculation includes all croplands, regardless of whether converted or not. Therefore, it is reported without distinction between converted or not, and the carbon stock changes in mineral soils in agricultural land converted from other land uses are included in this calculation.

- ***Carbon Stock Changes in Mineral Soils Associated by Biochar amendment***

Carbon stocks change in mineral soils in cropland by biochar amendments were estimated by applying Tier 1 method provided in *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas*

Inventories (hereafter *2019 Refinement*). This estimation includes hard charcoal, soft charcoal, bamboo charcoal, fine coal and sawdust coal produced in Japan considering the availability of its production data.

Furthermore, since information on amount of biochar applied into each subcategory is not available, the carbon stock changes were estimated and reported collectively in mineral soils in cropland remaining cropland. The estimation equation is as follows:

$$\Delta BC_{C\_ms} = \sum_{p} \left(BC_{TOT_p} \times F_{C_p} \times F_{perm_p} \right)$$

ΔBC_{C_ms} : Carbon stock changes in mineral soils land associated with biochar amendment in agricultural land , tonnes [t-C/yr]

BC_{TOTp} : Mass of biochar applied into mineral soil during the inventory year for each biochar production type p [t-d.m./yr]

F_{Cp} : Organic carbon content of biochar for p [t-C/t-d.m.]

F_{perm} : Fraction of biochar carbon for biochar p remaining (unmineralized) after 100 years [t-C/t-C]

p : Biochar type (hard charcoal, soft charcoal, bamboo charcoal, fine coal and sawdust coal)

- ***Carbon Stock Changes in Mineral soils in dilapidated farmland***

As it is described in the carbon stock changes in the biomass pool, carbon stock changes due to direct human management were considered zero in the dilapidated farmland area and so reported as "NA".

➢ ***CO_2 Emissions from Organic Soils Caused by Cultivation and Drainage***

- ***On-site CO_2 emissions from organic soils in rice fields and upland fields caused by cultivation and drainage***

On-site CO_2 emissions from organic soils in rice fields and upland fields were estimated by applying Tier 1 or Tier 2 estimation method described in section 5.2.3.1 in Volume 4 of the *2006 IPCC Guidelines*. Tier 2 method was applied to land-use subcategories for which country-specific emission factors were available.

$$L_{C\_os} = \sum_{j,z} \left(A_{j,z} \times EF_{j,z} \right)$$

L_{C_os} : Loss of Carbon in organic soils [t-C/yr]

$A_{j,z}$: Area of organic soils in subcategory j in Climate zone z [ha]

$EF_{j,z}$: CO_2 emission factor in subcategory j in Climate zone z [t-C/ha/yr]

j : Subcategory in cropland (rice fields, upland fields)

z : Climate zone (Cold temperate zone, warm temperate zone)

- ***Off-site CO_2 emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields***

Off- site CO_2 emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields were estimated by applying Tier 1 estimation method described in 2.2.1.2 section in the *Wetlands Guidelin*es. The estimation equation is as follows. See section 6.12. b) for the methodology of methane emission.

$$CO_2{-}C_{DOC_{C\_os}} = \sum_{j} \left(A_j \times EF_{DOC} \right)$$

$$EF_{DOC} = DOC_{FLUX_{NATURAL}} \times (1 + \Delta DOC_{DRAINAGE}) \times F_{rac_{DOC-CO_2}}$$

CO_2-C_{DOCC_os}	: Annual off-site CO_2-C emissions due to DOC loss from drained organic soils [t-C/yr]
A_j	: Land area of drained organic soils in land-use subcategory *j* [ha]
j	: subcategory in cropland (rice fields, upland fields)
EF_{DOC}	: Emission factors for annual CO_2 emissions due to DOC loss from drained organic soils [t-C/ha/yr]
$DOC_{FLUX\_NATURAL}$	: Flux of DOC from natural (undrained) organic soil [t-C/ha/yr]
$\Delta DOC_{DRAINAGE}$	: Proportional increase in DOC flux from drained sites relative to undrained sites
$Frac_{DOC\text{-}CO2}$	: Conversion factor for proportion of DOC converted to CO_2 following export from site

- ***CO_2 Emissions from Organic Soils Caused by Cultivation and Drainage in Orchard and Dilapidated farmland***

There are few organic soils area in orchard and it is common to grow fruit trees by either a method of cultivation by clean cultivation system or a method of cultivation by sod culture without cultivation and drainage of soils are not also implemented in dilapidated farmland. So, since no emissions occur in these inactive areas the emissions were reported as "NO" in accordance with the *2006 IPCC Guidelines*.

● ***Parameters***

➢ ***Key Assumption and parameters necessary for Roth C model estimating carbon stock changes in mineral soils in agricultural land (rice fields, upland fields and orchard)***

- ***Application of Roth C model for Agricultural Land in Japan***

Roth C is a soil carbon dynamic model validated by using long-term field experiments (Coleman and Jenkinson, 1996). The model had been tested against long-term experimental data sets in Japanese agricultural lands and some modifications were made after that in order to apply the model to Japanese agricultural conditions. It was found that the original model could be applied for non-volcanic upland soils without any modification or calibration (Shirato and Taniyama, 2003), however, for Andosols, the decomposition rate constant of the HUM (humified organic matter) pool of Roth C was reduced because the presence of Al-humus complexes enhances its stability and resistance to decomposition (Shirato *et al.* 2004). And, for paddy soils, the decomposition rate constants of all four active C pools was reduced on the basis of differences in organic matter decomposition rates between upland and paddy (submerged in the rice growing season) soil conditions (Shirato and Yokozawa, 2005).

- ***Input data for Roth C model estimation***

Weather data with 1km mesh resolution, soil property and land-use data obtained by 100m mesh were used. The statistical data and the questionnaire survey by prefecture were used for amount of carbon input from crop residue and organic manure. The input amount of crop residue was calculated in each crop by multiplying the crop yield by the ratio of residue generation and the ratio of plow-into soils. Since the amount of crop residue is related to the amount of crops rather than the amount of harvest, it is not considered that reflecting the annual fluctuation of the amount of harvest leads to accurate estimation. So, we decided to use the average yield (for rice fields, the average value of yield of rice calculated by the MAFF was used, and for upland fields and orchard, the average values of actual yield from 1970 to 2017 were used) for each year. The residue generation ratio is set by a same value all over the country for each crop from the literature values. And the ratio of plow-into soils are determined by the actual treatment ratio of plowing from the annual questionnairehttps://eow.alc.co.jp/search?q=questionnaire&ref=awlj survey. For rice, annual values are used for each region and for other crops, unified values for the entire period are used. For the farmland manure input, the amount of manure application in the item of "production cost of rice" in the *Statistics on Farm Management* is used for rice and the amount of manure application estimated by the questionnaire survey are used for crops other than rice (upland crops, vegetables, fruit trees, tea, feedstuff, pasture grass). However, since surveys are conducted over the course of several years except for rice fields, the values for the years when results of the survey are not compiled are complemented by interpolation or extrapolation, and if the number of samples is too small to assure representativeness, those data are used after statistical processing, such as exclusion from the usage for estimation.

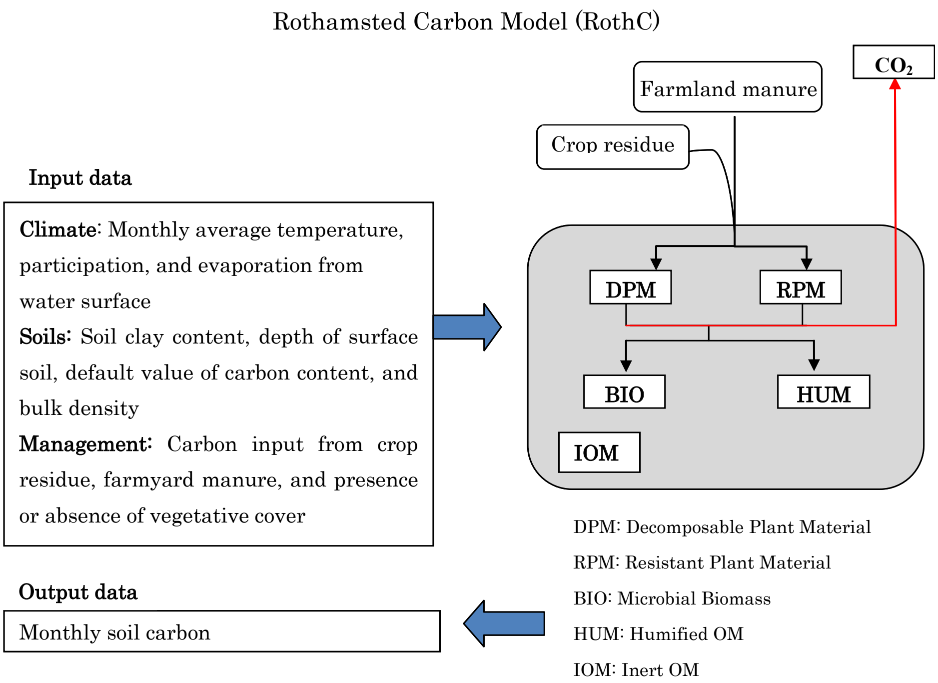


Figure 6-6 Roth C model

- ***Parameters of biochar (carbon content and fraction of carbon remaining after 100 years)***

As for organic carbon content of biochar, organic carbon content (0.778 t-C/t-d.m.)[5] at calcination temperatures of 350-450°C based on a domestic survey (Kurimoto et al. (2020)) was used for bamboo charcoal. Except for bamboo charcoal, the default value (0.77 t-C/t-d.m.) of heat treatment process for wood material provided in the *2019 Refinement* (Table 4Ap.1), was applied.

Fraction of carbon remaining after 100 years is based on the firing temperature of each biochar in Japan and the default value provided in the *2019 Refinement* (Table 4Ap.2). The default value (0.89 t-C/t-C) corresponding to firing temperature of 600 ℃ or more was applied to hard charcoal, soft charcoal and sawdust coal, the default value (0.80t-C/t-C) corresponding to firing temperature of 450 to 600°C to fine coal, and the value (0.65 t-C/t-C) of 350 to 600 ℃ to bamboo charcoal.

[5] Since information on bamboo charcoal production by firing temperature is not available, the data for firing temperatures between 350 and 450°C, which have the lowest organic carbon content, have been applied.

➢ ***CO_2 emission factors from organic soils (on-site)***

The following CO_2 emission factors from organic soils in rice fields and upland fields were applied to the estimation.

Table 6-28 Carbon emission factors resulting from cultivation of organic soils

Type of land use	Climate zone	Emission factors [t-C/ha/yr]	Reference
Rice fields	Cold temperate	1.55	Measured data[1)]
	Warm temperate	1.55	Data measured for cold temperate was applied.[2)]
Upland fields	Cold temperate	4.18	Measured data
	Warm temperate	10.0	Default value (*2006 IPCC Guidelines,* Vol.4, Table 5.6)

Note:
1) Measured data of rice field was set as if emission in waterlogging period was zero (0).
2) The emission factor of rice field in warm temperate was excluded in default values in *the 2006 IPCC Guidelines*; hence, the country-specific factor in cold temperate was applied as substitute.
3) Some areas of Japan belong to the subtropical climate zone, but the data used for the calculation shows that the cultivated area of organic soils in those areas is reported as “NO”, so the carbon emission factor for the subtropical zone is not used in the calculation.

➢ ***Parameters for calculating CO_2 emissions from organic soils (off-site)***

Tier 1 default parameters described in the *Wetlands Guidelines* were applied to the estimation.

Table 6-29 Parameters for calculating CO_2 emissions from organic soils (off-site)

Climate zone	$DOC_{FLUX\_NATURAL}$ [t-C/ha/yr]	$DOC_{DRAINAGE}$	$Frac_{DOC-CO2}$	EF_{DOC} [t-C/ha/yr]
Temperate	0.21	0.60	0.9	0.31

Reference: the *Wetlands Guidelines*: Table 2.2

● ***Activity Data***

➢ ***Area of mineral soils***

Areas of mineral soils in cropland which are multiplied by carbon stock changes per unit area calculated by Roth C model were estimated from the reported area in the *Statistics of Cultivated and Planted Area*, divided as rice field (only the area with rice really planted), upland field (including the area divided into rice field with other crops planted and with no crops) and orchards; and the areas of organic soils in each divided area (Table 6-30) is subtracted. Since the model calculation includes the agricultural land converted from other land use, the area of the agricultural land (mineral soils) converted from other land use are also included for activity data.

➢ ***Amount of biochar applied into cropland***

The amount of biochar applied to cropland, what is activity data, was calculated by multiplying the amount of wood charcoal production for agriculture use, by the proportion of biochar applied to cropland and the ratio of mineral soil area to total soil area.

As for the amount of wood charcoal production for agriculture use, the values classified as “agricultural use” obtained from *Statistical Survey on production of Special Forest Products* (MAFF), were applied. In addition, complete time series data were made using interpolation and allocation methods (If only the total value is available, allocation is conducted using the proportion of a certain wood charcoal in a certain year) due to lack of data for some years. Moreover, since wood charcoal were also used for “feed and other uses”, the amount of biochar amendments applied to cropland were calculated by subtracting wood charcoal production for “feed and other uses”, from the amount of wood charcoal production for “agricultural use”. Based on experts’ comments, the proportion of biochar applied to cropland was estimated as 95%. In addition, since it is difficult to obtain the amount of biochar production applied to mineral soil and organic soil in cropland separately, it is assumed that the same proportion (amount of biochar applied to cropland per unit area) of biochar production applied to all cropland for mineral soil and for organic soil in Japan. Therefore, the amount of biochar production applied to cropland in mineral soil and in organic soils were calculated based on percentage of total cropland occupied by mineral and organic soils as reported in GHG inventories.

However, since there is no default fraction of biochar C remaining after 100 years for organic soil in the *2019 Refinement* and data and information are not also available in Japan, carbon stock change associated with biochar amendments to organic soil in cropland was not subject to estimation. In addition, since the amount of import and export of biochar for “agricultural use” is infinitesimal, import and export of biochar applied to cropland were not estimated.

➢ ***Area of organic soils***

For the area of organic soils in subcategories of agricultural land, in the year when the soil area data by soil group is obtained, the proportion of soil classified as organic soil is calculated from the soil area data by soil group by prefecture and is multiplied by each area by prefecture (in 1992, 2001 and 2010). In other years, area of organic soils is calculated by adding or subtracting on or from the starting value at each fixed point in 1992, 2001, and 2010, using a certain rate for organic soils in the expanded / converted area. When the land is converted from other land use due to the expansion of agricultural land, the ratio of organic soil in the land-use category before conversion is basically used. However, regarding the conversion from wetlands, which covering reclaimed land from shallow water body, the ratio of organic soil was set to 0% (reported as "NO") because organic soil did not exist in the soil map around the reclaimed land in the reclaimed land corresponding to this activity.). In the case of conversion from agricultural land, the ratio of the changed area of the organic soil area to the changed total area that occurred during each survey year (1992-2001 or 2001-2010) is basically used. However, for land conversion before 1992, the organic soil ratio of each subcategory at the time of the 1992 survey is used, and for conversion after 1992, the value from 1992 to 2001 is used, and for conversion after 2001 onwards, the values from 2001 to 2010 is used.

Table 6-30 shows the total areas of organic soils (total organic soil area of cropland remaining cropland and land converted to cropland) by subcategories in cropland in Japan calculated by the method above. The CRF of the LULUCF sector requires the total area of organic soils to be reported regardless of cultivation or drainage as shown in Table 6-30, but the values used for activity data for emission estimation are the actual areas where those activities are conducted. The values of the areas of organic soils reported in the CRF Table in the Agricultural sector is the actually cultivated areas out of the total organic soils in the agricultural land. So, the values of the areas in the Agricultural sector were different from these in this table below (see section 5.5.1.6).

Table 6-30 Areas of organic soils in cultivated cropland

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Cropland remaining Cropland	kha	170.7	168.4	168.5	167.4	166.0	165.7	165.9	166.1	166.3	166.1	166.6	167.1	167.5	167.8	168.0
Rice fields	kha	131.6	129.8	129.1	127.3	125.3	124.9	125.0	125.1	125.0	124.8	124.9	124.9	124.9	124.9	124.8
Upland fields	kha	16.7	16.7	17.0	16.9	16.8	16.5	16.4	16.3	16.2	16.1	16.0	16.0	16.0	16.0	15.9
Orchards	kha	1.3	1.0	0.5	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.6
dilapidated farmland	kha	21.1	21.0	21.9	22.8	23.6	23.9	24.1	24.4	24.7	24.9	25.4	25.7	26.0	26.4	26.7

c) ***Uncertainties and Time-series Consistency***

● ***Uncertainty Assessment***

For the parameters and the activity data in biomass in orchards, the uncertainties of existing statistics and the default values described in the *2006 IPCC Guidelines* were applied. For the uncertainties of carbon stock changes in mineral soil estimated by Roth C model, the comparison of simulation results and observed values, when both input values and current measurement values of mineral soils are available, revealed that the uncertainty due to model structure was estimated about 10%. The uncertainty caused by input values has not been quantified yet and remains as an issue to be solved. For the uncertainties of change in mineral soil organic carbon stocks from biochar amendments, the uncertainties of statistical data and default values given in the *2019 Refinement* are used. For the uncertainties of organic soil, the uncertainties of statistical data and default values given in the *2006 IPCC Guidelines* are used. As a result, the uncertainty was estimated as 25% for the entire emission from the cropland remaining cropland.

● ***Time-series Consistency***

Time-series consistency for this category is ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

Although calibration for Roth C model has not been carried out, it was confirmed that the simulation results of Roth C have matched well with the observed data using the three modified versions of the Roth C model classified by land uses and soil types (Paddy soils, Andosols and non-Andosols). Verification and modification of plot scale were done with measured data.

Experiment fields are classified by soil characteristics into Paddy soils group, Andosols group and non-Andosols group. These 3 soil types are considered to be covered with all soil type. For detailed information, see references; Shirato & Taniyama, (2003), Shirato et al., (2004), Shirato & Yokozawa, (2005), Takata et al., (2011), Shirato, (2011) listed in this chapter.

e) ***Category-specific Recalculations***

● ***Correction in Accordance with Revision of the area converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation*, the area of cropland converted from forest land was recalculated, and the areas of cropland remaining cropland were recalculated for all years. With this recalculation, carbon stock changes in mineral soils and CO_2 emissions from organic soils were recalculated for all years.

- ***Correction of input data used for Roth C model calculation***

The five-year moving average of the plowing rates in each region for the carbon input data (rice straw) was used for the Roth C model calculations.

Updating the data in 2020, the amount of crop residue input after 2018 was corrected.

This change in the input data lead recalculation in the soil carbon stock changes per unit area in each land category for the FY2018-2020.

- ***Changes in the methodologies for estimating un-surveyed cultivation areas of orchard trees in some prefectures***

Due to the abolition of conducting annual surveys on the cultivation areas of orchard trees in some prefectures since 2017, those missing data are complemented by an assumption. With the revision in estimation method of this assumption, the area of the orchard trees and the amount of change in carbon stock of biomass from FY2017 to FY2019 were recalculated.

- ***Recalculation of correction in area of mineral soils and organic soils***

The method of estimating the area converted to cropland was revised between 1983 and 2002, so the area converted from other land in each district was revised. With this recalculation, the carbon stock changes and the CO_2 emissions from organic and mineral soils were recalculated for all years.

- ***Recalculation due to updated parameters for bamboo charcoal***

Due to the revision of organic carbon content and 100-year C remaining rate of bamboo charcoal, carbon stock changes in mineral soils were recalculated for all years.

See Chapter 10 for impact on trend.

f) ***Category-specific Planned Improvements***

No improvements are planned.

6.5.2. Land converted to Cropland (4.B.2.)

a) ***Category Description***

This subcategory deals with the carbon stock changes which occurred in the lands that were converted from other land-use categories to cropland within the past 20 years. Total area of land converted to cropland within the past 20 years by FY2021 is 59.7 kha, which represents 0.2% of the national total area.

The emissions from this subcategory in FY2021 were 454 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 50.8% compared to FY1990 and an increase of 285.8% compared to FY2020. Emissions from land converted to croplands decreased significantly from 1990 to 1993, but have not changed much since then. This decrease in the early 1990s was mainly due to the decrease in the area converted from forestland with high carbon stock to cropland.

b) ***Methodological Issues***

1) Carbon stock changes in Living Biomass in "Land converted to Cropland"

- ***Estimation Method***

The Tier 2 method which is estimation by summing the loss of carbon stock due to conversion ($\Delta C_{LB\_conversion\_to\_C}$) and the change of carbon stock accumulated after conversion ($\Delta C_{LC\_LB\_SC}$) was used for the annual carbon stock change in land converted to cropland (ΔC_{LC_LB}), using Equation 2.16 from the *2006 IPCC Guidelines* (Vol. 4, Section 2.3.1.2). And the country specific value of the amount of biomass accumulation is used for forest land converted to cropland. The Tier 1 method using default values is applied for land uses other than forest land converted to cropland.

$$\Delta C_{LC\_LB} = \Delta C_{LB\_conversion\_to\_C} + \Delta C_{LC\_LB\_SC}$$

$$\Delta C_{LB\_conversion\_to\_C} = \sum_i \{\Delta A_i \times (B_a \times CF_a - B_{b_i} \times CF_{b_i})\}$$

$$\Delta C_{LC\_LB\_SC} = \sum_j (\Delta A_j \times C_j)$$

ΔC_{LC_LB}	: Annual carbon stock change in the converted land [t-C/yr]
$\Delta C_{LB\_conversion\_to\_C}$	: Annual carbon stock change at the time of land conversion [t-C/yr]
$\Delta C_{LC\_LB\_SC}$	: Annual carbon stock change accumulated due to biomass growth in the converted land after conversion [t-C/yr]
i	: Land use before conversion
ΔA_i	: Area converted from land-use type *i* to cropland for the current year [ha/yr]
B_a	: Dry matter biomass weight per unit area immediately following conversion to cropland [t-d.m./ha/yr], default value=0
B_{bi}	: Dry matter biomass weight per unit area before conversion from land-use type *i* to cropland [t-d.m./ha/yr]
CF_a	: Carbon fraction of dry matter after conversion [t-C/t-d.m.]
CF_{bi}	: Carbon fraction of dry matter in land-use type *i* before conversion [t-C/t-d.m.]
ΔA_j	: Area converted to subcategory *j* in cropland for the current year [ha/yr]
C_j	: Change of dry matter biomass weight per unit area accumulated after conversion [t-d.m./ha/yr], see Table 6-9.
j	: Land use in cropland subcategory after conversion (rice fields, upland fields)
	Note: Carbon stock changes acculated after conversion in Orchard is estimated collectively in cropland remaining cropland.

- ***Parameters***

➢ ***Biomass stock in each Land-Use Category***

Table 6-9 is used for the estimation of biomass stock changes upon land-use conversion and Table 6-11 is used for subsequent changes in biomass stock due to biomass growth in the converted land. The carbon stock changes accumulated due to biomass growth after conversion in rice fields and upland fields equal to the amount of carbon stock acquired in one year after conversion (Table 6-11), so the same value was used assuming that the amount of carbon stock of annual crops set in Table 6-9 would be reached in one year.

The amount of crop residue which was used to estimate N_2O emissions from crop residues plowed into agricultural soil after harvesting in the Agriculture sector (3.D.a.4) was used for the amount of carbon stock in rice fields and upland fields in this Table 6-9. In addition, since the amount of crop residues plowed into cropland differs depending on the type of crop, the carbon content of the crop residues plowed into cropland per unit cultivation area was weighted average according to the annual cultivation area. And the average value from FY1990 to FY2017 was calculated using the weighted average value each year calculated above and was applied as parameter uniformly over the whole years (Table 6-9).

In addition, biomass carbon stocks of annual crops per unit area were also applied as biomass growth of annual crops for one year after conversion (Table 6-11).

➢ ***Carbon Fraction of Dry Matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines*.

● ***Activity Data***

For the calculation of the carbon stock changes of living biomass in land converted to cropland, the annual area converted to cropland was used.

➢ ***Areas of Forest land Converted to Other Land-use Categories***

It was assumed that the areas of forest land converted to other land-use categories (cropland, grassland, wetlands, settlement and other land) were consistent with the area of deforestation reported under Article 3, paragraph 3, of the Kyoto Protocol. Thus, the area of forest land converted to cropland was estimated by allocating the deforested area. Since the D survey by satellite image has been conducted since FY2005, the applied method to calculate the deforested area for FY1971 to FY1989, for FY1990 to FY2004 and for FY2005 onwards are described as follows, respectively.

- ***From FY2005 onwards***

Total “D areas (deforested area identified by the D survey)” and the share of land use after land conversion are identified by utilizing the orthophotos taken at the end of 1989 and satellite images taken from FY2005 onwards as same as the AR areas are identified. The areas of forest land converted to cropland, grassland, wetlands, settlements and other land were estimated by multiplying the total D area by the land ratios of forest land converted to each land-use category. Both the ratio and the area were estimated by the D survey. Regarding the land converted to cropland, we further estimated the area converted to rice fields, upland fields and orchard separately using statistical area data.

- ***From FY1990 to FY2004***

In the period from FY1990 to FY2004, annual conversion areas from forest land to other land-use categories were estimated dividing the total D areas occurred from FY1990 to FY2005 by the ratio of annual forest conversion areas for this period based on the Forest Agency’s record. To estimate areas of forest land converted to each land-use category, the ratios of conversions by land-use categories based on the same Forestry Agency’s records as above mentioned was used. This record only covers private forest, but the conversion from private forests to other land-use scategories accounts for 90% of the total areas of conversion from forest land. Thus, the record above is assumed as the value for total forest.

- ***From FY1971 to FY1989***

With respect to the areas before 1989, since D survey is not conducted in this period, the areas were obtained from statistics provided by the *Census of Agriculture and Forestry* and the Forestry Agency’s records, but the areas obtained from the surveys on D areas were larger than those from statistics. Hence, the total areas converted from forest land are estimated by setting an adjustment factor from the ratio between the D areas since FY1990 and the areas converted from forests provided by and the Forestry Agency's records, and multiplying the areas converted from forests since FY1970 by the adjustment factor.

- ***From FY1951 to FY1970***

The area at the time of conversion from forest land to cropland was estimated by considering a certain percentage (set from the time-series average percentage) of the newly expanded cultivation area of rice fields and upland fields obtained in the "Statistics of Cultivated Land and Planted Area" as cropland area converted from forests.

➢ ***Areas of Conversion from Land-use Categories Other than Forest land***

The areas of land converted from land-use categories other than forest land to cropland are determined by applying expansion area values provided by the *Statistics of Cultivated and Planted Area*. The converted areas from arable land are divided into upland fields, orchards, and pasture land proportionately by means of the current situation. The areas of rice fields, upland fields, and orchards are allocated to cropland, while the area of pasture land is allocated to grassland. In addition, settlements converted to cropland are reported as "IE" because the areas are included in other land remaining other land.

It should be noted that the area presented in the CRF "Table 4.B Sectoral background data for land use, land-use change and forestry－Cropland" is not the annually converted area but the sum of annually converted areas during the past 20 years.

Table 6-31 Area of land converted to cropland within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Cropland	kha	4.50	2.07	1.76	0.97	0.82	4.56	4.53	3.57	1.98	1.23	5.03	7.45	7.63	6.83	5.83
Forest land converted to Cropland	kha	3.98	0.93	0.31	0.55	0.78	0.76	0.50	0.50	0.49	0.49	0.22	0.22	0.36	0.36	1.34
Rice fields	kha	0.01	0.01	0.00	0.00	0.00	0.01	0.03	0.09	0.01	0.20	0.13	0.10	0.16	0.17	0.71
Upland fields	kha	3.83	0.89	0.30	0.43	0.61	0.60	0.38	0.33	0.38	0.23	0.07	0.10	0.16	0.16	0.51
Orchards	kha	0.15	0.02	0.01	0.12	0.16	0.16	0.10	0.09	0.10	0.06	0.02	0.02	0.04	0.04	0.12
Grassland converted to Cropland	kha	0.01	0.04	0.02	0.06	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.01
Wetlands converted to Cropland	kha	0.31	0.03	0.09	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Settlements converted to Cropland	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to Cropland	kha	0.21	1.08	1.35	0.36	0.04	3.79	4.03	3.06	1.48	0.74	4.80	7.23	7.26	6.46	4.48
Rice fields	kha	0.19	1.04	1.32	0.26	0.03	3.67	3.67	2.73	1.18	0.47	3.19	3.87	3.87	3.54	2.75
Upland fields	kha	0.02	0.04	0.03	0.08	0.01	0.10	0.28	0.26	0.24	0.21	1.29	2.70	2.73	2.36	1.40
Orchards	kha	0.00	0.00	0.00	0.02	0.00	0.03	0.07	0.07	0.06	0.05	0.32	0.66	0.66	0.56	0.33

2) Carbon Stock Change in Dead Organic Matter in "Land converted to Cropland"

● ***Estimation Method***

Carbon stock changes in dead organic matter in forest land converted to cropland were estimated by applying Tier 2 estimation method using forest-wide averages calculated using the results of the NIF survey (Forest Soil Inventory Survey) (Ugawa et al. (2012)). All carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as CO_2 within the year of conversion in accordance with the description in section 5.3.2.1 in the *2006 IPCC Guidelines*. In addition, as described in the Parameters section below, carbon stocks of dead organic matter in cropland are assumed to be zero.

$$\Delta C_{DOM} = \sum_i \{(C_{after,i} - C_{before,i}) \times \Delta A\}$$

ΔC_{DOM}	: Carbon stock changes in dead organic matter in the converted land [t-C/yr]
$C_{after,i}$	: Average carbon stock per unit area in dead wood or litter after conversion [t-C/ha] Note: carbon stocks after conversion are assumed as “0” (zero).
$C_{before,i}$	: Average carbon stock per unit area in dead wood or litter before conversion [t-C/ha]
ΔA	: Area of converted land within the year of conversion [ha/yr]
i	: type of dead organic matter (dead wood, litter)

- ***Parameters***

Average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-12 and Table 6-13. In addition, it is assumed that they become zero immediately after conversion, and will not accumulate after conversion. With regard to grassland converted to cropland, carbon stocks of dead wood and litter carbon pools were assumed to be minor and the stock changes could be ignored, and were set to zero. With regard to wetlands and settlements converted to cropland, these were also reported as “NA”, since it is assumed that carbon stock changes are from zero to zero, supposing that basically no such carbon pools exist in reclaimed wetland and that carbon stocks in dead organic matter in settlements before conversion could be negligible. Other land converted to cropland, which is estimated to be cropland restoration, was set to zero, because dead wood and litter in non-forest land are assumed as zero based on the Tier 1 method described in the *2006 IPCC Guidelines*.

- ***Activity Data***

Annually converted areas from forest land to cropland are used for estimating carbon stock changes in dead organic matter in land converted to cropland.

3) Carbon Stock Changes in Soils in “Land converted to Cropland”

- ***Estimation Method***

➢ ***carbon stock changes in mineral soils***

Carbon stock changes in mineral soils in “Land converted to Cropland” is reported under “Cropland remaining cropland” using Tier 3 modeling method as described in 6.5.1. b) 2). Therefore, carbon stock changes in mineral soils in cropland converted from other land-use categories was reported as “IE”.

➢ ***CO_2 emissions from organic soils caused by cultivation and drainage***

CO_2 emissions from organic soils were estimated in rice field and upland field converted from other land-use categories caused by cultivation (on-site) and from water soluble carbon loss from drained organic soils (off-site). For detailed information on the emission factors and activity data, see section 6.5.1. Note that no distinction is made here between land use prior to conversion, which is reported collectively in "agricultural land converted from grassland".

- ***Activity Data***

The areas of land converted to cropland including area of mineral soils and organic soils are shown in Table 6-32 below.

➢ ***Area of mineral soils***

The methodology for estimating the area of mineral soils in land converted to cropland was based on the 20-year cumulative total of the area converted in a single year used in the biomass calculation. The transition period for changes in soil carbon stocks on cropland converted from forest land is 40 years, and the area subject to such changes is also estimated. But as mentioned above, changes in carbon stocks are included in the model calculations for whole cropland reported under cropland remaining cropland.

➢ ***Area of organic soils***

The methodology for estimating the area of organic soils in land converted to cropland is as same as that in cropland remaining cropland (4.B.1.) explained in section 6.5.1. b.3).

Table 6-32 Area of land converted to cropland within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Cropland	kha	200.1	139.4	89.9	50.7	29.4	29.1	32.0	32.6	32.5	32.9	37.3	44.0	49.1	54.2	59.7
Forest land converted to Cropland	kha	107.8	96.7	75.0	37.7	15.5	12.3	12.0	11.6	11.2	11.1	10.7	10.3	10.1	10.2	11.3
Rice fields	kha	13.8	9.6	3.2	0.3	0.2	0.2	0.2	0.2	0.2	0.4	0.5	0.6	0.8	0.9	1.6
Upland fields	kha	74.7	75.4	65.6	35.8	13.8	10.6	10.1	9.7	9.2	8.8	8.4	7.9	7.5	7.4	7.7
Orchards	kha	19.2	11.7	6.2	1.6	1.4	1.6	1.6	1.7	1.8	1.8	1.8	1.8	1.8	1.9	2.0
Grassland converted to Cropland	kha	33.8	16.0	1.4	1.1	1.1	1.0	0.7	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Wetlands converted to Cropland	kha	10.9	3.0	1.6	1.1	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5
Settlements converted to Cropland	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to Cropland	kha	47.6	23.6	11.9	10.7	12.1	15.2	18.7	19.9	20.3	20.9	25.6	32.7	38.1	43.2	47.6
Rice fields	kha	24.0	13.7	10.7	9.4	10.8	13.8	17.1	18.2	18.4	18.7	21.8	25.6	27.6	29.8	32.4
Upland fields	kha	12.8	7.0	1.1	1.2	1.2	1.2	1.3	1.4	1.6	1.8	3.1	5.7	8.4	10.8	12.2
Orchards	kha	10.8	2.9	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.8	1.4	2.1	2.6	3.0

c) ***Uncertainties and Time-series Consistency***

● ***Uncertainty Assessment***

Uncertainties of the parameters and the activity data for living biomass, dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 20% for the entire emission from the land converted to cropland.

● ***Time-series Consistency***

The methods to estimate the area of forest land converted to other land-use categories are different between before FY1989 and after FY1990, however, the values before 1989 are adjusted using the ratio of the area before 1989 to the areas after 1990 as described in section 6.5.2.b)1). Thus, the time-series consistency for this subcategory is basically ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

● ***Correction in accordance with revision of the area converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation*, the area of cropland converted from forest was recalculated and carbon stock changes in living biomass, dead organic matter and CO_2 emissions from organic soils in this category were recalculated for all years. See Chapter 10 for impact on trend.

- ***Revision of carbon stocks of living biomass and dead organic matter (in forest land) before conversion***

Since the carbon stocks of living biomass and dead organic matter (in forest land) before conversion were revised losses in carbon stock were revised. This resulted in recalculations of carbon stock change for living biomass and dead organic matter in this category for all years.

f) ***Category-specific Planned Improvements***

- ***Change in the method of aggregating the amount of compost applied***

Because the statistical items used to tabulate compost application by crop, which serve as carbon input data for the soil model, have changed, a method of tabulating compost application for the new survey system is being considered.

6.6. Grassland (4.C.)

Grassland is generally covered with perennial pasture and is used mainly for harvesting fodder or grazing. In FY2021, Japan's grassland area was about 0.9 million ha, which is equivalent to about 2.4% of the national land. The area of organic soil in the grassland is about 0.053 million ha. The emissions from carbon stock changes in this category in FY2021 were 488 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 42.9% compared to FY1990 and a decrease of 12.4% compared to FY2020.

Table 6-33 Emissions and removals from grassland resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
4.C. Grassland	Total	kt-CO_2	855	65	-896	-312	131	753	1,069	1,680	1,349	1,055	813	574	694	557	488
	Living biomass	kt-CO_2	252	15	-5	60	165	55	116	119	82	82	35	30	15	13	199
	Dead wood	kt-CO_2	74	10	3	17	45	19	32	32	23	23	13	13	7	7	31
	Litter	kt-CO_2	36	5	1	8	22	10	16	16	11	11	7	7	3	3	15
	Mineral soil	kt-CO_2	465	7	-923	-426	-128	636	874	1,477	1,195	911	731	497	641	507	214
	Organic soil	kt-CO_2	27	28	29	28	27	34	31	36	38	28	28	28	28	28	28
4.C.1. Grassland remaining Grassland	Total	kt-CO_2	485	31	-897	-401	-103	666	903	1,511	1,231	937	757	524	668	533	241
	Living biomass	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dead wood	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Litter	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mineral soil	kt-CO_2	465	7	-923	-426	-128	636	874	1,477	1,195	911	731	497	641	507	214
	Organic soil	kt-CO_2	20	24	26	26	25	31	28	34	35	26	26	26	26	27	27
4.C.2. Land converted to Grassland	Total	kt-CO_2	370	35	2	89	235	87	166	169	118	118	56	51	26	24	247
	Living biomass	kt-CO_2	252	15	-5	60	165	55	116	119	82	82	35	30	15	13	199
	Dead wood	kt-CO_2	74	10	3	17	45	19	32	32	23	23	13	13	7	7	31
	Litter	kt-CO_2	36	5	1	8	22	10	16	16	11	11	7	7	3	3	15
	Mineral soil	kt-CO_2	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
	Organic soil	kt-CO_2	7.2	3.7	2.9	2.8	2.5	3.2	2.7	2.8	2.6	1.7	1.4	1.3	1.2	1.0	0.9

6.6.1. Grassland remaining Grassland (4.C.1.)

a) ***Category Description***

In this category carbon stock changes in grassland remaining grassland during the past 20 years are reported, divided into three subcategories: “pasture land”, “grazed meadow” and “wild land”.

The emissions from carbon stock changes in this category in FY2021were 241 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 50.4% compared to FY1990 value and a decrease of 54.9% compared to FY2020. Regarding the trend of emissions and removals, a peak of removals was occurred in FY1999, then the amount of removals has been on a decreasing and hit a peak of emissions in FY2014. The amount of emissions has been on a decreasing trend since then. This high variability was considered mainly caused by annual changes of amount of carbon input into soils and annual fluctuation of temperature, as it is described in the estimation of mineral soil pools in cropland. The amount of manure application had been on an increasing trend in the 1990s and has been decreasing since 2000. In addition, recently there have been no cold year; the relatively mild weather might facilitate more organic matter decomposition. Thus, it is considered that these factors are mainly contribute to the trend.

With respect to living biomass, carbon stock changes in pasture land and grazed meadow are assumed to be in a steady state and reported as “NA” in accordance with the Tier 1 estimation method in section 6.2.1.1 in the *2006 IPCC Guidelines*.

Carbon stock changes in dead organic matter in pasture land and grazed meadow are estimated as zero (0) by applying the Tier 1 method described in section 6.2.2.1 in the *2006 IPCC Guidelines*, which assumes that the carbon stocks are not changed. Thus, the carbon stock changes are reported as “NA”.

In regard to carbon stock changes in mineral soils, the carbon stock changes in pasture land were estimated by applying the Tier 3 method using Roth C model same as cropland remaining cropland. Grazed meadows were non-degraded and sustainably managed grassland, but without significant management improvements. Therefore, the default value of the carbon stock change factor for “Nominally managed (non-degraded)” in table 6.2 of the *2006 IPCC Guidelines*, which was “1.0”, was applied to grazed meadows. In this case, soil carbon stocks were not changed over time; therefore, the soil carbon stock changes in grazed meadows were reported as “NA”. On-site CO_2 emissions resulting from cultivation and drainage of organic soils and off-site CO_2 emissions via waterborne carbon losses from drained inland organic soils in pasture land were estimated by applying Tier 1 method.

CO_2 emission from organic soils in grazed meadow was reported as “NO” because the cultivation and drainage resulting from renewal of grazed meadow are not implemented.

Carbon stock changes in all carbon pools in wild land are reported as “NA” because anthropogenic management is not implemented to the wild land in general.

Table 6-34 Areas of grassland remaining grassland within the past 20 years

Category		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Grassland remaining Grassland		kha	679.2	826.0	923.0	966.9	963.8	926.4	924.2	930.8	929.1	915.5	922.6	918.8	916.3	873.3	870.2
	Pasture land	kha	294.3	465.1	556.2	590.4	587.4	586.4	584.2	580.8	579.1	575.5	572.6	568.8	566.3	563.3	560.2
	Grazed meadow	kha	105.0	100.9	96.8	96.5	96.4	96.4	96.3	96.3	96.3	96.3	96.3	96.2	96.2	96.2	96.2
	Wild land	kha	280.0	260.0	270.0	280.0	280.0	243.6	243.7	253.7	253.7	243.7	253.7	253.8	253.8	213.8	213.8

b) ***Methodological Issues***

1) Carbon Stock Changes in Soils in "Grassland remaining Grassland"

- ***Estimation Method***

➢ ***Estimation of Carbon stock changes in mineral soils***

Carbon stock change in mineral soils in pasture land was estimated by using the Tier 3 modeling method same as 6.5.1. b)2) cropland remaining cropland (4.B.1.).

➢ ***Estimation of on-site CO_2 emissions resulting from cultivation in organic soils***

With respect to CO_2 emissions from organic soils in pasture land were estimated by applying the Tier 1 estimation method described in section 6.2.3.1 in the *2006 IPCC Guidelines*. The estimation method is the same as cropland remaining cropland (4.B.1.).

➢ ***Estimation of off-site CO_2 emissions via waterborne carbon losses from drained inland organic soils***

Off-site CO_2 emissions via waterborne carbon losses from drained inland organic soils were estimated by applying Tier 1 estimation method described in section 2.2.1.2 in the *Wetlands Guidelines.* The estimation method is the same as cropland remaining cropland (4.B.1.).

- ***Parameters***

➢ ***Assumption for the Roth C model and parameters for estimating mineral soils***

The parameters used are omitted because they are the same as cropland remaining cropland (4.B.1.).

➢ ***Parameters for estimation of CO_2 emissions from organic soils***

Because there is little research data on CO_2 emission factor that is suitable for grassland in Japan, the default value provided in *the Wetlands Guidelines* (Table 2.1, 6.1 t-C/ha/year) which is considered to be most appropriate for the emission factor under the distribution of pasture land and current management system in Japan, was applied. As for off-site CO_2 emissions, the same parameters as cropland remaining cropland (4.B.1.) were used.

- ***Activity Data***

➢ ***Area of mineral soils***

The area of mineral soils applied for Roth C model is calculated by subtracting area of organic soils in pasture land from total area of pasture land reported in the *Statistics of Cultivated and Planted Area*.

➢ ***Area of organic soils***

Areas of organic soils in pasture land remaining pasture land and in pasture land converted from other land-use were obtained by applying the method same as section 6.5.1. b)3). The activity data (the actual area for conducting cultivation and drainage) was calculated by multiplying renewal ratio of pasture land by the area of organic soils in pasture land. For the renewal ratio of pasture land, the values (Hokkaido and other than Hokkaido) published in the report of "Survey on actual situation of grassland management for feed" (Hatano, 2017) which investigated the management status of pastures were applied (see section 5.5.1.6. in Chapter 5). Moreover, about renewal ratio of pasture land before FY2005, the average value between FY2006 and FY2010 was applied because the survey has not been implemented. Also, since there are no survey values for FY2016 and for FY2017, the average values from FY2006 to FY2010 were used as well. The area of organic soil in grazed meadow and in wild land in FY2009 were calculated by multiplying the area of grazed meadow (*Census of agriculture and Forestry*) and wild land (*Land Use Status Survey*) in FY2009, by ratio of organic soil area obtained from GIS (Geographic information system) data analysis results in FY2009. The area of organic soil before FY2009 and after FY2009 were calculated by adding organic soil area in grazed meadow and wild land converted other land-use to FY2009, and by subtracting organic soil area in land converted from grazed meadow and wild land from FY2009.

In addition, as described in section 6.5.1. , since the area of organic soil reported in the Agriculture sector does not include areas of organic soil in grazed meadow and in wild land, the area of organic soil reported in LULUCF sector is different to the value reported in the Agriculture sector.

Table 6-35 Area of organic soils in grassland remaining grassland within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Grassland remaining Grassland	kha	46.4	51.0	53.7	54.1	53.7	52.0	52.3	53.0	53.3	53.1	53.8	54.0	54.1	52.4	52.6
Pasture land	kha	28.7	34.2	36.5	36.4	36.0	36.0	36.3	36.6	36.9	37.1	37.4	37.6	37.7	37.9	38.0
Grazed meadow	kha	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Wild land	kha	13.2	12.2	12.7	13.2	13.2	11.4	11.4	11.9	11.9	11.4	11.9	11.9	11.9	10.0	10.0

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

Uncertainties of carbon stock change in mineral soil are the same as cropland remaining cropland (4.B.1); therefore, the description is omitted. Uncertainties of existing statistical data and the default values described in the *Wetlands Guidelines* were applied to estimate CO_2 emissions from organic soil. As a result, the uncertainty was estimated as 9% of the total emissions grassland remaining grassland.

- ***Time-series Consistency***

Time-series consistency for this category is ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

- ***Correction in accordance with revision of the area converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation*, the area of grassland converted from forest was recalculated, areas of grassland remaining grassland were recalculated for all years. With this recalculation, carbon stock change in mineral soils and CO_2 emissions from organic soils were recalculated for all years. See Chapter 10 for impact on trend.

f) ***Category-specific Planned Improvements***

No improvements are planned.

6.6.2. Land converted to Grassland (4.C.2.)

a) ***Category Description***

This subcategory deals with the carbon stock changes, which occurred in the lands that were converted from other land-use categories to grassland within the past 20 years. The emissions from carbon stock changes in this category in FY2021 were 247.2 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 33.1% compared to FY1990 and an increase of 942.1% compared to FY2020. With respect to living biomass, its carbon stock changes as a result of land-use conversion from other land use to grassland are estimated. The carbon stock changes include both temporary loss of living biomass in the land before and subsequent gain after conversion.

With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to grassland. Carbon stock changes in grassland converted from land-uses other than forest land were reported as “NA” or “NO” because suitable knowledge for estimating carbon stocks for the land-use categories was not available, or because it was assumed that no carbon stock change occurred, respectively.

Carbon stock changes in soils as a result of land-use conversion from other land use to grassland were estimated. With respect to carbon stock changes in mineral soils, the carbon stock changes in grassland converted from forest land, cropland, wetlands and other land were estimated together for the whole grassland, and reported in grassland remaining grassland (“IE” in land converted to grassland). CO_2 emissions from organic soils in pasture land converted from cropland were estimated. CO_2 emissions in forest land converted to grassland were reported as “NO” because conversion of organic soil area from forest land to grassland was not implemented in general in Japan. CO_2 emissions from organic soils in grassland converted from wetlands and Other land were reported as “IE” because the emissions were included in those in grassland remaining grassland.

Carbon stock changes in each carbon pool in settlements converted to grassland are reported as “NO” because the land conversion from settlements to grassland is not implemented in general in Japan.

b) ***Methodological Issues***

1) Carbon stock changes in Living biomass in “Land converted to Grassland”

- ***Estimation Method***

The Tier 2 method using Equation 2.16 from the *2006 IPCC Guidelines* (Vol. 4, Section 2.3.1.2), as well as cropland converted from other land uses, was applied to estimate forest land and cropland (rice fields) converted to grassland (pasture lands) using country specific amount of biomass accumulation. The Tier 1 method was used for land uses other than forest land and cropland (rice fields) using default value. The equations are given in section 6.5.2. b)1). While the annually converted areas were used for estimating the loss of living biomass upon land-use conversion, the biomass growth after land-use conversion was estimated by summing the converted areas for the latest five years, assuming that it takes five years after conversion to reach a steady state with a constant growing rate.

- ***Parameters***

➢ ***Biomass stock in each Land-Use Category***

The values shown in Table 6-9 Table 6-10, and Table 6-11 are used for the estimation of biomass stock changes upon land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

➢ ***Carbon Fraction of Dry Matter***

Average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied as the carbon fraction of dry matter of forest. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines.*

- ***Activity Data (Area)***

For the estimation of carbon stock change in living biomass in grassland converted from other land-use categories, the annually converted areas were used for estimating the loss (Table 6-36) and the areas of summing the converted areas for the latest five years are used for estimating the biomass growth after land-use conversion (Table 6-37).

➢ ***Area Converted from Forestland***

As described in 6.5.2. b)1), the methodology of "Areas of forest land converted to other land-use categories" is applied.

➢ ***Area Converted from other than Forestland***

As shown in Table 6-2, grassland is treated as a part of arable land in statistics of Japan. Therefore, the procedure to obtain the area of the grassland converted from other land-use categories is as described in 6.5.2. b)1). Areas of settlements converted to grassland are reported as "NO" because land conversion from settlements to grassland does not occur.

It should be noted that the area presented in the CRF Table 4.C is not the annually converted area in FY2021 but the sum of annually converted areas during the past 20 years.

Table 6-36 Area of land converted to grassland within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Grassland	kha	3.3	0.8	0.7	2.2	1.9	0.9	1.3	1.3	1.1	1.3	1.6	2.2	2.0	2.0	2.2
Forest land converted to Grassland	kha	2.0	0.3	0.1	0.5	1.2	0.5	0.9	0.9	0.6	0.6	0.4	0.4	0.2	0.2	0.9
Cropland converted to Grassland	kha	1.1	0.5	0.6	1.7	0.7	0.4	0.3	0.3	0.4	0.5	0.5	0.4	0.4	0.5	0.6
Wetlands converted to Grassland	kha	0.2	0.0	0.0	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Settlements converted to Grassland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other land converted to Grassland	kha	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.7	1.4	1.4	1.2	0.7

Table 6-37 Area of land converted to grassland within the past 5 years

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Grassland	kha	21.1	7.7	4.6	6.8	10.3	8.2	7.2	6.6	5.8	6.0	6.6	7.4	8.1	9.0	9.9
Forest land converted to Grassland	kha	12.6	3.5	0.9	0.7	5.4	4.7	4.4	4.0	3.4	3.5	3.3	2.8	2.1	1.7	1.9
Cropland converted to Grassland	kha	8.1	3.9	3.6	5.8	4.6	3.2	2.6	2.2	1.9	1.9	2.0	2.1	2.2	2.4	2.4
Wetlands converted to Grassland	kha	0.4	0.1	0.0	NO	0.2	0.2	NO	NO	NO	NO	NO	NO	NO	NO	NO
Settlements converted to Grassland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other land converted to Grassland	kha	0.1	0.2	0.0	0.3	0.1	0.1	0.2	0.3	0.5	0.6	1.2	2.5	3.8	4.9	5.5

2) Carbon Stock Change in Dead Organic Matter in "Land converted to Grassland"

- ***Estimation Method***

In this category, carbon stock changes in dead organic matter in forest land converted to grassland were estimated. The Tier 2 estimation method was applied to the subcategory using country specific values of the carbon stocks before and after conversion. It should be noted that the carbon stocks of dead organic matter after conversion to grassland are assumed as zero (Tier 1 method in the *2006 IPCC Guidelines,* Vol.4, section 6.3.2), because there are no quantitative data of them, although a subtle but certain amount of carbon stocks does generally exist on the soil surface. As described in section 6.5.2.b)2), cropland converted to grassland were reported as "NA" since the carbon stocks before and after conversion were assumed as zero. As for wetlands and other land converted to grassland, they include only reclamation and restoration. Thus, they were reported as "NA"[6], for the same reasons as described in section 6.5.2. b)2).

- ***Parameters***

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-12 and Table 6-13. The average carbon stocks in these categories from FY1990 to FY2004 are not estimated; therefore those in FY2005 are substituted for them. In addition, it is assumed that they become zero immediately after conversion, and are not accumulated after conversion. All carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as CO_2 within the year of conversion in accordance with the description in section 6.3.2.2 in the *2006 IPCC Guidelines*.

- ***Activity Data (Area)***

The sum of annually converted areas from other land-use categories to grassland for the past 20 years was regarded as the area of land converted to grassland during the past 20 years. The areas are shown in Table 6-38.

Table 6-38 Areas of land converted to grassland within the past 20 years

Category		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Grassland		kha	352.3	195.6	88.5	40.2	29.3	26.9	26.9	27.0	27.4	27.9	28.4	29.8	30.5	31.8	33.2
	Forest land converted to Grassland	kha	204.8	130.6	59.8	17.6	10.4	9.1	9.6	10.0	10.3	10.7	10.9	11.1	11.1	11.2	12.0
	Cropland converted to Grassland	kha	74.0	42.4	26.9	21.5	18.0	16.9	16.5	16.1	16.0	16.0	15.7	15.4	14.8	14.8	14.6
	Wetlands converted to Grassland	kha	1.9	1.7	1.1	0.5	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Settlements converted to Grassland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Other land converted to Grassland	kha	71.7	20.8	0.7	0.6	0.6	0.6	0.7	0.7	0.8	0.9	1.6	3.0	4.4	5.7	6.4

3) Carbon Stock Change in Soils in "Land converted to Grassland"

- ***Estimation Method***

Carbon stock changes in mineral soils in pasture land was estimated by applying the Tier 3 estimation method same as the one for Cropland remaining Cropland (4.B.1.) in section 6.5.1. b)2). For the estimation, land which was once pasture land since 1970's was regarded as pastures land and used for calculation; the result of the calculation includes all grassland, regardless of land conversion. Therefore, carbon stock pools in mineral soil was reported regardless of whether or not land conversion has been occurred and carbon stock changes in mineral soils in pasture land converted from other land use was reported as "IE" since it

[6] Cropland in the Japanese statistics includes pasture land which falls into grassland.

was included in carbon stock changes in mineral soils in pasture land remaining pasture land. CO_2 emissions (on-site and off-site) from organic soils were estimated in pastures land converted from other land use using the same method as in cropland converted from other land use. For detailed information on the emission factors and activity data, see section 6.5.1. b)2).

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 22% for the entire removal from the land converted to grassland.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.5.1. b)1), time-series consistency for this subcategory is basically ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

- ***Correction in accordance with revision of the area converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation*, the area of grassland converted from forest was recalculated, carbon stock changes in living biomass, dead organic matter and CO_2 emissions from organic soils in this category were recalculated for all years.

- ***Revision of carbon stocks of living biomass and dead organic matter (in forest land) before conversion***

Since the carbon stocks of living biomass and dead organic matter (in forest land) before conversion were revised losses in carbon stock were revised. This resulted in recalculations of carbon stock change for living biomass and dead organic matter in this category for all years.

- ***Recalculation of mineral soil area and organic soil area due to revisions***

The area converted from other lands in each district has been revised due to the revision of the method of estimating the area converted to cropland from 1983 to 2002.

See Chapter 10 for impact on trend.

f) ***Category-specific Planned Improvements***

- ***Method of Obtaining Data of the "Areas of Cropland converted from Other Land-use Categories to Grassland"***

The method used to obtain data on the area converted to grassland needs to be improved. For example, currently, the area of lands converted from forest land to grassland is estimated by multiplying the summed areas of forest land converted to cropland and grassland by the ratio of grazing land to the summed area. However, this estimation method may not represent the actual status of these areas. Therefore, the validity of the estimation method needs to be reviewed, and, if necessary, a new method of obtaining the area data should be developed.

- ***Method of Obtaining Data of the "Area of Cropland converted to Grassland"***

The area of Cropland converted to Grassland cannot be obtained from statistics except for the land-use conversion from cropland (rice field) to grassland (pasture land). For this reason, the estimates of the carbon stock changes in this land-use category may not fully reflect the actual conditions. Therefore, the methods used to detect the following area data need to be developed.

- from upland field / orchard to pasture land
- from rice field / upland field / orchard to grazed meadow

- ***Estimation Method of Soil Carbon Stock Change upon "Land-Use Conversion from Other Land to Cropland"***

The estimation method will be revised when new data and information are obtained.

6.7. Wetlands (4.D.)

Wetlands are lands that are covered with or soaked in water throughout the year. They do not fall into the categories of forest land, cropland, grassland, or settlements. The *2006 IPCC Guidelines* divides wetlands into three large groups: peat land for peat extraction, flooded land, and other wetlands.

In FY2021, Japan's wetland area was about 1.35 million ha, which is equivalent to about 3.6% of the national land. The emissions from this category in FY2021 were 35 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 48.4% compared to FY1990 and an increase of 49.4% compared to FY2020.

Table 6-39 Emissions and removals in wetlands resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
4.D. Wetlands	Total	kt-CO_2	68.5	276.8	329.1	33.8	94.0	50.6	18.2	18.3	62.8	62.4	24.4	23.9	23.6	23.7	35.4
	Living biomass	kt-CO_2	52.7	210.3	249.9	26.6	72.2	39.4	14.8	15.0	48.8	48.4	19.6	19.2	21.0	21.1	30.9
	Dead wood	kt-CO_2	11.4	45.5	54.1	5.8	15.6	8.5	3.2	3.2	10.4	10.4	4.2	4.2	2.7	2.7	4.0
	Litter	kt-CO_2	5.6	22.3	26.5	2.9	7.7	4.2	1.6	1.6	5.1	5.1	2.1	2.1	1.4	1.4	2.0
	Mineral soil	kt-CO_2	-1.2	-1.3	-1.4	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.6
	Organic soil	kt-CO_2	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO
4.D.1. Wetlands remaining Wetlands	Total	kt-CO_2	-1.8	-2.0	-2.1	-2.3	-1.7	-1.8	-2.3	-2.2	-1.5	-1.8	-1.8	-2.3	-2.2	-2.3	-2.3
	Living biomass	kt-CO_2	-0.5	-0.6	-0.6	-0.7	-0.2	-0.2	-0.7	-0.5	-0.003	-0.3	-0.3	-0.7	-0.6	-0.6	-0.6
	Dead wood	kt-CO_2	-0.08	-0.09	-0.10	-0.12	-0.03	-0.04	-0.11	-0.09	-0.0005	-0.05	-0.04	-0.11	-0.10	-0.10	-0.10
	Litter	kt-CO_2	-0.01	-0.01	-0.01	-0.01	-0.002	-0.003	-0.01	-0.01	-0.00003	-0.003	-0.003	-0.01	-0.01	-0.01	-0.01
	Mineral soil	kt-CO_2	-1.2	-1.3	-1.4	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	-1.6
	Organic soil	kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
4.D.2. Land converted to Wetlands	Total	kt-CO_2	70.3	278.7	331.3	36.1	95.7	52.4	20.4	20.5	64.3	64.3	26.2	26.2	25.8	25.9	37.6
	Living biomass	kt-CO_2	53.2	210.8	250.6	27.3	72.4	39.7	15.5	15.5	48.8	48.7	19.9	19.8	21.6	21.7	31.5
	Dead wood	kt-CO_2	11.5	45.6	54.2	5.9	15.6	8.5	3.3	3.3	10.4	10.4	4.3	4.3	2.8	2.8	4.1
	Litter	kt-CO_2	5.6	22.3	26.5	2.9	7.7	4.2	1.6	1.6	5.1	5.1	2.1	2.1	1.4	1.4	2.0
	Mineral soil	kt-CO_2	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
	Organic soil	kt-CO_2	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO

6.7.1. Wetlands remaining Wetlands (4.D.1.)

a) ***Category Description***

This subcategory deals with carbon stock changes in wetlands which have remained as wetlands during the past 20 years.

For carbon stock change in organic soils managed for peat extraction in peat land, as a result of the domestic survey, it is found out that although small amount of peat extraction is carried out in Japan, estimating emissions with high accuracy is difficult. Therefore, based on the amount of emissions expected, carbon stock changes in organic soils that are managed for peat extraction are reported as "NE" in line with the insignificant threshold provided by the *UNFCCC reporting Guidelines.* "Flooded land remaining flooded land" is not calculated at the present time as this is treated in an appendix in the *2006 IPCC Guidelines* and reported as "NE". There are less than 900ha of mangrove forest on Okinawa prefecture and Kagoshima prefecture, and a part of these are not included in the forest under forest planning for 4.A. Forest Land in Japan. The carbon stock changes for mangrove forests in coastal wetlands that are not included in the forest under forest planning are covered under "Other wetlands remaining other wetlands". Since the area of mangrove forest is not part of the total land area in Japan by definition, it is not included in the area for this category.

Table 6-40 Areas of wetlands remaining wetlands within the past 20 years

Category		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Wetlands remaining Wetlands		kha	1,281.5	1,295.3	1,323.0	1,318.5	1,310.0	1,320.9	1,321.5	1,321.9	1,323.3	1,315.9	1,336.3	1,338.5	1,340.6	1,342.5	1,344.2
	Organic soils managed for peat extraction	kha	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Flooded land	kha	1,281.5	1,295.3	1,323.0	1,318.5	1,310.0	1,320.9	1,321.5	1,321.9	1,323.3	1,315.9	1,336.3	1,338.5	1,340.6	1,342.5	1,344.2
	other wetlands	kha	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

b) ***Methodological Issues***

1) Emission from peats extraction

For adaptation of standard for small emission, the following estimation was implemented. A result of domestic survey, peats are extracted in Japan, but accurate emissions are not able to estimate. A rough calculation of emission from peat extraction was made both at "on-site" and "off-site" with the Tier1 methodology in Chapter 7 of the *2006 IPCC guidelines*. The peat extraction is carried out mainly in Hokkaido area, where is located in the northernmost part of Japan. So that we applied climatic zone as "Boreal and Temperate" and its soil condition as "Nutrient-Poor" under expert judgment in our preliminary calculation. To calculate on-site CO_2 emissions, we use the value, about "150 ha" for peat extraction area that from private company of peat extraction. And we also use the default values of EF, 0.2 t-C/ha (Boreal and Temperate, Nutrient- Poor on Table 7.4, Chp.7, Vol.4, 2006 *IPCC Guidelines*), and the result of this calculation is approximately 0.1 kt-CO_2. To calculate off-site CO_2 emissions, we use the value from National production data, which is available since 2003, ranged from 17 to 34 kt-d.m.. And we also use the default value of carbon fractions, 0.45 t-C/t-d.m. (Boreal and Temperate, Nutrient- Poor on Table 7.5, Chp.7, Vol.4, 2006 *IPCC Guidelines*). So the result of this calculation is ranged from 30 to 50 kt-CO_2. Furthermore, N_2O emissions from peat extraction are not included in these calculations, as the estimation is necessary only for "Nutrient –Rich" area in Tier 1 method. As a result of these calculations, we regarded that the emissions from peat extraction as "NE" in insignificant level of emissions. This value is below from threshold suggested by paragraph 37b) of Annex 1 in Decision 24/CP19 and country specific standard of 90 kt-CO_2 (this value is 0.1 % of the removals from LULUCF section in 2005). Please refer to annex 5 of NIR, for more information about our criteria for "NE".

2) Carbon Stock Changes in Living Biomass in "Mangrove Forest"

- ***Estimation Method***

Carbon stock change in living biomass in mangrove forest was estimated by using the gain-loss method of Tier 1. As stocked volume and volume of harvest in mangrove forest were not available, it assumed that carbon stock in land remaining mangrove forest has been stable, and the default value of the *Wetlands Guidelines* were used to set the average living biomass stocks of mangrove forests. Based on this, Carbon stock gains in living biomass associated with mangrove area increasing, and carbon losses of living biomass associated with area decreasing were estimated. The change of mangrove habitat area was estimated by each community level.

- ***Parameters***

➢ ***Average living biomass stock and biomass growth***

For amount of above ground living biomass stock, above and below ground living biomass ratio (R), and carbon fraction factor (CF), the default values in the *Wetlands Guidelines* were used (Table 6-41). For annual above ground biomass growth, which is used for newly increased mangrove area, it is assumed that living biomass stock has increased linearly to reach the average steady state in 20 years, which is the general transition period of land use change in IPCC Guidelines, because the growing period will be calculated as 4 years from default carbon stocks and annual increment mentioned in *Wetlands Guidelines,* and this was clearly too short to reach steady state. .

Table 6-41 Parameters of living biomass in mangrove forest

Parameter	Value	Reference
Amount of above ground living biomass stock	75 t-d.m./ha	Table 4.3, subtropical, *Wetlands Guidelines*
Above ground biomass growth	3.75 t-d.m./ha/yr	It is assumed that above ground living biomass grow to achieve 75 t-d.m./ha in 20 years.
Above and below ground living biomass ratio (R)	0.96	Table 4.5, subtropical, *Wetlands Guidelines*
Carbon fraction factor (CF)	0.451 t-C/t-d.m.	Table 4.2, *Wetlands Guidelines*

- ***Activity Data***

The area of mangrove increase over the past 20 years was used to calculate the biomass increase, and the area of mangrove decrease in the relevant year was used to calculate the biomass loss. These areas were obtained by summing each mangrove community level of gross increase or decrease in habitat area.

A change in area of mangrove forest was calculated by combining data from various domestic surveys including the data sources shown in Table 6-42 The areas in community level were linearly interpolated between years of data available.

Table 6-42 Area in mangrove forest

Fiscal year	Reference
1961 and 2007	*Transition of mangrove*, Okinawa Prefecture
1973	*Research about Mangrove I. Mangrove Distribution in Japan,* Nakasuga, et al., Japanese Journal of Ecology, 24(4)
1977, 1993-1995 and 2001	*Investigation of Mangrove Distribution in Okinawa for Coastal Ecosystem and Monitor the Sea Level Rise*, International Society for Mangrove Ecosystems, 2003
2019	*Explore the Mangrove in Kagoshima and Okinawa*, ManGlobal

3) Carbon Stock Changes in Dead Organic Matter in "Mangrove Forest"

- ***Estimation Method***

Generally, it is considered that dead organic matter in mangrove forest has not been saturant and has accumulated, but accumulation ratio is not available in observations in mangrove forest at present. Therefore, it was assumed that amount of dead organic matter is stable in land remaining mangrove forest, and the averaged amount of dead organic matter in mangrove forest was estimated. Based on this, carbon stock gains of increasing dead organic matter associate with mangrove area increasing was estimated with an assumption that that dead organic matter has linearly increased and to reach steady state in 20 years, which is the same period with living biomass. Also, carbon losses of dead organic matter associate with area decreasing were estimated by assuming that all amount of dead organic matter in mangrove that was lost in the year of area decreased.

- ***Parameters***

The default values of carbon stocks in mangrove for dead wood (10.7 t-C/ha) and litter (0.7t-C/ha) on Table 4.7 in the *Wetlands Guidelines* were used.

- ***Activity Data***

A change in area of mangrove forest was used the data same with 2) Carbon Stock Changes in Living Biomass in "Mangrove Forest".

4) Carbon Stock Changes in Soil in "Mangrove Forest"

- ***Estimation Method***

The Wetlands Guidelines provides default value as removal factor of soils for revegetation and creation of mangroves and also explains that this carbon accumulation of soils will continue until stocks are equivalent to soil carbon stocks in natural/undrained settings with mangrove vegetation. In mangrove forest, carbon input to soil is normally much larger than output. Therefore, we assumed that default removals factor of soils were applicable not only increased area since the year of data available (i.e around 1960), but for all area of mangrove. Thus, all area of mangrove were multiplied by removal factor as carbon stock in soil are increasing regularly.

Since mangrove forest is preserved in law in Japan, land use changes (converted to settlements and cropland) have not occur since 1990. But some mangrove area may decrease due to cutting mangrove trees which is overgrowth by direct or indirect human induced reasons or caused environmental disadvantage, and subject to natural disturbances. Soil carbon losses were estimated only the cases that mangrove area decreasing was accompanied with extraction of soils. The amount of soil carbon lost was estimated by those had accumulated since planted of the relevant community. Soil carbon losses were not estimated for other cases of area decreasing caused by such as logging of the living biomass only, sedimentation due to environmental change, and fallen trees and vegetation removal by natural disturbance and so on.

- ***Parameters***

Since Japan located in north part of mangrove habitat, cooler region compared with other mangrove habitat in the World, we consider removal factor is smaller. Removal factor was used the default value of 1.3 t-C/ha/yr (Minimum) on Table 4.12 in *Wetlands Guidelines*.

Loss of carbon stocks in soils were used that amount of carbon stocks in soils estimated the removal factor multiplied by years from planted mangrove trees until dredging by the area of dredging which is conducted since 1990.

- ***Activity Data***

The total area of mangrove forest was used, which is same with the area used for estimating 2) Carbon Stock Changes in Living Biomass in "Mangrove Forest".

Area of dredging were estimated from the area of Ishikawa River from Masuno, et al. 2012 and Hiyagon from Okinawa General Bureau, Cabinet Office.

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

Uncertainties of the parameters for living biomass, dead organic matter, and soil were individually assessed on the basis of the default values described in the W*etlands Guidelines* and uncertainties of the activity data were 10% for the general total inspection. The uncertainty was estimated as -64% to +38% of the total emissions from the wetlands remaining wetlands for year which emissions are calculated.

- ***Time-series Consistency***

Although some different statistics were used to estimate the area of mangrove forest, data continuity was checked and time-series consistency for this subcategory is basically ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

Carbon stock change for mangrove forest were estimated. Accordingly, carbon stock changes in this category were recalculated for all years. See Chapter 10 for impact on trend.

f) ***Category-specific Planned Improvements***

No improvements are planned.

6.7.2. Land converted to Wetlands (4.D.2.)

g) ***Category Description***

This subcategory deals with the carbon stock changes which occurred in the land that was converted from other land-use categories to wetlands, particularly to flooded land (i.e., dams) within the past 20 years. The emissions from this subcategory in FY2021 were 38 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.), this represents a decrease of 46.4% compared to FY1990 and an increase of 45.1% compared to FY2020.

With respect to living biomass, its carbon stock change (losses of living biomass in the land before conversion) as a result of land-use conversion from other land use to wetlands is estimated.

With respect to dead organic matter, and then estimated the carbon stock change in wetlands converted from forest land. Carbon stock changes in other subcategories were reported as "NA", supposing that no carbon stock change occur.

Carbon stock changes in soils in forest land converted to wetlands were reported as "NA". This was because after the areas came to be reservoirs (dams), and their soils were supposed to become anaerobic condition; hence CO_2 emissions resulting from organic matter decomposition seemed to be extremely little. Since methodology is not provided by the *2006 IPCC Guidelines* and due to lack of data, carbon stock changes in soils in wetlands (flooded land) converted from land use other than forest land were not estimated. Therefore, the carbon stock changes in soils were reported as "NE".

h) ***Methodological Issues***

1) Carbon stock change in Living biomass in "Land converted to Wetlands"

- ***Estimation Method***

The Tier 2 method was applied for estimating carbon stock changes in the land converted to wetlands (flooded land), as the same as land converted to cropland, which is estimated by country-specific amount of biomass stock with the equation 2.16 in section 2.3.1.2 in Vol.4 of the *2006 IPCC Guidelines*. The equations are given in section 6.5.2.b)1).

- ***Parameters***

➢ ***Biomass stock in each Land-Use Category***

The values shown in Table 6-9, Table 6-10 and Table 6-11 are used for the estimation of biomass stock changes resulting from land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

➢ ***Carbon Fraction of Dry Matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines*.

- ***Activity Data (Area)***

➢ ***Areas of land converted to wetlands (dam)***

Areas of land converted to wetlands (dam) were estimated based on the area of dam converted from forest land and the ratio of forest land among the area of land-use categories before conversion. The area of forest land converted to wetlands was calculated by the method described in section 6.5.2.b)1). With respect to areas of each land-use type before conversion to dam, percentages of each land area converted to dams from agricultural land (cropland and grassland), settlements and Other land were estimated based on the numbers of dwellings and agricultural land which were submerged into some large-scale dams. Breakdown of wetland areas converted from agricultural land into from cropland and grassland was determined based on the ratio of current area the same manner of other land-use categories. The differences between the areas of wetlands converted from forest land, cropland, grassland, and settlements and the total dam conversion area were regarded as other land converted to wetlands.

It should be noted that the area presented in the CRF "Table 4.D Sectoral background data for land use, land-use change and forestry－Wetlands" is not the annually converted area in FY2021 but the sum of annually converted areas during the past 20 years.

Table 6-43 Area of land annually converted to wetlands within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Wetlands	kha	0.43	1.72	2.04	0.22	0.59	0.32	0.13	0.13	0.39	0.39	0.16	0.16	0.11	0.11	0.15
Forest land converted to Wetlands	kha	0.31	1.24	1.48	0.16	0.43	0.23	0.09	0.09	0.28	0.28	0.12	0.12	0.08	0.08	0.11
Cropland converted to Wetlands	kha	0.029	0.106	0.135	0.014	0.035	0.018	0.007	0.007	0.024	0.025	NO	0.010	0.006	0.006	0.009
Rice field	kha	0.007	0.023	0.068	0.008	0.016	0.004	0.002	0.003	0.013	0.017	NO	0.005	0.003	0.003	0.005
Upland field	kha	0.012	0.054	0.029	0.004	0.015	0.011	0.004	0.003	0.009	0.006	NO	0.004	0.003	0.003	0.004
Orchard	kha	0.010	0.029	0.038	0.001	0.004	0.003	0.001	0.001	0.002	0.002	NO	0.001	0.001	0.001	0.001
Wetlands converted to Wetlands	kha	0.002	0.019	0.014	0.002	0.008	0.006	0.002	0.002	0.005	0.003	NO	0.002	0.001	0.001	0.002
Settlements converted to Wetlands	kha	0.0015	0.0061	0.0072	0.0008	0.0021	0.0011	0.0004	0.0004	0.0014	0.0014	0.0006	0.0006	0.0004	0.0004	0.0005
Other land converted to Wetlands	kha	0.09	0.34	0.41	0.04	0.12	0.06	0.03	0.03	0.08	0.08	0.04	0.03	0.02	0.02	0.03

2) Carbon Stock Change in Dead Organic Matter in "Land converted to Wetlands"

Carbon stock changes in dead organic matter and litter in forest land converted to wetlands were estimated in this category.

- ***Estimation Method***

The Tier 2 method was applied as described in section 6.5.2. b)2).

- ***Parameters***

➢ ***Carbon Stocks in Dead Organic Matter***

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-12 and Table 6-13. It is assumed that they become zero immediately after conversion, and are not accumulated after conversion.

- ***Activity Data (Area)***

➢ ***Area of forest land converted to wetlands***

The area of land that was converted to wetlands during the past 1 year was used. The areas are shown in Table 6-43.

Table 6-44 Area of land converted to wetlands within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Wetlands	kha	28.5	24.7	27.0	21.5	20.0	19.1	18.5	18.1	16.7	14.1	13.7	11.5	9.4	7.5	5.8
Forest land converted to Wetlands	kha	20.6	17.9	19.6	15.6	14.5	13.8	13.4	13.1	12.1	10.2	9.9	8.3	6.8	5.4	4.2
Cropland converted to Wetlands	kha	1.8	1.5	1.7	1.4	1.3	1.2	1.2	1.1	1.1	0.9	0.9	0.7	0.6	0.4	0.3
Rice field	kha	0.7	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.2	0.2
Upland field	kha	0.7	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.1
Orchard	kha	0.5	0.4	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.0
Grassland converted to Wetlands	kha	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Settlements converted to Wetlands	kha	0.10	0.09	0.10	0.08	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.04	0.03	0.03	0.02
Other land converted to Wetlands	kha	5.7	4.9	5.4	4.3	4.0	3.8	3.7	3.6	3.3	2.8	2.7	2.3	1.9	1.5	1.2

i) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 23% of the total emissions from the land converted to wetlands for year which emissions are calculated.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.5.2. b)1), time-series consistency for this subcategory is basically ensured.

j) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

k) ***Category-specific Recalculations***

- ***Correction in accordance with revision of area of land converted from forest***

Since the revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation* , which is used for estimating each land are converted from forest, the areas of wetlands converted from forest land were recalculated, carbon stock changes in living biomass and dead organic matter after FY2005 in this category were recalculated.

- ***Revision of carbon stocks of living biomass and dead organic matter (in forest land) before conversion***

Since the carbon stocks of living biomass and dead organic matter (in forest land) before conversion were revised losses in carbon stock were revised. This resulted in recalculations of carbon stock change for living biomass and dead organic matter in this category for all years.

See Chapter 10 for impact on trend.

l) ***Category-specific Planned Improvements***

- ***Validity of the Assumption used in the Method of Estimating the Area of Wetlands***

Under the present estimation method, wetlands are assumed to consist of "water surfaces", "rivers" and "canals", as defined in the national land-use classification, and the whole area is estimated by summing the areas covered by these three land types. However, this estimation method may fail to cover the entire wetland area. The validity of the assumption used in the estimation method is now under revision.

- ***Estimation Method of the Storage Reservoirs***

Preparatory work to apply the estimation method for GHG emissions from storage reservoirs in the *2019 Refinement* had started.

6.8. Settlements (4.E.)

Settlements are defined as all developed land, including transportation infrastructure and human habitats, but preclude forest land (4.A.), cropland (4.B.), grassland (4.C.), and wetland (4.D.). In settlements, trees existing in urban green areas such as special greenery conservation zones and urban parks, etc absorb carbon. Urban green areas are divided into two categories; "green spaces conserved by zoning[7]" for which conservation measures are taken and permanent protection is ensured, and "urban green facilities[8]" established as urban parks and others, and the amount of carbon stock changes is calculated for each green area. In addition, the method of classifying the area of the settlements and the sub-categories of the report shall be as follows.

Settlements are divided into "Settlements remaining settlements" and "Land converted to settlements." The cumulative area of settlements converted from other land use categories to settlements within the past 20 years is defined as "Land converted to settlements" based on the default setting of the *IPCC Guidelines*, and "Settlements remaining settlements" is reported as all settlements minus "Land converted to settlements."

"Settlements remaining settlements" is divided into three sub-parts corresponding to the calculation of carbon stock change: "green spaces conserved by zoning," "urban green facilities," and "other settlements." "other settlements" includes all land that is not classified as " green spaces conserved by zoning " or "urban green facilities." All of urban green areas are under the active growing period (AGP), and therefore the activity data area that are subject to carbon stock change calculations is used as the area for this category. Urban green area exceeded the AGP and where no carbon stock changes has occurred is included in "other settlements."

Since a small portion of "urban green facilities" is created on the land converted to settlements, the area of "urban green facilities under Settlements remaining settlements" can include the area of " urban green facilities converted from other land-uses," so technically, there is double counting between the area of "urban green facilities" and that of "Land converted to settlements." However, since the area of all settlements is rounded to the nearest 10,000 ha due to the source statistics, when uncertainty is considered, this level of double counting does not affect the accuracy of the overall area Also, "urban green facilities" existing in "Land converted to settlements" is treated in the calculation of emissions and removals as “IE,” and therefore, no substantial problem has occurred. In the "Land converted to

---

[7] Green spaces conserved by zoning are green areas which are conserved through land-use regulation with land-ownership still maintained. Of these areas, the Special Greenery Conservation Zones are stipulated in Article 12 of the Urban Green Area Law, and are designated as green area such as forestlands, grasslands, and swamp areas that form a favorable natural environment alone or in combination with their surroundings within an urban planning area. Of these areas, those that exclude waterfront areas are classified under this sub-category.

[8] Urban Green Facilities refer to green areas which are managed with the acquisition of title to the green areas. Specifically, they include urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, , green areas along rivers and erosion control sites, green areas around government buildings and green areas around public rental housing.

and removals as “IE,” and therefore, no substantial problem has occurred. In the "Land converted to settlements," only the amount of carbon stock loss associated with the loss in the original land use was accounted for, and the amount of carbon stock increase associated with the growth in the land converted to urban green facilities was calculated collectively under the "Settlements remaining Settlements." The area of each sub-category is shown in Table 6-45.

In FY2021, Japan’s settlement area was about 3.90 million ha, equivalent to about 10.3% of the national land. The emissions from carbon stock changes in this category in FY2021 were 2,197 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 79.4% compared to FY1990 and a decrease of 26.3% compared to FY2020.

Table 6-45 Each area in the subcategory of settlements

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Settlements (a)	kha	3200.0	3428.0	3594.0	3698.0	3779.0	3800.0	3808.0	3827.0	3835.0	3843.0	3862.0	3870.0	3889.0	3899.0	3897.0
Settlements remaining Settlements (a-b)	kha	2,288.3	2,637.5	2,874.1	3,072.6	3,284.6	3,372.5	3,408.2	3,446.3	3,469.7	3,492.3	3,523.5	3,536.8	3,559.9	3,571.7	3,571.7
Special greenery conservation zones (c)	kha	1.8	3.6	3.6	4.1	4.1	4.4	4.4	4.5	4.6	4.6	4.6	4.6	4.7	4.7	4.7
Urban green facilities (d)	kha	82.7	106.2	123.6	134.1	136.6	133.6	131.6	127.7	124.0	121.5	119.3	116.5	112.7	109.1	106.0
Other (a-b-c-d)	kha	2,203.8	2,527.7	2,746.9	2,934.4	3,143.9	3,234.6	3,272.2	3,314.1	3,341.1	3,366.2	3,399.6	3,415.7	3,442.4	3,457.9	3,461.1
Land converted to Settlements (b)	kha	911.7	790.5	719.9	625.4	494.4	427.5	399.8	380.7	365.3	350.7	338.5	333.2	329.1	327.3	325.3

Table 6-46 Emissions and removals in settlements resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
4.E. Settlements	Total	kt-CO_2	10,646	8,155	6,180	4,888	4,156	3,182	3,226	3,095	3,213	3,095	2,785	2,815	2,927	2,980	2,197
	Living Biomass	kt-CO_2	1,860	832	-297	-669	-327	-601	-394	-354	-146	-135	-280	-212	3	56	-591
	Dead Wood	kt-CO_2	533	371	187	148	235	173	208	208	248	248	210	210	156	156	66
	Litter	kt-CO_2	249	166	74	53	95	65	82	82	102	102	83	83	57	57	13
	Mineral soil	kt-CO_2	7,861	6,678	6,127	5,277	4,080	3,480	3,265	3,096	2,947	2,818	2,710	2,671	2,647	2,646	2,643
	Organic soil	kt-CO_2	144	108	89	79	74	65	64	63	62	61	61	63	64	65	66
4.E.1. Settlements remaining Settlements	Total	kt-CO_2	-1,015	-1,358	-1,644	-1,815	-1,852	-1,828	-1,805	-1,776	-1,747	-1,728	-1,704	-1,667	-1,640	-1,593	-1,551
	Living Biomass	kt-CO_2	-749	-1,039	-1,273	-1,416	-1,460	-1,447	-1,432	-1,407	-1,382	-1,368	-1,351	-1,321	-1,303	-1,265	-1,230
	Dead Wood	kt-CO_2	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA
	Litter	kt-CO_2	-12	-15	-18	-20	-20	-20	-20	-20	-20	-20	-20	-19	-19	-19	-19
	Mineral soil	kt-CO_2	-253	-305	-354	-379	-372	-361	-353	-349	-345	-340	-334	-327	-318	-310	-302
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2. Land converted to Settlements	Total	kt-CO_2	11,661	9,513	7,825	6,703	6,008	5,010	5,031	4,871	4,960	4,822	4,489	4,482	4,568	4,573	3,747
	Living Biomass	kt-CO_2	2,609	1,871	975	747	1,132	846	1,038	1,054	1,236	1,234	1,071	1,109	1,306	1,321	639
	Dead Wood	kt-CO_2	533	371	187	148	235	173	208	208	248	248	210	210	156	156	66
	Litter	kt-CO_2	261	182	92	73	115	85	102	102	121	121	103	103	76	76	32
	Mineral soil	kt-CO_2	8,114	6,982	6,481	5,656	4,453	3,841	3,619	3,445	3,292	3,158	3,044	2,998	2,966	2,955	2,944
	Organic soil	kt-CO_2	144	108	89	79	74	65	64	63	62	61	61	63	64	65	66

6.8.1. Settlements remaining Settlements (4.E.1.)

a) ***Category Description***

This subcategory deals with carbon stock changes in all urban green areas. The net removals in this subcategory in FY2021 was 1,551 kt-CO_2; this represents an increase of 52.8% compared to FY1990 and a decrease of 2.7 % compared to FY2020.

Note that "Other remaining other " in settlements includes trees growing in the yards of private residences, but based on the Tier 1 assumption that there is no change, it was reported as "NA".

b) ***Methodological Issues***

1) Carbon Stock Changes in Living Biomass in "Settlements remaining Settlements"

- ***Estimation Method***

The calculation of carbon stock change in living biomass in urban green areas was performed for tall trees[9] only, using the gain-loss method of Equation 2.7 described in the section 2.3.1.1, Vol.4 of the *2006 IPCC guidelines*. For the calculation of carbon stock increase due to growth ($\Delta C_{S\_LB\_G}$), based on the characteristics of urban green areas and available activity data, the Tier 2a crown cover area method is used for green spaces conserved by zoning, and Tier 2b individual plant growth method is used for urban green facilities, as described in the section 8.2.1.1, Vol.4 of the *2006 IPCC Guidelines*. In addition, AGP was set based on the results of measured surveys in Japan in accordance with the description in the section 8.2.1.2, Vol.4 of the *2006 IPCC Guidelines*. For trees older than AGP, it was conservatively assumed that gains and losses were the same and no carbon stock change was calculated, while up to AGP, only gains were calculated and losses ($\Delta C_{S\_LB\_L}$) were assumed to be zero.

- ***Tier 2a: green spaces conserved by zoning***

$$\Delta C_{Sa\_LB} = \Delta C_{Sa\_LB\_G} - \Delta C_{Sa\_LB\_L}$$

$$\Delta C_{Sa\_LB\_G} = A_{Sa\_AGP} \times PW \times CRW\text{s}$$

ΔC_{Sa_LB}	: Changes in carbon stocks in living biomass in green spaces conserved by zoning [t-C/yr]
$\Delta C_{Sa\_LB\_G}$	: Gains in carbon stocks due to growth in living biomass in green spaces conserved by zoning [t-C/yr]
$\Delta C_{Sa\_LB\_L}$	: Losses in carbon stocks due to losses in living biomass in green spaces conserved by zoning [t-C/yr]. Note: assumed as "0" (zero) because AGP is set
A_{Sa_AGP}	: Area of green spaces conserved by zoning younger than or equal to AGP years since designation (activity data area) [ha]
PW	: Rate of forested area (rate of forested area per green spaces conserved by zoning). Note: assumed as 100%
CRW	: Annual living biomass growth per forested area [t-C/ha crown cover/yr]

- ***Tier 2b: Urban green Facilities***

$$\Delta C_{Sb\_LB} = \sum_i \left(\Delta C_{Sb\_LB\_G_i} - \Delta C_{Sb\_LB\_L_i}\right)$$

$$\Delta C_{Sb\_LB\_G_i} = \sum_j NT_{Sb\_AGP_{i,j}} \times C_{Rate_{i,j}}$$

ΔC_{Sb_LB}	: Changes in carbon stocks in living biomass in urban green facilities [t-C/yr]
$\Delta C_{Sb\_LB\_Gi}$	: Gains in carbon stocks due to growth in living biomass in urban green facilities *i* [t-C/yr]

[9] Tall trees are consistent with the definition in "Standards for the quality and size of planted trees for the public (draft). "Standards for the quality and size of planted trees for the public (draft)" was decided by the Ministry of Land, Infrastructure, Transport and Tourism in order to promote proper enforcement of projects such as greening in public spaces. Tall tree is defined in the standards as tree which reaches 3 ~ 5 m in height.

$\Delta C_{Sb\_LB\_Li}$	: Losses in carbon stocks due to losses in living biomass in urban green facilities *i* [t-C/yr]. Note: assumed as "0" (zero) because AGP is set
$C_{Ratei,j}$	: Annual living biomass growth in urban green facility *i* in climate type *j* per tree [t-C/tree/yr] See Table 6-47
$NT_{Sb\_AGPi,j}$	: Number of tall trees younger than or equal to AGP years (AGP tall tree count) in urban green facility *i* in climate type *j*
i	: Types of urban green facilities (urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas along rivers and erosion control sites, green areas around government buildings, or green areas around public rental housing)
j	: Climate type (Hokkaido, other than Hokkaido)

- ***Parameters***

➢ ***Tier 2a: green spaces conserved by zoning***

- ***Annual living biomass growth per crown cover area***

The default value (2.9 t-C/ha crown cover/yr) indicated in Table 8.1 in vol.4 of the *2006 IPCC Guidelines* is taken for the annual rate of living biomass growth of trees per forested area in green spaces conserved by zoning.

- ***Rate of forested area***

The rate of forested area per green spaces conserved by zoning was assumed to be 100% considering the planting status of the green area.

➢ ***Tier 2b: urban green facilities***

- ***Annual living biomass growth per individual tree***

The following steps are taken to calculate the annual living biomass growth rates per tree by the type of urban green facility, and used throughout the time series. Each value is shown in Table 6-47.

A) Urban parks

1. A sample survey (for Hokkaido:176, for other than Hokkaido: 321, 497 in total) was conducted to determine the tree species composition of urban parks. The distribution ratio of tree types was calculated by using tree registers and plantation maps for all urban parks in Hokkaido and in other prefectures separately and for a total of 321 randomly extracted sites.

2. Annual living biomass growth by major tree species in Japan was determined as follows. The annual growth rates of living biomass for Japanese zelkova, ginkgo, bamboo-leaf oak and camphor tree, which are the main planted trees in Japan, are calculated by using the growth curve for each tree species (Matsue et al., 2009), which were developed based on the results of surveys conducted by the National Institute for Land and Infrastructure Management (NILIM) of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the average trunk diameter at breast height for each tree species (Parks and Green Spaces Division of the MLIT, 2005), which were determined from the results of surveys in urban parks. For the carbon fraction, the default value of 0.5 in Section 8.2.1.2 of Vol.4 of the *2006 IPCC Guidelines* is used.

3. The annual living biomass growth of trees in urban parks was calculated by using the country-specific value for annual growth rate of living biomass per tree, which was developed by combining the default values (0.0033-0.0142 t-C/tree/yr) provided in the *2006 IPCC Guidelines* (Vol.4, Table 8.2) and the country specific annual growth rates of living biomass for the trees in Japan calculated in 2 (0.0204 for Japanese zelkova, 0.0103 for ginkgo, 0.0095 for bamboo-leaf

oak and 0.0122 t-C/tree/yr for camphor tree), and by taking into account the distribution ratio of tree species in sample urban parks obtained in 1. The values were established separately for Hokkaido and areas other than Hokkaido.

B) Green Areas on Roads

1. The distribution ratio of tree types in green areas on roads is taken from the Road Tree Planting Status Survey (The Street tree of Japan VI), which covered green areas on roads throughout Japan.
2. The annual living biomass growth in green areas on roads is calculated by using the country-specific value for annual growth rate of living biomass per tree, which was developed by taking a weighted average of the *2006 IPCC Guidelines'* default values and the annual growth rates of living biomass for the trees in Japan (4 species), which were also used for the urban parks, using the distribution ratio of tree species obtained in 1. The values were established separately for Hokkaido and areas other than Hokkaido.

C) Urban parks, green areas at ports, green areas around sewage treatment facilities, green areas along rivers and erosion control sites, green areas around government buildings, and green areas around public rental housing

For the annual biomass growth of trees in these green areas, the same values as those for urban parks were applied, because the standard for planted trees, tree types and their distribution are applied in the same manner as in urban parks.

Table 6-47 Annual biomass growth rate per tree in urban green facilities

Climate category	Annual living biomass growth per tall tree [t-C/tree/yr]
Hokkaido	(Other than green areas on roads) 0.0098 (Green areas on roads) 0.0103
Areas other than Hokkaido	(Other than green areas on roads) 0.0105 (Green areas on roads) 0.0108

● ***Activity Data***

➢ ***green spaces conserved by zoning system***

For the activity data area for green spaces conserved by zoning, the AGP is defined as 30 years after designation as green spaces conserved by zoning, and the area of special greenery conservation zones and suburban greenery special conservation zones obtained through annual surveys[10] by the Ministry of Land, Infrastructure, Transport and Tourism, which are less than 30 years after designation, were extracted. Waterfront areas are excluded.

[10] The actual results of the survey are posted on the website of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) below.

https://www.mlit.go.jp/toshi/park/toshi_parkgreen_tk_000081.html (the area of special greenery conservation zones and suburban greenery special conservation zones)

Table 6-48 Activity data areas of green spaces conserved by zoning (younger than or equal to 30 yearsafter designation)

Category		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Special greenery conservation zones		kha	1.9	3.7	3.8	4.1	4.2	4.4	4.5	4.5	4.6	4.7	4.7	4.7	4.8	4.8	4.8
	Green space conservation zones	kha	0.6	0.9	1.4	1.9	1.9	2.0	2.0	2.0	2.1	2.2	2.2	2.2	2.2	2.2	2.2
	Suburban green space conservation zones	kha	1.2	2.7	2.4	2.2	2.3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

➢ ***Urban Green Facilities***

Based on the field survey, the AGP for urban green facilities basically set at 30 years after the creation of the green area, and 50 years for unpruned wooded area[11] in large urban parks.

The data used are as follows.

Table 6-49 Survey to determine the activity data area

Type of urban facility	Data type	Name of Survey and Year of Implementation
Urban parks	Service area for each urban park	Urban Parks Status Survey (conducted since 1960)
Green area on roads	Number of tall trees	Road Tree Planting Status Survey (conducted every year since FY2007)
	Activity area per tall tree	Basic Data Collection Survey on Tall Tree Planting on Roads (February 2007)
	Road extension and rate of greenery	Road statistics yearbook (Road extension) The Street tree of Japan (Rate of greenery)
Green areas at ports	Service area by facility	Complete census (conducted every year since FY2008)
Green areas around sewage treatment facilities	Green area by facility	Survey on carbon dioxide absorption at Sewage Treatment Facility Status Survey (conducted every year since FY2009)
Green areas along river and erosion control sites	Planted land area by facility	Survey on carbon dioxide absorption in river works (conducted every year since FY2008)
Green areas around government buildings	Total land area and building area by facility	Complete census (conducted every year since FY2008)

- ***Activity data area of urban green facilities***

A) Urban parks, Green areas at ports, Green areas around sewage treatment facilities, Green areas along rivers and erosion control sites, Green areas around government buildings, and Green areas around public rental housing

The area within AGP years of maintenance at the end of the fiscal year was obtained from the survey described in Table 6-49.

AGP of urban green facilities was basically set at 30 years, and 50 years for unpruned wooded areas in urban parks. For the area of activity prior to the year the survey was initiated.

The Activity data area of unpruned wooded areas in urban parks that are between 31 and 50 years old after maintenance was calculated by multiplying the unpruned ratio by the number of eligible urban parks, which only includes relatively large urban parks such as urban core parks and large-scale parks. The unpruned ratio was 55%, which was obtained from the results of the sample survey.

[11] Unpruned wooded area was defined as " wooded area excluding the inner 5 m area from the outer perimeter of the woodland affected by periodic pruning, etc.".

For green areas along rivers and erosion control sites, the planted land area was defined as shown in the table below.

Table 6-50 Planting works in green areas along rivers and erosion control sites and definition of planted land area

Planting works in green areas along rivers and erosion control sites	Definition of planted land area
(1) Planting in inspection passage of excavated channel	Area of land from levee wall shoulder to private land
(2) Planting in face of riverbank of excavated channel	Area of land from levee wall shoulder to private land
(3) Planting in backslope banquette	Area of embanked land
(4) Planting in levee marginal strip (second-class and third-class)	Area of marginal strip which is subject to greening works
(5) Planting in high water channel	Area of land from low-flow channel shoulder to foot of levee slope
(6) Planting in retarding basin	Area of retarding basin
(7) Planting in lake foreshore	Area of land from low-flow channel shoulder to foot of levee slope
(8) Planting in super levee	(Same as planting in excavated channel)
(9) Greening under erosion and sediment control works	Area of land which is subject to hillside works
(10) Greening under landslide control works	Area of land which is subject to hillside works
(11) Greening under steep slope failure prevention works	Area of land which is subject to hillside works

- ***Number of tall trees per area***

The number of tall trees per area was calculated separately for Hokkaido and non-Hokkaido based on the data obtained from the sample survey as described below, and then used as a fixed time series.

A) Urban parks

The number of tall trees per area is calculated based on the number of tall trees and the land areas of sample urban parks. Sample number was intended to satisfy the significance level of 95%. The number of tall trees per area in urban parks was calculated by using data from tree registers and planting maps for randomly extracted 176 sample urban parks in Hokkaido and 321 sample urban parks in the other prefectures.

B) Green areas at parks

The number of tall trees per area in green areas at ports was assumed to be the same as in urban parks because the standard of planted trees, tree types and their distribution are applied in the same manner as in urban parks.

C) Green areas around sewage treatment facilities

The number of tall trees per area for green areas around sewage treatment facilities was established by using data on the number of tall trees and greening areas measured in 59 green areas.

D) Green areas along rivers and erosion control sites

For green areas along rivers and erosion control sites, the number of tall trees was measured in approximately 95% of this green area. Based on these data, the number of planted trees per area was estimated in order to simplify the estimation of the number of tall trees in all green areas.

E) Green areas around government buildings

For green areas around government buildings, the number of tall trees per area was estimated by dividing the number of tall trees by the “total land area – building area” (these data were based on 30 facilities where planting maps were available). The common value is used for all prefectures, since the sample data were not sufficient enough to set values for Hokkaido and the other prefectures, respectively.

F) Green areas around public rental housing

For green areas around public rental housing, the number of tall trees per area was estimated for 33 facilities, where planting maps were available, by dividing the number of tall trees by the area “total land area – building area”. The common value is used for all prefectures, since the sample data were not sufficient enough to set values for Hokkaido and the other prefectures, respectively.

The number of tall trees per area established by the above calculations is shown in the table below.

Table 6-51 Number of tall trees per area

Item	Unit	Number of tall trees per area	
		Hokkaido	Areas other than Hokkaido
Urban parks	tree/ha	329.5	222.3
Green areas at ports	tree/ha	329.5	222.3
Green areas around sewage treatment facilities	tree/ha	129.8	429.2
Green areas along rivers and erosion control sites	tree/ha	1470.8	339.0
Green areas around government buildings	tree/ha	108.8	108.8
Green areas around public rental housings	tree/ha	219.9	219.9

B) Green areas on roads

As shown in Table 6-49, the number of tall trees planted in green areas on roads within 30 years after establishing green areas on roads is calculated by using data from the “*Road Tree Planting Status Survey*” which had been implemented in FY1987, FY1992, FY2007 and onward. Years for which data were not available were supplemented by interpolation. The activity data area of these green areas was obtained using model values (general roads: 0.006237 ha/tree, highways: 0.000830 ha/tree) set by a sample survey conducted in 2007 (95% level of significance). Model values were obtained by randomly selecting road green space and dividing the area of the land by the number of tall trees planted on the land.

Using the above, the Activity data area and number of tall trees in AGP were estimated as follows.

Table 6-52 Summary of Activity data area and number of tall trees in each urban green facilities

Item	Activity data	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Urban green facilities total	Activity areas	kha	82.7	106.2	123.6	134.1	136.6	133.6	131.6	127.7	124.0	121.5	119.3	116.5	112.7	109.1	106.0
Urban parks	Activity areas	kha	54.0	65.7	77.2	85.2	87.3	86.0	85.3	84.9	84.6	84.2	83.5	83.0	81.8	80.6	80.2
ess than 30 years after establishing	Activity areas	kha	52.9	63.1	72.8	77.5	75.5	73.0	71.4	70.4	69.4	68.4	67.0	65.5	63.6	61.9	60.3
31-50 years after establishing(for large urban parks)	Activity areas	kha	1.1	2.6	4.3	7.7	11.7	13.0	13.9	14.5	15.1	15.8	16.5	17.5	18.1	18.7	19.9
	number of tall trees		12,604,365	15,306,142	18,029,868	19,941,056	20,476,510	20,180,954	20,015,002	19,934,189	19,844,628	19,750,642	19,584,146	19,446,332	19,154,839	18,892,804	18,788,559
Green area on roads	Activity areas	kha	23.7	34.1	38.3	39.9	40.2	38.6	37.6	34.1	30.8	28.8	27.3	25.2	22.9	20.7	18.3
	number of tall trees		4,979,363	8,843,605	11,623,444	13,011,342	13,499,777	13,461,867	13,265,959	12,726,010	12,170,742	11,918,033	11,669,755	11,085,378	10,943,572	10,301,861	9,607,941
Green areas at ports	Activity areas	kha	0.4	0.8	1.1	1.5	1.8	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.7
	number of tall trees		101,284	178,275	246,452	331,776	406,421	420,859	422,275	429,353	428,114	434,147	430,930	429,318	435,241	408,713	385,551
Green areas around sewage treatment facilities	Activity areas	kha	0.4	0.5	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6
	number of tall trees		154,353	201,105	265,191	325,819	317,766	303,173	297,353	293,332	287,449	282,459	273,091	265,649	258,544	253,163	236,976
Green areas along river and erosion control sites	Activity areas	kha	0.8	1.0	1.3	1.6	1.8	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.6	1.6	1.6
	number of tall trees		445,857	541,929	782,801	919,020	1,032,977	1,017,824	1,009,572	995,316	980,966	964,605	955,175	934,799	895,888	881,346	885,998
Green areas around government buildings	Activity areas	kha	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	number of tall trees		27,397	35,072	42,375	45,324	44,642	43,523	42,391	41,711	40,799	39,838	39,858	38,838	40,887	39,906	39,245
green areas around public rental housing	Activity areas	kha	3.1	3.9	4.7	4.7	4.3	4.1	4.0	3.9	3.9	3.9	3.8	3.7	3.6	3.5	3.3
	number of tall trees		682,319	857,878	1,023,223	1,032,938	947,416	900,681	870,779	861,260	856,239	847,143	837,243	815,468	790,958	766,429	724,761

2) Carbon Stock Changes in dead wood and litter in "Settlements remaining Settlements"

- ***Estimation Method***

  - ***Green spaces conserved by zoning***

In accordance with Tier 1 assumptions in the section 8.2.2.1, Vol.4 of the *2006 IPCC guidelines*, the carbon stock change in dead wood and litter in green spaces conserved by zoning was assumed to remain unchanged and reported as "NA".

  - ***Urban Green Facilities***

For litter, carbon stock changes only in branches and leaves dropped naturally from tall trees, only in urban parks and green areas at ports among urban green facilities are estimated. Carbon stock changes in litter in the subcategories other than urban parks and green areas at ports were reported as "NA" by applying Tier 1 because it is difficult to accurately estimate the carbon stock changes in fallen leaves, branches etc. that are taken off site by management such as cleaning etc.

For dead wood, the number of tall trees per land area used in the estimation of activity data for living biomass includes trees which have died and have been complementary planted since the establishment of the park. Thus, the carbon stock changes in dead wood are thought to be included in the carbon stock changes in living biomass. Therefore, this category is reported as "IE".

To calculate the carbon stock change in litter, a country-specific method is applied for this estimation in accordance with the decision tree provided in the *2006 IPCC Guidelines*. The estimation method is described below.

$$\Delta C_{Sb\_Lit} = \sum_{i,j} \left(A_{Sb\_AGP_{i,j}} \times Lit_{i,j} \right)$$

ΔC_{Sb_Lit}	: Carbon stock changes in litter in urban green facilities [t-C/yr]
A_{Sb_AGPi}	: Activity data area of urban green facility *i* in climate type *j* [ha]
$L_{it\ I,j}$	: Carbon stock change in litter per area in urban green facility *i* in climate type *j* [t-C/ha/yr]
i	: Type of urban green facilities (urban parks or green areas at ports)
j	: Climate type (Hokkaido, areas other than Hokkaido)

- ***Parameters***

  - ***Urban green facilities (urban parks or green areas at ports)***

- ***Carbon stock changes in litter per urban park areas***

Carbon stock changes in litter per urban park area is calculated by using the following procedure.

1. The sample survey sites were selected according to differences in climatic zones, one in Hokkaido and one in non-Hokkaido prefecture, and the annual accumulation of litter (g/tree/yr) dropped naturally was measured for some tree types by using litter traps. Only those naturally falling to the ground surface were treated as litter in the measurements. The amount of litter (g/tree/yr) is sorted by tree species class described in table 8.2 of the *2006 IPCC guidelines*, and the amount per tall tree is combined by taking into account the distribution ratio of tree species in urban parks. The values were established separately for Hokkaido and areas other than Hokkaido. As a result, the values are calculated as 1,469.36 g/tree/yr and 1,466.41 g/tree/yr, respectively. After conversion

to carbon, the annual accumulation of litter per tree for Hokkaido and other prefectures was estimated to be 0.0006 t-C/tree/yr. (The carbon fraction in litter is assumed to be 0.4 t-C/t-d.m. which is a default value provided in the *2006 IPCC Guidelines* (Vol.4, p. 8.21)).

2. The ratio of litter moved off-site due to management including cleaning (54.4%) was taken into account. As shown in Table 6-50, the number of tall trees per area differs between Hokkaido and areas other than Hokkaido, carbon stock changes in litter per area have been calculated at 0.0882 t-C/ha/yr for Hokkaido and 0.0594 t-C/ha/yr for other prefectures.

3. The same values as those for urban parks were applied to green areas at ports, because the standard of planted trees, tree types and their distribution are applied in the same manner as in urban parks.

- ***Activity Data***

➢ ***Urban Green Facilities (urban park and green areas at ports)***

- ***Activity data area***

Activity data in this category are the same as the Activity data area of urban parks and green areas at ports, as described in section 6.8.1. b)1).

3) Carbon Stock Changes in Soils in "Settlements remaining Settlements"

- ***Estimation Method***

➢ ***Green spaces conserved by zoning***

In accordance with Tier 1 assumptions in the section 8.2.3.1, Vol.4 of the *2006 IPCC guidelines*, the carbon stock change in soils in the green spaces conserved by zoning was reported as "NA" since no carbon stock change was considered to have occurred due to there being no change in land use patterns.

➢ ***Urban Green Facilities***

Among the urban green facilities, urban parks for which the carbon stock changes in soils per area were determined, and green areas at ports whose management practices are similar with those for urban parks, are the subject to estimation. For green facilities other than urban parks and green areas at port, the patterns of carbon stock changes in soils are similar to those in urban parks, because planting, establishment and management practices are implemented in a similar way. The slopes on the expressway, where different plantation practices are applied, are assumed to be a sink, because field surveys have revealed that the carbon stocks keep increasing for at least 20 years after establishment.

However, it is difficult to accurately estimate the carbon stock changes in soils in these urban green facilities because of limited data. Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs.

In general, soils in urban green facilities are not classified as organic soils (peat soils and muck soils). Therefore, organic soils are reported as "NO".

Carbon stock changes in soils on settlements in newly established urban parks or green areas at ports are estimated based on Tier 2 (Country specific data are used) estimation method.

$$\Delta C_{Sb\_so} = \sum_i \left(A_{Sb\_AGP_i} \times So_i \right)$$

ΔC_{Sb_so} : Annual carbon stock changes in mineral soils in urban green facilities [t-C/yr]

A_{Sb_AGPi} : Activity data area of urban green facilities i [ha]
So_i : Annual carbon stock changes in mineral soils per area in urban green facilities i [t-C/ha/yr]
i : Type of urban green facilities (urban parks and green areas at ports)

- ***Parameters***

➢ ***Urban Green Facilities (urban parks and green areas at ports)***

- ***Carbon stock change in mineral soils per area***

The carbon stock change in mineral soils per area in urban parks was calculated using the following procedure.

1. Soil carbon stocks (at 30 cm depth) were measured for areas with different types of vegetation cover in urban parks (planted: 31 areas, lawn: 29 areas, bare: 21 areas), which are located in Tokyo and were established in different years.

2. The soil carbon stocks of the area, where basically carbon is not supplied by plants (bare area), are assumed to be the same as soil carbon stocks of sites immediately after conversion. Based on the soil carbon stocks in the areas with different types of vegetation cover (planted, lawn and bare) in urban parks, which were established in different years, "carbon accumulation rates in planted areas" and "carbon accumulation rates in lawn areas" are calculated:

   ・ Carbon accumulation rates in planted areas = "Difference in soil carbon stocks between planted and bare areas" / "Average years after establishment of surveyed planted areas"

   ・ Carbon accumulation rates in lawn areas = "Difference in soil carbon stocks between lawn and bare areas" / "Average years after establishment of surveyed lawn areas"

   Since urban parks are generally established by turning entire sites into urban parks, soil carbon stocks within the site immediately after establishment are assumed to be uniform irrespective of previous types of vegetation cover. The soil carbon stocks of bare area are about 38 t-C/ha when converted from the sample data.

3. Changes in soil carbon stocks per area are determined by taking the weighted average based on the typical area ratio among planted, lawn and bare sites in urban parks. As a result, carbon stock changes in soils per area of urban parks and green areas at port (integrated annual amount change during 0-20 years after establishment is 1.28t-C/ha/yr, integrated annual amount change during 21-30 years after establishment is 1.38t-C/ha/yr) are estimated. (Tonosaki et al., 2013, Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism, 2015).

4. This value is applicable to urban parks and green areas at port which were established within 30 years.

- ***Activity Data***

➢ ***Urban Green Facilities (Urban parks and Green areas at ports)***

- ***Activity data Area***

Activity data on this category are the same as the Activity data area of urban parks and green areas at ports, as described in section 6.8.1. b)1).

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

The default values shown in the *2006 IPCC Guidelines* (Vol.4, page 8.10) were applied to the annual carbon stock changes for trees in green spaces conserved by zoning. Following the decision tree, the uncertainty was determined ±50% through application of the standard value shown in the *2006 IPCC Guidelines* (Vol.4, page 8.12).

Moreover, for the uncertainty estimates for living biomass in green spaces conserved by zoning expert judgment is applied according to the decision tree for activity data.

Meanwhile, the uncertainty estimates for living biomass, dead organic matter and soil in urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas along rivers and erosion control sites, green areas around government buildings and green areas around public rental housing are 41%, 61%, 38%.

As a result, the uncertainty estimate was 34% for the entire removal by settlements remaining settlements.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post 2005, as described in section 6.5.2. b)1), time-series consistency for this subcategory is basically ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

- ***Recalculation due to revision of activity data of urban green areas***

A revision was conducted on some area of urban green areas for all years. Due to this revision, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years.

As for urban parks, unpruned wooded area in large urban parks up to 50 years after creation was newly added to the area. See Chapter 10 for impact on trend.

f) ***Category-specific Planned Improvements***

- ***Growth Rate of Living Biomass per Unit of Greening Area in "Green spaces conserved by zoning"***

The default values in the *2006 IPCC Guidelines* were applied to the living biomass growth rate per unit of greening area in green spaces conserved by zoning. However, the growth data needs to be further examined, and parameter that can be finally applied as the growth ratio should be determined. Therefore, based on the characteristics of greening activity, the most appropriate parameters need to be found.

- ***Validity of the Assumption used in the Method of Estimating the Area of Settlements***

The areas of forest land converted to settlements are presently assumed as “roads”, “human habitats”, “school reservations”, “parks and green areas”, “road sites”, “environmental facility sites”, “golf courses”, “ski courses” and “other recreation sites” in the national land-use categorization; however, this assumption may fail to cover all the areas. Therefore, the validity of the assumption needs to be re-examined.

6.8.2. Land converted to Settlements (4.E.2.)

g) ***Category Description***

This subcategory deals with the carbon stock changes in lands converted to settlements, which were converted from other land-use categories to settlements within the past 20 years. With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to settlements. However, the area of wetlands converted to settlements cannot be detected by the current method used for estimating land-use area. Thus, carbon stock changes in these carbon pools were reported as “NO”.

The net emissions by this subcategory in FY2021 were 3,747 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 67.9% compared to FY1990 and a decrease of 18.1% compared to FY2020. Emissions from land converted to settlements have been on a decreasing trend since 1993. These trends resulted from decreases in the annual changes of areas of land-use conversion area from forest land to settlements.

h) ***Methodological Issues***

1) Carbon stock changes in Living Biomass in “Land converted to Settlements”

- ***Estimation Method***

Carbon stock changes in land converted to settlements, similar to land converted to cropland are estimated by using the Tier 2 estimation method with the country-specific biomass stocks, and equation 2.16 in section 2.3.1.2 in Volume 4 of the *2006 IPCC Guidelines*. See the equation as in section 6.5.2. b)1). The carbon stock changes due to the growth in living biomass after conversion to settlements is assumed to be “0” (zero).

- ***Parameters***

➢ ***Living biomass stocks for each land-use category***

Table 6-9 Table 6-10 and Table 6-11 show the living biomass stocks before and after conversion.

➢ ***Carbon fraction of dry matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines*.

- ***Activity Data***

➢ ***Land Areas converted to Settlements***

The areas converted to settlements from forest land, cropland and grassland are obtained. Since no data is available on the area converted to settlements from wetlands or other land, “IE” was allocated to those land-use categories. Instead, they are reported as “IE” since they are included in “Other land remaining Other land”.

It should be noted that the area presented in the CRF “Table 4.E Sectoral background data for land use, land-use change and forestry－Settlements” is not the annually converted area in FY2020 but the sum of annually converted areas during the past 20 years.

\- ***Conversion from Forest land***

Areas of forest land converted to settlements were estimated as described in section 6.5.2. b).1).

\- ***Conversion from Cropland***

For former rice fields, upland fields, and orchards (according to “*Area Statistics for Cultivated and Commercially Planted Land*”), the areas of land converted to factories, roads, housing, and forest roads are used.

\- ***Conversion from Grassland***

Pasture land in land converted to factories, roads, housing, and forest roads in *“Area Statistics for Cultivated and Commercially Planted Land*” and grazed meadow land converted to settlements in *“A Move and Conversion of Cropland”* were subject to this category.

Table 6-53 Area of land converted to settlements within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Settlements	kha	39.8	33.4	22.7	12.9	13.2	11.2	14.7	16.0	18.1	16.8	17.7	23.3	20.8	20.8	18.5
Forest land converted to Settlements	kha	14.5	10.1	5.1	4.0	6.4	4.7	5.7	5.7	6.8	6.8	5.7	5.7	4.3	4.3	1.8
Cropland converted to Settlements	kha	23.3	20.6	15.4	7.4	5.8	5.6	7.3	8.6	9.0	8.9	10.5	15.4	14.9	14.6	14.5
Rice field converted to Settlements	kha	13.0	12.1	9.5	5.6	3.5	3.6	4.2	4.9	5.1	5.3	5.7	9.1	9.0	9.2	8.9
Upland field converted to Settlements	kha	5.7	5.6	2.6	1.4	1.8	1.6	2.4	2.9	3.1	2.9	3.9	5.0	4.8	4.3	4.5
Orchard converted to Settlements	kha	4.6	2.9	3.3	0.4	0.5	0.4	0.6	0.8	0.8	0.7	1.0	1.2	1.1	1.0	1.1
Grassland converted to Settlements	kha	1.2	2.0	1.3	0.7	0.7	0.4	1.2	1.5	1.3	1.2	1.4	1.9	1.6	1.9	2.1
Wetlands converted to Settlements	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to settlements	kha	0.8	0.7	0.9	0.8	0.3	0.5	0.5	0.2	1.1	NO	0.1	0.2	0.03	0.1	0.1

2) Carbon Stock Change in Dead Organic Matter in “Land converted to Settlements”

In this category carbon stock changes in dead wood and litter in settlements converted from forest land, and those in litter in urban parks and green areas at ports established in land converted to settlements are estimated.

- ***Estimation Method***

The Tier 2 method was applied to the estimation in accordance with the method for conversion from other land use to cropland, as described in section 6.5.2.b)2).

- ***Parameters***

➢ ***Carbon stocks in dead organic matter in Forest land***

Average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-12 and Table 6-13. In addition, it is assumed that they become zero immediately after conversion, and are not accumulated after conversion.

- ***Activity Data (Area)***

➢ ***Area of "Forest land converted to Settlements"***

The area of land that was converted from forest land to settlements within 1 year was used. For the areas, see Table 6-53.

3) Carbon stock change in mineral soils in Settlements converted from land use other than forest land

In this category, carbon stock change in forest land converted to settlements, crop land converted to settlements, and grass land converted to settlements were subject to estimation.

- ***Estimation Method***

Carbon stock changes in forest land converted to settlements, cropland converted to settlements, and grassland converted to settlements were estimated using the Tier 2 (use of country-specific data) method. Specifically, the annual change calculated by methods shown in Table 6-14 is multiplied by the area of land converted to settlements within the past 20 years (Table 6-54).

Table 6-54 Area of land converted to settlements within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Settlements	kha	911.7	790.5	719.9	625.4	494.4	427.5	399.8	380.7	365.3	350.7	338.5	333.2	329.1	327.3	325.3
Forest land converted to Settlements	kha	283.8	279.2	258.1	214.6	148.4	122.6	114.9	110.0	106.7	105.4	103.9	102.5	100.7	99.9	97.1
Cropland converted to Settlements	kha	528.6	424.1	395.8	354.7	295.6	258.9	243.6	230.9	219.2	207.7	198.6	195.5	193.4	192.6	193.3
Rice field converted to Settlements	kha	320.9	252.1	236.6	214.8	184.8	164.0	155.0	147.5	140.4	132.8	125.8	122.8	121.6	121.3	121.5
Upland field converted to Settlements	kha	127.3	100.0	85.9	76.5	67.6	58.8	55.4	52.9	50.4	48.9	49.2	50.3	52.4	54.2	57.4
Orchard converted to Settlements	kha	80.5	72.0	73.3	63.4	43.2	36.0	33.2	30.5	28.4	26.1	23.7	22.3	19.3	17.1	14.4
Grassland converted to Settlements	kha	51.3	42.2	36.3	31.9	28.4	25.5	25.3	24.8	24.1	23.3	22.3	22.3	22.9	23.6	24.4
Wetlands converted to Settlements	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to settlements	kha	48.0	45.1	29.7	24.2	21.9	20.5	15.9	15.0	15.3	14.3	13.6	12.9	12.1	11.3	10.5

4) CO_2 emissions from organic soils in "Land converted to Settlements"

- ***Estimation Method***

When land with organic soil is converted to settlements, it is common for the ground to be improved in accordance with the purpose of land use. However, it could not be denied that oxidation of organic soil occurred under construction work, for example, on road in soft ground being conducted on the premise of land subsidence. For CO_2 emissions from drainage of organic soils in land converted to settlements,

according to the *Wetlands Guidelines*, CO_2 emissions from cultivation of organic soils (on-site emissions) and emissions from water-soluble carbon losses from drained organic solids (off-site emissions) in land converted to settlements are estimated. The estimation equation is the same as 6.5.1. b) 2).

- ***Parameters***

For CO_2 emissions from organic soils in Settlements converted from other land use categories, since specific default emission factors for settlements have not been provided in the *2006 IPCC Guidelines* and the *Wetlands Guidelines* and country specific factors based on actual condition in Japan is under investigation, it was assumed that settlements converted from other land use would occur mainly from rice fields, CO_2 emission factor from organic soil in rice field was applied. (see section 6.5.1.).

- ***Activity data***

The activity data was organic soils area in settlements within 20 years after conversion. The organic soil area obtained from other lands was estimated in the same way as described in section 6.5.1.   This area was also used for estimating CH_4 and N_2O emissions reported in the CRF "Table 4(II)".

i) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

The uncertainties of the parameters and activity data for living biomass and dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty estimate was 49% for the entire emission from land converted to settlements.

- ***Time-series consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.5.2.b)1), time-series consistency for this subcategory is basically ensured.

j) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

k) ***Category-specific Recalculations***

- ***Correction in areas converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation* used for estimating the areas of Settlements converted from forest land were recalculated, carbon stock changes in living biomass, dead organic matter, carbon stock change in mineral soil and CO_2 emissions from organic soils in this category were recalculated for all years.

- ***Revision of carbon stocks of living biomass and dead organic matter (in forest land) before conversion***

Since the carbon stocks of living biomass and dead organic matter (in forest land) before conversion were revised losses in carbon stock were revised. This resulted in recalculations of carbon stock change for living biomass and dead organic matter in this category for all years.

- ***Revision of Soil Carbon Stocks***

Since the soil carbon stocks in forest land, cropland, grassland, and settlements were revised, carbon stock changes during conversion from forestland to settlements and cropland to settlements were recalculated for all years.

See chapter 10 for impact on trend.

l) ***Category-specific Planned Improvements***

No improvements are planned.

6.9. Other land (4.F.)

Other land consists of land areas that are not included in the other five land-use categories. As concrete examples of other land, the *2006 IPCC Guidelines* indicates bare land, rock, ice, and all land areas that do not fall into any of the five categories. In FY2021, Japan's other land area was about 2.64 million ha, which is equivalent to about 7.0% of the national land. The classification of other land is shown in Table 6-55 below[12].

Table 6-55 Land included in the other land category

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Other land	kha	2,518.5	2,535.0	2,526.0	2,420.7	2,459.1	2,535.0	2,325.6	2,374.5	2,586.9	2,722.7	2,632.3	2,613.3	2,601.7	2,599.7	2,639.0
Defense facility Site	kha	139.0	140.0	140.0	140.0	140.0	140.0	140.0	139.0	139.0	135.0	135.0	135.0	135.0	135.0	136.0
Coast	kha	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0
Northern territories	kha	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6
Wasteland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other	kha	1,829.9	1,845.4	1,836.4	1,731.1	1,769.5	1,845.4	1,636.0	1,685.9	1,898.3	2,038.1	1,947.7	1,928.7	1,917.1	1,915.1	1,953.4

The emissions from this category in FY2021 were 374 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 83.6% compared to FY1990 value and a decrease of 21.4% compared to FY2020.

In this section, other land is divided into two subcategories, "Other land remaining Other land (4.F.1.)" and "Land converted to Other land (4.F.2.)", and described separately in the following subsections.

[12] The *Defense of Japan* (Ministry of Defense) for "Defense Facility Site", the *Digital national land information* (MLIT) for "Coast" and *Land Survey of Prefectures, Shi, Ku, Machi and Mura* (GSI) for "Northern Territories"

Table 6-56 Emissions and removals resulting from carbon stock changes in other land

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
4.F. Other land	Total	kt-CO_2	2,287	2,022	1,659	1,056	852	758	686	655	638	624	567	555	506	476	374
	Living biomass	kt-CO_2	624	512	359	77	125	119	98	104	115	128	110	116	104	92	28
	Dead wood	kt-CO_2	132	106	75	12	26	23	19	19	23	23	19	19	10	10	1
	Litter	kt-CO_2	65	52	37	6	13	11	10	10	11	11	10	10	5	5	1
	Mineral soil	kt-CO_2	1,466	1,351	1,188	961	688	605	560	522	489	462	428	410	387	369	344
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.F.1. Other land remaining Other land	Total	kt-CO_2															
	Living biomass	kt-CO_2															
	Dead wood	kt-CO_2															
	Litter	kt-CO_2															
	Mineral soil	kt-CO_2															
	Organic soil	kt-CO_2															
4.F.2. Land converted to Other land	Total	kt-CO_2	2,287	2,022	1,659	1,056	852	758	686	655	638	624	567	555	506	476	374
	Living biomass	kt-CO_2	624	512	359	77	125	119	98	104	115	128	110	116	104	92	28
	Dead wood	kt-CO_2	132	106	75	12	26	23	19	19	23	23	19	19	10	10	1
	Litter	kt-CO_2	65	52	37	6	13	11	10	10	11	11	10	10	5	5	1
	Mineral soil	kt-CO_2	1466	1351	1188	961	688	605	560	522	489	462	428	410	387	369	344
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

6.9.1. Other land remaining Other land (4.F.1.)

a) ***Category Description***

This subcategory deals with carbon stock changes in other land remaining other land during the past 20 years. The land area of this subcategory is determined by subtracting the summed areas of the other five land-use categories from the total national land area shown in the *Statistical Reports on the Land Area by Prefectures and Municipalities in Japan* compiled by the Geospatial Information Authority of Japan. However, carbon stock changes in this subcategory are not considered in accordance with the *2006 IPCC Guidelines*.

Table 6-57 Areas of other land remaining other land within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Other land remaining Other land	kha	2,304.7	2,349.4	2,370.4	2,292.3	2,360.0	2,432.2	2,229.7	2,282.9	2,500.5	2,638.1	2,551.6	2,534.8	2,528.3	2,529.5	2,571.7

b) ***Category-specific Recalculations***

No recalculations are considered.

c) ***Category-specific Planned Improvements***

No improvements are planned.

6.9.2. Land converted to Other land (4.F.2.)

a) ***Category Description***

This subcategory deals with carbon stock changes in the land converted to other land within the past 20 years. The land area of this subcategory includes land converted for soil and stone mining, land damaged by natural disasters. “The land used for soil and stone mining activities” is the land which is artificially disturbed and the soil carbon in surface layer are removed and are considered not exist. Therefore, this categorization also takes the consistency of statistical division into consideration. By reading from satellite images to detect the land conversion, “the land used for soil and stone mining activities” is allocated under “Other land”.

The emissions from this subcategory in FY2021 were 374 kt-CO_2. This represents a decrease of 83.6% compared to FY1990 and a decrease of 21.4% compared to FY2020.

With respect to living biomass, its carbon stock change as a result of land-use conversion from forest land, cropland and grassland to other land were estimated.

With respect to dead organic matter, carbon stock changes in forest land converted to other land was estimated. Carbon stock changes in dead organic matter in other subcategories (conversion from cropland and grassland) were reported as "NA", since dead organic matter pools before and after conversion were assumed to be zero, as described in section 6.5.2. b)2) and 6.6.2. b)2).

With respect to carbon stock changes in soils, carbon stock changes in soils in forest land, cropland and grassland converted to other land are estimated.

In addition, the area of wetlands converted to other land and settlements converted to other land cannot be detected by the current method used for estimating land-use area. Thus, carbon stock changes in these carbon pools were reported as "NO".

b) ***Methodological Issues***

1) Carbon stock change in Living Biomass in "Land converted to Other land"

- ***Estimation Method***

The Tier 2 method was applied to estimate the country specific living biomass stock in land converted to other land to use equation 2.16 on section 2.3.1.2, Vol.4 in the *2006 IPCC Guidelines* as described in other land use converted to cropland in section 6.5.2. b)1). Carbon stock changes due to biomass growth in other land were assumed as zero.

- ***Parameters***

➢ ***Biomass stock in each Land-Use Category***

The values shown in Table 6-9, Table 6-10 and Table 6-11 are used for the estimation of biomass stock changes upon land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

➢ ***Carbon Fraction of dry matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with *the 2006 IPCC Guidelines*.

- ***Activity Data***

➢ ***Area of land converted to other land***

Only the areas converted from forest land and cropland to other land are determined during the past 1 year.

It should be noted that the area presented in the CRF "Table 4.F Sectoral background data for land use, land-use change and forestry - Other land" is not the annually converted area in FY2021 but the sum of annually converted areas during the past 20 years.

➢ ***Conversion from Forest Land***

See section 6.5.2. b)1).

➢ ***Conversion from Cropland***

For former rice fields, upland fields, and orchards, the area classified as “other, natural disaster damage” is used according to *the Area Statistics for Cultivated and Commercially Planted Land*.

➢ ***Conversion from Grassland***

For former pasture land and grazed meadow land, the area of former pasture land classified as “other, natural disaster damage” (according to *the Area Statistics for Cultivated and Commercially Planted Land*) and the area of former grazed meadow land which is classified as “other, classification unknown” (*the Move and Conversion of Cropland*) are used.

Table 6-58 Area of land converted to other land within the past 1 year

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Other land	kha	7.1	7.1	4.9	4.1	1.7	3.0	1.5	3.1	1.8	3.5	2.0	2.4	2.3	1.8	1.5
Forest land converted to Other land	kha	3.6	2.9	2.0	0.3	0.7	0.6	0.5	0.5	0.6	0.6	0.5	0.5	0.3	0.3	0.04
Cropland converted to Other land	kha	2.4	2.8	1.8	2.9	0.6	1.8	0.6	1.3	1.0	2.7	0.5	0.9	0.8	0.9	0.9
Rice field	kha	1.2	1.5	1.3	2.7	0.4	1.3	0.2	0.7	0.6	2.2	0.3	0.4	0.4	0.6	0.5
Upland field	kha	0.6	0.9	0.2	0.1	0.2	0.4	0.3	0.5	0.3	0.4	0.2	0.4	0.4	0.3	0.3
Orchard	kha	0.5	0.5	0.3	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1
Grassland converted to Other land	kha	0.1	0.3	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.7	0.9	1.0	0.5	0.5
Wetlands converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Settlements converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Non-land converted to Other land	kha	1.0	1.1	0.9	0.8	0.4	0.5	0.2	1.1	NO	0.1	0.2	0.0	0.1	0.1	NO

2) Carbon Stock Changes in Dead Organic Matter in “Land converted to Other land”

● ***Estimation Method***

Carbon stock changes in dead organic matter in forest land converted to other land were estimated by applying the Tier 2 estimation method as described in section 6.5.2.b)2).

● ***Parameters***

➢ ***Carbon Stocks in Dead Organic Matter in “Other Land converted from Forest Land”***

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-12 and Table 6-13. It is assumed that carbon stocks become zero immediately after conversion, and are not accumulated after conversion.

● ***Activity Data***

The values of annually converted area from forest land to other land during the past 1 year are used. (Table 6-58)

3) Carbon Stock Changes in Soils in “Land converted to Other land”

● ***In this category, carbon stock changes in mineral soils in forest land, cropland and grassland converted to other land were estimated. Estimation Method***

Carbon stock changes in mineral soils in this category were estimated by applying the Tier 2 estimation method to use country specific data. For particular, carbon stock change per year described in Table

6-14 were multiplied by area of land converted to other land within the past 20 years (Table 6-59). Besides, land converted to other land by natural disturbance were excepted from the area of mineral soil in other land to use the estimation, since land converted to other land represented the artificial soil alteration by the establishments.

Table 6-59 Area of land converted to other land within the past 20 years

Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Land converted to Other land	kha	213.7	185.6	155.6	128.3	99.1	102.8	95.9	91.6	86.4	84.6	80.7	78.5	73.4	70.2	67.3
Forest land converted to Other land	kha	102.3	96.6	85.2	64.1	42.8	36.9	33.4	30.5	28.2	26.2	23.0	20.9	18.3	16.5	14.4
Cropland converted to Other land	kha	56.9	43.0	38.4	37.3	31.4	46.2	44.0	42.3	40.6	41.5	41.0	40.9	38.2	37.3	36.9
Rice field	kha	32.4	20.9	19.5	19.7	18.0	32.7	31.5	30.6	29.8	31.5	31.2	31.0	28.6	27.8	27.8
Upland field	kha	14.8	12.8	10.2	9.6	8.3	8.8	8.2	7.8	7.3	6.9	6.9	7.0	7.1	7.2	7.3
Orchard	kha	9.7	9.3	8.8	7.9	5.1	4.8	4.3	3.9	3.5	3.1	2.9	2.8	2.6	2.4	1.8
Grassland converted to Other land	kha	5.5	5.0	3.9	4.0	3.5	3.8	3.6	3.5	3.4	3.2	3.8	4.6	5.5	5.9	6.2
Wetlands converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Settlements converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Non-land converted to Other land	kha	49.0	41.0	28.0	22.9	21.3	15.9	15.0	15.3	14.3	13.6	12.9	12.1	11.3	10.5	9.8

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

The uncertainties of the parameters and the activity data for living biomass and dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 82% for the entire emission from the land converted to other land.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990 - 2004 and post FY2005, as described in section 6.5.2. b)1), the time-series consistency for this subcategory is basically ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

- ***Correction in accordance with revision of area of land converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation* used for estimating each land are converted from forest, the areas of Other land converted from forest were recalculated, carbon stock changes in living biomass, dead organic matter and carbon stock change in mineral soils in this category were recalculated for all years.

- ***Recalculation due to revision of amount of carbon stock of living biomass and dead organic matter in forest land before conversion***

Due to the revision of amount of carbon stock of living biomass and dead organic matter in forest land before conversion, the amount for the loss of carbon stock were updated. Therefore, the carbon stock change of living biomass and dead organic matter in this category were recalculated for all years.

- ***Recalculation due to revision of amount of carbon stock in soil***

Since the revision of amount of carbon stock in soil in forest land, cropland and grassland, the carbon stock change in soil in this category were recalculated for all years. See Chapter 10 for impact on trend.

f) ***Category-specific Planned Improvements***

- ***Breakdown Analysis of Other Land and Reclassification into Other Land-Use Categories***

A further breakdown analysis of the other land is required, since it may still include some areas that are supposed to be classified into other land-use categories even after the reallocation carried out in this year.

- ***Carbon Stock Changes in Living Biomass in "Land converted to Other Land"***

The carbon stock changes in living biomass in land converted to other land were assumed to be zero because of a lack of reference information for other land. However, this assumption may differ from the actual situation. Therefore, the methods used to quantify the carbon stock are being examined.

- ***Estimation Method of Soil Carbon Stock Changes in "Forest land, Cropland and Grassland converted to Other Land"***

The estimation method will be considered when new data and information are obtained.

6.10. Harvested Wood Products (4.G.)

Harvested Wood Products (HWP) that have been removed from forest through harvest, store carbon in the wood while HWP remain in use, including as building materials and furniture. Eventually, CO_2 are emitted when HWP are discarded through incineration or decay.

This category deals with annual carbon stock changes in the HWP pool. The production approach is applied to the estimation of HWP, and thus the carbon stock changes associated with the use or disposal of domestic HWP (such as sawnwood, wooden board, plywood, paper and paperboard) are estimated. The carbon stock changes in imported HWP are not subject to estimation. The net removals (carbon stock changes) in this category in FY2021 were 1,596 kt-CO_2; this represents an increase of 504.0% compared to FY1990 and an increase of 298.7% compared to FY2020. The net removals in this category have been on an increasing trend since FY2014 due to an increase in the ratio of domestic wood. The removals had decreased in FY2020 from FY 2019 due to the effects of the Covid-19 pandemic but increased in FY2021 as wood production for construction and other uses increased due to recovery in residential construction.

In this section, the HWP pool is divided into three categories: "buildings", "wood for other uses than buildings" and "paper and paperboard", and reported respectively.

Table 6-60 CO_2 emissions and removals associated with carbon stock changes in the HWP pool

Category		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total		kt-CO_2	-264	1,597	1,732	623	42	338	638	-563	-725	-719	-1,098	-1,337	-1,327	-400	-1,596
Buildings	Total	kt-CO_2	-318	-751	-70	-791	-1,304	-1,378	-610	-1,225	-1,351	-1,349	-1,347	-1,569	-1,614	-1,541	-1,829
	Sawnwood	kt-CO_2	-105	-428	409	-253	-688	-491	356	-285	-380	-235	-204	-399	-267	-239	-488
	Wooden board	kt-CO_2	-254	-371	-523	-459	-379	-484	-479	-530	-506	-578	-566	-553	-636	-614	-639
	Plywood	kt-CO_2	41	48	43	-80	-238	-402	-487	-410	-465	-535	-578	-617	-711	-688	-702
Wood for other uses than building	Total	kt-CO_2	589	1,194	1,390	1,228	699	1,059	893	624	442	339	173	104	140	361	101
	Sawnwood	kt-CO_2	954	1,295	1,478	1,485	1,421	1,313	1,235	1,171	1,095	1,089	1,055	960	877	1,005	808
	Wooden board	kt-CO_2	-405	-215	-235	-182	25	22	-7	9	33	35	49	69	190	209	193
	Plywood	kt-CO_2	40	114	147	-74	-747	-276	-335	-555	-687	-785	-931	-925	-927	-853	-901
Paper and paperboard		kt-CO_2	-535	1,154	412	186	647	658	356	38	184	291	76	128	148	780	133

6.10.1. Buildings

a) ***Category Description***

This category deals with annual carbon stock changes in sawnwood, wooden board and plywood used in buildings. The net removals (carbon stock changes) in this subcategory in FY2021 were 1,829 kt-CO_2; this represents an increase of 474.7% over the FY1990 value and an increase of 18.7% over the FY2020 value.

Note that sawnwood, wooden board and plywood used in buildings are reported in "Sawnwood", and "Wood panels" under "Solid wood" in the CRF tables, respectively.

b) ***Methodological Issues***

- ***Estimation Method***

Since sawnwood, wooden board and plywood are mainly used for buildings and the statistics related to buildings have been compiled with a certain level of accuracy in Japan, carbon stock changes in these pools are estimated by using a country-specific stock inventory method (Tier 3). Carbon stocks in sawnwood, wooden board and plywood that are used when buildings are constructed are recorded as inflow and those released when the buildings are demolished are recorded as outflow. The net carbon stock changes are estimated by summing the inflow and outflow calculated separately. It is assumed that all the carbon stored in the buildings is immediately oxidized when the buildings are demolished. The estimation equation is as follows:

$$\Delta C_{j,i} = Inflow_{j,i} - Outflow_{j,i}$$

j	: Subcategories (sawnwood, wooden board, plywood)
i	: Year for calculation
$\Delta C_{j,i}$	: Carbon stock change in subcategory j of the building HWP pool during year i [t-C/year]
$Inflow_{j,i}$	: Inflow to subcategory j of the building HWP pool during year i [t-C/year]
$Outflow_{j,i}$	: Outflow from subcategory j of the building HWP during year i [t-C/year]

$$Inflow_{j,i} = S_{P_{st,i}} \times v_{DP_{j,st,i}} \times f_{DP_{j,i}} \times D_j \times CF_j$$

j	: Subcategory (sawnwood, wooden board, plywood)
i	: year for calculation
st	: Use (residential or nonresidential) and structure type of buildings
$Inflow_{j,i}$	: Inflow to subcategory j of the building HWP pool during year i [t-C/year]
$S_{P\,st,i}$	: Constructed floor area by use (residential or nonresidential) and by structure type (st) during year i [m^2/year]

$v_{DP\,j,st,i}$: Wood input amount of subcategory *j* per unit floor area of building constructed (new construction or extension) by uses (residential or nonresidential) and by structure type (*st*) in year *i* [m^3/m^2]
$f_{DP\,j,i}$: Ratio of domestic wood to total wood used for buildings of subcategory *j* in year *i* [%]
D_j : Density of subcategory *j* (oven dry mass over air dry volume) [t-d.m./m^3]
CF_j : Carbon fraction of subcategory *j* [t-C/t-d.m.]

$$Outflow_{j,i} = S_{W_{st,i}} \times v_{DW_{j,st,i}} \times f_{DW_{j,i}} \times D_j \times CF_j$$

j : Subcategory (sawnwood, wooden board, plywood)
i : year for calculation
st : Use (residential or nonresidential) and structure type of buildings
$Outflow_{j,i}$: Outflow from subcategory *j* of the building HWP pool during year *i* [t-C/year]
$S_{W\,st,i}$: Floor area of demolished buildings by use (residential or nonresidential) and by structure type (*st*) in year *i* [m^2/year]
$v_{DWj,st,i}$: Wood input amount of subcategory *j* per unit floor area of demolished buildings in year *i* by use (residential or nonresidential) and by structure type (*st*) [m^3/m^2]
$f_{DWj,i}$: Ratio of domestic wood to total wood used in demolished buildings of subcategory *j* during year *i* [%]
D_j : Density of subcategory *j* (oven dry mass over air dry volume) [t-d.m./m^3]
CF_j : Carbon fraction of subcategory *j* [t-C/t-d.m.]

- ***Parameters***

➢ ***Wood input amount per unit floor area of buildings constructed ($v_{DP\,j,st,i}$)***

- ***Sawnwood***

As for wooden buildings, the amount of wood used per unit floor area was obtained from the *Survey on Actual Demand of Construction Labor and Materials* (MLIT). As for non-wooden buildings, the values of 2013 from the survey conducted by the Forestry Agency of Japan were used, because the data from the *Survey on Actual Demand of Construction Labor and Materials* (MLIT) were available only until 1991. The same values as those of 2013 were applied from 2014 onwards. The values from 1992 to 2012 were calculated by linear interpolation. For other years where data are missing, the values were also calculated by linear interpolation.

- ***Wooden board***

The sales and consumption quantity of wooden board by type (particle board, hardboard, medium-density fibreboard and insulating board) and use was calculated by multiplying the total sales and consumption quantity of wooden board by type obtained from the *Current Production Statistics, Ceramics and building materials Statistics* (METI), by the ratio of the sales and consumption quantity of wooden board used for buildings, estimated from the Japan Fibreboard and Particleboard Manufacturers Association's statistics. The wood input per unit area was estimated by dividing the amount of wood calculated above, by the floor area of constructed buildings.

- ***Plywood***

The values obtained from the *Survey on Actual Demand of Construction Labor and Materials* (MLIT) were applied. As for the years where data are missing, the values were calculated by linear interpolation.

➢ ***Ratio of domestic wood for construction ($f_{DP\ j,i}$)***

- ***Sawnwood***

The ratio of domestic wood for sawnwood by conifer and non-conifer was calculated by dividing the shipment quantity of domestic sawnwood for buildings, by the total amount of shipment quantity of sawnwood for buildings and imported sawnwood used for buildings.

- ***Wooden board***

The sales and consumption quantity of wooden board (domestic wood) for buildings by raw material ((i) logs, (ii) wood residue in mills, (iii) wood residue in forestry practices and (iv) scrap wood) was calculated by multiplying the proportion of raw materials in particle board and fiberboard, by the ratio of domestic wood for each raw material. The ratio of domestic wood for each raw material was estimated as follows: for (i) logs, it was estimated from the production of domestic wood chips, imported wood chips, and quantity of wood used for wood chips (domestic and imported wood); for (ii) wood residue in mills, it was estimated from the shipment quantity of sawnwood (domestic and imported wood); for (iii) wood residue in forestry practices, it was estimated as 100%; and for (iv) scrap wood, the ratio of domestic wood for demolished buildings described below was applied. The ratio of domestic wood for each wooden board type was estimated by dividing the sales and consumption quantity of wooden board (domestic wood) above, by the sum of the sales and consumption quantity of wooden board for buildings.

- ***Plywood***

The ratio of domestic wood for plywood used in constructed buildings was calculated by dividing the production of plywood from domestic wood by the sum of plywood production and imports.

➢ ***The amount of wood input per unit floor area of demolished buildings ($v_{DP\ j,st,i}$) and the ratio of domestic wood for demolished buildings ($f_{Dw\ j,i}$)***

The amount of wood input per unit floor area of demolished buildings ($v_{DW\ j,st,i}$) and the rateioof domestic wood for demolished buildings ($f_{DW\ j,i}$) were calculated as the weighted average of the ratio of floor area built in year *n* ($S_{W\ st,I\ (n)}$) of the demolished floor area in year *i* ($S_{W\ st,i}$), respectively to reflect the wood input amount per unit demolished floor area ($v_{DP\ j,st,i}$) or the ratio of domestic wood for buildings ($f_{DP\ j,i}$) in subcategory *j*, as shown in the equations below.

$$v_{DW\ j,st,i} = \sum_n \left(\frac{S_{w\ ,st,i\ (n)}}{S_{w\ st,i}} \times v_{DP\ j,s,t,i\ (n)} \right)$$

$$f_{DW\ j,i} = \sum_n \left(\frac{S_{w\ st,i\ (n)}}{S_{w\ st,i}} \times f_{DP\ j,i\ (n)} \right)$$

➢ ***Density and carbon fraction***

The default values shown in Table 12.1 of Vol.4 of the *2019 Refinement* were applied. Note that the density applied in section 6.11 is the oven dry mass density over air dry volume.

Table 6-61 Default values of density and carbon fraction for the HWP categories

HWP categories		Density [Mg-d.m./m^3]	Carbon fraction [Mg-C/Mg-d. m.]
Sawnwood	Coniferous sawnwood	0.45	0.5
	Non-coniferous sawnwood	0.56	0.5
Wood panels (wooden board)	Particle board (PB)	0.596	0.451
	Hardboard (HDF)	0.788	0.425
	Medium-density fireboard (MDF)	0.691	0.427
	Insulating board (other board, low density fiber)	0.159	0.474
Wood panels (plywood)		0.542	0.493

Reference: The *2019 Refinement*, Table 12.1

Table 6-62 Data used for parameters (Buildings)

	Variable	Reference	Note
1	Shipment quantity of sawnwood (for buildings) (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
2	Shipment quantity of sawnwood (for buildings) (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	
3	Quantity of log input for sawnwood	*Report on Supply and Demand of Lumber* (MAFF)	
4	Imports of sawnwood (coniferous trees)	*Trade Statistics of Japan* (MOF)	Softwood (coniferous tree) and glued-laminated wood imports are assumed as building materials because imports for building structures cannot be obtained in the statistics.
5	Sales and consumption quantity of wooden board	*Current Production Statistics, Ceramics and Building Materials Statistics* (METI)	Including own-use
6	Imports of wooden board	*Trade Statistics of Japan* (MOF)	
7	Imported wood chips	*Trade Statistics of Japan* (MOF)	
8	Production of domestic wood chips	*Report on Supply and Demand of Lumber* (MAFF)	
9	Quantity of log input for wood chips (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
10	Quantity of log input for wood chips (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	
11	Shipment quantity of wooden board by use	*Shipments of wood-based board production* by Japan Fiberboard and Particleboard Manufacturers Association	
12	Production of plywood	*Report on Supply and Demand of Lumber* (MAFF)	
13	Imports of veneer for plywood	*Trade Statistics of Japan* (MOF)	
14	Imports of plywood	*Trade Statistics of Japan* (MOF)	Calculated by subtracting glued-laminated wood and bamboo of plywood from glued-laminated wood by *Trade Statistics of Japan*
15	Quantity of log input for plywood (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
16	Quantity of log input for plywood (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	

Note: MIC: Ministry of Internal Affairs and Communications; METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

- ***Activity Data***

  - ***Floor area of construction ($S_{P\ st,i}$)***

The floor area of new construction and extension by use (residential or nonresidential) and by structure in *Construction Statistics for Building* by MLIT was applied.

  - ***Floor area of demolition ($S_{W\ st,\ i}$)***

The floor area of demolition was estimated by using the floor area stock in the *Fixed Property Tax Division, Local Tax Bureau (Houses)* by MIC and the floor area of construction described above. The floor area of demolished buildings by use (residential or nonresidential) and by structure in year *i* ($S_{W\ st,\ i}$) was calculated by adding the constructed floor area in *i* year ($S_{P\ st,\ i}$) to the floor area stock in year *i-1* ($S_{S\ st,\ i-1}$), and then subtracting the floor area stock in *i* year ($S_{S\ st,\ i}$).

$$S_{W_{St,i}} = S_{S_{st,i-1}} + S_{P_{st,i}} - S_{S_{st,i}}$$

Since the floor area stock and the constructed floor area include the area of extension, the floor area of demolition also includes the floor area of buildings demolished after extension. However, the floor area of renovation has been deducted from the constructed floor area since renovation is not taken into account in the calculation of the amount of wood input per unit floor area of buildings constructed.

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

The uncertainties of carbon stock changes of buildings were assessed based on the uncertainties of the default factors provided in the *2019 Refinement* and the uncertainties of exiting statistical data. The uncertainty was estimated as 30% for the carbon stock changes in buildings.

- ***Time-series Consistency***

Since wood input per unit area was obtained from the *Survey on Actual Demand of Construction Labor and Materials* by the MLIT which is implemented every three years, the data for missing years were calculated by linear interpolation. The time-series consistency for this subcategory is ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on checking the parameters for activity data and emission factors and archiving reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

The carbon stock changes for all years were recalculated as errors in the input data were corrected and the data related to wooden board updated. The correction of errors concerned the following data: the ratio of renovation in the constructed floor area, the input of sawnwood and plywood per unit floor area, the shipment quantity of sawnwood for buildings, the ratio of domestic wood of plywood for buildings, the floor area demolished, the ratio of domestic wood for demolished buildings, the amount of scrap wood from demolished buildings, and the density of plywood in outflow. The data related to wooden board were updated, namely: the sales and consumption quantity, the ratio of wood volume used per unit area (m^3/m^2 ratio), the ratio of use for raw material, the ratio of domestic wood of chips from logs for raw material wood board by *Current Production Statistics, Ceramics and building materials* *statistics* (METI), and the shipment quantity of wooden board by use by Japan Fiberboard and Particleboard Manufacturers Association. See Chapter 10 for the impact of recalculations on the trend.

f) ***Category-specific Planned Improvements***

The wood input per unit floor area of buildings constructed may change in the future, through increased use of domestic wood for buildings.

The amount of wood per unit floor area of non-wood buildings has not been updated since 2013 when the Forestry Agency's survey was conducted, because that amount had no longer been included in the *Survey on Actual Demand of Construction Labor and Materials* (MLIT) since 1991. If the MLIT statistics are updated, the latest updated values will be used.

For the density of coniferous sawnwood, the default value (0.450) provided in the *2019 Refinement* is currently used. Taking into account the availability of domestic statistics, appropriate methods for calculating and implementing country-specific values for this parameter will be considered.

6.10.2. Wood for other uses than buildings

a) ***Category Description***

This category deals with carbon stock changes in sawnwood, wooden board and plywood for other uses than buildings. The net emissions from this subcategory in FY2021 were 101 kt-CO_2, a decrease of 82.9% from FY1990 and a decrease of 72.2% from FY2020.

In the CRF tables, this category is reported as "Sawnwood for non-buildings", "Wooden board for non-buildings" and "Plywood for non-buildings" under "Other (please specify)".

b) ***Methodological Issues***

- ***Estimation Method***

The carbon stock changes in the HWP pool of this category were estimated as the difference between the HWP pool in the reference year and prior year by using the first-order decay (FOD) function (Tier 2 method) described in the *2006 IPCC Guidelines.* Inflow to the HWP pool during one year was estimated by multiplying the amount of wood for other uses than buildings by the ratio of domestic wood of each subcategory (sawnwood, wooden board and plywood) and the carbon conversion factor. The estimation equations are as follows.

$$\Delta C_{j,i} = C_{j,i} - C_{j,i-1}$$

$$C_{j,i} = e^{-k_j} \times C_{j,i-1} + \left[\frac{\left(1 - e^{-k_j}\right)}{k_j}\right] \times Inflow_{j,i}$$

j	: Subcategory (sawnwood, wooden board, plywood)
i	: Year for calculation
$\Delta C_{j,i}$	: Carbon stock change in subcategory j of the wood for other uses than buildings HWP pool during year i [t-C/year]
$C_{j,i}$	: Carbon stock in subcategory j of the wood for other uses than buildings HWP pool at the beginning of year i [t-C]
	* $C_{j,(1900)} = 0$: Carbon stock in 1900 was assumed to be zero

k_j	: $k_j = \ln(2) / HLj$
	HLj: half-life in subcategory *j* of the wood for other uses than buildings HWP pool
$Inflow_{j,i}$	: Inflow to subcategory *j* of the wood used for other than buildings HWP pool during year *i* [t-C/year]

$$Inflow_{j,i} = V_{p\ j,i} \times f_{DP\ j,i} \times D_j \times CF_j$$

j	: Subcategory (sawnwood, wooden board, plywood)
i	: Year for calculation
$Inflow_{j,i}$	: Inflow to subcategory *j* of the wood for other uses than buildings HWP pool during year *i* [t-C/year]
$VP_{j,i}$	: Amount of wood in subcategory *j* for other uses than buildings [m^3/year]
$fDP_{j,i}$	: Ratio of domestic wood in subcategory *j* for other uses than buildings during year *i* [%]
D_j	: Density (oven dry mass over air dry volume) [t-d.m./m^3]
CF_j	: Carbon fraction [t-C/t-d.m.]

- ***Parameters***

➢ ***Ratio of domestic wood***

- ***Sawnwood***

The ratio of domestic wood for sawnwood for other uses than buildings was calculated by dividing the amount of shipped sawnwood produced from domestic wood by tree species, by the amount of shipment.

- ***Wooden board***

The sales and consumption quantity of wooden board (domestic wood) for other uses than buildings by raw material (logs, wood residue in mills and forestry practices and scrap wood) was calculated by multiplying the proportion of raw materials in particle board and fiberboard, by the ratio of domestic wood for each raw material. The ratio of domestic wood for each raw material was estimated in the same way as for that of wooden board for buildings described in 6.10.1. The ratio of domestic wood for each wooden board type was estimated by dividing the sales and consumption quantity of wooden board (domestic wood) above, by the sales and consumption quantity of wooden board for other uses than buildings.

- ***Plywood***

The ratio of domestic wood for plywood for other uses than buildings, was calculated by dividing the amount of input materials from domestic wood for plywood for other uses than buildings by the sum of the amount of input materials for plywood and imported veneers for plywood (in roundwood-equivalent volume).

➢ ***Default half-lives***

The default half-lives (sawnwood: 35 years, wood panels: 25 years) described in *the 2019 Refinement* were applied (Table 12.3). The default half-lives of wood panels are used for wooden board and plywood.

➢ ***Density and carbon fraction***

The default values used are the same as for the "Buildings" category (section 6.11.1) (See Table 6-61 for the details).

Table 6-63 Data used for parameters (wood for other uses than buildings)

	Variable	Reference	Note
	Variable	Reference	Note
1	Shipment quantity of sawnwood (domestic wood for other uses than buildings)	*Report on Supply and Demand of Lumber* (MAFF)	
2	Sales and consumption quantity of wooden board	*Current Production Statistics, Ceramics and Building Materials Statistics* (METI)	Including own-use
3	Imported wood chips	*Trade Statistics of Japan* (MOF)	
4	Production of domestic wood chips	*Report on Supply and Demand of Lumber* (MAFF)	
5	Domestic log chips (for pulp)	*Trends in Pulp Collection* by Japan Paper Association	
6	Quantity of log input for wood chips (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
7	Quantity of wood input for wood chips (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	
8	Imports of plywood (veneer)	*Trade Statistics of Japan* (MOF)	
9	Quantity of log input for plywood (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
10	Quantity of log input for plywood (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	

METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

● ***Activity Data***

Activity data used were the shipment of sawnwood, sales and consumption quantity of wooden board, and production of plywood. The shipment of sawnwood was estimated by subtracting the shipment quantity of sawnwood for buildings from the total shipment quantity of sawnwood in *the Report on Supply and Demand of Lumber* (MAFF). The sales and consumption quantity of wooden board for other uses than buildings was estimated by multiplying the sales and consumption quantity of wooden board of each type (PB, HB, MDF and LDF) in the *Current Production Statistics, Ceramics and building materials statistics* (METI), by the ratio of other uses than buildings, calculated from *Shipments of wood-based board production* (Japan Fiberboard and Particleboard Manufacturers Association) . The amount of production of plywood was obtained from the *Report on Supply and Demand of Lumber* (MAFF). The wood used for renovations, the floor area of which has been subtracted from that of building construction, is taken into account in this category.

➢ ***Method of tracing back up to 1900***

As for wood for other uses than buildings, the data were extrapolated backward to 1990 using the equation 12.6 described in section 12.2.3 in *the 2006 IPCC Guidelines*. For the estimated annual rate for industrial round wood production (*U*), the default value of Asia between 1900 and 1961 (0.0217) was used (*2006 IPCC Guidelines*, Table 12.3).

$$V_t = V_{1961} \times e^{[U \times (t-1961)]}$$

V_t	: Annual production for other wood use [kt-C/year]
t	: Year (1900-1961)
V_{1961}	: Annual production for other wood use for the year 1961 [kt-C/year]
U	: Estimated continuous rate of change in industrial roundwood consumption for the region that includes the reporting country between 1900 and 1961

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

The uncertainties of carbon stock changes of wood for other uses than buildings were assessed based on the uncertainties of the default factors provided in the *2019 Refinement* and the uncertainties of statistical data. The uncertainty was estimated as 30% for the carbon stock changes in wood for other uses than buildings.

- ***Time-series Consistency***

The data before 1961 were extrapolated backward to 1990 using the equation 12.6 described in section 12.2.3 in *the 2006 IPCC Guidelines*, and the time-series consistency for this subcategory is ensured. The activity data and any parameter after 1962 used consistent statistics.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on checking the parameters for activity data and emission factors and archiving reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

The carbon stock changes for all years were recalculated with the correction of errors in the input data, namely the amount of wood input of wooden board and plywood, as well as with the Category-specific Recalculations for the Buildings category described in 6.10.1. See Chapter 10 for the impact of recalculations on the trend.

f) ***Category-specific Planned Improvements***

Wood used mainly in the form of roundwood in the civil engineering and construction field is not included in the HWP estimation at present.

6.10.3. Paper and paperboard

a) ***Category Description***

This category deals with carbon stock changes in paper and paperboard (including waste paper). The net removals (carbon stock changes) in this subcategory in FY1990 were 535 kt-CO_2, the net emissions in FY2020 were 780 kt-CO_2, and the net emissions in FY2021 were 133 kt-CO_2.

b) ***Methodological Issues***

- ***Estimation Method***

The carbon stocks changes in the HWP pool in paper and paperboard were estimated from the difference between the HWP pool in the reference year and prior year in the same way as used in the "wood used for other uses than buildings" category by using the FOD function (Tier 2 method) described in the *2006 IPCC Guidelines.* Inflow to the HWP pool during one year was estimated by multiplying the amount of production of paper and paperboard, by the ratio of domestic wood for paper and paperboard and the carbon conversion factor. The estimation equations are as follows.

$$\Delta C_i = C_i - C_{i-1}$$

$$C_i = e^{-k} \times C_{i-1} + \left[\frac{(1-e^{-k})}{k}\right] \times Inflow_i$$

ΔC_i	: Carbon stock change of paper products HWP pool during year *i* [t-C/year]
C_i	: Carbon stock in paper products HWP pool at the end of year *i* [t-C]
	*$C_{(1900)}$=0; Carbon stock in 1900 was assumed to be 0.
$Inflow_i$	: Inflow to the HWP pool in year *i* [t-C/year]
k	: k=ln(2) / HL
	HL: half-life of the HWP pool: two years
i	: year for calculation

$$Inflow_i = PP_{p\,i} \times f_{DP\,i} \times C_{cf}$$

$Inflow_i$	: Inflow to the HWP pool in year *i*[t-C/year]
$PP_{P\,i}$	: Production of paper and paperboard during year *i* [t]
$f_{DP\,i}$	: Rate of domestic logs for paper and paperboard during year *i* [%]
C_{cf}	: C conversion fraction [t-C/t]
i	: year for calculation

- ***Parameters***

➢ ***Ratio of domestic wood***

The ratio of domestic wood for paper and paperboard was estimated by estimating the amount of domestic production of paper pulp and that of waste paper and waste paper pulp respectively and dividing the amount by the total amount of domestic production of paper and paperboard.

The ratio of domestic wood for paper pulp was estimated by dividing the domestic and imported consumption of paper pulp made from logs and chips, by the total consumption of raw materials in the *Current Production Statistics, Paper, printing, plastic products and rubber products statistics* (METI). Since domestic wood chips in these statistics included chips which were domestically produced from imported wood, the amount of such chips was excluded in the estimation of the ratio of domestic wood for paper pulp, using the input of domestic and imported raw materials for chips, and the ratio of domestic wood for buildings.

The ratios of domestic wood for waste paper and waste paper pulp were estimated by estimating the amount of domestic supply from the production of waste paper in the *Current Production Statistics Paper, printing, plastic products and rubber products statistics* by METI and from the import and export amounts of waste paper in the *Trade Statistics of Japan* by MOF.

Table 6-64 Data used for parameters (Paper and paperboard)

	Variable	Reference	Note
1	Consumption of raw materials for pulp products	*Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products Statistics (*METI)	Used for calculating rate of domestic logs
	Made from domestic wood		
	Logs		
	Chips		
	Chips made from imported wood		
2	Production of waste paper	*Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products Statistics* (METI)	FAOSTAT (Recovered paper)
3	Imports and Exports of waste paper	*Trade Statistics of Japan* (MOF)	FAOSTAT (Recovered paper)
4	Imports and Exports of paper and paperboard	*Trade Statistics of Japan* (MOF)	FAOSTAT (Paper and Paperboard)
5	Rate of production of wood chips	*Report on Supply and Demand of Lumber* (MAFF)	Used for estimating the ratio of domestic wood for pulp production chips
6	Quantity of wood input for wood chips (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
7	Quantity of wood input for wood chips (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	

METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

➢ ***Half-life***

The default half-life for paper and paperboard (2 years) described in the*2019 Refinement* (Vol.4, Tables 12.3) was used.

➢ ***Default conversion factors for Paper and paperboard***

The default parameters (C conversion factor: 0.386 t-C/t) for paper and paperboard described in the *2019 Refinement* (Tables 12.1) were used.

● ***Activity Data***

➢ ***Method since 1961***

The amount of domestic production of paper and paperboard used was the sum of domestic pulpwood and chips obtained from the *Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products Statistics* (METI). These are the same as the production amount of Paper and Paperboard in FAOSTAT.

➢ ***Method of tracing back up to 1900***

For paper and paperboard, the estimation method is the same as for wood for other uses than buildings. For detailed information on the equation and the parameters, see section 6.10.2.

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

The uncertainties of carbon stock changes of paper and paperboard were assessed based on the uncertainties of the default factors provided in the *2019 Refinement* and the uncertainties of exiting statistical data.

The uncertainty was estimated as 30% for carbon stock changes in paper and paperboard.

- ***Time-series Consistency***

The data before 1961 were extrapolated backward to 1990 using the equation 12.6 described in section 12.2.3 in *the 2006 IPCC Guidelines*, and the time-series consistency for this subcategory is ensured. The activity data and any parameter after 1962 used consistent statistics.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on checking the parameters for activity data and emission factors and archiving reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

The carbon stock changes for all years were recalculated with the correction of errors in the input data, namely the production of waste papers and carbon conversion factor. See Chapter 10 for the impact of recalculations on the trend.

f) ***Category-specific Planned Improvements***

No improvements are planned.

6.11. Direct N_2O emissions from N inputs to managed soils (4.(I))

a) ***Category Description***

This category deals with direct N_2O emissions from N fertilization in land other than cropland and grassland. Emissions from the application of N fertilizer to forest land was estimated assuming that all fertilizers were synthetic, since the survey by the Forestry Agency showed that the majority of N fertilizers applied to forest land were mineral N fertilizers (synthetic fertilizers). The amount of N fertilizers applied to wetlands or settlements is not individually distinguished, however, their direct N_2O emissions from those categories were reported as “IE” since all direct N_2O emissions from all application of N fertilizers except those applied to forest land are estimated and reported in the Agriculture sector. The emissions from N fertilization in other land were reported as “NO” because there were no actual activities involving N fertilizer in other lands. Fertilization to forest land was reported all together in forest land remaining forest land because it was not possible to separate forest land remaining forest land from forest land converted to forest land. The emissions by this subcategory in FY2021 were 0.51 kt-CO_2 eq. This represents a decrease of 38.7% compared to FY1990.

Table 6-65 Direct N_2O emissions from N fertilization

Category			Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total			kt-N_2O	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
			kt-CO_2 eq.	0.84	0.72	0.67	0.64	0.56	0.54	0.56	0.54	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Forest land		Inorganic N fertilizers	kt-N_2O	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	Forest land remaining Forest land	Inorganic N fertilizers	kt-N_2O	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
	Land converted to Forest land	Inorganic N fertilizers	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Wetlands		Inorganic N fertilizers	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Wetlands remaining Wetlands	Inorganic N fertilizers	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Land converted to Wetlands	Inorganic N fertilizers	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Settlements		Inorganic N fertilizers	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Settlements land remaining Settlements	Inorganic N fertilizers	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Land converted to Settlements	Inorganic N fertilizers	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other		Inorganic N fertilizers	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

b) ***Methodological Issues***

- ***Estimation Method***

The direct N_2O emissions from synthetic N fertilization in forest land were estimated by applying Tier 2 estimation method based on decision tree described in the *2006 IPCC Guidelines* because country specific emission factors can be used. The estimation equation was the same as the Agriculture sector.

- ***Parameters***

The emission factor (0.62% [kg-N_2O-N/kg-N[13]]), which was applied to the estimation of N_2O emissions resulting from application of synthetic N fertilizer (no nitrification inhibitors) to agricultural soils (other crops), was also applied to the estimation of N_2O emissions from synthetic N fertilization to soils in forest land. For detailed information on the emission factor, see section 5.5.1.1.b) in chapter 5.

- ***Activity Data***

Results of surveys from 2006 to 2008 on fertilizer application to soils in forest land by the Forestry Agency of Japan were used as activity data. The amount of synthetic N fertilizer applied to soils in forest land in the years in which the surveyed data did not exist was estimated by multiplying the total amount of synthetic N fertilizer application in *Yearbook of Fertilizer Statistics (Pocket Edition)* by the average percentage of synthetic N fertilizer application to soils in forest land in the period from 2006 to 2008. The average percentage is 0.047% of the total amount of synthetic N fertilizer application.

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

The uncertainty estimates of N_2O emissions from N fertilization were 31% by applying the same value as the estimation of the N_2O emissions from N fertilization in the Agriculture sector.

- ***Time-series Consistency***

The emission factor is constant throughout the time series. For activity data, the same sources are multiplied by same ratio throughout the time series. Time-series consistency for this category is ensured.

[13] Akiyama et al. (2006)

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

No recalculations are conducted.

f) ***Category-specific Planned Improvements***

No improvements are planned.

6.12. CH_4 and N_2O Emissions from Drainage and Other Management of Organic soils (4.(II))

a) ***Category Description***

Regarding the CRF-category 4.(II) "emissions and removals from drainage and rewetting and other management of organic and mineral soils", the CH_4 and N_2O emissions from drainage and cultivation of organic soils were estimated but removals from rewetting of organic soils nor mineral soils were not included. The estimation status of each land-use category is as follows. The emissions from soil drainage activities in forest land are reported as "NO" because soil drainage activities are not carried out in general in Japan. Among cropland and grassland, N_2O emissions from cultivation of organic soils in pasture land and CH_4 emissions from rice cultivation in rice fields were reported in the Agriculture sector. As for the estimation of CH_4 emissions in other cropland and grassland in this category, only the emissions from uplands fields are estimated since the emissions from orchards and dilapidated farmland are reported as "NO" because soil drainage activities are not carried out. In the case of grassland, only CH_4 emissions from pasture land are estimated in this category because no farming activities are conducted in grassland other than pasture land (grazed meadow and wild land). As explained in section 6.7.1. b)1) , peatlands classified as wetland are reported as "NE" because they are considered to be a minor emission source, while flooded lands and other wetlands are reported as "NA" because the methodologies proposed in the *2006 IPCC Guidelines* and the *Wetland Guidelines* were not applied in Japan. The emissions and removals in the coastal wetland in this category were also reported as "NA" similar to the above. In addition, CH_4 and N_2O emissions from organic soil drainage activities in settlements converted from other land-use categories were estimated. As there are no sub-categories under "settlements" under the CRF Table, the report was made in the new section, "H. Others".

The emissions by this subcategory in FY2021 were 40.9 kt-CO_2 eq. This represents a decrease of 1.9% compared to FY1990, and a decrease of 0.7 % compared to FY2020.

Table 6-66 CH_4 and N_2O emissions from drainage of organic soils

Category			Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total			kt-CO_2 eq.	60.2	51.9	47.9	45.5	43.9	42.0	41.4	41.3	41.1	40.0	39.9	40.2	40.4	40.6	40.9
CH_4 Total			kt-CH_4	2.29	1.99	1.84	1.76	1.70	1.63	1.61	1.60	1.59	1.55	1.55	1.56	1.56	1.57	1.58
			kt-CO_2 eq.	57.2	49.7	46.0	43.9	42.4	40.7	40.1	40.1	39.8	38.7	38.6	38.9	39.1	39.3	39.6
	Forest land		kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Cropland		kt-CH_4	0.97	0.97	0.99	0.99	0.98	0.96	0.96	0.95	0.94	0.94	0.93	0.93	0.93	0.93	0.93
	Grassland		kt-CH_4	0.09	0.09	0.09	0.09	0.08	0.11	0.10	0.11	0.12	0.09	0.09	0.09	0.09	0.09	0.09
	Wetlands		kt-CH_4	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA
		Peat land	kt-CH_4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Flooded land	kt-CH_4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Other wetlands	kt-CH_4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Other (Organic soil in settlements converted from other land-use categories)		kt-CH_4	1.23	0.93	0.76	0.68	0.63	0.56	0.55	0.54	0.53	0.53	0.53	0.54	0.55	0.55	0.57
N_2O Total			kt-N_2O	0.010	0.007	0.006	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005
			kt-CO_2 eq.	2.94	2.22	1.82	1.62	1.52	1.33	1.31	1.28	1.26	1.26	1.26	1.28	1.30	1.32	1.36
	Forest land		kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Wetlands		kt-N_2O	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA
		Peat land	kt-N_2O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Flooded land	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Other wetlands	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Other (Organic soil in settlements converted from other land-use categories)		kt-N_2O	0.010	0.007	0.006	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005

b) *Methodological Issues*

- ***Estimation Method***

As for upland fields, grassland and settlements converted from other land-use categories, CH_4 emissions from drained inland organic soils were estimated by using Tier 1 method (Equation 2.6) described in section 2.2.2.1 in the *Wetlands Guidelines*.

$$CH_{4_{os}} = A_{os} \times \left[(1 - Frac_{ditch}) \times EF_{CH4\_land} + Frac_{ditch} \times EF_{CH4\_ditch}\right]$$

CH_{4os} : Annual CH_4 emissions from drained organic soils [kg-CH_4]

A_{os} : Land area of drained organic soils [ha]

EF_{CH4_land} : Emission factors for direct CH_4 emissions from drained organic soil from land surface [kg-CH_4/ha]

EF_{CH4_ditch} : Emission factors for CH_4 emissions from drainage ditches [kg-CH_4/ha]

$Frac_{ditch}$: Fraction of the total area of drained organic soil which is occupied by ditches

N_2O emissions from drained organic soil in settlements converted from other land-use categories were estimated by using Tier 2 method (Equation 2.7) described in section 2.2.2.2 in the *Wetlands Guidelines*.

$$N_2O\text{-}N_{os} = A_{os} \times EF_{os}$$

$N_2O\text{-}N_{os}$: N_2O-N emissions from drained organic soil [kg-N_2O-N/yr]

A_{os} : Area of organic soil in settlements converted from other land-use categories [ha]

EF_{os} : N_2O emission factor form drained organic soil [kg-N_2O-N/ha/yr]

- ***Parameters***

As for upland fields, grassland and Land converted to Settlements, the following emission factors for CH_4 from drained organic soils, emission factors for CH_4 from drainage ditches, and the proportion of ditches to the total area of drained organic soils which were provided by the *Wetlands Guidelines* Table 2.3 and Table 2.4, were applied to the estimation. Regarding to emission factors for N_2O from settlements converted from other land-use categories, since default emission factors for settlements have not been provided in the *2006 IPCC Guidelines* and the *Wetlands Guidelines*, considering that conversion to settlements mainly occurs in rice fields in Japan, country specific emission factor for rice field was applied.

Table 6-67 CH_4 and N_2O emission factors for drained organic soils from land surface

Land-use category	Emission factor	Unit	Climate/ vegetation zones
Cropland/Land converted to Settlements	0	kgCH4/ha/yr	Cropland, drained, Boreal and Temperate (the *Wetlands Guidelines*, Table 2.3)
Grassland	16	kgCH4/ha/yr	Grassland, deep-drained, nutrient-rich, Temperate (the *Wetlands Guidelines*, Table 2.3)
Land converted to Settlements	0.297	kgN2O-N/ha/yr	Country specific data (Actual measurement in rice field in Hokkaido)

Table 6-68 CH_4 emission factors for drained organic ditches

Land-use category	Emission factor	Unit	Frac ditch (indicative values)	Climate/ vegetation zones
Deep-drained Grassland/ Cropland/Land converted to Settlements	1165	kgCH4/ha/yr	0.05	Boreal/ Temperate, Deep drained Grassland, Cropland (Wetlands Guidelines, Table2.3)

- ***Activity Data***

For detailed information on the methods of determining the areas of organic soils in upland fields, grassland and settlements converted from other land-use categories, see section 6.5.1. and section 6.6.1.

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

The uncertainties for parameters were assessed on the basis of default values described in the *Wetlands Guidelines.* As a result, the uncertainty estimates for the CH_4 emissions from drained inland organic soils were 65%.

- ***Time-series Consistency***

The emission factor is constant throughout the time series. For activity data, the same sources are used throughout the time series. Time-series consistency for this category is ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

Since area of organic soil were revised, CH_4 and N_2O emissions from this category were recalculated for all years. See Chapter 10 for impact on trend.

f) ***Category-specific Planned Improvements***

No improvements are planned.

6.13. Direct N_2O emissions from N mineralization associated with loss of soil organic matter resulting from change of land use or management of mineral soils (4.(III))

a) *Category Description*

The category 4.(III) deals with direct N_2O emissions from N mineralization or N immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils. In accordance with the *2006 IPCC Guidelines*, N immobilization associated with the gain of soil organic matter is not considered, and only N_2O emissions from mineralization associated with loss of soil organic matter were estimated.

For forest land, the N_2O emissions from N mineralization associated with loss of soil organic matter resulting from normal forest management of forest land remaining forest land are included in the calculation because soil organic matter increases in land converted to forest land. For cropland, only the emissions from land converted to cropland are included in the calculation because the emissions from cropland remaining cropland are calculated in the Agriculture sector. For grassland, only the emissions from pastures are considered for the calculation because changes of soil organic matter occur only in pastures among the three subcategories. Changes of soil organic matter were reported collectively as grassland remaining grassland because it is impossible to distinguish between changes resulting from change of land use and changes resulting from management. For wetlands remaining wetlands, other land remaining settlements and other land remaining other land, N_2O emissions were reported as “NA” because the decrease in soil carbon stocks does not occur. The emissions from wetlands converted from other land use were reported as “NE” because methodology is not provided. Also, the emissions from land converted to settlements and land converted to other land were included in the calculation because soil organic matter is lost resulting from change of land use.

The emissions from this subcategory in FY2021 were 266.5 kt-CO_2 eq. This represents a decrease of 59.0% compared to FY1990, and an increase of 0.3 % compared to FY2020.

Table 6-69 Direct N_2O emissions from N mineralization

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total	kt-N_2O	2.18	1.89	1.74	1.53	1.24	1.17	1.11	1.05	1.01	0.97	0.94	0.91	0.91	0.90	0.90	0.89
	kt-CO_2 eq.	649.3	563.4	519.9	456.4	369.3	349.5	329.6	313.7	301.4	290.5	280.7	272.5	270.1	268.2	267.3	266.5
Forest land	kt-N_2O	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20
Forest land remaining Forest land	kt-N_2O	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.20	0.20	0.20	0.20
Land converted to Forest land	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cropland	kt-N_2O	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Land converted to Cropland	kt-N_2O	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Graassland	kt-N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Grassland remaining Grassland	kt-N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Land converted to Graassland	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Wetlands	kt-N_2O	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA
Wetlands remaining Wetlands	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Land converted to Wetlands	kt-N_2O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Settlements	kt-N_2O	1.66	1.41	1.31	1.15	0.91	0.85	0.79	0.74	0.71	0.68	0.65	0.62	0.61	0.60	0.60	0.60
Settlements remaining Settlements	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Land converted to Settlements	kt-N_2O	1.66	1.41	1.31	1.15	0.91	0.85	0.79	0.74	0.71	0.68	0.65	0.62	0.61	0.60	0.60	0.60
Other land	kt-N_2O	0.27	0.25	0.22	0.18	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.07
Other land remaining Other land	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Land converted to Other land	kt-N_2O	0.27	0.25	0.22	0.18	0.13	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.08	0.07	0.07	0.07

b) ***Methodological Issues***

- ***Estimation Method***

Equation 11.1 and Equation 11.8 described in session 11.2.1 in Vol.4 of the *2006 IPCC Guidelines* is used for estimation.

$$N_2O\text{-}N_{direct\text{-}N_{Minerarl_i}} = F_{SOM_i} \times EF_i \quad \text{(Equation 11.1, Vol.4 of the 2006 IPCC Guidelines)}$$

$$F_{SOM_i} = \sum_k \left(\Delta C_{Mineral_{i,k}} \times \frac{1}{R_{i,k}} \right) \quad \text{(Equation 11.8, Vol.4 of the 2006 IPCC Guidelines)}$$

$$\Delta C_{Mineral_{i,k}} = \sum_j \left(c_{ms-loss_{i,j,k}} \times A_{i,j,k} \right)$$

$N_2O\text{-}N_{direct\text{-}NMineral}$	: Direct N_2O emissions from N mineralization as a result of loss of organic matter in mineral soils [kg-N_2O-N]
F_{SOM}	: Annual amount of N mineralized in mineral soils as a result of loss of organic matter in mineral soils [kg-N]
EF	: Emission factor for N_2O emissions per amount of N mineralization [kg-N_2O-N/kg-N]
$\Delta C_{Mineral}$	: Average annual loss of soil carbon as a result of loss of organic matter in mineral soils [kg-C]
R	: C:N ratio for the soil organic matter
$c_{ms\text{-}loss}$	: Soil carbon loss per unit area as a result of loss of organic matter in mineral soils [kg-C/ha]
A	: Area of Mineral soils with soil carbon loss as a result of loss of soil organic matter [ha].
i	: Land use/type of land (forest land remining forest land, land converted to cropland (rice fields, upland fields, orchards), grassland (pastureland), land converted to other land)
j	: Regions (Hokkaido, Tohoku, Kanto, Hokuriku, Tokai/Kinki, Chugoku/Shikoku, Kyushu/Okinawa)
k	: Soil type (soil type based on the classification from Yagasaki and Shirato (2014)) considered only for cropland and grassland

For cropland and grassland, the equations above were summarized as follows and set as the N_2O emission factor per unit area ($EF_{N2O\text{-}Ni,j}$) [kg-N_2O-N].

$$N_2O\text{-}N_{direct\text{-}N_{Minerarl_{i,j}}} = c_{ms-loss_{i,j,k}} \times A_{i,j,k} \times \frac{1}{R_{i,k}} \times EF_i$$

$$= \left\{ EF_i \times \sum_k \left(c_{ms-loss_{i,j,k}} \times \frac{1}{R_{i,k}} \right) \right\} \times \sum_k \left(A_{i,j,k} \right)$$

$$= EF_{N2O\text{-}N_{i,j}} \times A_{i,j}$$

- ***Parameters***

➢ ***Parameters used for forest land remaining forest land, Land converted to Settlements and Land converted to Other land***

- ***Soil carbon loss resulting from loss of organic matter in mineral soils in forests land remaining forest land ($\Delta C_{Mineral}$)***

The change in soil carbon stock per unit area obtained by the Century-jfos model described in 6.5.1.b)2 where the decrease in soil carbon occurred were multiplied by the area.

- ***Soil carbon loss resulting from loss of organic matter in mineral soils on other land converted to settlement and other land converted from other land use ($\Delta C_{Mineral}$)***

For the amount of soil carbon loss resulting from loss of organic matter in mineral soils in land converted to other land, the amount of loss in carbon stock in mineral soils caused by land-use change obtained in 6.8.2b)3 and 6.9.2b)3 was used.

- ***Emissions of N_2O per amount of N mineralization (EF_i)***

The default value [0.006 kg-N_2O-N/kg-N] described in the *2019 Refinement* was used.

- ***C/N ratio for solids (R_i)***

C/N ratio in forest land was used from the *2006 IPCC Guidelines.* Country specific C/N ratio were used for cropland and grassland, whcih were established by the result of domestic soil survey (Table 6-70).

Table 6-70 C/N ratio for soil by land use [kg-C/kg-N]

Land use	C/N ratio	Reference
Forest	15.0	*2006 IPCC Guidelines*, Vol.4, chp.11, p11-16
Average of Cropland and Grassland	12.0	Established by all carbon amount and all nitrogen amount in soil expect for organic soil in each land use from the data of soil group based on regular point observation from 2015 to 2018 in Matsui, et al. (2021).
Rice fields	11.5	
Paddy fields	12.3	
Orchards	11.6	
Pasture land	13.1	

➢ ***Parameters used for cropland (converted from other land use) and grassland***

The following parameters were set by Shirato et al. (2021). An overview of the settings is given as below. Note that the same parameters as those used in the agriculture sector are used (See section 5.5.1.5.b).

- ***Soil carbon loss per unit area resulting from loss of organic matter in mineral soil ($c_{ms\text{-}loss\ i,j,k}$)***

The decomposition amount of soil carbon per unit area not derived from the input of organic matter was calculated by using the Roth C model described in section 6.5.1.b)3) by setting the input of organic matter at zero for the most recent year after giving the long-term normal operation of the models calculating the changes in soil carbon stock for the past years. Calculations were performed for five years from FY2014 to FY2018, taking annual variations into account. The average value for five years was calculated for each land type, region, and soil type, and this constant value was used as a fixed value in the time series.

- ***C/N ratio for solids ($R_{i,k}$)***

The 0-30 cm depth data obtained from field surveys conducted in 2015-2018 for each land use and each soil type of cropland were used. The soil types were organized into three groups, and the results of the mean values for each land type are shown in Table 6-71.

Table 6-71 C/N ratio by soil type for each type of land use in cropland and grassland

Soil type	Rice fields	Upland fields	Orchards and tea plantations	Pasture land
Lowland soils	10.9	11.4	11.0	11.6
Andosols	13.5	12.8	13.0	13.9
Other soils	10.8	10.3	10.5	11.4

- ***Amount of emission factors of N_2O per unit area ($EF_{N2O\_Ni,j}$)***

The emissions of N_2O per unit area ($EF_{N2O-Ni,j}$) in land use and soil type of land (i) and region (j) were calculated using the N_2O statistical model of Mu et al. (2009) given by the following equation.

$$EF_{N2O\text{-}N_{i,j}} = 0.0801 \times e^{0.00722 \times c_{ms-loss_{i,j,k}} \times \frac{1}{R_{i,k}}}$$

However, since the aforementioned statistical model does not take into account for the data of rice fields, the default emission factor for N_2O per mineralized N in rice fields (EF_{1FR}=0.004) listed in Table 1 of section 11.2.1.2 in the *2019 Refinement* was applied for rice fields.

The results of the calculations performed by Shirato et al. (2021) are shown in the Table 6-72.

Table 6-72 Emission factors of N_2O per unit area in each region for each type of land use in cropland and grassland ($EF_{N2O-Ni,j}$)

Region	Rice fields	Upland fields	Orchards and tea plantations		Pasture land
			Orchards	Tea plantations	
Hokkaido	0.244	0.210	0.246	—	0.206
Tohoku	0.269	0.189	0.197	—	0.187
Kanto	0.291	0.166	0.181	0.178	0.178
Hokuriku	0.265	0.167	0.192	0.177	0.199
Tokai-Kinki	0.284	0.172	0.194	0.179	0.195
Chugoku-Shikoku	0.307	0.200	0.190	0.199	0.191
Kyusyu-Okinawa	0.310	0.197	0.181	0.178	0.173

- ***Activity Data***

  - ***Mineral soil area with loss of soil carbon resulting from loss of soil organic matter in cropland and grassland (A)***

In cropland and grassland, area of mineral soils in cropland and grassland (pasture land) was used as activity data because soil disturbance caused by land-use change and normal agricultural activities oxidizes the organic matter in mineral soils and causes carbon loss. In pasture land, the area of activity was defined as the mineral soil area multiplied by the renewal rate used in 6.7.1b), because the area where renewal was carried out was considered to be the area where there was actual activity involving soil disturbance.

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainty Assessment***

The uncertainties of emissions/removals for forest land, settlements and other land were assessed on the basis of carbon stock change in soil and C:N ratio for the soil organic matter. The uncertainties of parameters described in the *2006 IPCC Guidelines* were used. The uncertainty of emissions/removals for land converted to cropland and grassland were assessed by using the standard deviation for EFs described in Shirato et al. (2021) and by using the standard error for ADs given in the *Statistics of Cultivated and Planted Area*, which are the same as the assessments conducted in Agriculture sector. As a result, the uncertainties in the N_2O emissions from N mineralization associated with loss of soil organic matter were assessed at -54% to +145%.

- ***Time-series Consistency***

The emission factor is constant throughout the time series. For activity data, the same sources are used throughout the time series. Time-series consistency for this category is ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

Other land converted to settlements from N mineralization were estimated, and the revision of C/N ratio, emission of N_2O per amount of N mineralization and the area of mineral soils are recalculated in cropland and grassland, N_2O emissions in forest land, cropland, grassland and other land from this category were recalculated for all years. See Chapter 10 for impact on trend.

f) ***Category-specific Planned Improvements***

No improvements are planned.

6.14. Indirect nitrous oxide (N_2O) emissions from managed soils (4.(IV))

a) ***Category Description***

This category deals with indirect N_2O emissions from managed soils. The indirect N_2O emissions include, N_2O emissions from N volatilization as NH_3 and NO_x and deposition of these gases and their products NH_4^+ and NO_3^- onto soils and the surface of lakes and other waters, and N_2O emissions from leaching and runoff in regions where these events occur. In Japan, the indirect N_2O emissions from N fertilization in forest land and the indirect N_2O emissions from N mineralization associated with loss of soil organic matter were estimated.

The emissions from this category in FY2021 were 119.3 kt-CO_2 eq. This represents a decrease of 58.3% compared to FY1990, and a decrease of 0.1% compared to FY2020.

Table 6-73 Indirect N_2O emissions from managed soils

Category		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total		kt-N_2O	0.97	0.84	0.77	0.68	0.55	0.49	0.47	0.45	0.43	0.42	0.41	0.40	0.40	0.40	0.40
		kt-CO_2 eq.	290.3	250.3	229.9	201.7	163.4	146.1	139.3	133.9	129.1	124.8	121.4	120.5	119.8	119.5	119.3
	Atmospheric deposition	kt-N_2O	0.0007	0.0006	0.0006	0.0005	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
	Nitrogen leaching and run-off	kt-N_2O	0.97	0.84	0.77	0.68	0.55	0.49	0.47	0.45	0.43	0.42	0.41	0.40	0.40	0.40	0.40

b) *Methodological Issues*

1) N_2O emission from atmospheric deposition of N volatilized

- ***Estimation Method***

The Tier 1 method described in section 11.2.1.1 in the *2006 IPCC Guidelines* is used.

$$N_2O\text{-}N_{ATD} = (F_{SN} \times Frac_{GASF}) \times EF_4$$

$N_2O\text{-}N_{ATD}$	: Annual amount of N_2O–N produced from atmospheric deposition of N volatilized [kg N_2O-N]
F_{SN}	: Annual amount of synthetic fertilizer N applied to forest land [kg-N]
$Frac_{GASF}$	: Fraction of synthetic fertilizer N that volatilized as NH_3 and NO_X [kg-NH_3-N + NO_X-N/kg-N]
EF_4	: Emission factor for N_2O emissions from atmospheric deposition of N on soils and water surfaces [kg-N_2O-N/kg-NH_3-N+NO_X-N]

- ***Parameters***

Default values from the *2019 Refinement* were used.

- ***Fraction of synthetic fertilizer N that volatilized as NH_3 and NO_X***

0.11[kg NH_3-N +NOx-N/kg N applied] (Table 11.3 in Vol.4, aggregated)

- ***Emission factor (N volatilization and re-deposition)***

0.014 [kg N_2O-N/kg NH_3-N +NOx-N volatilized] (Table 11.3 in Vol.4, disaggregated, wet climate)

- ***Activity Data***

For amount of synthetic N fertilizer applied to forest land, see section 6.11.

2) N_2O emission from leaching/runoff

- ***Estimation Method***

The Tier 1 method described in section 11.2.2.1 in Vol.4 of the *2006 IPCC Guidelines* is used.

$$N_2O\text{-}N_{leach} = (F_{SN} + F_{SOM}) \times Frac_{LEACH-H} \times EF_5$$

$N_2O\text{-}N_{leach}$	: Annual amount of N_2O–N produced from leaching and runoff of N additions [kg N_2O-N]
F_{SN}	: Annual amount of synthetic fertilizer N applied to forest land [kg-N]
F_{SOM}	: Annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter [kg-N]
$Frac_{LEACH-H}$	: Fraction of all N mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff [kg-N/kg-N]
EF_5	: Emission factor for N_2O emissions from N leaching and runoff [kg-N_2O-N]

- ***Parameters***

Default values from the *2019 Refinement* were used.

- ***Fraction of all N mineralized in managed soils***

0.24 [kg N/kg nitrogen of fertilizer] (Table 11.3 in Vol.4, aggregated)

- ***Emission factor (N leaching and runoff)***

0.011 [kg N_2O-N/(kg N leaching/runoff)] (Table 11.3 in Vol.4, aggregated)

- ***Activity Data***

For amount of N fertilizer applied to forest land, see section 6.11. For amount of N mineralization associated with loss of soil organic matter, see section 6.12.

c) ***Uncertainties and Time-series Consistency***

The uncertainty of indirect N_2O emissions from N fertilizer was assessed based on the uncertainty of the emission factor (see the *2006 IPCC Guidelines*, p.11.24) and that of the amount of fertilizer. The uncertainty of indirect N_2O emissions from N mineralization associated with loss of soil organic matter was 288%, which is the same value with the uncertainty of in direct N_2O emissions from N mineralization associated with loss of soil organic matter. Consequently, the uncertainty of indirect N_2O emissions from this category was assessed at -92% to +276%.

- ***Time-series Consistency***

The emission factor is constant throughout the time series. For activity data, the same sources are used throughout the time series. Time-series consistency for this category is ensured.

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

- ***Changes due to the revision of the method for calculating N_2O emissions from N mineralization***

Emissions have been recalculated for all years following the revision of the methodology for calculating N_2O emissions from N mineralization of soil organic matter, as indicated in section 6.13.

- ***Correction in accordance with revision of area estimation***

Since area of the area of mineral soils are recalculated in cropland and grassland, the indirect N_2O emissions from managed soils were recalculated for all years (see section 6.13.). See Chapter 10 for impact on trend.

f) ***Category-specific Planned Improvements***

No improvements are planned.

6.15. Biomass burning (4.(V))

a) ***Category Description***

This category deals with emissions of CH_4, CO, N_2O and NOx from biomass burning. For the emissions of CO and NO_X, see Annex 3.

For forest land, the emissions resulting from wildfires in forest land remaining forest land and land converted to forest land are reported in a lump for wildfires in forest land remaining forest land, because the data in the statistics for forest fires include the wildfires occurred in both of the categories. Moreover, controlled burning activities in forests and land conversion from land-use categories other than forest land to forest land are not implemented in Japan because the activities are stringently restricted by the "Waste Management and Public Cleansing Act" and "Fire Service Act". Hence, the emissions resulting from controlled burning in forest land do not occur and are reported as "NO".

CH_4 and N_2O emissions from controlled burning in cropland are estimated for woody biomass burning of pruned branches from orchard. One of the characteristics of Japan's cropland is intensive management. Under this management style, the occurrences of wildfire are regarded as negligible. CH_4 and N_2O emissions from wildfires in cropland are reported as "NO". In addition, CH_4 and N_2O emissions from controlled burning in grassland are estimated. CH_4 and N_2O emissions from wildfires in grassland are reported as "NO" for the same reasons as cropland.

CH_4 and N_2O emissions from wildfires in land other than forest land, cropland and grassland are reported as "NE" because information on wildfires is not enough. CH_4 and N_2O emissions from biomass burning in Wetlands are reported as "NE" because it can be considered insignificant.

CO_2 emission is not included in this category because it was included in estimation of carbon stock changes.

The emissions by this subcategory in FY2021 were 56.0 kt-CO_2 eq. This represents a decrease of 19.3% compared to FY1990 and a increase of 14.3% compared to FY2020. These fluctuations are due to less amount of woody biomass burning of pruned branches from orchard over the long run, while, in the short run, inconsistencies of wildfire occurrences also effect it.

Table 6-74 Non-CO_2 emissions from biomass burning

Category		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total		kt-CO_2 eq.	69.4	66.8	63.0	62.9	54.9	51.0	53.0	73.1	54.7	49.2	72.6	49.5	52.1	49.0	56.0
CH_4 Total		kt-CH_4	1.9	1.8	1.7	1.7	1.4	1.3	1.3	2.1	1.4	1.2	2.1	1.2	1.3	1.2	1.47
		kt-CO_2 eq.	47.2	45.3	42.2	42.4	35.3	31.8	33.7	52.3	35.3	30.3	52.0	30.8	33.1	30.3	36.9
	Forest land	kt-CH_4	0.4	0.4	0.4	0.4	0.2	0.1	0.2	0.9	0.2	0.1	0.9	0.1	0.2	0.1	0.4
	Cropland	kt-CH_4	1.0	0.9	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6
	Grassland	kt-CH_4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Wetlands	kt-CH_4	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
	Settlements	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Other land	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Other	kt-CH_4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N_2O Total		kt-N_2O	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.07	0.06	0.06	0.07	0.06	0.06	0.06	0.064
		kt-CO_2 eq.	22.1	21.5	20.8	20.5	19.6	19.2	19.3	20.8	19.4	18.9	20.6	18.8	18.9	18.6	19.1
	Forest land	kt-N_2O	0.0028	0.0028	0.0025	0.0030	0.0013	0.0005	0.0011	0.0063	0.0017	0.0004	0.0064	0.0007	0.0014	0.0007	0.0026
	Cropland	kt-N_2O	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Grassland	kt-N_2O	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	Wetlands	kt-N_2O	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
	Settlements	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Other land	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Other	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

b) ***Methodological Issues***

1) CH_4 and N_2O emissions from forest fires

- ***Estimation Method***

For CH_4, and N_2O emissions due to biomass burning from forest fires, the Tier 1 method is used in the *2006 IPCC Guidelines*.

➢ ***Forest land***

- ***CH_4***

$$bbGHG_f = L_{forest\ fires} \times ER$$

- ***N_2O***

$$bbGHG_f = L_{forest\ fires} \times ER \times NC_{ratio}$$

$bbGHG_f$	: GHG emissions due to forest biomass burning
$L_{forest\ fires}$	: Carbon released due to forest fires [t-C/yr]
ER	: Emission ratio (CH_4 : 0.012, N_2O : 0.007)
NC_{ratio}	: Nitrogen Carbon ratio of the biomass

- ***Parameters***

➢ ***Emission ratio***

The following values are applied to emission ratios for non-CO_2 gases due to biomass burning.

CH_4: 0.012, N_2O: 0.007 (Default value stated in the *GPG-LULUCF*, Table 3A.1.15)

➢ ***NC ratio***

The following values are applied to NC ratio.

NC ratio: 0.01 (default value stated in the *GPG-LULUCF* p.3.50)

- ***Activity Data***

➢ ***Forest land***

As activity data in forest land, carbon stock loss due to forest fire is used. Carbon stock loss due to forest fire is estimated by the Tier 3 method in the *2006 IPCC Guidelines*. For each of the national forest land and private forest land, carbon stock loss are calculated from the fire-damaged timber volume multiplied by wood density, the biomass expansion factor and the carbon fraction of dry matter.

$$L_{forest\ fires} = \Delta C_n + \Delta C_p$$

$L_{forest\ fires}$	: carbon stock loss due to forest fire [t-C/yr]
ΔC_n	: carbon stock loss due to fire in national forests [t-C/yr]
ΔC_P	: carbon stock loss due to fire in private forests [t-C/yr]

Fire-damaged timber volume is separately estimated for national forests and private forests. With regard to national forests, the timber volume of standing trees damaged due to fires in national forests in the *Handbook of Forestry Statistics* is used. With regard to private forests, the damaged timber volume due to fires is estimated by using the actual damaged area and damaged timber volume by age class (inquiry survey by Forestry Agency). Damaged timber volume for age classes equal to or under 4 is calculated by multiplying the stand volume per unit area of age class equal to or under 4 estimated by the Forestry Status Survey and the NFRDB by loss ratio (ratio of damaged timber volume to stand volume) of damaged timber volumes whose age classes equal to or over 5 in private forests. The loss ratio is assumed to be constant regardless of age classes.

- ***National forest, Private forest***

$$\Delta C_{n,p} = Vf_{n,p} \times D_{n,p} \times BET_{n,p} \times CF_{n,p}$$

The values for wood density and biomass expansion factors for national and private forest land are

$\Delta C_{n,p}$	: Carbon loss due to fire in national forests and private forest [t-C/yr]
$Vf_{n,p}$	: Damaged timber volume due to fire in national forests and private forest [m^3/yr]
$D_{n,p}$	: Wood density in national forests and private forest [t-d.m./m^3]
$BEF_{n,p}$	: Biomass expansion factor for national forests and private forest
CF	: Carbon fraction of dry matter [t-C/t-d.m.]

determined as weighted averages using the ratios of intensively managed forests and semi-natural forests.

Table 6-75 Wood density and biomass expansion factors for national and private forests

Type	Wood density [t-d.m./m^3]	Biomass expansion factor
National forest	0.49	1.61
Private forest	0.46	1.61

Reference: Based on Forestry Agency data

Table 6-76 Damaged timber volume due to wildfire

Category			Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Damaged timber volume due to disturbance in national forest			m^3	3,688	1,014	1,599	359	16,091	360	279	5,326	2,472	916	75	112	49	275	498
Damaged timber volume due to disturbance in private forest			m^3	63,602	68,361	60,228	72,575	15,810	12,269	26,620	147,989	38,571	8,151	157,051	16,309	34,245	17,235	62,763
	≧5	Actual damaged area	kha	0.29	0.94	0.48	0.35	0.07	0.10	0.18	0.53	0.22	0.04	0.35	0.09	0.15	0.07	0.30
		Damaged timber volume	m^3	47,390	58,129	54,487	59,235	12,780	11,566	25,204	137,078	36,693	7,370	153,412	15,148	33,276	15,914	61,583
	≦4	Actual damaged area	kha	0.27	0.51	0.16	0.27	0.06	0.03	0.04	0.18	0.05	0.02	0.04	0.03	0.02	0.03	0.03
		Damaged timber volume	m^3	16,212	10,232	5,741	13,340	3,030	703	1,416	10,911	1,878	781	3,639	1,161	969	1,321	1,180

Reference: Based on *Handbook of Forestry Statistics* for national forest, and Forestry Agency data for private forest

- ***Note***

In Japan, emissions due to biomass burning are estimated separately for national forests and for private forests, because of different reporting procedures in regard to forest fire information. However, forest fires in Japan are covered by a set of data for both national forests and private forests, and the emissions are thus appropriately estimated.

2) CH_4 and N_2O emissions from burning of pruned branches from orchard trees

- ***Estimation Method***

For CH_4 and N_2O emissions due to biomass burning of pruned branches from orchard trees, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* was applied. The estimation equation is as follows:

$$L_{fire} = W_B \times C_f \times G_{ef} \times 10^{-6}$$

L_{fire}	: Amount of greenhouse gas emission from fire [kt- GHG]

W_B : Amount burnt [t-d.m.]
C_f : Combustion factor
G_{ef} : Emission factor [t/kt-d.m.]

- ***Parameters***

For the combustion factor, a value of 0.9 which has been used generally in field burning of crop residues in agriculture in Japan is applied. For emission factor, the default emission factors of “Agricultural residue” provided in the *2006 IPCC Guidelines* are used.

Table 6-77 Emission factors [t/kt-d.m.]

Category	CH_4	N_2O
Agricultural residue	2.7	0.07

Reference: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

- ***Activity Data (Amount burned)***

The amount burned data was calculated by multiplying the same the cultivation area of the orchard trees as used in the calculation of carbon stock change in 4.B., by the MAFF by dry matter residue weight per unit area (400kg/10a) from the domestic field survey conducted by the National Institute of Resources (1982), and ratio of burning of pruned branches in field (25%) from the result of monitoring survey of soils in 2008.

$$W_B = \sum_i (A_i \times E \times 10) \times R$$

W_B : Amount of burning pruned branches from orchard trees [kg-d.m.]
A : Cultivation area of orchard trees [ha]
E : Dry matter residue weight per unit area [kg-d.m./10a]
R : Combustion ratio of pruned branches from orchard trees
i : Type of orchard tree

3) CH_4 and N_2O from biomass burning in Grassland

- ***Estimation method***

For CH_4 and N_2O emissions due to biomass burning from grassland, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* was applied. The estimation equation is as follows:

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-6}$$

L_{fire} : Amount of greenhouse gas emission from fire [kt-GHG]
A : Area burnt [ha]
M_B : Mass of available fuel for combustion [t-d.m./ha]
C_f : Combustion factor
G_{ef} : Emission factor [t/kt-d.m.]

- ***Parameters***

For the combustion factor, value of 0.9 is applied according to expert judgment that considering survey data on burning of grassland in Japan. For emission factor, the default emission factors of "Savanna and grassland" provided in the *2006 IPCC Guidelines* are used.

Table 6-78 Emission factors [t/kt-d.m.]

Category	CH_4	N_2O
Savanna and grassland	2.3	0.21

Reference: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

- ***Activity data***

The total mass of fuel available for combustion in grassland is calculated by multiplying area burnt of grassland, by the average amount of dry mass per unit area. There is no comprehensive statistical information or official data relating to burnt area of grassland. However, the area of controlled large-scale burning events on grassland which may affect national GHG emissions is limited in Japan. The area burnt for this estimation is estimated based on the five controlled large-scale burning events exceeding 1,000 ha: Aso, Higashi-Fuji exercise area, Kita-Fuji exercise area, Watarase flood control basin, and Akiyoshidai. The total planned burnt areas of these five events of 24,400ha are used as activity data uniformly over the whole year. For the amount burnt per area unit, value of 10 t-d.m./ha is applied according to expert judgment that considering survey data on burning of grassland in Japan.

4) CH_4 and N_2O emissions from biomass burning in Wetlands

Controlled burning and wildfire occur only at riverside in Wetlands in Japan.

The emissions from biomass burning in Wetland were estimated with Tier 1 methodology (the *2006 IPCC Guidelines*, Equation 2.27) with default EF of All savanna and grassland on Table 2.5 in the *2006 IPCC Guidelines*. 'MB × Cf' was applied 10.0 t-d.m./ha of All savanna grasslands (mid/late dry season burns) on table 2.4 in *the 2006 IPCC Guidelines*. (i.e. 1.2 t-CO_2 eq./ha)

From the fire and disaster statistics, 5,500 - 8,000 wildfire occurred on non-forest, agriculture and settlement area per year which included wildfire at riverside. Under the assumption that all these wildfires occurred at riverside, if area burned per a wildfire accounts for more than 11 ha, total emission from this category is classified as "significant" in LULUCF sector in Committee for GHG Emissions Estimation Methods in Japan.

Area of wildfire in forest land in Japan reaches some hundreds ha at the most. Over 10 ha wildfire is regarded as massive fire in Japan. In the view of these facts and uncertainty of parameters, emission in this category was judged as insignificant. Furthermore, the emissions from biomass burning along downstream of Arakawa River at which data on wildfire is available was about 300 t-CO_2 eq. This value applied to estimate the upper limit of applicability of "NE" for being considered insignificant.

c) ***Uncertainties and Time-series Consistency***

- ***Uncertainly Assessment***

The uncertainties for parameters and activity data related to forest fires were individually assessed on the basis of field studies, expert judgment, or default values described in the *2006 IPCC Guidelines*. Regarding the uncertainties for parameters and activity data related to biomass burning for pruned branches from orchard trees, the uncertainties (CH_4: 296%, N_2O: 300%) for crop residues burning in the Agriculture sector were substituted. For the uncertainty for biomass burning from grassland, the uncertainties for parameters and activity data were assessed on the basis of field studies, and default values described in the *2006 IPCC Guidelines* (CH_4: 56%, N_2O: 63%). As a result, the uncertainty estimates for the emissions resulting from biomass burning were 71% for CH_4 and 46% for N_2O, respectively.

- ***Time-series Consistency***

Time-series consistency for biomass burning in forest land remaining forest land is ensured by using the same data sources (*Handbook of Forestry Statistics* compiled by the Forestry Agency, and the data provided by the Agency) and the same methodology from 1990 to 2021. Time-series consistency for biomass burning for pruned branches from orchard trees and for grassland is ensured by using the same data sources (*Statistics of Cultivated and Planted Area* by the MAFF.)

d) ***Category-specific QA/QC and Verification***

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) ***Category-specific Recalculations***

Since the estimation methods of cultivation area of orchard trees from 2017 were revised, CH_4 and N_2O emissions from burning of pruned branches from orchard trees after FY2017 were recalculated.

See Chapter 10 for impact on trend.

f) ***Category-specific Planned Improvements***

No improvements are planned.

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
2. IPCC, *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*, 2014.
3. IPCC, *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, 2014.
4. IPCC, *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2019.
5. FAO, *WORLD BAMBOO RESOURCES, A thematic study prepared in the framework of the Global Forest Resources Assessment 2005*, 2007.
6. FAO, *Food and Agriculture Organization Corporate Statistical Database*.
7. FRA, *COUNTRY REPORT GLOBAL FOREST RESOURCES ASSESSMENT 2010*, 2010.
8. UNFCCC, *Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to Convention* (FCCC/SBSTA/2013/10/Add.3), 2014.
9. UNFCCC, *Tables of the common reporting format for land use, land-use change and forestry* (FCCC/SBSTA/2013/L.29, FCCC/SBSTA/2013/L.29/Add.1), 2013.
10. National Institute of Resources, *Research on energy comprehensive utilization of biomass resources*, 1982.
11. Environmental Agency Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 1*, September 2000.
12. Ministry of the Environment Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 3*, August 2002.
13. Ministry of the Environment Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 5*, August 2006.
14. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics, Mineral Resources and Petroleum Products, Ceramics and Building Materials.*
15. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics, Paper, Printing, Plastics Products and Rubber Products.*
16. Ministry of Land, Infrastructure, Transport and Tourism, *Land Use Status Survey.*
17. Ministry of Land, Infrastructure, Transport and Tourism, *Urban Park Status Survey.*
18. Ministry of Land, Infrastructure, Transport and Tourism, *Road Tree Planting Status Survey.*
19. Ministry of Land, Infrastructure, Transport and Tourism, *Sewage Treatment Facility Status Survey.*
20. Ministry of Land, Infrastructure, Transport and Tourism, *Urban Greening Status Survey.*
21. Ministry of Land, Infrastructure, Transport and Tourism, *Survey on Carbon Dioxide Absorption at Source in River Works.*
22. Ministry of Land, Infrastructure, Transport and Tourism, *Progress Survey on Tree Planting for Public Rental Housing.*
23. Parks and Green Spaces Division of the Ministry of Land, Infrastructure and Transport, *FY2004 Survey on evaluation techniques for the effectiveness of greening in urban parks for preventing global warming*, March, 2005.

24. Parks, Green Spaces and Landscape Division of the Ministry of Land, Infrastructure, Transport and Tourism, *Survey on policies of sinks measures by urban planting for the next framework,* 2014.
25. Parks, Green Spaces and Landscape Division of the Ministry of Land, Infrastructure, Transport and Tourism, *FY 2014 Survey on promotion of greenhouse gas sink measures by urban planting,* 2015.
26. National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, Japan, *Technical note of National Institute for Land and Infrastructure Management No.506 The Street tree of Japan VI*, 2009.
27. Ministry of Land, Infrastructure, Transport and Tourism, *Digital national land information.*
28. Ministry of Land, Infrastructure, Transport and Tourism, *Construction Statistics, Building Starts.*
29. Ministry of Internal Affairs and Communications, *Survey on Supply and Demand of Construction Labor.*
30. National Land Policy Research Team, National Land Agency, *Handbook for National Land Planners*, November 1996.
31. Geographical Survey Institute, *Degrees of Latitudes and Longitudes of Japan's Northernmost, Southernmost, Easternmost and Westernmost Points.* (https://www.gsi.go.jp/KOKUJYOHO/center.htm)
32. Geographical Survey Institute, *Statistical Reports on the Land Area by Prefectures and Municipalities in Japan.* (http://www.gsi.go.jp/KOKUJYOHO/MENCHO-title.htm)
33. Ministry of Finance*, Trade Statistics of Japan.*
34. Ministry of Internal Affairs and Communications, *Housing and Land Survey of Japan*.
35. Ministry of Internal Affairs and Communications, *Fixed Property Tax Division, Local Tax Bureau (Houses).*
36. Ministry of Agriculture, Forestry and Fisheries, *Census of agriculture and Forestry*, 2000.
37. Ministry of Agriculture, Forestry and Fisheries, *Statistics of Cultivated and Planted Area* (Survey of Cropland area).
38. Ministry of Agriculture, Forestry and Fisheries, *A Move and Conversion of Cropland.*
39. Ministry of Agriculture, Forestry and Fisheries, *Survey on the Occurrence and Resolution of Dilapidated Farmland.*
40. Ministry of Agriculture, Forestry and Fisheries, *Report on Supply and Demand of Lumber* (the Survey on Lumber).
41. Ministry of Agriculture, Forestry and Fisheries, *Statistical Survey on production of Special Forest Products.*
42. Ministry of Defense*, Defense of Japan.*
43. Forestry Agency, *Handbook of Forestry Statistics.*
44. Forestry Agency of Japan, *Forest Status Survey.*
45. Forestry Agency of Japan, *National Forest Resources Database.*
46. Forestry Agency of Japan, *Annual Report on Forest and Forestry in Japan.*
47. Meteorological Agency of Japan, *Mesh climatic data of Japan for the 1970-2000* [CD-ROM], Japan Meteorological Business Support Center, Tokyo, 2002.
48. Japan Dam Foundation, *Dam Yearbook.*

49. National Astronomical Observatory, *2019 Chronological Scientific Tables*. p. 184-185, p 196-197, 2019.
50. Japan Fiberboard and Particleboard Manufacturers Association, *Shipment quantity of wooden board by use.*
51. Japan Paper Association, *Trends in Pulp Collection*.
52. Shirato, Y., Yokozawa, M. & Taniyama, I., *Modified Roth C Model for Paddy Soils and Andosols*, Research Highlights 27,56-57, 2011.
53. Takata, Y., Ohkura, T., Kohyama, K., Obara, H. & Shirato, Y., *Modification of Roth C Model for Andosols (Roth C-26.3_vPAC) Using Phosphate Adsorption Coefficient*, Research Highlights 28, 18-19, 2012.
54. Coleman, K. & Jenkinson, D. S. Roth C-26.3 - *A model for the turnover of carbon in soil. In Evaluation of Soil Organic Matter Models: Using Existing Long-Term Datasets*, Ed. D. S. Powlson, P. Smith and J. U. Smith, p. 237-246, Springer, Berlin, 1996.
55. Seino, H., *An Estimation of Distribution of Meteorological Elements using GIO and AMeDAS Data*, J.Agr, Met.,48(4), 379-383, 1993.
56. Mu, Z., Huang, A., Kimura, D. S., Jin, T., Wei, S. and Hatano, R., *Linking N_2O emission to soil mineral N as estimated by CO_2 emission and soil C/N ratio*, Soil Biology & Biochemistry, 41, 2593-2597, 2009.
57. Shirato, Y., *Validation and Modification of Soil Organic Matter Models in Arable Soils in Japan and Thailand*, Bull. Natl. Inst. Agro-Environ. Sci., 24, 23-94, 2006.
58. Shirato, Y., Kishimoto-Mo, W. A. and Takata, Y., "*A modeling approach to estimating N2O emission derived from loss of soil organic matter for the Japanese greenhouse gas inventory*" Soil Science and Plant Nutrition, 67(3), 347-352, 2021
59. Shirato, Y. & Taniyama, I., *Testing the suitability of the Rothamsted carbon model for long-term experiments on Japanese non-volcanic upland soils*. *Soil Sci. Plant Nutr.*, 49, 921-925, 2003.
60. Shirato, Y., Hakamata, T. & Taniyama, I. *Modified Rothamsted carbon model for Andosols and its validation: Changing humus decomposition rate constant with pyrophosphate-extractable Al. Soil Sci. Plant Nutr.*, 50, 149-158, 2004.
61. Shirato, Y. & Yokozawa, M., *Applying the Rothamsted Carbon Model for Long-Term Experiments on Japanese Paddy Soils and Modifying It by Simple Tuning of the Decomposition Rate*, Soil Science and Plant Nutrition, 51(3), 405-415, 2005.
62. Shirato, Y., Yagasaki, Y. & Nishida, M., *Using different versions of the Rothamsted Carbon model to Simulate soil carbon in long-term experimental plots subjected to paddy-upland rotation in Japan*, Soil Sci. Plant Nutr., 57, 597-606, 2011.
63. Takata, Y., Ito, T., Ohkura, T., Obara, H., Kohyama, K., & Shirato Y., *Phosphate adsorption coefficient can improve the validity of Roth C model for Andosols*, Soil Sci. Plant Nutr. 57: 421-428, 2011.
64. Tonosaki, K., Murayama, K., Imai, K. & Nagino, Y., *Estimation of Soil Carbon Accumulation Rate in Urban Parks*. Journal of the Japanese Society of Revegetation Technology, Vol. 38 (3), 373-380, 2013.

65. Tonosaki, K., Imai, K., Teshirogi J., Kida, K., & Ishizuka, S., "*Study on soil carbon stock changes due to land use changes from forest land and cropland to settlements*", Journal of the Japanese Society of Revegetation Technology 48(2), 374-385 (2022)

66. Nakai M., *Carbon accumulation in soils due to soil management,* Association for Advancement of Agricultural Science, Survey on method for quantification of amount of GHG emission cuts (2000).

67. Handa, M., Tonosaki, K., Imai K. & Goto, S., *"A study to estimate the amount of Carbon stocks of soil and litter in revegetation areas"*, Urban Green Tech. 69, 18-22, 2008.

68. Hatano, R., *"Project Title: Survey on actual situation of grassland management for feed"*, Project Report of Livestock Industry Promotion by Japan Racing Association in FY2016, 2017.

69. Metherell, A.K., Harding, L.A., Cole, C.V. and Parton, W.J., "CENTURY Soil Organic Matter Model Environment", Colorado State University: Fort Collins, Colorado, USA, 1993.

70. Morisada, K., Ono, K. & Kanomata, H., *Organic carbon stock in forest soil in Japan*, Geoderma 119, 21-32, 2004 a.

71. Morisada, K., "*The organic carbon stock of topsoil and its geographical distribution in Japan*", Journal of Environmental Information Science, 32 (5), 25-32, 2004 b.

72. Matsue, M., Nagahama, Y., Iizuka, Y., Murata, M. & Fujiwara, N., *Estimation equations for the amount of CO_2 fixed by planted trees in cities in Japan*, Journal of the Japanese Society of Revegetation Technology, 35 (2), 318-324, 2009.

73. Yagasaki, Y. & Shirato, Y., *Assessment on the rates and potentials of soil organic carbon sequestration in agricultural lands in Japan using a process-based model and spatially explicit land-use change inventories –Part 1: Historical trend and validation based on nation-wide soil monitoring,* Biogeosciences, 11, 4429-4442, doi:10.5194/bg-11-4429-2014, 2014.

74. Nagumo, T., Ando, M. & Mori C., *Bamboo biochar characterized by nutrient composition as soil amendment,* Japanese Society of Soil Science and Plant Nutrition, 85(1), 37-42, 2014.

75. Okinawa Prefecture, *Transition of mangrove.*

76. Nakasuga, T., Oyama, H. and Haruki, M., *Studies on the Mangrove Community: I. The Distribution of the Mangrove Community in Japan,* Japanese Journal of Ecology, 24(4),1974.

77. International Society for Mangrove Ecosystems, *Investigation of Mangrove Distribution in Okinawa for Coastal Ecosystem and Monitor the Sea Level Rise*, 2003.

78. ManGlobal, *Explore the Mangrove in Kagoshima and Okinawa.*

79. Masuno, T., Nakasuga, T., and Kishimoto, T., *Mangrove Trees and River Management in Japan: A Case Study at Ishikawa River, Okinawa Prefecture* Proceedings of the General Meeting of the Association of Japanese Geographers 2012a (0), 100032-, 2012.

80. Okinawa General Bureau, Cabinet Office, *Survey for Mangrove in Hiyagon*.

81. Ugawa, S., Takahashi, M., Morisada, K., Takeuchi, M., Matsuura, Y., Yoshinaga, S., Araki, M., Tanaka, N., Ikeda, S., Miura, S., Ishizuka, S., Kobayashi, M., Inagaki, M., Imaya, A., Nanko, K., Hashimoto, S., Aizawa, S., Hirai, K., Okamoto, T., Mizoguchi, T., Torii, A., Sakai, H., Ohnuki, Y. & Kaneko, S., "*Carbon stocks of dead wood, litter, and soil in the forest sector of Japan : general*

description of the National Forest Soil Carbon Inventory", Bulletin of FFPRI Vol.11 No.4 (No.425) 207 - 221 December 2012.

82. Yamashita, N., Ishizuka, S.,Hashimoto, S., Ugawa, S., Nanko, K., Osone, Y., Iwahashi, J., Sakai, Y., Inatomi, M., Kawanishi, A., Morisada, K., Tanaka, N., Aizawa, S., Imaya, A., Takahashi, M., Kaneko, S., Miura, S., & Hirai, K., "*National-scale 3D mapping of soil organic carbon in a Japanese forest considering microtopography and tephra deposition*", Geoderma Volume 406, 15 January 2022, 115534.

83. Matsui, K., Takata, Y., Maejima, Y., Kubotera, H., Obara, H., & Shirato, Y., "Soil carbon and nitrogen stock of the Japanese agricultural land estimated by the national soil monitoring database (2015-2018)", Soil Science and Plant Nutrition, Volume 67, 2021.

Chapter 7. Waste (CRF sector 5)

7.1. Overview of Sector

7.1.1. Overview of Waste Management and Estimation Category

In the waste sector, greenhouse gas (GHG) emissions from treatment and disposal of waste are estimated for solid waste disposal (5.A.), biological treatment of solid waste (5.B.), incineration and open burning of waste (5.C.), wastewater treatment and discharge (5.D.), and other (5.E.)[1] in accordance with treatment processes. Figure 7-1 and Figure 7-2 show the estimation categories of waste/wastewater treatment system and/or waste classification in Japan.

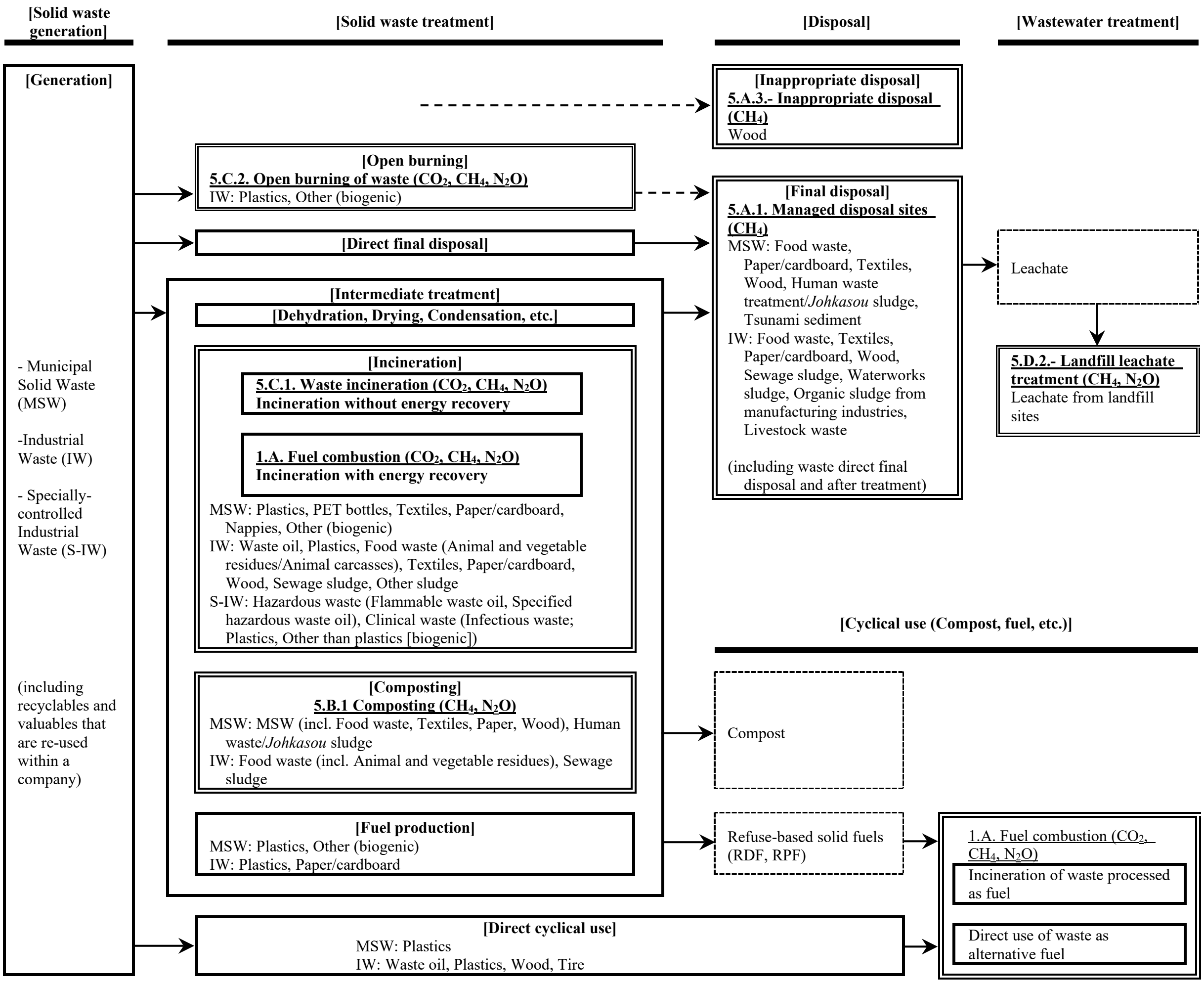


Figure 7-1 Flow chart of solid waste managements and the estimation categories

[1] Data for some emission source categories in the waste sector are complemented by estimation, when statistical data or related data are not available. The methodologies for this estimation are not described in this chapter. For details, refer to the website of MOE, *Committee for the Greenhouse Gases Emissions Estimation Methods* (http://www.env.go.jp/earth/ondanka/ghg-mrv/committee/).

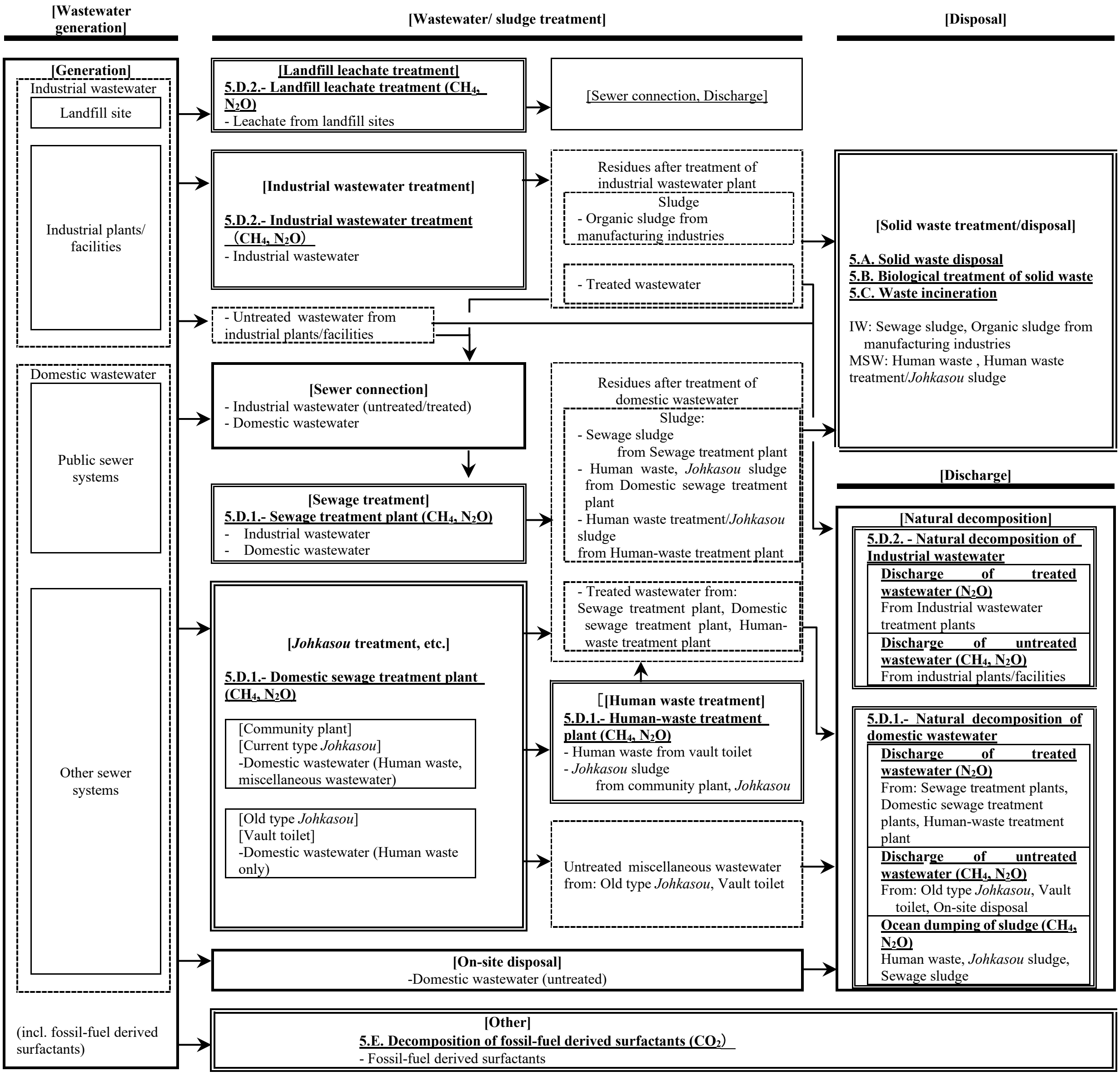


Figure 7-2 Flow chart of wastewater/sludge treatments and the GHG estimation categories

"Waste" to be covered in this sector is the waste as defined in the *2006 IPCC Guidelines*. In the case of Japan, the waste does not only include municipal waste and industrial waste as defined by the Waste Management and Public Cleansing Act, but also include recyclables and valuables that are re-used within a company, and are reported in category "7.3.1. Composting (5.B.1)", "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)", and "7.4.3.3. Incineration of Waste Processed as Fuel (1.A.)". Since the waste statistics are compiled separately for municipal waste and industrial waste in Japan, estimation methodologies for many of emission sources in the waste sector are discussed respectively for municipal waste and industrial waste. Emissions from the treatment of disaster waste caused by the Great East Japan Earthquake, which occurred on 11th March, 2011, are reported in this sector.

7.1.2. Overview of Greenhouse Gas Emissions on Waste Sector

In FY2021, emissions from the Waste sector resulted in 17,712 kt-CO_2 eq. and accounted for 1.5% of Japan's total GHG emissions (excluding LULUCF). Total emissions had decreased by 40.9% compared to those of FY1990 and decreased by 1.4% compared to those of FY2019. Breakdown of FY2021 emissions of the Waste sector by category shows that the largest contributor to the emissions is Incineration and Open Burning of Waste (5.C.) (excluding emissions from waste incineration and energy use reported on the energy sector) accounting for 65.5% (a decrease by 15.8% from FY1990) followed by the Wastewater Treatment and Discharge (5.D.) accounting for 20.0% (a decrease by 33.6% compared to FY1990), Solid Waste Disposal (5.A.) accounting for 8.9% (a decrease by 84.2% from FY1990), Other (5.E.) accounting for 3.8% (a decrease by 3.4% from FY1990) , and Biological Treatment of Solid Waste (5.B.) accounting for 1.8% (an increase by 35.9% from FY1990). Breakdown of the emissions of the Waste sector by gas shows that the largest contributor to the emissions is CO_2 emissions associated with the incineration/open burning of fossil-fuel derived waste such as waste plastic and waste oil accounting for 58%, followed by N_2O emissions from wastewater treatment and discharge accounting for 11%, CH_4 emissions from solid waste disposal on land accounting for 9%.

The changes in GHG emissions from the Waste sector since FY1990 show a trend in a decrease in CH_4 emissions from the solid waste disposal on land associated with a decrease in the amount of disposal of biodegradable waste due to the improvement in recycling rate since the enactment of the Basic Law for Establishing the Recycling-based Society and other recycling laws. Note that while the recycling rate of waste in Japan has increased in FY2019 (15.7%) in comparison with FY1990 (7.4%), the total disposal amount has reduced in FY2019 (13 Mt/year) in comparison with FY1990 (109 Mt/year) (Ministry of the Environment: MOE, 2022).On the other hand, emissions from the incineration of fossil-fuel derived waste with energy recovery, emissions from the direct use of fossil-fuel derived waste as alternative fuel, and emissions from the incineration of fossil-fuel derived waste processed as fuel, which are accounted for in the Energy sector, have increased along with an increase of waste recycling rate (an increase by 73.3% from FY1990).

7.1.3. General Description for Methodological Issues on the Waste Sector

➢ ***Estimation Method and Emission Factors***

Japan generally employs country specific methodologies and emission factors in GHG emission estimations on the waste sector. For the category on which sufficient views are not obtained from domestic survey, default methodologies and emission factors in the *2006 IPCC Guidelines* are partially applied. For details, see articles “*b) Methodological Issues*” in each category’s section.

Table 7-1 Summary for methods and emission factors used on waste sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
5. Waste	CS	CS	CS, D, T2, T3	CS, D	CS, D, T2	CS, D
A. Solid waste disposal	NA	NA	T3	CS		
B. Biological treatment of solid waste			T2	CS	T2	CS
C. Incineration and open burning of waste	CS	CS	CS, T2	CS, D	CS, T2	CS, D
D. Wastewater treatment and discharge			CS, D	CS, D	CS, D	CS, D
E. Other	CS	CS	NA	NA	NA	NA

Note:
D: IPCC default, T1: IPCC Tier 1, T2: IPCC Tier 2, T3: IPCC Tier 3, CS: country specific method or EF

➢ ***Activity Data***

As activity data in the methodologies on the waste sector, the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes – Volume on Cyclical Use* (Environmental

Regeneration and Material Cycles Bureau of MOE) (hereinafter referred to as the *Cyclical Use of Waste Report*), the *Waste Treatment in Japan* (the same agency of MOE), and the *annual editions of Sewage Statistics – Admin. Ed.* (Japan Sewage Works Association: JSWA) (hereinafter referred to as the *Sewage Statistics*) are mainly referred. Also, various other statistics related on the waste management and provided data from relevant agencies and bodies are used. For details, see articles "*b) Methodological Issues*" in each category's section.

Note that treatment and disposal amount of disaster wastes since FY2011, when the Great East Japan Earthquake occurred, are surveyed by Environmental Regeneration and Material Cycles Bureau of MOE, and are considered in the activity data to estimate GHG emissions from these sources.

7.1.4. General Assessment Procedure for the Uncertainty on the Waste Sector

The uncertainty of GHG emissions on the waste sector is assessed based on the *2006 IPCC Guidelines* and MOE (2013a). The general assessment procedures are indicated below. For details, see articles "*c) Uncertainties and Time-series Consistency*" in each category's section.

- ***Emission factors***

The uncertainties in emission factors are assessed by using the 95% confidence interval obtained from actual measurement, or by expert judgment. When emission factor is derived from formulas depending on several parameters, the uncertainty is assessed by combining the uncertainties of these parameters using error propagation equation.

- ***Activity data***

Regarding the uncertainty for activity data, due to the lack of information on statistical error in quoted references, it is difficult to assess uncertainties based on concrete evidence. Therefore, it is assessed by expert judgment as indicated in the Table 7-2.

Table 7-2 Uncertainty for statistics used for activity data on waste sector

Statistics used for activity data	Range of uncertainty		Justification for assessing the uncertainty
	(-)	(+)	
Municipal waste (Domestic wastewater excl. sewage)	-10%	+10%	In the uncertainty which is provided as default value in the *2006 IPCC Guidelines*, the value (±10%) in the case where waste weight is measured by truck scale is adopted based on expert judgment.
Industrial waste (Industrial wastewater)	-30%	+30%	In the uncertainty which is provided as default value in the *2006 IPCC Guidelines*, the value (±30%) "in the case where amount of generated waste is regularly collected" is adopted based on expert judgment.
Specially-controlled industrial waste	-60%	+60%	The twofold higher uncertainty than the value in industrial waste statistics is adopted based on expert judgment.
Valuables (valuable waste)	-30%	+30%	In the uncertainty which is provided as default value in the *2006 IPCC Guidelines*, the value (±30%) "in the case where amount of generated waste is regularly collected" is adopted based on expert judgment.
Sewage	-5%	+5%	Since the data has collected through complete survey for whole sewage treatment plants in Japan, it is considered that data is accurate enough to reflect the current status. Therefore, the uncertainty is evaluated at 5% based on expert judgment.
Water works	-5%	+10%	Sampling error in the statistics is evaluated at 5% based on expert judgment as well as sewage statistics. However, water works statistics target only water company and supplier of city water which have more than 5001 official water supplied population; sludge generated from small-sized filter plants by private water-supply system is not identified. Therefore, a 5% is added to the upper limit of uncertainty since the population of private water-supply system account for 5% of the total.

- ***Emissions***

Since emissions are calculated by formulas, the uncertainty is assessed by combining the uncertainties of emission factors and activity data using error propagation equation.

7.1.5. General Recalculations for Emissions from Waste Sector

- ***Update of the statistical data***

Most of statistics in Japan are compiled on the basis of Japan's fiscal year (starting on April 1 of the year and ending on March 31 of the following year). Therefore, some process of compiling statistics for the latest fiscal year, which is referred in waste sector inventory, does not complete in time for an inventory compilation.

In such a case, the activity data of previous fiscal year are generally adopted for the latest fiscal year in accordance with the *2006 IPCC Guidelines*, but adoptions of more appropriate estimations are desirable for data of latest fiscal year for the main categories. To obtain such better activity data related to solid waste to be quoted from the *Cyclical Use of Waste Report* (MOE) as main statistics, "the Committee for improvement of the research on cyclical use of waste" organized by Environmental Regeneration and Material Cycles Bureau of MOE, annually prepares preliminary data for the latest year estimated by using economic indexes such as volume/value of shipment of products to be finally disposed of (*Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics*, MOE). Thus, GHG emissions for the latest fiscal year on the waste sector are estimated by using this preliminary activity data. Consequently, every year, these preliminary data are updated with definite data, and emissions are recalculated in the inventory of its next annual submission.

- ***Improvement of estimation methodologies***

To better reflect the actual status of national GHG emissions in waste sector in the methodology, the choice of the estimation methodologies, activity data, emission factors and parameters used in this sector are reviewed by the breakout group on waste sector in the Committee for the Greenhouse Gases Emissions Estimation Methods. Methodological changes based on the considerations at the committee are reflected to the inventory submitted every year, and consequently the GHG emissions from categories whose methodologies have been changed are recalculated. For datils of the methodological changes in this submission, see the sections for recalculation for each category in this chapter and related Table 10-9 in Chapter 10.

7.2. Solid Waste Disposal (5.A.)

This category covers CH_4 emissions from solid waste disposal on land. For this emission source category, estimation methodologies are discussed separately for municipal waste and industrial waste in accordance with Japan's waste classification system, and emissions are estimated for the sources presented in Table 7-3.

Table 7-3 Categories whose emissions are estimated for solid waste disposal (5.A.)

Category	Waste type				Disposal type		CO_2	CH_4
5.A.1. (7.2.1)	Municipal solid waste	Food waste			Managed disposal sites	a. Anaerobic b. Semi-aerobic - Managed well - Managed poorly	NO	○
		Paper/cardboard						○
		Wood						○
		Textiles	Natural fiber 1)					○
		Sludge	Human waste treatment/*Johkasou* sludge					○
			Tsunami sediment 2)			a. Anaerobic7)	NO	○
	Industrial waste	Food waste 3)	Animal and vegetable residues, Animal carcasses			a. Anaerobic b. Semi-aerobic - Managed well - Managed poorly	NO	○
		Paper/cardboard						○
		Wood						○
		Textiles	Natural fiber 1)					○
		Sludge	Sewage sludge	Digested sewage sludge 4)				○
				Other sewage sludge				○
			Waterworks sludge					○
			Organic sludge from manufacturing industries					○
			Livestock waste 5)					○
5.A.2. (7.2.2)	–				Unmanaged disposal sites		NO	NO
5.A.3. (7.2.3)	Industrial waste	Wood			Inappropriate disposal 6) (Anaerobic landfill)		NE	○

Note:

1) Only natural fiber textiles are included in the estimation under the assumption that synthetic fiber waste is not biologically decomposed in landfills.
2) Part of tsunami sediment generated by the Great East Japan Earthquake, which occurred on 11th March, 2011, is disposed of finally. Since disposed tsunami sediment includes organic matters, CH_4 emissions from this source are estimated using the emission factor for wood by expert judgment.
3) Japan's industrial waste classifications of "Animal and vegetable residues" and "Animal carcasses" are aggregated as food waste.
4) "Digested sewage sludge" includes sewage sludge landfilled after digested and dehydrated. Because digestion treatment reduces the amount of carbon content biodegraded in sludge decreases, CH_4 emissions are estimated separately by landfilled sewage sludge with and without digestion treatment.
5) Although livestock waste is not classified as "sludge" under Japanese law, the emissions from the waste are estimated within the category of sludge since both properties are similar.
6) The emissions from wood are currently considered as inappropriate disposal of waste containing biodegradable carbon.
7) Since the disposal type for tsunami sediment have not been identified, it is conservatively assumed as anaerobic landfill (MCF=1.0) which derives larger emissions.

Table 7-4 GHG emissions from solid waste disposal (5.A.)

Gas	Category			Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	5.A.1. Managed waste disposal saites	a. Anaerobic landfill		kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		b. Semiaerobic landfill		kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	5.A.2. Unmanaged waste disposal sites			kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	5.A.3. Uncategorized waste disposal sites	Inappropriate disposal		kt-CO_2	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Total			kt-CO_2	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE	NO,NE
CH_4	5.A.1. Managed waste disposal saites	a. Anaerobic landfill	MSW	kt-CH_4	220.9	184.5	136.8	98.6	66.1	56.3	51.9	48.1	44.1	40.4	37.4	34.5	31.8	29.2	26.9
			IW	kt-CH_4	154.2	140.2	108.1	70.7	40.7	33.8	30.6	27.5	25.0	22.9	21.1	19.4	17.9	16.5	15.5
		b. Semiaerobic landfill	MSW	kt-CH_4	17.7	25.9	28.7	30.6	24.9	22.6	21.7	20.3	19.4	18.0	17.0	15.9	14.9	13.9	12.9
			IW	kt-CH_4	4.7	8.3	12.2	13.7	10.6	10.0	9.9	9.3	8.7	8.2	7.8	7.5	7.4	7.3	7.2
	5.A.2. Unmanaged waste disposal sites			kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	5.A.3. Uncategorized waste disposal sites	Inappropriate disposal		kt-CH_4	0.1	0.2	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3
	Total			kt-CH_4	397.6	359.1	286.4	214.1	142.7	123.0	114.5	105.5	97.6	89.9	83.7	77.6	72.3	67.3	62.8
				kt-CO_2 eq.	9,940	8,977	7,160	5,353	3,568	3,076	2,861	2,639	2,440	2,248	2,092	1,939	1,807	1,682	1,569
Total				kt-CO_2 eq	9,940	8,977	7,160	5,353	3,568	3,076	2,861	2,639	2,440	2,248	2,092	1,939	1,807	1,682	1,569

Estimated GHG emissions from solid waste disposal on land are shown in Table 7-4. In FY2021, GHG emissions from this source category are 1,569 kt-CO_2 eq. and accounted for 0.1% of the national total emissions (excluding LULUCF). Emissions from this category decreased by 84.2% compared to the emissions in FY1990. This CH_4 emissions decrease is the result of decrease in the amount of biodegradable waste landfilled due to the increase in the practice of waste incineration to reduce waste volume in Japan.

For the category "managed disposal sites", while trend in the disposal amount of biodegradable waste has steadily decreased since FY1990, trend in the estimations of CH_4 generated from degradation of waste has relatively slowly decrease due to the time lags derived from long half-lives of waste in the FOD method (e.g. 7 years for half-life of paper/cardboard). Hence trend in the implied emission factors (IEFs) has increased since FY1990. For the category "uncategorized waste disposal sites (inappropriate disposal)", while trend in the disposal amount irregularly fluctuate year by year since the estimations should consider only disposal amount for revealed matters, trend in CH_4 emissions estimated by FOD method is relatively stable. Hence trend in the IEFs also tend to irregularly fluctuate year by year.

7.2.1. Managed Disposal Sites (5.A.1.)

a) Category Description

In Japan, part of food waste, paper/cardboard, textiles, wood, and sludge in municipal solid waste (MSW) and industrial waste (IW) is landfilled without incineration; therefore, CH_4 is generated as a result of biodegradation of organic materials from the landfill sites. Because Japanese landfill sites are appropriately managed pursuant to the Waste Management and Public Cleansing Act, the amount of CH_4 emitted from there is reported under this category "Managed Disposal Sites (5.A.1.)". Emissions of CO_2 from waste incineration at the managed disposal sites are reported as NO, because waste incineration is not implemented at that site in Japan.

b) Methodological Issues

- ***Estimation Method***

The first order decay (FOD) method with country-specific parameters (Tier 3) given in the *2006 IPCC Guidelines* is used to estimate emissions from this source. In this method, for consistency with Japan's domestic estimation method under the *Mandatory GHG Accounting and Reporting System*, emission factors are specifically defined as "CH_4 emissions from biodegradable waste", and activity data are defined as "the amount of waste biodegraded within the reporting fiscal year". Note that there are no substantial differences between Japan's country-specific method (see following equation) and that in the *2006 IPCC Guidelines* (vol. 5, chap. 3, equation 3.1) since the emission factors and activity data in Japan's method are defined by combining parameters in a way that maintains their relevance shown in the guidelines.

$$E = \left\{ \sum_{i,j} \left(EF_{i,j} \times A_{i,j} \right) - R \right\} \times (1 - OX)$$

E	: CH_4 emissions from landfill sites [kg-CH_4]
$EF_{i,j}$	: Emission factor for a biodegradable waste *i* (dry basis) that is damped into a landfill site *j* without incineration [kg-CH_4/t]
$A_{i,j}$	: Amount of a biodegradable waste *i* (dry basis) that is damped into a landfill site j without incineration and is biodegraded within an inventory year) [t]
R	: Recovered CH_4 in an inventory year [kg-CH_4]

OX : Oxidation factor of CH_4 related to soil cover

- ***Emission Factors***

Emission factors are defined as the amount of CH_4 [kg] generated through decomposition of one ton of biodegradable landfill wastes (dry basis) without incineration. They are established by the type of biodegradable waste (i.e., food waste, paper/cardboard, natural fibers, wood, sewage sludge, human waste, waterworks sludge, organic sludge from manufacturing industries and livestock waste) and by the type of landfill site (i.e., anaerobic or semi-aerobic landfill). Emission factors are estimated as indicated below.

$$EF = DOC_i \times DOCf_i \times MCF_j \times F \times 1000 \times \frac{16}{12}$$

DOC_i : Fraction of carbon content in a biodegradable waste *i*
$DOCf_i$: Fraction of degradable organic carbon that decomposes for waste *i*
MCF_j : Methane correction factor in a landfill site *j* (Anaerobic, Managed well – semi-aerobic, Managed poorly – semi-aerobic)
F : Percentages of CH_4 in landfill gas

➢ ***Carbon Content (DOC: Per Dry Weight)***

Carbon content per dry weight, which is used as uniform value every year because the property of each waste type does not vary significantly over time, is determined based on MOE (2006b) and MOE (2010) as indicated in Table 7-5 below.

Table 7-5 Carbon content of waste disposed of in managed landfill sites (dry basis)

Item		Carbon Content	Reference
Municipal solid waste	Food waste	43.4 %	Calculated by taking the averages of carbon contents of MSW provided by Tokyo, Yokohama, Kawasaki, Kobe, and Fukuoka (FY1990-2004) (MOE, 2006b)
	Wood	45.2 %	
	Paper/cardboard	40.8 %	Calculated by taking the averages of carbon contents of MSW obtained from actual measurements at domestic 14 cities (MOE, 2020b)
	Textiles (natural fiber)	45.0 %	Calculated by taking a weighted average of carbon content estimated based on the constituent of each natural fiber type (cotton, wool, silk, linen, and recycled textiles) by the domestic demand of natural fibers (FY1990-2004) (MOE, 2006b)
	Human waste treatment /*Johkasou* sludge	40.0 %	Substituted the value for "Other sewage sludge"
	Tsunami sediment	4.5 %	Calculated by multiplying the fraction of organic matter in tsunami sediment by the fraction of carbon contents in the organic matter; assuming the fraction of organic matter in tsunami sediment finally disposed of is 10%, and 45.2% of fraction of carbon content for wood is substituted for tsunami sediment by expert judgment
Industrial waste	Food waste	43.4 %	Substituted the carbon content of MSW for that of IW because its properties are similar to those of MSW
	Wood	45.2 %	
	Paper/cardboard	40.8 %	
	Digested sewage sludge	30.0 %	Expert judgment based on Fujimoto (2000), Fujishima et al. (2004), Oshima et al. (1986) and Tanaka et al. (1980)
	Other sewage sludge	40.0 %	Expert judgment based on domestic researches (MOE, 2006b)
	Waterworks sludge	6.0 %	Average values of survey results conducted at 23 water purification plants (MOE, 2010)
	Organic sludge from manufacturing industries	45.0 %	Value for paper industry is substituted because it generates the largest amount of organic sludge finally disposed of. Estimated based on the carbon content of cellulose because the main constituent of organic sludge generated is paper sludge (MOE, 2006b)
	Livestock waste	40.0 %	Substituted the value for "Other sewage sludge"

➢ ***Fraction of the degradable organic carbon that decomposes (DOCf)***

For the fraction of the degradable organic carbon that decomposes (*DOCf*) for waste disposed of, default values in Table 7-6 given in the *2019 Refinement* are used.

Table 7-6 Fraction of the degradable organic carbon that decomposes for waste disposed of in managed landfill sites

Item		*DOCf*	Waste degradability	Reference
Municipal solid waste	Food waste	0.7	Highly decomposable	*2019 Refinement*
	Wood	0.1	Less decomposable	
	Paper/cardboard	0.5	Moderately decomposable	
	Textiles (natural fiber)	0.5	Moderately decomposable	
	Human waste treatment/ *Johkasou* sludge	0.7	Highly decomposable	
	Tsunami sediment	0.1	Less decomposable	
Industrial waste	Food waste	0.7	Highly decomposable	
	Wood	0.1	Less decomposable	
	Paper/cardboard	0.5	Moderately decomposable	
	Digested sewage sludge	0.7	Highly decomposable	
	Other sewage sludge	0.7	Highly decomposable	
	Waterworks sludge	0.7	Highly decomposable	
	Organic sludge from manufacturing	0.7	Highly decomposable	
	Livestock waste	0.7	Highly decomposable	

➢ ***Methane Correction Factor (MCF)***

For Methane correction factor (*MCF*) by the type of landfill sites, the below default values given in the *2019 Refinement* are used.

Table 7-7 Methane correction factors (*MCF*) by the type of landfill site

Types of landfill sites	*MCF*	Reference
Anaerobic landfill sites	1.0	*2019 Refinement*
Managed well – semi-aerobic landfill sites	0.5	
Managed poorly – semi-aerobic landfill sites	0.7	

➢ ***Proportions of CH_4 in Generated Gas (F)***

Default value (50%) given in the *2006 IPCC Guidelines* is used.

➢ ***Emission Factor (EF)***

Emission factors calculated by methodologies above are shown in Table 7-8.

Table 7-8 Emission factors by type of biodegradable waste and by treatment

Item		Anaerobic landfill [kg-CH_4/t (dry)]	Managed well – Semi-aerobic landfill [kg-CH_4/t (dry)]	Managed poorly – Semi-aerobic landfill [kg-CH_4/t (dry)]
Municipal solid waste	Food waste	203	101	142
	Paper/cardboard	136	68	95
	Textiles (natural fiber)	150	75	105
	Wood	30	15	21
	Human waste treatment/*Johkasou* sludge	187	93	131
	Tsunami sediment	3	NA	NA
Industrial waste	Food waste	203	101	142
	Paper/cardboard	136	68	95
	Textiles (natural fiber)	150	75	105
	Wood	30	15	21
	Digested sewage sludge	140	70	98
	Other sewage sludge	187	93	131
	Waterworks sludge	28	14	20
	Organic sludge from manufacturing	210	105	147
	Livestock waste	187	93	131

- ***Activity Data***

Out of the amount of waste landfilled without incineration (dry basis), the amount of waste degraded within the reporting year is calculated by multiplying the amount of waste remaining in landfills at the end of the previous reporting year by the methane generation rate constant for waste landfilled. The amount of biodegradable MSW and IW are determined by type of waste and landfill site.

The amount of waste landfilled in each fiscal year (dry basis) is calculated by multiplying the amount of biodegradable waste landfilled (wet basis) by the percentage of landfill site by the type of site (wet basis), and subtracting the water content by each type of waste.

$$A_{i,j}(T) = W_{i,j}(T-1) \times (1 - e^{-k_i})$$
$$W_{i,j}(T) = W_{i,j}(T-1) \times e^{-k_i} + w_{i,j}(T)$$

$A_{i,j}(T)$: Amount of waste i degraded in site j (Anaerobic, Semi-aerobic) in the calculated year (year T) (activity data: dry basis) [t (dry)]
$W_{i,j}(T)$: Amount of waste i remaining in site j in year T (dry basis) [t (dry)]
$w_{i,j}(T)$: Amount of waste i landfilled into site j in year T (dry basis) [t (dry)]
k_i : Methane generation rate constant of waste i [$year^{-1}$]

Where,

$$w_{i,j}(T) = w_{i,wet}(T) \times S_j \times (1 - u_i)$$
$$k_i = ln(2)/H_i$$

$w_{i,wet}(T)$: Amount of waste i landfilled in year T (wet basis) [t (wet)]
S_j : Percentage of landfill site structure type j (Anaerobic, Semi-aerobic) [%]
u_i : Percentage of water content in waste i [%]
H_i : Decomposition half-life of waste i (the time taken by landfilled waste i to reduce in amount by half) [year]

The amount of biodegradable waste degraded in semi-aerobic landfill site is divided into two types of waste by management conditions of landfill sites. In some semi-aerobic landfill sites in Japan, there are cases such as: the outflow port of leachate collection system is swamped, the system is full of water, it holds retaining of leachate, or leachate collection/gas extraction system is not properly extended. Considering these inappropriate management conditions of the leachate collection system at landfill sites, a country-specific parameter is defined as “percentage of open outflow port of leachate collection system” and used for the estimation of activity data of “Managed well – semi-aerobic landfill sites” and “Managed poorly – semi-aerobic landfill sites” for municipal solid waste disposal sites and industrial waste disposal sites, respectively, as follows:

$$A_{i,\ semiaerobic\text{-}well}(T) = A_{i,\ semiaerobic}(T) \times P$$
$$A_{i,\ semiaerobic\text{-}poorly}(T) = A_{i,\ semiaerobic}(T) \times (1 - P)$$

$A_{i,semiaerobic}(T)$: Amount of waste i degraded in semi-aerobic landfill site in the calculated year (year T) (activity data: dry basis) [t (dry)]
$A_{i,semiaerobic\text{-}well}(T)$: Amount of waste i degraded in Managed – well semi-aerobic landfill site in the calculated year (year T) (activity data: dry basis) [t (dry)]
$A_{i,semiaerobic\text{-}poorly}(T)$: Amount of waste i degraded in Managed poorly – semi-aerobic landfill site in the calculated year (year T) (activity data: dry basis) [t (dry)]

Where,

$$P = W'/W$$

P : Percentage of open outflow port of leachate collection system [%]
W' : Disposal amount in a reporting year at semi-aerobic landfill sites with open outflow port of leachate collection system [for municipal solid waste: t, for industrial waste: m^3]

W : Disposal amount in a reporting year at whole semi-aerobic landfill sites [for municipal solid waste: t, for industrial waste: m^3]

➢ *Amount of Biodegradable Waste Disposed of in Landfills*

Table 7-9 shows the annual amount of biodegradable waste landfilled (dry basis) in Japan.

Table 7-9 Annual amount of biodegradable waste disposed of in landfills
(Total amount of anaerobic and semi-aerobic landfilling)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
MSW																
Food waste	kt (dry)	424	272	196	78	30	22	21	18	16	13	13	13	10	9	8
Paper/ cardboad	kt (dry)	1,140	859	698	492	311	260	226	182	142	125	97	102	63	58	54
Textiles (natural fiber)	kt (dry)	59	46	34	67	3	4	3	3	3	2	1	1	1	1	1
Wood	kt (dry)	363	200	155	81	40	31	65	27	22	21	18	19	13	10	9
Human waste treatment/ *Johkasou* sludge	kt (dry)	78	51	46	47	20	15	10	8	7	8	9	12	12	11	13
Ttsunami sediment[1)]	kt (dry)	NO	NO	NO	NO	NO	10	29	NO	NO	NO	NO	NO	NO	NO	NO
IW																
Food waste	kt (dry)	65	177	109	45	22	30	11	15	12	13	14	14	18	18	17
Paper/ cardboad	kt (dry)	102	125	137	89	31	32	16	17	12	15	11	29	24	28	28
Textiles (natural fiber)	kt (dry)	4	16	15	17	7	7	6	10	11	11	9	7	10	10	9
Wood	kt (dry)	465	490	235	230	145	106	111	116	124	110	129	129	126	125	117
Digested sewage sludge	kt (dry)	59	50	31	11	3	5	4	5	3	3	3	4	3	4	3
Other sewage sludge	kt (dry)	219	185	114	42	17	22	11	12	12	12	10	10	7	5	7
Waterworks sludge	kt (dry)	199	166	146	66	67	67	67	67	67	67	67	67	67	67	67
Organic sludge from manufacturing industry	kt (dry)	347	157	69	48	31	27	17	14	13	11	12	12	12	12	13
Livestock waste	kt (dry)	12	12	11	11	11	9	12	13	13	13	12	13	13	13	13

Note:
1) Disposal amount of tsunami sediment has increased in FY2013, since disaster waste by the 2011 earthquake has massively treated in FY2013 due to the activation of disaster restoration service. The final disposal of this tsunami sediment has finished in FY2013; therefore, the amount is accounted as 0 kt/year from FY2014 onward.

The references for the amount of biodegradable waste landfilled by waste type are indicated in Table 7-10. The amount of biodegradable waste landfilled is estimated going back as far as FY1954, when the Public Cleansing Law (now the Waste Management and Public Cleansing Act) was enforced. The statistical survey of landfilling began in 1980s, and in the case that historical data on the amount of biodegradable waste landfilled are unavailable (primarily prior to FY1980), the data of the closest and more recent year available (primarily the data of FY1980) are applied. For the years where the data are unavailable even after FY1980, interpolated values are applied.

Table 7-10 Overview of data for the amount of biodegradable waste disposed of in landfill

<table>
<tr><th colspan="3">Waste type</th><th>Reference</th><th>Detail</th><th>Historical data</th></tr>
<tr><td rowspan="7">Municipal solid waste</td><td colspan="2">Food waste</td><td rowspan="4">Cyclical Use of Waste Report (MOE)</td><td rowspan="4">- Amount directly landfilled
- Amount landfilled after intermediate treatment.

* Fraction of natural fiber content in total waste textiles is calculated by using the fraction of natural fiber products in total textile products, which is determined by taking the ratio of the annual domestic demand for synthetic textiles to that of all textiles indicated in the Textile Handbook (Japan Chemical Fibers Association) and the Yearbook of Textiles and Consumer Goods Statistics (METI).</td><td rowspan="4">- Estimated by interpolation for some fiscal years,
- Substituted FY1980 value for the years prior to FY1980</td></tr>
<tr><td colspan="2">Paper/cardboard</td></tr>
<tr><td colspan="2">Wood</td></tr>
<tr><td colspan="2">Textiles (natural fiber) *</td></tr>
<tr><td rowspan="2">Human waste treatment/ Johkasou sludge</td><td>(Direct final disposal)</td><td>Waste Management in Japan (MOE)</td><td>Calculated by multiplying the amount of human waste sludge in “other treatment” (volume basis) by the weight-conversion factor (1.0 kg/L)</td><td>Substituted FY1978 value for the years prior to FY1978</td></tr>
<tr><td>(Final disposal after treatment)</td><td>Cyclical Use of Waste Report (MOE)</td><td>Amount landfilled after intermediate treatment, excluding ash after incineration</td><td>For the years prior to FY1998, estimated by using the amount of direct final disposal human waste sludge</td></tr>
<tr><td colspan="2">Tsunami sediment</td><td>Waste Treatment in Japan (MOE)</td><td>Direct final disposal of “Tsunami sediment”</td><td>Disposed from FY2011</td></tr>
<tr><td rowspan="12">Industrial waste</td><td colspan="2">Food waste
(Animal and vegetable residues, Animal carcasses)</td><td rowspan="4">Cyclical Use of Waste Report (MOE)</td><td rowspan="4">- Amount directly landfilled
- Amount landfilled after intermediate treatment, excluding ash after incineration by using reference data

* All textiles in industrial waste are considered to consist of natural fiber due to the Waste Management and Public Cleansing Act</td><td rowspan="4">- Estimated by interpolation for some fiscal years,
- Substituted FY1980 value for the years prior to FY1980</td></tr>
<tr><td colspan="2">Paper/cardboard</td></tr>
<tr><td colspan="2">Wood</td></tr>
<tr><td colspan="2">Textiles (natural fiber) *</td></tr>
<tr><td colspan="2">Digested sewage sludge</td><td>Data provided by MLIT</td><td>Compiled and provided by MLIT</td><td rowspan="2">- For some fiscal years, estimated by interpolation
- Substituted FY1985 value for the years prior to FY1985</td></tr>
<tr><td colspan="2">Other sewage sludge</td><td>Sewage Statistics (JSWA)</td><td>Total amount of sewage sludge excluding the amount of digested sewage sludge</td></tr>
<tr><td colspan="2">Waterworks sludge</td><td>Waterworks Statistics (Japan Water Works Association)</td><td>Estimated by “Total amount of soil disposed” and “landfilled percentage” of each purification plant</td><td>Substituted FY1980 value for the years prior to FY1980</td></tr>
<tr><td rowspan="3">Organic sludge from manufacturing industries</td><td>Paper industry</td><td>Data provided by Japan Paper Association, Japan Technical Association of the Pulp and Paper Industry</td><td>Total amount of organic sludge landfilled for paper industry</td><td>Substituted FY1989 value for the years prior to FY1989</td></tr>
<tr><td>Chemical industry</td><td rowspan="2">Survey of generation status of industry-specific by-products (industrial waste and recyclable waste) (METI), etc.</td><td rowspan="2">Total amount of organic sludge landfilled for chemicals industry and food manufacturing industry</td><td rowspan="2">- For some fiscal years, estimated by interpolation
-For the years from FY2015 onward, estimated with the data from Follow-up Action Result of the Voluntary Action Plan on the Environment (Japan Business Federation) and the Report on the State of Industrial Waste Generation and Treatment Survey (MOE)
-For the years prior to FY1998, estimated with the data from Follow-up Action Result of the Voluntary Action Plan on the Environment (Japan Business Federation)
- Substituted FY1990 value for the years prior to FY1990</td></tr>
<tr><td>Food manufacturing industry</td></tr>
<tr><td colspan="2">Livestock waste</td><td>Survey conducted by MOE</td><td>–</td><td>Substituted FY1980 value for the years prior to FY1980</td></tr>
</table>

Note:
METI: Ministry of Economy, Trade and Industry, MLIT: Ministry of Land, Infrastructure, Transport and Tourism.

➢ *Percentage of Water Content in Waste*

In Japan, activity data are estimated on a dry basis because the carbon content of waste can be identified more precisely. The percentages of water content by each type of waste to estimate activity data on a dry basis and their sources are given in Table 7-11. In order to estimate the CO_2 emissions for the category "Incineration and Open Burning of Waste (5.C.)" as well as this source category, dry basis activity data are used for the same reason.

Table 7-11 Percentage of water content in waste disposed of in managed landfill sites

Items			Intermediate treatment	Water content	Reference
Municipal solid waste	Food waste		Untreated	75%	Water percentage of food waste in the *Cyclical Use of Waste Report* (MOE)
			Treated	30%	Specified by considering material flow
	Paper/cardboard		(Unseparated)	20%	Expert judgment
	Wood		(Unseparated)	45%	Expert judgment
	Textiles (natural fiber)		(Unseparated)	20%	Expert judgment
	Human waste treatment/*Johkasou* sludge		Untreated	85%	Moisture content standard of landfill standard (sludge) specified by enforcement ordinance of the Waste Management and Public Cleansing Act
			Treated	70%	Expert judgment
	Tsunami sediment		(Unseparated)	45%	Substituted the value for wood by expert judgment
Industrial solid waste	Food waste		Untreated	75%	Water percentage of food waste in *Cyclical Use of Waste Report* (MOE)
			Treated	Specific to each FY	Specified by considering material flow
	Paper/cardboard		(Unseparated)	15%	Expert judgment
	Wood		(Unseparated)	45%	Expert judgment
	Textiles (natural fiber)		(Unseparated)	15%	Expert judgment
	Sewage sludge	Digested sewage sludge	(Unseparated)	Specific to each disposal site	Average water content of "delivered or final disposal sludge" in the *Sewage Statistics* (JSWA)
		Other sewage sludge	(Unseparated)		
	Waterworks Sludge		(Unseparated)	Not specified	Activity data on a dry basis are provided by the data sources
	Organic sludge from manufacturing industries	Paper industries	(Unseparated)	Not specified	
		Chemical industries	(Unseparated)	57%	Reference of Clean Japan Center Survey
		Food manufacturing	(Unseparated)	77%	
	Livestock waste		Untreated	83.1%	Japan Livestock Technology Association (2002)
			Treated	70%	Expert judgment

➢ *Percentages of Landfill Sites by Site Structure Type*

- *Percentages of MSW Landfill Sites by Site Structure Type*

Among the Japan's MSW disposal sites listed in the section "Facility by Type (Final Disposal Sites)" of the *Annual editions of Results of Study on Municipal Solid Waste Disposal* (Environmental Regeneration and Material Cycles Bureau of MOE) (hereinafter referred to as the *Results of Study on MSW Disposal*), landfill sites which have leachate treatment facilities and subsurface containment structures are regarded as semi-aerobic landfill sites, and the percentage of their total landfill capacity [m^3] is defined as the percentage of semi-aerobic landfill disposal volume.

Since the percentages of semi-aerobic landfill sites for the period FY1996 and before are not available, they are determined as indicated below:

- For the period FY1997 and after, they are determined based on actual data.
- For the period FY1977 and before, all the landfill sites including all the sea area landfills are considered to be anaerobic landfill sites since semi-aerobic landfill technology started in FY1977.
- For the period FY1977-1996, they are estimated by linear interpolation using actual data of FY1997 based on expert judgment.

- ***Percentages of IW Landfill Sites by Site Structure Type***

The percentages of landfill sites by site structure type for IW are determined as follows:

- For the period FY2008 and after, they are determined based on the *Survey of Industrial Waste Treatment Facilities* (MOE).
- For the period FY1977 and before, all the landfill sites including all the sea area landfills are considered to be anaerobic landfill sites since semi-aerobic landfill technology started in FY1977.
- For the period FY1990-2007, they are estimated by using the total amount of waste landfilled and the actual data of waste deposited of in semi-aerobic landfill sites in FY2008.
- For the period FY1977-1989, they are estimated by linear interpolation using the data of FY1990 based on expert judgment.

Table 7-12 Percentages of landfill sites by site structure

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
MSW																
Anaerobic landfill	%	74.2	64.2	54.4	43.5	36.1	33.1	39.9	28.4	28.8	29.1	35.4	30.6	31.8	30.0	30.0
Semi-aerobic landfill	%	25.8	35.8	45.6	56.5	63.9	66.9	60.1	71.6	71.2	70.9	64.6	69.4	68.2	70.0	70.0
IW																
Anaerobic landfill	%	90.2	81.1	66.4	48.3	47.0	28.5	30.0	35.0	37.7	33.4	29.5	24.3	23.1	26.5	26.5
Semi-aerobic landfill	%	9.8	18.9	33.6	51.7	53.0	71.5	70.0	65.0	62.3	66.6	70.5	75.7	76.9	73.5	73.5

➢ ***Decomposition Half-life***

Decomposition half-life is the time taken for 50% of waste landfilled in a certain year to be degraded from its initial mass. Conducting several actual measurements at the Central Breakwater Landfill Site in metropolitan Tokyo, the largest managed landfill for MSW in Japan at the time, Ito (1992) obtained a set of half-lives. Assuming this research was on a representative managed disposal site in Japan for temperate/boreal wet climate, the half-lives in his research for food waste, paper/cardboard, textiles (natural fiber), and wood are applied as country specific parameters (3, 7, 7, and 36 years respectively). Because no relevant research have been obtained to identify a country specific half-life for the sludge, the default value of 3.7 years provided in the spreadsheets attached to the *2006 IPCC Guidelines* is applied. The half-life for wood is used for the half-life of tsunami sediment as a substitute by expert judgment.

Table 7-13 Decomposition half-life for biodegradable waste

Item		Half-life [year]	Reference
Food waste [1]		3	Ito (1992)
Paper/cardboard		7	
Textiles (natural fiber)		7	
Wood [2]		36	
Sludge	Tsunami sediment	36	The half-life of wood is applied by expert judgment.
	Human waste treatment/*Johkasou* sludge	3.7	*2006 IPCC Guidelines*
	Digested sewage sludge		
	Other sewage sludge		
	Waterworks sludge		
	Organic sludge from manufacturing		
	Livestock waste [3]		

Note:

1) Ito (1992) identified the half-life for food waste that is shorter than the default value (4 years) for temperate/wet climate zone of the *2006 IPCC Guidelines*. This is considered to be the reason for that food waste in Japan is more rapidly degraded than theoretical waste the IPCC guidelines assume, since Japan's climate is warmer and more humid than typical temperate/wet climate assumed by the IPCC guidelines (MOE, 2006b).

2) Ito (1992) identified the half-life for wood that is longer than the default value (23 years) for temperate/wet climate zone of the *2006 IPCC Guidelines*. This is considered to be the reason for that meanwhile the IPCC default value covers wood and straw waste, the Japan's country specific parameter does only wood (MOE, 2006b).
3) Although livestock waste is not sludge on the "Wastes Disposal and Public Cleansing Act", the IPCC default half-life for sewage sludge is adopted as that of livestock waste since livestock waste has similar property of sewage sludge.

➢ ***Percentage of open outflow port of leachate collection system at semi-aerobic landfill sites***

Of semi-aerobic landfill sites, those that have open outflow ports for leachate collection are regarded as "Managed well – semi-aerobic landfill sites", and the percentage of total amount of wastes disposed of in the calculated year in these sites to those amount in all semi-aerobic disposal sites is defined as the percentage of open outflow port of leachate collection system at semi-aerobic landfill sites. To evaluate the parameter for municipal solid waste, the data of the condition of open outflow port and disposal amount in each semi-aerobic landfill sites provided in the *State of Municipal Waste Treatment Survey* are used. For industrial waste, those data in each semi-aerobic landfill sites indicated in a result of questionnaire survey by Environmental Regeneration and Material Cycles Bureau of MOE, are used.

Table 7-14 Percentage of open outflow port of leachate collection system at semi-aerobic landfill sites for municipal solid waste and industrial waste

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Municipal solid waste	%	64.7	64.7	64.7	64.7	69.1	71.2	69.7	71.9	70.3	73.2	71.2	70.5	71.8	71.2	71.2
Industrial waste	%	84.3	84.3	84.3	84.3	88.2	85.6	85.6	85.6	85.6	85.6	85.6	85.6	85.6	85.6	85.6

➢ ***Delay Time***

Delay time is the time lag from when the waste is landfilled until when the decomposition actually occurs. As no knowledge is obtained for making it possible to set a delay time specific to Japan, the default value (6 months) given in the *2006 IPCC Guidelines* is used.

Table 7-15 Amount of biodegraded waste decomposed of to be degraded in each estimation year (Activity data)

Item			Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
a. Anaerobic landfill	Mumicipal solid waste	Food waste	kt (dry)	358	278	172	99	44	32	27	23	19	16	14	12	10	9	7
		Paper/cardboard	kt (dry)	1,042	913	724	545	393	343	319	297	274	252	232	213	196	179	164
		Textiles (natural fiber)	kt (dry)	54	48	38	31	23	19	18	16	15	13	12	11	10	9	8
		Wood	kt (dry)	186	186	179	167	155	149	147	144	142	139	137	134	132	129	127
		Human waste treatment/ *Johkasou* sludge	kt (dry)	96	66	44	29	17	14	12	11	10	8	7	7	6	6	5
		Ttsunami sediment	kt (dry)	NO	NO	NO	NO	NO	0	0	1	1	1	1	1	1	1	1
	Industrial waste	Food waste	kt (dry)	69	102	117	74	32	24	21	17	15	12	11	9	8	7	7
		Paper/cardboard	kt (dry)	137	138	121	99	74	63	58	53	49	44	41	37	34	32	29
		Textiles (natural fiber)	kt (dry)	22	16	15	12	10	8	8	7	7	7	6	6	6	5	5
		Wood	kt (dry)	224	261	258	247	232	225	221	218	214	211	208	205	201	198	195
		Digested sewage sludge	kt (dry)	59	52	38	22	10	8	7	6	5	4	4	3	3	3	2
		Other sewage sludge	kt (dry)	221	196	144	83	39	30	26	22	19	17	15	13	11	9	8
		Waterworks sludge	kt (dry)	180	165	127	85	51	44	40	36	34	33	31	29	27	25	24
		Organic sludge from manufacturing industry	kt (dry)	343	265	155	88	43	34	30	26	22	19	17	14	12	11	10
		Livestock waste	kt (dry)	11	11	9	7	6	5	5	5	5	5	5	4	4	4	4
b. Semiaerobic landfill (Managed well)	Mumicipal solid waste	Food waste	kt (dry)	45	61	58	53	31	25	21	19	17	16	13	12	11	10	8
		Paper/cardboard	kt (dry)	77	124	150	170	171	169	161	160	150	149	137	127	122	112	104
		Textiles (natural fiber)	kt (dry)	4	7	8	11	11	10	9	8	8	7	6	6	5	5	5
		Woods	kt (dry)	6	10	14	16	18	19	18	19	19	19	18	18	18	18	18
		Human waste treatment/ *Johkasou* sludge	kt (dry)	9	12	13	14	12	11	10	9	8	8	7	6	6	6	6
	Industrial waste	Food waste	kt (dry)	4	13	30	33	20	17	17	15	13	12	11	11	10	11	11
		Paper/cardboard	kt (dry)	5	10	17	26	31	27	27	25	24	22	21	19	19	19	19
		Textiles (natural fiber)	kt (dry)	1	1	2	3	4	4	4	4	4	4	5	5	5	5	5
		Wood	kt (dry)	5	12	17	23	30	31	31	32	33	33	34	35	36	36	37
		Digested sewage sludge	kt (dry)	3	5	7	7	5	4	4	3	3	3	3	3	3	3	3
		Other sewage sludge	kt (dry)	11	19	27	27	18	16	16	14	13	12	11	10	10	9	8
		Waterworks sludge	kt (dry)	10	17	25	30	32	32	34	35	35	35	36	37	38	39	40
		Organic sludge from manufacturing industry	kt (dry)	18	24	24	26	20	19	18	17	15	14	13	12	11	11	10
		Livestock waste	kt (dry)	1	1	2	3	5	5	5	5	6	6	6	6	7	7	7
b. Semiaerobic landfill (Managed poorly)	Mumicipal solid waste	Food waste	kt (dry)	25	33	32	29	14	10	9	8	7	6	5	5	4	4	3
		Paper/cardboard	kt (dry)	42	68	82	93	77	68	70	62	63	54	55	53	48	45	42
		Textiles (natural fiber)	kt (dry)	2	4	4	6	5	4	4	3	3	3	3	2	2	2	2
		Woods	kt (dry)	3	6	7	9	8	8	8	7	8	7	7	8	7	7	7
		Human waste treatment/ *Johkasou* sludge	kt (dry)	5	6	7	8	5	4	4	4	3	3	3	3	2	3	2
	Industrial waste	Food waste	kt (dry)	1	2	6	6	3	3	3	2	2	2	2	2	2	2	2
		Paper/cardboard	kt (dry)	1	2	3	5	4	5	4	4	4	4	3	3	3	3	3
		Textiles (natural fiber)	kt (dry)	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
		Wood	kt (dry)	1	2	3	4	4	5	5	5	5	6	6	6	6	6	6
		Digested sewage sludge	kt (dry)	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
		Other sewage sludge	kt (dry)	2	4	5	5	2	3	3	2	2	2	2	2	2	1	1
		Waterworks sludge	kt (dry)	2	3	5	6	4	5	6	6	6	6	6	6	6	7	7
		Organic sludge from manufacturing industry	kt (dry)	3	4	4	5	3	3	3	3	3	2	2	2	2	2	2
		Livestock waste	kt (dry)	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1

Note: The declining trend in the amount of biodegraded waste is affected by the improvement of waste reduction that causes the decrease of landfilled waste.

- ***Amount of CH_4 recovered from Landfills***

In order to reduce the amount of organic matter content and CH_4 emissions at landfill sites, certain intermediate treatments and landfill methods have been conducted; CH_4 recovery from landfills is not very common practice in Japan. CH_4 recovery from landfilled MSW for the purpose of electric power generation implemented at the Tokyo Metropolitan Inner Landfill Site for the Central Breakwater Landfill Site is the sole practice example in Japan. For IW, there is no practice of CH_4 recovery from landfills implemented in Japan. Because CO_2 emitted from the combustion of recovered CH_4 is of biogenic-origin, it is not included in the total emissions. Amount of CH_4 recovered for energy in landfill sites is estimated as following equation.

$$R = r \times f \times 16/22.4/1000$$

R : Amount of CH_4 recovered in landfill [g]

r : Amount of recovered landfill gas used for electric power generation [m^3 N]

f : Ratio of CH_4 to recovered gas

- ***The amount of recovered landfill Gas used for electric power generation in the Central Breakwater Landfill Site***

The amount of recovered gas used for electric power generation is provided by the Waste Disposal Management Office of Tokyo.

- ***Fraction of CH_4 to the recovered gas***

The fraction of CH_4 to recovered landfill gas in the Central Breakwater Landfill Site has been annually provided since FY2005 by the Waste Disposal Management Office of Tokyo. The fractions for the years prior to FY2005 are determined based on the hearing conducted with the Waste Disposal Management Office of Tokyo: 60% for FY1987, when the recovery of landfill gas was started; 40% for FY1996; interpolated for FY1988 through FY1995; The FY1996 value is used for FY1997 through FY2004.

Table 7-16 Amount of CH_4 used at landfill sites in Japan

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Amount of landfill gas use	km^3 N	1,985	2,375	2,372	140	1,266	1,681	1,734	1,612	1,565	1,488	NO	NO	NO	NO	32
CH_4 ratio	%	53.3	42.2	40.0	48.5	43.8	49.5	44.9	41.0	39.2	40.2	NA	NA	NA	NA	68.8
Amount of CH_4 use	km^3 N	1,059	1,003	949	68	555	832	779	661	613	598	NO	NO	NO	NO	22
CH_4 unit conversion	Gg-CH_4	0.76	0.72	0.68	0.05	0.40	0.59	0.56	0.47	0.44	0.43	NO	NO	NO	NO	0.02

Note: The trend of landfill gas use significantly depends on the operation of the only power plant at the Central Breakwater Landfill Site.

➢ ***CH_4 Oxidation Factor Related by Landfill Cover Soil***

Based on law enforcement ordinances and local government ordinances, daily, intermediate and final soil coverings are practiced in the managed final disposal sites for MSW and IW in Japan. Therefore, the default oxidation factor for managed landfill sites (0.1) is used in accordance with the *2006 IPCC Guidelines*.

c) Uncertainties and Time-series Consistency

● ***Uncertainties***

The uncertainties in emission factors for municipal solid waste and industrial waste on the category are assessed by combining the uncertainties in carbon content, fraction of degradable organic carbon dissimilated, percentages of CH_4 in landfill gas, methane correction factor (*MCF*), and oxidation factor evaluated by using the 95% confidence interval obtained from actual measurement, or by expert judgment.

Regarding the uncertainty for activity data for this sector, due to the lack of information on statistical error in quoted references, it is difficult to assess uncertainties based on concrete evidence. Therefore, it is assessed by expert judgment as indicated in the Table 7-2. Details of the uncertainty assessment on this category are shown in the Table 7-17.

Table 7-17 Uncertainty assessment by waste type on the category "managed disposal sites (5.A.1.)"

Item		GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
			(-)	(+)	(-)	(+)	(-)	(+)			
Municipal waste	Food waste	CH_4	-47%	+47%	-10%	+10%	-48%	+48%	The uncertainties in emission factors are evaluated by combining the 95% confidence interval of actual measurement data of carbon content, the uncertainty in fraction of degradable organic carbon dissimilated and proportion of methane in generated gas based on expert judgment, and the uncertainty in default value of MCF and oxidation factor provided by the *2006 IPCC Guidelines*, by using the formula for propagation of errors. (Method 1)	The uncertainty in municipal waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.
	Paper/cardboard	CH_4	-47%	+47%	-10%	+10%	-48%	+48%			
	Textiles (natural fiber)	CH_4	-47%	+47%	-10%	+10%	-48%	+48%			
	Wood	CH_4	-47%	+47%	-10%	+10%	-48%	+48%			
	Human waste treatment/ *Johkasou* sludge	CH_4	-49%	+49%	-10%	+10%	-50%	+50%			
	Tsunami sediment	CH_4	-47%	+47%	-10%	+10%	-48%	+48%	The uncertainty in emission factor for wood is substituted, since the substance of tsunami sediment for estimation is assumed to be wood.		
Industrial waste	Food waste	CH_4	-47%	+47%	-30%	+30%	-56%	+56%	The uncertainty is evaluated by using method 1.	The uncertainty in industrial waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.
	Paper/cardboard	CH_4	-47%	+47%	-30%	+30%	-56%	+56%			
	Textiles (natural fiber)	CH_4	-47%	+47%	-30%	+30%	-56%	+56%			
	Wood	CH_4	-47%	+47%	-30%	+30%	-56%	+56%			
	Sewage sludge	CH_4	-49%	+49%	-5%	+5%	-49%	+49%	The uncertainty in emission factor is evaluated by using method 1. The uncertainty of carbon content in the method is evaluated based on expert judgment.	The uncertainty in sewage statistics based on expert judgment is applied.	
	Waterworks sludge	CH_4	-51%	+51%	-5%	+10%	-51%	+52%	The uncertainty is evaluated by using method 1.	The uncertainty in the waterworks statistics based on expert judgment is applied.	
	Organic sludge from manufacturing industries	CH_4	-58%	+58%	-30%	+30%	-65%	+65%	The uncertainty in emission factor is evaluated by using method 1. The uncertainty of carbon content in the method is evaluated by expert judgment.	The uncertainty in industrial waste statistics based on expert judgment is applied.	
	Livestock waste	CH_4	-51%	+51%	-30%	+30%	-59%	+59%	The uncertainty in emission factors is evaluated by using method 1. For the carbon content in the method, the uncertainty provided by the *2006 IPCC Guidelines* as default value is applied.		
Methane recovery		CH_4	-10%	+10%	-10%	+10%	-14%	+14%	The uncertainty of Methane concentration in recovered gas is evaluated based on expert judgment.	The uncertainty in municipal waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.

- ***Time-series Consistency***

Although some activity data in FY1990 and thereafter are not available, they are estimated by using the methods described in "Activity data" to develop consistent time-series data. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By adopting the default values of "fraction of the degradable organic carbon that decomposes (*DOCf*)" and "methane correction factor (*MCF*)" given in the *2019 Refinement*, CH_4 emissions for the whole time series were recalculated. By updating the statistical data, emissions for the whole time series were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

For future inventories, long-term efforts on further scientific investigations will be made to identify country-specific parameters (e.g. fraction of degradable organic carbon dissimilated for each type of biodegradable waste and country-specific half-life for sludge at final disposal sites).

7.2.2. Unmanaged Waste Disposal Sites (5.A.2.)

a) Category Description

Because landfill sites in Japan are appropriately managed pursuant to the Waste Management and Public Cleansing Act, there are no unmanaged waste disposal sites in Japan. Therefore, the emissions from this source category are reported as "NO".

7.2.3. Uncategorized Waste Disposal Sites (5.A.3.)

7.2.3.1. Inappropriate Disposal (5.A.3.-)

a) Category Description

In Japan, the definition of "inappropriate disposal" is waste disposal violating the Waste Management and Public Cleansing Act (illegal dumping and other forms of improper disposal on lands or areas other than landfill sites). Activities in the category of inappropriate disposal are identified as 1) illegal dumping, and 2) revealed matter; both are irregular events. The ratio of the amount of inappropriate waste disposal is quite small comparing to the one of appropriate waste disposal. Although these inappropriate disposal lands or areas generally satisfy the conditions of managed disposal sites defined in the *2006 IPCC Guidelines*, CH_4 emissions from inappropriate disposal are reported under "Uncategorized waste disposal sites (5.A.3.)".

Very few fires are observed in inappropriate landfill sites, and they may be emitting fossil-fuel derived CO_2. However, since actual data are not available, the emissions from the fires at inappropriate landfill sites are reported as "NE".

b) Methodological Issues

- ***Estimation Method***

Wood and paper/cardboard are the wastes containing biodegradable carbon and being inappropriately disposed without incineration; however, only wood is the subject for the estimation, because the residual amount of paper/cardboard should be very small.

In a similar manner for the "Managed Disposal Sites (5.A.1.)", a FOD method with Japan's country-specific parameters is used for the estimation. Emissions are estimated by multiplying the amount of wood (dry basis) degraded in a reporting year by an emission factor.

- ***Emission Factor***

The emission factor for wood in anaerobic disposal sites (30 kg-CH_4/t) shown in Table 7-8 is adopted for this category.

- ***Activity Data***

As activity data for this category, amount of wood (dry basis) degraded in a reporting year is estimated in a similar manner described in the section "7.2.1. Managed Disposal Sites (5.A.1.)". The parameters employed in the method to estimate activity data for this category are shown below.

➢ ***Amount of Waste Disposed of in Inappropriate Disposal Sites***

The amount of waste disposed of from FY1980 onward in inappropriate disposal sites and remaining without removal from these sites have been reported since FY2003 in the *Study on Residual Amounts of Industrial Waste from Illegal Dumping and other Sources* (Environmental Regeneration and Material Cycles Bureau, MOE) as data of residual amount by each disposal fiscal year (wet basis). Note that these reported residual amounts in inappropriate disposal sites can be changed in future reports due to new revealment of hidden inappropriate disposal and/or removal of waste from inappropriate disposal sites after the revealment. Based on the residual amount of wood (construction waste) in the data of "remaining case and residual amount of waste by type" in the investigation, considering changes in the data series in the past reports, initial amount of waste disposed of in the past are estimated as shown in Table 7-18.

Table 7-18 Annual amount of waste disposed of in inappropriate disposal sites

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Wood	kt (dry)	48.8	51.9	144.9	21.1	19.0	4.2	5.1	3.2	25.3	6.9	4.5	4.9	2.5	3.9	3.6

Note: Annual amount of waste disposed of in inappropriate disposal sites includes those which had already been removed from these sites, but excludes those that are not revealed at present. Note that the values in the table are indicated in dry basis considering percentage of water content in waste shown below.

➢ ***Percentage of Water Content in Waste***

Percentage of water content in industrial waste wood disposed of in managed disposal sites (45%) in Table 7-11 is adopted for this category.

➢ ***Landfill site structure***

Since the actual condition of CH_4 generation from inappropriate disposal is unidentified, all inappropriate disposal sites are conservatively assumed to be under anaerobic conditions in the CH_4 estimation.

➢ ***Decomposition Half-life***

A half-life for wood (36 years) in Table 7-13 is adopted for this category.

➢ ***Delay Time***

Similar to the category Managed Disposal Sites (5.A.1.), the default value (6 months) given in the *2006 IPCC Guidelines* is adopted for this category.

➢ ***Amount of Wood Decomposed in Each Year (Activity data)***

Amounts of waste inappropriately disposed of to be degraded in each estimation year are shown in Table 7-19. Note that it is considered in the estimation of these amount that the amount removed from inappropriate disposal sites cannot be degraded in these sites after the removal fiscal year.

Table 7-19 Amount of waste inappropriately disposed of to be degraded in each estimation year (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Wood	kt (dry)	2.3	5.6	16.3	16.3	14.7	14.5	13.7	12.8	12.3	12.4	12.1	11.7	11.6	11.4	9.9

● ***Amount of CH_4 recovered from Landfills***

Since activities of CH_4 recoveries both for flaring and energy use are not observed in inappropriate disposal sites in Japan, these reporting items in this category are reported as “NO”.

● ***CH_4 Oxidation Factor Related by Landfill Cover Soil***

Since no literature is available related to the condition of cover soil in inappropriate disposal sites, the default oxidation factor for uncategorized solid waste disposal site (0) given in the *2006 IPCC Guidelines* is adopted for this category.

c) Uncertainties and Time-series Consistency

● ***Uncertainties***

The uncertainties in emission factor and activity data are evaluated by using the same methods that are used for “Managed Disposal Sites (5.A.1.)”. Details of the uncertainty assessment on this category are shown in the Table 7-20.

Table 7-20 Uncertainty assessment on the category “inappropriate disposal sites (5.A.3.-)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Inappropriately disposed waste	CH_4	-42%	+41%	-60%	+60%	-74%	+73%	The uncertainty in emission factor for wood is substituted, since the source for estimation is assumed to be wood.	The twofold higher uncertainty than the value in industrial waste statistics is applied based on expert judgment.	Combined by using the formula for propagation of errors.

● ***Time Series Consistency***

Because data on inappropriate disposal are available only since FY2002, activity data prior to FY2002 are estimated. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By adopting the default values of "fraction of the degradable organic carbon that decomposes (*DOCf*)" given in the *2019 Refinement*, CH_4 emissions for the whole time series were recalculated. Also, due to the removals of inappropriate disposal, revelations of past inappropriate disposal, and etc., the amount of identified inappropriate disposal in the past has been updated annually. Due to the changes in the amount of inappropriate disposal, emissions for the whole time series were recalculated. See chapter 10 for impact on trend.

f) Category-specific Planned Improvements

For future inventories, long-term efforts on further scientific investigations will be made to identify country-specific parameters.

7.3. Biological Treatment of Solid Waste (5.B.)

In this category, CH_4 and N_2O emissions from biological treatment of solid waste are calculated. The target categories are shown in Table 7-21.

Table 7-21 Categories whose emissions are estimated for biological treatment of solid waste (5.B.)

Category	Waste type		Treatment type	CH_4	N_2O
5.B.1. (7.3.1)	Municipal solid waste	Food waste	Composting	○	○
		Paper/cardboard			
		Textiles			
		Wood (garden and park waste)		○	○
	Human waste/*Johkasou* sludge			○	○
	Industrial waste	Food waste (animal and vegetable residues, other food waste)		○	○
		Sewage sludge		○	○
5.B.2. (7.3.2)	–		Anaerobic digestion	NE	NO

Estimated GHG emissions from this category are shown in Table 7-22. I n FY2021, emissions from this source category are 319 kt-CO_2 eq. and accounted for 0.03% of the national total emissions (excluding LULUCF). The emissions from this source category had increased by 35.9% compared to those in FY1990. This emission increase is primarily due to the enhancement of effective utilization of waste as recycled resources. While Japan adopts country-specific emission factors (wet basis) in this category, due to low variation in time series of waste composition for composting, the IEFs for whole category are stable (approximately 2.8 kg-CH_4/t [dry] and 0.78-0.79 kg-N_2O/t [dry]).

Table 7-22 GHG emissions from biological treatment of solid waste (5.B.)

Gas	Category		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CH_4	5.B.1. Composting	Municipal solid waste	kt-CH_4	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1
		Human waste/ *Jokasou* sludge	kt-CH_4	NO	NO	NO	0.004	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02
		Industrial waste	kt-CH_4	2.1	2.1	2.1	3.7	3.6	3.9	3.9	3.8	3.9	3.9	3.4	3.4	3.1	2.8	2.8
	5.B.2. Anaerobic digestion at biogas facilities		kt-CH_4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Total		kt-CH_4	2.2	2.1	2.2	3.8	3.7	4.1	4.0	4.0	4.1	4.1	3.6	3.6	3.3	3.0	3.0
			kt-CO_2 eq.	54	53	54	95	93	101	100	100	102	103	90	89	82	74	74
N_2O	5.B.1. Composting	Municipal solid waste	kt-N_2O	0.02	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.03	0.03
		Human waste/ *Jokasou* sludge	kt-N_2O	NO	NO	NO	0.001	0.005	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		Industrial waste	kt-N_2O	0.59	0.59	0.59	1.05	1.00	1.10	1.09	1.08	1.10	1.11	0.96	0.95	0.88	0.79	0.79
	5.B.2. Anaerobic digestion at biogas facilities		kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total		kt-N_2O	0.61	0.60	0.61	1.07	1.04	1.14	1.12	1.12	1.14	1.15	1.00	0.99	0.92	0.83	0.82
			kt-CO_2 eq.	181	179	181	319	309	338	335	333	340	343	298	296	274	247	245
Total			kt-CO_2 eq.	235	233	235	414	402	440	435	433	441	446	388	385	356	321	319

7.3.1. Composting (5.B.1)

a) Category Description

Part of the MSW and industrial waste generated in Japan is composted, and CH_4 and N_2O generated in that process are emitted from composting facilities. Emissions from composting of livestock waste are reported under “5.3. Manure management (3.B)” in the agriculture sector.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated by taking the amount of organic waste composted, which is obtained from the statistical information available in Japan, and multiplying it by country-specific emission factors. The calculation method is the same for both CH_4 and N_2O emissions.

$$E = \sum_i EF_i \times A_i$$

E : Amount of CH_4 or N_2O emissions generated by composting organic waste [kg-CH_4], [kg-N_2O]

EF_i : Emission factor for organic waste i (wet basis) [kg-CH_4/t], [kg-N_2O/t]

A_i : Amount of composted organic waste i (wet basis) [t]

- ***Emission Factor***

Country-specific emission factors obtained from actual measurements at 9 facilities in summer and winter by MOE (2018a) are adopted (MOE, 2018b).

Table 7-23 GHG emission factors for composting (5.B.1) (wet basis)

Waste type		CH_4 emission factor [kg-CH_4/t]	N_2O emission factor [kg-N_2O/t]	Note
MSW	Wood (garden and park waste)	0.35	0.0015	Low degradable
	Food waste	0.96	0.27	High degradable
	Paper/cardboard			
	Textiles			
Human waste/*Johkasou* sludge				
IW	Food waste (animal and vegetable residues, other food waste)			
	Sewage sludge			

Note: Each composting facility in which actual measurement was conducted treats different type of waste respectively. According to the study, the emission factors for the facilities composting wood (garden and park waste) are lower than those for the facilities composting of food waste, human waste, *johkasou* sludge and sewage sludge. Although only one facility solely composts park and garden waste among facilities treated in this study, the expert acknowledged the significantly lower CH_4 and N_2O emissions from composting process for only garden and park waste by considering obviously lower degradability of garden and park waste than that of sludge and food waste. Hence based on these actual measurement, CH_4 and N_2O emission factors for composting distinguished by waste type, such as low degradable and high degradable waste, are defined and applied in the category 5.B.1 composting (MOE 2018b) as shown in Table 7-23.

Since management practice in Japanese composting facilities includes turning over compost regularly or blowing air into the lower part of fermentation tanks to keep aerobic conditions, the country-specific CH_4 emission factors are lower than the default value in the 2006 *IPCC Guidelines*.

- ***Activity Data***

Activity data for the category composting (5.B.1) are obtained from the references shown on the Table 7-24.

Table 7-24 References of activity data for composting (5.B.1)

Waste type		Reference	Note
MSW	Food waste	- *Waste Treatment in Japan* (MOE) - *Cyclical Use of Waste Report* (MOE)	Amount of MSW treated at waste composting facilities indicated in the *Waste Treatment in Japan* (MOE), is disaggregated by using MSW composition treated at high-rate composting facilities provided in the *Cyclical Use of Waste Report* (MOE).
	Paper/cardboard		
	Textiles		
	Wood (garden and park waste)		
Human waste/*Johkasou* sludge		*Waste Treatment in Japan* (MOE)	–
IW	Food waste (animal and vegetable residues, other food waste)	*Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics* (MOE)	This category includes; - Animal and vegetable residues generated by food and beverage manufacturing. - Food waste including valuables other than the above: although it falls under the category other than industrial waste in the Waste Management and Public Cleansing Act, it is included in industrial waste because of its source and properties.
	Additives (e.g. wood, etc.)	Expert judgment	Estimated by using additive ratio of 30% in food waste, derived from expert judgment referring to the *Cyclical Use of Waste Report* (MOE).
	Sewage sludge	*Sewage Statistics* (JSWA)	–
	Additives (e.g. wood, etc.)	Data provided by MLIT	

Activity data (wet basis) obtained is shown on the Table 7-25.

Table 7-25 Amounts of composted waste (Activity data: wet basis)

Item		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
MSW	Food waste	kt (wet)	35	20	29	66	117	120	121	115	122	134	141	133	131	122	115
	Paper/cardboard	kt (wet)	28	16	23	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Textiles	kt (wet)	3	2	2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Wood	kt (wet)	8	5	4	33	48	40	45	60	60	85	84	83	75	73	69
	Total	kt (wet)	74	42	58	99	165	160	166	175	182	219	225	216	206	195	184
Human waste/*Johkasou* sludge		kt (wet)	NO	NO	NO	4	17	21	19	25	35	30	21	21	23	22	23
IW	Food waste	kt (wet)	2,063	2,063	2,063	3,747	3,564	3,920	3,883	3,861	3,923	3,973	3,439	3,417	3,164	2,849	2,834
	Sewage sludge	kt (wet)	118	126	135	147	144	145	136	139	140	129	105	103	84	77	77
	Total	kt (wet)	2,180	2,189	2,198	3,894	3,708	4,065	4,019	4,000	4,063	4,102	3,543	3,520	3,249	2,925	2,911

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties in emission factors are evaluated according to the survey for EFs (MOE, 2018a). As for the uncertainty in activity data, since valuables account for much of activity data in biological treatment, the uncertainty of valuables indicated in Table 7-2 is adopted for that of activity data based on expert judgment. Details of the uncertainty assessment on this category are indicated in the Table 7-26.

Table 7-26 Uncertainty assessment on the category "composting (5.B.1.)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Composting	CH_4	-79%	+79%	-30%	+30%	-84%	+84%	The uncertainty is evaluated according to the survey for the EFs (MOE, 2018a)	The uncertainty in valuables based on expert judgment is applied since AD mostly consists of valuables.	Combined by using the formula for propagation of errors.
	N_2O	-167%	+167%	-30%	+30%	-170%	+170%			

- ***Time-series Consistency***

Since the amount of composted animal and plant residues generated by food manufacturing and food waste other than those for FY1990-2000 are unavailable, the data for FY2001 are used for those years. Since the data of the amount of additives (e.g. wood, etc.) to be added to sewage sludge treated at composting facilities for FY1990-1995 are unavailable, those data are estimated by multiplying the sewage sludge for FY1990-1995 by the ratio of additives for FY1996; thus, time series consistency in emission estimates has been ensured.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By updating the statistical data, emissions in FY2020 were recalculated. For detail, see the section "7.1.5. General Recalculations for Emissions from Waste Sector". See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

The implementation of emission estimates from domestic and commercial composting machine will be further considered. Because this kind of research could not be completed in a short period of time, a long-term effort on scientific investigations will be necessary.

7.3.2. Anaerobic Digestion at Biogas Facilities (5.B.2.)

a) Category Description

- ***Biogas facilities in Japan***

As biogas facilities to be considered in this category, anaerobic digestion equipment at sewage treatment plants, biogas facilities for municipal waste, and biogas facilities for industrial waste are operated in Japan.

➢ ***Anaerobic digestion equipment for sewage sludge at sewage treatment plants***

JSWA (2009) states that, digestion tanks for sludge at sewage treatment plants should be kept airtight to prohibit explosions and odors caused by biogas leakage. It also states that unutilized digestion gas from such equipment should be combusted in views of safety and climate change mitigation. In addition, Japan estimates CH_4 and N_2O emissions from sludge thickening tank and dehydration room by using emission factors considering whole treatment system including these processes; CH_4 and N_2O emissions from this source stated in the *2006 IPCC Guidelines* are included in “7.5.1.1. Sewage Treatment Plant (5.D.1.-)”.

➢ ***Biogas facilities for municipal waste***

MOE (2008) states that fermentation equipment at biogas facilities for municipal waste should be kept airtight. It also states that biogas from such equipment should be combusted by the excess gas combustion system and discharged safely when the facilities cannot supply biogas to consumers in emergencies or maintenances.

➢ ***Biogas facilities for industrial waste***

Although biogas facilities for industrial waste are not controlled by the guidelines such as for these for municipal waste, operators ought to keep airtight at the facilities in their installations as a safety measure.

- ***Emission estimates***

Biogas facilities in Japan for municipal waste and industrial waste are leaking small amounts of CH_4. By assuming 2% of the leakage fraction of biogas produced in a facility (a consideration of actual situation of the CH_4 emission) and 60% of the CH_4 concentration in biogas (the *JARUS Reference System for Information of Biomass Recycling Technology*, The Japan Association of Rural Resource Recycling Solutions), the CH_4 emissions from this source category were tentatively estimated as 1.4 [kt-CO_2 eq. per year] at a maximum. Hence the emissions from this source category are reported as “NE” which stands for “considered insignificant” guided by the decision tree on the Figure A5-2 of Annex 5.

Assumed to be negligible in accordance with the *2006 IPCC Guidelines*, N_2O emission from this source category are reported as “NO”.

7.4. Incineration and Open Burning of Waste (5.C.)

In Japan, waste disposed of has been reduced in volume primarily by incineration. Emissions from waste incineration are categorized into different types as shown in Table 7-27. CO_2, CH_4, N_2O emissions from "7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)" and "7.4.2. Open Burning of Waste (5.C.2.)" are reported under this category.

Table 7-27 Categories whose emissions are estimated for waste incineration and open burning (5.C.)

Category	Waste type			Category to be allocated to CRF	Treatment type		CO_2	CH_4	N_2O
5.C.1 (7.4.1)	Municipal solid waste (7.4.1.1)	Plastics	Fossil-fuel derived plastics	Non-biogenic/MSW	Incineration without energy recovery	Incinerator -continuous -semi-continuous -batch type Gasification melting furnace	○	○[2)]	○[2)]
			Biomass-based plastics	Biogenic/MSW			NA[1)]		
		PET bottles	Fossil-fuel derived PET bottles	Non-biogenic/MSW			○		
			Biomass-based PET bottles	Biogenic/MSW			NA[1)]		
		Paper/ cardboard	Fossil-fuel derived fraction	Non-biogenic/MSW			○		
			Biogenic fraction	Biogenic/MSW			NA[1)]		
		Nappies	Fossil-fuel derived fraction	Non-biogenic/MSW			○		
			Biogenic fraction	Biogenic/MSW			NA[1)]		
		Textiles	Synthetic textiles	Non-biogenic/MSW			○		
			Natural fiber	Biogenic/MSW			NA[1)]		
		Other (Biogenic)		Biogenic/MSW			NA[1)]		
	Industrial waste (7.4.1.2)	Waste oil	Fossil-fuel derived oil	Non-biogenic/ Fossil liquid waste		Incinerator	○	○	○
			Animal and vegetable oil	Biogenic/ Non- fossil liquid waste			NA[1)]	○	○
		Plastics	Fossil-fuel derived plastics	Non-biogenic/ISW			○	○	○
			Biomass-based plastics	Biogenic/ISW			NA[1)]	IE[3)]	IE[3)]
		Food waste [Animal and vegetable residues/animal carcasses]		Biogenic/ISW			NA[1)]	○	○
		Paper/ cardboard	Fossil-fuel derived fraction	Non-biogenic/ISW			○	IE[4)]	IE[4)]
			Biogenic fraction	Biogenic/ISW			NA[1)]	○	○
		Wood		Biogenic/ISW			NA[1)]	○	○
		Textiles	Synthetic textiles	-			IE[3)]	IE[3)]	IE[3)]
			Natural fiber	Biogenic/ISW			NA[1)]	○	○
		Sludge	Sewage sludge	Biogenic/Sludge		Various types of incinerations [5)]	NA[1)]	○	○
			Other than sewage sludge	Biogenic/Sludge		Incinerator	NA[1)]	○	○
	Specially-controlled industrial waste (7.4.1.3)	Hazardous waste (Waste oil)	Flammable waste oil	Non-biogenic/ Hazardous waste			○	○	○
			Specified hazardous industrial waste oil	Non-biogenic/ Hazardous waste			○	○	○
		Infectious waste	Plastics (Fossil-fuel derived)	Non-biogenic/ Clinical waste			○	○	○
			Other (except plastics)	Biogenic/ Clinical waste			NA[1)]	○	○
5.C.2 (7.4.2)	Municipal solid waste (7.4.2.1)			-	Open burning		NO	NO	NO
	Industrial waste (7.4.2.2)	Plastics (Fossil-fuel derived)		Non-biogenic/ISW			○	○	○
		Other (Biogenic)		Biogenic/ISW			NA[1)]	IE[6)]	IE[6)]

Note:
1) CO_2 emissions from the incineration of biomass-derived waste are not included in the total emissions in accordance with the *2006 IPCC Guidelines*; instead it is estimated as a reference value and reported under "Biogenic" in Table 5.C of the CRF.
2) CH_4 and N_2O emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported under "Non-biogenic/MSW" in Table 5.C of the CRF.
3) Included in fossil-fuel derived plastics in industrial solid waste (ISW)
4) Included in biogenic fraction of paper/cardboard
5) For details of incineration types for sewage sludge, see section 7.4.1.2.
6) CH_4 and N_2O emissions from open burning of industrial solid waste in bulk are reported under "Non-biogenic/ISW".

Also, waste incineration includes the following practices of waste used as raw material or fuel:

- Waste Incineration with Energy Recovery (1.A.) (See section 7.4.3.1.)

- Direct Use of Waste as Alternative Fuel (1.A.) (See section 7.4.3.2.)
- Incineration of Waste Processed as Fuel (1.A.) (See section 7.4.3.3.)

In accordance with the *2006 IPCC Guidelines*, estimated emissions from the sources listed above are allocated to Energy sector (Category 1) as “7.4.3. Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)”. For details of reporting category on energy sector, see Table 7-29.

In order to avoid double-counting or any other confusion, emissions from the categories indicated in Table 7-27, Table 7-28 and Table 7-29 with or without energy use are estimated collectively under the waste sector, thus the estimation methodology for these categories are provided in this section.

Table 7-28 Waste types whose emissions are estimated for
“Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)”

Category	Waste type			Fuel type on energy sector to be allocated to CRF	Treatment type		CO_2	CH_4	N_2O
1.A.4. (7.4.3.1)[7]	MSW	Plastics	Fossil-fuel derived plastics	Other fossil fuels	Incineration with energy recovery	・Incinerator -continuous, -semi-continuous -batch type ・Gasification melting furnace	○	○[2]	○[2]
			Biomass-based plastics	Biomass[8]			NA[1]		
		PET bottles	Fossil- fuel derived PET bottles	Other fossil fuels			○		
			Biomass-based PET bottles	Biomass[8]			NA[1]		
		Paper/ cardboard	Fossil-fuel derived fraction	Other fossil fuels[9]			○		
			Biogenic fraction	Biomass			NA[1]		
		Nappies	Fossil-fuel derived fraction	Other fossil fuels			○		
			Biogenic fraction	Biomass			NA[1]		
		Textiles	Synthetic textiles	Other fossil fuels			○		
			Natural fiber	Biomass			NA[1]		
		Other (biogenic)		Biomass			NA[1]		
	IW	Waste oil	Fossil-fuel derived oil	Other fossil fuels		Incinerator	○	○	○
			Animal and vegetable oil	Biomass			NA[1]	○	○
		Plastics	Fossil-fuel derived plastics	Other fossil fuels			○	○	○
			Biomass-based plastics	Biomass[8]			NA[1]	IE[3]	IE[3]
		Food waste [Animal and vegetable residues/animal carcasses]		Biomass			NA[1]	○	○
		Paper/ cardboard	Fossil-fuel derived fraction	Other fossil fuels[9]			○	IE[4]	IE[4]
			Biogenic fraction	Biomass			NA[1]	○	○
		Wood		Biomass			NA[1]	○	○
		Textiles	Synthetic textiles	–			IE[5]	IE[5]	IE[5]
			Natural fiber	Biomass			NA[1]	○	○
		Sludge	Sewage sludge	–			NO	NO	NO
			Other than sewage sludge	Biomass			NA[1]	○	○
	Specially-controlled industrial waste			–			IE[5]	IE[5]	IE[5]
1.A.1./ 1.A.2./ 1.A.4. (7.4.3.2)[7]	MSW	Plastics	Fossil-fuel derived plastics	Other fossil fuels	Direct use as alternative fuel		○	○	○
			Biomass-based plastics	Biomass[8]			NA[1]	IE[3]	IE[3]
		PET bottles		–			NO	NO	NO
	IW	Waste oil	Fossil-fuel derived oil	Other fossil fuels			○	○	○
			Animal and vegetable oil	Biomass			NA[1]	○	○
		Plastics	Fossil-fuel derived plastics	Other fossil fuels			○	○	○
			Biomass-based plastics	Biomass[8]			NA[1]	IE[3]	IE[3]
		Wood		Biomass			NA[1]	○	○
	Waste tire		Fossil-fuel derived fraction	Other fossil fuels			○	○	○
			Biogenic fraction	Biomass[8]			NA[1]	IE[6]	IE[6]
1.A.1./ 1.A.2. (7.4.3.3)[7]	Refuse Derived Fuel (RDF)		Fossil-fuel derived fraction	Other fossil fuels	Incineration of waste processed as fuel		○	○	○
			Biogenic fraction	Biomass[8]			NA[1]	IE[6]	IE[6]
	Refuse Paper and Plastic Fuel (RPF)		Fossil-fuel derived fraction	Other fossil fuels			○	○	○
			Biogenic fraction	Biomass[8]			NA[1]	IE[6]	IE[6]

Note:

1) CO_2 emissions from the incineration of biomass-derived waste are not included in the total emissions; instead it is estimated as a reference value and reported as “Biomass” fuel in the CRF tables.
2) CH_4 and N_2O emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported as “Other fossil fuels” in the CRF tables.
3) Included in fossil-fuel derived plastics in ISW
4) Included in biogenic fraction of paper/cardboard
5) Included in “Specially-controlled industrial waste” incineration without energy recovery

6) Included in the fossil-fuel derived fraction
7) For details of categories to be reported in the CRF, see Table 7-29.
8) For the biomass fraction in solid waste, etc. such as plastics, waste tire, RPF and RDF, it is difficult to distinguish the activity data on calorie basis for energy sector from the fossil-fuel derived fraction since there are no appropriate way to decompose calorimetric data of mixed solid waste. Hence, the activity data is reported as "IE", and is included in "other fossil fuels".
9) For the fossil-fuel derived fraction in "paper/cardboard", it is difficult to distinguish the activity data on calorie basis for energy sector from the biogenic fraction. Hence, the activity data is reported as "IE", and is included in "biomass".

Table 7-29 Reporting categories for waste incineration and energy use emissions (reported in the energy sector) (1.A.)

Treatment type	Waste type		Application breakdown	Major application	Reporting category on the energy sector	CO_2 [2]	CH_4	N_2O
Waste incineration with energy recovery	MSW		(Unclassified)	Waste incineration with energy recovery	1.A.4.a. Commercial/institutional	○	○	○
	Industrial waste					○	○	○
Direct use of waste as alternative fuel	MSW	Plastics	Liquefaction	Fuel	1.A.2.g. Other	○	○	○
			Blast furnace reducing agent	Reducing agent in blast furnace	1.A.2.a. Iron and steel	○	NO[3]	NO[3]
			Coke oven chemical feedstock	Raw material in coke oven	1.A.1.c. Manufacture of solid fuels and other energy industries	○	IE[4]	NO[5]
			Gasification	Fuel	1.A.2.g. Other	○	NE[6]	NE[6]
	Industrial waste	Waste oil	(Unclassified)	Fuel	1.A.2.g. Other	○	○	○
		Plastics	Blast furnace reducing agent	Blast furnace reducing agent	1.A.2.a. Iron and steel	○	NO[3]	NO[3]
			Chemical industry	boiler fuel	1.A.2.c. Chemicals	○	○	○
			Paper industry	boiler fuel	1.A.2.d. Pulp, paper and print	○	○	○
			Cement burning	Cement burning	1.A.2.f. Non-metallic minerals	○	○	○
			Automobile manufacturer	boiler fuel	1.A.2.g. Other	○	○	○
			Liquefaction	Fuel	1.A.2.g. Other	○	○	○
			Gasification	Fuel	1.A.2.g. Other	○	NE[6]	NE[6]
		Wood	(Unclassified)	Fuel	1.A.2.g. Other	NA	○	○
	Waste tire		Cement burning	Cement burning	1.A.2.f. Non-metallic minerals	○	○	○
			Boiler	Fuel	1.A.2.g. Other	○	○	○
			Iron manufacture	Raw materials in iron manufacturing	1.A.2.a. Iron and steel	○	NO[3]	NO[3]
			Gasification	Fuel in iron manufacturing	1.A.2.a. Iron and steel	○	○	○
			Metal refining	Fuel in metal refining	1.A.2.b. Non-ferrous metals	○	○	○
			Tire manufacture	Fuel in tire manufacturing	1.A.2.c. Chemicals	○	○	○
			Paper manufacture	Fuel in paper manufacturing	1.A.2.d. Pulp, paper and print	○	○	○
			Power generation	Power generation	1.A.4.a. Commercial/institutional	○	○	○
Incineration of waste processed as fuel	Refuse-derived fuel (RDF)		(Unclassified)	Fuel use (including power generation)	1.A.2.g. Other [1]	○	○	○
	Refuse Paper and Plastic fuel (RPF)		Petroleum product manufacturer	boiler fuel	1.A.1.b. Petroleum refining	○	○	○
			Chemical industry	boiler fuel	1.A.2.c. Chemicals	○	○	○
			Paper industry	Fuel use in paper manufacturing	1.A.2.d. Pulp, paper and print	○	○	○
			Cement manufacturer	Cement burning	1.A.2.f. Non-metallic minerals	○	○	○

Note:
1) Emissions from power generation and heat supply excluding in-house use should be included in the category 1.A.4.a. However, they are reported in the category 1.A.2.g., because the actual circumstances are not understood at the moment.
2) CO_2 emissions from the incineration of biomass-derived fraction are not included in the total emissions; instead it is estimated as a reference value and reported as "Biomass" fuel in the CRF tables. For detail, see Table 7-28 .
3) Blast furnace gas generated from steel industry is entirely recovered.
4) These emissions are included in "solid fuels" in same category 1.A.1.c.
5) N_2O is likely not produced since the atmosphere in coke oven is normally at least 1,000 degree Celsius, and reducing.
6) Considering that small fraction of these sources is combusted as alternative fuel but these are mostly used to obtain feedstock for ammonia productions, the emissions are not estimated.

Estimated GHG emissions from waste incineration (category 5.C.) are shown in Table 7-30. In FY2021, emissions from waste incineration are 11,606 kt-CO_2 eq. and accounted for 1.0% of the national total emissions (excluding LULUCF). The emissions from this source category decreased by 15.8% compared to those in FY1990. For the period FY1990-1997, CO_2 emissions increased as the practice of intermediate treatment by waste incineration increased in order to decrease the total volume of waste landfilled. From FY2001 onwards, as the use of waste as raw material or fuel has been replacing the incineration of fossil-origin waste for intermediate treatments, and these CO_2 emissions which used to be allocated to the waste sector is now allocated to the Energy sector, CO_2 emission estimates from the waste sector decreased. The trend in the IEFs of CO_2 for this category is basically stable and range from 2.59 to 2.70 [t-CO_2/t-waste (wet)]. On the other hand, N_2O emissions increased compared to FY1990 level due to the increase in sewage sludge incineration practice for the period FY1990-1997. From FY2005 onward, N_2O emissions from this source decreased because the practice of high temperature incineration of sewage sludge increased.

Table 7-30 GHG emissions from waste incineration and open burning (5.C.)

Gas	Category			Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	5.C.1. Waste incineration	Munisipal solid waste	Plastics[1]	kt-CO_2	3,981	3,973	4,067	2,385	1,638	2,038	2,122	1,753	1,927	1,283	1,267	1,548	1,606	1,677	1,613
			PET bottles[1]	kt-CO_2	289	289	366	202	131	142	161	178	184	118	116	178	192	194	181
			Paper/cardboard[1]	kt-CO_2	590	610	588	488	426	449	451	420	436	287	253	320	311	336	331
			Nappies[1]	kt-CO_2	153	180	162	171	195	199	211	206	224	153	145	185	181	189	191
			Synthetic textiles[1]	kt-CO_2	540	568	440	446	591	431	451	410	521	319	307	331	350	351	358
		Industrial waste	Waste oil[1]	kt-CO_2	3,670	4,366	4,799	4,270	4,128	4,430	3,652	3,990	3,324	3,856	3,699	3,740	3,400	3,224	3,272
			Plastics[1]	kt-CO_2	2,131	4,539	4,380	4,332	3,785	3,447	3,942	3,391	3,770	3,708	3,884	3,960	3,754	2,994	2,960
			Paper/cardboard[1]	kt-CO_2	41	86	87	39	34	37	17	14	12	12	13	12	1	2	2
		Specially-controlled industrial waste	Flammable waste oil[1]	kt-CO_2	698	1,036	1,526	1,402	1,143	784	796	782	692	816	652	772	930	912	909
			Specified hazardous industrial waste oil[1]	kt-CO_2	19	28	41	38	42	25	55	124	149	131	95	101	102	77	78
			Infectious waste (plastics)[1]	kt-CO_2	199	328	428	435	395	336	341	452	426	411	395	480	531	467	465
	5.C.2. Open burning (Industrial waste plastics)[1]			kt-CO_2	6.3	6.3	1.7	0.4	0.2	0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.1
	Total			kt-CO_2	12,319	16,010	16,884	14,209	12,509	12,319	12,200	11,721	11,666	11,095	10,826	11,628	11,358	10,424	10,359
CH_4	5.C.1. Waste incineration	Munisipal solid waste[2]		kt-CH_4	0.5	0.4	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
		Industrial waste	Waste oil[2]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Plastics[2]	kt-CH_4	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Food waste[3]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Paper/cardboard[2]	kt-CH_4	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Wood[3]	kt-CH_4	0.1	0.1	0.1	0.4	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2
			Natural fiber[3]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Sludge (sewage sludge/ other)[3]	kt-CH_4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Specially-controlled industrial waste	Flammable waste oil[1]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Specified hazardous industrial waste oil[1]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Infectious waste (plastics)[1]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Infectious waste (except plastics)[3]	kt-CH_4	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5.C.2. Open burning (Industrial waste)[2]			kt-CH_4	0.5	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total			kt-CH_4	1.1	1.2	0.8	0.7	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3
				kt-CO_2 eq.	28	29	21	18	12	11	12	10	10	9	10	11	10	9	9
N_2O	5.C.1. Waste incineration	Munisipal solid waste[2]		kt-N_2O	1.03	1.05	0.98	0.52	0.46	0.46	0.47	0.43	0.47	0.30	0.28	0.34	0.34	0.34	0.34
		Industrial waste	Waste oil[2]	kt-N_2O	0.02	0.02	0.02	0.10	0.09	0.10	0.08	0.09	0.08	0.09	0.08	0.09	0.08	0.07	0.08
			Plastics[2]	kt-N_2O	0.15	0.32	0.31	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
			Food waste[3]	kt-N_2O	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
			Paper/cardboard[2]	kt-N_2O	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
			Wood[3]	kt-N_2O	0.06	0.10	0.06	0.14	0.08	0.08	0.10	0.08	0.08	0.07	0.09	0.09	0.08	0.07	0.07
			Natural fiber[3]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Sewage sludge[3]	kt-N_2O	2.65	3.94	4.86	5.48	4.16	4.22	4.25	3.92	4.16	3.69	4.07	4.11	4.20	3.97	3.46
			Other sludge[3]	kt-N_2O	0.89	0.92	0.94	0.22	0.19	0.16	0.18	0.17	0.16	0.16	0.18	0.17	0.17	0.15	0.15
		Specially-controlled industrial waste	Flammable waste oil[1]	kt-N_2O	0.00	0.00	0.01	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.02	0.02
			Specified hazardous industrial waste oil[1]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
			Infectious waste (plastics)[1]	kt-N_2O	0.01	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Infectious waste (except plastics)[3]	kt-N_2O	0.00	0.00	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	5.C.2. Open burning (Industrial waste)[2]			kt-N_2O	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total			kt-N_2O	4.83	6.40	7.23	6.59	5.08	5.11	5.15	4.77	5.03	4.40	4.78	4.88	4.94	4.68	4.16
				kt-CO_2 eq.	1,438	1,908	2,156	1,963	1,515	1,523	1,535	1,423	1,498	1,312	1,423	1,453	1,473	1,395	1,239
Total				kt-CO_2 eq.	13,785	17,947	19,061	16,190	14,035	13,853	13,747	13,154	13,174	12,416	12,259	13,091	12,841	11,828	11,606

Note:
1) Include fossil-fuel derived component only.
2) Include both fossil-fuel derived component and biogenic component.
3) Include biogenic component only.
CO_2 emissions from the incineration of biomass-derived waste (including biomass-based plastics and waste animal and vegetable oil) is not included in the total emissions in accordance with the *2006 IPCC Guidelines*; instead, it is estimated as a reference value and reported under "Biogenic" in Table 5.C of the CRF.

For reference, the GHG emissions from waste incineration for energy purpose and with energy recovery are shown in Table 7-31. In FY2021, the emissions from waste incineration including these sources are 30,925 kt-CO_2, and it accounts for 2.6% of Japan’s total GHG emissions (excluding LULUCF). The emissions from this source’s category had increased by 24.0% compared to those in FY1990.

Table 7-31 Total GHG emissions from incineration of waste (reference value) including emissions from waste incineration for energy use and energy recovery

Gas	Category				Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	5.C. Waste Incineration and open burning (without energy recovery)[1]				kt-CO_2	12,319	16,010	16,884	14,209	12,509	12,319	12,200	11,721	11,666	11,095	10,826	11,628	11,358	10,424	10,359
	1.A. Fuel combustion	Waste Incineration with Energy Recovery	MSW	Plastics[1]	kt-CO_2	4,625	4,982	6,376	5,151	3,314	4,276	4,203	3,690	3,575	4,196	4,562	4,144	4,495	4,395	4,227
				PET bottles[1]	kt-CO_2	336	363	573	436	264	298	318	375	342	386	418	476	537	509	475
				Paper/cardboard[1]	kt-CO_2	686	765	922	1,055	861	941	893	885	808	939	911	857	870	880	866
				Nappy[1]	kt-CO_2	178	226	253	369	395	417	417	434	415	502	522	494	507	496	500
				Synthetic textiles[1]	kt-CO_2	627	713	689	964	1,196	905	894	862	967	1,045	1,106	887	980	920	938
			IW	Waste oil[1]	kt-CO_2	21	30	28	109	176	105	152	175	169	176	117	123	134	133	135
				Plastics[1]	kt-CO_2	31	66	188	307	581	731	607	677	898	837	830	817	983	1,042	1,030
				Paper/cardboard[1]	kt-CO_2	0.1	0.7	1.0	0.6	2.1	5.6	1.6	1.7	1.4	1.3	1.2	1.0	0.0	0.2	0.2
		Direct Use of Waste as Alternative Fuel	MSW	Plastics[1]	kt-CO_2	NO	NO	94	522	465	476	239	233	270	259	273	224	228	219	206
			IW	Waste oil[1]	kt-CO_2	3,592	4,193	4,150	5,215	4,778	4,952	4,796	4,592	5,015	4,678	4,680	5,079	5,328	4,996	5,059
				Plastics[1]	kt-CO_2	55	59	450	1,238	1,835	1,818	1,890	2,180	2,094	2,240	2,366	2,485	2,571	2,519	2,660
			Waste Tire[1]		kt-CO_2	527	845	1,044	869	1,008	951	958	1,014	1,037	997	1,036	1,064	973	946	940
		Incineration of Waste Processed	RDF[1]		kt-CO_2	34	40	151	423	387	391	393	394	366	365	364	367	322	312	311
			RPF[1]		kt-CO_2	NO	11	46	684	1,171	1,274	1,342	1,317	1,354	1,445	1,461	1,478	1,451	1,410	1,501
	Total				kt-CO_2	23,031	28,304	31,850	31,550	28,942	29,860	29,304	28,552	28,977	29,161	29,474	30,125	30,739	29,202	29,206
CH_4	5.C. Waste Incineration and open burning (without energy recovery)[2]				kt-CH_4	1.1	1.2	0.8	0.7	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3
	1.A. Fuel combustion	Waste Incineration with Energy Recovery	MSW[2]		kt-CH_4	0.5	0.5	0.6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
			IW	Waste oil[2]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Plastics[2]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Food waste[3]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Paper/cardboard[2]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Wood[3]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Natural fiber[3]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Sludge other than sewage sludge[3]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Direct Use of Waste as Alternative Fuel	MSW	Plastics[2]	kt-CH_4	NO	NO	0.0	0.0	0.0	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
			IW	Waste oil[2]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Plastics[2]	kt-CH_4	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
				Wood[3]	kt-CH_4	1.8	1.8	2.2	2.9	4.2	4.5	4.8	5.2	5.0	4.9	5.2	5.0	5.5	5.4	5.1
			Waste Tire[2]		kt-CH_4	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Incineration of Waste Processed as Fuel	RDF[2]		kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			RPF[2]		kt-CH_4	NO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total				kt-CH_4	3.5	3.6	3.8	4.0	5.0	5.3	5.6	6.1	5.8	5.7	6.1	5.9	6.4	6.2	5.9
					kt-CO_2 eq.	86	89	95	99	126	133	141	152	145	143	152	149	159	156	149
N_2O	5.C. Waste Incineration and open burning (without energy recovery)[2]				kt-N_2O	4.83	6.40	7.23	6.59	5.08	5.11	5.15	4.77	5.03	4.40	4.78	4.88	4.94	4.68	4.16
	1.A. Fuel combustion	Waste Incineration with Energy Recovery	MSW[2]		kt-N_2O	1.19	1.32	1.53	1.13	0.93	0.97	0.93	0.91	0.86	0.99	1.00	0.92	0.94	0.89	0.88
			IW	Waste oil[2]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Plastics[2]	kt-N_2O	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01
				Food waste[3]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Paper/cardboard[2]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Wood[3]	kt-N_2O	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
				Natural fiber[3]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Sludge other than sewage sludge[3]	kt-N_2O	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.03
		Direct Use of Waste as Alternative Fuel	MSW	Plastics[2]	kt-N_2O	NO	NO	0.00	0.00	0.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
			IW	Waste oil[2]	kt-N_2O	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01
				Plastics[2]	kt-N_2O	0.03	0.02	0.03	0.02	0.05	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06
				Wood[3]	kt-N_2O	0.02	0.02	0.03	0.03	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
			Waste Tire[2]		kt-N_2O	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		Incineration of Waste Processed as Fuel	RDF[2]		kt-N_2O	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
			RPF[2]		kt-N_2O	NO	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
	Total				kt-N_2O	6.10	7.80	8.87	7.84	6.18	6.26	6.27	5.90	6.10	5.60	5.99	6.02	6.11	5.80	5.27
					kt-CO_2 eq.	1,817	2,323	2,644	2,336	1,842	1,866	1,869	1,758	1,817	1,669	1,786	1,793	1,820	1,729	1,570
Total					kt-CO_2 eq.	24,934	30,716	34,589	33,985	30,910	31,859	31,314	30,462	30,940	30,973	31,412	32,066	32,718	31,086	30,925

Note:
1) Include fossil-fuel derived component only.
2) Include both fossil-fuel derived component and biogenic component.
3) Include biogenic component only.

7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)

7.4.1.1. Municipal Solid Waste (5.C.1.-)

a) Category Description

This category covers the emissions from incineration of municipal solid waste without energy recovery. Emissions of CO_2 are reported under either "Biogenic, Municipal solid waste (MSW)" or "Non-biogenic, Municipal solid waste" in accordance with the waste type as indicated in the Table 7-27. Emissions of CH_4 and N_2O are estimated for each type of furnace. The data used for the estimation on MSW incineration cannot distinguish biogenic-origin wastes and non-biogenic origin wastes. Therefore, total emissions including biogenic-origin ones are reported altogether under "Non-biogenic, Municipal solid waste".

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions of CO_2 from this emission source are calculated based on Japan's country-specific emission factors, the volume of waste incinerated (dry basis) and the percentage of municipal waste treated at the municipal incineration facilities that are accompanied by energy recovery, in accordance with the decision tree in the *2006 IPCC Guidelines* (Volume 5, Page 5.9, Fig. 5.1). In order to estimate CO_2 emissions from the incineration of fossil-fuel derived waste[2], emissions from fossil-fuel derived fraction in bottles made from polyethylene terephthalate (PET bottles), plastics other than PET bottles (herein after referred to "plastics"), synthetic textiles, paper/cardboard and nappies in municipal solid waste are estimated.

$$E = \sum_i EF_i \times A_i \times (1 - R)$$

E	: CO_2 Emissions from the incineration of municipal solid waste type i [kg-CO_2]
EF_i	: Emission factor for the incineration of waste type i (dry basis) [kg-CO_2/t]
A_i	: Volume of waste type i incinerated (dry basis) [t]
R	: Percentage of municipal solid waste incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Equation***

In accordance with the *2006 IPCC Guidelines*, the emission factor is calculated as follows.

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

EF_i	: Emission factor for the incineration of waste type i (dry basis) [kg-CO_2/t]
CF_i	: Carbon content in waste type i (dry basis) [%]
FCF_i	: Fossil-fuel derived fraction in carbon in waste type i [%]
OF	: Oxidation factor [%]

[2] CO_2 emissions from the incineration of food waste, biogenic fraction of paper/cardboard, natural fiber textiles, wood and biomass-based plastics are reported as the reference figures of "Biogenic Municipal solid waste". Estimation methods for their emissions are the same as those for emissions from the incineration of fossil-fuel derived waste.

➢ ***Carbon Content (CF)***

The carbon contents in MSW by waste type are shown in the following table.

Table 7-32 Carbon content of each waste type in MSW (*CF*: dry basis)

Item	Carbon content	Reference
Plastics	76.8 %	Survey for the fraction and carbon content in each plastic material composition in MSW generated by each of domestic 14 cities (MOE, 2020b)
PET bottles	62.1 %	Averaged value of the data obtained from actual measurements at domestic 10 cities (MOE, 2020b)
Synthetic textiles	63.0 %	Weighted average of carbon content by each type of synthetic textile (MOE, 2006b)
Paper/cardboard	40.8 %	Averaged value of the data obtained from actual measurements at domestic 14 cities (MOE, 2020b)
Nappies	56.0 %	Estimated based on an interview survey of *Japan Hygiene Products Industry Association* (MOE, 2021)

➢ ***Fossil-fuel derived fraction in carbon in waste (FCF)***

- ***Synthetic textiles, Paper/cardboard, Nappies***

The fossil-fuel derived fractions in carbon in synthetic textiles, paper/cardboard and nappies in MSW are shown in the following table.

Table 7-33 Fossil-fuel derived fraction in carbon in synthetic textiles, paper/cardboard and nappies in MSW (*FCF*)

Item	Fossil-fuel derived fraction in carbon	Reference
Synthetic textiles	100%	Assumed that all is fossil-fuel derived by expert judgement
Paper/cardboard	9.6%	Based on research of present Modern Carbon (pMC) from ^{14}C in the waste measured by Accelerator Mass Spectrometer (ASTM D6866) (MOE, 2020b)
Nappies	59%	Estimated based on an interview survey of *Japan Hygiene Products Industry Association* (MOE, 2021)

Note: Fossil-fuel derived carbon in paper/cardboard incinerated comes from loading materials, colorant, strength agents, adhesive, ink, laminate film, and other additives added at paper manufacturing or processing.

- ***Plastics, PET bottles***

Fossil-fuel derived fraction in carbon in plastics and PET bottles are estimated based on biomass-based plastic content in those items. Note that "biomass-based plastics" is a general term for plastics using the biomass as raw material, including bio composite plastics and plastic-like material. Fossil-fuel derived fraction in plastics is estimated as follows.

$$FCF_i(T) = 1 - \frac{BPW_i(T)}{PW_i(T)}$$

$FCF_i(T)$: Fossil-fuel derived fraction in plastic *i* (MSW plastics, MSW PET bottles, IW plastics) in FY *T* [%]

$BPW_i(T)$: Amount of biogenic fraction in plastic *i* (MSW plastics, MSW PET bottles, IW plastics) in FY *T* [t (dry)]

$PW_i(T)$: Amount of plastic *i* (MSW plastics, MSW PET bottles, IW plastics) generation in FY *T*, excluding impurities [t (dry)]

Amount of MSW plastics, MSW PET bottles and IW plastics generation in *FY T* ($PW_{msw}(T)$) are obtained from the *Cyclical Use of Wastes Report*. Amount of biogenic fraction in MSW plastics, MSW PET bottles and IW plastics in *FY T* ($BPW_i(T)$) are calculated by following equation.

$$BP_i(T) = \sum_t^T \sum_j (BP_{j,t} \times DP_{j,t} \times B_j \times W_{i,j,t}(T) \times DW_i(T))$$

$BP_{j,t}$: Amount of biomass-based plastics product *j* production in FY *t* [t (dry)]

$DP_{j,t}$: Share of domestic shipments of biomass-based plastics product *j* in FY *t* [%]

B_j : Biogenic fraction of biomass-based plastics product *j* [%]

$W_{i,j,t}(T)$: Probability that biomass-based plastic product *j*, which was produced in FY *t*, is disposed of as plastic *i* (MSW plastics, MSW PET bottles, IW plastics) in FY *T* after use [%]

$DW_i(T)$: Fraction of plastic *i* (MSW plastics, MSW PET plastic, IW plastics) treated domestically in FY *T* [%]

For the amount of biomass-based plastic products production ($BP_{j,t}$), the share of domestic shipments ($DP_{j,t}$), and the biogenic fraction (B_i) are obtained from a survey by the Japan Society of Biomass Industries and Japan BioPlastics Association. Note that the survey distinguishes final products made of bio-based resin by type (e.g. bio-PE, bio-PET, PLA, etc.) and by use (e.g. wrapping material, containers, daily use products, LCD, etc.).

The survey also provides the supplied amount of bio-based resin as intermediate products of bio-PE, bio-PET and PLA. By subtracting the amount of bio-based resin in final products identified above from the supplied amount of intermediate products by each bio-based resin type, unidentified amount of final products (*BP)* in the survey are also estimated as resin amounts. The shares of domestic shipments (*DP*) and the biogenic fractions (*B*) for those unidentified final products are given by an expert judgement.

A part of bio-PET resin in PET bottles, one of a bio-based resin widely used in Japan, are recovered after use, materially recycled as final products such as bottle or other commodities, and disposed/incinerated finally. In such a circumstance, amount of biogenic fraction in MSW PET bottles ($BPW_{MSW\ PET\ bottles}(T)$) are identified by considering disposal amount of bio-based resin not only after first use in products but also after use in recycled products. The amount of recycled bio-PET resin in each product are estimated by considering data of material recycled plastics after bottle use provided by the *Annual Report on PET Bottle Recycling* (the Council for PET Bottle Recycling).

The probability that is disposed of as MSW ($W_{i,j,t}(T)$) is estimated by the expert judgement.

Fractions of MSW plastics and IW plastics treated domestically in *FY T* ($DW_i(T)$) are assumed as 100% for plastics other than PET bottles since the export status are not clear. The parameters for PET bottles are obtained from *Annual report on PET bottle recycling* (Table 7-34).

Table 7-34 Fraction of waste plastic treated domestically (*DW*)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Plastics in MSW	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PET bottle in MSW	%	48.6	48.6	48.6	48.6	47.5	50.9	51.6	57.1	52.0	54.4	59.6	61.7	62.8	69.0	74.6
Plastics in IW	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Fossil-fuel derived fractions in plastics calculated by methodologies above are shown in Table 7-35.

Table 7-35 Fossil-fuel derived fraction in waste plastics (*FCF*)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Plastics in MSW	%	100.0	100.0	100.0	99.6	99.4	99.4	99.3	99.2	99.1	99.0	99.0	99.0	98.6	98.1	97.5
PET bottle in MSW	%	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.8	99.7	99.7	99.7	99.7	99.6	99.6
Plastics in IW	%	100.0	100.0	100.0	100.0	99.9	99.7	99.7	99.6	99.6	99.6	99.8	99.9	99.9	99.9	99.8

➢ ***Oxidation Factor***

Taking into account Japan's circumstances, the default value of 100% indicated in the *2006 IPCC Guidelines* is used.

➢ ***Emission Factor***

Emission factors calculated by methodologies above are shown in Table 7-36.

Table 7-36 Fossil-fuel derived CO_2 Emission factors for MSW incineration (dry basis)

Item	Unit	Emission factor	Note
Plastics	kg-CO_2/t	2,816	In case of *FCF*=1
PET bottles	kg-CO_2/t	2,277	
Synthetic textiles	kg-CO_2/t	2,310	–
Paper/cardboard	kg-CO_2/t	144	–
Nappies	kg-CO_2/t	1,220	–

● ***Activity Data***

As basic information to estimate activity data, the amount of plastic, PET bottles distinguished from plastics, textiles and paper/cardboard incinerated are obtained from the *Cyclical Use of Wastes Report*. Note the reported amounts of plastic including PET bottles potentially include biomass-based plastics. The details of activity data estimations are shown as follows.

➢ ***Plastics, PET bottle***

The activity data for CO_2 emissions from the incineration of plastics and PET bottles in MSW on a dry basis are calculated by following equation.

$$A_i = MSW_i \times (1 - u_i) \times (1 - F_{impurity,i})$$

A_i : Activity data for plastics or PET bottles in MSW incinerated (dry basis) [t (dry)]

MSW_i : Amount of plastics or PET bottles in MSW incinerated (wet basis) [t (wet)]

u_i : Percentage of water content in plastics or PET bottles in MSW [%]

$F_{impurity,\,i}$: Fraction of impurities adhered to plastics or PET bottles in MSW [%]

- ***Percentage of water content in plastics (u)***

The percentage of water contents in plastics and PET bottles in MSW are shown in following table.

Table 7-37 Percentage of water contents in plastics and PET bottles in MSW

Item	Water content	Reference
Plastics	26.1 %	Based on the surveys at domestic 13 cities (MOE, 2020b)
PET bottles	8.4 %	Based on the surveys at domestic 9 cities (MOE, 2020b)

- ***Fraction of impurities adhered to plastics ($F_{impurity}$)***

In many cases, some residual impurities such as biogenic food waste are adhered to the wastes categorized as plastics in investigation for MSW composition. Activity data of plastics incinerated are defined as the amount of plastics from which those impurities are subtracted. Fraction of impurities adhered to plastics are shown in the table below.

Table 7-38 Fraction of impurities adhered to plastics and PET bottles in MSW

Item	Fraction of impurities adhered	Reference
Plastics	11.9%	Based on the surveys at domestic 14 cities (MOE, 2020b)
PET bottles	0%	Expert judgement (MOE, 2020b)

➢ ***Synthetic textiles***

The activity data of synthetic textiles in MSW is estimated by disaggregating the amount of textiles in MSW incinerated (wet basis) by using the fraction of waste synthetic textiles in the total waste textiles, and subtracting the water content in textiles (percentage of water content: 20%; see also Table 7-11).

$$A_{textiles} = MSW_{textiles} \times (1 - u_{textiles}) \times F_{synthetic}$$

$A_{textiles}$: Activity data for incineration of synthetic textiles (MSW) incinerated (dry basis) [t (dry)]
$MSW_{textiles}$: Amount of textiles incinerated (wet basis) [t (wet)]
$u_{textiles}$: Percentage of water content in textiles [%]
$F_{synthetic}$: Fraction of synthetic fiber content in total waste textiles [%]

- ***Fraction of Synthetic Textiles in Total Waste Textiles ($F_{synthetic}$)***

Fraction of synthetic textiles content in total textiles contained in the MSW is calculated by using the amount of fiber based final consumption by each fiber type provided by the Japan Chemical Fibers Association.

$$F_{synthetic} = (C_{synthetic} + 0.4 \times C_{semisynthetic})/C_{total\,fiber}$$

$C_{synthetic}$: Amount of domestic final consumption of synthetic textiles (dry basis) [t (dry)]
$C_{semisynthetic}$: Amount of domestic final consumption of semisynthetic textiles (dry basis) [t (dry)]
$C_{total\,fiber}$: Amount of domestic final consumption of total textiles (dry basis) [t (dry)]

Note: Most semisynthetic textile for domestic use consists of acetate fiber derived from acetylcellulose, and its synthetic fraction by weight is assumed as 40% by expert judgement.

Table 7-39 Fraction of synthetic textiles in textiles

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fraction of synthetic textile	%	52.2	52.9	55.3	54.4	59.4	62.0	62.2	62.9	65.3	63.9	65.6	64.5	63.6	61.3	63.3

➢ ***Paper/cardboard***

The activity data of paper/cardboard in MSW is estimated by subtracting the water content (percentage of water content: 20%; see also Table 7-11) in paper/cardboard from the amount of paper/cardboard in MSW incinerated (wet basis). Since the item of paper/cardboard in the *Cyclical Use of Wastes Report* includes nappies, for activity data, activity data of nappies incinerated are subtracted from the amount of paper/cardboard incinerated.

$$A_{paper} = MSW_{paper} \times (1 - u_{paper}) - A_{nappy}$$

A_{paper} : Activity data for incineration of paper/cardboard (MSW) incinerated (dry basis) [t (dry)]
MSW_{paper} : Amount of paper/cardboard incinerated [t (wet)]
u_{paper} : Percentage of water content in paper/cardboard [%]
A_{nappy} : Activity data of nappies incinerated (dry basis) [t (dry)]

➢ ***Nappies***

Although nappies in Japan's municipal waste is generally classified into paper or textiles, the incinerated amount is not clearly distinguished from these categories.

- ***Prior to FY2004***

Based on expert judgement, the amount of domestic production of nappies is applied as the activity data for nappy incinerated prior to FY2004.

The amount of domestic production of nappies is derived from the reported amount of nappies for adult and infant (dry basis) on the *JHPIA news* published by Japan Hygiene Products Industry Association.

- ***FY 2005 onward***

The amount of nappies incinerated for FY2005 onward are estimated by following equation based on MOE (2020a), as the amount of nappy consumption.

$$A_{nappy} = \sum_i WT_i \times N_i \times PN_i \times 365/10^6$$

A_{nappy}	: Activity data of nappies incinerated (amount of nappy consumption: dry basis) [t (dry)]
WT_i	: Weight of nappy *i* (for adult or child) per piece (dry basis) [t (dry)]
N_i	: Number of nappy *i* (for adult or child) consumed per person and day [piece/person/day]
PN_i	: Number of nappy *i* (for adult or child) users [person]

Properties of each parameter in the estimation are as shown in following table.

Table 7-40 Parameters in estimation of amount of nappy consumption

Item	User	Volume	Reference
Weight of nappy per piece (*WT*)	Adult	292g (outer cover [84g×1] and inner pads [52g× 4])	MOE (2020a)
	Child	30g	
Number of nappies consumed per person per day (*N*)	Adult	1 piece (a set of 1 outer cover and 4 inner pads) /person/day	
	Child	5 pieces/person/day	
Number of nappy user (*PN*)	Adult	$PN_{adult} = \sum_a P_a \times (PS_{1/2,a} \times 0.2 + PC_{1/2,a} \times 0.64)$ P_a : Population in age-group *a* $PS_{1/2,a}$: Fraction of Requiring support 1 or 2 in age-group *a* $PC_{1/2,a}$: Fraction of Requiring long-term care 1 or 2 in age-group *a*	Equations: MOE (2020a) P_a : *Current Population Estimates* (MIC) $PS_{1/2,a}$, $PC_{1/2,a}$: *Status report of Long-Term Care Insurance System* (MHLW)
	Child	$PN_{child} = P_{0-3} \times 0.9$ P_{0-3} : Population in age from 0 to 3	

Note: MIC: Ministry of Internal Affairs and Communications, MHLW: Ministry of Health, Labour and Welfare

➢ ***Activity data***

Activity data calculated by methodologies above is shown in Table 7-41.

Table 7-41 Activity data to estimate CO_2 emissions from MSW incinerated (dry basis)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Plastics	kt (dry)	3,056	3,180	3,708	2,686	1,769	2,254	2,261	1,949	1,971	1,964	2,091	2,042	2,197	2,198	2,127
PET bottles	kt (dry)	275	286	412	280	173	193	211	244	232	222	236	288	321	310	290
Synthetic textile	kt (dry)	505	555	489	610	774	579	582	551	644	591	612	528	576	550	561
Paper/cardboad	kt (dry)	8,885	9,583	10,523	10,751	8,964	9,682	9,366	9,092	8,662	8,541	8,106	8,204	8,224	8,471	8,335
Nappy	kt (dry)	272	333	340	442	483	505	515	525	524	537	546	556	564	562	566

- ***Percentage of Municipal Waste Incinerated at Municipal Incineration Facilities for Energy Recovery***

Percentage of municipal waste that is incinerated at municipal incineration facilities with energy recovery stands for the one being incinerated at the facilities actually supply electricity or heat outside of them. These values are obtained from the *State of Municipal Waste Treatment Survey* (MOE).

Table 7-42 Percentage of municipal solid waste incinerated at incineration facilities with energy recovery

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
With off-field power generation or heat utilization	%	53.7	55.6	61.1	68.4	66.9	67.7	66.4	67.8	65.0	76.6	78.3	72.8	73.7	72.4	72.4
Without off-field power generation or heat utilization	%	46.3	44.4	38.9	31.6	33.1	32.3	33.6	32.2	35.0	23.4	21.7	27.2	26.3	27.6	27.6

2) CH_4

- ***Estimation Method***

CH_4 emissions from incinerator are estimated by multiplying the amount of MSW (wet basis) by incinerator method by each emission factor. CH_4 emissions from gasification melting furnace are estimated by multiplying the amount of MSW (wet basis) incinerated in gasification melting furnace by emission factors. Emissions from MSW with energy recovery are subtracted from the total emissions from this source and allocated to the waste sector.

$$E = \sum_i (EF_i \times A_i) \times (1 - R)$$

E : CH_4 emission from the incineration of MSW [kg-CH_4]

EF_i : Emission factor for incineration method *i* (or furnace type *i*) (wet basis) [kg-CH_4/t]

A_i : Amount of incinerated MSW by incineration method *i* (or furnace type *i*) (wet basis) [t]

R : Percentage of MSW incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Incinerator***

In order to implement countermeasures against dioxins, the renovations, repairs, or rebuilding of incineration facilities took place in the latter half of 1990 through the first half of 2000 in Japan. There have been some improvements made in CH_4 emission factors from the facilities renovated or rebuilt in FY2000 and later, compared to the values obtained before then (MOE, 2010). Therefore, based on the survey (MOE, 2010) and expert judgment, for the CH_4 emission factors for incinerator by incinerator type (stoker furnace and fluidized bed incinerator) and incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) for the period FY2001 and before (MOE, 2006b), and from FY2002 onward (MOE, 2010), respectively, different values are used. All the emission factors are established based on actual measurement survey.

In order to apply activity data based on the amount of incineration by incineration method, emission factors are established by incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) using the weighted average of fraction of the amount of incineration by incinerator type for each fiscal year. The Correction taking into account CH_4 concentrations in the atmosphere is not made to these emission factors.

➢ ***Gasification Melting Furnace***

Different emission factor is used for each furnace type (shaft furnace, fluidized bed, and rotary kiln) (MOE, 2010). Also, in order to apply activity data based on the total amount of incineration, emission factors are determined by taking the weighted average of the amount of incineration by gasification melting furnace type for each year.

Table 7-43 CH_4 emission factors by type of incineration method (MSW)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Continuous incinerator	g-CH_4/t	8.2	8.2	8.3	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.6
Semi-continuous incinerator	g-CH_4/t	69.6	69.6	75.1	19.9	20.9	21.1	20.9	21.1	20.7	20.4	20.5	20.9	20.5	20.9	20.9
Batch type incinerator	g-CH_4/t	80.5	80.5	84.1	13.2	11.6	11.6	11.7	11.7	11.8	11.8	10.9	10.9	11.0	11.0	11.0
Gasification melting furnace	g-CH_4/t	NA	NA	5.6	6.9	7.0	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.8	6.8

Reference: MOE (2000), MOE (2010), the *Waste Treatment in Japan* (MOE), Ishikawa Prefecture et al. (1991-1997), Japan Society for Atmospheric Environment: JSAE (1996), Ueno et al. (1992)

- ***Activity Data***

The activity data for CH_4 emissions for incinerator and gasification melting furnace are estimated by multiplying the amount of MSW incinerated (wet basis) provided in the *Cyclical Use of Waste Report* (MOE) (publicized reports and the most current data from the reports prior to publication) by the fraction of incineration by incineration method of incinerator or gasification meting furnace provided by the *Waste Treatment in Japan* (MOE).

Table 7-44 Amount of incineration of MSW by incineration method (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Continuous incinerator	kt (wet)	26,215	29,716	32,749	32,246	27,603	28,702	28,246	27,360	27,364	26,961	26,883	26,877	27,266	26,344	25,931
Semi-continuous incinerator	kt (wet)	4,810	5,455	5,882	4,047	2,968	2,849	2,827	2,524	2,349	2,164	2,072	1,894	1,849	1,760	1,732
Batch type incinerator	kt (wet)	5,643	4,328	3,131	1,562	1,078	1,061	970	867	842	744	693	660	625	589	580
Gasification melting furnace	kt (wet)	NO	NO	370	2,397	3,605	4,122	4,098	4,161	4,328	4,423	4,599	4,739	4,889	4,875	4,799

3) N_2O

- ***Estimation Method***

N_2O emissions from incinerator are estimated by multiplying the amount of MSW (wet basis) by incinerator method by each emission factor. N_2O emissions from gasification melting furnace are estimated by multiplying the amount of MSW (wet basis) incinerated in gasification melting furnace by emission factors. Emissions from MSW with energy recovery are subtracted from the total emissions from this source and allocated to the waste sector.

$$E = \sum_i (EF_i \times A_i) \times (1 - R)$$

E : N_2O emission from the incineration of MSW [kg-N_2O]

EF_i : Emission factor for incineration method i (or furnace type i) (wet basis) [kg-N_2O /t]

A_i : Amount of incinerated MSW by incineration method i (or furnace type i) (wet basis) [t]

R : Percentage of MSW incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Incinerator***

Same as for CH_4 emissions estimation, for the N_2O emission factors for incinerator by type and by incineration method, different values are used for the period FY2001 and before (MOE, 2006b), and from FY2002 onward (MOE, 2010), respectively. In order to apply activity data based on the amount of incineration by incineration method, emission factors are established by incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) using the weighted average of fraction of the amount of incineration by incinerator type for each fiscal year calculated based on the *Waste Treatment in Japan* (MOE).

➢ ***Gasification Melting Furnace***

Different emission factor is used for each furnace type (shaft furnace, fluidized bed, and rotary kiln) (MOE, 2010). In order to apply the activity data based on the total amount of incineration, emission factors are established by taking the weighted average of the amount of incineration by gasification melting furnace type for each year calculated based on the *Waste Treatment in Japan* (MOE).

Table 7-45 N_2O emission factors by incineration types (MSW)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Continuous incinerator	g-N_2O/t	58.8	58.8	59.1	37.9	38.0	38.0	38.0	38.1	38.1	38.1	37.9	37.8	37.9	37.9	37.9
Semi-continuous incinerator	g-N_2O/t	56.8	56.8	57.3	71.5	73.2	73.4	73.1	73.5	72.8	72.3	72.5	73.2	72.5	73.2	73.2
Batch type incinerator	g-N_2O/t	71.4	71.4	74.8	76.0	76.2	76.2	76.2	76.2	76.2	76.2	76.3	76.3	76.3	76.3	76.3
Gasification melting furnace	g-N_2O/t	NA	NA	16.9	12.0	11.5	11.7	11.7	12.0	12.2	12.5	12.1	12.4	12.3	12.7	12.7

Reference: MOE (2006b), MOE (2010), *Waste Treatment in Japan* (MOE), Ishikawa Prefecture et al. (1991-1997), JSAE (1996), Ueno et al. (1992)

- ***Activity Data***

The activity data for CH_4 emissions from incinerators and gasification melting furnaces are also applied for the activity data for N_2O emission from them.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties in CO_2 emission factors are evaluated by using the 95% confidence interval of carbon content data in plastics. The uncertainties in CH_4 and N_2O emission factors are evaluated by using the 95% confidence interval in the actual measurement on the surveys for emissions factors. As for the uncertainties in activity data, the uncertainties in municipal solid waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-46 and Table 7-47.

Table 7-46 Uncertainty assessment for municipal solid waste on the category “waste incineration (5.C.1.-)” (CO_2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	Quoted from MOE (2020b), a reference of emission factors.	The uncertainty in municipal waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.
PET bottles	CO_2	-0.4%	+0.4%	-10%	+10%	-10%	+10%	Quoted from MOE (2020b), a reference of emission factors.		
Synthetic textiles	CO_2	-2%	+2%	-10%	+10%	-10%	+10%	It is evaluated at the 95% confidence interval in actual measurement data of carbon content in synthetic textiles.		
Paper/ cardboard	CO_2	-13%	+13%	-10%	+10%	-16%	+16%	It is evaluated by combining the 95% confidence interval in actual measurement data of carbon content with that of fossil-derived carbon.		
Nappies	CO_2	-13%	+13%	-10%	+10%	-16%	+16%	Due to lack of information for the uncertainty of the emission factor, the uncertainty of Paper/ cardboard is substituted based on expert judgment.		

Table 7-47 Uncertainty assessment for municipal solid waste on the category “waste incineration (5.C.1.-)” (CH_4 and N_2O)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Continuous incineration /Stoker furnace	CH_4	-39%	+39%	-10%	+10%	-40%	+40%	The uncertainty is quoted from MOE (2010), a reference of emission factors.	The uncertainty based on expert judgment in municipal waste statistics is applied.	Combined by using the formula for propagation of errors.
	N_2O	-34%	+34%	-10%	+10%	-35%	+35%			
Continuous incineration /Fluidized bed furnace	CH_4	-100%	+719%	-10%	+10%	-100%	+719%			
	N_2O	-98%	+98%	-10%	+10%	-99%	+99%			
Semi-continuous incineration/ Stoker furnace	CH_4	-82%	+82%	-10%	+10%	-83%	+83%			
	N_2O	-82%	+82%	-10%	+10%	-82%	+82%			
Semi-continuous incineration / Fluidized bed furnace	CH_4	-100%	+162%	-10%	+10%	-100%	+162%			
	N_2O	-64%	+64%	-10%	+10%	-64%	+64%			
Batch-type incineration / Stoker furnace	CH_4	-75%	+75%	-10%	+10%	-76%	+76%			
	N_2O	-100%	+111%	-10%	+10%	-100%	+111%			
Batch-type incineration /Fluidized bed furnace	CH_4	-100%	+394%	-10%	+10%	-100%	+394%			
	N_2O	-100%	+133%	-10%	+10%	-100%	+134%			
Gasification melting furnace/ Shaft furnace	CH_4	-100%	+203%	-10%	+10%	-100%	+203%			
	N_2O	-45%	+45%	-10%	+10%	-46%	+46%			
Gasification melting furnace/ Fluidized bed furnace	CH_4	-100%	+133%	-10%	+10%	-100%	+134%			
	N_2O	-100%	+252%	-10%	+10%	-100%	+252%			
Gasification melting furnace/ Rotatory kiln	CH_4	-54%	+54%	-10%	+10%	-55%	+55%			
	N_2O	-87%	+87%	-10%	+10%	-88%	+88%			

- ***Time-series Consistency***

Because data on the amount of waste incinerated by type of waste are not available for years prior to FY1997, the data are estimated by using the total incinerated amount of MSW for each year and the ratio of amount of waste incinerated by waste type for FY1998. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By revising biomass-based plastic products data, CO_2 emissions from FY2005 onward were recalculated. By updating the statistical data, emissions from FY2018 onwards were recalculated. For detail, see the section "7.1.5. General Recalculations for Emissions from Waste Sector".

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.1.2. Industrial Waste (5.C.1.-)

a) Category Description

This category covers CO_2, CH_4 and N_2O emissions from incineration of industrial waste without energy recovery by each waste type and the emissions are reported in the corresponding category either "biogenic, industrial solid waste (ISW)", "biogenic, non-fossil liquid waste", "biogenic, sludge" "non-biogenic, industrial solid waste" or "non-biogenic, fossil liquid waste" (see Table 7-27).

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions of fossil-fuel derived CO_2 from this source are calculated by using the volume of fossil-fuel derived waste oil, plastics, and paper/cardboard incinerated, Japan's country-specific emission factors, and the percentage of incinerated industrial waste with energy recovery at industrial waste incineration facilities in accordance. Note that since it is difficult to estimate percentages of water content in waste oil and plastic in industrial waste, the emission factors for these sources are identified as wet basis. Also, since industrial textiles does not include synthetic textiles under the regulation of the Waste Management and Public Cleansing Act, the industrial textiles is regarded as waste natural fiber: thus the CO_2 emissions from incineration of industrial textiles are not included in national total because these emissions are biogenic-origin.

$$E_i = EF_i \times A_i \times (1 - R_i)$$

E_i : CO_2 Emissions from incineration of waste type *i* [kg-CO_2]

EF_i : Emission factor for incineration of waste type *i* [kg-CO_2/t]
(wet basis for waste oil and plastic; dry basis for paper/cardboard)

A_i : Amount of incinerated waste type *i* [t]
(wet basis for waste oil and plastic; dry basis for paper/cardboard)

R_i : Percentage of industrial waste incinerated at facilities with energy recovery (for waste type *i*)

● ***Emission Factor***

➢ ***Equation***

In accordance with the approach taken by the *2006 IPCC Guidelines*, emission factor is calculated as follows.

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

EF_i : Emission factor for industrial waste i [kg-CO_2/t]

CF_i : Carbon content in industrial waste i [%]

FCF_i : Fossil-fuel derived fraction in industrial waste i [%]

OF : Oxidation factor [%]

➢ ***Carbon Content (CF)***

Carbon contents in industrial waste are shown the table below.

Table 7-48 Carbon contents of industrial waste (*CF*)

Item	Carbon contents	Note	References
Fossil-fuel derived waste oil	80%	wet basis	Environmental Agency (1992)
Plastics	70%	wet basis	Environmental Agency (1992)
Paper/cardboard	40.8%	dry basis	Substituted the carbon content of MSW (MOE, 2020b) for that of IW because its properties are similar to those of MSW

➢ ***Fossil-fuel derived fraction in carbon in paper/cardboard in industrial waste (FCF)***

For the fossil-fuel derived fractions in carbon in industrial waste are shown following table.

Table 7-49 Fossil-fuel derived fractions in carbon in fossil-fuel derived industrial waste (*FCF*)

Item	Fossil-fuel derived fraction	Reference
Fossil-fuel derived waste oil	100%	Expert judgement
Plastics	Variable	See Table 7-35
Paper/cardboard	9.6%	Substituted the fossil-fuel derived fraction of MSW (MOE, 2020b) for that of IW because its properties are similar to those of MSW

➢ ***Oxidation factor (OF)***

The default value of 100% given in the *2006 IPCC Guidelines* is used.

➢ ***Emission factor (EF)***

Emission factors calculated by methodologies above are shown in Table 7-50.

Table 7-50 Emission factors for fossil-fuel derived fraction of waste oil, plastics and paper/cardboard in industrial waste (*EF*)

Item	Unit	Emission factor	Note
Fossil-fuel derived waste oil	kg-CO_2/t (wet)	2,933	–
Plastics	kg-CO_2/t (wet)	2,567	In case of *FCF*=1
Paper/cardboard	kg-CO_2/t (dry)	144	–

● ***Activity Data***

For the activity data for CO_2 emissions from the incineration of waste oil, plastics and paper/cardboard in industrial waste, the amount of incineration provided by the *Cyclical Use of Waste Report* (MOE) is used. Note that the statistical data for industrial waste from this report includes but does not distinguish specially-controlled industrial waste. To avoid double counting in the activity data estimation, the amount of specially-controlled industrial waste incinerated is subtracted from the statistical data (see also the section”7.4.1.3. Specially-Controlled Industrial Waste (5.C.1.-)”). Details of methodologies to estimate activity data are shown below.

$$A_{oil} = IW_{oil} \times (1 - F_{bio}) - SIW_{oil}$$

A_{oil}	: Activity data for the incineration of waste fossil-fuel derived oil (wet basis) [t (wet)]
IW_{oil}	: Amount of waste oil incinerated in industrial waste (wet basis) [t (wet)]
SIW_{oil}	: Amount of waste oil incinerated in specially-controlled industrial waste[1)] (wet basis) [t (wet)]
F_{bio}	: Fraction of waste oil from animal and vegetable origin[2)] [%]

Note:

1) All the waste oil in specially-controlled industrial waste to be estimated for emissions are waste fossil-fuel derived oil.
2) From the survey conducted by the MOE

Table 7-51 Fraction of waste oil from animal and vegetable origin

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fraction of waste animal and vegetable oil	%	2.6	3.5	4.5	5.4	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0

$$A_{plastics} = IW_{plastics} - A_{inf.\ plastics}$$

$A_{plastics}$	: Activity data for the incineration of plastics (wet basis) [t (wet)]
$IW_{plastics}$	: Amount of plastics incinerated in industrial waste (wet basis) [t (wet)]
$A_{inf.\ plastics}$	: Amount of infectious plastics incinerated in specially-controlled industrial waste (wet basis) [t (wet)]

Note: Fossil-fuel derived fraction of plastics in industrial waste plastics incinerated is estimated in the same way as indicated in “7.4.1.1. Municipal Solid Waste (5.C.1.-) b) 1) CO_2”. See also Table 7-35. Note it is assumed that activity data for plastics (IW) incinerated does not include PET bottles unlike MSW plastics.

$$A_{paper} = (IW_{paper} - A_{inf.exc.\ plastics}) \times (1 - u_{paper})$$

A_{paper}	: Activity data for the incineration of paper/cardboard (dry basis) [t (dry)]
IW_{paper}	: Amount of paper/cardboard incinerated in industrial waste (wet basis) [t (wet)]
$A_{inf.\ exc.\ plastics}$	: Amount of infectious waste incinerated in specially-controlled industrial waste except plastics (wet basis) [t (wet)]
u_{paper}	: Percentage of waste content in paper or cardboard in industrial waste [%]

Note: Of the specially-controlled industrial waste, infectious waste (except plastics) is assumed to be paper/cardboard. Percentage of water content in paper/cardboard in industrial waste is given the value 15% (see Table 7-11).

For more detail of activity data estimated, see Table 7-54.

- ***Percentage of Industrial Waste Incinerated at Industrial Incineration Facilities for Energy Recovery (by type)***

Percentage of industrial waste that is incinerated at industrial incineration facilities with energy recovery stands for the one being incinerated at the facilities actually supply electricity or heat outside of them. The values are obtained from the *Survey of Industrial Waste Treatment Facilities* (MOE).

In Japan, industrial incineration facilities are installed mainly by private sector waste disposal enterprises. In comparison with the municipal waste incinerators installed primarily by municipal governments, energy recovery (for use in power generation and as a heat source) has not yet been so popular. The percentage for the industrial waste category is therefore smaller.

Table 7-52 Percentage of IW incinerated at incineration facilities with energy recovery

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Waste oil 1)	%	0.6	0.7	0.6	2.5	4.1	2.3	4.0	4.2	4.8	4.4	3.1	3.2	3.8	4.0	4.0
Plastics	%	1.4	1.4	4.1	6.6	13.3	17.5	13.3	16.7	19.2	18.4	17.6	17.1	20.8	25.8	25.8
Wood 2)	%	0.2	0.8	1.1	1.5	5.9	13.1	8.5	10.5	10.2	9.7	8.5	7.6	7.9	9.5	9.5
Sludge 3)	%	0.9	0.8	1.0	1.1	2.2	3.4	8.3	12.5	12.2	12.0	10.6	11.5	11.2	14.5	14.5
Other 4)	%	0.2	0.8	1.1	1.5	1.5	1.8	1.9	2.6	4.2	5.0	3.3	3.6	3.3	11.4	11.4

Note:
1) "Waste oil" includes fossil-fuel derived/animal and vegetable oil.
2) "Wood" includes paper/cardboard and wood.
3) Not applicable for "sewage sludge".
4) "Other" includes textiles (natural fiber), and animal and vegetable residues/animal carcasses.

2) CH_4

- ***Estimation Method***

Emissions of CH_4 from this source have been calculated by multiplying the volume of industrial waste incinerated by Japan's country specific emission factor and by percentage of industrial waste incinerated at incineration facilities with energy recovery.

$$E = \sum_j \{EF_j \times A_j \times (1 - R_j)\}$$

E	: Emission of methane from the incineration of industrial waste [kg-CH_4]
EF_j	: Emission factor for waste type j (wet basis) [kg-CH_4/t]
A_j	: Incinerated amount of waste type j (wet basis) [t]
Rj	: Percentage of industrial waste j incinerated at facilities with energy recovery

- ***Emission Factor***

Based on expert judgment which takes into account the countermeasures against dioxin emissions from incinerators, for the emission factors by waste type for the period FY1990-2001 (MOE, 2006b) and from FY2002 onward (MOE, 2010), respectively, different values are used. These emission factors are established based on actual measurement survey. The correction taking into account CH_4 concentrations in the atmosphere is not made to these emission factors. The emission factor for paper/cardboard or wood in MOE (2006b) and MOE (2010) is substituted for the emission factor for textiles (natural fiber), and animal and vegetable residues/animal carcasses.

Table 7-53 CH_4 emission factors for industrial waste by waste type

Item	Unit	FY1990-2001	FY2002-
Waste oil (fossil-fuel derived/animal and vegetable)	g-CH_4 /t	4.8	4.0
Plastics	g-CH_4 /t	30	8.0
Paper/cardboard	g-CH_4 /t	22	225
Wood	g-CH_4 /t	22	225
Textiles (natural fiber)	g-CH_4 /t	22	225
Animal and vegetable residues/animal carcasses	g-CH_4 /t	22	225
Sludge	g-CH_4 /t	14	1.5
Other than sewage sludge	g-CH_4 /t	14	1.5

Reference: Environmental Agency (2000), MOE (2006b), MOE (2010), Ishikawa Pref. et al. (1991-1999), JSAE (1996)

- ***Activity Data***

The volume of waste incinerated (wet basis) by waste type is used as the activity data for CH_4 emissions from the incineration of industrial waste.

➢ ***Paper/cardboard, Wood, Textiles (natural fiber) and Animal and Plant Residues/Animal Carcasses:***

The volume of waste incinerated for each type is obtained from the *Cyclical Use of Waste Report* (MOE). Animal and vegetable residues/animal carcasses waste is defined as the sum of items "animal and vegetable residues" and "animal carcasses" in the said reference.

➢ ***Sludge***

Activity data is taken as the aggregate of the values obtained from the "Volume of Other Incinerated Organic Sludge" section in the *Cyclical Use of Waste Report* (MOE), and the "Volume of Incinerated Sewage Sludge" reported in a survey by the Ministry of Lands, Infrastructure, Transport and Tourism (MLIT).

➢ ***Waste Oil (Fossil-fuel derived/Animal and Vegetable) and Plastics***

The activity data for waste oil and plastics are provided by the *Cyclical Use of Waste Report* (MOE). Because the values provided by this report include the amount of specially-controlled industrial waste which is allocated to the category of specially-controlled industrial waste (5.C.1.-), it is subtracted from the total amount to avoid double counting. Unlike the activity data for CO_2 emission estimates, both fossil-fuel derived oil and animal and vegetable oil are included in waste oil for the activity data for CH_4 emission estimates. Note that activity data for plastics includes biomass-based plastics.

Table 7-54 Incinerated industrial waste by waste types (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Waste fossil-fuel derived oil	kt (wet)	1,258	1,498	1,646	1,493	1,467	1,546	1,297	1,420	1,191	1,375	1,301	1,317	1,205	1,145	1,161
Waste animal and vegetable oil	kt (wet)	40	69	103	115	121	117	103	115	100	113	103	107	103	97	99
Plastics	kt (wet)	842	1,794	1,780	1,808	1,703	1,632	1,778	1,591	1,826	1,777	1,840	1,864	1,848	1,574	1,557
Paper/cardboad	kt (wet)	335	712	718	323	292	349	152	130	114	109	116	103	5	18	15
Wood	kt (wet)	2,679	4,744	3,114	1,865	1,101	1,181	1,388	1,137	1,120	1,062	1,263	1,247	1,161	1,055	1,008
Textiles (natural fiber)	kt (wet)	31	49	50	43	24	24	35	39	27	36	29	21	23	30	30
Animal and vegetable residues/animal carcasses	kt (wet)	77	125	272	167	190	153	151	153	168	154	133	159	204	170	170
Sewage sludge	kt (wet)	3,060	3,827	4,300	4,988	4,694	4,817	4,934	4,753	4,550	4,452	4,684	4,709	4,602	4,445	4,938
Sludge other than sewage sludge	kt (wet)	1,972	2,023	2,071	2,288	2,010	1,713	1,954	2,021	1,880	1,884	2,003	1,938	1,962	1,790	1,796

3) N_2O

- ***Estimation Method***

Emissions of N_2O from this source are calculated separately for the major emission source, sewage sludge, and the waste other than sewage sludge. With respect to sewage sludge, emission factors are set by type of flocculants and furnaces; and the ones for "high-molecular-weight, flocculant fluidized bed incinerator" are further determined by the incineration temperatures. Emissions from the industrial waste other than sewage sludge are estimated by multiplying the volume of waste incinerated by Japan's country-specific emission factor. Among those emissions, the ones to be reported in the waste sector are calculated by multiplying the percentage of industrial waste incinerated at the industrial waste incineration facilities with energy recovery.

$$E = \sum \{EF_j \times A_j \times (1 - R_j)\}$$

E : Emission of nitrous oxide from the incineration of industrial waste [kg-N_2O]

EF_j : Emission factor for waste type j (wet basis) [kg-N_2O /t]

A_j : Incinerated amount of waste type j (wet basis) [t]

R_j : Percentage of industrial waste j incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Sewage Sludge***

Emission factor for N_2O emissions from sewage sludge incineration are determined by taking a weighted average of actually measured emission factors for N_2O at each incineration facility based on the survey on the volume of sewage sludge incinerated at the facilities conducted by MLIT. Since emission factors are different depending on the types of flocculants, incinerators, and furnace temperatures, they are established for each category as given in Table 7-55.

Table 7-55 N_2O emission factors for sewage sludge incineration (wet basis)

Type of flocculant	Type of incinerator	Combustion Temperature	Emission factor[1)] [g-N_2O/t]
High-molecular weight flocculant	Fluidized bed incinerator	Normal temperature combustion (around 800˚C)	1,508
	Fluidized bed incinerator[2)]	High temperature combustion (around 850˚C)	645
	Multiple hearth	–	882
Other	–	–	
Lime Sludge	–	–	294
–	- Multiple hearth air injection incineration method fluidized bed incinerator - Two-stage incineration method circulating fluidized bed incinerator - Stoker furnace	High temperature combustion (around 850˚C)	263
–	Carbonization furnace for solid fuel production	–	31.2

Reference:
Hyogo Pref. (1994), Kanagawa Pref. (1994), National Institute for Land and Infrastructure Management: NILIM (2001), NILIM (2002), Nakamura et al. (1998), Matsubara et al. (1994), Takeishi et al. (1996), MOE (2006b), MOE (2013b), MOE (2015)

Note:
1) The same emission factors are used for all the reporting years.
2) Excludes multiple hearth air injection incineration method fluidized bed incinerator and two-stage incineration method circulating fluidized bed incinerator.

➢ ***Waste other than Sewage Sludge***

Based on expert judgment which takes into account the countermeasures against dioxin emissions from incinerators, for the emission factors by waste type for the period FY1990-2001 (MOE, 2006b) and from FY2002 onward (MOE, 2010), respectively, different values are used. These emission factors are established based on actual measurement survey. The correction taking into account CH_4 concentrations in the atmosphere is not made to these emission factors. The emission factor applied for paper/cardboard or wood is also used for textiles (natural fiber) and animal and vegetable residues/animal carcasses in the MOE (2006b) and MOE (2010).

Table 7-56 N_2O Emission factors for industrial waste by type (wet basis)

Item	Unit	FY1990-2001	FY2002-
Waste oil (fossil-fuel derived/animal and vegetable)	g-N_2O /t	12	62
Plastics	g-N_2O /t	180	15
Paper/cardboard	g-N_2O /t	21	77
Wood	g-N_2O /t	21	77
Textiles (natural fiber)	g-N_2O /t	21	77
Animal and vegetable residues/animal carcasses	g-N_2O /t	21	77
Sludge (excluding sewage sludge)	g-N_2O /t	457	99

Reference: MOE (2000), MOE (2010), Ishikawa Pref. et al. (1991-1997), JSAE (1996), Nakamura et al. (1998), Matsubara et al. (1994), Suzuki et al. (2001), Takeishi et al. (1994), Takeishi et al. (1996), Ueno et al. (1995), Yasuda et al. (1994)

- ***Activity Data***

➢ ***Sewage Sludge***

Data in the "volume of incinerated sewage sludge, by flocculants and by incinerator types" reported in a survey by MLIT are used as activity data (wet basis).

Table 7-57 Amount of sewage sludge incinerated (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
High-molecular-weight flocculant/ fluidized bed incinerator (nomal temp.)	kt (wet)	1,112	1,869	2,397	2,839	1,535	1,552	1,549	1,318	1,695	1,218	1,531	1,551	1,715	1,581	878
High-molecular-weight flocculant/ fluidized bed incinerator (high temp.)	kt (wet)	128	219	723	1,469	2,581	2,641	2,644	2,644	2,283	2,665	2,503	2,522	2,257	2,275	2,840
High-molecular-weight flocculant/multiple hearth	kt (wet)	560	656	572	102	61	43	40	NO	NO	NO	NO	NO	NO	NO	1
Lime sludge	kt (wet)	1,010	663	272	289	109	74	22	1	1	1	1	1	1	0	NO
Other	kt (wet)	55	161	175	8	1	0	12	70	27	27	27	27	63	35	69
- Multiple hearth air injection/blowing incineration method fluidized bed incinerator, - Two-stage incineration method circulating fluidized bed incinerator, - Stoker furnace	kt (wet)	195	259	161	280	338	444	565	604	411	412	465	431	346	306	880
Carbonization furnace for solid fuel production	kt (wet)	NO	NO	NO	NO	70	63	103	116	133	128	156	177	220	248	272

➢ ***Industrial Waste other than Sewage Sludge***

Activity data (wet basis) is determined in the same manner as for the CH_4 emissions from industrial waste, with the exception that the "volume of other incinerated organic sludge" is used as activity data for the sludge (excluding sewage sludge).

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties in CO_2 emission factors are evaluated by using the 95% confidence interval of carbon content data in fossil fuel-based waste. The uncertainties in CH_4 and N_2O emission factors are evaluated by using the 95% confidence interval in the actual measurement on the surveys for emissions factors. As for the uncertainties in activity data, the uncertainties in industrial waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-58.

Table 7-58 Uncertainty assessment for industrial waste on the category "waste incineration (5.C.1.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Waste oil	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, twice as much as the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	CH_4	-100%	+181%	-30%	+30%	-104%	+184%	The uncertainty is quoted from MOE (2010), a reference of emission factors.		
	N_2O	-76%	+76%	-30%	+30%	-81%	+81%			
Plastics	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, twice as much as the uncertainty in municipal waste plastics is substituted based on expert judgment.		Combined by using the formula for propagation of errors.
	CH_4	-100%	+216%	-30%	+30%	-104%	+218%	The uncertainties are quoted from MOE (2010), a reference of emission factors.		
	N_2O	-44%	+44%	-30%	+30%	-53%	+53%			
Paper/ cardboard	CO_2	-13%	+13%	-30%	+30%	-104%	+401%	It is evaluated by combining the 95% confidence interval in actual measurement data of carbon content with that of fossil-derived fraction in the carbon.		Combined by using the formula for propagation of errors.
Paper/ cardboard or wood	CH_4	-100%	+412%	-30%	+30%	-104%	+413%	The uncertainty is quoted from MOE (2010), a reference of emission factors.		Combined by using the formula for propagation of errors.
	N_2O	-64%	+64%	-30%	+30%	-71%	+71%			
Sludge	CH_4	-100%	+201%	-30%	+30%	-104%	+203%			Combined by using the formula for propagation of errors.
	N_2O	-84%	+84%	-30%	+30%	-89%	+89%			
Textiles (Natural fiber)	CH_4	-100%	+412%	-30%	+30%	-104%	+413%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in paper/cardboard or wood is substituted based on expert judgment.		Combined by using the formula for propagation of errors.
	N_2O	-64%	+64%	-30%	+30%	-71%	+71%			
Animal and vegetable residues/ animal carcasses	CH_4	-100%	+412%	-30%	+30%	-104%	+413%			Combined by using the formula for propagation of errors.
	N_2O	-64%	+64%	-30%	+30%	-71%	+71%			

- ***Time-series Consistency***

Emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By revising biomass-based plastic products data, CO_2 emissions from FY2005 onward were recalculated. By updating the statistical data, emissions in FY2020 were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.1.3. Specially-Controlled Industrial Waste (5.C.1.-)

a) Category Description

The specially-controlled industrial waste includes wastes with properties, such as explosiveness, toxicity and infectivity, that may be harmful to human health or to living environment. Waste types in this category are indicated in the Table 7-59.

Table 7-59 Substance in incineration of specially-controlled industrial waste

Waste type	Substance
Flammable waste oil	Gasoline, Kerosene, Gas oil or diesel oil
Specified hazardous industrial waste oil	Trichlorethylene, tetrachlorethylene, dichloromethane, carbon tetrachloride, 1,2-dichloroethane, 1,1-dichloroethane, cis-1,2-dichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,3 dichloropropene, thiuram, simazine, thiobencarb, benzene, selenium, 1,4-dioxane
Infectious waste plastics	Plastics
Infectious waste (except plastic)	Glasses, Textile, Paper

In this category, CO_2, CH_4, and N_2O emissions from incineration of specially-controlled industrial waste are estimated by each waste type and reported in the corresponding category either “Non-biogenic, Hazardous waste”, Non-biogenic, Clinical waste” or “Biogenic, Clinical waste” (see Table 7-27).

Because the actual state of energy recovery from the incineration of specially-controlled industrial waste is not sufficiently understood, the emissions from specially-controlled industrial waste are reported entirely in “Waste Incineration (Category 5.C.)”.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions of CO_2 from the incineration of flammable waste oil, specified hazardous industrial waste oil and infectious waste plastic contained in specially-controlled industrial waste are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* (Page 5.9, Fig. 5.1) by using Japan’s country-specific emission factors and the volume of waste incinerated.

- ***Emission Factor***

\- ***Flammable waste oil***

Emission factors for waste oil in industrial waste is used for flammable waste oil in specially-controlled industrial waste, since the difference of carbon contents and oxidation factor in the two source categories is considered to be small.

\- ***Specified hazardous industrial waste oil***

In accordance with the approach taken by the *2006 IPCC Guidelines,* emission factor for specified hazardous industrial waste oil is estimated as follows.

$$EF = CF \times FCF \times OF \times (1 - u) \times 44/12$$

EF : Emission factor for the incineration of specified hazardous industrial waste oil [kg-CO_2/t]
CF : Carbon content in specified hazardous industrial waste oil (dry basis) [%]
FCF : Fossil-fuel derived fraction in specified hazardous industrial waste oil [%]
OF : Oxidation factor [%]
u : Percentage of water content in specified hazardous industrial waste oil [%]

Average carbon content in specified hazardous industrial waste oil (dry basis) is estimated using weighted average of carbon content in chemical formula of substances shown in Table 7-59 for incinerated substances based on MOE (2010-2011). For the fossil-fuel derived fraction in specified hazardous industrial waste oil, the default value of 100% indicated in the *2006 IPCC Guidelines* is used. For the oxidation factor, the default value of 100% indicated in the *2006 IPCC Guidelines* is used. The percentage of water content in specified hazardous industrial waste oil is determined to be 5% by expert judgment.

- ***Infectious plastic***

For infectious plastic, the emission factors for incineration of plastics in industrial waste are substituted since the difference in terms of carbon contents and oxidation factor in the two source categories is considered to be small.

Table 7-60 CO_2 emission factors for waste oil and infectious plastics of specially-controlled waste

Item	Unit	Emission factor
Flammable waste oil	kg-CO_2/t (wet)	2,933
Specified hazardous industrial waste oil	kg-CO_2/t (wet)	1,024
Infectious plastics	kg-CO_2/t (wet)	2,567

● ***Activity Data***

Generally, the amount of specially-controlled industrial waste incinerated obtained from the *Cyclical Use of Waste Report* (MOE) is used as the activity data in and after FY2008. As for the past activity data which the survey data is not available, output volume of waste oil indicated in the *Report on Survey of Organizations in Industrial Waste Administration* (Water Supply Division, Health Service Bureau, the Ministry of Health and Welfare) is used on the assumption that the entire volume of waste oil and infectious plastic waste contained in specially-controlled industrial waste is incinerated. Details are shown below.

- ***Flammable waste oil***

The amount of specially-controlled industrial waste oil incinerated from the *Cyclical Use of Waste Report* (MOE) is used as the activity data. Since the data includes both of incinerated amounts of flammable waste oil and specified hazardous industrial waste oil, the amounts of flammable waste oil are estimated by following equation. All the waste oil in specially-controlled industrial waste to be estimated for emissions is waste fossil-fuel derived oil.

$$A_{flam.oil} = SIW_{oil} - A_{s-hazard.oil}$$

$A_{flam.\ oil}$: Amount of flammable waste oil incinerated (wet basis) [t]
SIW_{oil} : Total amount of specially-controlled industrial waste oil incinerated (wet basis) [t]
$A_{s\text{-}hazard.\ oil}$: Amount of specified hazardous industrial waste oil incinerated (wet basis) [t]

- ***Specified hazardous industrial waste oil***

The activity data is obtained from following equation using the amount of specified hazardous industrial waste oil reduced in incineration from the *Report on the survey for the estimation of GHG emissions from specially-controlled industrial was*te (MOE) and Residual fraction of incinerated waste oil from the *Cyclical Use of Waste Report* (MOE).

$$A_{s-hazard.oil} = R_{s-hazard.oil} \times (1 + r)$$

$A_{s\text{-}hazard.\ oil}$	: Amount of specified hazardous industrial waste oil incinerated (wet basis) [t]
$R_{s\text{-}hazard.\ oil}$	: Amount of specified hazardous industrial waste oil reduced in incineration (wet basis) [t]
r	: Residual fraction of incinerated waste oil [%]

- ***Infectious plastic***

The activity data is obtained from following equation using the amount of infectious waste incinerated from the *Cyclical Use of Waste Report* (MOE) and the percentage of plastic content in infectious waste from Japan Society of Waste Management Experts: JSWME (1997). All of Infectious plastics are considered to be fossil-fuel derived.

$$A_{inf.plastics} = ISW_{inf.} \times C_{inf.plastics}$$

$A_{inf.\ plastics}$	: Amount of infectious plastics incinerated (wet basis) [t]
$ISW_{inf.}$	: Total amount of infectious waste incinerated (wet basis) [t]
$C_{inf.\ plastics}$	: Percentage of plastic content in infectious waste [%]

2) CH_4

● ***Estimation Method***

Emissions of CH_4 from the incineration of waste oil and infectious waste included in the specially-controlled industrial waste are calculated by multiplying the volume of incinerated waste by type (wet basis) by Japan's country-specific emission factor.

● ***Emission Factor***

Because actual measurement data are not available, the emission factors for the incineration of industrial waste are used as substitutes for the emission factor for the specially-controlled industrial waste by type. Specifically, the substitute emission factors used are: the waste fossil-fuel derived oil in industrial waste for the flammable waste oil and specified hazardous waste oil; the plastic in industrial waste for the infectious plastic; and the paper/cardboard and wood in industrial waste for the other infectious waste (biogenic).

● ***Activity Data***

- ***Flammable waste oil***

Activity data is the same as those used for CO_2 emission.

- ***Specified hazardous industrial waste oil***

Activity data is the same as those used for CO_2 emission.

- ***Infectious plastics***

Activity data is the same as those used for CO_2 emission.

- ***Infectious waste except plastics***

The activity data is obtained from similar equation to Infectious plastics, as follows.

$$A_{inf.exc.\ plastics} = ISW_{inf.} \times (1 - C_{inf.plastics})$$

$A_{inf.\ exc.\ plastics}$	: Amount of infectious waste except plastics incinerated (wet basis) [t]
$ISW_{inf.}$	: Total amount of infectious waste incinerated (wet basis) [t]
$C_{inf.\ plastics}$	: Percentage of plastic content in infectious waste [%]

3) N_2O

- ***Estimation Method***

Emissions of N_2O from the incineration of waste oil and infectious waste in specially-controlled industrial waste are calculated by multiplying the incinerated volume of each type of waste (wet basis) by Japan's country-specific emission factor.

- ***Emission Factor***

Because actual measurement data are not available, the N_2O emission factors for the incineration of industrial waste are used as substitutes for determining the emission factor for each type of specially-controlled industrial waste. Specifically, the substitute emission factors used are: the waste oil in industrial waste for the flammable waste oil and specified hazardous industrial waste oil; the plastics in industrial waste for the infectious plastics; and the paper/cardboard and wood in industrial waste for the waste other than infectious plastics.

- ***Activity Data***

The same activity data used for CH_4 emissions is used.

Table 7-61 Amount of incineration of specially-controlled industrial waste (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Flammable waste oil	kt (wet)	238	353	520	478	390	267	271	266	236	278	222	263	317	311	310
Specified hazardous industrial waste oil	kt (wet)	18	27	40	37	41	25	54	122	145	128	93	99	100	75	76
Infectious waste (plastics)	kt (wet)	78	128	167	169	154	131	133	176	166	160	154	187	207	182	181
Infectious waste (except plastics)	kt (wet)	105	172	225	228	106	90	92	121	114	110	106	129	142	125	125

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainty assessment is conducted as well as the assessment for the industrial waste incineration. As for the uncertainties in activity data, the uncertainties in specially-controlled industrial waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in Table 7-62.

Table 7-62 Uncertainty assessment for specially-controlled industrial waste on the category "waste incineration (5.C.1.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission/removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Specially-controlled industrial waste	CO_2	-2%	+2%	-60%	+60%	-60%	+60%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty in specially-controlled industrial waste based on expert judgment is used.	Combined by using the formula for propagation of errors.
	CH_4	-100%	+216%	-60%	+60%	-117%	+224%			
	N_2O	-44%	+44%	-60%	+60%	-74%	+74%			

- ***Time-series Consistency***

Since some basic data used for calculating activity data are available only for part of time series, consistent data over the time series are developed based on the estimation. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By updating the statistical data, emissions in FY2020 were recalculated. For detail, see the section "7.1.5. General Recalculations for Emissions from Waste Sector". See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.2. Open Burning of Waste (5.C.2.)

7.4.2.1. Municipal Solid Waste (5.C.2.-)

a) Category Description

In Japan, since the Waste Management and Public Cleansing Act prohibits open burning of waste, the emissions from open burning of municipal solid waste are reported as "NO".

7.4.2.2. Industrial Waste (5.C.2.-)

a) Category Description

This category covers CO_2, CH_4 and N_2O emissions from illegal open burning of industrial waste (wood, construction and demolition, plastics, and other/unknown), and the emissions are reported in the category "non-biogenic, industrial solid waste (ISW)".

b) Methodological Issues

1) CO_2

- ***Estimation Method***

CO_2 emissions from the open burning of industrial waste plastics are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* by using Japan's country-specific emission factors and the volume of waste burned in the open air.

- ***Emission Factor***

In accordance with the approach taken by the *2006 IPCC Guidelines*, emission factor is calculated as follows.

$$EF = CF \times FCF \times OF \times 44/12$$

EF : Emission factor for the open burning of industrial waste plastics (wet basis) [kg-CO_2/t]
CF : Carbon content in industrial waste plastics (wet basis) [%]
FCF : Fossil-fuel derived fraction in industrial waste plastics [%]
OF : Oxidation factor [%]

Table 7-63 CO_2 emission factors and relevant parameters of open burning of industrial waste plastics

Item	Value	Reference	Note
EF	1,822 [kg-CO_2/t (wet)]	–	Country-specific
CF	70 %	Environmental Agency (1992)	See also "7.4.1.2. Industrial Waste (5.C.1.-)".
FCF	100%	*2006 IPCC Guidelines*	Default value
OF	71 %	*2019 Refinement*	Default value

- ***Activity Data***

The amount of plastics as industrial waste burned in the open air obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE) is used as the activity data in and after FY1996. As for the past activity data from FY1990 to FY1995, for which the survey data is not available, the data of FY1996 is uniformly used as a substitute since there are no other appropriate way to estimate before FY1995. Since it is unclear that plastics burned in the open air include biogenic fraction, whole of those plastics are assumed to be derived from fossil-fuel.

Table 7-64 The amount of fossil-fuel derived industrial waste burned in the open air (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Plastics	kt (wet)	3.4	3.4	0.9	0.2	0.1	0.1	0.1	0.1	0.02	0.05	0.1	0.1	0.1	0.1	0.1

2) CH_4, N_2O

- ***Estimation Method***

Emissions of CH_4 and N_2O from the open burning of industrial waste are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* by using the IPCC default emission factors and the Japan's country-specific volume of waste burned in the open air.

- ***Emission Factor***

As no knowledge is obtained for making it possible to set emission factors specific to Japan, the default values given in the *2006 IPCC Guidelines* are applied.

Table 7-65 CH_4 and N_2O emission factors for open burning of industrial waste

Gas	Unit	EFs	Reference
CH_4	kg-CH_4/t (wet)	6.5	*2006 IPCC Guidelines*
N_2O	kg-N_2O/t (dry)	0.15	*2006 IPCC Guidelines*

- ***Activity Data***

The total amount (wet basis) summed up all industrial waste burned in the open air obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE) is used as the activity data for CH_4 emission estimates. As for the activity data for N_2O emission estimates, the amounts (wet basis) mentioned above are converted to dry basis by using water contents for each waste type. To be consistent with the IPCC default emission factor applied in estimations, default water contents of the *2006 IPCC Guidelines* (wood: 15%, plastics: 0%, construction and demolition: 0%, and other/unknown:10%) are applied in this conversion. As for the past activity data from FY1990 to 1995, for which the survey data is not available, the data of FY1996 is uniformly used as a substitute since there are no other appropriate way to estimate.

Table 7-66 The amount of industrial waste burned in the open air (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total wet weight amount	kt (wet)	72.2	72.2	28.9	3.5	1.3	0.9	1.3	0.6	1.0	0.5	0.7	0.8	0.8	0.8	0.8
Total dry weight amount	kt (dry)	62.4	62.4	25.5	3.1	1.1	0.8	1.2	0.5	0.8	0.5	0.6	0.7	0.7	0.7	0.7

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

Details of the uncertainty assessment on this category are indicated in Table 7-67.

Table 7-67 Uncertainty assessment on the category "open burning of waste (5.C.2.-)"

Item		GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission/removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
			(-)	(+)	(-)	(+)	(-)	(+)			
Industrial waste	Plastics	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty in specially-controlled industrial waste based on expert judgment is used.	Combined by using the formula for propagation of errors.
		CH_4	-100%	+100%	-30%	+30%	-104%	+104%	The uncertainties are assessed as those of the *2006 IPCC Guidelines*' default emission factors.		
		N_2O	-100%	+100%	-30%	+30%	-104%	+104%			

- ***Time-series Consistency***

Since activity data based on the survey are available only for and after FY1996, consistent data over the time series are developed based on the estimation. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By adopting the default oxidation factor (*OF*) given in the *2019 Refinement* in the calculation of CO_2 emission factor of industrial waste, CO_2 emissions for the whole time series were recalculated. By updating the statistical data, emissions in FY2019 and FY2020 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.3. Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)

7.4.3.1. Waste Incineration with Energy Recovery (1.A.)

a) Category Description

In this category, CO_2, CH_4, and N_2O emissions from the incineration of municipal and industrial waste with energy recovery are estimated and reported. The reporting category for the emissions is "Other sectors (Category 1.A.4.)" and the fuel types are classified as "Other fossil fuels" and/or "Biomass" as shown on the Table 7-28.

b) Methodological Issues

Methodologies similar to the ones used in "7.4.1.1. Municipal Solid Waste (5.C.1.-)" and "7.4.1.2. Industrial Waste (5.C.1.-)" are used. Emissions are calculated using the following equations:

1) CO_2

- ***Estimation Method***

➢ ***Municipal Solid Waste***

$$E = EF \times A \times R$$

E : Emission of CO_2 from waste incineration [kg-CO_2]
EF : Emission factor for incineration (dry basis) [kg-CO_2/t]
A : Amount of waste incinerated (dry basis) [t]
R : Percentage of municipal solid waste incinerated at incineration facilities with energy recovery

➢ ***Industrial Waste***

$$E = EF \times A \times R$$

E : Emission of CO_2 from waste incineration [kg-CO_2]
EF : Emission factor for waste incineration (wet basis) [kg-CO_2/t]
A : Amount of waste incinerated (wet basis) [t]
R : Fraction of industrial waste incinerated at industrial waste incineration facilities with energy recovery (by waste type)

2) CH_4, N_2O

- ***Estimation Method***

➢ ***Municipal Solid Waste***

$$E = \sum_i (EF_i \times A_i) \times R$$

E	: Emissions of CH_4 or N_2O from incineration of municipal solid waste [kg-CH_4], [kg-N_2O]
EFi	: Emission factor for municipal solid waste incinerator type *i* (wet basis) [kg-CH_4/t], [kg-N_2O/t]
Ai	: Amount of municipal solid waste incinerated for incinerator type *i* (wet basis) [t]
R	: Percentage of municipal solid waste incinerated at facilities with energy recovery

➢ ***Industrial Waste***

$$E = \sum_j \left(EF_j \times A_j \times R_j\right)$$

E	: Emissions of CH_4 or N_2O from incineration of industrial waste [kg-CH_4], [kg-N_2O]
EF_j	: Emission factor for industrial waste type *j* (wet basis) [kg-CH_4/t], [kg-N_2O/t]
A_j	: Amount of industrial waste type *j* incinerated (wet basis) [t]
R_j	: Fraction of industrial waste type *j* incinerated at industrial waste incineration facilities with energy recovery

- ***Activity Data Converted into Energy Units (Reference Value)***

Activity data converted into energy units to be reported in CRF is estimated as indicated below.

➢ ***Municipal Solid Waste***

$$A_E = A \times GCV \times R / 10^6$$

A_E	: Calorific value of activity data of MSW [TJ]
A	: Total amount of MSW incinerated [kg (wet basis)]
GCV	: Gross calorific value of MSW [MJ/kg]
R	: Fraction of MSW incinerated at MSW incineration facility with energy recovery

Based on the actual measurement results obtained at municipality, the calorific value of MSW is 9.9 (MJ/kg).

➢ ***Industrial Waste***

$$A_E = \sum_j A_j \times GCV_j \times R / 10^6$$

A_E	: Calorific value of activity data of industrial waste [TJ]
Aj	: Amount of industrial waste type *j* incinerated [kg (wet basis)]
GCVj	: Gross calorific value of industrial waste type *j* [MJ/kg]
R	: Fraction of industrial waste type *j* incinerated at industrial waste incineration facility with energy recovery

Calorific value of industrial waste is indicated in Table 7-72 (as referred to hereinafter).

c) Uncertainties and Time-series Consistency

Methodologies similar to the ones used in "7.4.1.1. Municipal Solid Waste (5.C.1.-)" and "7.4.1.2. Industrial Waste (5.C.1.-)" are used.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

Same recalculations as the category waste incineration (without energy recovery) were conducted. For details, see the paragraphs for category-specific recalculations on “7.4.1.1. Municipal Solid Waste (5.C.1.-)” and “7.4.1.2. Industrial Waste (5.C.1.-)”.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)

a) Category Description

In this category, CO_2, CH_4, and N_2O emissions from waste directly used as alternative fuel are estimated and reported. The reporting category for the emissions for each type of waste is included in, according to its use as raw material or fuel, either “Energy industries (Category 1.A.1.)”, “Manufacturing industries and Construction (1.A.2.)” or “Other sectors (Category 1.A.4.)” (Table 7-29). The fuel types are classified as “Other fossil fuels” and/or “Biomass” as indicated in Table 7-28.

GHG emissions during the direct use of waste as a raw material, such as plastics used as reducing agents in blast furnaces or as a chemical material in coking furnaces, or use of intermediate products manufactured using the waste as a raw material, are estimated in this category. The waste used as raw material and the ones used as alternative fuel are combined and expressed as “raw material or fuel (use)” in this section.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions are estimated by multiplying the incinerated volume of each type of waste used as raw material or fuel by Japan’s country-specific emission factor. The wastes included in the estimation are the portions used as raw material or fuel of: plastics in MSW, plastics and waste fossil-fuel derived oil in industrial waste, and waste tires.

- ***Emission Factor***

Emission factors are established for the plastics from MSW that are used as chemical raw material in coke ovens and waste tires. The remaining emission sources used the emission factors for “7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)”.

Table 7-68 CO_2 Emission factors specially defined for this category

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
MSW-coke oven	kg-CO_2/t (dry)	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467
Waste tire	kg-CO_2/t (dry)	1,867	1,794	1,799	1,746	1,759	1,743	1,744	1,736	1,698	1,677	1,673	1,661	1,645	1,641	1,562

- ***Activity Data***

For details of the amount of waste used as raw materials or fuels, see the7.4.3.2.a-7.4.3.2.c.

Table 7-69 Amount of direct use of waste as alternative fuel (Activity data: wet basis)

Waste type		Application brakedown	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
MSW	Plastics	Liquefaction	kt (wet)	NO	NO	3	7	1	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Blast furnace reducing agent	kt (wet)	NO	NO	25	37	27	26	30	27	31	29	28	28	28	29	30
		Coke oven chemical feedstock	kt (wet)	NO	NO	11	175	177	171	NO	17	29	25	32	17	25	24	24
		Gasification	kt (wet)	NO	NO	1	59	53	62	58	51	55	55	57	46	45	42	35
Industrial waste	Waste oil	(Unclassified)	kt (wet)	1,243	1,461	1,452	1,848	1,701	1,764	1,707	1,633	1,786	1,664	1,664	1,809	1,900	1,780	1,802
	Plastics	Blast furnace reducing agent	kt (wet)	NO	NO	57	160	134	134	107	149	144	156	168	132	148	115	148
		Chemical industry	kt (wet)	5	4	5	2	1	1	1	0.4	0.4	0.2	3	3	4	5	5
		Paper industry	kt (wet)	NO	NO	3	3	18	15	14	18	16	17	18	18	18	17	19
		Cement burning	kt (wet)	NO	9	102	302	445	479	518	595	576	623	643	718	746	746	774
		Automobile manufacturere	kt (wet)	16	10	8	4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Liquefaction	kt (wet)	NO	NO	1	1	1	1	1	1	1	0.1	NO	1	1	1	1
		Gasification	kt (wet)	NO	NO	NO	11	117	79	97	90	81	79	91	97	86	99	92
	Wood	(Unclassified)	kt (wet)	1,635	1,635	2,061	2,683	3,900	4,151	4,425	4,878	4,628	4,555	4,832	4,690	5,097	4,996	4,745
Waste tire		Cement burning	kt (wet)	111	275	361	181	95	66	62	53	59	63	70	64	70	69	73
		Boiler	kt (wet)	119	126	75	12	8	6	6	2	2	5	3	3	2	2	3
		Iron manufacture	kt (wet)	NO	NO	57	51	30	30	27	27	20	19	17	14	18	16	17
		Gasification	kt (wet)	NO	NO	NO	27	49	45	44	50	49	51	58	61	56	10	1
		Metal refining	kt (wet)	67	37	30	10	1	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Tire manufacture	kt (wet)	NO	32	39	24	23	27	27	22	23	23	21	20	9	2	2
		Paper manufacture	kt (wet)	NO	26	42	210	388	363	372	415	439	407	436	446	402	412	425
		Power generation	kt (wet)	NO	NO	7	9	9	37	40	46	51	58	47	66	66	96	112
Refuse-derived fuel		(Unclassified)	kt (wet)	34	39	148	415	380	384	386	388	361	360	359	362	318	310	310
Refuse paper and plastic fuel (RPF)		Petroleum product manufacturer	kt (wet)	NO	NO	0.4	5	4	4	3	4	4	3	4	0.2	0.1	0.4	NO
		Chemical industry	kt (wet)	NO	NO	7	15	22	27	26	20	22	19	18	17	17	9	3
		Paper industry	kt (wet)	NO	8	25	465	803	877	926	912	940	1,014	1,022	1,036	1,013	992	1,070
		Cement manufacturer	kt (wet)	NO	NO	0.2	8	15	14	16	17	14	11	13	15	18	16	12

Note:

- The amount of biogenic fraction such as biomass-based plastics, waste animal and vegetable oil, and wood are not included in the activity data for the estimation of CO_2 emissions.
- For the activity data to estimate CO_2 emissions except for waste oils and plastics in industrial waste, the figures in the above table are converted into dry basis amount by subtracting water contents.
- Waste oil includes “used lubricant” and “used solvent”.

2) CH_4, N_2O

- ***Estimation Method***

Emissions are estimated by multiplying the amount of each type of waste used as raw material or fuel by the country-specific emission factor.

- ***Emission Factor***

Emission factors for wastes used as raw material or fuel are determined by multiplying the emission factor for applicable types of furnaces by the calorific value of each waste type and converting the result to the weight-based values.

Table 7-70 shows the data used in the estimation.

$$EF_i = EF_{E,i} \times GCV_i / 1000$$

EF_i	: Emission factor for waste type *i* [kg-CH_4 / t(wet)], [kg-N_2O/ t(wet)]
$EF_{E,i}$	: Emission factor for waste type *i* on calorie basis [kg-CH4/TJ], [kg-N_2O/TJ]
GCV_i	: Gross calorific value of waste type *i* [MJ/kg]

Table 7-70 Data used for the calculation of CH_4 and N_2O emission factors for direct use of wastes as alternative fuel

Waste type		Application breakdown	Emission factor for furnaces and ovens (Energy sector): CH_4	Emission factor for furnaces and ovens (Energy sector): N_2O	Calorific value
MSW	Plastics	Liquefaction	Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)		Calorific value of plastics
		Blast furnace reducing agent	NA		NA
		Coke oven chemical feedstock	NA		NA
		Gasification	NA		NA
Industrial waste	Waste oil	(Unclassified)	Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)		Specific gravity of reclaimed oil/waste oil [1)]
	Plastics	Blast furnace reducing agent	NA		NA
		Chemical industry	Boilers (wood, charcoal, and other solid fuel)	Fluidized-bed boilers (solid fuel)	Calorific value of plastics
		Paper industry			
		Automobile manufacturer			
		Cement burning	Other industrial furnaces (solid fuel)		
		Liquefaction	Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)		
		Gasification	NA		NA
	Wood	(Unclassified)	Boilers (wood, charcoal)	Boilers (other than fluidized-bed) (solid fuel)	Calorific value of wood [2)]
Waste tire		Iron manufacture	NA		NA
		Cement burning	Other industrial furnaces (solid fuel)		Calorific value of waste tires
		Gasification	Other industrial furnaces (gas fuels) and other industrial furnaces (liquid fuels) [3)]		
		Metal refining (pyrolysis)	Boilers (gas fuels)		
		Boiler	Boilers (wood, charcoal, and other solid fuel)	Boilers (other than fluidized-bed) (solid fuel)	
		Tire manufacture			
		Paper manufacture			
		Power generation			
Refuse-derived fuel (RDF)		(Unclassified)	Boilers (wood, charcoal, and other solid fuel)	Boilers (other than fluidized-bed) (solid fuel)	Calorific value of RDF
Refuse-derived fuel (RPF)		Petroleum product manufacturer	Boilers (wood, charcoal, and other solid fuel)	Boilers (other than fluidized-bed) (solid fuel)	Calorific value of RPF
		Chemical industry			
		Paper industry			
		Cement manufacturer	Other industrial furnaces (solid fuel)		

Note:
1) Calorific value per unit volume is determined by dividing by the specific gravity of waste oil (0.9 kg/l) obtained from JSWME (1997).
2) Data from Environmental Agency (1995)
3) The percentage of substances recovered during the gasification of waste tires. A weighted average is calculated by using the proportions of gas and oil (22% and 43%) reported in the Hyogo Pref. (2003).

Table 7-71 CH_4 and N_2O emission factors for the use of waste as raw material or fuel used in the Energy sector

Furnace type/Fuel type	CH_4 Emission factor [kg-CH_4/TJ]	N_2O Emission factor [kg-N_2O/TJ]
Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)	0.26	0.19
Boilers (gas fuels)	0.23	0.17
Boilers (steam coal, coke, other solid fuels)	0.13	–
Boilers (wood, charcoal)	74.9	–
Boilers (other than fluidized-bed) (solid fuels)	–	0.85
Normal pressure fluidized-bed boilers (solid fuels)	–	54.39
Other industrial furnaces (liquid fuel)	0.83	1.8
Other industrial furnaces (solid fuel)	13.1	1.1
Other industrial furnaces (gaseous fuel)	2.3	1.2

Reference: MOE (2006a)

Table 7-72 Calorific Value of waste incinerated and used as raw material or fuel

Item		Unit	GCV	Reference
Waste oil (including reclaimed oil)		TJ/L	40.2	*General Energy Statistics* (ANRE); estimated with 0.9[kg/L] (JSWME, 1997)
Plastics		MJ/kg	29.3	*General Energy Statistics* (ANRE)
Paper/cardboard		MJ/kg	15.1	JSWME (1997), dry basis; value is obtained by subtracting water content
Wood		MJ/kg	14.4	*General Energy Statistics* (ANRE)
Textiles		MJ/kg	17.9	JSWME (1997), dry basis; value is obtained by subtracting water content
Food waste (Animal and vegetable residues/animal carcasses)		MJ/kg	4.4	JSWME (1997), dry basis; value is obtained by subtracting water content
Sludge (including sewage sludge)		MJ/kg	4.7	*General Energy Statistics* (ANRE), dry basis; value is obtained by subtracting water content
Waste tire	2004 and before	MJ/kg	20.9	*General Energy Statistics* (ANRE)
	2005 and later	MJ/kg	33.2	*General Energy Statistics* (ANRE)
RDF		MJ/kg	18.0	*General Energy Statistics* (ANRE)
RPF		MJ/kg	29.3	*General Energy Statistics* (ANRE)

- ***Activity Data***

➢ ***Amount of Waste Used as Raw Material or Fuel***

Activity data are determined for each category using the wet-basis values (Table 7-69). For more details, see each section.

➢ ***Activity Data Converted into Energy Units (Reference Value)***

Activity data converted into energy units to be reported in CRF are calculated as indicated below.

$$A_{E,i} = N_i \times GCV_i / 10^6$$

$A_{E,i}$: Activity data of waste type i, converted into energy units [TJ]
N_i : Amount of waste type i used as raw material or fuel [kg (wet)]
GCV_i : Gross calorific value of waste type i [MJ/kg]

c) Uncertainties and Time-series Consistency

See the respective section.

d) Category-specific QA/QC and Verification

See the respective section.

e) Category-specific Recalculations

See the respective section.

f) Category-specific Planned Improvements

See the respective section.

7.4.3.2.a. Municipal Waste (Plastic) Used as Alternative Fuel (1.A.1 and 1.A.2)

a) Category Description

This category covers the emissions from municipal waste (plastic) used as alternative fuels. Plastics in MSW collected under the Containers and Packaging Recycling Law are processed into petrochemical, blast furnace reducing agent, chemical raw material in coke oven, and gasification to be used as alternative fuel or raw material. Note that PET bottles are not included in municipal waste in this source.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions are calculated by multiplying the amount of fossil-fuel derived plastic in MSW by each usage (petrochemical, blast furnace reducing agent, chemical raw material in coke oven, and gasification) by Japan's country-specific emission factor.

- ***Emission Factor***

For the emission factors for plastics in MSW in the usage of petrochemical, blast furnace reducing agent, and gasification, the same values applied in "7.4.1.1. Municipal Solid Waste (5.C.1.-) are applied. The emission factor for plastics used as chemical raw material in coke ovens is set as the volume of hydrocarbon that is used as chemical raw material and from which no CO_2 is emitted into the air by subtracting the percentage of carbon in the plastics that migrates to hydrocarbon oil in the coke oven (47.9%) from emission factor for plastics (MSW).

$$EF_{coke} = EF_{plastics} \times (1 - M) \times FCF_{MSW\ plastics}$$

EF_{coke}	: Emission factor for plastics used as raw material in coke ovens (dry basis)
$EF_{plastics}$	: Emission factor for the incineration of plastics in municipal solid waste (dry basis)
M	: Fraction of carbon in plastics used as chemical raw material for coke ovens that migrates to hydrocarbon
$FCF_{MSW\ plastics}$	: Fossil-fuel derived fraction of plastics in MSW [%]

- ***Activity Data***

The amount of plastics in MSW used as raw material or fuel by usage (wet basis) is estimated by the total amount collected by designated legal bodies and municipalities to be processed as raw material or fuel by usage (wet basis). The methodology to estimate activity data for this category is the same as that in the section "7.4.1.1. Municipal Solid Waste (5.C.1.-) b) 1) CO_2".

$$A_i = WP_i \times (1 - u_{plastics})$$

A_i	: Amount of fossil-fuel derived plastics used as raw material or fuel for usage *i* [t (dry)]
WP_i	: Amount of plastics used as raw material or fuel for usage *i* [t (wet)]
$u_{plastics}$	: Percentage of water content in plastics [%]

➢ ***The Amount of Plastics in MSW Used as Raw Material or Fuel by Usage (Wet Basis)***

\- ***Processing of plastics collected by designated legal bodies***

The amount of the plastics in MSW collected by designated legal bodies into raw material or fuel is determined from the amount reported (pyrolytic oil: petrochemical, blast furnace reducing agent, chemical raw material in coke-oven, syngas, and gasification) in the "Plastic Containers and Packaging (Other Plastics, Food Trays)" section of the *Statistics of Commercial Recycling of Plastics (Recycling)* (Japan Containers and Packaging Recycling Association: JCPRA). Usage in products that do not emit CO_2 is deducted.

\- ***Processing of plastics collected by municipalities***

The amount of plastics in MSW collected by municipalities and processed into raw material or fuel is calculated as indicated below.

$$P_{LG} = \sum (PR - P_{JCPRA}) \times F_i \times R_i$$

P_{LG} : Amount of plastics in MSW collected by municipalities and processed into raw material or fuel [t (wet)]
PR : Amount of all plastics that are commercially recycled under the Plastic Containers and Packaging Recycling Law (wet basis)[1)] [t (wet)]
P_{JCPRA} : Amount of plastics (wet basis) that is commercially recycled through designated legal bodies[2)] [t (wet)]
F_i : Percentage of commercially recycled plastics by recycling method i[3)] [%]
R_i : Percentage of commercially recycled plastic products by recycling method i[4)] [%] (The percentage for designated legal bodies is substituted for the value for municipalities.)

Note:
1) The amount is determined from the *Annual Recycling Statistics under the Plastic Containers and Packaging Recycling Law* (MOE).
2) The amount is determined from the "Actual Collection of Plastic Containers and Packages" section of the *Statistics of Commercial Recycling of Plastics (Recycling)* (JCPRA).
3) The rates are obtained from the percentages for various methods of commercial recycling of the plastics collected through municipal channels in the Results of the *2001 Questionnaire to Municipalities on Waste Plastic Processing* compiled by the Plastic Waste Management Institute.
4) The values are calculated by using data from the *Annual Recycling Statistics under the Plastic Containers and Packaging Recycling Law* (MOE) and the *Statistics of Commercial Recycling of Plastic (Recycling)* (JCPRA).

➢ ***Water Content Ratio***

Water content ratio of 4% is determined based on the data provided by the Japan Containers and Packaging Recycling Association (MOE, 2006b).

➢ ***Fossil-fuel Derived Fraction of Plastics in MSW***

See Table 7-35 in the section "7.4.1.1. Municipal Solid Waste (5.C.1.-)."

2) CH_4, N_2O

For estimation method and emission factors, see the section "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)". The amount of plastics used as raw material or fuel by usage (wet basis) is determined by the total amount collected by designated legal bodies and municipalities to be processed as raw material or fuel by usage (wet basis); this value includes the amount of biomass-based plastics consumed.

c) Uncertainties and Time-series Consistency

● ***Uncertainties***

The uncertainty assessment is conducted as well as assessment in the category of the municipal waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-73.

Table 7-73 Uncertainty assessment for municipal waste plastics used as alternative fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	The equivalent assessment of the uncertainty in municipal waste plastics in "5.C Incineration" is used.	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	CH_4	-39%	+39%	-10%	+10%	-40%	+40%	The equivalent assessment of the uncertainty in municipal waste in "5.C Incineration" is used.		
	N_2O	-34%	+34%	-10%	+10%	-35%	+35%			

● ***Time-series Consistency***

Time series consistency in emission estimates has been ensured. However, the statistical data for activity data have been available since FY2000 because the use of waste as alternative fuel or raw material was not a common practice prior to FY2000 in Japan.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By revising biomass-based plastic products data, CO_2 emissions from FY2005 onward were recalculated. By updating the statistical data, emissions in FY2017, FY2018 and FY2020 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.3.2.b. Industrial Waste (Plastics, Waste Oil, and Wood) Used as Alternative Fuels (1.A.2.))

a) Category Description

This category covers GHG emissions from industrial waste (plastics, waste oil, and wood) used as raw material or fuels.

b) Methodological Issues

1) CO_2

- ***Estimation Method and Emission Factor***

Emissions are estimated by multiplying the amount of plastics and fossil-fuel derived waste oil used as raw material or fuels by emission factor used for incineration of industrial waste (See "7.4.1.2. Industrial Waste (5.C.1.-) ").

- ***Activity Data***

➢ ***Plastics***

Estimated activity data are the amounts of plastics (wet basis) in industrial waste used as raw material or fuel in steel industry, chemical industry, paper industry, cement Manufacturer, automobile manufacturer, and "other industry". The amount of plastics in industrial waste used as raw material or fuel in each industry is provided by the following data sources: for steel industry, the *Current State of Plastics Waste Recycling and Future Tasks* published by the Japan Iron and Steel Federation; for cement manufacturing industry, from the *Cement Handbook* published by the Japan Cement Association; for chemical industry, paper industry, and automobile manufacturer, the amount of plastics used for fluid bed boiler provided by the Japan Chemical Industry Association, the Japan Paper Association, the Japan Automobile Manufacturers Association. For "other industry", the activity data is obtained from the *Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics* (Environmental Regeneration and Material Cycles Bureau of MOE) distinguished between plastics liquefaction and gasification.

➢ ***Waste Oil (Fossil-fuel derived)***

The activity data for waste oil is mainly obtained from the *Cyclical Use of Waste Report* (MOE). The valuables, which are not included in the *Cyclical Use of Waste Report* (MOE), is additionally obtained from the other sources as "Used lubricant" and "Used solvent".

- ***Waste Oil***

The amount of waste oil indicated as "Fuel Usage" of "Direct Recycle Usage" and "Recycle Usage after Treatment" of industrial waste is used as the activity data of the waste oil that includes biogenic fraction. Hence in the estimation method for CO_2 emissions, the amount of biogenic "waste animal and vegetable oil" is subtracted from this item in the same way as indicated in "7.4.1.2. Industrial Waste (5.C.1.-) 7.4.1.2. b)1) CO_2". The data for FY1997 and before are estimated by using the trend of the amount of incinerated industrial waste oil.

- ***Used lubricants***

The amount of recycled heavy oil products derived from used lubricant, indicated in the *Lubricant Recycle Handbook,* Japan Lubricating Oil Society is also used as activity data of fossil fuel-derived waste oil. All used lubricants are assumed to be fossil-fuel derived. The data for FY2001 and before are estimated by using the trend of the amount of incinerated industrial waste oil.

- ***Used solvents***

The data of the amount of used solvents to be used as alternative fuel (valuables-origin), surveyed by the Japan Solvent Recycling Industry Association is also used as activity data for fossil fuel-derived waste oil. All used solvents are assumed to be fossil fuel- derived.

2) CH_4, N_2O

● ***Estimation Method and Emission Factor***

See the section "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)"

● ***Activity Data***

➢ ***Plastics***

The activity data used for CO_2 emission estimates from this source is also used for CH_4 and N_2O emission estimates. Note plastics as blast furnace reducing agent and plastics gasified are not included in the activity data (see also Table 7-29).

➢ ***Waste Oil (Fossil-fuel derived / Animal and Vegetable)***

The activity data used for CO_2 emission estimates from this source is also used for CH_4 and N_2O emission estimates. Unlike the activity data for CO_2 emissions, waste animal and vegetable oil are also included for the estimation of activity data from this source.

➢ ***Wood***

The amount of usage of wood as raw material or fuel is obtained from the "fuel usage" in the "direct recycle usage" and the "fuel usage" in the "recycle usage after treatment" in the *Cyclical Use of Waste Report* (MOE). The values before FY1997 are estimated by using the average value in the period of FY1998-2002.

c) Uncertainties and Time-series Consistency

● ***Uncertainties***

The uncertainty assessment is conducted as well as assessment in the category of the industrial waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-74.

Table 7-74 Uncertainty assessment for industrial waste plastics used as alternative fuels (1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	The equivalent assessment of the uncertainty in industrial waste plastics in “5.C Incineration” is used.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	CH_4	-100%	+216%	-30%	+30%	-104%	+218%			
	N_2O	-44%	+44%	-30%	+30%	-53%	+53%			
Waste oil	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	The equivalent assessment of the uncertainty in industrial waste oil in “5.C Incineration” is used.		Combined by using the formula for propagation of errors.
	CH_4	-100%	+181%	-30%	+30%	-104%	+184%			
	N_2O	-76%	+76%	-30%	+30%	-81%	+81%			
Wood	CH_4	-100%	+412%	-30%	+30%	-104%	+413%	The equivalent assessment of the uncertainty in industrial waste paper/cardboard or wood in “5.C Incineration” is used.		Combined by using the formula for propagation of errors.
	N_2O	-64%	+64%	-30%	+30%	-71%	+71%			

- ***Time-series Consistency***

Data on the amount of waste oil and wood used as alternative fuels have been available since FY1998. For waste oil, consistent data over the time series are developed by using the total amount of waste oil incinerated without the use of waste oil as alternative fuel. For wood, the average of FY1998-2002 data is used to estimate the amount of wood for the past years. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By revising biomass-based plastic products data, CO_2 emissions from FY2005 onward were recalculated. By updating the statistical data, emissions in FY2020 were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.3.2.c. Waste Tires Used as Alternative Fuels (1.A.1 and 1.A.2)

a) Category Description

This category covers the emissions from the use of waste tires as raw materials or fuels.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

The emissions are calculated by multiplying the incinerated amount of waste tires used as raw materials or fuels by Japan’s country-specific emission factor.

- ***Emission Factor***

The emission factor for waste tires is calculated by multiplying the fossil fuel-derived carbon content of the waste tires by the oxidation factor of the waste tires at the facilities that use waste tires as fuel. The volume of the fossil fuel-derived carbon in the waste tires is calculated by the material contents of new tires. The oxidation factor for waste tires is set to the default value of 100% indicated in the *2006 IPCC Guidelines*.

$$EF = CF \times OF \times 1000 \times 44/12$$

EF : Emission factor for the incineration of waste tires (dry basis) [kg-CO_2/t]
CF : Fossil fuel-derived carbon content in waste tires
OF : Oxidation factor of waste tires

- ***Activity Data***

Activity data (dry basis) is calculated by subtracting the water content in the waste tires determined from analyses of three constituents of divided tires (Environmental Sanitation Center, 2001) from the amount of waste tires used as raw material or fuel (wet basis) in the *Tire Industry of Japan* (Japan Automobile Tire Manufacturers Association).

2) CH_4, N_2O

- ***Estimation Method and Emission Factor***

See the section "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)"

- ***Activity Data***

The volume of waste tires used as raw material or fuel by usage that is determined during the calculation of the CO_2 emissions from this source is used. For the activity data, the volume of waste tires recorded in the following categories are used: "Cement burning" for use in cement kilns; "Small and medium size boilers", "Tire manufacture", "Paper manufacturer", and "Power generation" for use in boilers; "Metal refining" for use in carbonization; and "Gasification" for use in gasification processes.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainty assessment is conducted as well as assessment in the category of the industrial waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-75.

Table 7-75 Uncertainty assessment for waste tire used as alternative fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Waste tire	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in industrial waste plastic is substituted based on expert judgment.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	CH_4	-100%	+216%	-30%	+30%	-104%	+218%			
	N_2O	-44%	+44%	-30%	+30%	-53%	+53%			

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

No recalculations are conducted.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.3.3. Incineration of Waste Processed as Fuel (1.A.)

7.4.3.3.a. Incineration of Refuse-based Solid Fuels (RDF and RPF) (1.A.1 and 1.A.2)

a) Category Description

In this category, CO_2, CH_4, and N_2O emissions from waste that is processed and used as fuel are estimated and reported. Refuse-derived solid fuels (RDF as Refuse Derived Fuel and RPF as Refuse Paper and Plastic Fuel) are used for the estimation of emissions from fuels produced from waste. The reporting categories for the above emissions are included in “Energy industries (1.A.1.)” and “Manufacturing industries and construction (1.A.2)” as indicated in Table 7-29 The fuel types are classified as “Other fossil fuels” and/or “Biomass” as indicated in Table 7-28.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions are estimated by multiplying the amount of RDF and RPF incinerated by Japan’s country-specific emission factor.

$$E_{RDF} = EF_{RDF} \times AD_{RDF}$$

E_{RDF} : CO_2 Emissions from RDF use [kg-CO_2]
EF_{RDF} : Emission factor for RDF use (dry basis) [kg-CO_2/t]
AD_{RDF} : Activity data for RDF use (dry basis) [t]

$$E_{RPF} = EF_{RPF} \times AD_{RPF}$$

E_{RPF} : CO_2 Emissions from RPF use [kg-CO_2]
EF_{RPF} : Emission factor for RPF use (dry basis) [kg-CO_2/t]
AD_{RPF} : Activity data for RPF use (dry basis) [t]

● ***Emission Factor***

Emission factor associated with the use of the refuse-derived solid fuels (RDF and RPF) is calculated for RDF and RPF respectively by the equation shown below.

➢ ***RDF***

By considering fossil-fuel derived fraction in MSW (paper/cardboard, synthetic fibers and plastics) included in RDF, emission factor for RDF use is estimated by the equation shown below.

$$EF_{RDF} = 1000 \times \sum_i \left(F_{RDF,i} \times CF_i \times FCF_i\right) \times OF_{RDF} \times 44/12$$

$F_{RDF,i}$: Fraction of waste type i derived content contained in RDF (dry basis)
CF_i : Fraction of carbon content in waste type i in RDF (dry basis)
FCF_i : Fossil-fuel derived fraction of waste type i in RDF
OF_{RDF} : Oxidation factor of RDF at RDF combustion facilities

- ***Fraction of Each Waste Type Derived Content Contained in RDF (F_{RDF}: Dry basis)***

Fractions of each waste type derived content contained in RDF in wet basis are estimated based on the the averages of those from result on the waste composition analysis in MOE (2003), supplemented by information from MOE (2020b) and *the Textile Handbook* (Japan Chemical Fibers Association). Water content in each waste type shown in "7.2.1. Managed Disposal Sites (5.A.1.)" and "7.4.1.2. Industrial Waste (5.C.1.-), CO_2" are applied to convert wet basis waste composition into that of dry basis (paper/cardboard: 20%, synthetic textiles: 20% and plastics: 26.1%). Estimated fractions of these wastes in RDF in dry basis are 38.2% of paper/cardboard, 10.3% of synthetic textiles and 28% of plastics respectively. Note that it is assumed that RDF almost does not include PET bottles.

- ***Fraction of Carbon Content Contained in Each Waste Type in RDF (CF: Dry basis)***

Since RDF is usually made from municipal solid waste, the fractions of carbon content in each waste type used in "7.4.1.1. Municipal Solid Waste (5.C.1.-)" are also applied for this category (paper/cardboard: 40.8%, synthetic textiles: 63.0% and plastics: 76.8%).

- ***Fossil-fuel derived fraction of each waste type in RDF (FCF)***

Since RDF is usually made from municipal solid waste, fossil-fuel derived fractions of each waste type used in "7.4.1.1. Municipal Solid Waste (5.C.1.-)" are also applied for this category (paper/cardboard: 9.6%, synthetic textiles: 100% and plastics: see Table 7-35).

- ***Oxidation factor for RDF at RDF Combustion Facilities (OF_{RDF})***

The default value provided in the *2006 IPCC Guidelines* (100%) is applied for the oxidation factor for this category.

➢ ***RPF***

Because the quality of RPF is categorized into "coal-equivalent product" and "coke-equivalent product" (Japan RPF Association, 2004), emission factor for RPF is established for each quality of product. However, in the case that the amount of use of each quality of product for estimating activity data is unavailable, emission factor is established by the weighted average of each emission factor for coal-equivalent product and coke-equivalent product with the average fraction of amount of use of each product (see "*Emission Factor for the Use of RPF (Weighted Average) (Dry basis)*" as described herein below.)

Coal-equivalent product

$$EF_{RPF,coal} = 1000 \times P_{RPF,coal} \times C \times OF_{RPF} \times 44/12 \times FCF_{plastics}$$
$$= 1000 \times 0.528 \times 0.737 \times 1.0 \times 44/12 \times FCF_{plastics}$$
$$= 1426 \text{ [kg-CO}_2\text{/t]} \times FCF_{plastics}$$

Coke-equivalent product

$$EF_{RPF,coke} = 1000 \times P_{RPF,coke} \times C \times OF_{RPF} \times 44 / 12 \times FCF_{plastics}$$
$$= 1000 \times 0.910 \times 0.737 \times 1.0 \times 44 / 12 \times FCF_{plastics}$$
$$= 2457 \text{ [kg-CO}_2\text{/t]} \times FCF_{plastics}$$

$EF_{RPF,coal}$	: Emission factor for the use of coal-equivalent product RPF (dry basis) [kg-CO_2/t]
$EF_{RPF,coke}$	: Emission factor for the use of coke-equivalent product RPF (dry basis) [kg-CO_2/t]
$P_{RPF,coal}$	: Fraction of plastic-derived content contained in coal-equivalent product RPF (dry basis)
$P_{RPF,coke}$	: Fraction of plastic-derived content contained in coke-equivalent product RPF (dry basis)
C	: Fraction of carbon content contained in plastic (dry basis)
OF_{RPF}	: Oxidation factor of RPF at RPF combustion facilities
$FCF_{plastics}$	: Fossil-fuel derived fraction of plastics in RPF

- ***Fraction of Waste Plastic-derived Content Contained in RPF ($P_{RPF,coal/coke}$: Dry basis)***

The fraction of waste plastic-derived content contained in RPF in wet basis is established at 50% for coal-equivalent product and at 90% for coke-equivalent product based on the results of fact-finding survey conducted by the Japan RPF Industry Association (MOE, 2006b).
The fraction of waste plastic-derived content contained in RPF in dry basis is calculated with the fraction of water content of RDF, to which the average water content of industrial waste plastics used for RPF production is applied; it is established at 5% based on expert judgment.

- ***Fraction of Carbon Content Contained in Plastic (Dry basis) (C)***

Due to the fact that most of plastic contained in RDF is industrial waste-derive (Seki, 2004), the fraction of carbon content contained in plastic in dry basis (73.7%) is calculated by using the fraction of carbon content contained in industrial waste plastic applied in "7.4.1.2. Industrial Waste (5.C.1.-), CO_2" (70%) and the fraction of water content of industrial waste plastic (5%).

- ***Oxidation factor for RPF at RPF Fuel Facilities (OF_{RPF})***

As applied in "7.4.1.2. Industrial Waste (5.C.1.-)", the value provided in the *2006 IPCC Guidelines* (100%) is also applied for the oxidation factor for RPF at RPF combustion facilities.

- ***Fossil-fuel derived fraction of plastic in RPF ($FCF_{plastics}$)***

The same values for industrial waste plastics are applied (See Table 7-35).

- ***Emission Factor for RPF Use (Weighted Average) ($EF_{RPF,av}$: Dry basis)***

In the case that the amount of use of coal-equivalent product RPF and coke-equivalent product RPF for estimating activity data is unavailable, emission factor is determined by the weighted average of each emission factor for coal-equivalent product and coke-equivalent product with the average fraction of the amount of use of each product.

Production percentage of RPF of coal-equivalent product and coke-equivalent product (wet basis) is obtained from the survey results conducted by Japan RPF Industry Association and is converted into the value in dry basis. The fraction of water content of RPF is established at 3% for coal-equivalent product and at 1% for coke-equivalent product based on the RPF quality standards provided by the Japan RPF Industry Association. The estimated fractions of production percentage in dry basis are applied to all the reporting years because relevant statistics is unavailable.

$$
\begin{aligned}
EF_{RPF,av} &= EF_{RPF,coal} \times P_{coal} + EF_{RPF,coke} \times P_{coke} \\
&= (1426 \times FCF_{plastics}) \times 0.797 + (2457 \times FCF_{plastics}) \times 0.203 \\
&= 1636\ [\text{kg-CO}_2/\text{t}] \times FPF_{plastics}
\end{aligned}
$$

$EF_{RPF,av}$: Emission factor for RPF use (Weighted Average) (dry basis) [kg-CO_2/t]
P_{coal} : Fraction of the use of coal-equivalent product RPF (dry basis)
P_{coke} : Fraction of the use of coke-equivalent product RPF (dry basis)
$FCF_{plastics}$: Fossil-fuel derived fraction of plastic in RPF

Table 7-76 CO_2 emission factors for the emissions from the use of refused-derived fuel (RDF) or refuse paper and plastic fuel (RPF)

Item	Emission Factor [kg-CO_2/t (dry)]
RDF	1,081
RPF (coal-equivalent products)	1,426
RPF (coke-equivalent products)	2,457
RPF (weighted average values)	1,636

Note: Each emission factor indicated in the table are applied 100% of fossil-fuel derived fraction of plastics ($FCF_{plastics}$)

- ***Activity Data***

➢ ***RDF***

The amount of RDF production is used as the substitute for the amount of use of RDF. Activity data (dry basis) is calculated by subtracting the water content of RDF from the amount of RDF production at RDF production facilities (wet basis) provided by the *Report on Survey of State of Treatment of Municipal Solid Waste*. For the fiscal years that the data are unavailable, emission estimates are conducted substituting the values of the refuse processing capacity.

$$A_{RDF} = a_{RDF} \times (1 - u_{RDF})$$

A_{RDF} : Activity data for RDF use (dry basis)
a_{RDF} : Amount for RDF production at RDF production facilities (wet basis) [t]
u_{RDF} : Fraction of water content in RDF

➢ ***RPF***

The amounts of RPF used in chemical industry, paper industry, cement manufacturer, and petroleum product manufacturer are estimated (See also Table 7-69). The amount of RPF (dry basis) for paper industry is obtained from the survey results conducted by the Japan Paper Association. The amounts of RPF (dry basis) for the chemical industry, cement manufacturers, and petroleum product manufacturers are obtained by using the averaged water content of RPF and the survey results (wet basis) conducted by the *Japan Chemical Industry Association*, the *Japan Cement Association* and the *Petroleum Association of Japan*.

2) CH_4, N_2O

- ***Estimation Method and Emission Factor***

For the estimation method and the emission factors used, see “7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)”.

- ***Activity Data***

➢ ***RDF***

The entire amount of RDF production (wet basis) used for CO_2 emission estimates is also used for the amount of use of RDF for boiler.

➢ ***RPF***

Out of the amount of RPF used for CO_2 emission estimates, the amounts of RPF used in chemical industry, paper industry, and petroleum products manufacturer are adopted as the amount of fuel used for boiler (wet basis). The amount of RPF used in cement industry is adopted as the amount of fuel used for cement kiln (wet basis). Because the amount of RPF used in paper industry is on a dry basis, the average water content of RPF is added to obtain the value on a wet basis.

➢ ***Activity Data Converted into Energy Units (Reference Value)***

Activity data converted into energy units to be reported in CRF is calculated as indicated below.

$$A_{E,i} = A_i \times GCV_i / 10^6$$

$A_{E,i}$: Activity data of fuel type *i* converted into energy units [TJ]
A_i : Amount of consumed fuel type *i* [kg (wet)]
GCV_i : Gross calorific value of fuel type *i* [MJ/kg]

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainty assessment is conducted as well as the assessment for the municipal waste or industrial waste incineration. Details of the uncertainty assessment on this category are indicated in the Table 7-77.

Table 7-77 Uncertainty assessment for incineration of waste refuse-based solid fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
RDF	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	CH_4	-39%	+39%	-10%	+10%	-40%	+40%			
	N_2O	-34%	+34%	-10%	+10%	-35%	+35%			
RPF	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	CH_4	-100%	+216%	-30%	+30%	-104%	+218%			
	N_2O	-44%	+44%	-30%	+30%	-53%	+53%			

- ***Time-series Consistency***

Since data on the amount of RDF produced are not available for the years prior to FY1997, these data are estimated by using the trend on capacity of refuse-based fuel-producing facilities. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By revising biomass-based plastic products data, CO_2 emissions from FY2005 onward were recalculated. By updating the statistical data, emissions in FY2020 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5. Wastewater Treatment and Discharge (5.D.)

The CH_4 and N_2O emissions from domestic and industrial wastewater treatment and discharge are reported under the category “Wastewater Treatment and Discharge (5.D.)”. The target categories are shown in Table 7-78. Since an emission factor that takes into account emissions from wastewater and sludge treatment processes is used in Japan, emissions from these processes are reported altogether. Note since this category includes various type of sources, it is difficult to analyze the trend in the IEFs.

Table 7-78 Categories overview for wastewater treatment and discharge (5.D.)

Category	Wastewater type					Treatment type			CH_4	N_2O
5.D.1. (7.5.1)	Domestic wastewater	In treatment systems	Public sewer system	Sewage		Sewage treatment plants (7.5.1.1)	Standard activated sludge process		○	○
							Anaerobic-aerobic activated sludge process			○
							Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process			○
							Recycled nitrification-denitrification membrane bioreactor			○
			Other sewer system	Human waste	Miscellaneous wastewater	Domestic sewage treatment plants (mainly *Johkasou*) (7.5.1.2)	Community plant		○	○
							Current type *Johkasou* – Advanced type	TN removal type	○	○
								TN and TP removal type		
								BOD removal type		
								Other advanced type	○	○
							Current type *Johkasou* – Standard type		○	○
							Old type *Johkasou*		○	○
							Vault toilet		○	○
				Collected human waste	Human waste and *Johkasou* sludge (from domestic sewage treatment plants)	Human-waste treatment plants (7.5.1.3)	High-load denitrification treatment		○	○
							Membrane separation		○	○
							Anaerobic treatment		○	○
							Aerobic treatment		○	
							Standard denitrification treatment		○	
							Other		○	
		Into public waters	Wastewater		Untreated wastewater	Natural decomposition of domestic wastewater (7.5.1.4)	Discharge of untreated wastewater	From old type *Johkasou*	○	○
								From vault toilet	○	○
								From on-site treatment	○	○
					Treated wastewater		Discharge of treated wastewater	(From each treatment plant)	NA	○
			Sludge		Human waste and *Johkasou* sludge		Ocean dumping of sludge[1]	(From domestic sewage treatment plants)	○	○
					Sewage sludge			(From sewage treatment plants)	○	○
5.D.2. (7.5.2)	Industrial wastewater	In treatment systems	Manufacture of food			Industrial wastewater treatment (7.5.2.1)	(Industrial wastewater treatment plants)		○	○
			Manufacture of pulp, paper and paper products						○	○
			Manufacture of chemical and allied product						○	○
			Manufacture of iron and steel						○	○
			Manufacture of beverages, tobacco and feed						○	○
			Manufacture of textile products							
			Manufacture of petroleum and coal products							
			Manufacture of plastic products							
			Manufacture of rubber products							
			Manufacture of leather tanning, leather products and fur skins							
		Into public waters	Wastewater		Untreated wastewater	Natural decomposition of Industrial wastewater (7.5.2.2)	Discharge of untreated wastewater	(from industrial plants/facilities)	○	○
					Treated wastewater		Discharge of treated wastewater	(from industrial wastewater treatment plants)	NA	○
	Landfill leachate					Landfill leachate treatment (7.5.2.3)			○	○

Note:
1) Due to legal regulations on sludge disposal at sea, there has been no activity since FY2009.

Estimated GHG emissions from wastewater handling are shown in Table 7-79. In FY2021, emissions from this source category are 3,537 kt-CO_2 eq. and accounted for 0.3% of the national total emissions (excluding LULUCF). The emissions from this source category decreased by 33.6% compared to those in FY1990. This emission decrease is the result of decrease in the amount of CH_4 emissions from "Natural decomposition of domestic wastewater" because the practice of wastewater treatment at wastewater treatment plants increased in Japan. Due to the same reason, the N_2O emissions from the subcategory of "Sewage Treatment Plants (5.D.1.-)" for FY1995 through FY1998 increased.

Table 7-79 GHG emissions from wastewater treatment and discharge (5.D.)

Gas	Category		Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CH_4	5.D.1. Domestic wastewater	Sewage treatment plant	kt-CH_4	8.6	9.9	11.1	12.1	12.7	12.1	12.5	12.6	12.4	12.6	12.1	12.5	13.1	12.9	12.9
		Domestic sewage treatment plant	kt-CH_4	30.4	35.0	38.8	38.3	36.8	35.8	35.3	34.7	34.3	33.8	32.9	32.4	31.3	30.8	31.8
		Human-waste treatment plant	kt-CH_4	5.2	3.2	1.8	1.0	0.6	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2
		Natural decomposition of domestic wastewater	kt-CH_4	61.7	50.8	39.5	28.7	21.1	19.3	18.1	17.2	16.4	15.8	15.0	14.3	13.7	13.1	11.8
	5.D.2. Industrial wastewater	Industrial wastewater treatment	kt-CH_4	2.2	2.2	2.1	1.9	1.8	1.7	1.6	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
		Natural decomposition of industrial wastewater	kt-CH_4	8.2	7.8	7.9	8.3	4.9	4.5	4.1	4.3	4.6	4.1	3.7	3.7	3.7	3.7	3.7
		Landfill leachate treatment	kt-CH_4	1.2	1.2	1.1	0.8	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Total		kt-CH_4	117.7	110.0	102.2	91.2	78.1	74.2	72.5	71.2	70.0	68.6	65.9	65.1	64.0	62.6	62.2
			kt-CO_2 eq.	2,942	2,750	2,556	2,280	1,954	1,855	1,811	1,779	1,749	1,714	1,648	1,629	1,601	1,565	1,555
N_2O	5.D.1. Domestic wastewater	Sewage treatment plant	kt-N_2O	1.39	1.55	1.58	1.67	1.67	1.55	1.59	1.59	1.55	1.55	1.45	1.49	1.53	1.47	1.47
		Domestic sewage treatment plant	kt-N_2O	1.52	1.65	1.70	1.57	1.53	1.56	1.56	1.56	1.55	1.56	1.56	1.55	1.57	1.56	1.59
		Human-waste treatment plant	kt-N_2O	0.22	0.26	0.12	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		Natural decomposition of domestic wastewater	kt-N_2O	2.79	2.72	2.49	2.29	2.11	2.04	2.08	2.01	2.02	2.00	1.98	1.94	2.03	1.91	1.89
	5.D.2. Industrial wastewater	Industrial wastewater treatment	kt-N_2O	1.00	0.96	0.81	1.10	1.09	1.16	1.15	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13
		Natural decomposition of industrial wastewater	kt-N_2O	1.06	1.02	1.02	0.97	0.66	0.62	0.59	0.56	0.54	0.55	0.55	0.55	0.55	0.55	0.55
		Landfill leachate treatment	kt-N_2O	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.005	0.005	0.005	0.004	0.004	0.004
	Total		kt-N_2O	8.01	8.18	7.72	7.65	7.10	6.94	6.99	6.86	6.80	6.80	6.69	6.68	6.82	6.64	6.65
			kt-CO_2 eq.	2,387	2,439	2,301	2,280	2,115	2,069	2,082	2,045	2,027	2,028	1,992	1,990	2,033	1,979	1,982
Total			kt-CO_2 eq.	5,329	5,189	4,857	4,560	4,069	3,925	3,893	3,825	3,777	3,742	3,640	3,618	3,633	3,544	3,537

7.5.1. Domestic Wastewater (5.D.1.)

Domestic and commercial wastewater generated in Japan is treated at various wastewater treatment facilities (e.g., sewage treatment plants, Domestic sewage treatment plants, human-waste treatment plants) and GHG emissions from these sources are reported under "Domestic and Commercial Wastewater (5.D.1.)". Because the CH_4 and N_2O emission characteristics differ from one wastewater treatment facility to another, a different emission estimation method is established for each facility.

The characteristics, effectiveness, and economic efficiency of wastewater treatment systems are thoroughly reviewed, and the most suitable systems are selected for each area in Japan with care also being taken to avoid excessive expenditure. According to the data from the *Waste Treatment in Japan* (MOE), public sewerage system is spreading from large cities to smaller municipalities and used by 77.1% of the population at the end of FY2021.

Domestic sewage treatment plants (e.g. current type *Johkasou*) are being promoted as an effective means of supplementing sewerage systems in smaller municipalities with low population densities and little flat land. In FY2021, *Johkasou* (including rural sewerage and other facilities) is used by 18.8% of the population, with the remainder being treated after collection or on-site.

Note that activity data are reported as "NA" in the CRF table 5.B instead of the amount of organic carbon based on BOD values and nitrogen in effluents since country-specific methodology for this category requires various types of activity data by gas and facility type as shown below.

Table 7-80 Various type of activity data for the category "Domestic Wastewater (5.D.1.)"

Emission sources	Activity data for CH_4 estimation	Activity data for N_2O estimation
Sewage treatment plants	Yearly amount of sewage treated at sewage treatment plants [Unit: m^3]	
Domestic sewage treatment plants	Population requiring waste processing at domestic sewage treatment plants [Unit: persons]	
Human-waste treatment plants	Input volume of human waste and *Johkasou* sludge at human waste treatment plants [Unit: m^3]	Amount of nitrogen in human waste and *Johkasou* sludge input at human waste treatment plants [Unit: kg-N]
Natural decomposition of domestic wastewater	Amount of organic matter in domestic wastewater discharged [Unit: kg-BOD]	Amount of nitrogen in domestic wastewater discharged [Unit: kg-N]

7.5.1.1. Sewage Treatment Plant (5.D.1.-)

a) Category Description

This category covers CH_4 and N_2O emissions from treatment of wastewater at sewage treatment plants.

b) Methodological Issues

● ***Estimation Method***

Emissions of CH_4 and N_2O from this source are calculated using Japan's country-specific method in accordance with the decision tree of the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of sewage treated at sewage treatment plants by the emission factor.

$$E = EF \times A$$

E : Amount of CH_4 or N_2O emitted from sewage treatment plants in conjunction with domestic/commercial wastewater treatment [kg-CH_4], [kg-N_2O]
EF : Emission factor [kg-CH_4/m^3], [kg-N_2O/m^3]
A : Yearly amount of sewage treated at sewage treatment plants [m^3]

● ***Emission Factors***

1) CH_4

Emission factors are established by adding the simple averages for each treatment process, having taken the actual volume of CH_4 released from sludge treatment and water treatment processes measured at sewage treatment plants from research studies (sampling surveys) conducted in several different seasons for 8 plants in Japan (MOE, 2006b).

$$EF_{CH4} = EF_{WWTT} + EF_{SSTT} = 8.8 \times 10^{-4} \text{ [kg-CH}_4\text{/m}^3\text{]}$$

EF_{CH4} : CH_4 Emission factor
EF_{WWTT} : Average of emission factor for wastewater treatment processes (528.7 [mg-CH_4/m^3])
EF_{SSTT} : Average of emission factor for sludge treatment processes (348.0 [mg-CH_4/m^3])

2) N_2O

Emission factors are established on the basis of measured values of N_2O volume emitted from wastewater and sludge treatment processes at sewage treatment plants which is obtained from research studies (sampling surveys) conducted in several different seasons for 42 plants in Japan; these studies consist of measurements in several plants for each type of wastewater treatment process.

Since the research studies revealed that the amount of N_2O emission varies according to the type of wastewater treatment process at sewage treatment plants, the N_2O emission factor for each wastewater treatment type is developed based on the latest findings in the country (MOE, 2013b).

$$EF_{N2O} = EF_{WWTTi} + EF_{SSTT}$$

EF_{N2O}	: N_2O Emission factor
EF_{WWTTi}	: Emission factor for wastewater treatment process *i* (See Table 7-81.)
EF_{SSTT}	: Average of emission factor for sludge treatment process (0.6 [mg-N_2O/m^3])

Table 7-81 N_2O Emission factor by wastewater treatment process at sewage treatment plant

Wastewater treatment process	N_2O EF for wastewater treatment process[3)] [mg-N_2O/m^3]	N_2O EF for sludge treatment process [mg-N_2O/m^3]
Standard activated sludge process[1)]	142	0.6
Anaerobic-aerobic activated sludge process	29.2	0.6
Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process[2)]	11.7	0.6
Recycled nitrification-denitrification membrane bioreactor	0.5	0.6

Note:

1) Includes all the wastewater treatment processes other than indicated above.
2) Includes all the wastewater treatment processes which remove nitrogen the same level or greater than Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process, but excludes recycled nitrification-denitrification membrane bioreactor.
3) Since the main purpose of the “Standard activated sludge process” is to remove BOD from wastewater, the nitrification reaction cannot be completed during the process, resulting in more N_2O generated. In the meanwhile, advanced treatment procedures such as “Anaerobic-aerobic activated sludge process”, “Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process”, and “Recycled nitrification-denitrification membrane bioreactor” allow sufficient nitrification reaction to occur for nitrogen removal etc, and accordingly generate less N_2O.

- ***Activity Data***

Activity data for N_2O emissions by wastewater treatment process at sewage treatment plants are provided by MLIT. Total amount of wastewater treated used for N_2O emission estimates are also used for the activity data for CH_4 emission estimates.

Table 7-82 Activity data for wastewater treated at sewage treatment plant

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Standard activated sludge process	10^6 m^3	9,761	10,780	10,686	11,405	11,358	10,485	10,736	10,699	10,401	10,394	9,648	9,908	10,124	9,733	9,733
Anaerobic-aerobic activated sludge process	10^6 m^3	73	446	1,523	1,039	909	953	931	938	933	962	1,107	1,248	1,497	1,456	1,456
Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process	10^6 m^3	23	89	487	1,374	2,181	2,355	2,629	2,684	2,819	3,033	2,998	3,132	3,361	3,480	3,480
Recycled nitrification-denitrification membrane bioreactor	10^6 m^3	NO	NO	NO	0.1	2.0	20.2	14.9	0.1	0.2	4.8	0.4	6.3	5.8	6.2	6.2
Total	10^6 m^3	9,857	11,316	12,696	13,818	14,450	13,813	14,311	14,320	14,153	14,393	13,754	14,293	14,989	14,674	14,674

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties in emission factors for CH_4 and N_2O in sewage treatment plant are evaluated by using the 95% confidence intervals of actual measurement data which are used for calculation of emission factors. As for the uncertainties in activity data, the uncertainties in sewage data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in Table 7-83.

Table 7-83 Uncertainty assessment for sewage treatment plant on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Sewage treatment plant	CH_4	-31%	+31%	-5%	+5%	-31%	+31%	The uncertainty is assessed by using the 95% interval confidence of actual measurement data in MOE (2006b).	The uncertainty in sewage statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N_2O	-100%	+146%	-5%	+5%	-100%	+146%			

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By updating the statistical data, emissions in FY2019 and FY2020 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.1.2. Domestic Sewage Treatment Plant (Mainly *Johkasou*) (5.D.1.-)

a) Category Description

A part of domestic and commercial wastewater not processed in the public sewerage in Japan is processed in community plants, current type *Johkasou*, the old type *Johkasou*, and vaults. The *Johkasou* means decentralized wastewater treatment facilities installed at an individual home.

Table 7-84 Type of sewage and sewage treatment

<table>
<tr><th colspan="4">Plant type</th><th>Sewage type</th><th colspan="2">Description</th></tr>
<tr><td colspan="4">Community plants</td><td rowspan="6">Human waste and miscellaneous wastewater</td><td colspan="2">Small-scale wastewater treatment facility regionally installed</td></tr>
<tr><td rowspan="6">Johkasou</td><td rowspan="5">Current type</td><td rowspan="4">Advanced type</td><td>TN removal type</td><td rowspan="6">Wastewater treatment unit installed at an individual household</td><td rowspan="4">Advanced type certified in performance under the amended Building Standards Act in effect FY2001</td></tr>
<tr><td>TN and TP removal type</td></tr>
<tr><td>BOD removal type</td></tr>
<tr><td>Other advanced type</td></tr>
<tr><td colspan="2">Standard type</td><td>Standard type under former the Building Standards Act</td></tr>
<tr><td colspan="3">Old type</td><td rowspan="2">Human waste only</td><td>Old type which is not allowed to be newly installed under the amended Purification Tank Act since FY2001</td></tr>
<tr><td colspan="4">Vaults toilet</td><td colspan="2">Installed at an individual household</td></tr>
</table>

This category covers CH_4 and N_2O emissions from domestic sewage treatment plants. Emissions from human waste within its residence time in vault toilets are reported under this category, whereas the emissions that occur after the waste is collected from vault toilets are accounted for under "Human waste treatment plant (5.D.1.-)".

b) Methodological Issues

● *Estimation Method*

Emissions of CH_4 and N_2O from this source are calculated using Japan's country-specific method, in accordance with decision tree the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the annual population of treatment for each type of domestic sewage treatment plant by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

E : Emissions of methane and nitrous oxide from the processing of domestic and commercial wastewater at domestic sewage treatment plants (i.e. household *Johkasou*) [kg-CH_4], [kg-N_2O]

EF_i : Emission factor for domestic sewage treatment plant *i* [kg-CH_4/person], [kg-N_2O/person]

A_i : Population (persons) requiring waste processing at domestic sewage treatment plant *i* per year

● *Emission Factors*

CH_4 and N_2O emission factors for this source are determined from domestic research studies as shown on the Table 7-85.

Table 7-85 Emission factors for CH_4 and N_2O from domestic wastewater treatment systems

CH_4 emission factors (Unit: kg-CH_4 /person-year)							
Plant type			FY1990 -1995	FY1996 -2000	FY2001-2004	FY2005 -	Reference
Community plant[1]			0.195	Interpolation		0.062	1990-1995: Tanaka (1998) 2005-: Ike and Soda (2010)
Current type *Johkasou*	Advanced type	TN removal type	NA[2]		1.044		MOE (2012) and MOE (2013c)
		TN and TP removal type					
		BOD removal type					
		Other advanced type			1.984		
	Standard type [3]		2.477				
Old type *Johkasou* [3]			0.46				
Vault toilet [3]			0.062				
N_2O emission factors (Unit: kg-N_2O/person-year)							
Plant type			FY1990 -1995	FY1996 -2000	FY2001-2004	FY2005 -	Reference
Community plant[1]			0.0394	Interpolation		0.0048	1990-1995: Tanaka et al. (1995) [4] 2005-: Ike and Soda (2010)
Current type *Johkasou*	Advanced type	TN removal type	NA[2]		0.123		MOE (2012) and MOE (2013c)
		TN and TP removal type					
		BOD removal type					
		Other advanced type			0.055		
	Standard type [3]		0.0717				
Old type *Johkasou* [3]			0.039				
Vault toilet [3]			0.000022				

Note:
1) For the values from FY2005 onward, the emission factors are applied taking into account the performance improvement of the plants.
2) The installation of current advanced type *Johkasou* was started under the technical guidelines for *Johkasou* of the Building Standards Act revised in FY2001.
3) The same emission factor is applied for through the reporting years because there is no significant technological advancement
4) The simple mean values of the upper limit and the lower limit of actual measured values indicated in the reference is applied.

● *Activity Data*

Annual treatment population by type of domestic sewage treatment plant for community plants, current type *Johkasou,* old type *Johkasou,* and vault toilets given in the *Waste Treatment in Japan* (MOE) is used as the activity data for CH_4 and N_2O emitted in association with domestic sewage treatment plants.

Activity data for current type J*ohkasou* are classified as advanced type and standard type by using installation share derived from installation number of each type, which can be assumed as a share of annual treatment population, shown in the *Survey of guidance promotion of Johkasou* (MOE).

Table 7-86 Annual treatment population by type of domestic sewage treatment plant (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Community plant	1000 person	493	398	414	552	293	289	304	302	294	286	320	336	306	259	193
Current type *Johkasou* (Sub tatal)	1000 person	6,274	8,515	10,806	12,792	14,082	14,341	14,492	14,564	14,600	14,630	14,557	14,506	14,381	14,421	15,206
Advanced type																
TN removal type	1000 person	NO	NO	NO	263	1,433	2,261	2,612	2,948	3,105	3,447	3,862	3,954	4,507	4,772	5,032
TN and TP removal type	1000 person	NO	NO	NO	3	14	28	35	37	39	40	42	43	56	51	54
BOD removal type	1000 person	NO	NO	NO	34	33	22	25	22	19	18	20	29	54	58	61
Other advanced type	1000 person	NO	NO	NO	4,501	6,132	6,095	6,123	6,098	6,153	6,022	5,666	5,691	5,345	5,110	5,388
Standard type	1000 person	6,274	8,515	10,806	7,991	6,471	5,935	5,697	5,459	5,284	5,103	4,968	4,788	4,419	4,429	4,670
Old type *Johkasou*	1000 person	26,828	26,105	23,289	18,303	13,948	13,052	12,383	11,822	11,415	11,018	10,543	10,151	9,875	9,319	8,317
Vault toilet	1000 person	38,920	29,409	20,358	13,920	9,984	8,849	8,242	7,727	7,197	6,871	6,528	6,086	5,745	5,481	5,097
Total	1000 person	72,515	64,427	54,867	45,567	38,307	36,531	35,421	34,415	33,506	32,805	31,948	31,079	30,307	29,480	28,813

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties in emission factors for CH_4 and N_2O in current type *Johkasou*, old type *Johkasou*, and vault toilet are evaluated by using the 95% confidence intervals of actual measurement data which are used for calculation of emission factors. As for the uncertainties in emission factors for CH_4 and N_2O in community plant, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-87.

Table 7-87 Uncertainty assessment for domestic sewage treatment plant on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Community Plant	CH_4	-32%	+32%	-10%	+10%	-33%	+33%	The uncertainty is assessed based on expert judgment. (The uncertainty in current type *Johkasou* is substituted).	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N_2O	-45%	+45%	-10%	+10%	-46%	+46%			
Current type *Johkasou*	CH_4	-32%	+32%	-10%	+10%	-33%	+33%	Quoted from MOE (2013c).		Combined by using the formula for propagation of errors.
	N_2O	-45%	+45%	-10%	+10%	-46%	+46%			
Old type *Johkasou*	CH_4	-84%	+84%	-10%	+10%	-84%	+84%			Combined by using the formula for propagation of errors.
	N_2O	-87%	+87%	-10%	+10%	-88%	+88%			
Vault toilet	CH_4	-49%	+49%	-10%	+10%	-50%	+50%			Combined by using the formula for propagation of errors.
	N_2O	-72%	+72%	-10%	+10%	-73%	+73%			

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

No recalculations are conducted.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.1.3. Human-Waste Treatment Plant (5.D.1.-)

a) Category Description

This category covers emissions of CH_4 and N_2O emissions from treatment of vault toilet human waste and *Johkasou* sludge collected at human waste treatment plants.

b) Methodological Issues

1) CH_4

- ***Estimation Method***

Emissions of CH_4 from this source are calculated using Japan's country-specific methodology in accordance with decision tree of the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of domestic wastewater treated at human waste treatment plants by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

E : Emission of methane from the processing of domestic and commercial wastewater at human waste treatment plants [kg-CH_4]

EF_i : Emission factor for human waste treatment plants (for treatment process i) [kg-CH_4/m^3]

A_i : Input volume of human waste and *Johkasou* sludge at human waste treatment plants (for treatment process i) [m^3]

- ***Emission Factors***

Emission factors for CH_4 are determined by treatment processes type, including anaerobic, aerobic, standard denitrification and high-load denitrification treatments as well as membrane separation systems, for each of the human waste treatment plants (MOE, 2006b).

Table 7-88 CH_4 emission factors by each treatment process

Treatment method	CH_4 Emission factor [$kg\text{-}CH_4/m^3$]	Reference
Anaerobic treatment	0.543	Estimated by multiplying the actual methane emissions given in Japan Environmental Sanitation Center (1990) by the value of 1 – CH_4 recovery rate (90%).
Aerobic treatment	0.00545	Simple average value of standard de-nitrification and high-load de-nitrification since actual data on emissions is not available.
Standard de-nitrification treatment	0.0059	Tanaka et al. (1995)
High load de-nitrification treatment	0.005	Tanaka et al. (1995)
Membrane separation	0.00545	Because the current status of its emissions is not identified, substituted the emission factor for aerobic treatment.
Other	0.00545	Because the current status of its emissions is not identified, substituted the emission factor for aerobic treatment.

- ***Activity Data***

Activity data for CH_4 emissions associated with the processing of wastewater at human waste treatment plants is determined from the calculated throughput volume for each of the treatment processes (Table 7-91), by multiplying the total volume of human waste and *Johkasou* sludge processed at human waste treatment plants that are indicated in *Waste Treatment in Japan* (MOE) (Table 7-89) by the capacity of each treatment process (Table 7-90).

$$A_i = W_H \times C_i / C_T$$

A_i : Activity data for human waste treatment method i [kL]
W_H : Total amount of human waste and septic tank sludge [kL]
C_i : Capacity of waste treatment method i [kL]
C_T : Total capacity of all waste treatment methods [kL]

Table 7-89 Volume of human waste and *Johkasou* sludge treated at their treatment plants

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Human waste from vault toilet	1000 kL	20,406	18,049	14,673	10,400	7,917	7,018	6,771	6,375	6,153	5,890	5,627	5,415	5,191	4,974	4,781
Johkasou sludge	1000 kL	9,224	11,545	13,234	13,790	13,760	13,519	13,726	13,562	13,537	13,648	13,536	13,534	13,415	13,372	13,260
Total	1000 kL	29,630	29,594	27,907	24,190	21,677	20,537	20,497	19,937	19,690	19,538	19,163	18,949	18,606	18,346	18,041

Table 7-90 Trends in treatment capacity by treatment process

Unit	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Anaerobic treatment	kL/day	34,580	19,869	10,996	6,476	3,891	3,159	3,059	2,779	2,245	2,155	1,799	1,574	1,527	1,330	898
Aerobic treatment	kL/day	26,654	19,716	12,166	8,465	6,753	6,469	6,001	5,899	5,979	5,600	4,743	4,468	3,760	3,666	4,967
Standard denitrification	kL/day	25,196	30,157	31,908	29,655	26,173	25,608	25,153	24,663	24,023	22,812	21,544	21,113	21,599	21,322	20,416
High-intensity denitrification	kL/day	8,158	13,817	16,498	17,493	16,104	15,030	14,529	14,336	13,831	13,651	13,838	13,289	13,153	12,601	12,330
Membrane separation	kL/day	NO	1,616	2,375	3,055	3,684	4,062	4,074	2,204	3,373	3,184	2,853	2,404	2,458	2,410	2,240
Other	kL/day	13,777	20,028	25,917	30,277	34,577	33,556	33,975	34,983	33,940	36,074	37,430	40,223	40,137	40,882	40,906

Table 7-91 Activity Data for human waste by treatment types

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Anaerobic treatment	1000 kL	9,455	5,589	3,073	1,642	925	738	722	653	530	504	419	359	344	297	198
Aerobic treatment	1000 kL	7,288	5,546	3,400	2,146	1,605	1,512	1,417	1,386	1,412	1,311	1,106	1,019	847	818	1,096
Standard denitrification	1000 kL	6,889	8,483	8,917	7,518	6,222	5,984	5,940	5,794	5,672	5,339	5,022	4,816	4,863	4,758	4,505
High-intensity denitrification	1000 kL	2,231	3,887	4,611	4,435	3,828	3,512	3,431	3,368	3,266	3,195	3,226	3,031	2,962	2,812	2,721
Membrane separation	1000 kL	NO	455	664	774	876	949	962	518	796	745	665	548	553	538	494
Other	1000 kL	3,767	5,634	7,243	7,676	8,220	7,841	8,024	8,219	8,014	8,443	8,725	9,175	9,037	9,123	9,026
Total	1000 kL	29,630	29,594	27,907	24,190	21,677	20,537	20,497	19,937	19,690	19,538	19,163	18,949	18,606	18,346	18,041

2) N_2O

- ***Estimation Method***

Emissions of N_2O from this source are calculated using Japan's country-specific methodology, in accordance with decision tree of the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of nitrogen treated at human waste treatment plants, by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

E : Emission of nitrous oxide from the processing of domestic and commercial wastewater at human waste treatment plants [kg-N_2O]
EF_i : Emission factor for human waste treatment plants (by treatment process i) [kg-N_2O/kg-N]
A_i : Amount of nitrous oxide in human waste and Johkasou sludge input at human waste treatment plants (by treatment process i) [kg-N]

- ***Emission Factors***

The emission factors for N_2O are determined for each treatment process including high-load denitrification treatment and membrane separation systems using the results of actual case studies in Japan (MOE, 2006b).

According to the survey study on the emission factors for human waste treatment facilities conducted in FY1994 (Tanaka et al., 1997) and FY2003 (Ohmura et al., 2004) in Japan, because of the advancement of the structure of human waste treatment facilities and the technology of operation and maintenance, actual measurement results show the improvement in the emission factors for high load de-nitrification treatment and membrane separation; therefore, different emission factors are used for FY1994 or before and from FY2003 onwards.

Table 7-92 N_2O emission factors by each treatment process

Treatment method	N_2O emission factors [kg-N_2O-N/kg-N]		
	FY1990-1994	FY1995-2002	From FY2003
High load de-nitrification treatment	0.033 1)	Interpolation	0.0029 2)
Membrane separation	0.033 1)	Interpolation	0.0024 2)
Other (including anaerobic treatment, aerobic treatment, standard de-nitrification treatment)	0.0000045 3)		

Note:
1) Use median value of actual measurements at 13 plants given in Tanaka et al. (1998)
2) Use median value of actual measurements at 13 plants given in Omura et al. (2004)
3) Referred to Tanaka et al. (1995) (Calculated by dividing upper limit value for standard de-nitrification treatment (1.0×10^{-5} kg-N_2O/m^3) by treated nitrogen concentration in FY1994 (2,211 mg/l)).

- ***Activity Data***

The volume of nitrogen treated at human waste treatment plants is calculated by multiplying treated nitrogen concentration by the volume of human waste treated at these facilities (the sum of collected human waste and sewage in sewerage tank), given in the *Waste Treatment in Japan* (MOE). The treated nitrogen concentration is based on weighted average of the volume of nitrogen contained in collected human waste and sewage in sewerage tank derived using the volume of collected human waste and sewage in sewerage tank treated at human waste treatment plants.

$$A_i = (W_H \times N_H + W_J \times N_J) \times F_i / 1000$$

A_i	: Activity data for human waste treatment method *i* [kg-N]
W_H	: Input volume of human waste at human waste treatment plants [m^3]
W_J	: Input volume of *Johkasou* sludge at human waste treatment plants [m^3]
N_H	: Nitrogen concentration in human waste [mg-N/L]
N_J	: Nitrogen concentration in *Johkasou* sludge [mg-N/L]
F_i	: Percentage throughput of treatment process *i* [%]

➢ ***Input Volume of Human Waste and Johkasou sludge at Human Waste Treatment Plants:***

See the data used for the calculation of CH_4 emissions from human waste treatment plants (Table 7-89).

➢ ***Percentage Throughput of the Human Waste Treatment Processes:***

See the data used for the calculation of CH_4 emission from human waste treatment plants (Table 7-90).

➢ ***Nitrogen Concentration in Human Waste and Johkasou Sludge Input at Treatment Plants:***

For the nitrogen concentration in human waste and *Johkasou* sludge input at treatment plants, the values analyzed for the period FY1989-1991, FY1992-1994, FY1995-1997, and FY1998-2000, respectively, are used based on the research conducted by Okazaki (2001). The value of FY2000 is substituted for the values from FY2001 onward. (See Table 7-93).

Table 7-93 Concentration of nitrogen contained in collected human waste and *Johkasou* sludge

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Human waste from vault toilet	mg-N/L	3,940	3,100	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700
Johkasou sludge	mg-N/L	1,060	300	580	580	580	580	580	580	580	580	580	580	580	580	580
Weighted average	mg-N/L	3,043	2,008	1,695	1,491	1,354	1,304	1,280	1,258	1,242	1,219	1,203	1,186	1,171	1,155	1,142

Table 7-94 Amount of nitrogen in human waste and *Johkasou* sludge processed at human waste treatment plants (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Anaerobic treatment	kt-N	28.8	11.2	5.2	2.4	1.3	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.3	0.2
Aerobic treatment	kt-N	22.2	11.1	5.8	3.2	2.2	2.0	1.8	1.7	1.8	1.6	1.3	1.2	1.0	0.9	1.3
Standard denitrification	kt-N	21.0	17.0	15.1	11.2	8.4	7.8	7.6	7.3	7.0	6.5	6.0	5.7	5.7	5.5	5.1
High-intensity denitrification	kt-N	6.8	7.8	7.8	6.6	5.2	4.6	4.4	4.2	4.1	3.9	3.9	3.6	3.5	3.2	3.1
Membrane separation	kt-N	NO	0.9	1.1	1.2	1.2	1.2	1.2	0.7	1.0	0.9	0.8	0.7	0.6	0.6	0.6
Other	kt-N	11.5	11.3	12.3	11.4	11.1	10.2	10.3	10.3	10.0	10.3	10.5	10.9	10.6	10.5	10.3
Total	kt-N	90.2	59.4	47.3	36.1	29.4	26.8	26.2	25.1	24.5	23.8	23.0	22.5	21.8	21.2	20.6

c) Uncertainties and Time-series Consistency

● ***Uncertainties***

As for the uncertainties in emission factors for CH_4 and N_2O in human waste treatment plant, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-95.

Table 7-95 Uncertainty assessment for human waste treatment plant on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Human waste treatment plant	CH_4	-84%	+84%	-10%	+10%	-84%	+84%	The uncertainty is assessed based on expert judgment. (The uncertainty in Old type *Johkasou* is substituted).	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N_2O	-87%	+87%	-10%	+10%	-88%	+88%			

- ***Time-series Consistency***

For N_2O emission factor, consistent data over the time series are constructed based on the actual measurement data by using the methods described in Table 7-92. For other parameters, data are constructed consistently for the entire time series. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By updating the statistical data, emissions in FY2019 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)

a) Category Description

Although most of the domestic wastewater generated by Japanese households is processed at wastewater treatment plants, treated wastewater which is discharged into public waters contains residual nitrogen. Also, some miscellaneous wastewater is discharged into public waters without any treatment. The CH_4 and N_2O emissions from untreated wastewater and sludge decomposing in public waters and the N_2O from treated wastewater are reported under this category. The emission sources for this category are shown on Table 7-96.

Table 7-96 Emission sources of category "Natural Decomposition of Domestic Wastewater (5.D.1.-)"

Emission source	Detail
Untreated wastewater (CH_4, N_2O)	Untreated miscellaneous wastewater from households using old type *Johkasou*
	Untreated miscellaneous wastewater from households using vault toilet
	Untreated miscellaneous wastewater from households using on-site disposal systems
Treated wastewater (N_2O)	Treated wastewater from sewage treatment plants
	Treated wastewater from community plants and current advanced/standard type *Johkasou*
	Treated wastewater derived from human waste in old type *Johkasou*
	Treated wastewater from treatment of human waste/*Johkasou* sludge in human waste treatment plants
Sludge (CH_4, N_2O)	Human waste and *Johkasou* sludge dumped into the ocean
	Sewage sludge dumped into the ocean

b) Methodological Issues

- ***Estimation Method***

Estimation method is established in accordance with the method described in the *2006 IPCC Guidelines*. In the natural decomposition of wastewater, both the volume of organic matter extracted as sludge and recovered CH_4 are zero. Accordingly, CH_4 emissions are calculated by multiplying the volume of organic matter contained in the untreated domestic wastewater that is discharged into public waters by the emission factor. The N_2O emission is calculated by multiplying the volume of nitrogen contained in the wastewater by the emission factor.

$$E = EF \times A$$

E : Emission of methane or nitrous oxide from the natural decomposition of domestic wastewater [kg-CH_4], [kg-N_2O]
EF : Emission factor [kg-CH_4/kg-BOD], [kg-N_2O/kg-N]
A : Amount of organic matter [kg-BOD] or nitrogen [kg-N] in domestic wastewater

- ***Emission Factors***

Emission factors are determined in accordance with the *2006 IPCC Guidelines*. The emission factor for CH_4 is established by multiplying the maximum CH_4 generation potential (B_0) by a CH_4 conversion factor (MCF). The maximum CH_4 generation potential is set to 0.6 kg-CH_4/kg-BOD, given in the *2006 IPCC Guidelines*, and the MCF is set to 0.1, a default value for "Sea, river and lake discharge" of "Untreated systems".

$$EF_{CH4} = B_0 \times MCF$$
$$= 0.6\ [\text{kg-}CH_4/\text{kg-BOD}] \times 0.1$$
$$= 0.06\ [\text{kg-}CH_4/\text{kg-BOD}]$$

The emission factor for N_2O is calculated from the value of 0.005 kg N_2O-N/kg N after conversion of the units.

$$EF_{N2O} = 0.005\ [\text{kg-}N_2O\text{-N/kg-N}] \times 44/28$$
$$= 0.0079\ [\text{kg-}N_2O/\text{kg-N}]$$

- ***Activity Data***

➢ ***Untreated wastewater***

Activity data for CH_4 and N_2O emissions from untreated wastewater are obtained from the following equation:

$$A = \sum_i P_i \times U$$

A : Activity data of untreated miscellaneous wastewater from households [g-BOD], [g-N]
P_i : User population of treatment system type i (old type *Johkasou*, vault toilet, on-site disposal system) [1)] [person]
U : Unit BOD effluent (40 [g-BOD/person-day][2)]), or unit nitrogen effluent (2 [g-N/person-day][2)]) from untreated miscellaneous wastewater

Reference:
1) *Waste Treatment in Japan* (MOE)
2) JSWA (1999)

Note that a portion of the human waste in on-site disposal systems is utilized as fertilizer on farmlands in Japan. The N_2O emission from this is already included in the "Direct soil emission (3.D.1.)" category in the Agriculture sector, and therefore, not included in the calculation for this source.

➢ ***Treated wastewater***

Activity data for N_2O emissions from treated wastewater are obtained from the following equations:

$$A = A_{sp} + A_{dp} + A_{hp}$$

A : Total nitrogen in treated domestic wastewater (activity data) [t-N]
A_{sp} : Total nitrogen in treated wastewater from sewage treatment plants [t-N]
A_{dp} : Total nitrogen in treated wastewater from domestic sewage treatment plants [t-N]
A_{hp} : Total nitrogen in treated wastewater from human waste treatment plants [t-N]

- ***Sewage treatment plants***

Total nitrogen in treated wastewater from sewage treatment plants are obtained from the equation below:

$$A_{sp} = \sum_i (W_i \times D_i) \times 10^{-6}$$

W_i : Amount of treated wastewater in sewage treatment plant i [m^3]
D_i : Nitrogen concentration in treated wastewater from sewage treatment plant i [mg-N/L]

References:
1) *Sewage Statistics* (JSWA) for both parameters

- ***Domestic sewage treatment plant***

Total nitrogen in treated wastewater from domestic sewage treatment plants (community plant, current advanced/standard type *Johkasou*, and old type *Johkasou*) are obtained from the equation below:

$$A_{dp} = \sum_i \{TN_i \times d \times P_i \times (1 - R_i)\} \times 10^{-6}$$

TN_i : Unit total nitrogen effluent from domestic sewage plant type i [g-N/person-day] (see Table 7-97)
P_i : User population of domestic sewage treatment plant type i [person] (see Table 7-86)
R_i : Fraction of nitrogen removal in domestic sewage plant type i [%] (see Table 7-98)
d : Annual days [days]

Unit nitrogen effluent from each domestic sewage plant type and fraction of nitrogen removal in these plants are shown in the following tables:

Table 7-97 Unit nitrogen effluent from domestic sewage plants

Treatment system	Sewage type	Unit nitrogen effluent [g-N/person-day]	Reference
Community plant	Human waste and miscellaneous wastewater	10	MOE (2009)
Current type *Johkasou* (both advanced and standard type)			
Old type *Johkasou*	Human waste	8	

Table 7-98 Fraction of nitrogen removal in domestic sewage plants

Treatment system			Fraction of nitrogen removal	Reference
Community plant			20%	Expert judgement based on the result of Tokyo Environmental Public Service Corporation (1996).
Current type *Johkasou*	Advanced type	TN removal type	60%	Estimated by assuming averaged nitrogen concentration in treated wastewater from these systems (20 mg/L), unit nitrogen effluent (10 g-N/person-day) and amount of discharged wastewater (200 L/ person-day).
		TN and TP removal type		
		BOD removal type	20%	Expert judgement based on the result of Tokyo Environmental Public Service Corporation (1996).
		Other advanced type		
	Standard type			
Old type *Johkasou*				

- ***Human waste treatment plant***

Total nitrogen in treated wastewater from human waste treatment plant are obtained from the equation below:

$$A_{hp} = W \times D \times 10^{-6}$$

W : Amount of human waste and *Johkasou* sludge treated in human waste treatment plant[1)] [m^3]
D : Nitrogen concentration in treated wastewater from human waste treatment plant [mg-N/L]

References:
1) *Waste Treatment in Japan* (MOE)

Nitrogen concentration in treated wastewater of this subcategory is obtained as weighted averages of those in discharged wastewater from each human waste treatment type (Table 7-99) weighted by treatment capacities by treatment process (Table 7-90).

Table 7-99 Nitrogen concentrations in discharged wastewater from each human waste treatment method

Treatment method	Nitrogen concentration [mg-N/l]	Reference
Anaerobic treatment	98.0	Okazaki et al. (2001)
Aerobic treatment	32.5	
Standard de-nitrification treatment	5.5	
High load de-nitrification treatment	19.0	
Membrane separation	10.0	

➢ ***Sludge***

Activity data for CH_4 and N_2O emissions from sludge dumped into ocean are obtained from the equations below:

- ***Human waste/Johkasou sludge***

$$A = V_H \times D_H + V_J \times D_J$$

A : Activity data of human waste/*Jokasou* sludge dumped into ocean [g-BOD], [g-N]
V_H : Human waste dumped in ocean [1)] [kL]
D_H : BOD/Nitrogen concentration in human waste[2)] [mg-BOD/L], [mg-N/L]
V_J : *Jokasou* sludge dumped in ocean [1)] [kL]
D_J : BOD/Nitrogen concentration in *Jokasou* sludge [2)] [mg-BOD/L], [mg-N/L]

Reference:
1) *Waste Treatment in Japan* (MOE)
2) Okazaki et al. (2001)

- ***Sewage sludge***

$$A = V \times D$$

A : Activity data of sewage sludge dumped into ocean [g-BOD], [g-N]
V : Sewage sludge dumped into ocean [1)] [kL]
D : BOD/Nitrogen concentration into sewage sludge [2)] [mg-BOD/L], [mg-N/L]

Reference:
1) *Sewage Statistics* (JSWA)
2) The value for *Johkasou* sludge is substituted by Expert judgement based on Okazaki et al. (2001).

Estimated activity data are shown in Table 7-100.

Table 7-100 Amount of organic material and nitrogen in untreated domestic wastewater and discharged into public water zone (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Organic mater in:																
Untreated wastewater (from old type *Johkasou*)	kt-BOD	392	381	341	267	204	191	181	173	167	161	154	148	144	136	121
Untreated wastewater (from Vault toilet)	kt-BOD	568	429	298	203	146	130	120	113	105	101	95	89	84	80	74
Untreated wastewater (from On-site disposal)	kt-BOD	46	21	9	4	2	2	1	1	1	1	1	1	1	1	1
Human waste, *Johkasou* sludge (Ocean dumping)	kt-BOD	22	14	9	4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewege sludge (Ocean dumping)	kt-BOD	1	1	0.05	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	kt-BOD	1,029	846	658	478	351	322	302	287	273	263	250	238	229	218	197
Nitrogen in:																
Untreated wastewater (from old type *Johkasou*)	kt-N	19.6	19.1	17.0	13.4	10.2	9.6	9.0	8.6	8.3	8.1	7.7	7.4	7.2	6.8	6.1
Untreated wastewater (from Vault toilet)	kt-N	28.4	21.5	14.9	10.2	7.3	6.5	6.0	5.6	5.3	5.0	4.8	4.4	4.2	4.0	3.7
Untreated wastewater (from on-site disposal)	kt-N	2.3	1.1	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.05	0.05	0.1	0.1	0.04	0.04
Treated wastewater	kt-N	297.0	301.2	281.8	267.0	251.6	243.2	250.0	241.3	243.0	241.9	239.2	235.2	246.8	231.8	231.0
Human waste, *Johkasou* sludge (Ocean dumping)	kt-N	7.2	3.2	2.2	0.8	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewege sludge (Ocean dumping)	kt-N	0.1	0.1	0.01	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	kt-N	354.6	346.0	316.4	291.5	269.1	259.3	265.1	255.6	256.7	255.0	251.7	247.2	258.2	242.7	240.9

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

As for the uncertainties in emission factors for CH_4 and N_2O in this category, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-101.

Table 7-101 Uncertainty assessment for natural decomposition of domestic wastewater on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission/ removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Natural decomposition	CH_4	-58%	+58%	-10%	+10%	-59%	+59%	Since the *2006 IPCC Guidelines* provide the emission factors as default value for this category, the uncertainty is assessed in accordance with the default method in the guidelines.	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N_2O	-58%	+58%	-10%	+10%	-59%	+59%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in CH_4 is substituted based on expert judgment.		

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

No recalculations are conducted.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.2. Industrial Wastewater (5.D.2.)

CH_4 and N_2O emissions from industrial effluent, which is treated by plants/facilities in accordance with the regulations based on the Water Pollution Prevention Law and the Sewerage Law, are allocated to "Industrial wastewater treatment (5.D.2.-)" , CH_4 and N_2O emissions from untreated/treated industrial effluent discharged from plants/facilities and decomposed in public waters, are allocated to "Natural decomposition of Industrial wastewater (5.D.2.-)", and CH_4 and N_2O emissions from landfill leachate treatment are allocated to "Landfill leachate treatment (5.D.2.-)" under the sub-category of "Industrial Wastewater (5.D.2.)".

7.5.2.1. Industrial Wastewater Treatment (5.D.2.-)

a) Category Description

CH_4 and N_2O emissions from industrial effluent, which is treated by factories and other facilities in accordance with the regulations based on the Water Pollution Prevention Law and the Sewerage Law, are allocated to "Industrial wastewater treatment (5.D.2.-)."

b) Methodological Issues

- ***Estimation Method***

In accordance with the decision tree of the *2006 IPCC Guidelines* (Page 6.19, Fig. 6.3), CH_4 and N_2O emissions are estimated for the industries that release organic-rich wastewater. Since default values given in the *2006 IPCC Guidelines* are considered to be unsuited to Japan's circumstances, CH_4 emissions are estimated based on Japan's country-specific methodology, namely, by multiplying the annual amount of organic matter in industrial wastewater subject to report (BOD basis) by the CH_4 emission factor per unit BOD that is based on Japan's country-specific wastewater handling. Because CH_4 is emitted in wastewater biological treatment processes, BOD-based activity data (amount of organic matter in wastewater degraded through biological treatment) is thought to be preferable to COD-based data. For this reason, CH_4 emissions are calculated using BOD in Japan. With regard to N_2O emissions, no estimation methodologies are given in the *2006 IPCC Guidelines*. Therefore, in the same manner for estimating CH_4 emissions, N_2O emissions are estimated by multiplying the amount of nitrogen in industrial wastewater by Japan's country-specific N_2O emission factor.

$$E = EF \times A$$

E : Amount of CH_4 or N_2O emissions generated when treating industrial wastewater [kg-CH_4], [kg-N_2O]
EF : Emission factor [kg-CH_4/kg-BOD], [kg-N_2O/kg-N]
A : Amount of BOD or nitrogen in industrial wastewater [kg-BOD], [kg-N]

- ***Emission Factor***

Country-specific emission factors obtained from a set of actual measurement at 8 plants in summer and winter (MOE, 2018 a) are adopted (MOE, 2018 b).

Table 7-102 Emission Factors for industrial wastewater treatment facilities

Category of Manufacturing	CH_4 Emission factor [g-CH_4/kg-BOD]	N_2O Emission factor [g-N_2O/kg-N]
Manufacture of food	1.2	0.47
Manufacture of pulp, paper and paper products	2.5	0.014
Manufacture of chemical and allied product	0.92	17
Manufacture of iron and steel	7.3	4.0
Other manufactures (average emission factors for above categories)	3.0	5.3

In Japan, CH_4 emissions generated by anaerobic wastewater treatment are entirely recovered. For a small amount of CH_4 emissions generated under partially anaerobic conditions created during aerobic treatment, a country-specific emission factor is applied for emission estimates because the condition for this particular CH_4 emission differs from that for the use of default value for the CH_4 emissions generated from anaerobic treatment defined in *the 2006 IPCC Guidelines*.

- ***Activity Data***

The activity data for CH_4 emission are estimated based on the amount of organic matter contained in wastewater using BOD concentrations. The emission estimates are conducted for the industries which generate large amount of CH4 emissions with high BOD concentrations from the treatment of wastewater referring to the industry types provided in the *Revised 1996 IPCC Guidelines* (Table 7-103). The amount of organic matter is obtained by sorting and aggregating by industry type according to the middle industrial classification provided by JSWA (2009).

The use of COD concentrations is required to report activity data on CRF; however, activity data are reported as "NE" because country-specific methodology is used for this source.

$$A_{CH4,i} = W_i \times BOD_i / 1000$$

Where,

$$W_i = I_i \times F_{CH4,i} \times F_{onsite,i}$$

$A_{CH4,i}$: Amount of BOD in industrial wastewater from industry type *i* (Activity data) [kg-BOD]

W_i : Amount of industrial wastewater from industry type *i* flowing into wastewater treatment facilities [m^3]

BOD_i : BOD concentration of runoff water from industry type *i* [mg-BOD/L]

I_i : Amount of industrial wastewater from industry type *i* used for product processing and/or washing [m^3]

$F_{CH4,i}$: Percentage of industrial wastewater from industry type *i* treated at treatment facilities emitting CH_4 [%]

$F_{onsite,i}$: Percentage of industrial wastewater from industry type *i* treated on-site [%]

The activity data for N_2O emissions are obtained based on the amount of nitrogen contained in industrial wastewater and aggregated by the same industrial sub-category as that applied to the estimation of CH_4 emissions.

$$A_{N2O,i} = W_i \times TN_i / 1000$$

Where,

$$W_i = I_i \times F_{N2O,i} \times F_{onsite,i}$$

$A_{N2O,i}$: Amount of nitrogen in industrial wastewater from industry type *i* (Activity data) [kg-N]
W_i : Amount of industrial wastewater from industry type *i* flowing into wastewater treatment facilities [m^3]
TN_i : Total nitrogen concentration of runoff water from industry type *i* [mg-N/L]
I_i : Amount of industrial wastewater from industry type *i* used for product processing and/or washing [m^3]
$F_{N2O,i}$: Percentage of industrial wastewater from industry type *i* treated at treatment facilities emitting N_2O [%]
$F_{onsite,i}$: Percentage of industrial wastewater from industry type *i* treated on-site [%]

- ***Amount of Industrial Wastewater Inflowed into Wastewater Treatment Facilities***

The amount of water used for the treatment of products by industrial sub-category and the volume of water used for washing given in the *Table of Industrial Statistics - Land and Water* (METI) are used for the amount of industrial wastewater treated at wastewater treatment facilities.

- ***Percentage of Industrial Wastewater Treated at Facilities Generating CH_4***

Emissions of CH_4 from industrial wastewater treatment are believed to be generated from the treatment of wastewater with the activated sludge method and from the anaerobic treatment. Industrial wastewater treatment percentages for each industry code are set from the percentages of reported wastewater amounts in total wastewater, as given under "active sludge", "other biological treatment", "membrane treatment", "nitrification and denitrification" and "other advanced treatment" in the *Study on the Control of Wastewater loading* (Water and Air Environment Bureau of MOE).

- ***Percentage of Industrial Wastewater Treated at Facilities Generating N_2O***

Emissions of N_2O from industrial wastewater treatment are believed to be generated mainly from biological treatment processes such as denitrification. Data on the fraction of industrial wastewater treated at facilities generating CH_4 is also used for N_2O emission estimates.

- ***Percentage of Industrial Wastewater Treated On-site***

Percentage of industrial wastewater treated on-site is set at 1.0 in all industrial sub-categories because there is no statistical information available making it possible to ascertain this percentage.

- ***BOD and Nitrogen Concentrations in Runoff Wastewater***

For the BOD concentrations for industrial sub-categories, the BOD raw water quality for industrial sub-categories given in JSWA (1999) is used. For the nitrogen concentrations for industrial sub-categories, emission intensities (TN: Total Nitrogen) provided by the same survey for industrial sub-categories are used.

Table 7-103 BOD and nitrogen concentrations by industry type used for emission estimates

Industry code	Category of Manufacturing	mg-BOD/L	mg-N/L
9	Manufacture of food	1,470	62
10	Manufacture of beverages, tobacco and feed	1,138	77
11	Manufacture of textile products	386	36
14	Manufacture of pulp, paper and paper products	556	37
16	Manufacture of chemical and allied product	1,093	191
17	Manufacture of petroleum and coal products	975	289
18	Manufacture of plastic products	268	11
19	Manufacture of rubber products	112	32
20	Manufacture of leather tanning, leather products and fur skins	1,810	60
22	Manufacture of iron and steel	246	310

Table 7-104 BOD load and TN load of industrial wastewater (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
BOD load																
Manufacture of food	kt-BOD	297.8	326.2	306.8	289.4	311.7	288.0	307.2	348.4	348.4	348.4	348.4	348.4	348.4	348.4	348.4
Manufacture of beverages, tobacco and feed	kt-BOD	88.7	100.5	92.0	71.5	58.0	55.7	52.8	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0
Manufacture of textile products	kt-BOD	98.1	94.2	65.5	47.7	40.1	45.4	38.2	36.4	36.4	36.4	36.4	36.4	36.4	36.4	36.4
Manufacture of pulp, paper and paper products	kt-BOD	471.8	422.7	457.3	423.4	365.4	340.9	321.4	324.0	324.0	324.0	324.0	324.0	324.0	324.0	324.0
Manufacture of chemical and allied product	kt-BOD	110.2	95.3	103.0	160.1	162.9	151.3	154.2	146.1	146.1	146.1	146.1	146.1	146.1	146.1	146.1
Manufacture of petroleum and coal products	kt-BOD	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Manufacture of plastic products	kt-BOD	6.2	5.9	6.2	6.9	6.9	7.4	7.1	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Manufacture of rubber products	kt-BOD	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manufacture of leather tanning, leather products and fur skins	kt-BOD	1.3	1.1	0.8	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Manufacture of iron and steel	kt-BOD	1.2	1.3	1.3	1.5	1.8	1.7	1.6	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
TN load																
Manufacture of food	kt-N	15.5	16.9	16.3	15.0	16.0	14.6	15.8	17.4	17.4	17.4	17.4	17.4	17.4	17.4	17.4
Manufacture of beverages, tobacco and feed	kt-N	3.8	4.2	4.3	3.9	2.6	2.4	2.8	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Manufacture of textile products	kt-N	10.8	10.5	7.4	5.2	4.4	5.3	4.3	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Manufacture of pulp, paper and paper products	kt-N	18.4	16.5	17.7	16.2	14.4	13.2	11.8	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Manufacture of chemical and allied product	kt-N	40.0	38.8	30.1	48.5	50.8	50.6	50.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8	49.8
Manufacture of petroleum and coal products	kt-N	0.1	0.1	0.1	0.1	0.03	0.03	0.02	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Manufacture of plastic products	kt-N	0.2	0.2	0.3	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Manufacture of rubber products	kt-N	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Manufacture of leather tanning, leather products and fur skins	kt-N	0.1	0.1	0.05	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Manufacture of iron and steel	kt-N	57.7	53.9	55.5	54.7	45.6	61.2	58.9	57.5	57.5	57.5	57.5	57.5	57.5	57.5	57.5

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties in emission factors are evaluated according to the survey for EFs (MOE, 2018a). As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-105.

Table 7-105 Uncertainty assessment for industrial wastewater treatment on the category "Industrial wastewater (5.D.2.-)"

Item	GHGs	Emission/ removal factor uncertainty [%]		Activity data uncertainty [%]		Emission/ removal uncertainty [%]		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Industrial wastewater treatment	CH_4	-60%	+60%	-30%	+30%	-67%	+67%	The uncertainty is evaluated according to the survey for EFs (MOE, 2018a).	The uncertainty in industrial waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N_2O	-95%	+95%	-30%	+30%	-100%	+100%			

- ***Time-series Consistency***

Data on the percentage of industrial wastewater treated at CH_4- and N_2O-generating facilities since FY2001 are available only for FY2004. Therefore, data are interpolated and extrapolated for the remaining years. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

No recalculations are conducted.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.2.2. Natural Decomposition of Industrial Wastewater (5.D.2.-)

a) Category Description

Although most of the industrial wastewater in Japan generated in industrial plants and facilities is processed at industrial wastewater treatment plants, treated wastewater which is discharged into public waters contains residual nitrogen. Also, some industrial wastewater is discharged into public waters without any treatment. The CH_4 and N_2O emissions from untreated wastewater decomposing in public waters and the N_2O from treated wastewater are reported under this category.

b) Methodological Issues

- ***Estimation Method***

CH_4 and N_2O emissions from untreated/treated industrial wastewater discharged into public waters are estimated in accordance with the method in the *2006 IPCC Guidelines*, as shown below.

$$E = EF \times A$$

E : Emission of methane or nitrous oxide from the natural decomposition of industrial wastewater [kg-CH_4], [kg-N_2O]

EF : Emission factor [kg-CH_4/kg-BOD], [kg-N_2O/kg-N]

A : Volume of organic matter [kg-BOD] or nitrogen [kg-N] in industrial wastewater

- ***Emission Factor***

As for CH_4 and N_2O emission factors for both of untreated and treated wastewater discharged into public waters, the default values of the *2006 IPCC Guidelines* are applied in a similar way of the category "7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)".

Table 7-106 CH_4 and N_2O emission factors for the category natural decomposition of industrial wastewater

Gas	Unit	Emission factor	Reference
CH_4	kg-CH_4/ kg-BOD	0.06	*2006 IPCC Guidelines*
N_2O	kg-N_2O/ kg-N	0.0079	*2006 IPCC Guidelines*

- ***Activity Data***

Activity data for this category cover 10 middle industrial classification shown on the Table 7-103 of "7.5.2.1. Industrial Wastewater Treatment (5.D.2.-).

- ***Untreated wastewater***

Activity data for this category are defined as a sum up of BOD or TN loadings from industrial plants/facilities which directly discharge untreated wastewater into public waters. The BOD or TN loadings in wastewater from each plant/facility are calculated by multiplying amount of wastewater and BOD or TN concentration in wastewater from each plant/facility, which data are obtained from the *Comprehensive Survey on Water Pollutant Discharge* (MOE).

$$A = \sum_i (V_i \times Q_i)$$

A : Activity data of untreated wastewater (BOD or TN loadings) [kg-BOD/L], [kg-N/L]

V_i : Amount of untreated industrial wastewater discharged into public waters from industrial plant/facility i [m^3]

Q_i : BOD or TN concentration of untreated industrial wastewater discharged from industrial plant/facility i [g-BOD/L], [g-N/L]

Table 7-107 BOD and TN loadings in untreated wastewater discharged into public waters (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
BOD load																
Manufacture of food	kt-BOD	8.0	8.5	9.0	16.3	6.2	5.3	4.3	4.6	5.0	5.3	5.5	5.5	5.5	5.5	5.5
Manufacture of beverages, tobacco and feed	kt-BOD	0.6	0.6	0.6	0.6	0.3	0.3	0.3	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4
Manufacture of textile products	kt-BOD	3.4	2.9	2.2	2.2	4.4	4.8	5.1	3.8	2.5	2.9	3.3	3.3	3.3	3.3	3.3
Manufacture of pulp, paper and paper products	kt-BOD	9.4	8.9	8.9	8.4	3.6	5.3	6.9	5.2	3.4	3.7	4.1	4.1	4.1	4.1	4.1
Manufacture of chemical and allied product	kt-BOD	49.5	50.6	44.9	46.7	28.3	25.9	23.4	25.3	27.2	24.0	20.8	20.8	20.8	20.8	20.8
Manufacture of petroleum and coal products	kt-BOD	25.4	20.8	24.6	26.9	11.3	9.3	8.5	9.8	11.2	10.2	9.1	9.1	9.1	9.1	9.1
Manufacture of plastic products	kt-BOD	0.6	0.6	0.6	0.8	0.7	0.6	0.5	0.6	0.6	0.4	0.1	0.1	0.1	0.1	0.1
Manufacture of rubber products	kt-BOD	0.2	0.1	0.1	0.1	0.1	0.1	0.04	0.1	0.1	0.1	0.04	0.04	0.04	0.04	0.04
Manufacture of leather tanning, leather products and fur skins	kt-BOD	0.3	0.3	0.2	0.1	0.001	0.001	0.001	0.001	0.002	0.001	0.0002	0.0002	0.0002	0.0002	0.0002
Manufacture of iron and steel	kt-BOD	39.7	37.3	40.3	36.5	26.1	22.8	19.1	22.5	26.0	22.2	18.5	18.5	18.5	18.5	18.5
TN load																
Manufacture of food	kt-N	5.0	5.3	5.6	5.3	3.2	3.3	3.3	2.9	2.6	2.5	2.4	2.4	2.4	2.4	2.4
Manufacture of beverages, tobacco and feed	kt-N	0.6	0.6	0.6	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Manufacture of textile products	kt-N	0.8	0.7	0.5	0.4	1.7	1.8	1.8	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Manufacture of pulp, paper and paper products	kt-N	0.7	0.7	0.7	0.5	0.6	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Manufacture of chemical and allied product	kt-N	31.4	32.2	28.5	28.2	21.3	18.3	16.1	15.8	15.5	15.9	16.2	16.2	16.2	16.2	16.2
Manufacture of petroleum and coal products	kt-N	19.6	16.0	18.9	8.8	7.6	7.4	7.2	7.0	6.7	6.5	6.3	6.3	6.3	6.3	6.3
Manufacture of plastic products	kt-N	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.4	0.2	0.1	0.1	0.1	0.1	0.1
Manufacture of rubber products	kt-N	0.3	0.3	0.2	0.3	0.1	0.1	0.1	0.1	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Manufacture of leather tanning, leather products and fur skins	kt-N	0.01	0.01	0.01	0.01	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Manufacture of iron and steel	kt-N	33.3	31.2	33.7	41.8	17.6	16.3	14.9	14.6	14.2	14.7	15.2	15.2	15.2	15.2	15.2

- ***Treated wastewater***

Activity data are defined as a sum up of TN loadings from industrial plants/facilities which discharge treated wastewater into public waters. The TN loadings in wastewater from each plant/facility are calculated by multiplying amount of wastewater and TN concentration for each plant/facility, which data are obtained from the *Comprehensive Survey on Water Pollutant Discharge* (MOE).

$$A = \sum_i (V_i \times TN_i)$$

A	: Activity data of treated wastewater (TN loadings) [kg-N/L]
V_i	: Amount of treated industrial wastewater discharged into public water from industrial plant/facility i [m^3]
TN_i	: TN concentration in treated industrial wastewater discharged from industrial plant/facility i [g-N/L]

Table 7-108 TN loadings in treated industrial wastewater discharged into public waters (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Manufacture of food	kt-N	5.8	6.2	6.5	7.0	4.0	6.0	7.9	6.6	5.3	5.3	5.4	5.4	5.4	5.4	5.4
Manufacture of beverages, tobacco and feed	kt-N	1.1	1.1	1.1	0.7	0.6	0.5	0.5	0.4	0.4	0.7	1.1	1.1	1.1	1.1	1.1
Manufacture of textile products	kt-N	2.5	2.1	1.6	2.1	1.7	1.6	1.5	1.3	1.1	1.2	1.4	1.4	1.4	1.4	1.4
Manufacture of pulp, paper and paper products	kt-N	8.4	8.0	8.0	8.0	5.4	4.6	3.8	4.1	4.4	5.6	6.8	6.8	6.8	6.8	6.8
Manufacture of chemical and allied product	kt-N	17.0	17.4	15.5	14.2	15.9	14.6	13.7	13.2	12.7	11.2	9.7	9.7	9.7	9.7	9.7
Manufacture of petroleum and coal products	kt-N	2.2	1.8	2.1	1.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Manufacture of plastic products	kt-N	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manufacture of rubber products	kt-N	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manufacture of leather tanning, leather products and fur skins	kt-N	0.28	0.23	0.18	0.09	0.04	0.03	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Manufacture of iron and steel	kt-N	5.3	5.0	5.4	4.1	3.1	2.6	2.1	2.4	2.7	2.8	2.9	2.9	2.9	2.9	2.9

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

As for the uncertainties in emission factors for CH_4 and N_2O in this category, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-109.

Table 7-109 Uncertainty assessment for natural decomposition of industrial wastewater on the category "Industrial wastewater (5.D.2.-)"

Item	GHGs	Emission/ removal factor uncertainty		Activity data uncertainty		Emission/ removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Natural decomposition	CH_4	-58%	+58%	-30%	+30%	-66%	+66%	Since the *2006 IPCC Guidelines* provide the emission factors as default value for this category, the uncertainty is assessed in accordance with the default method in the guidelines.	The uncertainty in industrial waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N_2O	-58%	+58%	-30%	+30%	-66%	+66%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in CH_4 is substituted based on expert judgment.		

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

No recalculations are conducted.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.2.3. Landfill Leachate Treatment (5.D.2.-)

a) Category Description

CH_4 and N_2O emissions from landfill leachate treatment in MSW and IW landfill sites are estimated and allocated to "Landfill leachate treatment (5.D.2.-)."

b) Methodological Issues

- ***Estimation Method***

Potential BOD load [kg-BOD] and TN load [kg-N] to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites are applied for its activity data, and the methodology for the natural decomposition of domestic wastewater given in *the 2006 IPCC Guidelines* is applied to estimate CH_4 and N_2O emissions from this source as described below:

$$E = EF \times L_i$$

E	: CH_4 and N_2O emissions
EF	: CH_4 and N_2O emission factor
L_i	: Potential BOD load [kg-BOD] and TN load [kg-N] to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites

- ***Emission Factors***

Emission factors for CH_4 and N_2O are determined in accordance with the methodology for the natural decomposition of domestic wastewater given in the *2006 IPCC Guidelines* as described below.

➢ ***CH_4***

According to the *2006 IPCC Guidelines,* the emission factor for CH_4 is established by multiplying the maximum CH_4 generation potential (B_0) by a CH_4 conversion factor (MCF). The maximum CH_4 generation potential (B_0) is determined to be 0.6 kg-CH_4/kg-BOD which is a default value for "Domestic waste water" given in the *2006 IPCC Guidelines*, and MCF is determined to be 0.8 which is also a default value for "Anaerobic reactor" of "Treated systems" given in the *2006 IPCC Guidelines*.

$$\begin{aligned} EF_{CH4} &= B_0 \times MCF \\ &= 0.6 \quad [\text{kg-CH}_4/\text{kg-BOD}] \quad \times 0.8 \\ &= 0.48 \quad [\text{kg-CH}_4/\text{kg-BOD}] \end{aligned}$$

B_0	: Maximum CH_4 generation potential [kg-CH_4/kg-BOD], (IPCC default value:0.6)
MCF	: CH_4 conversion factor (IPCC default value: 0.8)

➢ ***N_2O***

The emission factor for N_2O is determined from a default value of 0.005 (kg N_2O-N/kg N) given in the *2006 IPCC Guidelines* after unit conversion.

$$EF_{N2O} = 0.005 \ [\text{kg-N}_2\text{O-N/kg-N}] \times 44/28$$
$$= 0.0079 \ [\text{kg-N}_2\text{O /kg-N}]$$

- ***Activity Data***

Based on MOE (2010), the activity data for CH_4 and N_2O emission estimates are determined by establishing the ratio of organic and nitrogen contents to be remained in leachate for the amount of organic waste disposed of in MSW and IW landfill sites to obtain potential BOD load [kg-BOD/year] and TN load [kg-N/year].

➢ ***CH₄***

$$L_{BODi} = F_{BOD} \times W \times T_i$$

L_{BODi} : Potential BOD load to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites [kg-BOD]
F_{BOD} : Ratio of organic contents for the amount of organic waste landfilled [kg-BOD/t] determined to be 0.188 [kg-BOD/t] based on MOE (2010)
W : Amount of organic waste landfilled with or without intermediate treatments including incineration ash [t] obtained by the *Cyclical Use of Waste Report* (MOE)
T_i : Ratio of leachate to be biologically treated in landfill site [%] determined to be 87.6% based on MOE (2010)

➢ ***N₂O***

$$L_{TNi} = F_{TN} \times W \times T_i$$

L_{TNi} : Potential TN load to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites [kg-N]
F_{TN} : Ratio of nitrogen contents for the amount of organic waste landfilled [kg-N/t] determined to be 0.254 [kg-N/t] based on MOE (2010)
W : Amount of organic waste landfilled with or without intermediate treatments including incineration ash [t] obtained by the *Cyclical Use of Waste Report* (MOE)
T_i : Ratio of leachate to be biologically treated in landfill site [%] determined to be 87.6% based on MOE (2010)

Table 7-110 BOD load and TN load of landfill leachate (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
BOD load	kt-BOD	2.6	2.5	2.2	1.6	0.8	0.8	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3
TN load	kt-N	3.5	3.3	3.0	2.2	1.1	1.0	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

As for the uncertainties in emission factors for CH_4 and N_2O in landfill leachate treatment (5.D.2.-), the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-111.

Table 7-111 Uncertainty assessment for landfill leachate treatment on the category "Industrial wastewater (5.D.2.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Landfill leachate treatment	CH_4	-39%	+39%	-100%	+100%	-107%	+107%	The uncertainty is quoted from MOE (2010), a reference of emission factors.	Due to the lack of information for the uncertainty of the activity data, the uncertainty is assessed by expert judgment.	Combined by using the formula for propagation of errors.
	N_2O	-39%	+39%	-100%	+100%	-107%	+107%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in the EF of CH4 in this category is substituted based on expert judgment.		

- ***Time-series Consistency***

As described in detail in the preceding sections, emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By updating the statistical data, emissions in FY2020 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.3. Other (5.D.3)

Since there is no source for CH_4 and N_2O in the category "Wastewater Treatment and Discharge (5.D.)" except for domestic and industrial wastewater, the emissions from category Other (5.D.3) are reported as "NO".

7.6. Other (5.E.)

In this category, CO_2 emissions as a result of the decomposition of fossil-fuel derived surfactants are calculated. Estimated GHG emissions from category "Other" are shown in Table 7-113.

Table 7-112 Categories whose emissions are estimated for Other (5.E.)

Category	Waste type	Treatment type	CO_2	CH_4	N_2O
5.E.1. (7.6.1)	Fossil-fuel Derived Surfactants	Decomposition at wastewater treatment facilities and/or the environment	○	NA	NA

In FY2021, emissions from this source category are 679 kt-CO_2 eq. and accounted for 0.06% of the national total emissions (excluding LULUCF). The emissions from this source category had decreased by 3.4% compared to those in FY1990. This emission decrease is primarily due to the decrease in CO_2 emissions from the use of alkylbenzenes by introduction of the Pollutant Release and Transfer Register (PRTR).

Table 7-113 GHG emissions from category Other (5.E.)

Gas	Category	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	5.E. Other (Decomposition of fossil-fuel derived surfactants)	kt-CO_2	703	668	656	507	527	528	605	617	625	619	637	673	582	597	679

7.6.1. Decomposition of Fossil-fuel Derived Surfactants (5.E.-)

a) Category Description

Surfactants are used for various cleaning activities at home and factories in Japan. Fossil-fuel derived surfactants discharged into wastewater treatment facilities and into the environment, and emit CO_2. As this emission source did not correspond to any of the existing waste categories (5.A. to 5.D.), it is included in the "Other (5.E.)" section. Because "CH_4 and N_2O emissions from wastewater treatment" and "CO_2 emissions from the decomposition of fossil-fuel derived surfactants" concern different types of gas, they are unrelated to each other and pose no duplicate inventory issues.

b) Methodological Issues

- ***Estimation Method***

As neither the *2006 IPCC Guidelines* specified a method for determining CO_2 emissions, a method specifically established in Japan is applied to the calculation. Because carbon contained in surfactants that emitted into wastewater treatment facilities and into the environment is eventually oxidized to CO_2 and emitted into the atmosphere as a result of surfactants decomposition, CO_2 emissions are estimated based on the amount of carbon contained in surfactants that emitted into wastewater treatment facilities and into the environment.

Based on the facts stated above, the CO_2 emissions are calculated by multiplying the volume of the fossil-fuel derived surfactant for each type of raw material by the carbon content of each of the materials. The calculation covered synthetic alcohols, alkylbenzenes, alkylphenols, and ethylene oxide. Some of the carbon contained in surfactants discharged into wastewater treatment facilities are adsorbed and assimilated by sludge. However, this portion of carbon is not decomposed biologically. It is released into the atmosphere as CO_2 through incineration and landfilling of sludge. Therefore, the emission is included in CO_2 emission estimates.

- ***Emission Factor***

Emission factor is determined for each type of material by calculating the amount of CO_2, expressed in kg that is emitted from the decomposition of 1 t of a surfactant using the average carbon content in the molecules.

$$EF_i = CF_i \times 1{,}000 \times 44/12$$

EF_i : Emission factor for fossil-fuel derived raw material *i* used in a surfactant
CF_i : Average carbon content of fossil-fuel derived raw material *i* used in a surfactant

Table 7-114 Average carbon content of surfactants, by fossil-fuel derived raw material

Raw material	Carbon number	Molecular weight	Carbon content	Basis for determination
Synthetic alcohol	12	186	77.4%	C12-alcohol as the main constituent.
Alkylbenzene	18	246	87.8%	C12-alkylbenzene as the main constituent.
Alkylphenol	15	220	81.8%	C9-alkylphenol as the main constituent.
Ethylene oxide	2	44	54.5%	Based on ethylene oxide molecules (C_2H_4O)

- ***Activity Data***

Activity data is the amount of raw materials consumed for fossil-fuel derived surfactants. As some of the surfactants produced in Japan are exported, the activity data are determined by multiplying the volume of raw materials used in the surfactants obtained from the statistical data for surfactant use by an import/export adjustment factor.

➢ ***Volume of Surfactants Used***

The volumes of the use of surfactant by material are obtained from the consumption of raw materials for surfactants indicated in the *Current Production Statistics - Chemical Industry*. As there is no compilation of usage since FY2002, the volume of use is estimated using the simple averages (k value) of ratio of consumption and production in the period from FY1990 to FY2001.

➢ ***Export/import Correction Factor***

Correction factor is calculated from the export/import statistics in *International Trade Statistics* by the Ministry of Finance (MOF) for categories of anionic surfactants, cationic surfactants, non-ionic surfactants, and other organic surfactants and the volume of surfactants used. As some of the materials for surfactants are used in several types of surfactants, an average of the export/import correction factor is weighted by surfactant production volume as necessary to calculate the correction factor for each classification of surfactant.

$$F_{corr.} = (P + I - E)/P$$

$F_{corr.}$: Export/Import correction factor
P : Surfactant production [t]
I : Surfactant imported [t]
E : Surfactant exported [t]

Table 7-115 Activity data associated with decomposition of fossil-fuel derived surfactants

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Synthetic alcohol	t	29,239	16,253	28,285	31,609	33,750	36,193	43,324	42,947	44,299	45,551	45,601	47,840	43,762	48,057	53,151
Alkyl benzene	t	105,432	102,794	80,832	47,349	50,519	44,502	44,980	47,494	44,044	39,485	42,769	44,565	31,291	25,309	26,984
Alkyl phenol	t	10,141	8,798	7,454	3,448	2,054	2,910	4,318	4,885	4,873	4,638	5,661	6,211	4,711	3,677	4,363
Ethylene oxide	t	124,984	132,175	146,509	127,150	131,148	136,679	161,969	163,777	171,380	174,243	176,247	187,729	171,687	184,127	214,129

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty in emission factor for CO_2 is evaluated by using molecular weight which is used for calculation of emission factors, based on expert judgment. As for activity data, the same assessment as municipal waste statistics is applied based on expert judgment since information on the uncertainty is not available.

Table 7-116 Uncertainty assessment for decomposition of fossil-fuel derived surfactants on the category "Other (5.E.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Decomposition of fossil-fuel derived surfactants	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	The uncertainty is assessed by using molecular weight data based on expert judgment.	Due to the lack of information for the uncertainty of the activity data, the uncertainty in municipal waste statistics is substituted by expert judgment.	Combined by using the formula for propagation of errors.

- ***Time-series Consistency***

Consistent methodology is used in the estimation. However, data on the amount of raw materials consumed for surfactants have become not available since FY2002 and activity data are estimated from the production amount of the surfactants.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

By revising the statistical data, emissions in FY2020 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

References

1. ASTM International, *Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis*, ASTM D6866-20, 2020.
2. IPCC, *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, 1997.
3. IPCC, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, 2000.
4. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
5. IPCC, *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2019
6. Environmental Agency, *The Report on Estimation of CO_2 Emissions in Japan*, 1992.
7. Environmental Agency, *General Survey of Emissions of Air Pollutants*, 1995.
8. Environmental Agency, Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 2*, 2000.
9. Ministry of the Environment, Study Group for Proper Management of RDF, *Proper Management of Refuse-derived Fuels,* 2003.
10. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 1*, 2006a.
11. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 4*, 2006b.
12. Ministry of the Environment, Waste Management and Recycling Department, *Manual on biogas facilities maintenance,* 2008.
13. Ministry of the Environment, Waste Management and Recycling Department, *Self-management manual for Johkasou to promote aquatic conservation*, 2009.
14. Ministry of the Environment, *FY2009, Report on Survey Study on Improving the Accuracy of Emission Factors for Greenhouse Gas Emissions from the Waste Sector,* 2010.
15. Ministry of the Environment, Waste Management and Recycling Department, *FY2009 and FY2010, report on the survey for the estimation of GHG emissions from specially-controlled industrial waste*, 2010-2011.
16. Ministry of the Environment, *FY2011, Survey and Studies for the Development of Emission Factor for the preparation for the National Greenhouse Gas Inventory,* 2012.
17. Ministry of the Environment, *The guideline of uncertainty assessment for National GHG inventories* 2013a.
18. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *FY2012, Review of Greenhouse Gases Emissions Estimation Methods, Waste Sector, Part 2*, 2013b.
19. Ministry of the Environment, *FY2012, Survey and Studies for the Development of Emission Factor for the Decentralized Commercial Wastewater Treatment for the National Greenhouse Gas Inventory,* 2013c.
20. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *FY2014, Review of Greenhouse Gases Emissions Estimation Methods, Waste Sector, Part 2*, 2015.
21. Ministry of the Environment, *Survey for the Development of Emission Factor to Estimate Effect of the Mitigation Measures for GHG Emissions from the Waste Sector*, 2018a.
22. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods, Waste Sector, Part 2*, 2018b.
23. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Guidelines for recycling of used disposable diapers*, 2020a.
24. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *FY2020, Review of Greenhouse Gases Emissions Estimation Methods, Waste Sector, Part 1*, 2020b.
25. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *FY2020, Review of Greenhouse Gases Emissions Estimation Methods, Waste Sector, Part 2*, 2021.
26. Ministry of the Environment, *the Annual Report on the Environment in Japan*, 2022.

27. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Waste Treatment in Japan.*
28. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *The state of municipal waste treatment survey.*
29. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Report of the research on the state of wide-range movement and cyclical use of wastes (the volume on cyclical use).*
30. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics*.
31. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Study on Residual Amounts of Industrial Waste from Illegal Dumping and other Sources.*
32. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Annual Recycling Statistics under the Plastic Containers and Packaging Recycling Law.*
33. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Survey of guidance promotion of Johkasou*.
34. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, the *Survey of Industrial Waste Treatment Facilities.*
35. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, Report on the *state of Industrial Waste generation and Treatment survey.*
36. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Report on Survey of Organizations in Industrial Waste Administration.*
37. Ministry of the Environment, Water and Air Environment Bureau, *Study on the Control of Wastewater Loading*.
38. Ministry of the Environment, Water and Air Environment Bureau, *Comprehensive Survey on Water Pollutant Discharge.*
39. Ministry of Health, Labour and Welfare, Water Supply Division, Health Service Bureau, *Report on Survey of Organizations in Industrial Waste Administration*, 1995 – 1999.
40. Ministry of Health, Labour and Welfare, *Status report of Long-Term Care Insurance System.*
41. Ministry of Internal Affairs and Communications, *Current Population Estimates.*
42. Ministry of Land, Infrastructure, Transport and Tourism, *Manual for Developing Plans for Biosolids Utilization (Draft)*, 2003.
43. Ministry of Economy, Trade and Industry, *Table of Industrial Statistics - Land and Water.*
44. Ministry of Economy, Trade and Industry, *Current Production Statistics - Chemical Industry.*
45. Ministry of Economy, Trade and Industry, *Yearbook of Textile and Consumer Goods Statistics.*
46. Ministry of Economy, Trade and Industry, *Survey of generation status of industry-specific by-products (industrial waste and recyclable waste).*
47. Agency for Natural Resources and Energy, *General Energy Statistics.*
48. Ministry of Finance, *Trade statistics of Japan.*
49. Ishikawa Prefecture, City of Osaka, Kanagawa Prefecture, City of Kyoto, City of Kobe, Niigata Prefecture, Hiroshima Prefecture, Hyogo Prefecture, Fukuoka Prefecture, Hokkaido, *Survey of Compilation of Emission Units of Greenhouse Gas from Stationary Sources*, 1991-1997.
50. Ishikawa Prefecture, City of Osaka, Kanagawa Prefecture, City of Kyoto, Hiroshima Prefecture, *Hyogo Prefecture, Survey of Compilation of Emission Units of Greenhouse Gas from Stationary Sources*, 1991-1999.
51. Hyogo Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1994.
52. Hyogo Prefecture, *Hyogo Eco-town project*, 2003.
53. Kanagawa Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1994.
54. Ministry of Land, Infrastructure, Transport and Tourism, National Institute for Land and Infrastructure Management, *2000 Annual Report of Investigation and Research for Sewer*, NILIM Report 10: pp93-96, 2001.

55. Ministry of Land, Infrastructure, Transport and Tourism, National Institute for Land and Infrastructure Management, *2001 Annual Report of Investigation and Research for Sewer*, NILIM Report 64: pp119-122, 2002.
56. Japan Containers and Packaging Recycling Association, *Statistics of Commercial Recycling of Plastic (Recycling)*.
57. Japan Environmental Sanitation Center, *Basic Waste Data* (Fact Book 2000), 2001.
58. Japan Environmental Sanitation Center, *Report of Analytical Survey of Methane Emissions*, FY1989 Commissioned by the Environmental Agency.
59. Tokyo Environmental Public Service Corporation, *Nitrogen in effluent in waterside environment; development of small scale Gappei-shori johkasou with denitrification process*, Tokyo Metropolitan Research Institute for Environmental Protection News, No. 7, 1996
60. Japan Business Federation, *Follow-up Action Result of the Voluntary Action Plan on the Environment*.
61. Japan Iron and Steel Federation, *Current State of Approaches to Global Warming Countermeasures – Report on the Action Plan for Carbon Neutral.*
62. Japan Cement Association, *Cement Handbook.*
63. Japan Automobile Tire Manufacturers Association, *Tire Industry of Japan.*
64. Japan Hygiene Products Industry Association, *JHPIA news*.
65. Japan Livestock Technology Association, *Controlling the Generation of Greenhouse Gases in the Livestock Industry*, 2002.
66. Japan Lubricating Oil Society, *Lubricant Recycle Handbook*.
67. Japan Sewage Works Association, *Guidelines and Analysis of Comprehensive Planning Surveys for the Provision of Water Mains, Catchment Area* 1999 Edition, 1999.
68. Japan Water Works Association, *Guidelines and Explanation of Sewerage Facility Design, Japan Sewage Works Association*, 2009.
69. Japan Sewage Works Association, *Waterworks Annual editions of Sewage Statistics (Admin. Ed.).*
70. Japan Water Works Association, *Waterworks Statistics.*
71. Japan Association of Rural Resource Recycling Solutions, *JARUS Reference System for Information of Biomass Recycling Technology.*
72. Japan Chemical Fibers Association, *Textile Handbook.*
73. Japan Society of Waste Management Experts, *Waste Handbook*, 1997.
74. Japan Society for Atmospheric Environment, *Method of Estimating Greenhouse Gas Emissions-Survey Report*, 1996.
75. The Council for PET Bottle Recycling, *Annual Report on PET Bottle Recycling.*
76. Fujimoto, M., *Survey study on recycle by mud of sewage*, Snow Management & Construction Technology Research Center of Fukui Pref.- Annual Report, 2002.
77. Fujishima, Y., Kitagawa, K., Nakamura, S. & Kizu, R., *Establishment of Zero-emission Processing Technology for Organic Sludge by Multistage Distillation-Chemical Analysis of Sewage Sludge*, Industrial Research Institute of Ishikawa Research Report, FY2004.
78. Ike, M. & Soda, S., *B-071, Estimation on Carbon and Nitrogen Flows and* CH_4 *and* N_2O *Reduction of Wastewater Stream in Japan, FY2010 Global Environment Research Fund*, 2010.
79. Ito, K., *A Study on Estimating Amounts of Landfill Gas*, Metropolitan Tokyo Sanitation Engineering Journal No. 18, 1992.
80. Ueno, H., Tatsuichi, S. & Iwasaki, Y., *Review of Causes of Emissions of Nitrous Oxide and Methane from Waste Incinerators,* Annual Report of the Tokyo Metropolitan Research Institute for Environmental Protection, 1992.
81. Nakamura, T., Yasuda, K., Tadokoro, M. & Sakurai, T., *Emission of Nitrous Oxide from Incineration of Sewage Sludge*, Proceedings of the 20th Japan Urban Cleaning Research Conference, pp391-393, 1998.
82. Matsubara, M. & Mizuochi, M., *Survey of Emissions of Nitrous Oxide from Sewage Treatment Plants*, Environmental and Sanitary Engineering Research, 8(3), 1994.

83. Okazaki, T., Shimizu, T. & Morita, A.,*Study of Operation Records Based on Precision Function Inspection of Human Waste Management Plant*, Japan Environmental Sanitation Center Report 28, 2001.
84. Omura, T., Kawakubo, Y. & Yamada, M., *Study of Emission Factors for N_2O from High-load Human Waste Management*, Journal of Waste Management 57, 260, 2004.
85. Oshima, Y. & Kawai, T., *Technical Note of PWRI Number 2509, Survey Study on Sewage Sludge Fuel Conversion, Annual Report of Sewage Works Research 1986, Public Works Research Institute* (PRWI), 1986.
86. Seki, K., *Current Condition of New Solid Fuel and New Technology C-RPF,* Environment Management, 40(8), 2004.
87. Suzuki, Y., Ochi, S. & Miyata, K., *Continuous Measurement of Nitrous Oxide Emissions from Sewage Sludge Flux Furnaces*, Proceedings of the 11th Environmental Engineering Symposium 2001, pp387-390, 2001.
88. Takeishi, K., Watanabe, H., Matsubara, M., Sato, K., Maebashi, R., Tanaka, T., Sampa, H., Wakasugi, Y. & Yamashita, K., *Report on Joint Research into the Behavior and Reduction of Waste Gas Components in Flux Furnaces,* Public Works Research Institute, Ministry of Construction and Nagoya City Water Authority, 1994.
89. Takeishi, K., Watanabe, H., Matsubara, M., Hirayama, T., Maebashi, R., Koma, A., Wakasugi, Y. & Yoshikawa, K., *Report on Joint Research into the Behavior and Reduction of Waste Gas Components in Flux Furnaces*, Public Works Research Institute, Ministry of Construction and Nagoya City Water Authority, 1996.
90. Tanaka, N., Adachi, T., Seno, S. & Yoshida, A., *Components of Sewage Sludge, Tohoku Agriculture Research*, National Agricultural Research Center for Tohoku Region Research Report, 27, 1980.
91. Tanaka, M., Inoue, Y., Matsuzawa, Y., Osako, M. & Watanabe, I., *B-2(1) Research into Volumes Released from Waste Treatment Plants*, 1994 Global Environment Research Fund Outcome Report, 1995.
92. Tanaka, M., Inoue, Y., Osako, M., Yamada, M. & Watanabe, I., *B-16(7) Research into Limiting Generation of Methane and Nitrous Oxide from the Waste Sector*, FY1997 Global Environment Research Fund Outcome Report, 1998.
93. Tanaka, M., *Outline of waste management*, Maruzen, 1998.
94. Ueno, H., Tatsuichi, S. & Ooiwakawa, Y., *Review of Measures to Reduce Nitrous Oxide in Sewage Treatment Plants*, Tokyo Metropolitan Research Institute for Environmental Protection, 1995.
95. Yasuda, K., Takahashi, M., Yajima, I. & Kaneko, M., *Behavior of Nitrous Oxide Emissions Associated With Incineration of Sewage Sludge,* Journal of Japan Society of Waste Management Experts Vol. 5, No. 4, 1994.

Chapter 8. Other

8.1. Overview of Sector

UNFCCC Reporting Guidelines (Decision 24/CP.19) paragraph 38 indicates that Annex I Parties should report and explicitly describe the details of each country-specific source or sink which are not part of the *IPCC Guidelines*. According to this requirement, emissions from the Other sector (CRF sector 6) are indicated below.

8.2. CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3

Among CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3, no emissions or removals are reported in the Other sector.

8.3. NO_x, CO, NMVOC, and SO_x

Among precursors (NO_x, CO, NMVOC) and SO_x, CO and NMVOC emissions from smoking are reported in the Other sector (see Annex 3).

Chapter 9. Indirect CO_2 and N_2O Emissions

9.1. Overview of Sector

a) Category Description

Since Parties may now choose to report indirect CO_2, in accordance with paragraph 29 of the UNFCCC Inventory Reporting Guidelines, and since the estimation method reflecting Japan's actual status has been established, Japan elects to report indirect CO_2 emissions from the atmospheric oxidation of CH_4, CO, and NMVOCs, and not to report indirect N_2O emissions arising from sources other than those in the agriculture and LULUCF sectors.

Indirect CO_2 emissions originating from the use and/or evaporation of NMVOCs and CH_4 from the sectors/categories indicated in Table 9-1 are estimated. Other than evaporation of CH_4 and NMVOCs, CH_4, CO, and NMVOCs originating from fuel combustion, evaporative fuel emissions from vehicles[1], and CH_4, CO, and NMVOCs from the incineration of fossil-fuel derived waste are oxidized to CO_2 in the atmosphere; these indirect CO_2 emissions are not reported, because these emissions are included in CO_2 emissions from fuel combustion (1.A.), and CO_2 emissions from waste incineration and open burning (5.C.) [2], respectively. Indirect CO_2 emissions originating from biogenic CH_4, CO, and NMVOC emissions were not reported from the viewpoint of avoiding double-counting, in accordance with the *2006 IPCC Guidelines*.

Table 9-1 Sector/Category of indirect CO_2

Sector/Category	Originated from CH_4	Originated from CO	Originated from NMVOCs
1.B Fugitive emissions from Fuels	○	NE, NO	○
2. Industrial processes and product use	○	NE	○

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions occurring from the oxidation of evaporative NMVOCs and CH_4 in the atmosphere are estimated with the following conversion formulae which are mentioned in the *2006 IPCC Guidelines*;

$$E_{CO2} = E_{CH4} \times \frac{44}{16}$$

$$E_{CO2} = E_{NMVOC} \times C \times \frac{44}{12}$$

E_{CO2} : Indirect CO_2 emissions [kt]

E_{CH4} : CH_4 emissions [kt]

E_{NMVOC}: NMVOC emissions [kt]

C : Average carbon content of NMVOCs for each source

[1] Emissions are reported in 1.A.3. Transport.

[2] Japan assumes 100% oxidation during the combustion of fuel in 1.A. Fuel combustion and in 5.C. Waste incineration and open burning.

- ***Parameters***

The average carbon content of NMVOCs is calculated by weighting it by the composition ratio of each NMVOC substance emitted from each source. The carbon contents of each substance are obtained from molecular formulae, and the type of substance and composition ratio of NMVOCs were estimated based on the national emission inventory for volatile organic compounds (VOC) by the Ministry of Environment and other information. The average carbon content is calculated for each emission source. They are set for each year until FY2020, and the FY2020 value is applied for years FY2021 and onward.

- ***Activity Data***

Refer to Chapter 3 for information on CH_4 emissions from fugitive emissions from fuels (1.B.). Refer to Chapter 4 for information on CH_4 emissions from the chemical industry (2.B.) and metal industry (2.C.). Refer to Annex 3 for information on emissions from carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs).

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

Refer to Annex 2.

- ***Time-series Consistency***

For average carbon content of NMVOCs, the composition for each substance is calculated using statistics which are consistent throughout the time-series. Refer to the relevant chapter for activity data.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
2. UNFCCC, *Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention*, Decision 24/CP.19, FCCC/CP/2013/10/Add.3, 2014.
3. Ministry of the Environment, *The national emission inventory for volatile organic compounds (VOCs).*

Chapter 10. Recalculation and Improvements

10.1. Explanations and Justifications for Recalculations

This section explains improvements on estimation of emissions and removals in the inventory submitted in 2023.

In accordance with the *UNFCCC Reporting Guidelines* and the *2006 IPCC Guidelines*, Annex I Parties should recalculate their inventories for the base year and all subsequent years of the times series in the cases of 1) application of new estimation methods, 2) addition of new categories for emissions and removals, and 3) data refinement. Major changes from the previous inventory are indicated below.

10.1.1. General Issues

As Japan's own specific circumstance, it can generally be said that activity data for the latest year available at the time when the inventory is compiled are often revised in the year following the submission year because of such as the publication of data in the fiscal year basis. In the national inventory submitted this year, activity data in many sources for FY2020 have been changed and as a result, the emissions from those sources for the inventory year have been recalculated.

10.1.2. Recalculations in Each Sector

The information of recalculation for sectors (energy; industrial processes and product use; agriculture; land use, land-use change and forestry; and waste), occurring due to Japan's own specific circumstance and needs, is described separately under sections named as "Category-specific Recalculations" in Chapters 3 to 7.

10.2. Implications for Emission Levels

The following shows the changes made to the overall emission estimates due to the recalculations indicated in "Section 10.1. Explanations and Justifications for Recalculations".

10.2.1. GHG Inventory

Compared to the values reported in the previous year's inventory, total emissions (excluding the LULUCF sector, and including indirect CO_2) in the base year (FY 1990) under the UNFCCC decreased by 0.05%, and the total emissions in year FY 2020 decreased by 0.29% (Table 10-1).

Comparisons with the previous year's inventory for each sector, by category and by gas are as shown in Table 10-2 to Table 10-6. See each category for details on the reasons of recalculations.

Table 10-1 Comparison of emissions and removals in the inventories submitted in 2022 and 2023

[Mt-CO_2 eq.]

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2	JNGI 2022	1,092.5	1,096.1	1,102.4	1,092.1	1,147.4	1,160.4	1,168.7	1,160.4	1,120.4	1,157.9	1,179.6	1,164.4	1,192.0	1,189.6	1,188.6
with LULUCF	JNGI 2023	1,092.9	1,095.8	1,101.9	1,091.6	1,146.9	1,159.6	1,168.3	1,160.0	1,119.8	1,157.2	1,178.8	1,163.6	1,191.4	1,188.4	1,187.3
(excl. Indirect CO_2)	*difference*	*0.04%*	*-0.03%*	*-0.04%*	*-0.04%*	*-0.04%*	*-0.07%*	*-0.03%*	*-0.03%*	*-0.06%*	*-0.06%*	*-0.07%*	*-0.07%*	*-0.05%*	*-0.10%*	*-0.11%*
CO_2	JNGI 2022	1,158.1	1,169.8	1,179.5	1,172.5	1,227.5	1,239.9	1,252.4	1,245.1	1,205.2	1,241.8	1,264.6	1,250.0	1,279.4	1,287.7	1,283.1
without LULUCF	JNGI 2023	1,157.2	1,168.9	1,178.7	1,171.7	1,226.7	1,239.0	1,251.5	1,244.3	1,204.4	1,241.0	1,263.8	1,249.2	1,278.8	1,287.3	1,282.7
(excl. Indirect CO_2)	*difference*	*-0.08%*	*-0.08%*	*-0.07%*	*-0.07%*	*-0.07%*	*-0.07%*	*-0.07%*	*-0.07%*	*-0.07%*	*-0.06%*	*-0.07%*	*-0.07%*	*-0.04%*	*-0.03%*	*-0.03%*
CH_4	JNGI 2022	44.2	43.6	43.6	42.8	42.9	41.8	40.6	40.2	38.6	38.3	37.7	36.6	35.9	35.0	34.8
with LULUCF	JNGI 2023	44.6	44.0	43.9	43.0	43.1	41.9	40.6	40.1	38.4	38.0	37.4	36.2	35.4	34.5	34.2
	difference	*1.09%*	*0.98%*	*0.81%*	*0.64%*	*0.42%*	*0.20%*	*0.00%*	*-0.20%*	*-0.45%*	*-0.69%*	*-0.91%*	*-1.17%*	*-1.40%*	*-1.62%*	*-1.79%*
CH_4	JNGI 2022	44.1	43.5	43.5	42.6	42.8	41.7	40.5	40.1	38.5	38.2	37.6	36.5	35.8	34.9	34.7
without LULUCF	JNGI 2023	44.5	43.9	43.8	42.9	42.9	41.8	40.5	40.0	38.3	37.9	37.3	36.1	35.3	34.4	34.1
	difference	*1.10%*	*0.98%*	*0.81%*	*0.64%*	*0.43%*	*0.21%*	*0.01%*	*-0.20%*	*-0.45%*	*-0.68%*	*-0.91%*	*-1.17%*	*-1.40%*	*-1.62%*	*-1.79%*
N_2O	JNGI 2022	32.6	32.3	32.4	32.3	33.6	33.8	34.9	35.7	34.2	28.0	30.6	26.9	26.3	26.2	26.0
with LULUCF	JNGI 2023	33.2	32.8	33.0	32.8	34.0	34.3	35.4	36.2	34.6	28.4	31.0	27.3	26.7	26.6	26.4
	difference	*1.78%*	*1.75%*	*1.65%*	*1.65%*	*1.42%*	*1.38%*	*1.30%*	*1.25%*	*1.28%*	*1.51%*	*1.29%*	*1.41%*	*1.38%*	*1.40%*	*1.31%*
N_2O	JNGI 2022	32.4	32.0	32.2	32.1	33.3	33.6	34.7	35.5	33.9	27.8	30.3	26.7	26.1	26.0	25.8
without LULUCF	JNGI 2023	32.2	31.9	32.1	32.0	33.2	33.5	34.6	35.4	33.8	27.7	30.2	26.6	26.0	25.8	25.7
	difference	*-0.43%*	*-0.41%*	*-0.44%*	*-0.37%*	*-0.45%*	*-0.42%*	*-0.42%*	*-0.41%*	*-0.43%*	*-0.54%*	*-0.54%*	*-0.61%*	*-0.63%*	*-0.57%*	*-0.61%*
HFCs	JNGI 2022	15.9	17.3	17.8	18.1	21.1	25.2	24.6	24.4	23.7	24.4	22.9	19.5	16.2	16.2	12.4
	JNGI 2023	15.9	17.4	17.8	18.1	21.1	25.2	24.6	24.4	23.7	24.4	22.9	19.5	16.2	16.2	12.4
	difference	*0.05%*	*0.04%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.01%*	*0.00%*	*-0.02%*
PFCs	JNGI 2022	6.5	7.5	7.6	10.9	13.4	17.7	18.3	20.0	16.6	13.1	11.9	9.9	9.2	8.9	9.2
	JNGI 2023	6.6	7.5	7.6	11.0	13.5	17.7	18.3	20.1	16.6	13.2	11.9	9.9	9.2	8.9	9.2
	difference	*0.25%*	*0.20%*	*0.16%*	*0.11%*	*0.09%*	*0.08%*	*0.07%*	*0.08%*	*0.10%*	*0.12%*	*0.14%*	*0.12%*	*0.13%*	*0.12%*	*0.12%*
SF_6	JNGI 2022	12.9	14.2	15.6	15.7	15.0	16.4	17.0	14.5	13.2	9.2	7.0	6.1	5.7	5.4	5.3
	JNGI 2023	12.9	14.2	15.6	15.7	15.0	16.4	17.0	14.5	13.2	9.2	7.0	6.1	5.7	5.4	5.3
	difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
NF_3	JNGI 2022	0.03	0.03	0.03	0.04	0.08	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5
	JNGI 2023	0.03	0.03	0.03	0.04	0.08	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5
	difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Indirect CO_2	JNGI 2022	5.5	5.4	5.1	4.9	4.9	4.8	4.8	4.6	4.2	4.2	4.3	3.9	3.6	3.4	3.4
	JNGI 2023	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.5	4.2	4.2	4.2	3.8	3.6	3.4	3.3
	difference	*-1.21%*	*-1.31%*	*-1.43%*	*-1.74%*	*-1.73%*	*-1.76%*	*-1.66%*	*-1.83%*	*-1.80%*	*-1.81%*	*-1.70%*	*-1.63%*	*-1.30%*	*-1.08%*	*-0.69%*
Total	JNGI 2022	1,269.9	1,284.4	1,296.2	1,292.0	1,353.2	1,374.7	1,387.8	1,379.9	1,331.4	1,354.8	1,374.6	1,349.0	1,372.8	1,379.6	1,371.0
without LULUCF	JNGI 2023	1,269.3	1,283.8	1,295.6	1,291.4	1,352.4	1,373.8	1,386.7	1,378.8	1,330.3	1,353.7	1,373.3	1,347.6	1,371.6	1,378.5	1,369.8
excl. Indirect CO_2	*difference*	*-0.04%*	*-0.04%*	*-0.05%*	*-0.05%*	*-0.06%*	*-0.07%*	*-0.07%*	*-0.08%*	*-0.09%*	*-0.09%*	*-0.10%*	*-0.10%*	*-0.09%*	*-0.08%*	*-0.08%*
Total	JNGI 2022	1,204.6	1,211.0	1,219.4	1,211.9	1,273.4	1,295.5	1,304.4	1,295.5	1,246.9	1,271.2	1,289.9	1,263.7	1,285.8	1,281.8	1,276.8
with LULUCF	JNGI 2023	1,206.1	1,211.7	1,219.8	1,212.4	1,273.6	1,295.3	1,304.5	1,295.5	1,246.6	1,270.7	1,289.2	1,262.8	1,285.1	1,280.4	1,275.2
excl. Indirect CO_2	*difference*	*0.12%*	*0.06%*	*0.03%*	*0.03%*	*0.01%*	*-0.02%*	*0.01%*	*0.00%*	*-0.03%*	*-0.04%*	*-0.06%*	*-0.07%*	*-0.06%*	*-0.11%*	*-0.12%*
Total	JNGI 2022	1,275.4	1,289.7	1,301.3	1,296.9	1,358.1	1,379.5	1,392.6	1,384.5	1,335.7	1,359.1	1,378.9	1,352.8	1,376.4	1,383.0	1,374.4
without LULUCF	JNGI 2023	1,274.8	1,289.1	1,300.6	1,296.2	1,357.2	1,378.5	1,391.5	1,383.4	1,334.5	1,357.8	1,377.5	1,351.4	1,375.2	1,381.9	1,373.2
incl. Indirect CO_2	*difference*	*-0.05%*	*-0.05%*	*-0.05%*	*-0.06%*	*-0.06%*	*-0.07%*	*-0.08%*	*-0.08%*	*-0.09%*	*-0.09%*	*-0.10%*	*-0.11%*	*-0.09%*	*-0.08%*	*-0.09%*
Total	JNGI 2022	1,210.1	1,216.4	1,224.5	1,216.8	1,278.3	1,300.3	1,309.2	1,300.1	1,251.2	1,275.4	1,294.3	1,267.6	1,289.4	1,285.3	1,280.2
with LULUCF	JNGI 2023	1,211.5	1,217.0	1,224.9	1,217.1	1,278.4	1,299.9	1,309.2	1,300.1	1,250.7	1,274.8	1,293.5	1,266.6	1,288.7	1,283.8	1,278.5
incl. Indirect CO_2	*difference*	*0.12%*	*0.05%*	*0.03%*	*0.03%*	*0.01%*	*-0.03%*	*0.00%*	*0.00%*	*-0.03%*	*-0.04%*	*-0.06%*	*-0.07%*	*-0.06%*	*-0.11%*	*-0.13%*

		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CO_2	JNGI 2022	1,201.6	1,183.3	1,223.5	1,163.4	1,097.4	1,144.9	1,196.7	1,235.8	1,252.3	1,203.2	1,166.9	1,151.3	1,131.7	1,087.4	1,054.8	989.9
with LULUCF	JNGI 2023	1,200.5	1,182.4	1,222.2	1,161.2	1,095.4	1,143.2	1,194.9	1,233.4	1,250.0	1,201.8	1,166.5	1,149.7	1,130.0	1,085.4	1,053.4	987.7
(excl. Indirect CO_2)	*difference*	*-0.09%*	*-0.07%*	*-0.10%*	*-0.19%*	*-0.19%*	*-0.15%*	*-0.15%*	*-0.19%*	*-0.19%*	*-0.12%*	*-0.03%*	*-0.14%*	*-0.15%*	*-0.19%*	*-0.13%*	*-0.22%*
CO_2	JNGI 2022	1,290.6	1,267.6	1,303.4	1,232.5	1,163.4	1,215.1	1,265.0	1,306.2	1,315.6	1,264.4	1,223.6	1,203.9	1,188.4	1,143.4	1,106.0	1,042.2
without LULUCF	JNGI 2023	1,290.1	1,267.1	1,302.8	1,232.0	1,163.1	1,214.7	1,264.6	1,305.9	1,315.2	1,264.1	1,223.2	1,202.5	1,186.8	1,141.7	1,104.5	1,039.8
(excl. Indirect CO_2)	*difference*	*-0.04%*	*-0.04%*	*-0.04%*	*-0.04%*	*-0.03%*	*-0.03%*	*-0.03%*	*-0.02%*	*-0.03%*	*-0.03%*	*-0.04%*	*-0.12%*	*-0.13%*	*-0.15%*	*-0.13%*	*-0.23%*
CH_4	JNGI 2022	34.8	34.3	33.7	33.0	32.5	32.1	30.9	30.2	30.2	29.7	29.3	29.3	29.1	28.7	28.5	28.5
with LULUCF	JNGI 2023	34.1	33.6	32.9	32.2	31.6	31.2	29.9	29.3	29.2	28.7	28.3	28.3	28.1	27.7	27.6	27.4
	difference	*-1.97%*	*-2.19%*	*-2.39%*	*-2.59%*	*-2.74%*	*-2.84%*	*-3.00%*	*-3.11%*	*-3.15%*	*-3.21%*	*-3.35%*	*-3.34%*	*-3.36%*	*-3.46%*	*-3.47%*	*-3.56%*
CH_4	JNGI 2022	34.7	34.2	33.7	32.9	32.4	32.0	30.8	30.1	30.1	29.6	29.3	29.2	29.0	28.7	28.5	28.4
without LULUCF	JNGI 2023	34.1	33.5	32.9	32.1	31.5	31.1	29.9	29.2	29.1	28.6	28.3	28.2	28.0	27.7	27.5	27.4
	difference	*-1.97%*	*-2.19%*	*-2.39%*	*-2.60%*	*-2.75%*	*-2.84%*	*-3.01%*	*-3.11%*	*-3.16%*	*-3.22%*	*-3.36%*	*-3.35%*	*-3.37%*	*-3.47%*	*-3.48%*	*-3.57%*
N_2O	JNGI 2022	25.7	25.6	25.0	24.1	23.5	23.0	22.6	22.3	22.2	21.8	21.5	21.0	21.3	20.8	20.5	20.2
with LULUCF	JNGI 2023	26.0	25.9	25.3	24.4	23.8	23.3	22.9	22.5	22.4	21.9	21.6	21.1	21.3	20.8	20.4	20.1
	difference	*1.27%*	*1.24%*	*1.18%*	*1.14%*	*1.12%*	*1.07%*	*0.93%*	*0.74%*	*0.57%*	*0.47%*	*0.35%*	*0.28%*	*0.19%*	*0.13%*	*-0.21%*	*-0.55%*
N_2O	JNGI 2022	25.5	25.4	24.8	23.9	23.3	22.8	22.5	22.1	22.0	21.6	21.3	20.8	21.1	20.6	20.3	20.0
without LULUCF	JNGI 2023	25.3	25.2	24.7	23.8	23.2	22.7	22.3	22.0	21.9	21.5	21.2	20.6	20.9	20.4	20.0	19.7
	difference	*-0.59%*	*-0.53%*	*-0.56%*	*-0.57%*	*-0.51%*	*-0.49%*	*-0.52%*	*-0.60%*	*-0.67%*	*-0.71%*	*-0.77%*	*-0.79%*	*-0.81%*	*-0.85%*	*-1.19%*	*-1.53%*
HFCs	JNGI 2022	12.8	14.6	16.7	19.3	20.9	23.3	26.1	29.4	32.1	35.8	39.3	42.6	45.0	47.0	49.7	51.7
	JNGI 2023	12.8	14.6	16.7	19.3	20.9	23.3	26.1	29.4	32.1	35.8	39.3	42.6	45.0	47.1	50.0	52.2
	difference	*-0.04%*	*-0.03%*	*-0.03%*	*-0.18%*	*-0.07%*	*0.02%*	*0.02%*	*0.02%*	*0.03%*	*0.01%*	*0.01%*	*0.01%*	*0.00%*	*0.09%*	*0.47%*	*0.94%*
PFCs	JNGI 2022	8.6	9.0	7.9	5.8	4.1	4.3	3.8	3.4	3.3	3.4	3.3	3.4	3.5	3.5	3.4	3.5
	JNGI 2023	8.6	9.0	7.9	5.8	4.1	4.3	3.8	3.5	3.3	3.4	3.3	3.4	3.5	3.5	3.4	3.5
	difference	*0.13%*	*0.12%*	*0.14%*	*0.18%*	*0.18%*	*0.19%*	*0.20%*	*0.22%*	*0.18%*	*0.18%*	*0.18%*	*0.19%*	*0.16%*	*0.39%*	*0.62%*	*0.76%*
SF_6	JNGI 2022	5.0	5.2	4.7	4.2	2.4	2.4	2.2	2.2	2.1	2.0	2.1	2.2	2.1	2.1	2.0	2.0
	JNGI 2023	5.0	5.2	4.7	4.2	2.4	2.4	2.2	2.2	2.1	2.0	2.1	2.2	2.1	2.1	2.0	2.0
	difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
NF_3	JNGI 2022	1.5	1.4	1.6	1.5	1.4	1.5	1.8	1.5	1.6	1.1	0.6	0.6	0.4	0.3	0.3	0.3
	JNGI 2023	1.5	1.4	1.6	1.5	1.4	1.5	1.8	1.5	1.6	1.1	0.6	0.6	0.4	0.3	0.3	0.3
	difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*10.55%*	*12.68%*	*16.67%*
Indirect CO_2	JNGI 2022	3.3	3.2	3.0	2.8	2.5	2.5	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.1	2.0
	JNGI 2023	3.2	3.2	3.0	2.7	2.5	2.4	2.3	2.3	2.3	2.2	2.2	2.1	2.1	2.1	2.0	1.9
	difference	*-0.50%*	*-0.86%*	*-0.82%*	*-1.53%*	*-1.38%*	*-1.41%*	*-1.41%*	*-1.13%*	*-1.14%*	*-1.08%*	*-1.28%*	*-1.18%*	*-1.61%*	*-2.22%*	*-2.69%*	*-4.93%*
Total	JNGI 2022	1,378.7	1,357.5	1,392.8	1,320.0	1,247.9	1,301.4	1,352.2	1,395.0	1,406.8	1,357.9	1,319.4	1,302.7	1,289.4	1,245.5	1,210.2	1,148.1
without LULUCF	JNGI 2023	1,377.5	1,356.1	1,391.3	1,318.5	1,246.5	1,300.0	1,350.7	1,393.6	1,405.4	1,356.5	1,317.8	1,300.1	1,286.7	1,242.7	1,207.7	1,144.9
excl. Indirect CO_2	*difference*	*-0.09%*	*-0.10%*	*-0.11%*	*-0.11%*	*-0.11%*	*-0.10%*	*-0.11%*	*-0.10%*	*-0.10%*	*-0.11%*	*-0.12%*	*-0.20%*	*-0.21%*	*-0.23%*	*-0.20%*	*-0.28%*
Total	JNGI 2022	1,290.0	1,273.4	1,313.1	1,251.2	1,182.2	1,231.5	1,284.2	1,324.8	1,343.9	1,297.0	1,263.0	1,250.4	1,233.1	1,189.9	1,159.2	1,096.1
with LULUCF	JNGI 2023	1,288.6	1,272.1	1,311.4	1,248.4	1,179.5	1,229.2	1,281.6	1,321.7	1,340.7	1,294.8	1,261.7	1,247.9	1,230.5	1,186.9	1,157.0	1,093.3
excl. Indirect CO_2	*difference*	*-0.11%*	*-0.10%*	*-0.13%*	*-0.22%*	*-0.23%*	*-0.19%*	*-0.20%*	*-0.24%*	*-0.23%*	*-0.17%*	*-0.10%*	*-0.21%*	*-0.21%*	*-0.25%*	*-0.19%*	*-0.25%*
Total	JNGI 2022	1,382.0	1,360.7	1,395.8	1,322.7	1,250.4	1,303.9	1,354.6	1,397.3	1,409.1	1,360.2	1,321.6	1,304.9	1,291.6	1,247.7	1,212.2	1,150.1
without LULUCF	JNGI 2023	1,380.7	1,359.2	1,394.3	1,321.2	1,249.1	1,302.5	1,353.1	1,395.9	1,407.6	1,358.7	1,320.0	1,302.3	1,288.8	1,244.8	1,209.7	1,146.8
incl. Indirect CO_2	*difference*	*-0.09%*	*-0.10%*	*-0.11%*	*-0.12%*	*-0.11%*	*-0.11%*	*-0.11%*	*-0.10%*	*-0.11%*	*-0.11%*	*-0.12%*	*-0.20%*	*-0.21%*	*-0.23%*	*-0.20%*	*-0.29%*
Total	JNGI 2022	1,293.3	1,276.6	1,316.2	1,253.9	1,184.7	1,234.0	1,286.5	1,327.1	1,346.2	1,299.2	1,265.2	1,252.6	1,235.2	1,192.0	1,161.3	1,098.1
with LULUCF	JNGI 2023	1,291.9	1,275.3	1,314.4	1,251.1	1,182.0	1,231.6	1,284.0	1,324.0	1,343.0	1,297.0	1,263.9	1,250.0	1,232.6	1,189.0	1,159.0	1,095.2
incl. Indirect CO_2	*difference*	*-0.11%*	*-0.10%*	*-0.13%*	*-0.23%*	*-0.23%*	*-0.19%*	*-0.20%*	*-0.24%*	*-0.24%*	*-0.17%*	*-0.10%*	*-0.21%*	*-0.21%*	*-0.25%*	*-0.19%*	*-0.26%*

Table 10-2 Comparison of emissions and removals in the inventories submitted in 2022 and 2023 (Energy sector)

1. Energy [Mt-CO_2 eq.]

Category	Gas		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
A. Fuel Combustion	CO_2	JNGI 2022	368.5	369.4	374.3	357.0	391.5	378.9	381.5	377.5	365.0	386.9	395.5	386.6	413.4	432.5	430.2	449.7	440.7	490.9	471.7	441.4	473.8	534.8	581.5	583.5	553.4	527.3	522.5	508.6	471.3	449.0	436.3
1. Energy Industries		JNGI 2023	368.5	369.4	374.3	357.0	391.5	378.9	381.5	377.5	365.0	386.9	395.5	386.6	413.4	432.5	430.2	449.7	440.7	490.9	471.7	441.4	473.8	534.8	581.5	583.5	553.4	527.3	521.5	507.7	470.2	447.7	436.0
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.19%*	*-0.17%*	*-0.24%*	*-0.30%*	*-0.08%*
	CH_4	JNGI 2022	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4
		JNGI 2023	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.01%*	*-0.01%*	*-0.01%*	*-0.01%*	*-0.27%*
	N_2O	JNGI 2022	0.9	0.9	0.9	0.9	1.0	1.4	1.4	1.4	1.5	1.6	1.6	1.8	1.8	1.9	1.9	2.1	2.1	2.2	2.1	2.1	2.1	2.3	2.3	2.4	2.3	2.4	2.3	2.4	2.3	1.9	1.9
		JNGI 2023	0.9	0.9	0.9	0.9	1.0	1.4	1.4	1.4	1.5	1.6	1.6	1.8	1.8	1.9	1.9	2.1	2.1	2.2	2.1	2.1	2.1	2.3	2.3	2.4	2.3	2.4	2.3	2.4	2.3	1.9	1.9
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.04%*	*-0.02%*	*-0.04%*	*-0.06%*	*0.01%*
A. Fuel Combustion	CO_2	JNGI 2022	349.8	346.3	341.2	342.1	350.9	357.7	361.0	357.0	332.3	336.9	346.9	341.1	346.6	344.6	344.1	334.6	332.1	330.3	301.2	284.3	301.1	300.1	299.8	304.9	297.3	288.1	274.3	270.0	267.4	260.0	233.8
2. Manufacturing Industries		JNGI 2023	349.8	346.3	341.2	342.1	350.9	357.7	361.0	357.0	332.3	336.9	346.9	341.1	346.6	344.6	344.1	334.6	332.1	330.3	301.2	284.3	301.1	300.1	299.8	304.9	297.3	288.1	274.3	269.9	267.4	260.0	233.7
and Construction		*difference*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.01%*	*0.00%*	*-0.01%*	*-0.06%*
	CH_4	JNGI 2022	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.5
		JNGI 2023	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.5
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-1.35%*
	N_2O	JNGI 2022	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.8	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.9	1.8	1.8	1.7	1.7	1.7	1.8	1.7	1.7	1.7	1.7	1.6	1.6	1.5
		JNGI 2023	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.8	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.9	1.8	1.8	1.7	1.7	1.7	1.8	1.7	1.7	1.7	1.7	1.6	1.6	1.5
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.13%*
A. Fuel Combustion	CO_2	JNGI 2022	202.1	213.9	220.5	224.3	233.5	242.8	249.6	251.3	249.5	253.6	253.1	257.2	253.6	249.5	243.6	238.1	235.3	232.5	224.9	221.6	222.0	217.1	218.0	215.1	210.1	208.9	207.1	205.3	203.0	198.6	177.6
3. Transport		JNGI 2023	202.1	213.9	220.5	224.3	233.5	242.8	249.6	251.3	249.5	253.6	253.1	257.2	253.6	249.5	243.6	238.1	235.3	232.5	224.9	221.6	222.0	217.1	218.0	215.1	210.1	208.9	207.1	205.3	203.0	199.0	176.6
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.22%*	*-0.60%*
	CH_4	JNGI 2022	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2023	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.01%*	*-0.01%*	*-0.02%*	*-0.02%*	*-0.02%*	*-0.02%*	*-0.02%*	*-0.02%*	*-0.02%*	*-0.02%*	*0.01%*	*0.06%*	*0.15%*	*0.37%*
	N_2O	JNGI 2022	3.7	3.9	4.0	3.9	4.0	4.1	4.2	4.2	4.1	4.1	4.0	3.8	3.6	3.3	3.0	2.8	2.6	2.5	2.4	2.2	2.1	2.0	1.9	1.8	1.7	1.7	1.7	1.7	1.7	1.6	1.5
		JNGI 2023	3.7	3.9	4.0	3.9	4.0	4.1	4.2	4.2	4.1	4.1	4.0	3.8	3.6	3.3	3.0	2.8	2.6	2.5	2.4	2.2	2.1	1.9	1.9	1.8	1.7	1.7	1.6	1.6	1.6	1.6	1.4
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.01%*	*0.01%*	*0.01%*	*0.03%*	*0.04%*	*-0.35%*	*-0.86%*	*-1.55%*	*-2.29%*	*-3.05%*	*-3.78%*	*-4.35%*	*-4.76%*	*-4.79%*	*-4.95%*
A. Fuel Combustion	CO_2	JNGI 2022	158.2	159.4	161.8	168.9	167.5	175.4	174.3	175.2	180.6	186.3	190.3	188.9	192.7	188.8	193.6	196.0	187.6	178.1	166.6	156.2	156.9	152.7	145.8	149.3	141.9	139.2	140.9	145.0	142.0	140.6	138.8
4. Other Sectors		JNGI 2023	158.2	159.4	161.8	168.9	167.5	175.4	174.3	175.2	180.6	186.3	190.3	188.9	192.7	188.8	193.6	196.0	187.6	178.1	166.6	156.2	156.9	152.7	145.8	149.3	141.9	139.2	140.9	144.7	141.8	140.7	140.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.26%*	*-0.13%*	*0.10%*	*0.98%*
	CH_4	JNGI 2022	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.5	0.5	0.5	0.5	0.4	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		JNGI 2023	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.5	0.5	0.5	0.5	0.4	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.30%*	*-0.17%*	*-0.07%*	*-2.57%*
	N_2O	JNGI 2022	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7
		JNGI 2023	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.06%*	*-0.03%*	*0.26%*	*0.13%*
B. Fugitive Emissions	CO_2	JNGI 2022	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1. Solid Fuels		JNGI 2023	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		difference	*8.58%*	*11.35%*	*15.60%*	*21.46%*	*29.01%*	*40.92%*	*50.60%*	*60.11%*	*66.69%*	*74.87%*	*93.84%*	*110.5%*	*205.0%*	*238.6%*	*236.1%*	*238.7%*	*249.5%*	*294.2%*	*294.3%*	*284.9%*	*305.4%*	*331.3%*	*373.5%*	*412.4%*	*423.5%*	*445.2%*	*495.1%*	*517.5%*	*614.7%*	*685.8%*	*664.2%*
	CH_4	JNGI 2022	4.9	4.5	3.7	3.1	2.9	2.5	2.2	2.0	1.9	1.8	1.6	1.4	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.6	0.5	0.5	0.5
		JNGI 2023	4.9	4.5	3.7	3.1	2.9	2.5	2.2	2.0	1.9	1.8	1.6	1.4	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.6	0.5	0.5	0.5
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
B. Fugitive Emissions	CO_2	JNGI 2022	0.2	0.2	0.2	0.2	0.2	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.3
2. Oil and Natural Gas		JNGI 2023	0.2	0.2	0.2	0.2	0.2	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.45%*	*4.57%*	*13.41%*
	CH_4	JNGI 2022	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2
		JNGI 2023	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.03%*	*0.45%*	*2.14%*
	N_2O	JNGI 2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		JNGI 2023	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.09%*
1. Total	GHG	JNGI 2022	1,091.9	1,102.3	1,110.4	1,104.4	1,155.4	1,167.4	1,178.9	1,173.5	1,139.3	1,175.9	1,197.8	1,185.6	1,217.2	1,226.1	1,221.9	1,228.8	1,206.1	1,242.3	1,174.4	1,113.0	1,163.1	1,213.8	1,254.1	1,261.7	1,211.5	1,172.3	1,153.5	1,137.9	1,092.5	1,056.3	994.4
		JNGI 2023	1,091.9	1,102.3	1,110.4	1,104.4	1,155.4	1,167.4	1,178.9	1,173.5	1,139.3	1,175.9	1,197.8	1,185.6	1,217.2	1,226.1	1,221.9	1,228.8	1,206.1	1,242.3	1,174.4	1,113.0	1,163.1	1,213.8	1,254.1	1,261.7	1,211.5	1,172.3	1,152.5	1,136.6	1,091.1	1,055.5	994.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.09%*	*-0.11%*	*-0.13%*	*-0.08%*	*-0.02%*

*Excluding Indirect CO_2

Table 10-3 Comparison of emissions and removals in the inventories submitted in 2022 and 2023 (Industrial processes and product use sector) (1/2)

2. Industrial Processes and Product Use
(1/2) [Mt-CO_2 eq.]

Category	Gas		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
A. Mineral Industry	CO_2	JNGI 2022	49.2	50.5	51.0	50.3	51.3	51.1	51.5	48.8	43.9	43.6	43.9	43.0	40.5	40.1	39.8	41.2	41.2	40.2	37.4	32.8	32.8	33.1	33.6	35.0	34.7	33.7	33.5	34.0	33.6	32.5	31.2
		JNGI 2023	48.7	50.1	50.5	49.8	50.8	50.7	51.0	48.4	43.4	43.2	43.5	42.5	40.2	40.0	39.7	41.1	41.1	40.1	37.3	32.7	32.7	33.0	33.6	34.9	34.7	33.5	33.4	33.9	33.6	32.2	30.7
		difference	*-1.05%*	*-0.97%*	*-0.88%*	*-0.85%*	*-0.86%*	*-0.89%*	*-0.86%*	*-0.88%*	*-0.97%*	*-0.96%*	*-0.98%*	*-1.09%*	*-0.64%*	*-0.31%*	*-0.19%*	*-0.29%*	*-0.31%*	*-0.27%*	*-0.29%*	*-0.39%*	*-0.23%*	*-0.32%*	*-0.10%*	*-0.21%*	*-0.15%*	*-0.40%*	*-0.34%*	*-0.09%*	*-0.24%*	*-0.77%*	*-1.65%*
B. Chemical Industry	CO_2	JNGI 2022	7.0	7.0	6.8	6.4	6.8	7.0	7.1	7.1	6.4	6.9	6.8	6.3	6.2	6.1	6.1	5.8	5.9	6.0	5.1	4.9	5.4	5.1	4.7	4.8	4.7	4.6	4.3	4.5	4.2	4.3	3.7
		JNGI 2023	6.5	6.5	6.3	5.9	6.3	6.5	6.5	6.5	5.9	6.5	6.3	5.9	5.9	5.7	5.8	5.5	5.5	5.6	4.8	4.6	5.1	4.8	4.4	4.5	4.4	4.3	4.0	4.2	3.9	4.0	3.4
		difference	*-7.65%*	*-7.25%*	*-7.41%*	*-7.83%*	*-7.19%*	*-7.41%*	*-7.90%*	*-7.82%*	*-7.99%*	*-6.68%*	*-6.87%*	*-6.49%*	*-5.72%*	*-5.00%*	*-5.12%*	*-5.58%*	*-5.59%*	*-5.53%*	*-6.44%*	*-5.50%*	*-5.25%*	*-5.54%*	*-5.43%*	*-5.50%*	*-5.14%*	*-5.44%*	*-7.11%*	*-6.81%*	*-7.24%*	*-7.03%*	*-8.32%*
	CH_4	JNGI 2022	0.04	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
		JNGI 2023	0.04	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	N_2O	JNGI 2022	9.6	9.1	9.0	8.7	9.8	9.7	10.7	11.3	10.0	3.8	6.3	3.0	2.8	2.9	3.1	2.6	2.7	2.0	2.2	2.4	1.8	1.5	1.3	1.3	1.0	0.8	0.7	0.6	0.5	0.6	0.7
		JNGI 2023	9.6	9.1	9.0	8.7	9.8	9.7	10.7	11.3	10.0	3.8	6.3	3.0	2.8	2.9	3.1	2.6	2.7	2.0	2.2	2.4	1.8	1.5	1.3	1.3	1.0	0.8	0.7	0.6	0.5	0.6	0.7
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	HFCs	JNGI 2022	15.9	17.3	17.6	17.1	18.9	22.0	20.3	19.0	17.7	18.0	16.0	12.2	8.1	6.9	1.9	1.0	1.2	0.6	0.9	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2
		JNGI 2023	15.9	17.3	17.6	17.1	18.9	22.0	20.3	19.0	17.7	18.0	16.0	12.2	8.1	6.9	1.9	1.0	1.2	0.6	0.9	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	PFCs	JNGI 2022	0.3	0.4	0.4	0.6	0.7	0.9	1.2	1.7	1.6	1.6	1.7	1.3	1.3	1.2	1.1	1.0	1.1	1.0	0.6	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2023	0.3	0.4	0.4	0.6	0.7	0.9	1.2	1.7	1.6	1.6	1.7	1.3	1.3	1.2	1.1	1.0	1.1	1.0	0.6	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	SF_6	JNGI 2022	3.5	3.9	4.3	4.3	4.1	4.5	4.0	2.5	2.0	1.5	0.8	0.8	0.8	0.8	0.7	0.9	1.3	1.1	1.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.04	0.05	0.04	0.05
		JNGI 2023	3.5	3.9	4.3	4.3	4.1	4.5	4.0	2.5	2.0	1.5	0.8	0.8	0.8	0.8	0.7	0.9	1.3	1.1	1.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.04	0.05	0.04	0.05
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	NF_3	JNGI 2022	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.03	0.05	0.1	0.1	0.2	0.1	0.1	1.2	1.1	1.2	1.2	1.1	1.3	1.6	1.3	1.5	1.0	0.4	0.4	0.2	0.06	0.02	0.02
		JNGI 2023	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.03	0.05	0.1	0.1	0.2	0.1	0.1	1.2	1.1	1.2	1.2	1.1	1.3	1.6	1.3	1.5	1.0	0.4	0.4	0.2	0.06	0.02	0.02
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
C. Metal Industry	CO_2	JNGI 2022	7.3	7.1	6.8	6.7	6.7	6.9	6.9	6.9	6.6	6.6	6.8	6.9	6.7	6.5	6.7	6.7	6.8	6.9	6.4	5.7	6.3	6.2	6.3	6.4	6.3	6.1	6.0	5.9	5.8	5.6	5.4
		JNGI 2023	7.3	7.1	6.8	6.7	6.7	6.9	6.9	6.9	6.6	6.6	6.8	6.9	6.7	6.5	6.6	6.6	6.7	6.8	6.4	5.7	6.3	6.1	6.2	6.4	6.3	6.1	6.0	5.9	5.8	5.4	5.0
		difference	*-0.05%*	*-0.04%*	*-0.03%*	*-0.01%*	*-0.01%*	*-0.01%*	*-0.04%*	*-0.02%*	*0.00%*	*0.01%*	*-0.01%*	*0.01%*	*0.10%*	*-0.02%*	*-0.47%*	*-0.50%*	*-1.01%*	*-1.64%*	*-0.96%*	*0.79%*	*-0.34%*	*-0.72%*	*-0.73%*	*-1.08%*	*-1.21%*	*-1.33%*	*-0.64%*	*-0.26%*	*-0.98%*	*-3.23%*	*-7.49%*
	CH_4	JNGI 2022	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
		JNGI 2023	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	HFCs	JNGI 2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		JNGI 2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		difference	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	PFCs	JNGI 2022	0.20	0.17	0.11	0.11	0.11	0.17	0.16	0.15	0.12	0.07	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.00	NO	NO	NO	NO	NO	NO
		JNGI 2023	0.20	0.17	0.11	0.11	0.11	0.17	0.16	0.15	0.12	0.07	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.00	NO	NO	NO	NO	NO	NO
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	SF_6	JNGI 2022	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.6	1.0	1.1	1.1	1.1	1.1	1.1	1.0	1.0	0.6	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.3
		JNGI 2023	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.6	1.0	1.1	1.1	1.1	1.1	1.1	1.0	1.0	0.6	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.3
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
D. Non-energy Products from Fuels and Solvent Use	CO_2	JNGI 2022	2.0	2.1	2.1	2.1	2.3	2.4	2.5	2.6	2.5	2.6	2.7	2.7	2.8	2.8	2.9	2.9	3.1	3.0	2.8	2.9	2.7	2.7	2.6	2.7	2.5	2.5	2.6	2.7	2.7	2.6	2.3
		JNGI 2023	2.0	2.1	2.1	2.1	2.3	2.4	2.5	2.6	2.5	2.6	2.7	2.7	2.8	2.8	2.9	2.9	3.1	3.0	2.8	2.9	2.8	2.7	2.6	2.7	2.5	2.5	2.6	2.7	2.7	2.6	2.3
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.01%*	*0.02%*	*0.04%*	*0.04%*	*0.06%*	*0.09%*	*0.13%*	*0.16%*	*0.21%*	*0.26%*	*0.34%*	*0.38%*	*0.46%*	*0.15%*	*-0.49%*

*Excluding Indirect CO_2

Table 10-3 Comparison of emissions and removals in the inventories submitted in 2022 and 2023 (Industrial processes and product use sector) (2/2)

2. Industrial Processes and Product Use
(2/2) [Mt-CO_2 eq.]

Category	Gas		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
E. Electronic Industry	HFCs	JNGI 2022	0.00	NO	0.02	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2023	0.00	NO	0.02	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		difference	0.00%	NA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	PFCs	JNGI 2022	1.5	1.7	1.7	2.5	3.1	4.0	4.7	6.0	6.1	6.5	7.0	5.3	5.4	5.3	5.6	4.7	5.1	4.5	3.4	2.1	2.3	1.9	1.7	1.6	1.7	1.7	1.8	1.9	1.9	1.8	1.9
		JNGI 2023	1.5	1.7	1.7	2.5	3.1	4.0	4.7	6.0	6.1	6.5	7.0	5.3	5.4	5.3	5.6	4.7	5.1	4.5	3.4	2.1	2.3	1.9	1.7	1.6	1.7	1.7	1.8	1.9	1.9	1.8	1.9
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.40%	0.52%	0.69%
	SF_6	JNGI 2022	0.4	0.5	0.5	0.5	0.5	0.5	0.8	1.1	1.2	1.4	1.5	1.3	1.4	1.4	1.4	1.3	1.0	0.8	0.6	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.3	0.3	0.3
		JNGI 2023	0.4	0.5	0.5	0.5	0.5	0.5	0.8	1.1	1.2	1.4	1.5	1.3	1.4	1.4	1.4	1.3	1.0	0.8	0.6	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.3	0.3	0.3
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	NF_3	JNGI 2022	0.03	0.03	0.03	0.04	0.07	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.4	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3
		JNGI 2023	0.03	0.03	0.03	0.04	0.07	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.3	0.4	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.27%	13.68%	17.59%
F. Product Uses as Substitutes for ODS	HFCs	JNGI 2022	0.0	NO	0.1	0.9	1.9	2.9	4.1	5.1	5.7	6.1	6.6	7.0	7.9	9.1	10.3	11.5	13.2	15.8	18.2	20.5	23.0	25.8	29.1	31.9	35.6	39.1	42.3	44.7	46.8	49.5	51.4
		JNGI 2023	0.0	NO	0.1	0.9	1.9	2.9	4.1	5.1	5.7	6.1	6.6	7.0	7.9	9.1	10.3	11.5	13.2	15.8	18.1	20.5	23.0	25.8	29.1	31.9	35.6	39.1	42.3	44.7	46.9	49.7	51.9
		difference	0.00%	NA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.04%	-0.05%	-0.08%	-0.09%	-0.08%	-0.07%	-0.21%	-0.09%	0.01%	0.01%	0.01%	0.02%	0.00%	0.00%	0.00%	0.00%	0.09%	0.46%	0.93%
	PFCs	JNGI 2022	4.5	5.3	5.4	7.8	9.6	12.6	12.2	12.3	8.8	5.0	3.2	3.2	2.6	2.3	2.5	2.8	2.8	2.4	1.6	1.4	1.7	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.5
		JNGI 2023	4.5	5.3	5.4	7.8	9.6	12.6	12.2	12.3	8.8	5.0	3.2	3.2	2.6	2.3	2.5	2.8	2.8	2.4	1.6	1.4	1.7	1.6	1.6	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.5
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
G. Other Product Manufacture and Use	N_2O	JNGI 2022	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.6	0.4	0.4	0.4	0.4	0.4	0.4
		JNGI 2023	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.6	0.4	0.4	0.4	0.4	0.4	0.4
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	HFCs	JNGI 2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		JNGI 2023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		difference	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PFCs	JNGI 2022	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	NA,NO	0.01	0.01	0.01	0.02	0.02	0.04	0.05	0.06
		JNGI 2023	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.03	0.03	0.05	0.06	0.07
		difference	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	29500%	11404%	6728%	3811%	1737%	806.5%	445.3%	231.6%	190.0%	125.4%	NA	55.79%	68.01%	77.04%	30.18%	29.30%	15.72%	25.28%	23.56%
	SF_6	JNGI 2022	8.8	9.7	10.7	10.8	10.3	11.3	12.1	10.8	9.6	5.7	3.7	2.9	2.4	2.2	2.0	1.7	1.8	1.7	1.7	1.5	1.4	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4
		JNGI 2023	8.8	9.7	10.7	10.8	10.3	11.3	12.1	10.8	9.6	5.7	3.7	2.9	2.4	2.2	2.0	1.7	1.8	1.7	1.7	1.5	1.4	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
H. Other	CO_2	JNGI 2022	0.06	0.07	0.07	0.06	0.07	0.07	0.08	0.09	0.09	0.09	0.09	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.07	0.07	0.08	0.09	0.10	0.09	0.09	0.10	0.11	0.11	0.11	0.10	0.09
		JNGI 2023	0.06	0.07	0.07	0.06	0.07	0.07	0.08	0.09	0.09	0.09	0.09	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.07	0.07	0.08	0.09	0.10	0.09	0.09	0.10	0.11	0.11	0.11	0.10	0.09
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2. Total	GHG	JNGI 2022	111.0	115.5	117.3	119.5	127.0	137.2	139.4	136.5	123.7	111.1	109.1	98.1	91.2	89.8	86.4	87.6	90.5	89.6	85.1	77.7	81.0	82.9	85.4	89.8	92.3	93.5	96.5	99.2	100.2	101.5	101.4
		JNGI 2023	109.9	114.5	116.4	118.6	126.1	136.3	138.4	135.5	122.8	110.2	108.3	97.3	90.6	89.4	86.0	87.1	89.9	89.0	84.6	77.4	80.6	82.5	85.1	89.4	92.0	93.0	96.1	98.9	99.9	101.1	100.7
		difference	-0.93%	-0.85%	-0.80%	-0.76%	-0.72%	-0.70%	-0.71%	-0.70%	-0.74%	-0.77%	-0.80%	-0.88%	-0.65%	-0.46%	-0.48%	-0.54%	-0.57%	-0.61%	-0.61%	-0.46%	-0.45%	-0.50%	-0.37%	-0.43%	-0.38%	-0.48%	-0.45%	-0.34%	-0.34%	-0.44%	-0.67%

*Excluding Indirect CO_2

Table 10-4 Comparison of emissions and removals in the inventories submitted in 2022 and 2023 (Agriculture sector)

3. Agriculture [Mt-CO_2 eq.]

Category	Gas		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
A. Enteric Fermentation	CH_4	JNGI 2022	9.4	9.6	9.7	9.6	9.4	9.3	9.2	9.2	9.1	9.1	9.0	9.0	8.9	8.9	8.7	8.7	8.6	8.7	8.6	8.5	8.2	8.2	8.0	7.7	7.5	7.5	7.5	7.5	7.5	7.6	7.6
		JNGI 2023	9.4	9.6	9.7	9.6	9.4	9.3	9.2	9.2	9.1	9.1	9.0	9.0	8.9	8.9	8.7	8.7	8.6	8.7	8.6	8.5	8.2	8.2	8.0	7.7	7.5	7.5	7.5	7.5	7.5	7.6	7.6
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.02%
B. Manure Management	CH_4	JNGI 2022	3.3	3.3	3.3	3.3	3.2	3.2	3.1	3.1	3.1	3.0	3.0	2.9	2.9	2.9	2.8	2.8	2.7	2.7	2.6	2.6	2.5	2.5	2.5	2.4	2.4	2.4	2.3	2.4	2.4	2.4	2.4
		JNGI 2023	3.4	3.4	3.4	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.0	3.0	3.0	2.9	2.9	2.8	2.8	2.7	2.7	2.6	2.6	2.6	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4
		difference	1.60%	1.57%	1.55%	1.56%	1.55%	1.52%	1.53%	1.54%	1.56%	1.56%	1.55%	1.50%	1.48%	1.48%	1.47%	1.48%	1.51%	1.51%	1.52%	1.50%	1.52%	1.54%	1.57%	1.61%	1.62%	1.60%	1.64%	1.68%	1.68%	1.65%	1.53%
	N_2O	JNGI 2022	4.2	4.2	4.2	4.1	4.1	4.0	3.9	3.9	3.8	3.8	3.8	3.8	3.9	3.9	3.9	4.1	4.2	4.2	4.3	4.3	4.3	4.2	4.1	4.0	3.9	3.8	3.8	3.9	3.8	3.8	3.8
		JNGI 2023	4.3	4.4	4.3	4.3	4.2	4.1	4.0	4.0	4.0	3.9	4.0	4.0	4.0	4.0	4.0	4.2	4.3	4.3	4.4	4.4	4.4	4.3	4.2	4.1	4.0	3.9	3.9	4.0	3.9	3.9	3.9
		difference	3.13%	3.16%	3.16%	3.18%	3.19%	3.18%	3.18%	3.19%	3.18%	3.17%	3.08%	2.95%	2.84%	2.75%	2.68%	2.62%	2.58%	2.50%	2.41%	2.36%	2.40%	2.45%	2.46%	2.50%	2.55%	2.59%	2.66%	2.72%	2.76%	2.76%	2.48%
C. Rice Cultivation	CH_4	JNGI 2022	12.1	11.8	12.6	12.7	13.5	13.1	12.6	12.9	12.0	12.1	12.2	11.7	11.9	11.6	11.9	12.2	12.1	11.9	11.8	11.9	12.2	11.6	11.5	12.1	12.1	12.0	12.1	12.1	12.0	12.0	12.0
		JNGI 2023	12.1	11.8	12.6	12.7	13.5	13.1	12.6	12.9	12.0	12.1	12.2	11.7	11.9	11.6	11.9	12.2	12.1	11.9	11.8	11.9	12.2	11.6	11.5	12.1	12.1	11.9	12.1	12.1	12.0	11.9	12.0
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	0.00%	0.00%	0.00%	0.00%	-0.17%	-0.17%	-0.16%	-0.33%	-0.33%	-0.39%
D. Agricultural Soils	N_2O	JNGI 2022	7.6	7.4	7.4	7.5	7.3	7.0	6.9	6.8	6.8	6.7	6.8	6.6	6.5	6.5	6.4	6.4	6.3	6.7	5.9	5.6	6.0	5.9	5.9	6.0	5.9	5.9	5.9	5.9	5.9	5.8	5.8
		JNGI 2023	7.3	7.2	7.1	7.2	7.1	6.8	6.6	6.5	6.5	6.5	6.5	6.3	6.3	6.2	6.1	6.1	6.1	6.4	5.6	5.4	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6
		difference	-3.58%	-3.58%	-3.74%	-3.36%	-3.80%	-3.82%	-3.92%	-3.94%	-3.98%	-4.02%	-4.18%	-4.21%	-4.21%	-3.95%	-4.14%	-4.01%	-3.84%	-3.65%	-4.08%	-3.95%	-3.58%	-3.63%	-3.70%	-3.68%	-3.61%	-3.55%	-3.42%	-3.38%	-3.39%	-3.52%	-3.15%
F. Field Burning of Agricultural Residues	CH_4	JNGI 2022	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.08	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06
		JNGI 2023	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.08	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.11%
	N_2O	JNGI 2022	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		JNGI 2023	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.11%
G. Liming	CO_2	JNGI 2022	0.6	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2
		JNGI 2023	0.6	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2
		difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
H. Urea Application	CO_2	JNGI 2022	0.06	0.02	0.02	0.04	0.05	0.06	0.06	0.07	0.08	0.08	0.11	0.12	0.14	0.18	0.17	0.18	0.15	0.18	0.13	0.12	0.16	0.17	0.15	0.20	0.19	0.20	0.19	0.19	0.19	0.19	0.19
		JNGI 2023	0.18	0.14	0.14	0.17	0.17	0.17	0.16	0.16	0.17	0.16	0.17	0.17	0.17	0.21	0.19	0.20	0.17	0.20	0.16	0.15	0.18	0.19	0.17	0.21	0.20	0.21	0.21	0.21	0.21	0.21	0.21
		difference	210.0%	591.9%	785.7%	300.1%	239.8%	205.2%	181.5%	139.6%	115.3%	103.5%	53.03%	42.50%	22.93%	14.34%	16.58%	9.77%	9.75%	12.91%	19.55%	22.20%	15.19%	12.00%	14.52%	8.19%	8.08%	7.05%	7.98%	7.98%	7.98%	7.98%	7.98%
3. Total	GHG	JNGI 2022	37.5	37.1	37.9	37.8	38.0	37.1	36.3	36.4	35.2	35.3	35.3	34.6	34.8	34.3	34.2	34.6	34.4	34.8	33.7	33.5	33.7	33.0	32.6	32.8	32.4	32.2	32.2	32.3	32.1	32.1	32.2
		JNGI 2023	37.5	37.1	37.9	37.9	38.0	37.1	36.3	36.4	35.2	35.3	35.2	34.5	34.7	34.3	34.1	34.5	34.4	34.7	33.6	33.4	33.7	32.9	32.6	32.8	32.4	32.1	32.1	32.3	32.0	32.0	32.1
		difference	0.10%	0.11%	0.09%	0.15%	0.05%	0.05%	0.02%	0.00%	-0.03%	-0.07%	-0.17%	-0.20%	-0.26%	-0.23%	-0.26%	-0.26%	-0.23%	-0.22%	-0.21%	-0.16%	-0.15%	-0.16%	-0.17%	-0.20%	-0.18%	-0.25%	-0.21%	-0.19%	-0.25%	-0.26%	-0.26%

Table 10-5 Comparison of emissions and removals in the inventories submitted in 2022 and 2023 (Land use, land-use change and forestry sector)

4. Land Use, Land-Use Change and Forestry

[Mt-CO_2 eq.]

Category	Gas		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
A. Forest Land	CO_2	JNGI 2022	-79.1	-86.2	-86.6	-86.9	-87.3	-87.6	-91.3	-91.1	-91.0	-90.8	-90.6	-90.5	-90.3	-99.0	-98.5	-92.6	-86.8	-85.5	-80.7	-75.8	-76.3	-78.1	-77.7	-70.0	-68.3	-63.1	-58.5	-60.8	-59.2	-55.2	-57.1
		JNGI 2023	-86.3	-93.9	-94.3	-94.7	-95.1	-95.4	-98.7	-98.5	-98.3	-98.1	-98.0	-97.8	-97.6	-106.9	-106.3	-99.8	-93.4	-91.9	-87.2	-82.5	-82.6	-84.3	-84.1	-76.3	-73.4	-66.9	-62.3	-64.4	-62.9	-58.7	-60.4
		difference	*9.11%*	*8.94%*	*8.93%*	*8.94%*	*8.94%*	*8.94%*	*8.11%*	*8.10%*	*8.09%*	*8.08%*	*8.07%*	*8.06%*	*8.05%*	*7.95%*	*7.93%*	*7.74%*	*7.64%*	*7.42%*	*8.09%*	*8.72%*	*8.20%*	*8.01%*	*8.25%*	*9.07%*	*7.48%*	*6.02%*	*6.48%*	*5.86%*	*6.16%*	*6.23%*	*5.63%*
	CH_4	JNGI 2022	0.01	0.01	0.01	0.03	0.02	0.01	0.03	0.04	0.01	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.03	0.01	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.02	0.00	0.01	0.00
		JNGI 2023	0.01	0.01	0.01	0.03	0.02	0.01	0.03	0.04	0.01	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.03	0.01	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.02	0.00	0.01	0.00
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	N_2O	JNGI 2022	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13
		JNGI 2023	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
		difference	*-54.23%*	*-54.30%*	*-54.36%*	*-53.46%*	*-53.72%*	*-54.13%*	*-53.28%*	*-53.04%*	*-54.04%*	*-54.27%*	*-54.15%*	*-53.96%*	*-53.62%*	*-54.32%*	*-53.98%*	*-54.11%*	*-54.38%*	*-54.42%*	*-53.66%*	*-54.20%*	*-54.36%*	*-54.32%*	*-54.48%*	*-54.40%*	*-53.74%*	*-54.35%*	*-54.53%*	*-53.77%*	*-54.49%*	*-54.41%*	*-54.50%*
B. Cropland	CO_2	JNGI 2022	9.0	7.9	4.3	2.6	3.3	3.9	3.1	3.9	5.1	5.0	4.0	3.6	3.0	1.5	4.5	3.9	2.7	6.1	11.4	8.7	5.9	6.9	6.6	5.5	6.2	5.7	5.5	4.6	4.0	4.7	4.7
		JNGI 2023	8.3	7.6	3.9	2.4	3.2	3.8	3.0	3.9	5.0	4.9	4.0	3.5	3.0	1.5	4.4	3.9	2.7	6.0	11.3	8.6	5.8	6.8	6.5	5.5	6.2	5.7	5.4	4.6	4.0	4.7	4.6
		difference	*-7.00%*	*-4.26%*	*-9.02%*	*-5.19%*	*-3.89%*	*-2.46%*	*-2.37%*	*-1.60%*	*-1.10%*	*-1.40%*	*-0.64%*	*-0.61%*	*-0.73%*	*-1.28%*	*-0.39%*	*-0.90%*	*-1.31%*	*-0.99%*	*-0.85%*	*-0.49%*	*-0.51%*	*-0.43%*	*-0.92%*	*-0.29%*	*-0.25%*	*-0.22%*	*-0.26%*	*-0.19%*	*-0.02%*	*0.46%*	*-0.16%*
	CH_4	JNGI 2022	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
		JNGI 2023	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
		difference	*-0.02%*	*-0.02%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.05%*	*0.12%*	*0.12%*	*0.12%*	*0.10%*	*0.08%*	*-0.14%*	*-0.33%*	*-0.51%*	*-0.67%*
	N_2O	JNGI 2022	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2023	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		difference	*-6.41%*	*-6.98%*	*-7.57%*	*-8.14%*	*-8.53%*	*-9.30%*	*-10.43%*	*-11.47%*	*-11.99%*	*-12.28%*	*-12.69%*	*-13.10%*	*-13.62%*	*-11.94%*	*-10.02%*	*-8.30%*	*-6.88%*	*-6.15%*	*-5.08%*	*-4.07%*	*-2.93%*	*-2.31%*	*-1.47%*	*-1.26%*	*-1.20%*	*-1.22%*	*-1.07%*	*-0.91%*	*-0.80%*	*-0.71%*	*-0.68%*
C. Grassland	CO_2	JNGI 2022	0.7	0.3	-0.5	-1.0	-0.7	0.1	-0.6	-1.09	-1.03	-1.3	-0.90	-0.8	-0.8	-1.2	-0.6	-0.3	-0.1	-0.4	-0.1	0.43	0.18	0.78	0.80	1.10	1.71	1.37	1.08	0.83	0.59	0.69	0.55
		JNGI 2023	0.9	0.4	-0.4	-1.0	-0.6	0.07	-0.6	-1.1	-1.0	-1.3	-0.9	-0.8	-0.8	-1.2	-0.6	-0.3	-0.09	-0.4	-0.21	0.36	0.13	0.76	0.75	1.07	1.68	1.35	1.06	0.81	0.57	0.69	0.56
		difference	*29.78%*	*26.02%*	*-21.64%*	*-2.55%*	*-4.49%*	*7.60%*	*-1.23%*	*-0.96%*	*-0.07%*	*-1.65%*	*-0.04%*	*-0.66%*	*-0.84%*	*0.02%*	*-0.11%*	*9.92%*	*46.50%*	*21.56%*	*157.1%*	*-15.82%*	*-26.78%*	*-2.73%*	*-5.38%*	*-2.48%*	*-1.62%*	*-1.65%*	*-2.14%*	*-2.07%*	*-2.92%*	*0.98%*	*1.18%*
	CH_4	JNGI 2022	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
		JNGI 2023	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
		difference	*-0.08%*	*-0.04%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.02%*	*0.04%*	*0.04%*	*0.04%*	*0.05%*	*0.04%*	*0.03%*	*0.01%*	*0.00%*	*-0.02%*
	N_2O	JNGI 2022	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		JNGI 2023	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
D. Wetlands	CO_2	JNGI 2022	0.09	0.08	0.3	0.1	0.1	0.4	0.6	0.1	0.5	0.5	0.4	0.4	0.09	0.06	0.06	0.05	0.05	0.08	0.09	0.12	0.11	0.06	0.07	0.02	0.02	0.07	0.07	0.03	0.03	0.03	0.03
		JNGI 2023	0.07	0.06	0.2	0.1	0.1	0.3	0.5	0.1	0.4	0.4	0.3	0.3	0.07	0.05	0.04	0.03	0.03	0.06	0.06	0.09	0.09	0.05	0.05	0.02	0.02	0.06	0.06	0.02	0.02	0.02	0.02
		difference	*-24.34%*	*-24.60%*	*-23.03%*	*-23.67%*	*-23.94%*	*-22.84%*	*-22.60%*	*-23.93%*	*-22.68%*	*-22.78%*	*-22.79%*	*-22.87%*	*-24.57%*	*-25.79%*	*-26.25%*	*-27.46%*	*-27.48%*	*-24.25%*	*-32.98%*	*-21.15%*	*-16.36%*	*-17.78%*	*-28.88%*	*-23.11%*	*-22.62%*	*-15.79%*	*-16.48%*	*-20.58%*	*-22.09%*	*-11.86%*	*-11.99%*
E. Settlements	CO_2	JNGI 2022	2.9	3.5	3.9	2.4	1.5	1.3	0.6	0.4	0.3	-0.10	-0.4	-0.6	-1.3	-1.4	-1.4	-0.9	-0.9	-0.2	0.1	-0.3	-0.4	-0.8	-0.5	-0.4	-0.3	0.2	0.2	0.0	0.1	0.1	0.2
		JNGI 2023	10.6	10.9	11.0	9.5	8.5	8.2	7.5	7.2	7.0	6.59	6.2	5.8	5.2	5.0	4.8	4.9	4.6	5.0	4.7	4.4	4.2	3.5	3.2	3.2	3.1	3.2	3.1	2.8	2.8	2.9	3.0
		difference	*270.6%*	*212.0%*	*182.5%*	*301.6%*	*477.1%*	*530.6%*	*1095%*	*1751%*	*2688%*	*-6922%*	*-1549%*	*-1012%*	*-512.9%*	*-465.4%*	*-447.3%*	*-622.1%*	*-603.0%*	*-2460%*	*8948%*	*-1596%*	*-1189%*	*-555.6%*	*-698.3%*	*-862.3%*	*-1261%*	*2018%*	*1188%*	*8215%*	*2040%*	*2656%*	*1576%*
	N_2O	JNGI 2022	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO
		JNGI 2023	0.49	0.48	0.46	0.45	0.43	0.42	0.41	0.41	0.41	0.40	0.39	0.38	0.37	0.37	0.36	0.34	0.33	0.32	0.30	0.29	0.27	0.25	0.24	0.22	0.21	0.20	0.19	0.19	0.18	0.18	0.18
		difference	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
F. Other Land	CO_2	JNGI 2022	1.3	1.4	1.1	1.4	1.2	1.0	0.9	1.2	0.9	1.0	0.8	0.8	0.8	0.6	0.6	0.3	0.2	0.4	0.4	0.3	0.3	0.4	0.3	0.2	0.3	0.3	0.3	0.2	0.3	0.2	0.2
		JNGI 2023	2.3	2.4	2.1	2.3	2.2	2.0	1.9	2.1	1.9	1.9	1.7	1.6	1.6	1.4	1.4	1.1	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5
		difference	*80.82%*	*70.48%*	*90.62%*	*71.01%*	*78.22%*	*94.39%*	*104.0%*	*72.41%*	*100.8%*	*87.66%*	*120.0%*	*108.6%*	*109.3%*	*130.4%*	*121.2%*	*316.6%*	*343.8%*	*190.6%*	*155.1%*	*184.4%*	*189.4%*	*119.7%*	*139.9%*	*176.7%*	*157.2%*	*135.6%*	*122.3%*	*139.6%*	*91.81%*	*105.1%*	*95.48%*
	N_2O	JNGI 2022	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2023	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02
		difference	*244.2%*	*246.7%*	*252.2%*	*258.4%*	*263.2%*	*267.7%*	*280.0%*	*289.3%*	*293.0%*	*292.4%*	*291.7%*	*291.9%*	*293.7%*	*296.4%*	*293.4%*	*280.6%*	*274.3%*	*265.5%*	*253.7%*	*244.6%*	*242.7%*	*185.3%*	*183.1%*	*174.7%*	*166.3%*	*161.7%*	*152.1%*	*132.9%*	*125.6%*	*118.5%*	*104.3%*
G. Harvested Wood Products	CO_2	JNGI 2022	-0.5	-0.7	0.5	1.1	1.7	1.4	2.9	1.8	0.4	1.8	1.8	1.7	1.2	1.4	0.9	0.6	0.5	-0.3	-0.3	0.6	0.1	2.4	0.1	0.3	-0.9	-1.2	-1.1	-1.5	-1.7	-1.7	-0.8
		JNGI 2023	-0.3	-0.5	0.7	1.3	1.9	1.6	3.1	2.0	0.4	1.8	1.7	1.7	1.1	1.3	0.8	0.6	0.5	-0.4	-0.5	0.4	0.0	2.5	0.3	0.6	-0.6	-0.7	-0.7	-1.1	-1.3	-1.3	-0.4
		difference	*-41.30%*	*-28.53%*	*63.37%*	*19.32%*	*13.76%*	*14.01%*	*9.31%*	*13.11%*	*11.58%*	*2.97%*	*-1.89%*	*1.36%*	*-3.51%*	*-5.22%*	*-4.71%*	*0.96%*	*1.59%*	*25.64%*	*83.31%*	*-40.28%*	*-58.69%*	*4.36%*	*542.7%*	*109.7%*	*-37.36%*	*-40.06%*	*-36.52%*	*-26.28%*	*-23.19%*	*-22.86%*	*-50.41%*
H. Other (Organic soil in settlements converted from other land-use categories)	CH_4	JNGI 2022	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2023	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		difference	*-2.56%*	*-3.16%*	*-3.67%*	*-4.55%*	*-5.32%*	*-5.94%*	*-6.53%*	*-7.00%*	*-7.44%*	*-8.41%*	*-9.11%*	*-10.00%*	*-10.17%*	*-9.81%*	*-9.37%*	*-8.92%*	*-8.52%*	*-8.07%*	*-7.63%*	*-6.71%*	*-5.81%*	*-5.57%*	*-5.81%*	*-4.84%*	*-4.06%*	*-3.51%*	*-2.98%*	*-1.48%*	*1.70%*	*5.63%*	*9.15%*
	N_2O	JNGI 2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		JNGI 2023	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		difference	*-2.56%*	*-3.16%*	*-3.67%*	*-4.55%*	*-5.32%*	*-5.94%*	*-6.53%*	*-7.00%*	*-7.44%*	*-8.41%*	*-9.11%*	*-10.00%*	*-10.17%*	*-9.81%*	*-9.37%*	*-8.92%*	*-8.52%*	*-8.07%*	*-7.63%*	*-6.71%*	*-5.81%*	*-5.57%*	*-5.81%*	*-4.84%*	*-4.06%*	*-3.51%*	*-2.98%*	*-1.48%*	*1.70%*	*5.63%*	*9.15%*
(IV) Indirect N_2O emissions from managed soils	N_2O	JNGI 2022	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
		JNGI 2023	0.29	0.28	0.27	0.27	0.26	0.25	0.25	0.24	0.24	0.23	0.23	0.23	0.22	0.22	0.21	0.20	0.19	0.19	0.18	0.17	0.16	0.15	0.15	0.14	0.13	0.13	0.12	0.12	0.12	0.12	0.12
		difference	*452.2%*	*447.3%*	*443.8%*	*438.4%*	*430.4%*	*433.6%*	*445.7%*	*456.7%*	*455.5%*	*449.3%*	*441.8%*	*434.9%*	*427.9%*	*424.0%*	*420.0%*	*408.1%*	*394.1%*	*381.3%*	*367.3%*	*347.6%*	*331.4%*	*304.1%*	*276.2%*	*256.9%*	*241.1%*	*227.7%*	*215.1%*	*201.0%*	*192.0%*	*185.3%*	*181.1%*
4. Total	GHG	JNGI 2022	-65.3	-73.4	-76.8	-80.1	-79.8	-79.2	-83.4	-84.4	-84.5	-83.7	-84.7	-85.2	-87.0	-97.8	-94.2	-88.7	-84.0	-79.6	-68.8	-65.7	-69.9	-68.0	-70.1	-63.0	-60.9	-56.4	-52.3	-56.3	-55.7	-51.0	-52.0
		JNGI 2023	-63.3	-72.1	-75.8	-79.0	-78.8	-78.6	-82.3	-83.3	-83.7	-83.0	-84.1	-84.7	-86.5	-98.0	-94.6	-88.8	-84.0	-79.9	-70.1	-67.0	-70.9	-69.1	-71.9	-64.7	-61.7	-56.1	-52.3	-56.2	-55.8	-50.7	-51.6
		difference	*-3.13%*	*-1.75%*	*-1.32%*	*-1.29%*	*-1.19%*	*-0.81%*	*-1.34%*	*-1.32%*	*-0.93%*	*-0.84%*	*-0.70%*	*-0.60%*	*-0.57%*	*0.29%*	*0.45%*	*0.16%*	*-0.10%*	*0.36%*	*1.92%*	*2.04%*	*1.38%*	*1.63%*	*2.55%*	*2.70%*	*1.31%*	*-0.55%*	*0.02%*	*-0.16%*	*0.22%*	*-0.50%*	*-0.80%*

Table 10-6 Comparison of emissions and removals in the inventories submitted in 2022 and 2023 (Waste sector)

5. Waste [Mt-CO_2 eq.]

Category	Gas		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
A. Solid Waste Disposal	CH_4	JNGI 2022	9.5	9.4	9.4	9.3	9.2	8.9	8.7	8.4	8.1	7.8	7.5	7.3	7.0	6.7	6.4	6.1
		JNGI 2023	9.9	9.8	9.7	9.5	9.3	9.0	8.7	8.3	7.9	7.5	7.2	6.8	6.4	6.1	5.7	5.4
		difference	*4.52%*	*3.96%*	*3.19%*	*2.39%*	*1.45%*	*0.43%*	*-0.52%*	*-1.53%*	*-2.72%*	*-3.94%*	*-5.14%*	*-6.47%*	*-7.79%*	*-9.10%*	*-10.38%*	*-11.95%*
B. Biological Treatment of Solid Waste	CH_4	JNGI 2022	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.08	0.08	0.1
		JNGI 2023	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.07	0.08	0.08	0.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	N_2O	JNGI 2022	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
		JNGI 2023	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
C. Incineration and Open Burning of Waste	CO_2	JNGI 2022	12.3	12.3	13.4	13.2	15.7	16.0	16.4	17.0	17.0	16.8	16.9	15.7	15.1	15.2	14.7	14.2
		JNGI 2023	12.3	12.3	13.4	13.2	15.7	16.0	16.4	17.0	17.0	16.8	16.9	15.7	15.1	15.2	14.7	14.2
		difference	*0.01%*	*0.01%*	*0.01%*	*0.01%*	*0.01%*	*0.01%*	*0.01%*	*0.00%*	*0.01%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	CH_4	JNGI 2022	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		JNGI 2023	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	N_2O	JNGI 2022	1.4	1.5	1.6	1.6	1.8	1.9	2.0	2.1	2.1	2.2	2.2	2.1	1.9	1.9	1.9	2.0
		JNGI 2023	1.4	1.5	1.6	1.6	1.8	1.9	2.0	2.1	2.1	2.2	2.2	2.1	1.9	1.9	1.9	2.0
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
D. Wastewater Treatment and Discharge	CH_4	JNGI 2022	2.9	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.6	2.6	2.6	2.5	2.4	2.4	2.3	2.3
		JNGI 2023	2.9	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.6	2.6	2.6	2.5	2.4	2.4	2.3	2.3
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	N_2O	JNGI 2022	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3
		JNGI 2023	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
E. Other	CO_2	JNGI 2022	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.6	0.7	0.7	0.6	0.6	0.5	0.5	0.5
		JNGI 2023	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.6	0.7	0.7	0.6	0.6	0.5	0.5	0.5
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
5. Total	GHG	JNGI 2022	29.6	29.5	30.7	30.3	32.8	33.0	33.2	33.6	33.2	32.6	32.4	30.7	29.6	29.3	28.5	27.7
		JNGI 2023	30.0	29.9	31.0	30.5	32.9	33.0	33.1	33.5	33.0	32.3	32.0	30.2	29.1	28.7	27.8	27.0
		difference	*1.46%*	*1.27%*	*0.98%*	*0.74%*	*0.41%*	*0.12%*	*-0.13%*	*-0.38%*	*-0.66%*	*-0.94%*	*-1.20%*	*-1.53%*	*-1.84%*	*-2.08%*	*-2.33%*	*-2.62%*

Category	Gas		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
A. Solid Waste Disposal	CH_4	JNGI 2022	5.8	5.5	5.1	4.8	4.5	4.3	4.1	3.9	3.6	3.4	3.2	3.1	2.9	2.8	2.7
		JNGI 2023	5.0	4.6	4.2	3.9	3.6	3.3	3.1	2.9	2.6	2.4	2.2	2.1	1.9	1.8	1.7
		difference	*-13.70%*	*-15.45%*	*-17.42%*	*-19.24%*	*-20.97%*	*-22.61%*	*-24.12%*	*-25.70%*	*-27.33%*	*-29.08%*	*-30.69%*	*-32.30%*	*-33.90%*	*-35.29%*	*-36.61%*
B. Biological Treatment of Solid Waste	CH_4	JNGI 2022	0.1	0.1	0.1	0.1	0.09	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.08	0.08
		JNGI 2023	0.1	0.1	0.1	0.1	0.09	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.08	0.07
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.02%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-9.11%*
	N_2O	JNGI 2022	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
		JNGI 2023	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.02%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-9.20%*
C. Incineration and Open Burning of Waste	CO_2	JNGI 2022	13.4	13.6	14.7	12.2	12.5	11.7	12.3	12.2	11.7	11.7	11.1	10.8	11.6	11.4	11.5
		JNGI 2023	13.4	13.6	14.7	12.2	12.5	11.7	12.3	12.2	11.7	11.7	11.1	10.8	11.6	11.4	10.4
		difference	*0.00%*	*0.01%*	*0.01%*	*0.01%*	*0.01%*	*0.01%*	*0.02%*	*0.02%*	*0.02%*	*0.02%*	*0.02%*	*0.01%*	*0.01%*	*0.01%*	*-9.28%*
	CH_4	JNGI 2022	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2023	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.03%*	*-13.07%*
	N_2O	JNGI 2022	1.8	1.7	1.6	1.6	1.5	1.5	1.5	1.5	1.4	1.5	1.3	1.4	1.5	1.5	1.4
		JNGI 2023	1.8	1.7	1.6	1.6	1.5	1.5	1.5	1.5	1.4	1.5	1.3	1.4	1.5	1.5	1.4
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.94%*
D. Wastewater Treatment and Discharge	CH_4	JNGI 2022	2.2	2.1	2.1	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.6	1.6
		JNGI 2023	2.2	2.1	2.1	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.6	1.6
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.39%*	*-0.84%*
	N_2O	JNGI 2022	2.2	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.1	2.1
		JNGI 2023	2.2	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-3.04%*	*-5.34%*
E. Other	CO_2	JNGI 2022	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6
		JNGI 2023	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.56%*
5. Total	GHG	JNGI 2022	26.5	26.1	26.7	23.7	23.5	22.5	22.8	22.5	21.7	21.5	20.5	20.0	20.7	20.3	20.2
		JNGI 2023	25.7	25.3	25.9	22.8	22.6	21.6	21.8	21.5	20.7	20.5	19.5	19.0	19.7	19.2	18.0
		difference	*-2.98%*	*-3.23%*	*-3.34%*	*-3.92%*	*-4.01%*	*-4.27%*	*-4.28%*	*-4.38%*	*-4.57%*	*-4.65%*	*-4.86%*	*-4.98%*	*-4.80%*	*-5.20%*	*-10.97%*

10.3. Implication for Emission Trends, including Time Series Consistency

Table 10-7 shows the changes made to the emission trends due to the recalculations indicated in “Section 10.1. Explanation and Justification for Recalculations”. The comparison between the 2022 submission and the 2023 submission is made through the comparison of values between FY1990 and FY2020.

10.3.1. GHG Inventory

The change between FY1990 and FY2020 total emissions (excluding the LULUCF sector and including indirect CO_2) in the 2023 submission decreased by approximately 2.7 million tonnes (in CO_2 equivalents) and decreased by 0.21 percentage points, compared to the data reported in the previous submission.

Table 10-7 Comparison of change between 1990 and 2020 total emissions (excluding the LULUCF sector, and including indirect CO_2) between the inventories submitted in 2022 and 2023

	Emissions (2020) - Emissions (1990) [Mt-CO_2 eq.]			Emissions (2020) / Emissions (1990) - 1 [%]		
	JNGI 2022	JNGI 2023	Difference	JNGI 2022	JNGI 2023	Difference
CO_2	-115.9	-117.4	-1.5	-10.0%	-10.1%	-0.14%
CH_4	-15.7	-17.2	-1.5	-35.6%	-38.5%	-2.98%
N_2O	-12.4	-12.5	-0.2	-38.2%	-38.9%	-0.68%
HFCs	35.8	36.3	0.5	224.7%	227.5%	2.88%
PFCs	-3.1	-3.1	0.0	-46.9%	-46.6%	0.27%
SF_6	-10.8	-10.8	0.0	-84.2%	-84.2%	0.00%
NF_3	0.3	0.3	0.0	785.7%	933.4%	147.68%
Indirect CO_2	-3.6	-3.6	0.0	-64.6%	-65.9%	-1.33%
Total	-125.4	-128.0	-2.7	-9.83%	-10.04%	-0.21%

10.4. Recalculations and improvement plan, including response to the review process

10.4.1. Improvements after submission of the inventory

The major improvements carried out after the submission of the 2022 inventory are listed below.

10.4.1.1. Methodology for estimating emissions and removals of GHGs

Changed calculation methods are provided in Table 10-8.

10.4.1.1.a. GHG Inventory

Table 10-8 Changes in estimation methods

Sector and category		Changes in estimation methods
1.A.3.b	Road transportation	The emission factors were revised for diesel regular cargo trucks since FY2011, because the number of trucks by NOx control technology was revised.
1.B.1.b	Solid fuel transformation	The CO_2 emissions from flaring of coke oven gas were newly estimated.
1.B.2.a.ii	Oil production	The emission factors for NMVOC leaks from oil production were revised to the default values of the *2019 Refinement*.
2.B.1	Ammonia Production	Methodology was revised to subtract CO_2 recoveries for urea production from CO_2 emissions from ammonia production.
2.D.3.-	Urea used as a catalyst	Estimation for activity data was revised.
2.G.4	Waterproofing electronic circuits	PFCs and HFCs emissions were newly estimated.
3.B.3	Manure Management – CH_4 Emissions Swine	The equation used for the estimation of the amount of excretion for swine was revised.
3.B.1. 3.B.3. 3.B.4. 3.D.a.2. 3.D.b.1. 3.D.b.2.	Manure Management – Cattle/ Swine/ Poultry Manure Management - Indirect N_2O Emissions - Atmospheric Deposition Agricultural Soils - Direct N_2O Emissions - Organic Fertilizer Agricultural Soils - Indirect N_2O Emissions – N mineralization associated with loss of soil organic matter	The emission factors for "Composting – Intensive windrow" and "Composting – In Vessel" were separately established using country specific values and default values in the *2019 Refinement*.
3.B.2. 3.B.4.	Manure Management - Sheep/ Buffalo/ Goats/ Horses	The N_2O emission factors for sheep, goats, horses and buffalo grazed in Pasture/Range/Paddock were revised to that in the *2019 Refinement*.
3.D.a.4.	Agricultural Soils - Direct N_2O Emissions - Crop Residues	The emission factor for N_2O emissions from crop residues plowed into soil was revised to that in the *2019 Refinement*.
3.D.a.6.	Agricultural Soils - Direct N_2O Emissions - Plowing of Organic Soils	The emission factor of N_2O emissions from the plowing of organic soil for upland field and grassland were revised to that in the *2019 Refinement*.
3.H.	Urea application – CO_2 Emissions	The activity data were revised from imported urea fertilizer to the total demand for urea fertilizer in Japan including domestically produced urea in accordance with the *2006 IPCC Guidelines*.
4.A.1 4.A.2 4.(III) 4.(IV)	Forest land remaining forest land, land converted to forest land, Direct/indirect emissions from N mineralization associated with loss of soil organic matter	Areas of intensively managed forests in forest land remaining forest land was recalculated to be consistent with the revision of interpretations of the Survey of land use change status by satellite interpretation which are used as original data for determining areas of forests converted from other land-use. Following the revision, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years.

Sector and category		Changes in estimation methods
4.B.1 4.B.2 4.C.1 4.C.2 4.D.2 4.E.2 4.F.2 4.(II) 4.(III) 4.(IV)	Each subcategory in cropland and grassland and land converted to wetlands, settlements, and other land Direct/indirect emissions from drainage and other management of organic soils Direct/indirect emissions from N mineralization associated with loss of soil organic matter	Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation*, areas of land converted from forest land were recalculated. Accordingly, carbon stock changes in living biomass, dead organic matter and mineral soils in these subcategories were recalculated in all years. CH_4 emissions from drainage and other management of organic soils and N_2O emissions from N mineralization associated with loss of soil organic matter in cropland and grassland were also recalculated in all years.
4.A.1	Forest land remaining forest land	The revised yield tables for private intensively managed forests, which are used to estimate volume per unit area, recalculated the carbon stock changes of living biomass, dead wood, litter, and mineral soil for all years.
4.A.2 4.B.2 4.C.2 4.D.2 4.E.2 4.F.2 4.(III) 4.(IV)	Each subcategory of land converted to forest land, cropland, grassland, wetlands, settlements and other land and Direct/indirect emissions from N mineralization associated with loss of soil organic matter	Since the carbon stocks of living biomass and dead organic matter before conversion were revised losses in carbon stock were revised. This resulted in recalculations of carbon stock change for living biomass and dead organic matter in these subcategories for all years.
4.B.1	Cropland remaining cropland	By modifying the input data used in the Roth C model calculation, the amount of stock change per unit of area from FY2018 to FY2020 in each subcategory was recalculated. With this recalculation, carbon stock changes in mineral soils in rice field, upland fields and orchard were recalculated for FY2018-2020.
4.B.1 4.C.2 4.E.2 4.(II) 4.(IV)	Each subcategory in cropland, grassland and land converted to settlements Direct/indirect emissions from drainage and other management of organic soils	The method of estimating the area converted to cropland was revised between 1983 and 2002, so the area converted from other land in each district was revised. With this recalculation, the carbon stock changes and the CO_2 emissions from organic and mineral soils were recalculated for all years.
4.B.1	Cropland remaining cropland	Due to a revision of organic carbon content and 100-year C remaining rate of bamboo charcoal, soil carbon stock changes were recalculated for all years.
4.D.1	Wetlands remaining wetlands	Carbon stock change for mangrove forest were estimated. Accordingly, carbon stock changes in this category were recalculated for all years.
4.E.1	Settlements remaining settlements	A revision was conducted on some area of urban green areas for all years. Due to this revision, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years. As for urban parks, unpruned wooded area in large urban parks up to 50 years after creation was newly added to the area.
4.(III) 4.(IV)	Direct/indirect emissions from N mineralization associated with loss of soil organic matter	The C/N ratio by land use were revised, N_2O emissions in forest land, cropland, grassland and other land from this category were recalculated for all years.
5.A	Solid Waste Disposal	By adopting the default values of "fraction of the degradable organic carbon that decomposes *(DOCf)*" and "methane correction factor (*MCF*)" given in the *2019 Refinement*, CH_4 emissions were recalculated.
5.C.2	Open Burning of Waste	By adopting the default oxidation factor (*OF*) given in the *2019 Refinement* in the calculation of CO_2 emission factor of industrial waste, CO_2 emissions were recalculated.
5.C.1/1.A	Waste incineration/ Waste Incineration and Energy Use (Reported on Energy Sector)	By revising biomass-based plastic products data, CO_2 emissions were recalculated.

10.4.1.2. Improvements by following UNFCCC-ERT recommendations

Actions taken in response to recommendations from UNFCCC review are summarized below. See relative sections for details.

The Committee for Greenhouse Gas Estimation Methods (see "Committee for Greenhouse Gas Estimation Methods" (Chapter 1.2.1.2.) address all the recommendations raised by ERT, and efforts have been made to tackle the issues and improve the national GHG inventory with due consideration of the priority.

Table 10-9 Summary of improvements made to the national inventory in response to recommendations from UNFCCC review

Sector/Category	Recommendations by ERT	Actions taken	NIR/CRF
Energy/ Reference approach (1.A(b))	Include in the NIR detailed information on the conversion factors used to convert GCV to NCV for all fuels. (ARR2022, E.1)	The IPCC default factor of 0.95 for Orimulsion and coal tar was included in NIR.	NIR Annex 4 (Table A4-26)
Energy/ Petroleum refining (1.A.1.b)	Include in the NIR the explanation provided during the review regarding the revision of the GCVs and regarding the use of crude oil for refinery. (ARR2022, E.2)	The source of the revisions to GCVs reported in the NIR (i.e., "the 2013 survey") was clarified. The information regarding which ministries conducted the survey and that the survey outline was available in the NIR was included.	NIR Chapter 3 (3.2.4.b)
Energy/ Sectoral approach (1.A(a))	Explain and justify in the NIR all recalculations made for energy sector categories, including the cause of the recalculations, namely, revisions to the key data source (i.e. the *General Energy Statistics*). (ARR2022, E.4)	Recalculations made to the *General Energy Statistics* were explained in the NIR.	NIR Chapter 3 (3.2.4.e)
Energy/ Feedstocks, reductants and other non-energy use of fuels (1.A(d))	Report accurate values of CO_2 emissions from liquid fuel consumption for non-energy uses in CRF table 1.A(d) that are neither overestimated nor underestimated and that maintain time-series consistency. (ARR2022, E.5)	Accurate values were reported in the CRF.	CRF table 1.A(d)
Energy/ Public electricity and heat production (1.A.1.a)	If the method does not change in the next submission, include in the NIR a description of the revised method/data for estimating CO_2 emissions from public electricity and heat production for 2016–2019 (see also ID# E.4 above) and a description of the reasons for the long-term declining trend in CO_2 emissions under this category. (ARR2022, E.6)	A description of the reasons for the long-term declining trend was included in the NIR.	NIR Chapter 3 (3.2.4.a)
Energy/ Manufacture of solid fuels and other energy industries (1.A.1.c)	Include in the NIR a detailed explanation for any recalculations made to this category in its next submission. Include a description of the trend in CO_2 emissions under this category, including an explanation as to why CO_2 emissions from gaseous fuels are considerably lower for 2019 and 2020 than those reported for 2007–2018. (ARR2022, E.7)	An explanation as to why CO_2 emissions from gaseous fuels are considerably lower for 2019 and 2020 than those reported for 2007–2018 was included in the NIR.	NIR Chapter 3 (3.2.4.a)
Energy/ Solid fuel transformation (1.B.1.b)	(1) Clarify in the NIR that the flaring of coke oven gas is included under category 1.A (fuel combustion) and that recovery/flaring of the fugitive CH_4 emissions from charcoal production, reported in CRF table 1.B.1, is not	(1) The CO_2 emissions from flaring of coke oven gas were newly estimated in this submission. It was clarified in the NIR that recovery/flaring of the fugitive CH_4	NIR Chapter 3 (3.3.1.2)

Sector/Category	Recommendations by ERT	Actions taken	NIR/CRF
	estimated and (2) Justify in the NIR the use of "NE" for CH_4 recovery/flaring under category 1.B.1.b in the NIR and CRF table 9, and either explain that no IPCC method is available or provide an estimate of the likely level of emissions in NIR table A5-2. (ARR2022, E.8)	emissions from charcoal production, reported in CRF table 1.B.1, was not estimated. (2) The reasoning of the use of "NE" for CH_4 recovery/flaring under category 1.B.1.b and no method available in the *2006 IPCC Guidelines* were explained in the NIR.	
Energy/ Oil (1.B.2.a)	Enhance the justification for reporting CO_2 emissions for category 1.B.2.a.4 (refining/storage) and CH_4 and CO_2 emissions for 1.B.2.a.5 (distribution of oil products) as "NE" in CRF table 9 by stating that no default EFs are provided in the *2006 IPCC Guidelines* (vol. 2, chap. 4, table 4.2.4) for these categories. (ARR2022, E.9)	The explanation of no default EFs was stated in the CRF.	CRF Table 9
Energy/ Oil (1.B.2.a)	If Japan continues using for its annual submission the current EF for estimating CH_4 emissions for category 1.B.2.a.4 (refining/storage) (which is the lowest value of the *Revised 1996 IPCC Guidelines* factor), explain in the NIR the rationale provided during the review for its selection. If a different EF is used, fully explain in the NIR the rationale for its choice. (ARR2022, E.10)	The rationale including history was provided in the NIR.	NIR Chapter 3 (3.3.2.1.d.d)
Energy/ Natural gas (1.B.2.b)	Change in CRF table 1.B the notation key for reporting CO_2 emissions under categories 1.B.2.b.4 (natural gas transmission) and 1.B.2.b.5 (natural gas distribution) from "NA" to "NE" and include in the NIR the rationale provided during the review. Update CRF table 9 to reflect the rationale for using "NE" to report CO_2 emissions for these categories and include in NIR table A5-2 the level analysis showing emissions are lower than 0.5 kt CO_2/year. (ARR2022, E.11)	The notation keys of CO_2 under 1.B.2.b.iv and 1.B.2.b.v were changed from "NA" to "NE" in the CRF Table 1.B.2, and the rationale was included in the NIR 3.3.2.2.d.a and 3.3.2.2.e.a. In response to this, the notation key of CO_2 under 1.B.2.b.vi was changed from "NA" to "IE" (included in 1.B.2.b.v). The CRF Table 9 was updated to clarify the CO_2 emissions as insignificant "NE". The level analysis was included in the NIR Table A5-2.	NIR Chapter 3 (3.3.2.2.d.a, 3.3.2.2.e.a), Annex 5 (Table A5-2) CRF Table 1.B.2, Table 9
Energy/ Natural gas (1.B.2.b)	If Japan continues using for its annual submission the country-specific EF for calculating CH_4 emissions for category 1.B.2.b.v (distribution), justify in the NIR its use by including the information provided during the review. Describe its national circumstances relating to natural gas distribution in its NIR, and explain the logical basis for using a CH_4 EF that is significantly lower than the IPCC default values. Update CRF table summary3s1 to include the correct tier (i.e. tier 2 if the method does not change) of the method used for estimating CH_4 emissions for this category. (ARR2022, E.12)	It is clarified that the CSEF is derived from CH_4 contents in the city gas, pipeline length of construction, number of inspections, etc. in the NIR 3.3.2.2.e.b. The difficulty of the comparison between the default value and the CSEF is explained in the NIR 3.3.2.2.e.d). The correct tier is reported in the CRF Table Summary3s1.	NIR Chapter 3 (3.3.2.2.e) CRF Table Summary3s1

Sector/Category	Recommendations by ERT	Actions taken	NIR/CRF
IPPU/Petrochemical and carbon black production (2.B.8)	Justify that the country-specific CO_2 EF has been developed in a manner consistent with the *2006 IPCC Guidelines*, covers the total CO_2 emissions from the steam cracking process and is considered to be more accurate than the IPCC default EF; or recalculate the CO_2 emissions from ethylene production by applying the default EF provided in the *2006 IPCC Guidelines* (vol. 3, chap. 3.9.2.2). (ARR2022, I.4)	The explanation is provided in the NIR.	NIR Chapter 4 (4.3.8.2.b)
IPPU/General	The ERT recommends that the Party include in the NIR a clear explanation of the reasons behind the decreases in (1) CO_2 emissions observed from 2019 to 2020 for categories 2.A.4.a (ceramics), 2.A.4.b (other uses of soda ash), 2.A.4.d (other), 2.B.1 (ammonia production), 2.B.2 (nitric acid production), 2.B.8.f (carbon black) and 2.C.1.a (use of electric arc furnaces), including that the coronavirus disease 2019 pandemic had an impact on the AD and emissions, and (2) fugitive NF_3 emissions observed from 2014 to 2015 for the category 2.B.9, which was driven by the expansion of destruction unit installation. (ARR2022, I.13)	The explanation is provided in the NIR.	NIR Chapter 4 (4.1 and 4.3.9.2.b)
IPPU/Cement Production (2.A.1)	The ERT recommends that the Party (1) determine whether the waste types used in cement production included in NIR table 4-4 have carbon available for combustion and if so, assess whether the CO_2 emissions are estimated and accounted for under the appropriate categories of the energy, IPPU or waste sectors; (2) if not accounted for, to estimate emissions report the findings from this assessment in the NIR. (ARR2022, I.14)	The explanation is provided in the NIR.	NIR Chapter 4 (4.2.1.b)
IPPU/ Adipic acid production (2.B.3)	The ERT recommends that, while ensuring the confidentiality of the information, the Party include in the NIR an explanation for the increase in N_2O emissions from adipic acid production from 2019 to 2020, noting that the explanation provided during the review was a decrease in the operation rate of N_2O decomposition units for adipic acid production. (ARR2022, I.15)	The explanation is provided in the NIR.	NIR Chapter 4 (4.3.3.b)
IPPU/Refrigeration and air conditioning (2.F.1)	The ERT recommends that the Party report in the NIR and CRF table 2(II)B-Hs2 the HFC-134a emissions from manufacturing, stocks and disposal separately for automatic vending machines in category 2.F.1.a (commercial refrigeration). (ARR2022, I.16)	Emissions from manufacturing, stocks and disposal are separately reported in NIR.	NIR Chapter 4 (4.7.1.2.b) CRF table 2(II)B-Hs2
IPPU/Refrigeration and air conditioning (2.F.1.c)	The ERT recommends that the Party include in the NIR or CRF table 9 the reasons for using “IE” to report emissions of an unspecified mix of HFCs for category 2.F.1.c (industrial refrigeration), that it is not possible to separate emissions of commercial refrigeration and industrial refrigeration because the industrial association that provides the data does not differentiate between the two in its data collection process. (ARR2022, I.17)	The explanation is provided in the NIR.	NIR Chapter 4 (4.7.1.4)
IPPU/Refrigeration and air conditioning (2.F.1.c)	The ERT recommends that the Party use the correct notation key, that is, change “NE” to “IE”, for the AD for category 2.F.1.c (industrial refrigeration) in CRF table 2(II)B-Hs2.	Notation keys in the CRF table are changed.	CRF Table2(II)B-Hs2

Sector/Category	Recommendations by ERT	Actions taken	NIR/CRF
	(ARR2022, I.18)		
Agriculture/ Inorganic N fertilizers – N_2O (3.D.a.1)	The ERT recommends that the Party include in the annual submission of NIR a transparent clarification of the use of nitrification inhibitors; (1) the information provided during the review, that is, that the survey of relevant data started in 1996, and (2) an estimate based on expert judgment of nitrification inhibitor use prior to 1996 would resolve this issue. (ARR2022, A.4)	The explanation is provided in the NIR.	NIR Chapter 5 (5.5.1.1)
Agriculture/ Cattle – CH_4 and N_2O (3.A., 3.B., 3.D.)	The ERT recommends that the Party include in the NIR the explanation provided during the review for the declining dairy cattle population since 1990, such as the decreasing number of livestock farmers, which is caused by the aging population of dairy farm owners and the lack of successors, including any recent factors affecting this trend. (ARR2022, A.7)	The explanation is provided in the NIR.	NIR Chapter 5 (5.2.)
Agriculture/ Manure Management - Cattle – CH_4 and N_2O (3.B.1)	The ERT recommends that the Party provide in the NIR (1) a detailed explanation of how the variables dry matter intake (DMI) and percentage of TDN (as substitutes for GE and percentage of DE) are applied when estimating the amount of excretion per head per day for non-dairy cattle, including the equation used, and (2) a justification for substituting these variables, including the references supporting the substitution. (ARR2022, A.10)	The explanation including equation and its reference is provided in the NIR.	NIR Chapter 5 (5.3.1)
Agriculture/ Manure Management - Other livestock – CH_4 and N_2O (3.B.4)	The ERT recommends that the Party provide in the NIR information, addressing more than water content of manure, and including references, to support its rationale for using swine EFs for estimating CH_4 and N_2O emissions from hens and broilers manure management. (ARR2022, A.11)	The explanation is provided in the NIR.	NIR Chapter 5 (5.3.1)
Agriculture/ Manure Management - Indirect Emissions - Atmospheric Deposition – N_2O (3.B.5)	The ERT recommends that the Party provide in the NIR clarification regarding the country's high humidity and the impact that this has on the country-specific $Frac_{GASM}$ values used for estimating indirect N_2O emissions from manure management. (ARR2022, A.12)	The explanation is provided in the NIR.	NIR Chapter 5 (5.3.1)
Agriculture/Agricultural Soils - Direct N_2O Emissions - managed soils – N_2O (3.D.a)	The ERT recommends that the Party (1) clarify in the NIR that N_2O emissions from the application of synthetic and organic N fertilizers applied to pastureland are included in the estimates of direct N_2O emissions from managed soils, (2) include pastureland as a separate row in the relevant tables in the NIR (e.g. table 5-56) and (3) report the area of pastureland. (ARR2022, A.13)	The format of the relevant table is changed, and the explanation is provided in the NIR.	NIR Chapter 5 (5.5.1)
Agriculture/Agricultural Soils - Direct N_2O Emissions - managed soils – N_2O (3.D.a.5)	The ERT recommends that the Party provide in the agriculture sector chapter of the NIR a statement that N_2O emissions from the mineralization of mineral soils under pastureland are estimated and reported on under the LULUCF sector. (ARR2022, A.14)	The explanation is provided in the NIR.	NIR Chapter 5 (5.5.1.5)
Agriculture/Agricultural Soils - Indirect N_2O Emissions - managed soils – N_2O (3.D.b)	The ERT recommends that the Party include in the NIR a justification for using the default values for EFs from the *2019 Refinement* to the *2006 IPCC Guidelines* values for estimating indirect N_2O emissions from managed soils. (ARR2022, A.15)	The explanation is provided in the NIR.	NIR Chapter 5 (5.5.2.1, 5.5.2.2)
Agriculture/ Other (field burning of agricultural	The ERT recommends that the Party explain in the NIR, regarding the amount of rice straw	The explanation is provided in the NIR.	NIR Chapter 5 (5.7)

Sector/Category	Recommendations by ERT	Actions taken	NIR/CRF
residues) – CH_4 and N_2O (3.F.)	and rice chaff burned on crop fields, that NIR table 5-77 contains values for the wet weight of the material while CRF table 3.F contains values for the dry biomass and report in the NIR the coefficient and equation used to convert the wet weight values to the dry biomass values. The ERT further recommends that the Party include information in the documentation box of CRF table 3.C that the dry weight values are reported for organic amendments for rice, and include information in the additional information section of CRF table 3.F where appropriate. (ARR2022, A.16)		
LULUCF/ General	Include in the NIR the information that CO_2 emissions do not occur from organic soils that are currently not included in the estimates, noting equation 2.26 from the *2006 IPCC Guidelines* (vol. 4, chap. 2), which applies to drained organic soils, in particular the required AD. (ARR2022, L.1)	The information that drainage in forest land with organic soils is not implemented in Japan, and the information when the expert judgement was made were include in NIR.	NIR Chapter6 (6.4.1 b) 2))
LULUCF/ Forest land remaining forest land (4.A.1)	Verify the value for the carbon stock of deadwood and include in the NIR an explanation of the reasons why this value is high. (ARR2022, L.2)	The value for the carbon stock of deadwood were verified and revised.	NIR Chapter 6 (Table 6-12)
LULUCF/ Forest land remaining forest land (4.A.1)	Improve the description of the methodology used to calculate carbon stock changes, including by adding specific information in the NIR on the parameters used to calculate carbon stock changes in living biomass for cutover forests and lesser stocked forests on the basis of expert judgment. (ARR2022, L.4)	The information was added in NIR.	NIR Chapter 6 (6.4.1.b) 2))
LULUCF/ Land representation	Demonstrate how approach to the identification of total land area across the time series does not lead to an over or underestimate of GHG emissions and removals, as far as can be judged. (ARR2022, L.15)	The reason that this approach does not lead to an over or underestimation of GHG emissions and removals were included in NIR.	NIR Chapter6 (6.2.1)
LULUCF/ Cropland (4.B)	Collect AD on area of organic soils in the tropical/subtropical climate zone and apply the default EF from the *2006 IPCC Guidelines* (vol. 4, table 5.6) or provide a justification for organic soils in the tropical/subtropical climate zone not occurring in Japan. (ARR2022, L.17)	The information was added in NIR.	NIR Chapter 6 (Table 6-29 note)
LULUCF/ Direct N_2O emissions from N mineralization/ immobilization (4(III)	Review the area of mineral soils reported for other land in CRF table 4.F and the area of mineral soils for land converted to other land reported in CRF table 4(III), ensure that the same values are reported across the time series, and explain this recalculation in the NIR. (ARR2022, L.18)	The same value were reported in CRF table 4.F and CRF table 4(III).	CRF table 4.F and CRF table 4(III) NIR Chapter 6
Waste/ Solid waste disposal on land (5.A)	Provide in the NIR the description provided during the 2020 review explaining the difference between the FOD methodology in the *2006 IPCC Guidelines* and Japan's FOD method, thus confirming that the country-specific FOD method is in accordance with the *2006 IPCC Guidelines* (vol. 5, chap. 3, equation 3.1). (ARR2022 W.1)	It was described in the NIR that there are no substantial differences between Japan's method and the FOD method in the *2006 IPCC Guidelines* (vol. 5, chap. 3, equation 3.1).	NIR Chapter 7 (7.2.1)
Waste/ Uncategorized waste disposal sites (5.A.3)	Provide in the NIR detailed information on the investigation into and methodology used for estimating the amount of uncategorized waste disposal used as AD for 1980–2001. (ARR2022 W.6)	A detailed information for the methodology was added in the NIR.	NIR Chapter 7 (7.2.3)

Sector/Category	Recommendations by ERT	Actions taken	NIR/CRF
Waste/ Wastewater treatment and discharge (5.D)	Include the same explanation in the NIR and CRF table 5.D for reporting as “NA” the AD for the subcategories of category 5.D (wastewater treatment and discharge). (ARR2022 W.7)	An explanation shown below was provided in the NIR and CRF tables: Activity data are reported as “NA” since country-specific methodologies for this category require various type of activity data by gas and facility type.	NIR Chapter 7 (7.5.1) CRF Table 5.D

10.4.2. Planned Improvements

The following improvements are continuously performed and reflect in an inventory preparation process accordingly. See relative sections for details.

1. Review of estimation methods, activity data, emission factors and other elements
   Japan holds meetings of a Committee for Greenhouse Gas Emission Estimation Methods and considers improvements of estimation methods, activity data, emission factors and other elements used in the current inventory. In case of implementation, Japan prioritizes highly important issues such as those relevant to key-categories and those pointed out in the past review reports.
2. Improvement of transparency
   Japan will further improve transparency of the inventory by examining descriptions of methodologies, assumptions, data, and other elements in NIR, and by adding necessary information to NIR.

Annex 1. Key Categories

A1.1. Outline of Key Category Analysis

The *UNFCCC Inventory Reporting Guidelines* (Decision 24/CP.19 Annex I) require the application of the *2006 IPCC Guidelines*, and the key category analysis given in the Guidelines. The key category analyses were done for both data of FY2021 (the latest reported year) and of FY1990 (the base year for the UNFCCC). Their results are presented here.

A1.2. Results of Key Category Analysis

A1.2.1 Key Categories

Key categories were assessed in accordance with the *2006 IPCC Guidelines* assessment methods (Approach 1 level assessment, Approach 1 trend assessment, Approach 2 level assessment, and Approach 2 trend assessment), using all of the inventory categories including the LULUCF sector.

As a result, 51 and 43 sources and sinks were identified as the key categories for FY2021 and FY1990, respectively (Table A1-1 and Table A1-2).

Table A1-1 Japan's key categories (FY2021)

	A IPCC Code	B IPCC Category		C GHGs	Ap1-L	Ap1-T	Ap2-L	Ap2-T
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	#1	#1	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#20	#11	
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#3	#7	#2	#10
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#4	#4	#8	#17
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#6	#24	#22
#6	4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	#6	#8	#4	#7
#7	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#7	#2	#30	#14
#8	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#8	#3	#31	#19
#9	2.F.	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	#9	#5	#6	#6
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#10	#9	#29	
#11	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#11	#10	#34	
#12	2.A.	Mineral Industry	1. Cement Production	CO_2	#12	#12	#21	#24
#13	3.C.	Rice Cultivation		CH_4	#13		#28	
#14	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	#14	#18	#9	#15
#15	5.C.	Incineration and Open Burning of Waste		CO_2	#15		#13	
#16	1.A.3.	Transport	d. Domestic Navigation	CO_2	#16			
#17	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#17		#14	#25
#18	3.A.	Enteric Fermentation		CH_4	#18		#7	
#19	1.A.3.	Transport	a. Domestic Aviation	CO_2	#19			
#20	1.A.4.	Other Sectors	Solid Fuels	CO_2	#20	#19		#29
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#21			
#22	2.A.	Mineral Industry	2. Lime Production	CO_2	#22			
#23	4.B.	Cropland	1. Cropland remaining Cropland	CO_2			#20	#20
#24	3.B.	Manure Management		N_2O			#5	
#25	4.E.	Settlements	2. Land converted to Settlements	CO_2		#15	#12	#3
#26	3.D.	Agricultural Soils	1. Direct Emissions	N_2O			#25	
#27	2.F.	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs		#23	#15	#12
#28	2.B.	Chemical Industry	Other products except Anmonia	CO_2			#16	#27
#29	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O			#3	#16
#30	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2			#19	
#31	5.D.	Wastewater Treatment and Discharge		N_2O			#27	
#32	1.A.1.	Energy Industries		N_2O			#32	
#33	2.E.	Electronics Industry		PFCs			#17	
#34	4.G.	Harvested Wood Products		CO_2				#28
#35	5.A.	Solid Waste Disposal		CH_4		#14		#9
#36	4.E.	Settlements	1. Settlements remaining Settlements	CO_2			#33	
#37		Indirect CO_2	from IPPU sector	Ind CO_2			#26	#11
#38	2.G.	Other Product Manufacture and Use		SF_6		#16	#10	#2
#39	2.F.	Product uses as substitutes for ODS	5. Solvents	PFCs		#24		
#40	5.C.	Incineration and Open Burning of Waste		N_2O			#22	
#41	1.A.3.	Transport	b. Road Transportation	N_2O			#18	#8
#42	4.A.	Forest Land	2. Land converted to Forest Land	CO_2		#13		#18
#43	1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH_4		#21		#4
#44	4.F.	Other Land	2. Land converted to Other Land	CO_2				#13
#45	2.E.	Electronics Industry		SF_6			#23	
#46	4.(III)	Direct N_2O emissions from N mineralization/immobilization		N_2O				#23
#47	2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs		#11		
#48	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O				#5
#49	4.(IV)	Indirect N_2O Emissions from Managed Soils		N_2O				#26
#50	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O		#17		#21
#51	2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF_6		#22		

Note: Ap1-L: Approach1-Level Assessment, Ap1-T: Approach1-Trend Assessment,
Ap2-L: Approach2-Level Assessment, Ap2-T: Approach2-Trend Assessment
Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

Table A1-2 Japan's key categories (FY1990)

	A IPCC Code	B IPCC Category		C GHGs	Ap1-L	Ap2-L
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#1	#2
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#14
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#3	#15
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#4	#21
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#22
#6	1.A.1.	Energy Industries	Solid Fuels	CO_2	#6	#5
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#7	#23
#8	4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	#8	#4
#9	2.A.	Mineral Industry	1. Cement Production	CO_2	#9	#20
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#10	
#11	2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	#11	
#12	1.A.3.	Transport	d. Domestic Navigation	CO_2	#12	
#13	5.C.	Incineration and Open Burning of Waste		CO_2	#13	#17
#14	3.C.	Rice Cultivation		CH_4	#14	
#15	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#15	
#16	4.E.	Settlements	2. Land converted to Settlements	CO_2	#16	#7
#17	5.A.	Solid Waste Disposal		CH_4	#17	#13
#18	4.A.	Forest Land	2. Land converted to Forest Land	CO_2	#18	#32
#19	3.A.	Enteric Fermentation		CH_4	#19	#11
#20	2.G.	Other Product Manufacture and Use		SF_6	#20	#1
#21	4.B.	Cropland	1. Cropland remaining Cropland	CO_2	#21	#19
#22	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	#22	
#23	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#23	
#24	1.A.3.	Transport	a. Domestic Aviation	CO_2	#24	
#25	2.A.	Mineral Industry	2. Lime Production	CO_2	#25	
#26	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#26	#25
#27	1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH_4	#27	#8
#28	2.F.	Product uses as substitutes for ODS	5. Solvents	PFCs	#28	
#29		Indirect CO_2	from IPPU sector	Ind CO_2		#12
#30	3.D.	Agricultural Soils	1. Direct Emissions	N_2O		#28
#31	3.B.	Manure Management		N_2O		#6
#32	2.B.	Chemical Industry	Other products except Anmonia	CO_2		#16
#33	1.A.3.	Transport	b. Road Transportation	N_2O		#10
#34	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O		#3
#35	5.D.	Wastewater Treatment and Discharge		N_2O		#30
#36	4.F.	Other Land	2. Land converted to Other Land	CO_2		#18
#37	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2		#29
#38	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O		#9
#39	2.E.	Electronics Industry		PFCs		#26
#40	5.C.	Incineration and Open Burning of Waste		N_2O		#27
#41	4.(III)	Direct N_2O emissions from N mineralization/immobilization		N_2O		#31
#42	2.E.	Electronics Industry		SF_6		#24
#43	4.(IV)	Indirect N_2O Emissions from Managed Soils		N_2O		#33

Note: Ap1-L: Approach1-Level Assessment, Ap2-L: Approach2-Level Assessment
Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

A1.2.2 Level Assessment

Level assessment involves an identification of categories as a key by calculating the proportion of emissions and removals in each category to the total emissions and removals. The calculated values of proportion are added from the category that accounts for the largest proportion, until the sum reaches 95% for Approach 1 and 90% for Approach 2. Approach 1 level assessment uses emissions and removals from each category directly and Approach 2 level assessment analyzes the emissions and removals of each category, multiplied by the uncertainty of each category.

Approach 1 level assessment of the latest emissions and removals (FY2021) gives the following 22 sub-categories as the key categories (Table A1-3). Approach 2 level assessment of the latest emissions and removals (FY2021) gives the following 34 sub-categories as the key categories (Table A1-4).

Table A1-3 Results of Approach 1 level assessment (FY2021)

	A IPCC Code	B IPCC Category		C GHGs	F Current Year Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	Cumulative contrib. [%]
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	257,985.88	0.208	20.8%	20.8%
#2	1.A.3.	Transport	b. Road Transportation	CO_2	160,345.04	0.129	12.9%	33.7%
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	156,884.43	0.126	12.6%	46.3%
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	134,345.01	0.108	10.8%	57.2%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	76,466.20	0.062	6.2%	63.3%
#6	4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	-57,604.03	0.046	4.6%	68.0%
#7	1.A.1.	Energy Industries	Liquid Fuels	CO_2	51,948.65	0.042	4.2%	72.2%
#8	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	51,541.61	0.042	4.2%	76.3%
#9	2.F.	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	49,516.70	0.040	4.0%	80.3%
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	44,213.25	0.036	3.6%	83.9%
#11	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	30,645.01	0.025	2.5%	86.3%
#12	2.A.	Mineral Industry	1. Cement Production	CO_2	24,395.61	0.020	2.0%	88.3%
#13	3.C.	Rice Cultivation		CH_4	11,942.42	0.010	1.0%	89.3%
#14	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	10,477.57	0.008	0.8%	90.1%
#15	5.C.	Incineration and Open Burning of Waste		CO_2	10,358.56	0.008	0.8%	90.9%
#16	1.A.3.	Transport	d. Domestic Navigation	CO_2	10,278.96	0.008	0.8%	91.8%
#17	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	8,336.77	0.007	0.7%	92.4%
#18	3.A.	Enteric Fermentation		CH_4	7,717.70	0.006	0.6%	93.1%
#19	1.A.3.	Transport	a. Domestic Aviation	CO_2	6,818.82	0.005	0.5%	93.6%
#20	1.A.4.	Other Sectors	Solid Fuels	CO_2	6,468.54	0.005	0.5%	94.1%
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	5,458.73	0.004	0.4%	94.6%
#22	2.A.	Mineral Industry	2. Lime Production	CO_2	4,970.76	0.004	0.4%	95.0%

Table A1-4 Results of Approach 2 level assessment (FY2021)

	A IPCC Code	B IPCC Category		C GHGs	F Current Year Estimate [Gg-CO_2 eq.]	L Source/Sink Uncertainty [%]	N Ap2-L Contrib. [%]	Cumulative contrib. [%]
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	257,985.88	6%	18.4%	18.4%
#2	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	156,884.43	6%	11.2%	29.6%
#3	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,341.38	246%	6.6%	36.2%
#4	4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	-57,604.03	9%	6.0%	42.2%
#5	3.B.	Manure Management		N_2O	3,910.76	132%	5.9%	48.1%
#6	2.F.	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	49,516.70	6%	3.4%	51.5%
#7	3.A.	Enteric Fermentation		CH_4	7,717.70	29%	2.6%	54.1%
#8	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	134,345.01	2%	2.5%	56.6%
#9	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	10,477.57	19%	2.3%	58.8%
#10	2.G.	Other Product Manufacture and Use		SF_6	1,383.16	143%	2.3%	61.1%
#11	1.A.3.	Transport	b. Road Transportation	CO_2	160,345.04	1%	2.1%	63.2%
#12	4.E.	Settlements	2. Land converted to Settlements	CO_2	3,747.40	49%	2.1%	65.3%
#13	5.C.	Incineration and Open Burning of Waste		CO_2	10,358.56	15%	1.8%	67.2%
#14	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	8,336.77	19%	1.8%	69.0%
#15	2.F.	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	2,941.23	50%	1.7%	70.6%
#16	2.B.	Chemical Industry	Other products except Anmonia	CO_2	2,614.45	55%	1.6%	72.3%
#17	2.E.	Electronics Industry		PFCs	1,611.80	81%	1.5%	73.8%
#18	1.A.3.	Transport	b. Road Transportation	N_2O	1,204.47	107%	1.5%	75.2%
#19	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,293.32	53%	1.4%	76.6%
#20	4.B.	Cropland	1. Cropland remaining Cropland	CO_2	4,211.77	25%	1.2%	77.8%
#21	2.A.	Mineral Industry	1. Cement Production	CO_2	24,395.61	4%	1.1%	79.0%
#22	5.C.	Incineration and Open Burning of Waste		N_2O	1,239.14	77%	1.1%	80.1%
#23	2.E.	Electronics Industry		SF_6	299.47	300%	1.0%	81.1%
#24	1.A.4.	Other Sectors	Liquid Fuels	CO_2	76,466.20	1%	1.0%	82.1%
#25	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	3,286.61	25%	1.0%	83.1%
#26		Indirect CO_2	from IPPU sector	Ind CO_2	1,423.03	59%	1.0%	84.0%
#27	5.D.	Wastewater Treatment and Discharge		N_2O	1,982.05	42%	0.9%	85.0%
#28	3.C.	Rice Cultivation		CH_4	11,942.42	6%	0.8%	85.8%
#29	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	44,213.25	2%	0.8%	86.6%
#30	1.A.1.	Energy Industries	Liquid Fuels	CO_2	51,948.65	1%	0.7%	87.3%
#31	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	51,541.61	1%	0.7%	88.0%
#32	1.A.1.	Energy Industries		N_2O	1,903.53	30%	0.7%	88.7%
#33	4.E.	Settlements	1. Settlements remaining Settlements	CO_2	-1,550.62	34%	0.6%	89.3%
#34	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	30,645.01	2%	0.6%	89.8%

Approach 1 level assessment of the base year emissions and removals (FY1990) gives the following 28 sub-categories as the key categories (Table A1-5). Approach 2 level assessment of the base year emissions and removals (FY1990) gives the following 33 sub-categories as the key categories (Table A1-6).

Table A1-5 Results of Approach 1 level assessment (FY1990)

	A IPCC Code	B IPCC Category		C GHGs	D FY1990 Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	Cumulative contrib. [%]
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,587.36	0.144	14.4%	14.4%
#2	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	0.130	13.0%	27.4%
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,960.86	0.129	12.9%	40.3%
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	0.097	9.7%	50.0%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	0.093	9.3%	59.3%
#6	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	0.079	7.9%	67.2%
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	0.058	5.8%	73.0%
#8	4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	-76,685.74	0.055	5.5%	78.5%
#9	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	0.028	2.8%	81.3%
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	0.016	1.6%	82.9%
#11	2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	15,930.24	0.011	1.1%	84.0%
#12	1.A.3.	Transport	d. Domestic Navigation	CO_2	13,674.88	0.010	1.0%	85.0%
#13	5.C.	Incineration and Open Burning of Waste		CO_2	12,318.70	0.009	0.9%	85.9%
#14	3.C.	Rice Cultivation		CH_4	12,129.25	0.009	0.9%	86.8%
#15	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	0.009	0.9%	87.6%
#16	4.E.	Settlements	2. Land converted to Settlements	CO_2	11,660.91	0.008	0.8%	88.5%
#17	5.A.	Solid Waste Disposal		CH_4	9,939.57	0.007	0.7%	89.2%
#18	4.A.	Forest Land	2. Land converted to Forest Land	CO_2	-9,579.10	0.007	0.7%	89.9%
#19	3.A.	Enteric Fermentation		CH_4	9,422.90	0.007	0.7%	90.6%
#20	2.G.	Other Product Manufacture and Use		SF_6	8,814.04	0.006	0.6%	91.2%
#21	4.B.	Cropland	1. Cropland remaining Cropland	CO_2	7,406.88	0.005	0.5%	91.7%
#22	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	7,210.88	0.005	0.5%	92.3%
#23	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	7,207.71	0.005	0.5%	92.8%
#24	1.A.3.	Transport	a. Domestic Aviation	CO_2	7,162.41	0.005	0.5%	93.3%
#25	2.A.	Mineral Industry	2. Lime Production	CO_2	6,674.45	0.005	0.5%	93.8%
#26	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	0.005	0.5%	94.2%
#27	1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH_4	4,894.72	0.004	0.4%	94.6%
#28	2.F.	Product uses as substitutes for ODS	5. Solvents	PFCs	4,549.94	0.003	0.3%	94.9%

Table A1-6 Results of Approach 2 level assessment (FY1990)

	A IPCC Code	B IPCC Category		C GHGs	D FY1990 Estimate [Gg-CO_2 eq.]	L Source/Sink Uncertainty [%]	N Ap2-L Contrib. [%]	Cumulative contrib. [%]
#1	2.G.	Other Product Manufacture and Use		SF_6	8,814.04	143%	10.8%	10.8%
#2	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,587.36	6%	10.7%	21.4%
#3	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,988.43	246%	6.3%	27.7%
#4	4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	-76,685.74	9%	5.9%	33.7%
#5	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	6%	5.9%	39.5%
#6	3.B.	Manure Management		N_2O	4,346.32	132%	4.9%	44.4%
#7	4.E.	Settlements	2. Land converted to Settlements	CO_2	11,660.91	49%	4.9%	49.3%
#8	1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH_4	4,894.72	84%	3.5%	52.8%
#9	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,672.86	223%	3.2%	56.0%
#10	1.A.3.	Transport	b. Road Transportation	N_2O	3,457.24	107%	3.2%	59.2%
#11	3.A.	Enteric Fermentation		CH_4	9,422.90	29%	2.4%	61.5%
#12		Indirect CO_2	from IPPU sector	Ind CO_2	4,448.92	59%	2.2%	63.8%
#13	5.A.	Solid Waste Disposal		CH_4	9,939.57	23%	2.0%	65.7%
#14	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	1%	1.8%	67.5%
#15	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,960.86	1%	1.8%	69.3%
#16	2.B.	Chemical Industry	Other products except Anmonia	CO_2	3,623.06	55%	1.7%	71.0%
#17	5.C.	Incineration and Open Burning of Waste		CO_2	12,318.70	15%	1.6%	72.6%
#18	4.F.	Other Land	2. Land converted to Other Land	CO_2	2,286.70	82%	1.6%	74.2%
#19	4.B.	Cropland	1. Cropland remaining Cropland	CO_2	7,406.88	25%	1.6%	75.8%
#20	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	4%	1.4%	77.2%
#21	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	1%	1.3%	78.5%
#22	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	1%	1.3%	79.8%
#23	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	2%	1.1%	80.9%
#24	2.E.	Electronics Industry		SF_6	418.70	300%	1.1%	82.0%
#25	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	19%	1.1%	83.0%
#26	2.E.	Electronics Industry		PFCs	1,454.78	81%	1.0%	84.0%
#27	5.C.	Incineration and Open Burning of Waste		N_2O	1,438.04	77%	0.9%	85.0%
#28	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,347.57	25%	0.9%	85.9%
#29	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,039.82	53%	0.9%	86.9%
#30	5.D.	Wastewater Treatment and Discharge		N_2O	2,387.11	42%	0.9%	87.7%
#31	4.(III)	Direct N_2O emissions from N mineralization/immobilization		N_2O	649.32	145%	0.8%	88.5%
#32	4.A.	Forest Land	2. Land converted to Forest Land	CO_2	-9,579.10	9%	0.7%	89.3%
#33	4.(IV)	Indirect N_2O Emissions from Managed Soils		N_2O	290.27	276%	0.7%	89.9%

A1.2.3 Trend Assessment

The difference between the rate of change in emissions and removals in a category and the rate of change in total emissions and removals is calculated. The trend assessment is calculated by multiplying this value by the ratio of contribution of the relevant category to total emissions and removals. The calculated results, regarded as trend assessment values, are added from the category whose proportion to the total of trend assessment values is the largest, until the total reaches 95% for Approach 1 and 90% for Approach 2. At this point, these categories are defined as the key categories. Approach 1 trend assessment uses emissions and removals from each category directly and Approach 2 trend assessment analyzes the emissions and removals of each category, multiplied by the uncertainty of each category.

Approach 1 trend assessment of the latest emissions and removals (FY2021) gives the following 24 sub-categories as the key categories (Table A1-7). Approach 2 trend assessment of the latest emissions and removals (FY2021) gives the following 29 sub-categories as the key categories (Table A1-8).

Table A1-7 Results of Approach 1 trend assessment (FY2021)

	A IPCC Code	B IPCC Category		C GHGs	D FY1990 Estimate [Gg-CO_2 eq.]	F Current Year Estimate [Gg-CO_2 eq.]	J Ap1-T	K Ap1-T Contrib. [%]	Cumulative contrib. [%]
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	257,985.88	0.113	21.7%	21.7%
#2	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,960.86	51,948.65	0.082	15.7%	37.4%
#3	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	51,541.61	0.052	10.0%	47.4%
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	134,345.01	0.044	8.4%	55.7%
#5	2.F.	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	0.00	49,516.70	0.036	6.8%	62.6%
#6	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	76,466.20	0.031	5.9%	68.5%
#7	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,587.36	156,884.43	0.020	3.8%	72.2%
#8	4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	-76,685.74	-57,604.03	0.018	3.5%	75.7%
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	44,213.25	0.017	3.3%	79.0%
#10	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	30,645.01	0.014	2.7%	81.7%
#11	2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	15,930.24	251.27	0.010	2.0%	83.7%
#12	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	24,395.61	0.008	1.6%	85.3%
#13	4.A.	Forest Land	2. Land converted to Forest Land	CO_2	-9,579.10	-738.67	0.007	1.3%	86.6%
#14	5.A.	Solid Waste Disposal		CH_4	9,939.57	1,569.41	0.005	1.1%	87.6%
#15	4.E.	Settlements	2. Land converted to Settlements	CO_2	11,660.91	3,747.40	0.005	1.0%	88.6%
#16	2.G.	Other Product Manufacture and Use		SF_6	8,814.04	1,383.16	0.005	0.9%	89.5%
#17	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	7,210.88	48.43	0.005	0.9%	90.5%
#18	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	4,207.45	10,477.57	0.005	0.9%	91.4%
#19	1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	6,468.54	0.004	0.8%	92.2%
#20	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	160,345.04	0.004	0.8%	93.1%
#21	1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH_4	4,894.72	455.86	0.003	0.6%	93.6%
#22	2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF_6	3,470.78	45.62	0.002	0.4%	94.1%
#23	2.F.	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1.34	2,941.23	0.002	0.4%	94.5%
#24	2.F.	Product uses as substitutes for ODS	5. Solvents	PFCs	4,549.94	1,382.17	0.002	0.4%	94.9%

Table A1-8 Results of Approach 2 trend assessment (FY2021)

	A IPCC Code	B IPCC Category		C GHGs	D FY1990 Estimate [Gg-CO_2 eq.]	F Current Year Estimate [Gg-CO_2 eq.]	L Source/Sink Uncertainty [%]	O Ap2-T	P Ap2-T Contrib. [%]	Cumulative contrib. [%]
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	257,985.88	6%	7.08	15.7%	15.7%
#2	2.G.	Other Product Manufacture and Use		SF_6	8,814.04	1,383.16	143%	6.98	15.5%	31.2%
#3	4.E.	Settlements	2. Land converted to Settlements	CO_2	11,660.91	3,747.40	49%	2.49	5.5%	36.7%
#4	1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH_4	4,894.72	455.86	84%	2.48	5.5%	42.2%
#5	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,672.86	141.05	223%	2.26	5.0%	47.2%
#6	2.F.	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	0.00	49,516.70	6%	2.17	4.8%	52.0%
#7	4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	-76,685.74	-57,604.03	9%	1.64	3.6%	55.6%
#8	1.A.3.	Transport	b. Road Transportation	N_2O	3,457.24	1,204.47	107%	1.53	3.4%	59.0%
#9	5.A.	Solid Waste Disposal		CH_4	9,939.57	1,569.41	23%	1.27	2.8%	61.9%
#10	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,587.36	156,884.43	6%	1.23	2.7%	64.6%
#11		Indirect CO_2	from IPPU sector	Ind CO_2	4,448.92	1,423.03	59%	1.14	2.5%	67.1%
#12	2.F.	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1.34	2,941.23	50%	1.06	2.4%	69.5%
#13	4.F.	Other Land	2. Land converted to Other Land	CO_2	2,286.70	374.12	82%	1.03	2.3%	71.8%
#14	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,960.86	51,948.65	1%	0.96	2.1%	73.9%
#15	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	4,207.45	10,477.57	19%	0.90	2.0%	75.9%
#16	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,988.43	2,341.38	246%	0.74	1.6%	77.5%
#17	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	134,345.01	2%	0.70	1.5%	79.1%
#18	4.A.	Forest Land	2. Land converted to Forest Land	CO_2	-9,579.10	-738.67	9%	0.63	1.4%	80.5%
#19	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	51,541.61	1%	0.61	1.4%	81.8%
#20	4.B.	Cropland	1. Cropland remaining Cropland	CO_2	7,406.88	4,211.77	25%	0.48	1.1%	82.9%
#21	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	7,210.88	48.43	9%	0.44	1.0%	83.8%
#22	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	76,466.20	1%	0.36	0.8%	84.6%
#23	4.(III)	Direct N_2O emissions from N mineralization/immobilization		N_2O	649.32	266.51	145%	0.35	0.8%	85.4%
#24	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	24,395.61	4%	0.34	0.7%	86.2%
#25	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	8,336.77	19%	0.32	0.7%	86.9%
#26	4.(IV)	Indirect N_2O Emissions from Managed Soils		N_2O	290.27	119.30	276%	0.30	0.7%	87.5%
#27	2.B.	Chemical Industry	Other products except Anmonia	CO_2	3,623.06	2,614.45	55%	0.29	0.6%	88.2%
#28	4.G.	Harvested Wood Products		CO_2	-264.17	-1,595.59	30%	0.28	0.6%	88.8%
#29	1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	6,468.54	6%	0.28	0.6%	89.4%

Data utilized for the key category analysis are shown in Table A1-9 and Table A1-10 as references.

Table A1-9 Data used for the key category analysis (FY2021)

A IPCC Code	B IPCC Category		C GHGs	E Absolute Value of FY1990 Estimate [Gg-CO_2 eq.]	G Absolute Value of Current Year Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	J Ap1-T	K Ap1-T Contrib. [%]	L Source/Sink Uncertainty [%]	M Ap2-L	N Ap2-L Contrib. [%]	O Ap2-T	P Ap2-T Contrib. [%]
1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,960.86	51,948.65	0.042	4.2%	0.0817	15.7%	1%	0.007	0.7%	0.96	2.1%
1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	257,985.88	0.208	20.8%	0.1131	21.7%	6%	0.184	18.4%	7.08	15.7%
1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	134,345.01	0.108	10.8%	0.0436	8.4%	2%	0.025	2.5%	0.70	1.5%
1.A.1.	Energy Industries	Other Fossil Fuels	CO_2	0.00	33.44	0.000	0.0%	0.0000	0.0%	19%	0.000	0.0%	0.00	0.0%
1.A.1.	Energy Industries		CH_4	459.35	403.43	0.000	0.0%	0.0000	0.0%	69%	0.003	0.3%	0.01	0.0%
1.A.1.	Energy Industries		N_2O	889.48	1,903.53	0.002	0.2%	0.0008	0.1%	30%	0.007	0.7%	0.23	0.5%
1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	51,541.61	0.042	4.2%	0.0521	10.0%	1%	0.007	0.7%	0.61	1.4%
1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,587.36	156,884.43	0.126	12.6%	0.0197	3.8%	6%	0.112	11.2%	1.23	2.7%
1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	30,645.01	0.025	2.5%	0.0142	2.7%	2%	0.006	0.6%	0.23	0.5%
1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	4,207.45	10,477.57	0.008	0.8%	0.0048	0.9%	19%	0.023	2.3%	0.90	2.0%
1.A.2.	Manufacturing Industries and Construction		CH_4	359.76	546.92	0.000	0.0%	0.0002	0.0%	69%	0.004	0.4%	0.11	0.2%
1.A.2.	Manufacturing Industries and Construction		N_2O	1,259.81	1,475.18	0.001	0.1%	0.0002	0.0%	30%	0.005	0.5%	0.07	0.1%
1.A.3.	Transport	a. Domestic Aviation	CO_2	7,162.41	6,818.82	0.005	0.5%	0.0001	0.0%	1%	0.001	0.1%	0.00	0.0%
1.A.3.	Transport	a. Domestic Aviation	CH_4	5.64	1.25	0.000	0.0%	0.0000	0.0%	52%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	a. Domestic Aviation	N_2O	64.02	60.48	0.000	0.0%	0.0000	0.0%	141%	0.001	0.1%	0.00	0.0%
1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	160,345.04	0.129	12.9%	0.0044	0.849%	1%	0.021	2.1%	0.05	0.1%
1.A.3.	Transport	b. Road Transportation	CH_4	252.59	78.70	0.000	0.0%	0.0001	0.0%	104%	0.001	0.1%	0.12	0.3%
1.A.3.	Transport	b. Road Transportation	N_2O	3,457.24	1,204.47	0.001	0.1%	0.0014	0.3%	107%	0.015	1.5%	1.53	3.4%
1.A.3.	Transport	c. Railways	CO_2	935.40	468.04	0.000	0.0%	0.0003	0.1%	1%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	c. Railways	CH_4	1.34	0.66	0.000	0.0%	0.0000	0.0%	151%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	c. Railways	N_2O	109.95	54.28	0.000	0.0%	0.0000	0.0%	200%	0.001	0.1%	0.07	0.2%
1.A.3.	Transport	d. Domestic Navigation	CO_2	13,674.88	10,278.96	0.008	0.8%	0.0017	0.3%	1%	0.001	0.1%	0.02	0.0%
1.A.3.	Transport	d. Domestic Navigation	CH_4	31.73	23.01	0.000	0.0%	0.0000	0.0%	52%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	d. Domestic Navigation	N_2O	108.07	78.35	0.000	0.0%	0.0000	0.0%	141%	0.001	0.1%	0.02	0.0%
1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	76,466.20	0.062	6.2%	0.0308	5.9%	1%	0.010	1.0%	0.36	0.8%
1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	6,468.54	0.005	0.5%	0.0044	0.8%	6%	0.005	0.5%	0.28	0.6%
1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	44,213.25	0.036	3.6%	0.0171	3.3%	2%	0.008	0.8%	0.27	0.6%
1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	8,336.77	0.007	0.7%	0.0017	0.3%	19%	0.018	1.8%	0.32	0.7%
1.A.4.	Other Sectors		CH_4	238.65	189.30	0.000	0.0%	0.0000	0.0%	69%	0.001	0.1%	0.02	0.0%
1.A.4.	Other Sectors		N_2O	689.41	629.10	0.001	0.1%	0.0000	0.0%	30%	0.002	0.2%	0.00	0.0%
1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CO_2	5.90	3.43	0.000	0.0%	0.0000	0.0%	19%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH_4	4,894.72	455.86	0.000	0.0%	0.0029	0.6%	84%	0.004	0.4%	2.48	5.5%
1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	N_2O	1.98	0.42	0.000	0.0%	0.0000	0.0%	163%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emission from Fuel	2.a. Oil	CO_2	0.03	0.02	0.000	0.0%	0.0000	0.0%	89%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emission from Fuel	2.a. Oil	CH_4	25.37	16.46	0.000	0.0%	0.0000	0.0%	68%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emission from Fuel	2.b. Natural Gas	CO_2	0.63	0.71	0.000	0.0%	0.0000	0.0%	80%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emission from Fuel	2.b. Natural Gas	CH_4	174.24	198.79	0.000	0.0%	0.0000	0.0%	75%	0.002	0.2%	0.02	0.0%
1.B.	Fugitive Emission from Fuel	2.c. Venting & Flaring	CO_2	81.17	162.83	0.000	0.0%	0.0001	0.0%	14%	0.000	0.0%	0.01	0.0%
1.B.	Fugitive Emission from Fuel	2.c. Venting & Flaring	CH_4	7.96	4.25	0.000	0.0%	0.0000	0.0%	49%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emission from Fuel	2.c. Venting & Flaring	N_2O	0.11	0.07	0.000	0.0%	0.0000	0.0%	31%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emission from Fuel	2.d. Other (Geothermal)	CO_2	104.42	191.86	0.000	0.0%	0.0001	0.0%	17%	0.000	0.0%	0.01	0.0%
1.B.	Fugitive Emission from Fuel	2.d. Other (Geothermal)	CH_4	5.21	9.54	0.000	0.0%	0.0000	0.0%	17%	0.000	0.0%	0.00	0.0%

Table A1-9 Data used for the key category analysis (FY2021) (Continued)

A IPCC Code	B IPCC Category		C GHGs	E Absolute Value of FY1990 Estimate [Gg-CO_2 eq.]	G Absolute Value of Current Year Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	J Ap1-T	K Ap1-T Contrib. [%]	L Source/Sink Uncertainty [%]	M Ap2-L	N Ap2-L Contrib. [%]	O Ap2-T	P Ap2-T Contrib. [%]
2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	24,395.61	0.020	2.0%	0.0082	1.6%	4%	0.011	1.1%	0.34	0.7%
2.A.	Mineral Industry	2. Lime Production	CO_2	6,674.45	4,970.76	0.004	0.4%	0.0009	0.2%	4%	0.002	0.2%	0.03	0.1%
2.A.	Mineral Industry	3. Glass Production	CO_2	312.93	174.31	0.000	0.0%	0.0001	0.0%	6%	0.000	0.0%	0.00	0.0%
2.A.	Mineral Industry	4. Other Process Uses of Carbonates	CO_2	3,025.31	1,596.15	0.001	0.1%	0.0009	0.2%	6%	0.001	0.1%	0.05	0.1%
2.B.	Chemical Industry	1. Ammonia Production	CO_2	2,879.46	1,457.65	0.001	0.1%	0.0009	0.2%	2%	0.000	0.0%	0.02	0.0%
2.B.	Chemical Industry	Other products except Anmonia	CO_2	3,623.06	2,614.45	0.002	0.2%	0.0005	0.1%	55%	0.016	1.6%	0.29	0.6%
2.B.	Chemical Industry	2. Nitric Acid Production	N_2O	736.06	256.40	0.000	0.0%	0.0003	0.1%	85%	0.002	0.2%	0.26	0.6%
2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	7,210.88	48.43	0.000	0.0%	0.0048	0.9%	9%	0.000	0.0%	0.44	1.0%
2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,672.86	141.05	0.000	0.0%	0.0010	0.2%	223%	0.004	0.4%	2.26	5.0%
2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	15,930.24	251.27	0.000	0.0%	0.0104	2.0%	2%	0.000	0.0%	0.21	0.5%
2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	PFCs	330.92	79.08	0.000	0.0%	0.0002	0.0%	2%	0.000	0.0%	0.00	0.0%
2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF_6	3,470.78	45.62	0.000	0.0%	0.0023	0.4%	2%	0.000	0.0%	0.05	0.1%
2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	NF_3	2.79	23.88	0.000	0.0%	0.0000	0.0%	2%	0.000	0.0%	0.00	0.0%
2.B.	Chemical Industry	Whole of Chemical Industries	CH_4	37.49	27.02	0.000	0.0%	0.0000	0.0%	58%	0.000	0.0%	0.00	0.0%
2.C.	Metal Industry	1. Iron and Steel Production	CO_2	7,207.71	5,458.73	0.004	0.4%	0.0009	0.2%	4%	0.002	0.2%	0.03	0.1%
2.C.	Metal Industry	1. Iron and Steel Production	CH_4	18.42	14.03	0.000	0.0%	0.0000	0.0%	163%	0.000	0.0%	0.00	0.0%
2.C.	Metal Industry	2. Ferroalloys Production	CH_4	4.63	2.57	0.000	0.0%	0.0000	0.0%	163%	0.000	0.0%	0.00	0.0%
2.C.	Metal Industry	3. Aluminium Production	CO_2	57.97	0.00	0.000	0.0%	0.0000	0.0%	10%	0.000	0.0%	0.00	0.0%
2.C.	Metal Industry	3. Aluminium Production	PFCs	203.66	0.00	0.000	0.0%	0.0001	0.0%	47%	0.000	0.0%	0.06	0.1%
2.C.	Metal Industry	4. Magnesium Production	HFCs	0.00	1.72	0.000	0.0%	0.0000	0.0%	5%	0.000	0.0%	0.00	0.0%
2.C.	Metal Industry	4. Magnesium Production	SF_6	146.54	319.20	0.000	0.0%	0.0001	0.0%	5%	0.000	0.0%	0.01	0.0%
2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,039.82	2,293.32	0.002	0.2%	0.0003	0.1%	53%	0.014	1.4%	0.16	0.3%
2.E.	Electronics Industry		HFCs	0.73	107.17	0.000	0.0%	0.0001	0.0%	100%	0.001	0.1%	0.08	0.2%
2.E.	Electronics Industry		PFCs	1,454.78	1,611.80	0.001	0.1%	0.0002	0.0%	81%	0.015	1.5%	0.16	0.3%
2.E.	Electronics Industry		SF_6	418.70	299.47	0.000	0.0%	0.0001	0.0%	300%	0.010	1.0%	0.19	0.4%
2.E.	Electronics Industry		NF_3	29.82	356.23	0.000	0.0%	0.0002	0.0%	71%	0.003	0.3%	0.17	0.4%
2.F.	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	0.00	49,516.70	0.040	4.0%	0.0357	6.8%	6%	0.034	3.4%	2.17	4.8%
2.F.	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1.34	2,941.23	0.002	0.2%	0.0021	0.4%	50%	0.017	1.7%	1.06	2.4%
2.F.	Product uses as substitutes for ODS	3. Fire Protection	HFCs	0.00	10.05	0.000	0.0%	0.0000	0.0%	16%	0.000	0.0%	0.00	0.0%
2.F.	Product uses as substitutes for ODS	4. Aerosols	HFCs	0.00	598.71	0.000	0.0%	0.0004	0.1%	10%	0.001	0.1%	0.04	0.1%
2.F.	Product uses as substitutes for ODS	5. Solvents	HFCs	0.00	127.60	0.000	0.0%	0.0001	0.0%	11%	0.000	0.0%	0.01	0.0%
2.F.	Product uses as substitutes for ODS	5. Solvents	PFCs	4,549.94	1,382.17	0.001	0.1%	0.0020	0.4%	10%	0.002	0.2%	0.20	0.5%
2.G.	Other Product Manufacture and Use		N_2O	290.86	582.92	0.000	0.0%	0.0002	0.0%	4%	0.000	0.0%	0.01	0.0%
2.G.	Other Product Manufacture and Use		HFCs	7.71	6.59	0.000	0.0%	0.0000	0.0%	200%	0.000	0.0%	0.00	0.0%
2.G.	Other Product Manufacture and Use		PFCs	16.18	82.50	0.000	0.0%	0.0000	0.0%	35%	0.000	0.0%	0.02	0.0%
2.G.	Other Product Manufacture and Use		SF_6	8,814.04	1,383.16	0.001	0.1%	0.0049	0.9%	143%	0.023	2.3%	6.98	15.5%
2.H.	Other	Use of Dry Ice	CO_2	64.61	80.94	0.000	0.0%	0.0000	0.0%	5%	0.000	0.0%	0.00	0.0%
3.A.	Enteric Fermentation		CH_4	9,422.90	7,717.70	0.006	0.6%	0.0007	0.1%	29%	0.026	2.6%	0.21	0.5%
3.B.	Manure Management		CH_4	3,382.86	2,458.31	0.002	0.2%	0.0005	0.1%	17%	0.005	0.5%	0.08	0.2%
3.B.	Manure Management		N_2O	4,346.32	3,910.76	0.003	0.3%	0.0001	0.0%	132%	0.059	5.9%	0.10	0.2%
3.C.	Rice Cultivation		CH_4	12,129.25	11,942.42	0.010	1.0%	0.0005	0.1%	6%	0.008	0.8%	0.03	0.1%
3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,347.57	3,286.61	0.003	0.3%	0.0005	0.1%	25%	0.010	1.0%	0.13	0.3%
3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,988.43	2,341.38	0.002	0.2%	0.0003	0.1%	246%	0.066	6.6%	0.74	1.6%
3.F.	Field Burning of Agricultural Residues		CH_4	127.03	63.87	0.000	0.0%	0.0000	0.0%	296%	0.002	0.2%	0.11	0.3%
3.F.	Field Burning of Agricultural Residues		N_2O	39.26	19.74	0.000	0.0%	0.0000	0.0%	300%	0.001	0.1%	0.04	0.1%
3.G.	Liming		CO_2	550.24	225.38	0.000	0.0%	0.0002	0.0%	50%	0.001	0.1%	0.10	0.2%
3.H.	Urea Application		CO_2	181.77	208.19	0.000	0.0%	0.0000	0.0%	50%	0.001	0.1%	0.01	0.0%
4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	76,685.74	57,604.03	0.046	4.6%	0.0180	3.5%	9%	0.060	6.0%	1.64	3.6%
4.A.	Forest Land	2. Land converted to Forest Land	CO_2	9,579.10	738.67	0.001	0.1%	0.0069	1.3%	9%	0.001	0.1%	0.63	1.4%
4.B.	Cropland	1. Cropland remaining Cropland	CO_2	7,406.88	4,211.77	0.003	0.3%	0.0019	0.4%	25%	0.012	1.2%	0.48	1.1%
4.B.	Cropland	2. Land converted to Cropland	CO_2	924.04	454.42	0.000	0.0%	0.0003	0.1%	20%	0.001	0.1%	0.06	0.1%
4.C.	Grassland	1. Grassland remaining Grassland	CO_2	485.28	240.80	0.000	0.0%	0.0001	0.0%	9%	0.000	0.0%	0.01	0.0%
4.C.	Grassland	2. Land converted to Grassland	CO_2	369.69	247.21	0.000	0.0%	0.0001	0.0%	22%	0.001	0.1%	0.01	0.0%
4.D.	Wetlands	1. Wetlands Remaining Wetlands	CO_2	1.81	2.28	0.000	0.0%	0.0000	0.0%	64%	0.000	0.0%	0.00	0.0%
4.D.	Wetlands	2. Land converted to Wetlands	CO_2	70.29	37.64	0.000	0.0%	0.0000	0.0%	23%	0.000	0.0%	0.00	0.0%
4.E.	Settlements	1. Settlements remaining Settlements	CO_2	1,015.07	1,550.62	0.001	0.1%	0.0003	0.1%	34%	0.006	0.6%	0.11	0.2%
4.E.	Settlements	2. Land converted to Settlements	CO_2	11,660.91	3,747.40	0.003	0.3%	0.0051	1.0%	49%	0.021	2.1%	2.49	5.5%
4.F.	Other Land	2. Land converted to Other Land	CO_2	2,286.70	374.12	0.000	0.0%	0.0013	0.2%	82%	0.004	0.4%	1.03	2.3%
4.G.	Harvested Wood Products		CO_2	264.17	1,595.59	0.001	0.1%	0.0009	0.2%	30%	0.005	0.5%	0.28	0.6%
4.H.	Other (Organic soil in settlements converted from other land-use categories)		CH_4	30.81	14.24	0.000	0.0%	0.0000	0.0%	71%	0.000	0.0%	0.01	0.0%
4.H.	Other (Organic soil in settlements converted from other land-use categories)		N_2O	2.94	1.36	0.000	0.0%	0.0000	0.0%	200%	0.000	0.0%	0.00	0.0%
4.(I)	Direct N_2O emissions from N inputs to managed soils		N_2O	0.84	0.51	0.000	0.0%	0.0000	0.0%	31%	0.000	0.0%	0.00	0.0%
4.(II)	CH_4 Emissions from drainage of organic soils		CH_4	26.40	25.35	0.000	0.0%	0.0000	0.0%	65%	0.000	0.0%	0.00	0.0%
4.(II)	N_2O Emissions from drainage of organic soils		N_2O	0.00	0.00	0.000	0.0%	0.0000	0.0%	0%	0.000	0.0%	0.00	0.0%
4.(III)	Direct N_2O emissions from N mineralization/immobilization		N_2O	649.32	266.51	0.000	0.0%	0.0002	0.0%	145%	0.004	0.4%	0.35	0.8%
4.(IV)	Indirect N_2O Emissions from Managed Soils		N_2O	290.27	119.30	0.000	0.0%	0.0001	0.0%	276%	0.004	0.4%	0.30	0.7%
4.(V)	Biomass Burning		CH_4	47.20	36.87	0.000	0.0%	0.0000	0.0%	71%	0.000	0.0%	0.00	0.0%
4.(V)	Biomass Burning		N_2O	22.15	19.10	0.000	0.0%	0.0000	0.0%	46%	0.000	0.0%	0.00	0.0%
5.A.	Solid Waste Disposal		CH_4	9,939.57	1,569.41	0.001	0.1%	0.0055	1.1%	23%	0.004	0.4%	1.27	2.8%
5.B.	Biological Treatment of Soild Waste		CH_4	53.99	73.78	0.000	0.0%	0.0000	0.0%	84%	0.001	0.1%	0.01	0.0%
5.B.	Biological Treatment of Soild Waste		N_2O	180.77	245.37	0.000	0.0%	0.0001	0.0%	170%	0.005	0.5%	0.10	0.2%
5.C.	Incineration and Open Burning of Waste		CO_2	12,318.70	10,358.56	0.008	0.8%	0.0007	0.1%	15%	0.018	1.8%	0.11	0.2%
5.C.	Incineration and Open Burning of Waste		CH_4	27.78	8.68	0.000	0.0%	0.0000	0.0%	248%	0.000	0.0%	0.03	0.1%
5.C.	Incineration and Open Burning of Waste		N_2O	1,438.04	1,239.14	0.001	0.1%	0.0001	0.0%	77%	0.011	1.1%	0.05	0.1%
5.D.	Wastewater Treatment and Discharge		CH_4	2,941.55	1,555.41	0.001	0.1%	0.0008	0.2%	21%	0.004	0.4%	0.17	0.4%
5.D.	Wastewater Treatment and Discharge		N_2O	2,387.11	1,982.05	0.002	0.2%	0.0002	0.0%	42%	0.009	0.9%	0.07	0.1%
5.E.	Other		CO_2	702.83	679.10	0.001	0.1%	0.0000	0.0%	10%	0.001	0.1%	0.00	0.0%
	Indirect CO_2	from Energy sector	Ind CO_2	1,032.59	448.64	0.000	0.0%	0.0004	0.1%	40%	0.002	0.2%	0.15	0.3%
	Indirect CO_2	from IPPU sector	Ind CO_2	4,448.92	1,423.03	0.001	0.1%	0.0019	0.4%	59%	0.010	1.0%	1.14	2.5%
Absolute Figure Total (including LULUCF)				1,386,635.13	1,241,253.92	1.00	100.0%	0.5214	1.00		1.000	100.0%	45.1	100.0%

Table A1-10 Data used for the key category analysis (FY1990)

A IPCC Code	B IPCC Category		C GHGs	E Absolute Value of FY1990 Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	L Source/Sink Uncertainty [%]	M Ap2-L	N Ap2-L Contrib. [%]
1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,960.86	0.129	12.9%	1%	0.018	1.8%
1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	0.079	7.9%	6%	0.059	5.9%
1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	0.058	5.8%	2%	0.011	1.1%
1.A.1.	Energy Industries	Other Fossil Fuels	CO_2	0.00	0.000	0.0%	19%	0.000	0.0%
1.A.1.	Energy Industries		CH_4	459.35	0.000	0.0%	69%	0.003	0.3%
1.A.1.	Energy Industries		N_2O	889.48	0.001	0.1%	30%	0.002	0.2%
1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	0.097	9.7%	1%	0.013	1.3%
1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,587.36	0.144	14.4%	6%	0.107	10.7%
1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	0.009	0.9%	2%	0.002	0.2%
1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	4,207.45	0.003	0.3%	19%	0.007	0.7%
1.A.2.	Manufacturing Industries and Construction		CH_4	359.76	0.000	0.0%	69%	0.002	0.2%
1.A.2.	Manufacturing Industries and Construction		N_2O	1,259.81	0.001	0.1%	30%	0.003	0.3%
1.A.3.	Transport	a. Domestic Aviation	CO_2	7,162.41	0.005	0.5%	1%	0.001	0.1%
1.A.3.	Transport	a. Domestic Aviation	CH_4	5.64	0.000	0.0%	52%	0.000	0.0%
1.A.3.	Transport	a. Domestic Aviation	N_2O	64.02	0.000	0.0%	141%	0.001	0.1%
1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	0.130	13.0%	1%	0.018	1.8%
1.A.3.	Transport	b. Road Transportation	CH_4	252.59	0.000	0.0%	104%	0.002	0.2%
1.A.3.	Transport	b. Road Transportation	N_2O	3,457.24	0.002	0.2%	107%	0.032	3.2%
1.A.3.	Transport	c. Railways	CO_2	935.40	0.001	0.1%	1%	0.000	0.0%
1.A.3.	Transport	c. Railways	CH_4	1.34	0.000	0.0%	151%	0.000	0.0%
1.A.3.	Transport	c. Railways	N_2O	109.95	0.000	0.0%	200%	0.002	0.2%
1.A.3.	Transport	d. Domestic Navigation	CO_2	13,674.88	0.010	1.0%	1%	0.001	0.1%
1.A.3.	Transport	d. Domestic Navigation	CH_4	31.73	0.000	0.0%	52%	0.000	0.0%
1.A.3.	Transport	d. Domestic Navigation	N_2O	108.07	0.000	0.0%	141%	0.001	0.1%
1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	0.093	9.3%	1%	0.013	1.3%
1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	0.000	0.0%	6%	0.000	0.0%
1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	0.016	1.6%	2%	0.003	0.3%
1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	0.005	0.5%	19%	0.011	1.1%
1.A.4.	Other Sectors		CH_4	238.65	0.000	0.0%	69%	0.001	0.1%
1.A.4.	Other Sectors		N_2O	689.41	0.000	0.0%	30%	0.002	0.2%
1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CO_2	5.90	0.000	0.0%	19%	0.000	0.0%
1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH_4	4,894.72	0.004	0.4%	84%	0.035	3.5%
1.B.	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	N_2O	1.98	0.000	0.0%	163%	0.000	0.0%
1.B.	Fugitive Emission from Fuel	2.a. Oil	CO_2	0.03	0.000	0.0%	89%	0.000	0.0%
1.B.	Fugitive Emission from Fuel	2.a. Oil	CH_4	25.37	0.000	0.0%	68%	0.000	0.0%
1.B.	Fugitive Emission from Fuel	2.b. Natural Gas	CO_2	0.63	0.000	0.0%	80%	0.000	0.0%
1.B.	Fugitive Emission from Fuel	2.b. Natural Gas	CH_4	174.24	0.000	0.0%	75%	0.001	0.1%
1.B.	Fugitive Emission from Fuel	2.c. Venting & Flaring	CO_2	81.17	0.000	0.0%	14%	0.000	0.0%
1.B.	Fugitive Emission from Fuel	2.c. Venting & Flaring	CH_4	7.96	0.000	0.0%	49%	0.000	0.0%
1.B.	Fugitive Emission from Fuel	2.c. Venting & Flaring	N_2O	0.11	0.000	0.0%	31%	0.000	0.0%
1.B.	Fugitive Emission from Fuel	2.d. Other (Geothermal)	CO_2	104.42	0.000	0.0%	17%	0.000	0.0%
1.B.	Fugitive Emission from Fuel	2.d. Other (Geothermal)	CH_4	5.21	0.000	0.0%	17%	0.000	0.0%

Table A1-10 Data used for the key category analysis (FY1990) (Continued)

A IPCC Code	B IPCC Category		C GHGs	E Absolute Value of FY1990 Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	L Source/Sink Uncertainty [%]	M Ap2-L	N Ap2-L Contrib. [%]
2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	0.028	2.8%	4%	0.014	1.4%
2.A.	Mineral Industry	2. Lime Production	CO_2	6,674.45	0.005	0.5%	4%	0.002	0.2%
2.A.	Mineral Industry	3. Glass Production	CO_2	312.93	0.000	0.0%	6%	0.000	0.0%
2.A.	Mineral Industry	4. Other Process Uses of Carbonates	CO_2	3,025.31	0.002	0.2%	6%	0.002	0.2%
2.B.	Chemical Industry	1. Ammonia Production	CO_2	2,879.46	0.002	0.2%	2%	0.001	0.1%
2.B.	Chemical Industry	Other products except Anmonia	CO_2	3,623.06	0.003	0.3%	55%	0.017	1.7%
2.B.	Chemical Industry	2. Nitric Acid Production	N_2O	736.06	0.001	0.1%	85%	0.005	0.5%
2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	7,210.88	0.005	0.5%	9%	0.006	0.6%
2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,672.86	0.001	0.1%	223%	0.032	3.2%
2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	15,930.24	0.011	1.1%	2%	0.003	0.3%
2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	PFCs	330.92	0.000	0.0%	2%	0.000	0.0%
2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF_6	3,470.78	0.003	0.3%	2%	0.001	0.1%
2.B.	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	NF_3	2.79	0.000	0.0%	2%	0.000	0.0%
2.B.	Chemical Industry	Whole of Chemical Industries	CH_4	37.49	0.000	0.0%	58%	0.000	0.0%
2.C.	Metal Industry	1. Iron and Steel Production	CO_2	7,207.71	0.005	0.5%	4%	0.002	0.2%
2.C.	Metal Industry	1. Iron and Steel Production	CH_4	18.42	0.000	0.0%	163%	0.000	0.0%
2.C.	Metal Industry	2. Ferroalloys Production	CH_4	4.63	0.000	0.0%	163%	0.000	0.0%
2.C.	Metal Industry	3. Aluminium Production	CO_2	57.97	0.000	0.0%	10%	0.000	0.0%
2.C.	Metal Industry	3. Aluminium Production	PFCs	203.66	0.000	0.0%	47%	0.001	0.1%
2.C.	Metal Industry	4. Magnesium Production	HFCs	0.00	0.000	0.0%	5%	0.000	0.0%
2.C.	Metal Industry	4. Magnesium Production	SF_6	146.54	0.000	0.0%	5%	0.000	0.0%
2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,039.82	0.001	0.1%	53%	0.009	0.9%
2.E.	Electronics Industry		HFCs	0.73	0.000	0.0%	100%	0.000	0.0%
2.E.	Electronics Industry		PFCs	1,454.78	0.001	0.1%	81%	0.010	1.0%
2.E.	Electronics Industry		SF_6	418.70	0.000	0.0%	300%	0.011	1.1%
2.E.	Electronics Industry		NF_3	29.82	0.000	0.0%	71%	0.000	0.0%
2.F.	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	0.00	0.000	0.0%	6%	0.000	0.0%
2.F.	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1.34	0.000	0.0%	50%	0.000	0.0%
2.F.	Product uses as substitutes for ODS	3. Fire Protection	HFCs	0.00	0.000	0.0%	16%	0.000	0.0%
2.F.	Product uses as substitutes for ODS	4. Aerosols	HFCs	0.00	0.000	0.0%	10%	0.000	0.0%
2.F.	Product uses as substitutes for ODS	5. Solvents	HFCs	0.00	0.000	0.0%	11%	0.000	0.0%
2.F.	Product uses as substitutes for ODS	5. Solvents	PFCs	4,549.94	0.003	0.3%	10%	0.004	0.4%
2.G.	Other Product Manufacture and Use		N_2O	290.86	0.000	0.0%	4%	0.000	0.0%
2.G.	Other Product Manufacture and Use		HFCs	7.71	0.000	0.0%	200%	0.000	0.0%
2.G.	Other Product Manufacture and Use		PFCs	16.18	0.000	0.0%	35%	0.000	0.0%
2.G.	Other Product Manufacture and Use		SF_6	8,814.04	0.006	0.6%	143%	0.108	10.8%
2.H.	Other	Use of Dry Ice	CO_2	64.61	0.000	0.0%	5%	0.000	0.0%
3.A.	Enteric Fermentation		CH_4	9,422.90	0.007	0.7%	29%	0.024	2.4%
3.B.	Manure Management		CH_4	3,382.86	0.002	0.2%	17%	0.005	0.5%
3.B.	Manure Management		N_2O	4,346.32	0.003	0.3%	132%	0.049	4.9%
3.C.	Rice Cultivation		CH_4	12,129.25	0.009	0.9%	6%	0.006	0.6%
3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,347.57	0.003	0.3%	25%	0.009	0.9%
3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,988.43	0.002	0.2%	246%	0.063	6.3%
3.F.	Field Burning of Agricultural Residues		CH_4	127.03	0.000	0.0%	296%	0.003	0.3%
3.F.	Field Burning of Agricultural Residues		N_2O	39.26	0.000	0.0%	300%	0.001	0.1%
3.G.	Liming		CO_2	550.24	0.000	0.0%	50%	0.002	0.2%
3.H.	Urea Application		CO_2	181.77	0.000	0.0%	50%	0.001	0.1%
4.A.	Forest Land	1. Forest Land remaining Forest Land	CO_2	76,685.74	0.055	5.5%	9%	0.059	5.9%
4.A.	Forest Land	2. Land converted to Forest Land	CO_2	9,579.10	0.007	0.7%	9%	0.007	0.7%
4.B.	Cropland	1. Cropland remaining Cropland	CO_2	7,406.88	0.005	0.5%	25%	0.016	1.6%
4.B.	Cropland	2. Land converted to Cropland	CO_2	924.04	0.001	0.1%	20%	0.002	0.2%
4.C.	Grassland	1. Grassland remaining Grassland	CO_2	485.28	0.000	0.0%	9%	0.000	0.0%
4.C.	Grassland	2. Land converted to Grassland	CO_2	369.69	0.000	0.0%	22%	0.001	0.1%
4.D.	Wetlands	1. Wetlands Remaining Wetlands	CO_2	1.81	0.000	0.0%	64%	0.000	0.0%
4.D.	Wetlands	2. Land converted to Wetlands	CO_2	70.29	0.000	0.0%	23%	0.000	0.0%
4.E.	Settlements	1. Settlements remaining Settlements	CO_2	1,015.07	0.001	0.1%	34%	0.003	0.3%
4.E.	Settlements	2. Land converted to Settlements	CO_2	11,660.91	0.008	0.8%	49%	0.049	4.9%
4.F.	Other Land	2. Land converted to Other Land	CO_2	2,286.70	0.002	0.2%	82%	0.016	1.6%
4.G.	Harvested Wood Products		CO_2	264.17	0.000	0.0%	30%	0.001	0.1%
4.H.	Other (Organic soil in settlements converted from other land-use categories)		CH_4	30.81	0.000	0.0%	71%	0.000	0.0%
4.H.	Other (Organic soil in settlements converted from other land-use categories)		N_2O	2.94	0.000	0.0%	200%	0.000	0.0%
4.(I)	Direct N_2O emissions from N inputs to managed soils		N_2O	0.84	0.000	0.0%	31%	0.000	0.0%
4.(II)	CH_4 Emissions from drainage of organic soils		CH_4	26.40	0.000	0.0%	65%	0.000	0.0%
4.(II)	N_2O Emissions from drainage of organic soils		N_2O	0.00	0.000	0.0%	0%	0.000	0.0%
4.(III)	Direct N_2O emissions from N mineralization/immobilization		N_2O	649.32	0.000	0.0%	145%	0.008	0.8%
4.(IV)	Indirect N_2O Emissions from Managed Soils		N_2O	290.27	0.000	0.0%	276%	0.007	0.7%
4.(V)	Biomass Burning		CH_4	47.20	0.000	0.0%	71%	0.000	0.0%
4.(V)	Biomass Burning		N_2O	22.15	0.000	0.0%	46%	0.000	0.0%
5.A.	Solid Waste Disposal		CH_4	9,939.57	0.007	0.7%	23%	0.020	2.0%
5.B.	Biological Treatment of Soild Waste		CH_4	53.99	0.000	0.0%	84%	0.000	0.0%
5.B.	Biological Treatment of Soild Waste		N_2O	180.77	0.000	0.0%	170%	0.003	0.3%
5.C.	Incineration and Open Burning of Waste		CO_2	12,318.70	0.009	0.9%	15%	0.016	1.6%
5.C.	Incineration and Open Burning of Waste		CH_4	27.78	0.000	0.0%	248%	0.001	0.1%
5.C.	Incineration and Open Burning of Waste		N_2O	1,438.04	0.001	0.1%	77%	0.009	0.9%
5.D.	Wastewater Treatment and Discharge		CH_4	2,941.55	0.002	0.2%	21%	0.005	0.5%
5.D.	Wastewater Treatment and Discharge		N_2O	2,387.11	0.002	0.2%	42%	0.009	0.9%
5.E.	Other		CO_2	702.83	0.001	0.1%	10%	0.001	0.1%
	Indirect CO_2	from Energy sector	Ind CO_2	1,032.59	0.001	0.1%	40%	0.004	0.4%
	Indirect CO_2	from IPPU sector	Ind CO_2	4,448.92	0.003	0.3%	59%	0.022	2.2%
Total (including LULUCF)				1,386,635.13	1.00	100.0%		1.00	100%

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Inventories,* 2006.
2. UNFCCC, *UNFCCC reporting guidelines on annual greenhouse gas inventories* (Decision 24/CP.19 Annex I), 2013.

Annex 2. Assessment of Uncertainty

A2.1. Methodology of Uncertainty Assessment

"Uncertainty" is a conceptual framework which represents the differences between emissions/ removals inventory estimates and true underlying values, resulting from lack of data or representativeness, sampling error, or, errors in measurement values, etc. In the paragraph 15 and 42 in the *UNFCCC Inventory Reporting Guidelines* (Decision 24/CP.19 Annex I), it is noted that Annex I Parties shall quantitatively estimate and report the uncertainty of inventories. The assessment of uncertainties is intended to contribute to improve the accuracy of national inventories continuously and to guide decisions on methodological choice but not to evaluate justification of inventories nor make a comparison of accuracy of inventories among the parties.

The fundamental methodological issues of uncertainties assessment are provided in the IPCC guidelines; however, uncertainty assessment for specific emission sources and removal sinks is mainly subject to country-specific method determined by each party depending on country's own circumstances. In Japan, the uncertainties were assessed based on the country-specific guidelines (MOE, 2013).

A2.2. Results of Uncertainty Assessment

A2.2.1 Uncertainty of Japan's Total Emissions

In FY2021, total net emissions in Japan were approximately 1,118 million tons (carbon dioxide equivalents). Uncertainty of total net emissions in FY2021 has been assessed at -3% to +2% and uncertainty introduced into the trend in total net emissions has been assessed at -3% to +2%. Thus, the uncertainty level was low in Japan, mainly because CO_2 emissions from low-uncertainty fuel combustion (1.A.) accounted for 90% of the net emissions.

Table A2-1 Uncertainty of Japan's total net emissions

A	B	C	D	G-1990		G-2021		I	J	
Category	GHGs	1990 emissions / removals	2021 emissions / removals	Combined uncertainty in 1990		Combined uncertainty in 2021		Inventory trend in national emissions for 2021 increase with respect to 1990	Uncertainty introduced into the trend in total national emissions	
		kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	%	(-) %	(+) %
1A. Fuel Combustion (CO_2)	CO_2	1,078,663	1,007,257	-2%	+1%	-3%	+2%	-6.6%	-3.2%	+2.2%
1A. Fuel Combustion (Stationary:CH_4,N_2O)	CH_4, N_2O	3,896	5,147	-23%	+29%	-24%	+28%	32.1%	0.0%	+0.0%
1A. Fuel Combustion (Transport:CH_4,N_2O)	CH_4, N_2O	4,031	1,501	-32%	+92%	-30%	+87%	-62.8%	0.0%	+0.0%
1B. Fugitive Emissions from Fuels	CO_2, CH_4, N_2O	5,302	1,044	-38%	+78%	-22%	+40%	-80.3%	0.0%	+0.0%
2. IPPU (CO_2,CH_4,N_2O)	CO_2, CH_4, N_2O	74,558	44,114	-6%	+6%	-5%	+5%	-40.8%	-0.1%	+0.1%
2. IPPU (HFCs,PFCs,SF_6,NF_3)	HFCs, PFCs, SF_6, NF_3	35,378	59,144	-7%	+36%	-6%	+7%	67.2%	-0.6%	+0.6%
3. Agriculture	CO_2, CH_4, N_2O	37,516	32,174	-11%	+28%	-10%	+25%	-14.2%	0.0%	+0.0%
4. LULUCF	CO_2, CH_4, N_2O	-63,272	-51,695	-15%	15%	-11%	+11%	-18.3%	-0.4%	+0.4%
5. Waste	CO_2, CH_4, N_2O	29,990	17,712	-10%	+10%	-12%	+12%	-40.9%	-0.2%	+0.2%
Indirect CO_2	Ind CO_2	5,482	1,872	-26%	+48%	-25%	+46%	-65.9%	0.0%	+0.0%
Total Net Emissions		1,211,543	1,118,272	-2.0%	+2.1%	-2.5%	+2.0%	-7.7%	-3.2%	+2.3%

Data used for estimating emissions in each category are as follows:

Table A2-2　　Data used for uncertainty assessment (Energy Sector)

A		B	C	D	E		F		G		H-1990		H-2020		T	I	J	K		L		M	
Category		GHG	1990 emissions / removals	2021 emissions / removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Combined Uncertainty as % of Total National Emissions in 1990		Combined Uncertainty as % of Total National Emissions in 2021		Emission increase rate	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/ estimation parameter uncertainty		Uncertainty in trend in national emissions introduced by activity data uncertainty		Uncertainty introduced into the trend in total national emissions	
			Input Data	Input Data	Input Data		Input Data		(E^2+F^2)^1/2		G*C/ΣC		G*D/ΣD		D/C	Note*	D/ΣC	I*F		J*E*√2		(K^2+L^2)^1/2	
			kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-)%	(+)%	(-)%	(+)%	%	%	%	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %
Total			1,211,543	1,118,272							-2.0%	+2.1%	-2.5%	+2.0%	-7.7%							-3.2%	+2.3%
1.A. Fuel Combustion	Liquid Fuels	CO_2	644,302	357,817	-1%	+1%	-	-	-1%	+1%	-0.6%	0.4%	-0.4%	0.3%	-44.5%	0.2%	29.5%	0.0%	0.0%	-0.5%	0.3%	0.5%	0.3%
1.A. Fuel Combustion	Solid Fuels	CO_2	309,482	421,340	-6%	+4%	-	-	-6%	+4%	-1.6%	1.1%	-2.4%	1.6%	36.1%	0.1%	34.8%	0.0%	0.0%	-3.1%	2.1%	3.1%	2.1%
1.A. Fuel Combustion	Gaseous Fuels	CO_2	114,167	209,252	-1%	+1%	-	-	-1%	+2%	-0.1%	0.2%	-0.3%	0.3%	83.3%	0.1%	17.3%	0.0%	0.0%	-0.3%	0.3%	0.3%	0.3%
1.A. Fuel Combustion	Other Fossil Fuels	CO_2	10,712	18,848	-	-	-	-	-19%	+19%	-0.2%	0.2%	-0.3%	0.3%	75.9%	0.0%	1.6%	0.0%	0.0%	-0.4%	0.4%	0.4%	0.4%
1.A. Stationary Combustion		CH_4	1,058	1,140	-	-	-	-	-29%	+69%	0.0%	0.1%	0.0%	0.1%	7.7%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A. Stationary Combustion		N_2O	2,839	4,008	-	-	-	-	-30%	+30%	-0.1%	0.1%	-0.1%	0.1%	41.2%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	a. Domestic Aviation	CH_4	6	1	-5%	+5%	-57%	+100%	-57%	+100%	0.0%	0.0%	0.0%	0.0%	-77.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	a. Domestic Aviation	N_2O	64	60	-5%	+5%	-70%	+150%	-70%	+150%	0.0%	0.0%	0.0%	0.0%	-5.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	b. Road Transportation	CH_4	253	79	-	-	-	-	-36%	+104%	0.0%	0.0%	0.0%	0.0%	-68.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	b. Road Transportation	N_2O	3,457	1,204	-	-	-	-	-37%	+107%	-0.1%	0.3%	0.0%	0.1%	-65.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	c. Railways	CH_4	1	1	-5%	+5%	-60%	+151%	-60%	+151%	0.0%	0.0%	0.0%	0.0%	-50.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	c. Railways	N_2O	110	54	-5%	+5%	-50%	+200%	-50%	+200%	0.0%	0.0%	0.0%	0.0%	-50.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	d. Domestic Navigation	CH_4	32	23	-13%	+13%	-50%	+50%	-52%	+52%	0.0%	0.0%	0.0%	0.0%	-27.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	d. Domestic Navigation	N_2O	108	78	-13%	+13%	-40%	+140%	-42%	+141%	0.0%	0.0%	0.0%	0.0%	-27.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	1. Solid Fuels	CO_2	6	3	-	-	-	-	-9%	+19%	0.0%	0.0%	0.0%	0.0%	-41.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	1. Solid Fuels	CH_4	4,895	456	-	-	-	-	-41%	+84%	-0.2%	0.3%	0.0%	0.0%	-90.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	1. Solid Fuels	N_2O	2	0	-2%	+2%	-75%	+163%	-75%	+163%	0.0%	0.0%	0.0%	0.0%	-79.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.a. Oil	CO_2	0	0	-	-	-	-	-89%	+89%	0.0%	0.0%	0.0%	0.0%	-43.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.a. Oil	CH_4	25	16	-	-	-	-	-68%	+68%	0.0%	0.0%	0.0%	0.0%	-35.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.b. Natural Gas	CO_2	1	1	-	-	-	-	-80%	+80%	0.0%	0.0%	0.0%	0.0%	12.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.b. Natural Gas	CH_4	174	199	-	-	-	-	-70%	+75%	0.0%	0.0%	0.0%	0.0%	14.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.c. Venting & Flaring	CO_2	81	163	-	-	-	-	-14%	+14%	0.0%	0.0%	0.0%	0.0%	100.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.c. Venting & Flaring	CH_4	8	4	-	-	-	-	-49%	+49%	0.0%	0.0%	0.0%	0.0%	-46.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.c. Venting & Flaring	N_2O	0	0	-	-	-	-	-31%	+31%	0.0%	0.0%	0.0%	0.0%	-32.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.d. Other (Geothermal)	CO_2	104	192	-15%	+15%	-7%	+7%	-17%	+17%	0.0%	0.0%	0.0%	0.0%	83.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.d. Other (Geothermal)	CH_4	5	10	-15%	+15%	-7%	+7%	-17%	+17%	0.0%	0.0%	0.0%	0.0%	83.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table A2-3 Data used for uncertainty assessment (Industrial Processes and Product Use Sector)

A		B	C	D	E		F		G		H-1990		H-2020		T	I	J	K		L		M	
Category		GHG	1990 emissions / removals	2021 emissions / removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Combined Uncertainty as % of Total National Emissions in 1990		Combined Uncertainty as % of Total National Emissions in 2021		Emission increase rate	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/ estimation parameter uncertainty		Uncertainty in trend in national emissions introduced by activity data uncertainty		Uncertainty introduced into the trend in total national emissions	
			Input Data	Input Data	Input Data		Input Data		(E^2+F^2)^1/2		G*C/ΣC		G*D/ΣD		D/C	Note*	D/ΣC	I*F		J*E*√2		(K^2+L^2)^1/2	
			kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-)%	(+)%	(-)%	(+)%	%	%	%	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %
2.A. Mineral Industry	1. Cement Production	CO_2	38,701	24,396	-2%	+2%	-4%	+4%	-4%	+4%	-0.1%	0.1%	-0.1%	0.1%	-37.0%	0.0%	2.0%	0.0%	0.0%	-0.1%	0.1%	0.1%	0.1%
2.A. Mineral Industry	2. Lime Production	CO_2	6,674	4,971	-3%	+3%	-2%	+2%	-4%	+4%	0.0%	0.0%	0.0%	0.0%	-25.5%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.A. Mineral Industry	3. Glass Production	CO_2	313	174	-3%	+3%	-5%	+5%	-6%	+6%	0.0%	0.0%	0.0%	0.0%	-44.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.A. Mineral Industry	4. Other Process Uses of Carbonates	CO_2	3,025	1,596	-3%	+3%	-5%	+5%	-6%	+6%	0.0%	0.0%	0.0%	0.0%	-47.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B. Chemical Industry	1. Ammonia Production	CO_2	2,879	1,458	-	-	-	-	-2%	+1%	0.0%	0.0%	0.0%	0.0%	-49.4%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	Other Production Except Anmonia	CO_2	3,623	2,614	-	-	-	-	-55%	+55%	-0.2%	0.2%	-0.1%	0.1%	-27.8%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B. Chemical Industry	2. Nitric Acid Production	N_2O	736	256	-2%	+2%	-85%	+85%	-85%	+85%	-0.1%	0.1%	0.0%	0.0%	-65.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B. Chemical Industry	3. Adipic Acid Production	N_2O	7,211	48	-2%	+2%	-9%	+9%	-9%	+9%	-0.1%	0.1%	0.0%	0.0%	-99.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B. Chemical Industry	4. Caprolactam Production	N_2O	1,673	141	-2%	+2%	-223%	+223%	-223%	+223%	-0.3%	0.3%	0.0%	0.0%	-91.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B. Chemical Industry	Whole of Chemical Industries	CH_4	37	27	-	-	-	-	-58%	+51%	0.0%	0.0%	0.0%	0.0%	-27.9%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.C. Metal Industry	1. Iron and Steel Production	CO_2	7,208	5,459	-	-	-	-	-4%	+4%	0.0%	0.0%	0.0%	0.0%	-24.3%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.C. Metal Industry	1. Iron and Steel Production	CH_4	18	14	-5%	+5%	-163%	+163%	-163%	+163%	0.0%	0.0%	0.0%	0.0%	-23.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.C. Metal Industry	2. Ferroalloys Production	CH_4	5	3	-5%	+5%	-163%	+163%	-163%	+163%	0.0%	0.0%	0.0%	0.0%	-44.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.C. Metal Industry	3. Aluminium Production	CO_2	58	0	-2%	+2%	-10%	+10%	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.D. Non-energy Products from Fuels and Solvent Use		CO_2	2,040	2,293	-	-	-	-	-53%	+53%	-0.1%	0.1%	-0.1%	0.1%	12.4%	0.0%	0.2%	NA	NA	NA	NA	0.0%	0.0%
2.G. Other Product Manufacture and Use		N_2O	291	583	-	-	-	-	-4%	+4%	0.0%	0.0%	0.0%	0.0%	100.4%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.H. Other	Use of Dry Ice	CO_2	65	81	-	-	-	-	-5%	+5%	0.0%	0.0%	0.0%	0.0%	25.3%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	9. Fluorochemical Production (By-product emissions)	HFCs	15,929	132	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-99.2%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	2	120	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	7813.1%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	PFCs	331	79	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-76.1%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF_6	3,471	46	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-98.7%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	NF_3	3	24	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	756.3%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.C. Metal Industry	3. Aluminium Production	PFCs	204	0	-2%	+2%	-47%	+28%	-47%	+28%	0.0%	0.0%	0.0%	0.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.C. Metal Industry	4. Magnesium Production	HFCs	0	2	-	-	-	-	-5%	+5%	0.0%	0.0%	0.0%	0.0%	NA	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.C. Metal Industry	4. Magnesium Production	SF_6	147	319	-	-	-	-	-5%	+5%	0.0%	0.0%	0.0%	0.0%	117.8%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.E. Electronics Industry		HFCs	1	107	-10%	+10%	-100%	+100%	-100%	+100%	0.0%	0.0%	0.0%	0.0%	14538%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E. Electronics Industry		PFCs	1,455	1,612	-10%	+10%	-80%	+80%	-81%	+81%	-0.1%	0.1%	-0.1%	0.1%	10.8%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E. Electronics Industry		SF_6	419	299	-10%	+10%	-300%	+300%	-300%	+300%	-0.1%	0.1%	-0.1%	0.1%	-28.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E. Electronics Industry		NF_3	30	356	-10%	+10%	-70%	+70%	-71%	+71%	0.0%	0.0%	0.0%	0.0%	1094.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.F. Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	0	49,517	-	-	-	-	-6%	+6%	0.0%	0.0%	-0.3%	0.3%	NA	0.0%	4.1%	0.0%	0.0%	-0.6%	0.6%	0.6%	0.6%
2.F. Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1	2,941	-	-	-	-	-50%	+50%	0.0%	0.0%	-0.1%	0.1%	219078%	0.0%	0.2%	NA	NA	NA	NA	0.0%	0.0%
2.F. Product uses as substitutes for ODS	3. Fire Protection	HFCs	NO	10	-	-	-	-	-16%	+16%	NA	NA	0.0%	0.0%	NA	NA	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.F. Product uses as substitutes for ODS	4. Aerosols	HFCs	0	599	-	-	-	-	-10%	+10%	0.0%	0.0%	0.0%	0.0%	NA	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.F. Product uses as substitutes for ODS	5. Solvents	HFCs	0	128	-10%	+10%	-5%	+5%	-11%	+11%	0.0%	0.0%	0.0%	0.0%	NA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.F. Product uses as substitutes for ODS	5. Solvents	PFCs	4,550	1,382	-10%	+10%	-	-	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-69.6%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
2.G. Other Product Manufacture and Use		HFCs	8	7	-5%	+5%	-200%	+200%	-200%	+200%	0.0%	0.0%	0.0%	0.0%	-14.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.G. Other Product Manufacture and Use		PFCs	16	82	-	-	-	-	-35%	+35%	0.0%	0.0%	0.0%	0.0%	409.8%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.G. Other Product Manufacture and Use		SF_6	8,814	1,383	-	-	-	-	-22%	+143%	-0.2%	1.0%	0.0%	0.2%	-84.3%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table A2-4 Data used for uncertainty assessment (Agriculture Sector)

A		B	C	D	E		F		G		H-1990		H-2020		T	I	J	K		L		M	
Category		GHG	1990 emissions / removals	2021 emissions / removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Combined Uncertainty as % of Total National Emissions in 1990		Combined Uncertainty as % of Total National Emissions in 2021		Emission increase rate	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/ estimation parameter uncertainty		Uncertainty in trend in national emissions introduced by activity data uncertainty		Uncertainty introduced into the trend in total national emissions	
			Input Data	Input Data	Input Data		Input Data		(E^2+F^2)^1/2		G*C/ΣC		G*D/ΣD		D/C	Note*	D/ΣC	I*F		J*E*√2		(K^2+L^2)^1/2	
			kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-)%	(+)%	(-)%	(+)%	%	%	%	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %
3.A. Enteric Fermentation	1. Dairy cattle	CH_4	4,803	3,440	-1%	+1%	-26%	+32%	-26%	+32%	-0.1%	0.1%	-0.1%	0.1%	-28.4%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A. Enteric Fermentation	1. Non-dairy cattle	CH_4	4,164	3,925	-1%	+1%	-40%	+49%	-40%	+49%	-0.1%	0.2%	-0.1%	0.2%	-5.7%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A. Enteric Fermentation	2. Sheep	CH_4	4	4	-9%	+9%	-50%	+50%	-51%	+51%	0.0%	0.0%	0.0%	0.0%	-4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A. Enteric Fermentation	3. Swine	CH_4	397	313	-1%	+1%	-69%	+69%	-72%	+157%	0.0%	0.1%	0.0%	0.0%	-21.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A. Enteric Fermentation	4. Other Livestock	CH_4	56	36	-9%	+9%	-50%	+50%	-51%	+51%	0.0%	0.0%	0.0%	0.0%	-35.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	1. Dairy cattle	CH_4	2,674	2,065	-1%	+1%	-20%	+20%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	-22.8%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	1. Dairy cattle	N_2O	632	636	-1%	+1%	-71%	+112%	-71%	+112%	0.0%	0.1%	0.0%	0.1%	0.6%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	1. Non-dairy cattle	CH_4	92	160	-1%	+1%	-20%	+20%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	74.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	1. Non-dairy cattle	N_2O	719	695	-1%	+1%	-71%	+112%	-71%	+112%	0.0%	0.1%	0.0%	0.1%	-3.3%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	2. Sheep	CH_4	0	0	-9%	+9%	-30%	+30%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	-4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	2. Sheep	N_2O	NO	NO	-9%	+9%	-71%	+112%	-72%	+112%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0%	0.0%
3.B. Manure Management	3. Swine	CH_4	555	163	-1%	+1%	-20%	+20%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	-70.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	3. Swine	N_2O	1,100	1,216	-1%	+1%	-71%	+112%	-71%	+112%	-0.1%	0.1%	-0.1%	0.1%	10.6%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	4. Poultry	CH_4	52	65	-9%	+9%	-20%	+20%	-22%	+22%	0.0%	0.0%	0.0%	0.0%	24.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	4. Poultry	N_2O	341	274	-9%	+9%	-71%	+112%	-72%	+112%	0.0%	0.0%	0.0%	0.0%	-19.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	4. Other Livestock	CH_4	10	4	-9%	+9%	-30%	+30%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	-53.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	4. Other Livestock	N_2O	8	1	-9%	+9%	-71%	+112%	-72%	+112%	0.0%	0.0%	0.0%	0.0%	-82.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	5. Indirect Emissions	N_2O	1,548	1,088	-9%	+9%	-106%	+447%	-106%	+447%	-0.1%	0.6%	-0.1%	0.4%	-29.7%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.C. Rice Cultivation		CH_4	12,129	11,942	-1%	+1%	-6%	+6%	-6%	+6%	-0.1%	0.1%	-0.1%	0.1%	-1.5%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	a.1. Inorganic Fertilizers	N_2O	1,843	1,140	-1%	+1%	-31%	+31%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	-38.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	a.2. Organic Fertilizers	N_2O	1,475	1,291	-	-	-	-	-23%	+23%	0.0%	0.0%	0.0%	0.0%	-12.5%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	a.3. Pasture, Range and Paddock	N_2O	27	18	-1%	+1%	-65%	+200%	-65%	+200%	0.0%	0.0%	0.0%	0.0%	-33.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	a.4. Crop Residue	N_2O	424	329	-1%	+1%	-70%	+200%	-70%	+200%	0.0%	0.1%	0.0%	0.1%	-22.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	a.5. Mineralization	N_2O	455	390	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-14.2%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
3.D. Agricultural Soils	a.6. Plowing of Organic Soils	N_2O	124	119	-1%	+1%	-75%	+200%	-75%	+200%	0.0%	0.0%	0.0%	0.0%	-4.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	b.1. Atomospheric Deposition	N_2O	1,075	883	-9%	+9%	-106%	+447%	-106%	+447%	-0.1%	0.4%	-0.1%	0.4%	-17.9%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	b.2. N leaching and Run-off	N_2O	1,913	1,458	-9%	+9%	-115%	+287%	-115%	+287%	-0.2%	0.5%	-0.2%	0.4%	-23.8%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.F. Field Burning of Agricultural Residues		CH_4	127	64	-1%	+1%	-296%	+296%	-296%	+296%	0.0%	0.0%	0.0%	0.0%	-49.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.F. Field Burning of Agricultural Residues		N_2O	39	20	-1%	+1%	-300%	+300%	-300%	+300%	0.0%	0.0%	0.0%	0.0%	-49.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.G. Liming		CO_2	550	225	-1%	+1%	-50%	+50%	-50%	+50%	0.0%	0.0%	0.0%	0.0%	-59.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.H. Urea Application		CO_2	182	208	-1%	+1%	-50%	+50%	-50%	+50%	0.0%	0.0%	0.0%	0.0%	14.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table A2-5 Data used for uncertainty assessment (LULUCF Sector)

A		B	C	D	E		F		G		H-1990		H-2020		T	I	J	K		L		M	
Category		GHG	1990 emissions / removals	2021 emissions / removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Combined Uncertainty as % of Total National Emissions in 1990		Combined Uncertainty as % of Total National Emissions in 2021		Emission increase rate	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/ estimation parameter uncertainty		Uncertainty in trend in national emissions introduced by activity data uncertainty		Uncertainty introduced into the trend in total national emissions	
			Input Data	Input Data	Input Data		Input Data		(E^2+F^2)^1/2		G*C/ΣC		G*D/ΣD		D/C	Note*	D/ΣC	I*F		J*E*√2		(K^2+L^2)^1/2	
			kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-)%	(+)%	(-)%	(+)%	%	%	%	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %
4.A. Forest Land	1. Forest Land remaining Forest Land	CO_2	-76,686	-57,604	-	-	-	-	-9%	+9%	-0.6%	0.6%	-0.5%	0.5%	-24.9%	0.0%	4.8%	0.0%	0.0%	-0.4%	0.4%	0.4%	0.4%
4.A. Forest Land	2. Land converted to Forest Land	CO_2	-9,579	-739	-	-	-	-	-9%	+9%	-0.1%	0.1%	0.0%	0.0%	-92.3%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4.B. Cropland	1. Cropland remaining Cropland	CO_2	7,407	4,212	-	-	-	-	-25%	+25%	-0.2%	0.2%	-0.1%	0.1%	-43.1%	0.0%	0.3%	NA	NA	NA	NA	0.0%	0.0%
4.B. Cropland	2. Land converted to Cropland	CO_2	924	454	-	-	-	-	-20%	+20%	0.0%	0.0%	0.0%	0.0%	-50.8%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.C. Grassland	1. Grassland remaining Grassland	CO_2	485	241	-	-	-	-	-9%	+9%	0.0%	0.0%	0.0%	0.0%	-50.4%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.C. Grassland	2. Land converted to Grassland	CO_2	370	247	-	-	-	-	-22%	+22%	0.0%	0.0%	0.0%	0.0%	-33.1%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.D. Wetlands	1. Wetland remaining Wetland	CO_2	-2	-2	-	-	-	-	-64%	+38%	0.0%	0.0%	0.0%	0.0%	26.0%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.D. Wetlands	2. Land converted to Wetlands	CO_2	70	38	-	-	-	-	-23%	+23%	0.0%	0.0%	0.0%	0.0%	-46.4%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.E. Settlements	1. Settlements remaining Settlements	CO_2	-1,015	-1,551	-	-	-	-	-34%	+34%	0.0%	0.0%	0.0%	0.0%	52.8%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
4.E. Settlements	2. Land converted to Settlements	CO_2	11,661	3,747	-	-	-	-	-49%	+49%	-0.5%	0.5%	-0.2%	0.2%	-67.9%	0.0%	0.3%	NA	NA	NA	NA	0.0%	0.0%
4.F. Other Land	2. Land converted to Other Land	CO_2	2,287	374	-	-	-	-	-82%	+82%	-0.2%	0.2%	0.0%	0.0%	-83.6%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.G. Harvested Wood Products		CO_2	-264	-1,596	-	-	-	-	-30%	30%	0.0%	0.0%	0.0%	0.0%	504.0%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
4.H. Other (Organic soil in settlements converted from other land-use categories)		CH_4	31	14	-1%	+1%	-71%	71%	-71%	+71%	0.0%	0.0%	0.0%	0.0%	-53.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4.H. Other (Organic soil in settlements converted from other land-use categories)		N_2O	3	1	-1%	+1%	-75%	200%	-75%	+200%	0.0%	0.0%	0.0%	0.0%	-53.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4.(I) Direct N_2O emissions from N inputs to managed soils		N_2O	1	1	-	-	-	-	-31%	31%	0.0%	0.0%	0.0%	0.0%	-38.7%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(II) CH_4 Emissions from drainage of organic soils		CH_4	26	25	-	-	-	-	-65%	+65%	0.0%	0.0%	0.0%	0.0%	-4.0%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(II) N_2O Emissions from drainage of organic soils		N_2O	NO,NA	NO,NA	-	-	-	-	-	-	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0%	0.0%
4.(III) Direct N_2O emissions from N mineralization/immobilization		N_2O	649	267	-	-	-	-	-54%	+145%	0.0%	0.1%	0.0%	0.0%	-59.0%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(IV) Indirect N_2O Emissions from Managed Soils		N_2O	290	119	-	-	-	-	-92%	+276%	0.0%	0.1%	0.0%	0.0%	-58.9%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(V) Biomass Burning		CH_4	47	37	-	-	-	-	-71%	+71%	0.0%	0.0%	0.0%	0.0%	-21.9%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(V) Biomass Burning		N_2O	22	19	-	-	-	-	-46%	+46%	0.0%	0.0%	0.0%	0.0%	-13.8%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%

Table A2-6 Data used for uncertainty assessment (Waste Sector, Indirect CO_2)

A		B	C	D	E		F		G		H-1990		H-2020		T	I	J	K		L		M	
Category		GHG	1990 emissions / removals	2021 emissions / removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Combined Uncertainty as % of Total National Emissions in 1990		Combined Uncertainty as % of Total National Emissions in 2021		Emission increase rate	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/ estimation parameter uncertainty		Uncertainty in trend in national emissions introduced by activity data uncertainty		Uncertainty introduced into the trend in total national emissions	
			Input Data	Input Data	Input Data		Input Data		(E^2+F^2)^1/2		G*C/ΣC		G*D/ΣD		D/C	Note*	D/ΣC	I*F		J*E*√2		(K^2+L^2)^1/2	
			kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-)%	(+)%	(-)%	(+)%	%	%	%	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %
5.A. Solid Waste Disposal	1. Managed disposal site (MSW)	CH_4	5,965	994	-	-	-	-	-33%	+33%	-0.2%	0.2%	0.0%	0.0%	-83.3%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.A. Solid Waste Disposal	1. Managed disposal site (IW)	CH_4	3,973	568	-	-	-	-	-29%	+29%	-0.1%	0.1%	0.0%	0.0%	-85.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.A. Solid Waste Disposal	3. Uncategorized (Inappropriate disposal)	CH_4	2	7	-60%	+60%	-42%	+41%	-74%	+73%	0.0%	0.0%	0.0%	0.0%	326.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.B. Biological Treatment of Soild Waste	1. Composting	CH_4	54	74	-30%	+30%	-79%	+79%	-84%	+84%	0.0%	0.0%	0.0%	0.0%	36.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.B. Biological Treatment of Soild Waste	1. Composting	N_2O	181	245	-30%	+30%	-167%	+167%	-170%	+170%	0.0%	0.0%	0.0%	0.0%	35.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (MSW)	CO_2	5,554	2,673	-	-	-	-	-7%	+7%	0.0%	0.0%	0.0%	0.0%	-51.9%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (IW oil)	CO_2	3,670	3,272	-30%	+30%	-2%	+2%	-30%	+30%	-0.1%	0.1%	-0.1%	0.1%	-10.9%	0.0%	0.3%	0.0%	0.0%	-0.1%	0.1%	0.1%	0.1%
5.C. Incineration and Open Burning of Waste	1. Incineration (IW solid)	CO_2	2,172	2,962	-	-	-	-	-30%	+30%	-0.1%	0.1%	-0.1%	0.1%	36.4%	0.0%	0.2%	0.0%	0.0%	-0.1%	0.1%	0.1%	0.1%
5.C. Incineration and Open Burning of Waste	1. Incineration (Specially-Contorolled IW)	CO_2	916	1,451	-60%	+60%	-2%	+2%	-60%	+60%	0.0%	0.0%	-0.1%	0.1%	58.4%	0.0%	0.1%	0.0%	0.0%	-0.1%	0.1%	0.1%	0.1%
5.C. Incineration and Open Burning of Waste	2. Open burning (IW)	CO_2	6	0	-30%	+30%	-2%	+2%	-30%	+30%	0.0%	0.0%	0.0%	0.0%	-98.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (MSW)	CH_4	12	1	-	-	-	-	-29%	+52%	0.0%	0.0%	0.0%	0.0%	-91.4%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (IW oil)	CH_4	0	0	-30%	+30%	-100%	+181%	-104%	+184%	0.0%	0.0%	0.0%	0.0%	-22%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (IW sludge)	CH_4	2	0	-30%	+30%	-100%	+201%	-104%	+203%	0.0%	0.0%	0.0%	0.0%	-86.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (IW solid)	CH_4	2	6	-	-	-	-	-84%	+334%	0.0%	0.0%	0.0%	0.0%	173.7%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (Specially-Contorolled IW)	CH_4	0	1	-60%	+60%	-100%	+216%	-117%	+224%	0.0%	0.0%	0.0%	0.0%	427.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	2. Open burning (IW)	CH_4	12	0	-30%	+30%	-100%	+100%	-104%	+104%	0.0%	0.0%	0.0%	0.0%	-99.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (MSW)	N_2O	306	100	-	-	-	-	-27%	+27%	0.0%	0.0%	0.0%	0.0%	-67.3%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (IW oil)	N_2O	5	22	-30%	+30%	-76%	+76%	-81%	+81%	0.0%	0.0%	0.0%	0.0%	392.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (IW sludge)	N_2O	1,056	1,075	-30%	+30%	-84%	+84%	-89%	+89%	-0.1%	0.1%	-0.1%	0.1%	1.9%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (IW solid)	N_2O	64	30	-	-	-	-	-50%	50%	0.0%	0.0%	0.0%	0.0%	-52.5%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Incineration (Specially-Contorolled IW)	N_2O	6	11	-60%	+60%	-44%	+44%	-74%	+74%	0.0%	0.0%	0.0%	0.0%	89.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	2. Open burning (IW)	N_2O	3	0	-30%	+30%	-100%	+100%	-104%	+104%	0.0%	0.0%	0.0%	0.0%	-98.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Sewage treatment plant)	CH_4	216	322	-5%	+5%	-31%	+31%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	48.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Domestic wastewater treatment plant)	CH_4	759	795	-	-	-	-	-31%	+31%	0.0%	0.0%	0.0%	0.0%	4.6%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Human waste treatment plant)	CH_4	131	5	-10%	+10%	-84%	+84%	-84%	+84%	0.0%	0.0%	0.0%	0.0%	-96.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Natural decomposition)	CH_4	1,543	295	-10%	+10%	-58%	+58%	-59%	+59%	-0.1%	0.1%	0.0%	0.0%	-80.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Industrial wastewater treatment)	CH_4	56	42	-30%	+30%	-60%	+60%	-67%	+67%	0.0%	0.0%	0.0%	0.0%	-24.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Natural decomposition)	CH_4	206	93	-30%	+30%	-58%	+58%	-66%	+66%	0.0%	0.0%	0.0%	0.0%	-54.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Landfill leachate treatment)	CH_4	31	4	-100%	+100%	-39%	+39%	-107%	+107%	0.0%	0.0%	0.0%	0.0%	-86.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Sewage treatment plant)	N_2O	416	439	-5%	+5%	-100%	+146%	-100%	+146%	0.0%	0.1%	0.0%	0.1%	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Domestic wastewater treatment plant)	N_2O	453	474	-	-	-	-	-42%	42%	0.0%	0.0%	0.0%	0.0%	4.6%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Human waste treatment plant)	N_2O	67	3	-10%	+10%	-87%	+87%	-88%	+88%	0.0%	0.0%	0.0%	0.0%	-95.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Natural decomposition)	N_2O	830	564	-10%	+10%	-58%	+58%	-59%	+59%	0.0%	0.0%	0.0%	0.0%	-32.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Industrial wastewater treatment)	N_2O	298	336	-30%	+30%	-95%	+95%	-100%	+100%	0.0%	0.0%	0.0%	0.0%	12.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Natural decomposition)	N_2O	316	165	-30%	+30%	-58%	+58%	-66%	+66%	0.0%	0.0%	0.0%	0.0%	-47.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Landfill leachate treatment)	N_2O	8	1	-100%	+100%	-39%	+39%	-107%	+107%	0.0%	0.0%	0.0%	0.0%	-86.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.E. Other	Decomposition of fossil-fuel derived surfactants	CO_2	703	679	-10%	+10%	-1%	+1%	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-3.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

A		B	C	D	E		F		G		H-1990		H-2021		T	I	J	K		L		M	
Indirect CO_2	from Energy sector	Ind CO_2	1,033	449	-	-	-	-	-23%	+40%	0.0%	0.0%	0.0%	0.0%	-56.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Indirect CO_2	from IPPU sector	Ind CO_2	4,449	1,423	-	-	-	-	-32%	+59%	-0.1%	0.2%	0.0%	0.1%	-68.0%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%

Note*: Type A sensitivity $= \frac{0.01\times D_x+\sum D_i-(0.01\times C_x+\sum C_i)}{(0.01\times C_x+\sum C_i)}\times 100-\frac{\sum D_i-\sum C_i}{\sum C_i}\times 100$

Where: C_x, D_x = entry of row x of column C and D respectively in Table A2

$\sum C_i$, $\sum D_i$ = sum of column C and D respectively

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Inventories,* 2006.
2. UNFCCC, *UNFCCC Reporting Guidelines on Annual Greenhouse Gas Inventories* (Decision 24/CP.19 Annex I), 2013.
3. Ministry of the Environment, *Guidelines for Uncertainty Assessment of GHG inventories in Japan*, 2013.

Annex 3. Detailed Methodological Descriptions for Individual Source or Sink Categories

A3.1. Methodology for Estimating Emissions of Precursors

In addition to the mandatory greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3), Japan reports on the emissions of precursors (NO_X, CO, Non-Methane Volatile Organic Compounds [NMVOCs], and SO_X[1]) calculated by established methods. This section explains the categories for which estimation methodologies were established, and emissions are reported.

A3.1.1 Energy Sector

A3.1.1.1. Stationary Combustion (1.A.1., 1.A.2., 1.A.4.: NO_X, CO, NMVOCs, and SO_X)

A3.1.1.1.a. Energy Industries (1.A.1), Manufacturing Industries and Construction (1.A.2), Commercial/institutional (1.A.4.a) and Agriculture/forestry/fishing (1.A.4.c)

a) Category Description

This section provides the estimation methods for emissions of precursors and other substances (NO_X, CO, NMVOCs, and SO_X) from Energy industries (1.A.1), Manufacturing industries and construction (1.A.2), Commercial/institutional (1.A.4.a) and Agriculture/forestry/fishing (1.A.4.c).

b) Methodological Issues

1) NO_X and SO_X

- ***Methodology for Estimating Emissions***

➢ ***Facilities emitting soot and smokes***

General Survey of the Emissions of Air Pollutants by the Ministry of the Environment (MOE) was used as data source for NO_X and SO_X emissions from fuel combustion of the "facilities emitting soot and smokes" specified in laws such as the Air Pollution Control Act. To ensure consistency with the categorization of the common reporting format (CRF), the emissions from the energy sector were isolated from the emissions listed in the *General Survey of the Emissions of Air Pollutants* by the following operation:

1. All emissions from the following facilities and industry sectors are reported under Energy:

   Facility: [0101–0103: Boilers]; [0601–0618: Metal rolling furnaces, metal furnaces, and metal forge furnaces]; [1101–1106: Drying ovens]; [2901–3202: Gas turbines, diesel engines, gas engines, and gasoline engines]

   Industry sector: [A–D: Accommodation/eating establishments, health care/educational and academic institutions, public bathhouses, laundry services]; [F–L: Agriculture/fisheries, mining, construction, electricity, gas, heat distribution, building heating/other operations]

[1] Most SO_X consists of SO_2. For major sources, SO_2 emissions are estimated.

2. For emissions from the facilities and industry sectors other than the above and [1301–1304: Waste incinerators], after emissions from the Industrial Processes and Product Use (IPPU) sector were identified, the emissions from the Energy sector are estimated by subtracting the emissions of the IPPU sector from the emissions listed in the *General Survey of the Emissions of Air Pollutants.* For estimation method in the IPPU sector, see A3.1.2.1. Mineral Industry, Chemical Industry, Metal Production, and Other Production (2.A., 2.B., 2.C., 2.D.: NO_X, SO_X).

➢ ***Small facilities***

NO_X and SO_X emitted by the "small facilities" (i.e. the facilities in commercial/institutional and manufacturing categories that do not correspond to the facilities emitting soot and smokes) were calculated by multiplying the energy consumption in each facility type by Japan's country-specific emission factor.

● ***Emission factors***

➢ ***Facilities emitting soot and smokes***

Not applicable.

➢ ***Small facilities***

Emission factors were established for each fuel type for [0102: Heating system boilers] for facilities listed in [L: Heating systems for buildings/other places of business] in the *General Survey of the Emissions of Air Pollutants* by aggregating emissions and energy consumption by fuel type.

● ***Activity data***

➢ ***Facilities emitting soot and smokes***

Not applicable.

➢ ***Small facilities***

Energy consumption by small facilities by fuel type was calculated by subtracting energy consumption by fuel type, identified by the *General Survey of the Emissions of Air Pollutants*, from energy consumption by fuel type provided in the *General Energy Statistics* (Agency for Natural Resources and Energy). If the activity data shown in the *General Survey of the Emissions of Air Pollutants* exceeded the activity data provided in the *General Energy Statistics*, the activity data for the specified sources was deemed to be zero. The fuels covered were city gas, LPG, kerosene, and fuel oil A.

2) CO and NMVOCs

● ***Estimation Method***

Emissions of CO and NMVOCs from the specified sources were calculated by multiplying the energy consumption in each facility type by Japan's country-specific emission factor.

● ***Emission factors***

CO emission factors were established based on the summary data of the Japan Society for Atmospheric Environment (1996).

NMVOC emission factors for each facility by fuel type were established by multiplying the CH_4 emission factor by the ratio of the NMVOC emission factor to the CH_4 emission factor (NMVOC/CH_4 ratio). The CH_4 emission factors are elaborated in Chapter 3. The NMVOC/CH_4 ratios were determined from Japan Environmental Sanitation Center (1989), Institute of Behavioral Science (1984), and United States Environmental Protection Agency (1985).

- ***Activity data***

Energy consumption calculated for estimation of CH_4 and N_2O was used for activity data. (see Chapter 3.)

A3.1.1.1.b. Residential Sector (1.A.4.b)

a) Category Description

This section provides the estimation methods for emissions of precursors and other substances (NO_X, CO, NMVOCs, and SO_X) from fuel combustion of households.

b) Methodological Issues

- ***Estimation Method***

NO_X, CO, NMVOCs, and SO_X emissions from the target source were calculated by multiplying energy consumed of each fuel type by Japan's country-specific emission factors or the default emission factors from *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016*.

- ***Emission factors***

1) NO_X

For solid fuels (coal briquettes), emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid (kerosene) and gaseous (LPG and city gas) fuels, the emission factors by usage by fuel type provided in a report by Air Quality Management Bureau, Environmental Agency (1996) were used. This report calculated the emission factors by taking the average of the concentration of NO_X emissions by product, obtained through questionnaires and interviews in the household gas appliances industry, weighted by the number of products sold.

2) CO

For solid fuels (coal briquettes), emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid (kerosene) and gaseous (LPG and city gas) fuels, the emission factors by usage by fuel type provided in the report by Institute of Behavioral Science (1997) were used. This report tabulated the emission factors by usage by fuel type from the actual values measured in Tokyo, Yokohama City and Chiba Prefecture.

3) NMVOCs

For solid fuels (coal briquettes), liquid fuels (kerosene), gaseous fuels (LPG and city gas), emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

4) SO_X

For solid fuels (coal briquettes), emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid fuel (kerosene), emission factors were calculated from energy consumption, specific gravity and sulfur content based on the fuel characteristics of kerosene described in information material compiled by the Petroleum Association of Japan.

- ***Activity data***

Fuel consumption by fuel type for residential use in the *General Energy Statistics* has been taken for the activity data. The fuels covered were coal briquettes, kerosene, LPG, and city gas. For the ratio of consumption by fuel type by type of use in households, the *Handbook of Energy & Economic Statistics in Japan* (Energy Data and Modeling Center) is used.

A3.1.1.1.c. Incineration of Waste for Energy Purposes and With Energy Recovery

Emissions of NO_X, CO, NMVOCs and SO_X from the incineration of waste for energy purposes and from the incineration of waste with energy recovery are reported under the relevant subcategories of 1.A.1, 1.A.2 and 1.A.4. Explanations for estimation method, emission factors, and activity data are all given in the section "A3.1.5 Waste".

A3.1.1.2. Mobile Combustion (NO_X, CO, NMVOCs, and SO_X)

A3.1.1.2.a. Domestic Aviation (1.A.3.a) and International Aviation (NOx, CO, and NMVOCs)

a) Category Description

This section provides the estimation methods for emissions of precursors (NOx, CO, and NMVOCs) from combustion of aviation fuel.

b) Methodological Issues

- ***Estimation Method***

NO_X, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *2006 IPCC Guidelines* and the *Revised 1996 IPCC Guidelines*.

- ***Emission factors***

Data in the following table are used.

Table A 3-1 IPCC default emission factors for domestic aviation

Gas	EF [g/MJ(NCV)]
NO_X	0.25 [1)]
CO	0.12 [2)]
NMVOCs	0.018 [2)]

Reference: 1) *2006 IPCC Guidelines*, Vol. 2; Page 3.64, Table 3.6.5
2) *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.90, Table 1-47, Jet and Turboprop Aircraft

- ***Activity data***

For domestic aviation, figures for jet fuel consumption (for domestic scheduled flights and others [commuter, sightseeing and charter flights]) converted to net calorific value from data described in the *Statistical Yearbook of Air Transport* (Ministry of Land, Infrastructure, Transport and Tourism (MLIT)) are used. For international aviation, the totals for bonded imports and bonded exports given in *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) (METI) are used. It is assumed that jet fuel is used by aircrafts.

c) Completeness

For aviation gasoline, emissions of NO_X, CO, and NMVOCs are reported as "NE".

A3.1.1.2.b. Road Transportation (1.A.3.b.): Fuel Combustion (NO_X, CO, NMVOCs, and SO_X)

a) Description of emission source categories

This section provides the estimation methods for emissions of precursors and other substances (NO_X, CO, NMVOCs, and SO_X) from fuel combustion of vehicles.

b) Methodological Issues

1) NO_X, CO, and NMVOCs

- ***Estimation Method***

NO_X, CO, and NMVOC emissions from the specified mobile sources are calculated by multiplying the distance traveled per year for each vehicle type per fuel by Japan's country-specific emission factor.

- ***Emission factors***

Emission factors are established for each vehicle class per fuel type based on the *Survey for Estimation of Emission Factors and Total Emissions of Exhaust Gas from Automobiles* (MOE, 2002) and the *Survey for Consideration of Estimation of Emission Factors and Total Emissions of Exhaust Gas from Automobiles* (MOE, 2004, 2007, 2008, and every year after 2011). The NMVOC emission factors, however, are calculated by multiplying the emission factor of total hydrocarbon (THC) of the Survey by the percentage of NMVOCs in the THC emissions (60% for gasoline and LPG vehicles and 99% for diesel vehicles; surveyed by MOE).

The trend of these emission factors over the years includes not only the impact of replacement to vehicles compatible with the latest exhaust gas regulation, but also the impact of the methodological change in the calculation of the emission factors among the survey years.

For reference, Table A 3-5 shows the outline of motor vehicle exhaust emission standards of air pollutants.

- ***Activity data***

For the activity data, the travel distance per year for each vehicle class by fuel type, estimated for CH_4 and N_2O emissions, are used. (See Chapter 3)

Table A 3-2 NO_X emission factors for automobiles [g-NOx/km]

Fuel	Vehicle type	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	Light vehicle	0.23	0.16	0.16	0.08	0.15	0.12	0.10	0.08	0.06	0.09	0.07	0.07	0.05	0.04	0.04
	Passenger vehicle (including LPG)	0.24	0.20	0.20	0.08	0.14	0.09	0.07	0.06	0.05	0.09	0.08	0.06	0.06	0.04	0.04
	Light cargo truck	0.87	0.66	0.38	0.20	0.27	0.27	0.23	0.19	0.18	0.32	0.32	0.25	0.26	0.19	0.17
	Small cargo truck	1.12	0.90	0.48	0.09	0.15	0.09	0.08	0.07	0.06	0.14	0.10	0.07	0.07	0.05	0.04
	Regular cargo truck	1.83	1.09	0.56	0.16	0.33	0.25	0.23	0.23	0.20	0.24	0.20	0.16	0.12	0.09	0.07
	Bus	4.45	3.65	2.44	0.09	0.15	0.07	0.06	0.06	0.05	0.08	0.08	0.10	0.07	0.08	0.08
	Special-purpose vehicle	1.47	0.87	0.43	0.12	0.32	0.19	0.17	0.15	0.12	0.31	0.22	0.17	0.16	0.12	0.10
Diesel	Passenger vehicle	0.64	0.53	0.44	0.45	0.47	0.44	0.38	0.34	0.26	0.40	0.39	0.35	0.28	0.26	0.26
	Small cargo truck	1.33	1.10	1.01	1.00	1.06	0.93	0.89	0.79	0.73	1.87	1.02	0.96	0.94	0.90	0.88
	Regular cargo truck	5.35	4.59	4.33	4.50	3.26	2.86	2.73	2.64	2.40	3.05	2.50	2.28	1.96	1.84	1.73
	Bus	4.23	3.83	3.60	4.07	3.38	3.39	3.23	3.13	2.96	3.74	3.46	3.25	3.04	2.88	2.71
	Special-purpose vehicle	3.38	2.76	2.15	3.63	2.97	2.50	2.41	2.24	2.05	3.21	2.97	2.75	2.42	2.30	2.18

Table A 3-3 CO emission factors for automobiles [g-CO/km]

Fuel	Vehicle Type	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	Light vehicle	1.75	1.55	1.54	0.97	1.51	1.47	1.22	1.08	0.94	1.39	1.32	1.29	1.26	1.23	1.20
	Passenger vehicle (including LPG)	2.32	2.06	2.03	0.94	1.37	1.07	0.92	0.81	0.75	1.33	1.27	1.16	1.14	1.03	0.98
	Light cargo truck	10.42	8.54	5.51	2.77	2.87	3.17	2.76	2.38	2.27	2.46	2.48	2.06	2.21	1.85	1.73
	Small cargo truck	9.66	10.08	8.31	2.05	2.73	1.85	1.61	1.40	1.25	1.67	1.19	1.05	1.00	0.90	0.85
	Regular cargo truck	12.62	10.60	8.95	3.62	7.53	5.67	5.04	4.77	4.36	4.18	3.06	2.89	2.25	2.02	1.84
	Bus	26.21	25.08	21.94	2.07	2.62	1.77	1.78	1.65	1.57	1.79	1.72	1.60	1.61	1.40	1.36
	Special-purpose vehicle	12.47	10.67	8.92	2.30	5.34	3.69	3.44	3.09	2.76	3.51	2.23	1.79	1.95	1.61	1.50
Diesel	Passenger vehicle	0.48	0.43	0.43	0.37	0.39	0.36	0.29	0.22	0.17	0.24	0.23	0.20	0.11	0.09	0.08
	Small cargo truck	0.98	0.90	0.81	0.59	0.45	0.36	0.34	0.30	0.25	0.54	0.34	0.28	0.21	0.15	0.12
	Regular cargo truck	3.22	2.99	2.44	2.04	1.10	0.80	0.72	0.65	0.55	0.50	0.36	0.31	0.21	0.17	0.15
	Bus	2.58	2.53	2.20	2.03	1.24	1.14	1.05	0.98	0.89	0.86	0.76	0.66	0.55	0.46	0.40
	Special-purpose vehicle	2.11	1.89	1.30	1.60	0.93	0.63	0.58	0.50	0.43	0.53	0.48	0.41	0.29	0.24	0.21

Table A 3-4 NMVOC emission factors for automobiles [g-NMVOC/km]

Fuel	Vehicle Type	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	Light vehicle	0.08	0.03	0.03	0.03	0.08	0.06	0.05	0.04	0.04	0.05	0.05	0.04	0.03	0.03	0.03
	Passenger vehicle (including LPG)	0.11	0.07	0.06	0.02	0.06	0.04	0.04	0.03	0.03	0.06	0.06	0.06	0.05	0.05	0.04
	Light cargo truck	0.64	0.37	0.16	0.09	0.14	0.13	0.12	0.10	0.10	0.12	0.11	0.08	0.09	0.06	0.06
	Small cargo truck	0.71	0.53	0.21	0.04	0.07	0.05	0.04	0.04	0.03	0.10	0.05	0.04	0.04	0.04	0.04
	Regular cargo truck	0.99	0.58	0.28	0.06	0.17	0.14	0.13	0.14	0.11	0.14	0.07	0.06	0.05	0.05	0.04
	Bus	2.16	1.90	1.32	0.04	0.07	0.04	0.04	0.03	0.03	0.06	0.05	0.06	0.05	0.05	0.05
	Special-purpose vehicle	0.97	0.47	0.19	0.05	0.16	0.10	0.10	0.09	0.08	0.24	0.09	0.08	0.08	0.08	0.07
Diesel	Passenger vehicle	0.11	0.10	0.10	0.09	0.10	0.10	0.08	0.07	0.05	0.06	0.05	0.04	0.03	0.02	0.02
	Small cargo truck	0.39	0.34	0.26	0.20	0.14	0.10	0.09	0.08	0.07	0.14	0.09	0.07	0.06	0.04	0.03
	Regular cargo truck	1.62	1.47	1.03	0.75	0.35	0.23	0.21	0.19	0.15	0.14	0.08	0.06	0.05	0.03	0.02
	Bus	1.26	1.24	0.98	0.80	0.43	0.38	0.34	0.32	0.28	0.32	0.26	0.21	0.18	0.14	0.11
	Special-purpose vehicle	1.09	0.96	0.52	0.57	0.27	0.17	0.16	0.13	0.12	0.14	0.11	0.08	0.06	0.05	0.04

Table A 3-5 Outline of motor vehicle exhaust emission standards (for reference)

Fuel	Vehicle	Class	Item	1990	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2007	2008	2009	2010	2011	2016	2018	2019	
Gasoline and LPG	Light passenger vehicle and passenger vehicle		CO	2.1	2.1								0.67					1.15		1.15			1.15		1.15		
			HC	0.25	0.25								0.08					0.05		0.05			0.05		0.1		
			NOx	0.25	0.25								0.08					0.05		0.05			0.05		0.05		
			Unit	g/km	g/km								g/km					g/km		g/km			g/km		g/km		
			Mode	10	10·15								10·15					10·15+11		10·15+JC08C			JC08H+JC08C		WLTC		
			CO	60									19														
			HC	7									2.2														
			NOx	4.4									1.4														
			Unit	g/test									g/test														
			Mode	11									11														
	Truck and bus	Light cargo truck	CO	13	13						6.5				3.3				4.02	4.02			4.02			4.02	
			HC	2.1	2.1						0.25				0.13				0.05	0.05			0.05			0.1	
			NOx	0.5	0.5						0.25				0.13				0.05	0.05			0.05			0.05	
			Unit	g/km	g/km						g/km				g/km					10·15+JC08C			g/km			g/km	
			Mode	10	10·15						10·15				10·15				10·15+11				JC08H+JC08C			WLTC	
			CO	100							76				38												
			HC	13							7				3.5												
			NOx	5.5							4.4				2.2												
			Unit	g/test							g/test				g/test												
			Mode	11							11				11												
		Light duty	CO	2.1	2.1								0.67					1.15		1.15			1.15		1.15		
			HC	0.25	0.25								0.08					0.05		0.05			0.05		0.1		
			NOx	0.25	0.25								0.08					0.05		0.05			0.05		0.05		7)
			Unit	g/km	g/km								g/km					g/km		g/km			g/km		g/km		
			Mode	10	10·15								10·15					10·15+11		10·15+JC08C			JC08H+JC08C		WLTC		
			CO	60									19														
			HC	7									2.2														
			NOx	4.4									1.4														
			Unit	g/test									g/test														
			Mode	11									11														
		Medium duty	CO	13	13			13			6.5			2.1				2.55		2.55			2.55			2.55	
			HC	2.1	2.1			2.1			0.25			0.08				0.05		0.05			0.05			0.15	
			NOx	0.7	0.7			0.4			0.4			0.13				0.07		0.07			0.07			0.07	7)
			Unit	g/km	g/km			g/km			g/km			g/km				g/km		g/km			g/km			g/km	
			Mode	10	10·15			10·15			10·15			10·15				10·15+11		10·15+JC08C			JC08H+JC08C			WLTC	
			CO	100				100			76			24													
			HC	13				13			7			2.2													
			NOx	6.5				5			5			1.6													
			Unit	g/test				g/test			g/test			g/test													
			Mode	11				11			11			11													
		Heavy duty	CO	1.2		102			102		51			16				16									
			HC	410		6.2			6.2		1.8			0.58				0.23									
			NOx	650		5.5			4.5		4.5			1.4				0.7									7)
			Unit	ppm		g/kWh			g/kWh		g/kWh			g/kWh				g/kWh									8)
			Mode	6		G13			G13		G13			G13				JE05									
	Common name							Short-term regulation			Long-term regulation			New short-term regulation				New long-term regulation									
				1990	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2007	2008	2009	2010	2011	2016	2018	2019	
Diesel	Passenger vehicle		CO	2.1	2.1	2.1				2.1	2.1				0.63			0.63		0.63	0.63				0.63		
			HC	0.4	0.4	0.4				0.4	0.4				0.12			0.024		0.024	0.024				0.024		
			NOx	0.5|0.9	0.5|0.9	0.5|0.6				0.4|0.6	0.4				0.28|0.3			0.14|0.15		0.14|0.1	0.08				0.15		9)
			Unit	g/km	g/km	g/km				g/km	g/km				g/km			g/km		10·15+JC08C					g/km		
			Mode	10	10·15	10·15				10·15	10·15				10·15			10·15+11			JC08H+JC08C				WLTC		
	Truck and bus	Light duty	CO	2.1	2.1		2.1			2.1					0.63			0.63		0.63	0.63				0.63		
			HC	0.4	0.4		0.4			0.4					0.12			0.024		0.024	0.024				0.024		
			NOx	0.9	0.9		0.6			0.4					0.28			0.14		0.14	0.08				0.15		10)
			Unit	g/km	g/km		g/km			g/km					g/km			g/km		10·15+JC08C					g/km		
			Mode	10	10·15		10·15			10·15					10·15			10·15+11			JC08H+JC08C				WLTC		
		Medium duty	CO	790			2.1			2.1						0.63		0.63		0.63	0.63					0.63	
			HC	510			0.4			0.4						0.12		0.024		0.024	0.024					0.024	
			NOx	380/260			1.3			0.7						0.49		0.25		0.25	0.15					0.24	10)
			Unit	ppm			g/km			g/km						g/km		g/km		10·15+JC08C						g/km	11)
			Mode	6			10·15			10·15						10·15		10·15+11			JC08H+JC08C					WLTC	
		Heavy duty	CO	790				7.4		7.4	7.4	7.4				2.22	2.22	2.22			2.22	2.22		2.22	2.22	2.22	
			HC	510				2.9		2.9	2.9	2.9				0.87	0.87	0.17			0.17	0.17		0.17	0.17	0.17	
			NOx	400/260				6/5		4.5	4.5	4.5				3.38	3.38	2			0.7	0.7		0.4	0.4	0.4	10)
			Unit	ppm				g/kWh		(2.5-	(3.5-	(>12t)				(2.5-	(>12t)	g/kWh			(>12t)	(3.5-		(>7.5t)	(trac-	(3.5-	11)
			Mode	6				D13		3.5t)	12t)					12t)		JE05			JE05	12t)		WHDC	tor)	7.5t)	
	Common name						Short-term regulation			Long-term regulation					New short-term regulation			New long-term regulation			Post new long-term regulation						

Note: 1) This table is compiled based on the materials prepared by Ministry of the Environment and Ministry of Land, Infrastructure, Transport and Tourism.
2) This table omits the regulations of particular matter (PM) and fuel evaporation for the vehicles above and the regulations of exhaust gas for motorcycles and off-road vehicles.
3) The values in this table represent average value for new vehicle type.
4) 1990 column represents the regulations as of 1990 and other columns represent the years the regulations started for new vehicle type.
5) The shaded letters show the difference from the previous regulation.
6) HC do not include methane since the regulations enforced since 2005.
7) For gasoline and LPG vehicles, "light duty vehicles" are vehicles with gross vehicle weight (GVW) of 1.7t or less.
Until 2000, "middle duty vehicles" are vehicles with GVW of 1.7-2.5t and "heavy duty vehicles" are vehicles with GVW of more than 2.5t.
Since 2001, "middle duty vehicles" are vehicles with GVW of 1.7-3.5t and "heavy duty vehicles" are vehicles with GVW of more than 3.5t.
8) Different regulations are adopted for LPG heavy duty vehicles until 1997, but omitted from this table for simplicity.
9) 0.5|0.9 in diesel passenger vehicles stands for "0.5 for small size vehicles (vehicle weight of 1,265 kg or less) and 0.9 for medium size vehicles (vehicle weight of more than 1,265 kg)".
10) For diesel vehicles, "light duty vehicles" are vehicles with GVW of 1.7t or less.
Until 2004, "middle duty vehicles" are vehicles with GVW of 1.7-2.5t and "heavy duty vehicles" are vehicles with GVW of more than 2.5t.
Since 2005, "middle duty vehicles" are vehicles with GVW of 1.7-3.5t and "heavy duty vehicles" are vehicles with GVW of more than 3.5t.
11) "380/260" for diesel truck and bus in 1990s stands for "380 for direct injection and 260 for indirect injection".

2) SO_X

- ***Estimation Method***

The emissions of SO_X from these sources are calculated by multiplying the fuel consumption of each fuel type by Japan's country-specific emission factors.

- ***Emission factors***

Sulfur content (by weight) by fuel type was used.

Table A 3-6 Sulfur content (by weight) by fuel type

Fuel	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Gasoline	0.008%	0.008%	0.008%	0.005%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%
Diesel	0.350%	0.136%	0.050%	0.005%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%
LPG	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%

Reference: Gasoline – The Institute of Behavioral Science (until 2004); Upper limits of regulations (2005 onward),
Diesel oil – Petroleum Association of Japan (until 1997); Upper limits of regulations (1998 onward)
LPG – The Institute of Behavioral Science

- ***Activity data***

Activity data, fuel consumption data of weight value, are calculated by multiplying the fuel consumption of each fuel type, reported in in the *General Energy Statistics* (Agency for Natural Resources and Energy), by the specific gravity of each fuel type.

c) Completeness

Emissions of NO_X, CO, NMVOCs, and SO_X from natural gas vehicles and motorcycles are reported as "NE".

A3.1.1.2.c. Road Transportation (1.A.3.b.): Fuel Volatilization (Excluding Motorcycle) (NMVOCs)

a) Description of emission source categories

This section provides the estimation methods for emissions of NMVOCs caused by fuel volatilization of vehicles. NMVOCs are emitted from vehicles which run on gasoline, by volatilization of the gasoline component in the tank. Fuel evaporative emission is classified into the following three types. Evaporating gas in filling gasoline is included in the calculation of fugitive emissions from fuels at gas stations (1.b.2.a.v.).

Table A 3-7 Classification of fuel evaporative gases

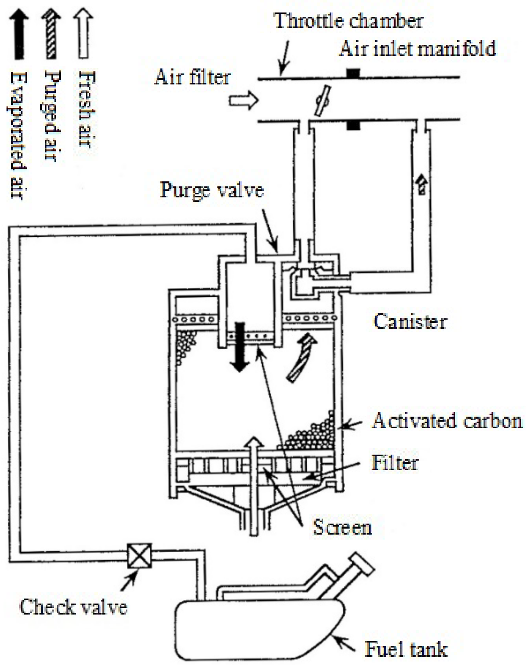
Types	Description
Diurnal Breathing Loss (DBL)	Evaporated gas which is generated when gasoline vapor, generated mainly due to the change in temperature during parking, is vented to the atmosphere after breakthrough[1)] from the canister[2)].
Hot Soak Loss (HSL)	Evaporated gas which is generated from gasoline attached to the induction pipe within one hour after shutdown of an engine.
Running Loss (RL)	Evaporated gas which is generated when the temperature of gasoline rises during driving and it goes beyond the limitation of canister purging[3)].

Note:

1) "Breakthrough" means going through the absorption process without being absorbed when the amount of gas/gasoline goes beyond the absorption capacity of canister.

2) Canister is absorption equipment in which activated carbon and other substances are included to prevent generating evaporated gas in the fuel system of gasoline car. Evaporated gas during parking is absorbed by the canister; absorbed evaporated gas is delivered to the intake manifold during driving, then, absorption capacity of the canister recovers.
3) Purge means delivering evaporated gas, together with air, to intake manifold.

Reference: *Estimation Methods for Releases from Sources not Required to Report under PRTR (Pollutant Release and Transfer Register)* (Ministry of Economy, Trade and Industry (METI), and Ministry of the Environment (MOE), 2012)



Reference: Society of Automotive Engineers of Japan, Inc. (2008)

Figure A 3-1 Structure of fuel tank and canister

b) *Methodological issues*

Fuel evaporated emissions are estimated by adjusting THC emission data of DBL, HSL, and RL in 2002 by the annual number of cars owned and annual travel distance. The emissions in 2002 are provided in *Development Research of New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)* (MOE, FY2003). This methodology is similar to that described in the *Estimation Methods for Releases from Sources not Required to Report under PRTR* (METI and MOE).

In estimating emissions in RL, PRTR emission data is used after 2003.

It was assumed that THC emissions = NMVOC emissions, since methane is not included in fuel evaporated gas[2]. The outline of estimation method for each emission source and used data is shown in Table A 3-8.

[2] Regarding concrete volatile element composition, please refer to Yokota *et al.* (2011) for example.

Table A 3-8 Descriptions for estimating emissions from evaporated gas by mobile fuel combustion

Category	Equation	Data for calculation
DBL	$$E_n = \sum_p \sum_q \sum_r \left(E_{2002} \times \frac{N_{n,p,q,r}}{N_{2002,p,q,r}} \right)$$ E_n : DBL emissions in fiscal year (FY) n [t-NMVOC] $N_{n,p,q,r}$: Number of gasoline vehicles owned in FY n in a prefecture p, by vehicle type q, by status if regulated or not r	E_{2002}: THC emission amount in FY2002 provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)* (MOE, FY2003) N: Based on *Monthly Report Statistics of Vehicles* (Japan Automobile Manufacturers Association, Inc. (JAMA)) and *Statistics of AIRIA/ Number of Motor Vehicles* (Automobile Inspection & Registration Information Association (AIRIA))
HSL	$$E_n = \sum_p \sum_q \left(E_{2002} \times \frac{N_{n,p,q}}{N_{2002,p,q}} \right)$$ E_n: DBL emissions in FY n [t-NMVOC] $N_{n,p,q}$: Number of gasoline vehicles owned in FY n in a prefecture p, by usage q	E_{2002}: THC emission amount in FY2002 provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)* N: Based on *Monthly Report Statistics of Vehicles* and *Statistics of AIRIA/ Number of Motor Vehicles*
RL	[1990-2002] $$E_n = \sum_p \sum_q \left(E_{2002} \times \frac{N_{n,p,q}}{N_{2002,p,q}} \times \frac{M_{n,p}}{M_{2002,p}} \right)$$ E_n: RL emissions in FY n [t-NMVOC] $N_{n,p,q}$: Number of gasoline vehicles owned in FY n in a prefecture p, by status if regulated or not q $M_{n,p}$: Travel distance of motorcycle [km] in FY n in a prefecture p [2003-] PRTR emissions were used.	E_{2002}: THC emission amount in FY2002 provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road Vehicle)* N: Based on *Monthly Report Statistics of Vehicles* and *Statistics of AIRIA/ Number of Motor Vehicles* M: Based on *Monthly Report of Motor Vehicle Transport Statistics* and *Monthly Report Statistics of Vehicles*

A3.1.1.2.d. Road Transportation (1.A.3.b.): Fuel Volatilization (Motorcycle) (NMVOCs)

a) Description of emission source categories

This section provides the estimation methods for emissions of NMVOCs by motorcycle caused by fuel volatilization. NMVOCs are emitted from motorcycles which run on gasoline, by volatilization of the gasoline component in the tank due to changes in temperature as described in the above section. This section provides the estimation method for DBL and HSL as described in the *PRTR*.

b) Methodological issues

Fuel evaporated emissions from motorcycle are estimated by using THC emissions in 2001, provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)* (MOE, FY2002), which are yearly-adjusted by the activity data, number of motorcycles owned and travel distance, using the same methodology as that in the *Estimation Methods for Releases from Sources not Required to Report under PRTR* (METI and MOE).

Table A 3-9 Description of estimating emissions from evaporated gas by motorcycle fuel combustion

Category	Equation	Data for calculation
DBL	$$E_n = \sum_p \sum_q \left(E_{2001} \times \frac{M_{n,p,q}}{M_{2001,p,q}} \right)$$ E_n: DBL emissions in FY *n* [t-NMVOC] $M_{n,p,q}$: travel distance of motorcycle [km] in FY *n* in a prefecture *p*, by vehicle type *q*	E_{2001}: THC emission amount in FY2001 estimated based on *Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)* (MOE, FY2002) *M*: Based on *Monthly Report Statistics of Vehicles* (JAMA), and *Survey of Motorcycle Market Trends* (JAMA)
HSL	$$E_n = \sum_p \sum_q \left(E_{2001} \times \frac{M_{n,p}}{M_{2001,p}} \times R_{n,p} \right)$$ E_n: DBL emissions in FY *n* [t-NMVOC] $M_{n,p}$: travel distance of motorcycle [km] in FY *n* by vehicle type *p* $R_{n,p}$: Use factor adjustment ratio in FY *n* by vehicle type *p*	E_{2001}: THC emission amount in FY2001 estimated based on *Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)* *M*: Based on *Monthly Report Statistics of Vehicles*, and *Survey of Motorcycle Market Trends* *R*: Estimated by multiplying the sales unit for domestic sales of each vehicle type (Website of JAMA) by survival rate of each elapsed year (MOE), by the usage factor of each elapsed year (*Estimation Methods for Releases from Sources not Required to Report under PRTR*)

A3.1.1.2.e. Railways (1.A.3.c.: NO_X, CO, and NMVOCs)

a) Category Description

This section provides the estimation methods for emissions of precursors (NOx, CO, and NMVOCs) caused by combustion of diesel railway fuel.

b) Methodological Issues

NO_X, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *Revised 1996 IPCC Guidelines*.

- ***Emission factors***

The default emission factors provided for the “Locomotives” category in the *Revised 1996 IPCC Guidelines* are used.

Table A 3-10 IPCC default emission factors for locomotives

Gas	Emission factor [g/MJ(NCV)]
NO_X	1.8
CO	0.61
NMVOCs	0.13

Reference: *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.89, Table 1-47

- ***Activity data***

The diesel oil consumption by railways in the *General Energy Statistics* (Agency for Natural Resources and Energy) is used.

A3.1.1.2.f. Domestic Navigation (1.A.3.d) and International Navigation (NO_X, CO, NMVOCs, and SO_X)

a) Category Description

This section provides the estimation methods for emissions of precursors (NOx, CO, and NMVOCs) and SO_X from combustion of marine fuel.

b) Methodological Issues

1) NO_X, CO, and NMVOCs

- ***Estimation Method***

NO_X, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *Revised 1996 IPCC Guidelines*.

- ***Emission factors***

The default emission factors provided in the "Ocean-Going Ships" category in the *Revised 1996 IPCC Guidelines* are used.

Table A 3-11 IPCC default emission factors for ocean-going ships

Gas	Emission factor [g/MJ(NCV)]
NO_X	1.8
CO	0.18
NMVOCs	0.052

Reference: *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.90, Table 1-48

- ***Activity data***

For domestic navigation, the marine fuel consumption data converted to net calorific value by fuel type (diesel oil, fuel oil A, fuel oil B, and fuel oil C) from the *General Energy Statistics* (Agency for Natural Resources and Energy) are used. For international navigation, the totals for bonded imports and bonded exports given in *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) (METI) are used. It is assumed that fuel oil A, B, C, diesel oil, kerosene and lubricants are used by vessels.

2) SO_X

- ***Estimation Method***

Emissions from the specified sources are calculated by multiplying the fuel consumption by the emission factors.

- ***Emission factors***

Emission factors are calculated by multiplying the specific gravity of each marine fuel by the sulfur ratio of each fuel by the molecular weight ratio of sulfur dioxide[3] versus sulfur. The sulfur ratio of each fuel is restricted by domestic law and *Japanese Industrial Standard*. Therefore, the regulation values are used for the sulfur ratio in the estimation.

[3] Most SO_X consists of SO_2. For major sources, SO_2 emissions are estimated.

Table A 3-12 Specific gravity and sulfur ratio of fuel for ocean-going ships

Fuel	Specific Gravity [kg/L]	Sulfur Ratio [% in weight]
Diesel Oil	0.83	0.5 (1990-1991) 0.2 (1992-1997) 0.05 (1998-2004) 0.005 (2005-2006) 0.001 (2007 onward)
Fuel Oil A	0.84	2.0 (1990-2019) 0.5 (2020 onward)
Fuel Oil B	0.91	3.0 (1990-2019) 0.5 (2020 onward)
Fuel Oil C	0.93	3.5 (1990-2019) 0.5 (2020 onward)

Reference: Sulfur ratio of diesel oil based on Petroleum Association of Japan (2015)
Sulfur ratio of each fuel oil based on *Japanese Industrial Standard* K2205 until 2019, and MARPOL Annex VI for 2020 onward
Specific gravity based on Environmental Research and Control Center (2000)

- ***Activity data***

The marine fuel consumption data of each fuel type (diesel oil, fuel oil A, fuel oil B, and fuel oil C) provided in the *General Energy Statistics* (Agency for Natural Resources and Energy) are used for the activity data.

A3.1.1.3. Fugitive Emissions from Fuel (Oil and Natural Gas) (1.B.2: NMVOCs)

A3.1.1.3.a. Oil Production (1.B.2.a.ii)

a) Category Description

This section provides the estimation methods for NMVOC leaks occurring during production of crude oil in oil fields. The NMVOC emissions from venting and flaring during oil production are included in the category “Venting and Flaring” (1.B.2.c). As for the NMVOC emissions when lowering measuring instruments into operating wells at servicing, the estimation methods are provided in the section “Fugitive emissions during servicing of operating gas fields” (1.B.2.b.ii).

b) Methodological Issues

The emissions from offshore and onshore oil fields are estimated separately.

- ***Estimation Method***

Using the equation below, the emission amount of NMVOCs in this category is estimated by multiplying the amounts of crude oil production from offshore oil fields and onshore oil fields by the default emission factors for offshore and onshore given in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereinafter, *2019 Refinement*).

$$E = \sum_i (AD_i \times EF_i)$$

E : NMVOC fugitive emissions caused by crude oil production [kg-NMVOC]
AD_i : Amount of crude oil production (excluding condensate) from offshore oil fields or onshore oil fields [kL]
EF_i : Emission factor for crude oil production from offshore oil fields or onshore oil fields [kg-NMVOC/kL]

- ***Emission factors***

The emission factors are established by multiplying the default emission factors for oil production from onshore and offshore oil fields, shown in the *2019 Refinement* (Vol.2, Table 4.2.4A), by the disaggregation factor of leaks in the *2019 Refinement* (Vol.2, Table 4A.2.2). The emission factor of lower-emitting technologies is adopted for onshore oil fields because flaring facilities and vapor recovery units (VRU) have been installed in the most oil fields since FY1990 according to the Natural Gas Association.

Table A 3-13 Emission factor for NMVOC leaks from oil production

Emission source	Emission factor [kg-NMVOC/kL]	Disaggregation factor (Leaks)	Emission factor (Leaks) [kg-NMVOC/kL]
Onshore (lower-emitting technologies)	1.25	9%	0.11
Offshore	1.06	20%	0.21

- ***Activity Data***

The amount of crude oil production (excluding condensate) by offshore and onshore oil field is used for activity data.

As for the amount of crude oil production (excluding condensate) in offshore oil fields, the condensate production in offshore gas fields is estimated by multiplying the production amount of condensate by the ratio of natural gas production amount in offshore fields to the total production amount of natural gas, and then subtracted from the crude oil production amount in offshore fields.

The amount of crude oil production (excluding condensate) in offshore fields estimated above is deducted from the total amount of domestic crude oil production (excluding condensate) to obtain the production amount of crude oil (excluding condensate) in onshore oil fields.

Total production volumes of natural gas, crude oil, and condensate are obtained from the data given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* (FY1990-2000), the *Yearbook of Mineral Resources and Petroleum Products* (FY2001-2010), and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* (FY2011 onward), all by METI. The production amounts of natural gas and crude oil from offshore are obtained from *Natural Gas Data Yearbook* compiled by the Japan Natural Gas Association.

A3.1.1.3.b. Oil Transport (1.B.2.a.iii): Distribution of Crude Oil

a) Category Description

This section provides the estimation methods for NMVOC emissions which are, like evaporating gas, emitted in losses from breathing and acceptance for storage tank, and loading to lorry tank during distributing domestic crude oil.

b) Methodological Issues

- ***Estimation Method***

Emission amount of NMVOCs in this category is estimated by multiplying the amount of domestic production of crude oil by the emission factor for NMVOCs per production volume.

$$E = AD \times EF$$

E : NMVOC emissions caused by oil transport [t-NMVOC]
AD : Amount of domestic crude oil production [1000 kL]
EF : Emission factor per crude oil production [t-NMVOC/1000 kL]

- ***Emission factors***

Emission factors for oil transport are established by dividing the emission amount from crude oil (evaporating gas) estimated in *Study to Develop the National Emission Inventory for Volatile Organic Compounds* (hereafter, "*Study on the VOC Emission Inventory*") (MOE) by the activity data (amount of crude oil production). Since emission data indicated in the *Study on the VOC Emission Inventory* is limited only to FY2000 and FY2005 onward, emission factors in and before FY2004 are established by dividing the emissions estimated by Japan Natural Gas Association[4] by the activity data.

- ***Activity Data***

The activity data for this category are the amount of crude oil production (including condensate) which is provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

A3.1.1.3.c. Oil Transport (1.B.2.a.iii): Navigation

a) Category Description

NMVOCs are emitted in the process of ocean transportation of liquid cargo including gasoline, gas-free operation, and ship loading. This section provides the estimation methods for NMVOCs which are emitted from cargo operations by two types of tanker, crude oil tanker and product tanker.

Naphtha is also highly volatile and NMVOCs are likely to be emitted. However, naphtha is delivered by chemical tankers, which have high airtightness and pressure resistance, and is prohibited from being delivered by product tankers, which are not enough treated for electrostatic generation which involves the risk of auto-ignition. Therefore, it is considered that naphtha is not emitted into the air during delivering, thus, the naphtha delivery is not subject to the emission estimation. (Although chemical agents are usually delivered by chemical tankers, sometimes they are delivered by product tankers, so all chemical agents are used for estimation to avoid underestimation).

VOC emissions from "crude oil" and "oil products (gasoline)" are also included in "1.b.2.a.iv. Refining and storage of oil". Therefore, the emissions are subtracted from the total emissions in "1.B.2.a.iv. Refining and storage of oil" and included and reported in this category.

[4] Japan Natural Gas Association provided the emissions from the following five sources: "breathing and acceptance", "shipping (lorry)", "reboiler vent (GDH)", "gas release" and "CO_2 venting". The first two sources were chosen as the emissions from this subcategory and the rest of the sources were chosen as the emissions from processing of natural gas (1.B.2.b.iii) in accordance with the *Studies on VOC Emission Inventories*.

VOC emissions from “chemical agent” are also estimated in “A3.1.2.2.n Chemicals Manufacture” in “2. Industrial Process and Product Use”. Therefore, the emissions are subtracted from the total emissions in “Chemicals Manufacture” and included and reported in this category.

b) Methodological Issues

- ***Estimation Method***

The NMVOC emissions are estimated by multiplying the amount of exported or domestically transported “crude oil”, “oil products (gasoline)”, and “chemical agents” which are reported in the tables entitled “Export cargo volume by type of goods, by destination” and “Delivery cargo volume by type of goods, by destination” in the *Statistical Yearbook of Port* (MLIT), by the emission factors.

The following equation is used:

$$E = \sum_i (AD_i \times EF_i)$$

E : Emission amount of NMVOCs from evaporation in vessels [t-NMVOC]
AD_i : Traffic volume of cargo i (export volume + transport volume) [t]
EF_i : Emission factor for cargo i [kg-NMVOC/t]
i : Type of cargo (crude oil, gasoline, chemical agent)

- ***Emission factors***

Emission factors for this category are established as can be seen in Table A 3-14.

Table A 3-14 Emission factors for evaporation from vessels

Activity data		Emission factors [kg-NMVOC/t]
Crude oil	With vapor recovery (only in port of Kiire for FY2007 onward)	0.03
	Without vapor recovery	0.14
Gasoline	During loading	0.12
	During gas-freeing	0.14
Chemical agent	Benzene	0.011
	Methanol	0.006
	Toluene	0.004
	Dichloroethane	0.016
	Acetone	0.023

Reference: Ocean Policy Research Foundation (2006)

- ***Activity Data***

Based on the tables entitled “Export cargo volume by type of goods, by destination” and “Delivery cargo volume by type of goods, by destination” in the *Statistical Yearbook of Port*, the following methods in Table A 3-15 are used for activity data for this category.

Table A 3-15 Activity data for NMVOC emissions from vessels

Activity data	Description
Crude oil	The volume of export and transport of crude oil is used.
Gasoline	Estimated by multiplying the volume of export and transport of crude petroleum products by the percentage of gasoline in the volume of domestic sales and export of petroleum products provided in the *Yearbook of Mineral Resources and Petroleum Products Statistics*.
Chemical agent	Estimated by multiplying the volume of export and transport of chemical agents by the percentage of NMVOCs in chemical agents. The percentage of NMVOCs in chemical agents was established by the percentage of the transport volume in 2003 of five chemical agents (benzene, methanol, toluene, dichloroethane, and acetone), probable emission sources of NMVOCs, to the total chemical agents transported from the *Statistical Yearbook of Port* (Ocean Policy Research Foundation, 2012).

Note: Each activity data is based on calendar year (CY); therefore, CY-based-activity data are converted into FY-based data by combining 75% of the data from corresponding CY and 25% of the data from the subsequent CY.

A3.1.1.3.d. Refining and Storage of Oil (1.B.2.a.iv): Fugitive Emissions From Oil Refineries

a) Category Description

This section provides the estimation methods for NMVOC emissions from fugitive emissions in the process of refining crude oil and producing oil products.

b) Methodological Issues

- ***Estimation Method***

The NMVOC emissions are estimated by multiplying BPSD (Barrel per Stream Day), production amount per Steam day of crude oil distillation unit at normal pressure, by Steam day per year by the emission factor. Steam day per year are estimated by multiplying the number of days per year (365 days, but 366 days in leap years) by the annual operating rate.

$$E = AD \times D \times R \times EF$$

E	: NMVOC emissions from fugitive emissions in refinery [g-NMVOC/year]
AD	: Fugitive Barrel per Stream Day [BPSD]
D	: Number of working days in a year (365 days, but 366 days in leap years)
R	: Annual operating rate [%]
EF	: Emission factor [g-NMVOC/BPSD]

- ***Emission factors***

Emission factor for this category is established at 5.675 [kg/day/10^5BPSD] which is provided in Institute of Behavioral Sciences (2000), in accordance with the *Study on the VOC Emission Inventory*.

- ***Activity Data***

In accordance with the *Study on the VOC Emission Inventory*, the capacity of oil refineries (BPSD: Barrels per Stream Day) by *Sekiyu Shiryô* (Sekiyu Tsushin) is used for activity data. Stream days in a year are calculated by multiplying 365 days (366 days for leap years: FY1991, 1995, 1999, 2003, 2007, 2011, 2015, 2019) by the annual operating ratio of the crude oil distillation units at normal pressure, which is provided by *Sekiyu Shiryô* (=annual processing amount [bbl/year] / annual capacity [bbl/year].

A3.1.1.3.e. Refining and Storage of Oil (1.B.2.a.iv): Production of Lubricant Oil

a) Category Description

This section provides the estimation methods for NMVOC emissions from fugitive emissions in the process of dewaxing and deasphalting during production of lubricants.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from the specified sources are calculated by multiplying the amount of domestic gross sales of lubricants to consumers by Japan's country-specific emission factors for toluene and methyl ethyl ketone.

- ***Emission factors***

Based on measurements in Japan shown in Institute of Behavioral Science (1987), emission factors for lubricant oil production are established as 333.2 [g/kL] for toluene and 415.5 [g/kL] for methyl ethyl ketone.

- ***Activity data***

The activity data for this category are the domestic gross sales amount of lubricants to consumers, provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*.

A3.1.1.3.f. Refining and Storage of Oil (1.B.2.a.iv): Fugitive Emissions From Storage/Shipping Facilities

a) Category Description

NMVOCs are emitted, with accompanying fuel-evaporated fugitive gases, by storage and shipping of fuel (e.g., gasoline, crude oil, and naphtha) in crude oil transshipment stations, refineries, and oil tank facilities.

NMVOC emissions from storage facilities include losses from breathing and acceptance for fixed-roof type tanks and shipping losses from floating-roof type storage tanks at refineries, and the NMVOC emissions from shipping facilities include shipping losses in loading crude oil or oil products to tanker, tank car, or tank lorry.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from storage and shipping of fuel in crude oil transshipment stations, refineries and oil tank facilities are estimated by multiplying the activity data of received amount of crude oil, gasoline and naphtha, by the emission factor per received amount.

$$E = (AD_1 + AD_2 + AD_3) \times EF$$

E : Fugitive NMVOC emissions at fuel storage and shipping facilities [kg-NMVOC]
AD_1 : Received amount of crude oil [kL]
AD_2 : Received amount of gasoline [kL]
AD_3 : Received amount of naphtha [kL]

EF : Emission factor per received amount of petroleum products [kg-NMVOC/kL]

The above-estimated NMVOC emissions include emissions during loading "crude oil" and "oil products (gasoline)" to tankers, which are included and reported in "Oil transport (1.B.2.a.iii)"; therefore, these emissions are subtracted from this category.

- ***Emission factors***

The emission factors are established by dividing the emission amount in fuel storage and shipping in crude oil transshipment stations, refineries, and oil tank facilities, which has been estimated in the *Study on the VOC Emission Inventory*, by the following activity data (the received amounts of crude oil, gasoline and naphtha). The emission amount provided in the *Study on the VOC Emission Inventory* are limited to FY2000 and from FY2005 onward, therefore, the emission factors for the other years are established as follows.

For FY1990-1999, no relevant information is available since no measures based on voluntary action plan on environment had been implemented during the period. Therefore, the emission factor for FY2000 is adopted for this period.

For FY2001-2003, emission factors are established by interpolating the figures in FY2000 and FY2004 under the assumption of linearly decreasing emissions factors, since member companies of Petroleum Association of Japan had been continuously implementing voluntary measures for reducing emissions.

For FY2004, emission factors are established by dividing the emissions reported in Petroleum Association of Japan's voluntary action plan by the activity data.

- ***Activity Data***

The activity data are the processed amount of crude oil, and the received amounts of gasoline and naphtha provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*. As for the crude oil, the received amount has not yet been identified, therefore the processed amount is used instead.

A3.1.1.3.g. Distribution of Oil Products (1.B.2.a.v): Fugitive Emissions From Gas Stations

a) Category Description

NMVOCs are emitted by evaporation from underground gasoline storage tanks (loss from acceptance) or by filling gasoline in cars (loss from filling gasoline).

b) Methodological Issues

- ***Estimation Method***

The NMVOC emissions by prefecture and by month in this category are estimated by multiplying the sales volume of each prefecture and month of gasoline by the emission factors per sales volume of each prefecture and month of gasoline. By such estimation by prefecture and by month, the influences of monthly temperature difference and of vapor pressure drop of gasoline for summer season to the emissions are taken into consideration.

$$E = \sum_{i,j} (AD_{i,j} \times EF_{i,j})$$

E : NMVOC emissions at gas filling stations [kg-NMVOC]
$AD_{i,j}$: Sales amount of gasoline in prefecture i in month j [kL]
$EF_{i,j}$: Emission factor per sales amount of gasoline in prefecture i in month j (loss from acceptance, loss from filling gas) [kg-NMVOC/kL]

- ***Emission factors***

1) Loss from acceptance

Emission factors are established, taking into consideration the temperature difference among prefectures and months, according to the following equation which is based on Agency for Natural Resources and Energy (1975).

The average monthly temperature in each prefectural capital provided in *Weather Statistics Information* (Japan Meteorological Agency) is used for calculation.

$$EF_{i,j} = (0.46 \times T_{i,j} + 13.92)/21$$

$EF_{i,j}$: Emission factor for loss from acceptance in prefecture i in month j [kg-NMVOC/kL]
$T_{i,j}$: Average of temperature in prefecture i in month j [°C]

As for seven prefectures (Saitama, Tokyo, Kanagawa, Fukui, Aichi, Kyoto and Osaka) where the installation of vapor recovery instrument for acceptance is required by ordinance, the emission factors for losses from acceptance are established by multiplying the emission factors calculated from the equation above by 0.15, under the assumption of the 85% emission reduction by vapor recovery instrument, since the fiscal year when the ordinances are effective, according to the *Study on the VOC Emission Inventory*.

Also, in summer season, the gasoline vapor control action is performed, therefore the emission factors from June to September are consistently multiplied by the value of 0.9, according to the *Study on the VOC Emission Inventory*.

2) Loss from filling gasoline

The NMVOC emission factors for loss from filling gasoline are established by using the formula below which is developed in the *Study on the VOC Emission Inventory* based on the domestic test results. The average temperature by prefecture and by month used for parameter setting are the same as those used for emission factors for loss from acceptance.

$$EF_{i,j} = 0.0359 \times A_{i,j} - 0.0486 \times B_{i,j} - 0.0092 \times C + 0.0149 \times D - 0.1804$$

$EF_{i,j}$: Emission factor for loss from filling gasoline in prefecture i in month j [kg-NMVOC/kL]
$A_{i,j}$: Fuel temperature in car tank in prefecture i in month j (Established as $T_{i,j} + 5$ [°C])
$B_{i,j}$: $A_{i,j} - E_{i,j}$ [°C]
C : Gasoline filling speed (Established as 35 [L/minute])
D : Reid vapor pressure (Established as 63.2 [kPa] for June to September and 86.0 [kPa] for October to May)
$T_{i,j}$: Average temperature in prefecture i in month j [°C]
$E_{i,j}$: Fuel filling temperature (fuel temperature in underground tank) in prefecture i in month j [°C]

$E_{i,j}$ is established depending on $T_{i,j}$ as follows:

$T_{i,j} < 15$: $E_{i,j} = T_{i,j} + 5$
$15 \leq T_{i,j} < 20$: $E_{i,j} = T_{i,j} + 2.5$

$20 \leq T_{i,j} < 25$: $E_{i,j} = T_{i,j}$
$25 \leq T_{i,j} < 30$: $E_{i,j} = T_{i,j} - 2.5$
$30 \leq T_{i,j}$: $E_{i,j} = T_{i,j} - 5$

- ***Activity Data***

The activity data are domestic sales volume of gasoline by prefecture and by month, which are calculated by proportionally dividing the domestic monthly gasoline sales volume, provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*, by annual gasoline sales volume by prefecture, provided in the *Oil Product Sales Summary by Prefecture* (Petroleum Association of Japan).

A3.1.1.3.h. Production of Natural Gas (1.B.2.b.ii)

a) Category Description

This section provides the estimation methods for NMVOC emissions occurring during production of natural gas in gas fields. As for the NMVOC emissions when lowering measuring instruments into wells at servicing, the estimation methods are provided in the section "Fugitive emissions during servicing of operating gas fields" (1.B.2.b.ii).

b) Methodological Issues

In order to keep consistency with the methods to estimate CH_4 and CO_2, the emissions from offshore and onshore are estimated separately.

- ***Estimation Method***

The NMVOC emissions are estimated by multiplying the amounts of natural gas production from offshore gas fields and onshore gas fields by the default emission factors for offshore and onshore gas fields given in the *2006 IPCC Guidelines*.

$$E = \sum_i (AD_i \times EF_i)$$

E : NMVOC fugitive emissions caused by natural gas production [kt-NMVOC]
AD_i : Amount of natural gas production from offshore gas fields or onshore gas fields [million m^3]
EF_i : Emission factor for natural gas production from offshore gas fields or onshore gas fields [kt-NMVOC/million m^3]

- ***Emission factors***

For NMVOC emission factors of fugitive emissions from gas production, the default values for fugitive emissions of gas production from onshore and offshore gas fields (onshore: 5.5×10^{-4}, offshore: 9.1×10^{-5} kt-NMVOC/million m^3), which are indicated in the *2006 IPCC Guidelines*, are used.

- ***Activity Data***

The production volume of natural gas from offshore gas fields is taken from the *Natural Gas Data Yearbook*. The production volume of natural gas from onshore gas fields is estimated by subtracting the production volume of natural gas from offshore gas fields above from the total production volume of natural gas in Japan given in the *Yearbook of Production, Supply and*

Demand of Petroleum, Coal and Coke, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

A3.1.1.3.i. Fugitive Emissions During Servicing of Operating Gas Fields (1.B.2.b.ii)

a) Category Description

This section provides the estimation methods for the NMVOC emissions which occur when lowering measuring instruments into operating wells at servicing.

b) Methodological Issues

For the fugitive emissions relating to well servicing, the estimation method of using the crude oil production amount as activity data is indicated in the *2006 IPCC Guidelines*, however, the correlation between the crude oil production amount and the emissions relating to natural gas well servicing is not clear. Therefore, the number of operation wells is used for the activity data for CO_2, CH_4 and N_2O emission estimation based on IPCC, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* 2000 (hereafter, *GPG2000*). However as for NMVOCs, the emission factor based on the number of operating wells is not indicated in the *GPG2000*, thus the estimation method of using the crude oil production amount is adopted based on the *2006 IPCC Guidelines*.

- ***Estimation Method***

Emission amount of NMVOCs in this category is estimated by multiplying the amount of domestic production of crude oil by the default emission factor for NMVOC.

$$E = AD \times EF$$

E : NMVOC emissions during well servicing [kt-NMVOC]
AD : Amount of domestic crude oil production [1000 kL]
EF : Emission factor per crude oil production [kt-NMVOC/1000 kL]

- ***Emission factors***

For NMVOC emission factor for flaring and venting during well servicing, the default value per crude oil production amount (1.7×10^{-5} kt-NMVOC/1000 kL), which is indicated in the *2006 IPCC Guidelines*, is used. In CO_2, CH_4 and N_2O emission estimation, the emissions from other than flaring and venting are also estimated for well servicing, however the emission factor, which is available for NMVOC emission estimation for well servicing, is only the default value for flaring and venting during well servicing shown in the *2006 IPCC Guidelines*, thus such emission factor is used.

- ***Activity Data***

The activity data for this category are the production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

A3.1.1.3.j. Processing of Natural Gas (1.B.2.b.iii)

a) Category Description

In the distribution process to the sellers of mined natural gas, NMVOCs originated from natural gas treatment are emitted by vapor from removal device of fluid or impurities (e.g., carbon dioxide gas) contained in natural gas, or, by being released into the air in construction of pipeline relocation.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions by processing of natural gas are estimated by multiplying the domestic production volume of natural gas by the NMVOC emission factors per production volume.

$$E = AD \times EF$$

E : NMVOC emission amount by processing of natural gas [t-NMVOC]
AD : Production volume of natural gas [million m^3]
EF : Emission factor per production volume of natural gas [t-NMVOC/million m^3]

- ***Emission factors***

Emission factors are established by dividing the emissions related to natural gas, which has been estimated in the *Study on the VOC Emission Inventory* by MOE (based on the reported figures of voluntary action plan by Japan Natural Gas Association), by the later-indicated activity data (domestic production volume of natural gas). Emission factors in and before FY2004 are established by dividing the emissions provided by Japan Natural Gas Association by the activity data, since the emission amounts in the *Study on the VOC Emission Inventory* are limited only to FY2000 and from FY2005 onward (same as shown in “Oil transport (1B.2.a.iii)”).

- ***Activity data***

The activity data for this category are domestic production volume of natural gas provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

- ***Completeness***

The emissions from this source include the emissions from “transmission and storage of natural gas (1.B.2.b.iv)” and “venting (gas) (1.B.2.c.Venting.ii)”.

A3.1.1.3.k. Natural Gas Distribution (1.B.2.b.v): City Gas Production

a) Category Description

NMVOCs are emitted by fugitive emissions from naphtha tanks in the process of city gas production. In Japan, no emission activity in this category has been made since FY2006, because naphtha has not been used for city gas production due to the completion of shifting raw materials of city gas from low calorific gas made of naphtha to high calorific gas made of LNG in FY2005.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from naphtha tank in city gas production are estimated by multiplying the consumption amount of gasoline used as raw material for city gas production by the NMVOC emission factor per consumption amount. The emissions in this category from FY2006 onward are reported as "NO" since no emission activity has been made during this period.

$$E = AD \times EF$$

E : NMVOC emission amount in city gas production [t-NMVOC]
AD : Consumption amount of gasoline used as raw material for city gas production [kL]
EF : NMVOC emission factor per consumption amount [t-NMVOC/kL]

- ***Emission factors***

Emission factors for city gas production are established by dividing the emission amount from "gas production facilities" (estimated based on *Report on Voluntary Action Plan* by the Japan Gas Association) provided in the *Study on the VOC Emission Inventory*, by the activity data (the consumption amount of crude gasoline for city gas production).

Since the emitted amount provided by the *Study on the VOC Emission Inventory* is limited to FY2000 and FY2005 onward, the emission factors for the other years are established as follows. For FY1990-1999, the emission factor for FY2000 is used. For FY2001-2003, emission factors are established by interpolation, using the emission factors for FY2000 and FY2004. For FY2004, the emission factor is established by dividing the emission amount in FY2004 provided in the *Voluntary Action Plan* by the activity data.

- ***Activity data***

The activity data for this category are the consumption amount of gasoline used as raw material for city gas production provided in the *Current Survey of Production Concerning Gas Industry* (Agency for Natural Resources and Energy).

A3.1.1.3.l. Venting (Oil) (1.B.2.c.Venting.i)

a) Category Description

This category provides the estimation method for NMVOC emissions from venting in the petroleum industry.

b) Methodological Issues

- ***Estimation Method***

The emissions are estimated by multiplying the amount of domestic production of crude oil by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

E : NMVOC emissions from venting in oil production [kt-NMVOC]
AD : Amount of domestic crude oil production [1000 kL]
EF : Emission factor per crude oil production [kt-NMVOC/1000 kL]

- ***Emission factors***

For the emission factor, the NMVOC default emission factor for venting in oil production (4.3×10^{-4} kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for this category are the production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke,* the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

A3.1.1.3.m. Flaring (Oil) (1.B.2.c.Flaring.i)

a) Category Description

This category provides the estimation method for NMVOC emissions from flaring in the petroleum industry.

b) Methodological Issues

- ***Estimation Method***

The emissions are estimated by multiplying the amount of domestic production of crude oil by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

E : NMVOC emissions from flaring in oil production [kt-NMVOC]
AD : Amount of domestic crude oil production [1000 kL]
EF : Emission factor per crude oil production [kt-NMVOC/1000 kL]

- ***Emission factors***

For the emission factor, the NMVOC default emission factor for flaring in oil production (2.1×10^{-5} kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for this category are the production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

A3.1.1.3.n. Flaring (Gas) (1.B.2.c.Flaring.ii)

a) Category Description

This category provides the estimation method for NMVOC emissions from flaring in the natural gas industry.

b) Methodological Issues

- ***Estimation Method***

The emissions are estimated by multiplying the amount of domestic production of natural gas by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

E : NMVOC emissions from flaring in gas production [kt-NMVOC]
AD : Amount of domestic natural gas [1000 m^3]
EF : Emission factor per natural gas production [kt-NMVOC/1000 m^3]

- ***Emission factors***

For the emission factor, the NMVOC default emission factor for flaring in gas production (6.2×10^{-7} kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for this category are the production amount of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

A3.1.1.3.o. Flaring (Combined) (1.B.2.c.Flaring.iii)

a) Category Description

In Japan, the statistical data are reported for two categories of oil and natural gas. Therefore, the fugitive emissions whose categories can be distinguished are reported in Flaring (Oil) (1.B.2.c.Flaring.i) or in Flaring (Gas) (1.B.2.c.Flaring.ii) respectively. In this category, CO_2, CH_4 and N_2O emissions arising from exploration and test before production of oil and natural gas, which are unable to be distinguished by their categories of oil industry or natural gas industry, are reported.

b) Methodological Issues

For the fugitive emissions arising from exploration and test before production of oil and natural gas, the default emission factors, which are established using the crude oil production as activity data, are indicated in the *2006 IPCC Guidelines*. However, in case of CO_2, CH_4, and N_2O emission estimation, the correlation between the emissions which accompany exploration and testing of natural gas fields, and the crude oil production amount, and the correlation between the emissions from exploration and testing and the production amount from commercial plants are not clear, thus the number of drilled and tested wells is used for the activity data based on *GPG2000* similar to the emissions from well servicing. Especially, as for the emissions from the exploration of wells, the number of wells is extremely small compared to the number of operating wells in Japan, thus there is a possibility of overestimation if the crude oil production amount is adopted as activity data. However, as for NMVOCs, the emission factor based on the number of operating wells is not indicated in the *GPG2000*, thus the estimation method of using the crude oil production amount is adopted based on the *2006 IPCC Guidelines*. Also, as for NMVOC emissions from flaring in well drilling and well testing, the default values are not prepared for oil industry and gas industry separately but the total of both values is indicated in the *2006 IPCC Guidelines*, thus the emissions are estimated together and reported in this category.

- ***Estimation Method***

The emissions are estimated by multiplying the amount of domestic production of crude oil by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

E : NMVOC emissions from flaring and venting in well drilling and well testing [kt-NMVOC]
AD : Amount of domestic crude oil [1000 kL]
EF : Emission factor per crude oil production [kt-NMVOC/1000 kL]

- ***Emission factors***

For the emission factor, the sum of NMVOC default emission factors for flaring and venting in well drilling and well testing (well drilling: 8.7×10^{-7}, well testing: 1.2×10^{-5} kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for this category are the production amount of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

A3.1.2 Industrial Processes and Product Use (IPPU)

A3.1.2.1. Mineral Industry, Chemical Industry, Metal Production, and Other Production (2.A., 2.B., 2.C., 2.D.: NO_X, SO_X)

a) Category Description

This section provides the estimation methods for emissions of precursors and other substances (NO_X and SO_X) from the process of producing mineral products, chemical products, metal production and other production.

b) Methodological Issues

- ***Estimation Method***

NO_X and SO_X emissions from the specified sources, not included in the following facilities or industry sectors, were estimated by isolating the emissions of the IPPU sector from the data in the *General Survey of the Emissions of Air Pollutants* (MOE).

Facility: [0101– 0103: Boilers]; [0601– 0618: Metal rolling furnaces, metal furnaces, and metal forge furnaces]; [1101–1106: Drying ovens]; [1301–1304: Waste incinerators]; [2901–3202: Gas turbines, diesel engines, gas engines, and gasoline engines]

Industry sector: [A–D: Accommodation/eating establishments, health care/educational and academic institutions, public bathhouses, laundry services]; [F–L: Agriculture/fisheries, mining, construction, electricity, gas, heat distribution, building heating/other operations]

➢ ***NO_X***

For raw material falling under either [44: Metallurgical coal] or [45: Metallurgical coke], the following equation is used:

$$E=\Sigma\{EF_{NO_X} \times A \times (1\text{-}R)\}$$

E	: NO_X emissions from metallurgical coal or metallurgical coke [t-NO_X]
EF_{NOx}	: NO_X emission factor by material [t- NO_X /kcal]
A	: Energy consumed by material [kcal]
R	: Nitrogen removal rate [%]

For raw material falling under either [41: Iron/ironstone] or [46: Other], the following equation is used:

$$E=\Sigma\{N \times (1\text{-}R)\}$$

E	: NO_X emissions from iron/iron ore or other material [t-NO_X]
N	: Nitrogen content in each material [t-NO_X]
R	: Nitrogen removal rate [%]

However, when the emissions from the IPPU sector calculated by the above equations exceed the emission amount listed in the *General Survey of the Emissions of Air Pollutants*, the total emissions listed in the Survey are considered to be the emissions from the IPPU sector. Materials listed in the categories [42: Sulfide minerals] and [43: Non-ferrous metal ores] are excluded from the calculation due to the lack of data.

➢ ***SO_X***

Emissions from the IPPU sector is calculated from the consumption and sulfur content of the materials in categories [41: Iron/ironstone] to [46: Other materials]. Energy sector emissions are estimated by subtracting IPPU sector emissions from the emissions listed in the *General Survey of the Emissions of Air Pollutants* to determine SO_X emissions.

$$E=\Sigma\{S \times (1-R)\}$$

E	: SO_X emissions [t-SO_X]
S	: Sulfur content in each material [t-SO_X]
R	: Desulfurization rate [%]

● ***Emission factors***

➢ ***NO_X emission factors for metallurgical coal and coke***

NO_X emission factors for the materials used in calculation of NO_X emissions from metallurgical coal and coke (in the IPPU sector) were established for each facility and material type based on the *General Survey of the Emissions of Air Pollutants*.

➢ ***Nitrogen removal rate***

The nitrogen removal rate was calculated by the following equation:

$$R = RE \times (O_{removal} / O_{furnace}) \times (P / E)$$

R	: Nitrogen removal rate [%]
RE	: Nitrogen removal efficiency
$O_{removal}$	: Hours of operation of nitrogen removal unit [h/yr]
$O_{furnace}$	: Hours of operation of furnace [h/yr]
P	: Processing capacity of nitrogen removal unit [m^3/yr]
E	: Maximum exhaust gas emissions [m^3/yr]

$$RE = (V_{before} - V_{after}) / V_{SS}$$

RE	: Nitrogen removal efficiency
V_{before}	: NO_X volume before treatment
V_{after}	: NO_X volume after treatment
V_{SS}	: Volume of smoke and soot

The *General Survey of the Emissions of Air Pollutants* data was used for all items.

➢ ***Desulfurization rate***

The desulfurization rate was calculated by the following equation:

$$R = DE \times (O_{removal} / O_{furnace}) \times (P / E)$$

R	: Desulfurization rate [%]
DE	: Desulfurization efficiency
$O_{removal}$	: Hours of operation of desulfurization unit [h/yr]
$O_{furnace}$	: Hours of operation of furnace [h/yr]
P	: Processing capacity of desulfurization unit [m^3/yr]
E	: Maximum exhaust gas emissions [m^3/yr]

$$DE = (V_{before} - V_{after}) / V_{SS}$$

DE	: Desulfurization efficiency
V_{before}	: SO_X volume before treatment
V_{after}	: SO_X volume after treatment
V_{SS}	: Volume of smoke and soot

The *General Survey of the Emissions of Air Pollutants* data were used for all items.

● ***Activity data***

➢ ***Energy consumption of metallurgical coal or coke***

The activity data was calculated by multiplying the consumption of materials (under [44: Metallurgical coal] and [45: Metallurgical coke]) provided in the *General Survey of the Emissions of Air Pollutants* by the gross calorific value.

➢ ***Nitrogen content of iron/ironstone and other materials***

The activity data was calculated by multiplying the weighted average of nitrogen content, calculated from the nitrogen content and consumption of the materials (under [41: Iron/ironstone] and [46: Other raw materials]) provided in the *General Survey of the Emissions of Air Pollutants*, by the consumption amount of the materials.

➢ ***Sulfur content of various materials***

The activity data was calculated by multiplying the weighted average of sulfur content, calculated on the basis of sulfur content and consumption of the materials (under [41: Iron/ironstone] through [46: Other materials]) provided in the *General Survey of the Emissions of Air Pollutants*, by the consumption amount of the materials.

A3.1.2.2. Non-energy Products From Fuels and Solvent Use (2.D.3.) (NMVOCs)

A3.1.2.2.a. Use of Paint

a) Category Description

NMVOCs are emitted from paint containing solvent and diluent, in the process of using paint including painting industrial products or buildings[5].

b) Methodological Issues

- ***Estimation Method***

Emissions were estimated by multiplying the sales amount of paint by the emission factors per sales amount of paint.

$$E = AD \times EF$$

E	: NMVOC emissions from use of paint [1000t -NMVOC]
AD	: Sales amount of paint [1000t]
EF	: Emission factors per sales amount of paint [t-NMVOC/t]

- ***Emission factors***

The annual survey on VOC emissions from use of paint by Japan Paint Manufacturers Association has been conducted since FY2000 (excluding FY2002). The NMVOC emissions per sales amount of paint which was calculated by dividing the emissions provided in the survey by the sales amount of paints are used for emission factor for use of paint. For FY2002, the emission factor was established by interpolating between the FY2001 and FY2003 emission factors that were each established by dividing emissions by activity data.

Due to the lack of quantified data for establishing emission factors for FY1999 and before, emission factors for these periods were established by extrapolation based on the trend during FY2000-FY2010. A decreasing trend was obvious during FY2000-FY2010, and FY2010 was the target year of voluntary action plan based on the Air Pollution Control Act; it was assumed, similarly, that during FY1990-1999 emissions might have decreased because of a possible shift to aqueous paint and installation of VOC processing instruments.

- ***Activity Data***

The sales amount of paint provided in the *Yearbook of Current Production Statistics - chemical industry* (METI) (hereafter, *Yearbook of chemical industry*) was used for activity data.

A3.1.2.2.b. Dry-Cleaning

a) Category Description

NMVOCs are emitted from dry-cleaning laundry equipment by using solvent for dry cleaning of clothes.

[5] The emissions in the process of manufacturing were estimated in “A3.1.2.2.n Chemicals Manufacture”

b) Methodological Issues

NMVOC emissions from dry-cleaning were estimated by deducting "weight as waste" (including residual weights in cartridge and distilling sludge) from "used weight of dry cleaning solvent"

$$E = AD - A - B$$

E : NMVOC emissions from use of dry-cleaning solvent [t -NMVOC]
AD : Used weight of dry-cleaning solvent (Industrial gasoline No.5, Tetrachloroethylene) [t]
A : Absorbed residual solvent in cartridge filter to be disposed as waste (Transferred weight of absorption solution during the changing of cartridge filters) [t]
B : Residual solvent containing distilling sludge to be disposed as waste (Transferred weight of residual solvents during the distilling of sludge) [t]

- ***Emission factors***

No emission factor was established, as all the solvents used in dry cleaning were assumed to be discharged into the atmosphere.

- ***Activity data***

1) Used weight of dry-cleaning solvent

Estimated according to the below tables, based on data in the *Study on the VOC Emission Inventory*.

Table A 3-16 Method of estimating activity data for dry-cleaning solvent (Industrial gasoline No.5)

Fiscal year (FY)	Method of estimating activity data
1990, 1991	Estimated by multiplying the used weight of industrial gasoline No.5 in FY1992 by the installation ratio of laundry machines which use petroleum dissolution in FY1992, provided in *The survey on usage of dry-cleaning solvent* (Ministry of Health, Labour and Welfare (hereafter, MHLW))
1992-1999	Estimated by multiplying the shipping weight of petroleum dry-cleaning solvent in FY2000, provided in *Shipping weight of solvents* by Japan Cleaning Chemicals Association, by the used weight of industrial gasoline no.5 in FY2000
2000, 2005-	Used the result of the survey on the shipping weight of dry-cleaning solvent by petroleum solvent manufacturer, indicated in the *Study on the VOC Emission Inventory*.
2001-2004	Estimated by interpolating the values in FY2000 and FY2005.

Table A 3-17 Method of estimating activity data for dry-cleaning solvent (Tetrachloroethylene)

Fiscal year (FY)	Method of estimating activity data
1990, 1991	Estimated by multiplying the total consumption weight of the solvent in FY1990 and FY1991 by the percentage for dry-cleaning in FY1992 which was calculated based on *Demand by end-use* by Japan Association for Hygiene of Chlorinated Solvents (hereafter, JAHCS), since the data for FY1990 and 1991 was not available.
1992, 1995-	Used weight of tetrachloroethylene provided in *Demand by end-use* by JAHCS was used for activity data.
1993, 1994	Estimated by interpolating the value provided in *Demand by end-use* by JAHCS for FY1992 and FY1995.

2) Weight transferred as waste

The weight of waste transfer (including residual weights in cartridge and distilling sludge) was estimated using the equations in Table A 3-18, in accordance with the method of the *Study on the VOC Emission Inventory*; the weight was deducted from the used weight of dry-cleaning solvent. Values used for the *Study on the VOC Emission Inventory* based on hearings and other surveys were used as parameters for estimation.

As for installed units of dry-cleaning laundry, values provided in the *Survey on usage and management of solvent for dry-cleaning* (MHLW) were used. However, the survey has been conducted biennially after FY2001; therefore, the same values as those in the previous fiscal year were used for years in which the survey was not conducted.

Table A 3-18 Method of estimation for weight of waste transfer in dry-cleaning solvent

Type of waste	Method of estimation for weight of waste transfer in dry-cleaning solvent
Transfer weight of absorbed solvent in changing cartridge filter	Since 2L solvent per 1kg of laundry is absorbed in changing cartridge on average, the estimated annual weight is calculated according to the following formula. $A = A_{unit} \times L \times D \times W_{ave.} / T \times N$ A : Absorbed weight in cartridge [kg/year] A_{unit} : Absorbed VOC weight [L/time/kg] in each changing of cartridge per 1kg of loading weight by washer L : Standard load of washer per washing [kg] D : Density [kg/L] $W_{ave.}$: Annual average of operating washer [time/year] T : Average washer times per changing cartridge filter [time/time] N : Number of laundry units installed [unit]
Transfer weight of residual solvent in distilling sludge	Transferred weight of solvent in distilling was estimated according to the following formula. $R = L \times T \times F \times N \times I$ R : Contained residual solvent in distilling sludge [kg/year] L : Standard load of washer [kg/unit] T : Annual average of operating times of washer [time/year] F : Factors by type of filter [kg/kg] N : Unit of installation of laundry [unit] I : Installation rate of distilling [%]

Reference: *Study on the VOC Emission Inventory*

A3.1.2.2.c. Metallic Cleaning

a) Category Description

NMVOCs are emitted from cleaning of metallic components by industrial cleaners in the process of manufacturing electrical/electronic products or metallic components.

b) Methodological Issues

- ***Estimation Method***

1) Chlorine Cleaners

NMVOC emissions from the use of chlorine cleaners were estimated by multiplying the used amount of chlorine cleaners by the emission rate. Since some chlorine cleaners are recycled, the emissions were adjusted for the recycling.

$$E = AD \times R \times EF$$

E : NMVOC emissions from the use of chlorine cleaners [1000t -NMVOC]
AD : Sales amount of chlorine cleaners [1000t]
R : Adjustment rate for recycling (x 1.1)[6]
EF : Atmospheric emission rate by use of chlorine cleaners [%]

2) Non-chlorine cleaners

NMVOC emissions from the use of non-chlorine cleaners (semi-aquatic, hydrocarbon system, alcohol system, fluorinated, and other types of cleaners) were estimated by multiplying the used weight of cleaners by the atmospheric emission rate.

$$E = AD \times EF$$

E : NMVOC emissions from the use of each non-chlorine cleaner [1000t -NMVOC]
AD : Used weight of each non-chlorine cleaner [1000t]
EF : Atmospheric emission rate from the use of each non-chlorine cleaner [%]

- ***Emission factors***

Emission factors provided in the *Study on the VOC Emission Inventory*, as shown in Table A 3-19, were used for chlorine cleaners and non-chlorine cleaners.

Table A 3-19 NMVOC emission factors for use of each type of cleaner

Type of cleaner	Atmospheric emission rate	Reference
Chlorine cleaner	75%	*Commission report on manual for promoting voluntary approach for emission control of VOCs in FY2005* (Japan Industrial Conference on Cleaning (hereafter, JICC))
Semi-aquatic cleaner	0.4%	The result of the survey by JICC
Hydrocarbon system cleaner	31.3%	
Alcohol system cleaner	60% (45% for FY2010 and thereafter)	
Fluorinated cleaner	84%	
Other types of cleaners	75%	

- ***Activity Data***

1) Chlorine cleaners

Activity data for chlorine cleaner was established as shown in the following Table A3-19 which was based on the *Study on the VOC Emission Inventory* by the Ministry of the Environment and data provided by JAHCS. According to the *Study on the VOC Emission Inventory*, about 10% of the sales amount of chlorine cleaners are recycled and resupplied; therefore, this was taking into consideration, by multiplying the estimates of the amount of cleaners used by 110%, to adjust for recycling and to use as activity data.

[6] The research by the Japan Industrial Conference on Cleaning at Japan Solvent Recycling Industry Association found that approximately 10 % of the sales amount of chlorine cleaners were recycled and resupplied by recycling companies. (*Studies to develop the national emissions inventory for volatile organic compounds (VOC), FY 2011*, Ministry of the Environment)

Table A 3-20 Activity data for the use of chlorine cleaners (dichloromethane, trichloroethylene, tetrachloroethylene)

Fiscal Year (FY)	Activity data
1990-1994	Estimated by multiplying the total consumption amount in each fiscal year by the proportion of metallic cleaners in FY1995 (calculated based on the *Demand by use* (JAHCS), (hereafter *Demand by use*)) since data was not available for FY1990-1994.
1995-	The sales amount of dichloromethane, trichloroethylene, and tetrachloroethylene for metallic cleaning provided in the *Demand by use* was adopted for activity data.

Table A 3-21 Activity data for the use of chlorine cleaners (other types of chlorine cleaner)

Fiscal Year (FY)	Activity data
1990-1999	Estimated by multiplying the total consumption amount for three major chlorine cleaners (*Demand by use*) for 2000 by the ratio in FY1990-1999 to the activity data in FY2000.
2000, 2005-	The sales amount provided in the *Study on the VOC Emission Inventory* was used for activity data. (the results of research by JICC).
2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005.

2) Non-chlorine cleaner

Activity data for non-chlorine cleaners was established as shown in Table A 3-22 based on the information provided in the *Study on the VOC Emission Inventory*.

Table A 3-22 Activity data for non-chlorine cleaner

Fiscal year (FY)	Activity data
FY1990-1999	Total amount of raw materials by type of cleaner was estimated by multiplying the proportion for each type of manufacturer provided in the *Study on the VOC Emission Inventory* (Table A 3-23) by the corresponding used weight of raw material; then, the activity data (the used weight) for each year was estimated by multiplying the estimated total weight by the ratio from FY2000.
FY2000	Used weight of each type of cleaner in the *Study on the VOC Emission Inventory* was adopted for activity data.
FY2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005.
FY2005-	Used weight of each type of cleaner in the *Study on the VOC Emission Inventory* was adopted for activity data. As for values in the *Study on the VOC Emission Inventory*, the results of a sampling survey were used after an adjustment. The survey has not been conducting every year. Therefore, for years when the survey was not conducted, data has been supplemented by using the interpolation method.

Table A 3-23 Proportion by type of manufacturer in VOC emissions from non-chlorine cleaner

Manufacture	n-Methyl-pyrrolidone admixture	Glycol ether admixture	n-Paraffin cleaner	Isoparaffin cleaner	Naphthene cleaner	Other carbon hydride cleaner	Isopropyl alcohol cleaner	Other alcohol cleaner	HFC cleaner	Other fluorine cleaner	Bromine cleaner	Other cleaner
Plastic Products			3%	6%	4%			12%				
Iron and Steel			3%	0.1%	5%				1%	2%		
Non-Ferrous Metals and Products			16%	0.05%	7%				1%	2%		
Fabricated Metal Products		2%	17%	30%	26%	8%					4%	
Machinery			11%	8%	15%	11%			1%	2%		
Communications		19%					1%					
Electric device	70%	49%	17%	15%	7%	13%	25%	28%	28%	38%	30%	33%
Transport		2%	16%	26%	36%	10%		12%	7%	19%	18%	67%
Precision apparatus	30%	18%	17%	15%		18%	74%	46%	61%	37%	48%	
Other		10%	0.1%		1%	41%		3%				
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Reference: The *Study on the VOC Emission Inventory*

A3.1.2.2.d. Use of Thinner for Cleaning Manufacturing Equipment

a) Category Description

NMVOCs are emitted from the use of thinner for cleaning manufacturing equipment.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from the use of thinner for cleaning manufacturing equipment were estimated by multiplying the sales volume of thinner excluding that for painting by the emission factor for NMVOC per sales volume.

$$E = AD \times EF$$

E : NMVOC emissions from the use of cleaning thinner [t-NMVOC]
AD : The sales volume of thinner excluding that for painting [kL]
EF : Emission factor per sales volume of cleaning thinner [t-NMVOC/kL]

- ***Emission factors***

Emission factor was established by using the emissions from “thinner for cleaning manufacturing equipment” provided in the *Study on the VOC Emission Inventory* and later-described activity data.

Although the emission factor has a slightly decreasing trend after FY2000, the emission factor for FY2000 is applied for fiscal years FY1990 to FY1999, since there are no quantitative data for estimating emission factors in the related organization and that difficulties have been faced for implementation of technical measures for reduction of emissions from thinner cleaning (Table A3-24).

Table A 3-24 The Method of establishing emission factors of cleaning thinner for manufacturing equipment

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied for all fiscal years.
2000, 2005-	Estimated by dividing the emissions for each fiscal year provided in the *Study on the VOC Emission Inventory* by the activity data for each fiscal year.
2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005.

- ***Activity data***

Established based on the sales amount of thinner, etc. in the *Yearbook of chemical industry* as shown in the below table.

Table A 3-25 Method of estimating activity data for the use of cleaning thinner for manufacturing equipment

Fiscal Year (FY)	Activity data
1990-2004	Since data on the consumption amount of diluent thinner in and before FY2004 was unidentified, the consumption amount of diluent thinner for this period, which was estimated by multiplying the proportion of the amount of diluent thinner to the sales volume of thinner in FY2005 by the sales volume of thinner in and before FY2004, and, deducting the amount from the total sales volume of thinner, was adopted for activity data.
2005-	Estimated by deducting the consumption amount of diluent thinner for painting provided in *Summary of estimation for the current status of VOC emissions from painting* (Japan Paint Manufacturers Association) from the sales amount of thinner given in the *Yearbook of chemical industry*, where the whole time series data from FY1990 were available.

A3.1.2.2.e. Use of Printing Ink Solvents

a) Category Description

VOCs are emitted from printing ink solvent or other types of diluent in the process of printing. Ink included in stationaries, solvent for cleaning of printing machine (estimated as “A3.1.2.2.d thinner for cleaning manufacturing equipment”), and emissions at the stage of production of printing ink (estimated as “A3.1.2.2.n Chemicals Manufacture”) were excluded from emissions in this category.

b) Methodological Issues

- ***Estimation Method***

VOC emissions were estimated by multiplying the used weight of VOCs in the process of printing, which was provided in the *Study on the VOC Emission Inventory*, by the atmospheric emission rate.

$$E = AD \times EF$$

E : NMVOC emissions from the use of printing ink solvents [t-NMVOC]
AD : Used weight of VOCs in the process of printing [t]
EF : Atmospheric emission rate per used weight of VOCs [%]

- ***Emission factors***

Atmospheric emission rate by type of ink, provided in the *Study on the VOC Emission Inventory* was adopted for emission factor. As for printing ink other than planographic and photogravure ink, the same atmospheric emission rate was adopted for the emission factor for FY2000 and thereafter; in a similar way, the atmospheric emission rate in FY2000 was adopted for and before

FY1999.

As for emissions from planographic ink and photogravure ink, the atmospheric emission rate for FY1990-1999 was estimated by extrapolation, using the trend in FY2000-2010: the decreasing trend after FY2000 suggested that some measures aimed at reducing emissions might have been implemented during this period. (Table A 3-26) However, as for photogravure ink, the emission factor was established by interpolating between of the FY1983 value from the *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (Institute of Behavioral Science, 1984) and the FY2000 value, since the atmospheric emission rate in FY1990 would surpass 100% by a simple extrapolating calculation.

Table A 3-26 The method of establishing emission factor for the use of printing ink solvent (Planographic ink, photogravure ink)

Fiscal Year (FY)	The method of establishing of emission factor	
	Planographic ink	Photogravure ink
1990-1999	Estimated by extrapolation, using the trend in FY2000-2010.	Interpolated between the 1983 value from the *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (Institute of Behavioral Science, 1984) and the 2000 value.
2000	Established based on the *Study on the VOC Emission Inventory* in FY2000.	
2001-2004	Established by interpolating the figures in FY2000 and FY2005.	
2005-	Emission factors in each fiscal year provided in the *Study on the VOC Emission Inventory*.	

Note: The same emission factor was applied for resin anastatic ink, metallic printing ink, news ink, and other inks for all time-series.

- ***Activity data***

The used amount of VOCs, provided in the *Study on the VOC Emission Inventory* (estimated based on the results of the survey by Japan Printing Ink Makers Association and voluntary action plan of Japan Federation of Printing Industries) was used for activity data and was estimated as shown in Table A 3-27.

Table A 3-27 Method of estimating activity data

Fiscal Year (FY)	Activity data
1990-1999	Estimated by multiplying the ratio of sales amount of print ink for each product type in each year to that in FY2000, provided in the *Yearbook of Chemical Industry*, by the activity data of FY2000.
2000, 2005-	Used amount of VOCs in the process of printing, provided in the *Study on the VOC Emission Inventory*, was used.
2001-2004	Estimated by interpolating the activity data of FY2000 and 2005.

A3.1.2.2.f. Use of Adhesive Agent for Laminate

a) Category Description

VOC are emitted from lamination, caused by solvent contained in adhesive agents for bonding base material and laminate. VOC emissions from producing adhesive agents for laminate are estimated in “A3.1.2.2.n Chemicals Manufacture”.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from polyethylene laminate were estimated by multiplying the sales amount of film for laminate, which was adopted for activity data, by the NMVOC emission factor per sales amount of film for laminate.

$$E = AD \times EF$$

E : NMVOC emissions from lamination [t-NMVOC]
AD : Sales amount of film for laminate [t]
EF : Emission factor per sales amount of film for laminate [t-NMVOC/t]

- ***Emission factors***

Emission factor was established by dividing VOC emissions, which was estimated based on reported values in voluntary action plan in the *Study on the VOC emission inventory*, by the sales amount of film for laminating for FY2000, and FY2005 and thereafter. For fiscal years which were not subject to the voluntary action plan, emission factor in FY2000 was adopted for FY1990-1999. The emission factor for FY2001-2004 was established by interpolating between the emission factors for FY2000 and FY2005.

- ***Activity data***

The sales amount of film for laminate provided in the *Yearbook of Current Production Statistics - paper, printing, plastics products and rubber products* (METI), (hereafter, *Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics*) was used for activity data.

A3.1.2.2.g. Use of Solvent-Type Adhesives

a) Category Description

VOCs are emitted from the use of solvent-type adhesive.

b) Methodological issues

- ***Estimation Method***

As for VOC emissions from the use of solvent-type adhesive, the atmospheric emission rate was regarded as 100%; the total amount was used for estimating emissions.

$$E = AD$$

E : NMVOC emissions from the use of adhesive [t-NMVOC]
AD : The used amount of VOCs from the use of adhesive [t]

- ***Emission factors***

No emission factors were established since it was assumed that the total amount of the solvent used for adhesive were emitted into the air.

- ***Activity Data***

Activity data was estimated as shown in the following table, and based on the *Study on the VOC Emission Inventory* and the *Current Survey Report on Adhesives* (Japan Adhesive Industry Association).

Table A 3-28 Method of establishing activity data for the use of adhesive

Fiscal year (FY)	Activity data
1990-1999	Estimated by multiplying the used amount of VOCs in FY2000 by the ratio of the total of shipping weight of each type of adhesive in each year to the 2000 level.
2000, 2005-	Used amount of VOC emissions provided in the *Study on the VOC Emission Inventory* (estimated by the Committee for the VOC Emission Inventory).
2001-2004	Estimated by interpolation, using activity data for FY2000 and FY2005.

A3.1.2.2.h. Use of Gum Solvents

a) Category Description

VOCs are emitted from gum solvent in the manufacturing of gum products.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from gum solvents for gum production were estimated by multiplying the consumption of volatile oil for solvent use for gum production by the NMVOC emission factor per consumption of volatile oil for solvent use, which was estimated based on the *Study on the VOC Emission Inventory*.

$$E = AD \times EF$$

E : NMVOC emissions from gum production [t-NMVOC]
AD : Consumption of volatile oil for solvent use for gum production [t]
EF : Emission factor per consumption of volatile oil for solvent use [t-NMVOC/t]

- ***Emission Factors***

VOC emissions per consumption of volatile oil for solvent use, which was calculated by dividing emissions based on reported values in the voluntary action plan by the Japan Rubber Manufacturers Association in the *Study on the VOC Emission inventory*, by the consumption of volatile oil for solvent use, were adopted as emission factors for gum production for FY2000, and FY2005 and thereafter. For fiscal years which were not subject to the voluntary action plan, emission factor in FY2000 was applied for FY1990-1999 and the median value of FY2000 and FY2005 was applied for FY2001-2004.

- ***Activity data***

Consumption of volatile oil for solvent use, which was obtained from the *Yearbook of Rubber Products Statistics* by the Ministry of Economy, Trade and Industry and the survey results by the Japan Rubber Manufacturers Association, was applied for activity data. The consumption was converted from volume to mass using the solvent density. As for FY2006-2010, the activity data was adjusted using interpolation since the business entities surveyed for this period was possibly different from before/after this period.

A3.1.2.2.i. Use of Adhesive Solvents and Detachment Solvents

a) Category Description

NMVOCs are emitted from the use of adhesive solvent and detachment solvent in manufacturing adhesive tape or adhesive label. This source category does not deal with the NMVOC emissions in manufacturing adhesive solvent and detachment solvent since the emissions are included in “A3.1.2.2.n Chemicals Manufacture”.

b) Methodological Issues

- ***Estimation Method***

The shipping amount of adhesive tape was used for activity data. NMVOC emissions from the use of adhesive solvent and detachment solvent were estimated by multiplying the activity data by the emission factor per shipping amount.

$$E = AD \times EF$$

E : NMVOC emissions from the use of adhesive and detachment solvent [t-NMVOC]
AD : Shipping amount of adhesive tape [million m^2]
EF : Emission factor per shipping amount of adhesive tape [t-NMVOC/million m^2]

- ***Emission factors***

Emission factors for FY2000, and FY2005 and thereafter per adhesive for use of solvent and detachment solvent were established by dividing emissions, which were based on the reported values in voluntary action plan by four business associations including Japan Paper Association, by the shipping amount of adhesive tape. For fiscal years which were not subject to the voluntary action plan, emission factor in FY2000 was applied for FY1990-1999 and emission factors in FY2001-2004 were established by interpolating between the FY2000 and FY2005 EFs.

- ***Activity data***

The shipping amount provided by Japan Adhesive Tape Manufacturers Association was adopted for activity data.

A3.1.2.2.j. Use of Repellents and Air Fresheners

a) Category Description

NMVOCs are emitted from the sublimation of chemical agents during the use of repellents or air fresheners such as at home. The major substance in the emissions is p-dichlorobenzene.

b) Methodological Issues

- ***Estimation Method***

Repellents and air fresheners are mainly used in general households, and therefore it is considered that the total amount of them are released into the atmosphere. Therefore, the atmospheric emission rate was regarded as 100% and the amount of p-dichlorobenzene contained in repellents or air fresheners was applied for VOC emissions.

- ***Emission factors***

It was assumed that the total amount of p-dichlorobenzene contained in repellent and air fresheners was released into the atmosphere. Therefore, no emission factor has been established.

- ***Activity data***

Total amount of p-dichlorobenzene shipped as repellent and air fresheners, which was provided by Japan Moth Repellent Association and indicated in *Estimation Methods for Releases from Sources not Required to Report under PRTR* (METI and MOE) was applied for activity data.

The shipping amount provided by Japan Moth Repellent Association was not available for and before FY2000; therefore, for this period, the shipping amount was estimated by multiplying the amount in FY 2001 by the growth rate of market size from FY2001. For FY1990 and 1991, it was estimated by extrapolation from the shipping amount.

A3.1.2.2.k. Use of Aerosols Inhalers

a) Category Description

NMVOCs are emitted from inhalers by the use of aerosols products including pesticide, lacquer, and hair spray. NMVOC emissions from content fluid including paint solvent are estimated in other categories such as the use of paint or cosmetic products. Therefore, to avoid double counting, only NMVOC emissions from liquefied gas in inhalers are included in this category. As for inhalers for aerosols products, propane (LPG) and dimethyl ether (DME) are mainly used.

b) Methodological Issues

- ***Estimation Method***

The emissions were estimated based on the estimation method provided in the *Research Report on VOC emissions from private sector* by the Institute of Behavioral Science (hereafter, Survey by Tokyo Metropolitan Government), in March in 2010. The emissions were estimated as shown in the following equation, by multiplying the production amount for each type of product, by the emission factors for LPG and DME.

$$E = \sum (AD_i \times EF_{LPG,DME})$$

E	: NMVOC emissions from the use of aerosols products [g]
AD_i	: Production capacity of aerosols product *i* [cc]
$EF_{LPG,\,DME}$	: LPG and DME emission factor [g/cc]

- ***Emission factors***

Based on each parameter which was used by the Survey by Tokyo Metropolitan Government, the LPG and DME emission amount per aerosols production capacity was applied using the following equation.

$$EF_{LPG,DME} = R_{LPG,DME} \times R_P \times C_{LPG,DME} \times d_{LPG,DME}$$

$EF_{LPG,\,DME}$	: LPG and DME emission factor per aerosols production capacity [g/cc]
$R_{LPG,\,DME}$	: Percentage of LPG and DME aerosols products [%]
R_P	: Percentage of aerosols propellant in can [%]
C_{LPG}, C_{DME}	: Percentage of LPG and DME in propellant [%]
d_{LPG}, d_{DME}	: Specific gravity of LPG and DME [g/cc]

Emission factors for LPG and DME by aerosols products were shown in Table A 3-29.

Table A 3-29 Emission factors for aerosols products (g/cc)

Type of products		LPG	DME
Pesticide	For fly and mosquito	0.223	0.0296
	Other pesticides	0.223	0.0296
Paint	Paint	0.227	0.0151
Household product	Room air freshener	0.236	-
	Cleaner	0.236	-
	Wax and polish	0.236	-
	Laundry articles	0.236	-
	Other household products	0.236	-
Body care products	Hair spray	0.202	0.0269
	Other hair care products	-	0.269
	Shaving cream	0.202	0.0269
	Perfume and cologne	0.112	0.134
	Pharmaceutical products	0.176	0.0905
	Deodorizing and antiperspirant agents	0.225	-
	Other body care products	0.112	0.134
Car-related items	Anti-fog	0.213	-
	Other car-related products	0.213	-
Others	Handy extinguisher	-	-
	Others	0.221	-

Reference: Established based on the *Survey by Tokyo Metropolitan Government*

1) Percentage of aerosol products which used LPG and DME as propellent

As for the percentage of aerosols products which used LPG and DME as propellant, it was calculated by deducting the percentages indicated in Table A 3-30 (established by Tokyo Metropolitan Government research) from 100% for each product and was adapted to each use. As for paint and pharmaceutical products, 100% was applied since no data was available. (Table A 3-31)

Table A 3-30 Percentage of aerosols products which used compressed gas as propellant aerosols

Product	Percentage
Pesticide	1.8%
Household product	6.2%
Cosmetic items	10.8%
Industrial goods	2.3%
Car-related items	15.3%
Others	12.5%

Reference: *Survey by Tokyo Metropolitan Government*

Table A 3-31 Percentage of aerosol products which used LPG and DME as propellants

Type of product		Percentage
Pesticide	For fly and mosquito	98.2%
	Other pesticides	98.2%
Paint	Paint	100.0%
Household product	Room air freshener	93.8%
	Cleaner	93.8%
	Wax and polish	93.8%
	Laundry articles	93.8%
	Other household products	93.8%
Body care products	Hair spray	89.2%
	Other hair care products	89.2%
	Shaving cream	89.2%
	Perfume and cologne	89.2%
	Pharmaceutical products	100.0%
	Deodorizing and antiperspirant agents	89.2%
	Other body care products	89.2%
Car-related items	Anti-fog	84.7%
	Other car-related products	84.7%
Others	Handy extinguisher	87.5%
	Others	87.5%

Note: Established based on the *Survey by the Tokyo Metropolitan Government*

2) Percentage of propellant gas contained in aerosols cans

According to the Survey by Tokyo Metropolitan Government, the percentage of propellant gas contained in aerosols cans was estimated to be 45%.

3) Percentage of LPG and DME in propellant gas

According to the Survey by Tokyo Metropolitan Government, the percentage of LPG and DME in propellant gas was estimated as shown in Table A 3-32.

Table A 3-32 Percentage of LPG and DME in propellant

Type of product		LPG	DME
Pesticide	For fly and mosquito	90%	10%
	Other pesticides	90%	10%
Paint	Paint	90%	5%
Household products	Room air freshener	100%	0%
	Cleaner	100%	0%
	Wax and polish	100%	0%
	Laundry articles	100%	0%
	Other household products	100%	0%
Body care products	Hair spray	90%	10%
	Other hair care products	0%	100%
	Shaving cream	90%	10%
	Perfume and cologne	50%	50%
	Pharmaceutical products	70%	30%
	Deodorizing and antiperspirant agents	100%	0%
	Other body care products	50%	50%
Car-related products	Anti-fog	100%	0%
	Other car-related products	100%	0%
Others	Handy extinguisher	0%	0%
	Others	100%	0%

Note: Established based on the *Survey by Tokyo Metropolitan Government*

4) Specific gravity of LPG and DME

Based on the Survey by Tokyo Metropolitan Government, specific gravity of LPG and DME was established as 0.56 and 0.67, respectively.

- ***Activity data***

Following the Survey by Tokyo Metropolitan Government, production volume of aerosols products was adopted as activity data; it was estimated by multiplying the production volume of aerosols products for each type of container and capacity, by the average capacity per a can for each type of container and capacity, which converts it to capacity base.

$$AD_i = \sum (N_{i,k} \times P_{ave,k})$$

AD_i : Production capacity of aerosols product *i* [cc]
$N_{i,k}$: Production amount of aerosols Product *i*, Container capacity *k* [can]
$P_{ave,k}$: Average capacity of aerosol cans with container capacity *k* [cc/can]

As for "Production volume for each type of container and capacity", the results of the *Survey of Production Amounts of Aerosols* which has been annually conducted by the Aerosols Industry Association of Japan were used. As for "average capacity", the values were set by the type of container and capacity which was provided in the Survey by Tokyo Metropolitan Government, based on the hearing survey of the Aerosols Industry Association of Japan (shown in Table A 3-33 and TableA3-33).

Table A 3-33 Average capacity by capacity class (tinplate container, aluminum container)

Tinplate container	Capacity class [cc]	100-	150-	180-	220-	280-	420-
	Average capacity[cc]	125	165	200	250	350	420
Aluminum container	Capacity class [cc]	-49	50-	100-	150-	200-	300-
	Average capacity[cc]	25	75	125	175	250	300

Table A 3-34 Average capacity by capacity class (synthetic resin container)

Capacity class [cc]	*
Average capacity[cc]	210

Note: * Same for all capacity classes
Reference: Survey by Tokyo Metropolitan Government (TableA3-32 and TableA3-33)

A3.1.2.2.l. Use of Cosmetic Products

a) Category Description

VOCs contained in various types of cosmetic products are emitted to the atmosphere by the use of cosmetics.

b) Methodological Issues

- ***Estimation Method***

Following the methodology of the *Survey by Tokyo metropolitan government*, VOC emissions were estimated by multiplying the sales amount of cosmetic products for each type by the VOC content rate for each type of cosmetic product, by the atmospheric emission rate for each type of cosmetic product.

$$E = \sum_i (AD_i \times C_i \times EF_i)$$

E	: NMVOC emissions from the use of cosmetic product [t-NMVOC]
AD_i	: Sales amount of cosmetic items i [t]
C_i	: VOC content in cosmetic products i [%]
EF_i	: Atmospheric emission rate of cosmetic products i [%]

- ***Emission factors***

The VOC content rate of products was classified according to the *Yearbook of chemical industry* from the VOC content rate which was provided in the Survey by Tokyo Metropolitan Government based on some reports. (Table A3-34)

The smaller classified categories in the Survey by Tokyo Metropolitan Government than those in *Yearbook of chemical industry* were integrated by weighted average using shipping amount allocated ratio provided in *Cosmetic Products Marketing Directory* (Fuji Keizai CO., Ltd.), to make them correspond to the categories in the *Yearbook of chemical industry*.

Table A 3-35 VOC content rate and atmospheric emission rate based on classification in *Yearbook of Chemical Industry*

Cosmetic products		VOC content rate	Atmospheric emission rate
Skin care	Massage and cold cream	7.5%	100%
	Moisturizing cream	7.5%	100%
	Cleansing foam	10.0%	0%
	Cleansing cream	10.0%	0%
	Lotion	10.0%	100%
	Milk	6.0%	100%
	Beauty essence	8.5%	100%
	Facial mask 1)	4.4%	100%
	Other skincare products	7.5%	100%
Makeup	Foundation 1)	2.6%	100%
	Face powder	0.0%	100%
	Eye makeup	4.0%	100%
	Eyebrow and eyelash cosmetics	0.0%	100%
	Cheek rouge	0.0%	100%
	Lip rouge	0.0%	100%
	Nail cosmetics (including nail-polish remover) 1)	76.8%	100%
Fragrance	Perfume and cologne	7.5%	100%
Body care	Lip balm	10.0%	100%
	Sunscreen and cosmetics for sun-burns	83.5%	100%
Hair care in bath	Shampoo	1.5%	0%
	Rinse	1.5%	0%
	Hair conditioner	1.5%	0%
Hair making	Pomade, hair oil, hair dress, perfume oil 1) Hairdressing 1), Setting lotion 1)	10.6%	100%
	Hair spray	27.5%	100%
	Other items for hair (including permanent wave lotion)	1.5%	100%
Hair color	Hair color (Including hair bleach) 1)	22.1%	100%
For men	Products for shaving or bath	25.0%	100%
	Skin care products	7.5%	100%
	Hair tonic (including hair growing agents)	42.5%	100%

Note: 1) Integrated categories by weighted average

Reference: *Survey by Tokyo Metropolitan Government*

The atmospheric emission rate, as well as VOC content in the category were reset, so that they correspond to the categories in the *Yearbook of chemical industry*. Assuming that cosmetic products were used in a normal way, atmospheric emission rate of solid products and liquid products were set at either 0% or 100% (Table A 3-36 and Table A 3-37).

Table A 3-36 Atmospheric emission rate by the way of usage, provided in the Survey by Tokyo Metropolitan Government

State of matter	Usage and process	Atmospheric emission rate
Solid	To use in water or wash away	0%
	To leave it and volatilize component	100%
Liquid	To use in water or wash away in a short time	0%
	To leave it for a long time and dry it	100%
	To volatilize component	100%
	To spray mist (only undiluted solution is used for estimation. Propellant solvent is separately estimated.)	100%

Reference: *Survey by Tokyo Metropolitan Government*

Table A 3-37 Atmospheric emission rate based on the Survey by Tokyo Metropolitan Government

Cosmetic products			Atmospheric emission rate
Skin care	Massage and Cold cream *1		100%
	Remover		0%
	Facial-wash	Facial-wash	0%
		Cleansing	0%
	Lotion	Lotion	100%
	Milk	Milk	100%
	Beauty essence	Beauty essence	100%
	Facial mask	Wash-off facial mask	0%
		Peel-off pack	100%
		Sheet pack	100%
	Face cream	(Classified into *1)	-
	Others	Spot care	100%
Makeup	Base	Makeup base	100%
	Foundation, concealer	Foundation, etc.	100%
	Face powder	Face powder	100%
	Eye color	Eye shadow	100%
	Eye liner	Eye liner	100%
	Eyelash liner	Eyelash liner	100%
	Eyebrow	Eyebrow	100%
	Cheek rouge	Cheek rouge	100%
	Lip color	Lip color	100%
	Nail color	Nail enamel	100%
		Nail care (including remover)	100%
Body care	Body cream, lotion	Body cream, lotion, etc.	100%
	Lip cream	Lip cream	100%
	Hand cream	Hand cream	100%
	UV care product	Suntan, sunscreen	100%
	Unwanted hair treatment agent	Hair removal, depilatory	100%
	Anhidrotic deodorant *2	Deodorant (for foot, for underarm)	100%
Fragrance	Perfume *3	Parfum, Eau de Parfum	0%
	Eau de toilette *3		100%
	Cologne *3		0%
Hair care in bath	Shampoo	Shampoo	0%
	Rinse, Hair conditioner	Rinse, Hair conditioner	0%
	Hair treatment, pack	Hair treatment	0%
Hair make	Blow styling agent, Hair spray, Hair gross	Hair styling agent	100%
	Hair tonic for female	(Classified into *6)	-
	Hair growing agent for female	(Classified into *7)	-
	Permanent wave lotion	Cold wave treating agent	100%
Hair color	Hair coloring agent for black hair, Hair coloring agent for white hair*4	Hair coloring agent for white hair	100%
		Hair coloring agent for black hair	100%
		Hair manicure for white hair	100%
		Hair manicure for black hair	100%
		Other types of hair color (including spray)	100%
		Bleach (decoloring)	100%
For men	Pre-shaving agent, shaving agent	Shaving agent	100%
	Face wash, pack	Skin care products	0%
	Skin lotion		100%
	Skin cream and milk		0%
	Make-up items		0%
	Hair tonic for men *6	Hair tonic	100%
	Hair growing agent *7	Hair growing agent, tonic	100%
	Blow styling agent	(Classified into *4)	-
	Hair spray, hair gloss		0%
	Hair coloring agent for black hair	(Classified into *5)	-
	Hair coloring agent for white hair	(Classified into *5)	-
	Anhidrotic deodorant	(Classified into *2)	-
	Fragrance	(Classified into *3)	-

Reference: *Survey by Tokyo Metropolitan Government*

- ***Activity data***

Sales amount of cosmetic products by types provided in the *Yearbook of chemical industry* is used for activity data. However, since import goods are not included in the *Yearbook of chemical industry* there might be a wide gap between reported sales amount and actual consumption amount. Therefore, as for "perfume and cologne", since the percentage of import excess was especially high, correction measures were conducted.

Table A 3-38 Cosmetic products provided in *Yearbook of chemical industry*

Skin care	Massage and cold cream
	Moisturizing cream
	Cleansing foam
	Cleansing cream
	Lotion
	Milk
	Beauty essence
	Facial mask
	Other skincare products
Makeup	Foundation
	Face powder
	Eye makeup
	Eyebrow and eyelash cosmetics
	Cheek rouge
	Lip rouge
	Nail cosmetics (including nail-polish remover)
Fragrance	Perfume and cologne
Body care	Lip balm
	Sunscreen and cosmetics for sun-burns
Hair care in bath	Shampoo
	Rinse
	Hair conditioner
Hair making	Pomade, hair oil, hair dress, perfume oil
	Hairdressing
	Setting lotion
	Hair spray
	Other items for hair (including permanent wave lotion)
Hair color	Hair color (including hair bleach)
For men	Products for shaving or bath
	Skin care products
	Hair tonic (including hair growing agents)

A3.1.2.2.m. Use of Products for Car Washing and Repair

a) Category Description

VOC components contained in various products for car washing and repairing including wax and cleaner are emitted into the air.

b) Methodological Issues

- ***Estimation Method***

Following the methodology of the Survey by Tokyo Metropolitan Government, the VOC amount used was estimated by multiplying the production amount of car repairing and washing products for each type of product, by the VOC content by type of product. The whole amount of VOCs contained in car repairing and washing products is assumed to be emitted into the atmosphere by the use of the products. The used amount of VOCs was applied for VOC emissions from this source category.

$$E = \sum_i (AD_i \times C_i)$$

E : NMVOC emissions from the use of car washing and repairing products [t-NMVOC]
AD_i : The production amount of i [t]
C_i : VOC content of car washing and repairing products i [%]

- ***Emission factors***

VOC content rate was newly established based on various statistical data and existing VOC content provided in the Survey by Tokyo Metropolitan Government; as for some whose minimum value and maximum value was indicated, the median value was calculated. (Table A 3-39)

Table A 3-39 VOC content rate for car washing and repairing products

Product		VOC	VOC content rate
Wax for cars, coating material		Hydrocarbon compounds including kerosene	50.0%
Products for car window	Window washer fluid	Methanol	25.0%
	Water repellent product	Ethanol	49.0%
		Isopropyl alcohol	42.0%
	Oil film remover	Ethanol	6.5%
		Isopropyl alcohol	12.5%
		Diethanolamine	5.0%
		Petroleum solvent	30.0%
	Frost remover	Ethylene glycol	25.0%
		Isopropyl alcohol	25.0%
Car cleaner		Ethylene glycol	10.0%
Paint for car, repairing agent	Paint		-
	Adhesive		-
Air fresher and air freshener for cars	Air fresher	Aroma chemical (liquid)	1.5%
		Ethanol	2.3%
		Methanol	3.5%
		Aroma chemical (gel)	3.5%
	Air freshener	Ethanol	50.0%

Reference: Established based on the *Survey by Tokyo Metropolitan Government*

- ***Activity data***

Production weight by type of chemical product for car indicated in *Research report on the current status of auto chemical manufacturing* (Japan Auto Chemical Industry Association) was used for activity data for FY1991-1996 and FY1999-2005. Activity data in FY2006 and thereafter was estimated by multiplying the consumption of car washing and repairing products per vehicle by the number of registered vehicles provided in *Statistical Yearbook of Motor Vehicle Transport* (Ministry of Land, Infrastructure, Transport and Tourism).Consumption of car washing and repairing products per vehicle was estimated by dividing the production weight for each type of chemical product for car of FY2003 to FY2005 by the number of registered vehicles of each fiscal year, and multiplying the average weight of the three years[7] by the growth rate of travel distance per vehicle from FY2005. The average value was used to reflect the trend of travel distance per vehicle because the consumption of wax and coating material for cars has been showing a downward trend since FY1990 and according to Auto-parts & Accessories Retail Association, recently, consumption per vehicle has been decreasing due to a decline in the rate of

[7] Three-year average was used since the FY2005 value drastically increased from the previous year.

utilization of cars, miniaturization of cars, and the prevalence of car washing machines. The consumption of other products for cars was also estimated based on the growth rate of travel distance per vehicle. For FY1990, the value for FY1991 was used. For FY1997 and FY1998, it was estimated by interpolation, using activity data in FY1996 and FY1999.

A3.1.2.2.n. Chemicals Manufacture

a) Category Description

This source category provides the methods for estimating NMVOC emissions from highly-volatile substances in manufacturing facilities to polymerize or synthesize chemical products, fugitive emissions by storage or shipping of chemical products, and emissions from solvent in chemical reaction by polymerizing or component extraction.

b) Methodological Issues

● ***Estimation Method***

NMVOC emissions from chemicals manufacture were estimated by multiplying source-specific activity data (production amount of paint, production amount of print ink, shipping amount of solvent-type adhesive, amount of VOC of surface finishing equipment, shipping value of chemical industry-related products and production amount of film soft chemical products for wrapping) by each NMVOC emission factor defined by dividing source-specific VOC emissions in the *Study on the VOC Emission Inventory* by activity data.

$$E = AD \times EF$$

E : NMVOC emissions by chemical manufacture [t-NMVOC]
AD : Activity data by source
EF : Emission factor per activity data

The emissions estimated by the equation above include the emissions from chemical tankers estimated in A3.1.1.3.c Oil Transport (1.B.2.a.iii): Navigation. Therefore, the emissions from chemical tankers were subtracted from the total emissions in this category.

● ***Emission factors***

Emission factor was established by dividing emissions from emission activities indicated in the *Study on the VOC Emission Inventory* by each activity data shown in Table A 3-46. The emission factor for each fiscal year which was not subject to the voluntary action plan / the PRTR report was established as shown in Table A 3-40 - Table A 3-45.

Table A 3-40 Method of establishing NMVOC emission factors for chemical manufacture (paint manufacturing)

FY	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Paint Manufacturers Association) by the production amount of paint.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 3-41 Method of establishing NMVOC emission factors for chemical manufacture (print ink manufacturing)

FY	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Printing Ink Makers Association) by the production amount of print ink.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 3-42 Method of establishing NMVOC emission factors for chemical manufacture (solvent-type adhesive manufacturing)

FY	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Adhesive Industry Association) by the shipping amount of solvent-type adhesive.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 3-43 Method of establishing NMVOC emission factors for chemical manufacture (manufacturing of surface finishing equipment)

FY	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Surface Finishing Suppliers Association) by the used amount of VOCs by manufacturing of surface finishing equipment.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 3-44 Method of establishing NMVOC emission factors for chemical manufacture (manufacturing of various chemical products)

FY	Method of establishing emission factor
1990-1994	Since no aggressive actions to reduce emissions have been taken, the emission factor for FY1995 was used for all fiscal years.
1995-1999	Since voluntary actions started in FY1995, it is considered that emissions have been on a downward trend since then. Therefore, emissions were estimated by extrapolation, using the trend for 2000-2010[1].
2000, 2005-	Established by dividing VOC emissions from chemical industry (estimated figure based on voluntary action plan by Japan Chemical Industry Association) by shipping value of chemical industry-related products.
2001-2004	Estimated by interpolation, using emission factors in FY2000 and 2005.

Note: 1) In the case that emission factor for FY1990-1999 is established by extrapolation, it should be established based on the trend for and before FY2010, which is the target year of the voluntary action plans for VOC emission reduction.

Table A 3-45 Method of establishing emission factors for chemical manufacture (cellophane manufacturing)

FY	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied for all fiscal years.
2000, 2005-	Established by dividing VOC emissions from cellophane manufacturing (emissions reported to the PRTR) by the production amount of film soft chemical products for wrapping.
2001-2004	Average value of FY2000 and 2005 was used.

- ***Activity data***

The following data indicated in Table A 3-46 was used for activity data, since it is considered to be correlated to each emission activity. As for "Manufacturing of various chemical products", the total shipping value for all various chemical products was used for activity data due to difficulty in selecting specific chemical products from many chemical products provided in voluntary action plan by Japan Chemical Industry Association. Since the total shipping value is available only for calendar year, the value was converted from calendar year to fiscal year using the following equation.

$$S_{FYi} = S_{CYi} \times 0.75 + S_{CY(i+1)} \times 0.25$$

S : Shipping value
FY_i : Fiscal year i
CY_i : Calendar year i

Table A 3-46 Activity data for chemical manufacture

Emission source	Activity data	Reference
Paint manufacturing	The production amount of paint	*Yearbook of chemical industry* (METI)
Print ink manufacturing	The production amount of print ink	*Yearbook of chemical industry* (METI)
Solvent-type adhesive manufacturing	The shipping amount of solvent-type adhesive	*Current Survey Report on Adhesive* (Japan Adhesive Industry Association)
Manufacturing of surface finishing equipment	Used amount of VOCs by manufacturing surface finishing equipment. Note: For FY1990-1999, the value for FY2000 was applied. For FY2001-2004, the average of the values for FY2000 and 2005 was used.	*VOC voluntary action plan and achievement report* (METI)
Manufacturing of various chemical products	Total shipping value of various chemical products reported in PRTR in voluntary action plan. ("Chemical industry" and "Manufacturing plastic products (not specified elsewhere)")	*Census of manufactures* (METI)
Cellophane manufacturing	The production amount of film-soft chemical products for wrapping.	*Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics* (METI)

A3.1.2.2.o. Use of Removers

a) Category Description

Dichloroethane is used to remove paint before re-painting and is emitted during use.

b) Methodological issues

- ***Estimation Method***

It is difficult to take measures to reduce emissions such as through local venting during the use of removers. Therefore, the total amount of Dichloroethane used for removers was used for estimating emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The Dichloroethane used for removers was established based on the data provided by the JAHCS data as follows:

Table A 3-47 The method of establishing activity data for the use of removers

FY	Method of establishing activity data
1990-1994	Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of remover-use to the total consumption of FY1995.
1995-	The Dichloroethane used for removers in *Consumption by End-Use* by the JAHCS.

A3.1.2.2.p. Use of Reagents

a) Category Description

NMVOCs are included in reagents that are used to induce chemical reactions during chemical experiments and component analyses, etc, and are emitted during use.

b) Methodological issues

- ***Estimation Method***

Following the estimation method in the *Study on the VOC Emission Inventory*, the amount of reagents used by substance is multiplied by the emission rate by substance, to estimate emissions.

$$E = AD \times EF$$

E : NMVOC emissions from the use of reagents [t-NMVOC]
AD : Amount of reagents used [t]
EF : Emission rate during reagent use [t-NMVOC/t]

- ***Emission factors***

Following the *Study on the VOC Emission Inventory*, the EF for reagent use as described in the *Report on the Promotion of Chemical Substance Safety Measures (The Survey on Methods for Emission Estimation for Below-threshold Entities and Methods for Emission Estimation for Ozone-depleting Substances and Low-content Substances)* is used for FY2000 and FY2005. Emission factor for FY2000 was used for the EFs up to FY1999, and the emission factors for FY2001- FY2004 are estimated by interpolating between FY2000 and FY2005 EFs.

- ***Activity Data***

The Dichloroethane/Trichloroethylene used for reagents was established based on the *Study on the VOC Emission Inventory* and the data provided by the JAHCS data as follows:

Table A 3-48 The method of establishing activity data for the use of reagents

Fiscal year（FY）	Method of establishing activity data
1990-1994	Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of reagent-use to the total consumption of FY1995. (calculated from the *Consumption by End-Use* by the JAHCS).
1995-	The Dichloroethane/Trichloroethylene used for reagents in *Consumption by End-Use* by the JAHCS.

For other reagents, Dichloroethane used for reagents in *Consumption by End-Use* by the JAHCS is multiplied by the ratio of reported substances in the *Study on the VOC Emission inventory* (from the environmental ordinance of Tokyo) that are used as reagents to the amount of Dichloroethane used as reagents, to estimate emissions.

A3.1.2.2.q. Use of Blowing Agents

a) Category Description

Dichloroethane is used as an auxiliary blowing agent for flexible polyurethane foams of polyurethane and is emitted during use.

b) Methodological issues

- ***Estimation Method***

The total amount of Dichloroethane used for blowing agents was used for estimating emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The Dichloroethane used for blowing agents production was established based on the data provided by JAHCS as follows:

Table A 3-49 The method of establishing activity data for the use of blowing agents production

Fiscal year (FY)	Method of establishing activity data
1990-1994	Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of blow agent-use to the total consumption of FY1995.
1995-	The Dichloroethane used for blowing agents in *Consumption by End-Use* by JAHCS.

A3.1.2.2.r. Use of Fishing Net Antifouling Agents

a) Category Description

Solvents are used to dilute fishing net antifouling agents which are applied to nets used in fish farms or stationary nets. The nets are first immersed in the chemicals and then dried off before use. Solvents are emitted into the atmosphere at this stage.

b) Methodological issues

- ***Estimation Method***

Total amount of xylene used (sea aquaculture and stationary nets) from the 'Total amounts used for fishing net antifouling agents in sea aquaculture, etc' (surveyed by the Fisheries Agency), in the ‘emissions from fishing net antifouling agents’, from the Emissions from Sources not Required to Report under PRTR, was used for emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

Activity data is established as shown in the below Table, based on *Emissions from Sources not Required to Report under PRTR* and data provided by the Fisheries Agency.

Table A 3-50 The method of establishing activity data for the use of Fishing Net Antifouling Agents

Fiscal year (FY)	Method of establishing activity data
1990-1997	Xylene used for fishing net antifouling agents for sea aquaculture and stationary nets in FY1998 is used, since no data exist for xylene used for fishing net antifouling agents.
1998-2001	Data provided by the Fisheries Agency is used.
2002-	Total amount of xylene used (sea aquaculture and stationary nets) from the 'Total amounts used for fishing net antifouling agents in sea aquaculture, etc' (surveyed by the Fisheries Agency), in the 'emissions from fishing net antifouling agents', from the Emissions from So*urces not Required to Report under PRTR*, was used.

A3.1.2.2.s. Use of Converting Solvents

a) Category Description

The solvents used at the drying stage of the converting processing facilities, the drying and baking (wrinkle-resistant processing) stage during finishing, and the drying stage of printing, are emitted into the atmosphere.

b) Methodological issues

- ***Estimation Method***

Emissions were estimated by multiplying the product quantity in the dyeing and finishing processes, by the emission factor per product quantity.

- ***Emission factors***

Emission factors were established by dividing emissions based on the reported values in the Voluntary Action Plan of the Japan Textile Finishers' Association in the *Study on the VOC Emission Inventory*, by product quantity totals in the dyeing and finishing processes (excluding wool fabrics).

Table A 3-51 The method of establishing emission factors for the use of converting solvents

Fiscal Year (FY)	The method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied.
2000, 2005-	Emission factors were established by dividing VOC emissions from the use of converting solvents (estimated values based on the reported values in the Voluntary Action Plan of the Japan Textile Finishers' Association), by product quantity in the dyeing and finishing processes (excluding wool fabrics).
2001-2004	Estimated by interpolating between FY2000 and FY2005 EFs.

- ***Activity Data***

Product quantity in the dyeing and finishing processes (excluding wool fabrics) in the *Yearbook of Current Production Statistics - Textiles and Consumer Goods Statistics* (METI) is used. As for wool fabrics, converting solvents are not used in the production process and is therefore excluded from the activity data.

A3.1.2.2.t. Use of Coating Solvents

a) Category Description

Emissions occur from solvents used when coating plastic films for special functions (antistatic agents, abrasion and scratch resistants, anti-fogging agents, electromagnetic shielding, conductivity imparting agents, UV absorbers, etc).

b) Methodological issues

- ***Estimation Method***

Emissions were estimated by multiplying the film sales amount by the emission factor per sales amount.

- ***Emission factors***

Emission factors were established by dividing emissions based on the reported values in the Voluntary Action Plan of the Japan Polyethylene Products Industrial Federation in the *Study on the VOC Emission Inventory* by film sales amounts.

Table A 3-52 The method of establishing emission factors for the use of coating solvents

Fiscal Year (FY)	The method of establishing emission factor
1990-2004	The EF for FY2005 is applied.
2005-	Emission factors were established by dividing VOC emissions from the use of coating solvents (estimated values based on the reported values in the Voluntary Action Plan of Japan Polyethylene Products Industrial Federation) by film sales amounts.

- ***Activity Data***

The film sales amounts in the *Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics* are used.

A3.1.2.2.u. Use of Synthetic Leather Solvents

a) Category Description

N, N-dimethylformamide is used to dissolve polyurethane when manufacturing synthetic leather and is emitted in the process of use.

b) Methodological issues

- ***Estimation Method***

The sum of the atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry reported under the PRTR and the emissions similar as the above but from below-threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR, are used as emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The sum of the atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry under the PRTR and the emissions similar as the above but from below-threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR, are used as emissions.

Table A 3-53 The method of establishing activity data for the use of synthetic leather solvents

<table>
<tr><th rowspan="2">Fiscal Year (FY)</th><th colspan="2">Method of establishing activity data</th></tr>
<tr><th>Emissions under the PRTR</th><th>Emissions from sources not required to report under the PRTR</th></tr>
<tr><td>1990-2000</td><td colspan="2">Estimated by multiplying FY2001 atmospheric emissions by the ratio to the FY2001 data for consumption amounts of other resin for synthetic leather in the Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics.</td></tr>
<tr><td>2001-2012</td><td rowspan="2">The atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry, reported under the PRTR is used as emissions.</td><td>Estimated by multiplying FY2001 to FY2012 emissions reported under the PRTR, by the ratio of FY2017[8] emissions from sources not required to report under PRTR to the FY2017 emissions reported under the PRTR.</td></tr>
<tr><td>2013-</td><td>The atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry from below-threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR is used.</td></tr>
</table>

A3.1.2.2.v. Use of Fumigants

a) Category Description

Methyl bromide is emitted from the use of fumigants on croplands and in warehouses, etc.

b) Methodological issues

- ***Estimation Method***

Emissions were estimated by multiplying the amount of methyl bromide used for fumigants by the emission factor per use amount.

- ***Emission factors***

An emission factor (64%) based on the *Survey of Actual Use of Methyl Bromide* (National Institute for Environmental Studies, 1998) is applied to all years, following the *Study on the VOC Emission Inventory*.

- ***Activity Data***

The activity data was established as follows, based on the amount of methyl bromide used for fumigants provided in the domestic shipment amounts by use from the Methyl Bromide Association. As for the Soil and Quarantine categories, it is assumed that 100% is used as fumigants. As for the Other category, although it includes uses for industrial raw material, details are unknown and is therefore assumed that 50% is used as fumigants.

[8] The value of the year with the highest ratio was used to avoid underestimation.

Table A 3-54 The method of establishing activity data for the use of fumigants

Fiscal Year (FY)	Method of establishing activity data
1990-1999	Amount of methyl bromide provided in the domestic shipment amounts by use (Surveyed by the Agricultural Safety Management Section, Food Safety and Consumer Affairs Bureau, MAFF) The Other category is estimated using this data.
2000, 2005-	Amount of methyl bromide used for fumigants provided in the domestic shipment amounts by use from the Methyl Bromide Association.
2001-2004	Amount of methyl bromide provided in the domestic shipment amounts by use (Surveyed by the Agricultural Safety Management Section, Food Safety and Consumer Affairs Bureau, MAFF) The Other category is estimated using this data.

A3.1.2.2.w. Use of Dampening Solutions

a) Category Description

Isopropyl alcohol, included in etch solutions that are added to dampening solutions used in offset printing, is emitted into the atmosphere as a VOC.

b) Methodological Issues

- ***Estimation Method***

Emissions were estimated by multiplying the sales amount of planographic printing ink by the NMVOC emissions per sales amount of planographic printing ink.

$$E = AD \times EF$$

E : NMVOC emissions from the use of dampening solutions [t-NMVOC]
AD : Sales amount of planographic printing ink [t]
EF : NMVOC emissions per sales amount of planographic printing ink [t-NMVOC/t]

- ***Emission factors***

The emission factors were established as follows, based on the reported values in the voluntary action plan of the Japan Federation of Printing Industries.

Table A 3-55 The method of establishing emission factors for the use of dampening solutions

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied.
2000, 2004-	Emission factors were established by dividing VOC emissions from the use of dampening solutions (estimated values based on the reported values in the voluntary action plan of the Japan Federation of Printing Industries) by sales amounts of planographic printing ink.
2001-2003	Estimated by interpolating between FY2000 and FY2004 EFs.

- ***Activity data***

The sales amounts of planographic printing ink in the *Yearbook of Chemical Industry* are used.

A3.1.2.2.x. Use of Fabric Treatment Agents

a) Category Description

NMVOCs are emitted into the atmosphere from the use of fabric treatment agents (anti-static agents for fabrics, water repellents, fabric refreshers, and stain removers) through volatilizing or spraying the substances.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions are estimated by multiplying the sales amounts of each type of fabric treatment agent by the VOC content for each type of fabric treatment agent, and by the atmospheric emission rate for each type of fabric treatment agent.

$$E = \sum_i (AD_i \times R_i \times EF_i)$$

E : NMVOC emissions from the use of fabric treatment agents [t-NMVOC]

AD_i : Sales amount of fabric treatment agent i [t] (Estimated by multiplying the sales amount by specific gravity (0.8) when its unit is in volume)

R_i : VOC content in fabric treatment agent i [%]

EF_i : Atmospheric emission rate of fabric treatment agent i [%]

- ***Emission factors***

The VOC content and atmospheric emission rate were established as follows, based on how the value in the *Survey by the Tokyo Metropolitan Government* was established. The VOC content was established for each type, using the medium value of minimum and maximum VOC contents in the *Survey by the Tokyo Metropolitan Government.*

Table A 3-56 VOC content and atmospheric emission rate for the use of fabric treatment agents

Type of products	VOC content	Atmospheric emission rate
Anti-static agents for fabrics	50%	100%
Water repellents (for clothing, shoes, etc.)	35%	100%
Fabric refreshers	8%	100%
Stain removers (surfactants)	30%	100%
Stain removers (benzines)	50%	100%

- ***Activity data***

Established as follows, based on the method of the *[Expanded] National Emission Inventory for Volatile Organic Compounds* (MOE) (hereafter, *Expanded VOC Emission Inventory*)

Table A 3-57 Method of establishing activity data for the use of fabric treatment agents

Fiscal Year (FY)	Method of establishing activity data
2005-2007	Sales amounts of fabric treatment agents in the *Survey by the Tokyo Metropolitan Government*
Excluding the above	Estimated by multiplying the three-year average of FY2005 to FY2007 in the *Survey by the Tokyo Metropolitan Government* by each year's growth rate of annual expenditures of all households as compared to the average value of FY2005 to FY2007, where expenditures of all households are calculated by multiplying annual expenditures per household from “Other domestic non-durable goods – Others,” etc in the *Survey of Household Economy* (Ministry of Internal Affairs and Communications) by the number of all households in the *Population, vital statistics and number of households survey based on the Basic Resident Registration* (Ministry of Internal Affairs and Communications)

A3.1.2.2.y. Use of Air Fresheners

a) Category Description

NMVOCs contained in air fresheners are emitted into the atmosphere from the placing and use of air fresheners through volatilizing the substances.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions are estimated by multiplying the sales amounts of each type of air freshener by the VOC content for each type of air freshener, and by the atmospheric emission rate for each type of air freshener.

$$E = \sum_i (AD_i \times R_i \times EF_i)$$

E : NMVOC emissions from the use of air fresheners [t -NMVOC]

AD_i : Sales amounts of air freshener i [t] (Estimated by multiplying the sales amounts by specific gravity (0.8) when its unit is in volume)

R_i : VOC content in air freshener i [%]

EF_i : Atmospheric emission rate of air freshener i [%]

- ***Emission factors***

The VOC content and atmospheric emission rate were established as follows, based on how the value in the *Survey by the Tokyo Metropolitan Government* was established. The VOC content was established for each type, using the medium value of minimum and maximum VOC contents in the *Survey by the Tokyo Metropolitan Government.*

Table A 3-58 VOC content and atmospheric emission rate for the use of air fresheners

Type of air freshener		VOC content	Atmospheric emission rate
Air fresheners, etc for rooms	Aerosol	30%	100%
	Plugin air freshener	30%	100%
	Others	30%	100%
Air fresheners, etc for bathrooms	Aerosol	30%	100%
	Mists	30%	100%
	Others	30%	100%
Deodorizers	Refrigerator deodorizers	1%	100%

- ***Activity data***

Established as follows, based on the method of establishing activity data for the *Expanded VOC Emission Inventory* and the *Survey by the Tokyo Metropolitan Government.*

Table A 3-59 Method of establishing activity data for the use of air fresheners

FY	Method of establishing activity data
2005-2007	Estimated sales amounts of air fresheners by dividing the sales total of air fresheners by the unit price in the *Survey by the Tokyo Metropolitan Government.*
Excluding the above	Same as the method of establishing activity data for fabric treatment agents excluding FY2005-2007.

A3.1.2.2.z. Use of Skin Disinfectants / Sanitizers

a) Category Description

Alcohols such as ethanol and isopropanol, etc. contained in skin disinfectants / sanitizers are emitted into the atmosphere during use.

b) Methodological Issues

● ***Estimation Method***

Emissions are estimated by multiplying the shipment amounts of each type of skin disinfectant / sanitizer by the VOC content for each type of skin disinfectant / sanitizer, and by the atmospheric emission rate for each type of skin disinfectant / sanitizer.

$$E = \sum_i (AD_i \times 0.8 \times R_i \times EF_i)$$

E : NMVOC emissions from the use of skin disinfectants / sanitizers [t-NMVOC]
AD_i : Shipment amounts of skin disinfectant / sanitizer i [t]
0.8 : Approximate value of specific gravity of alcohol [t/kL]
R_i : VOC content in skin disinfectant / sanitizer i [%]
EF_i : Atmospheric emission rate of skin disinfectant / sanitizer i [%]

● ***Emission factors***

The VOC content and atmospheric emission rate were established based on the value established in the *Survey by the Tokyo Metropolitan Government* and the *Expanded VOC Emission Inventory*, etc. The VOC content was established for each type as follows, and the atmospheric emission rate was set to 100%.

Table A 3-60 VOC content for the use of skin disinfectants / sanitizers

Type of skin disinfectant / sanitizer			VOC content
Disinfectant and sanitizer for external use (drugs, quasi-drugs)			45% (the medium value of the minimum/ maximum values (20%, 70%) in the *Survey by the Tokyo Metropolitan Government*)
Skin sanitizers	Alcohol formulations	Isopropanol	100% (Established conservatively, based on the specification tables of manufacturers)
		Isopropanol (liquid) 50%	50% (product specification)
		Isopropanol (liquid) 70%	70% (product specification)
		Ethanol	96% (the medium value of the minimum / maximum values (95.1, 96.9 vol%) of the specification of the *Japanese Pharmacopoeia* (Ministry of Health, Labour and Welfare))
		Ethanol for sanitization	79% (the medium value of the minimum / maximum value (76.9, 81.4 vol%) of the specification of the *Japanese Pharmacopoeia*)
		Absolute ethanol	100% (Established conservatively, based on the specification of the *Japanese Pharmacopoeia* (99.5% or more))
		Ethanol (liquid)	79% (Same as ethanol for sanitization)
	Others		1% (the value established in the *Expanded VOC Emission Inventory*)

● ***Activity data***

Established as follows, based on the value established in the *Survey by the Tokyo Metropolitan Government* and the shipment amounts, etc. for the "skin disinfectant and sanitizer" in the *Statistics of Production by Pharmaceutical Industry* (Ministry of Health, Labour and Welfare).

Table A 3-61 Method of establishing activity data for the use of skin disinfectants / sanitizers

Calendar Year (CY)	Disinfectant and sanitizer for external use (drugs, quasi-drugs)	Skin sanitizer
2005-2007	The value established in the *Survey by the Tokyo Metropolitan Government was used.*	Shipment amounts of "skin disinfectant and sanitizer" in the *Statistics of Production by Pharmaceutical Industry* (Ministry of Health, Labour and Welfare) was used with partial correction.
Excluding the above	Estimated by multiplying the three-year average of FY2005 to FY2007 in the *Survey by the Tokyo Metropolitan Government* by each year's growth rate of production value of "household medicines" given in the *Statistics of Production by Pharmaceutical Industry* as compared to the average value of FY2005 to FY2007.	

A3.1.2.2.aa. Use of Food Trays and Expanded Polystyrene

a) Category Description

Butanes or isobutanes remaining in food trays (polystyrene paper) or expanded polystyrene, are emitted into the atmosphere during use.

b) Methodological Issues

- ***Estimation Method***

Emissions are estimated by multiplying the shipment amounts of polystyrene paper and expanded polystyrene by the VOC content, and by the atmospheric emission rate.

$$E = AD \times R \times EF$$

E : NMVOC emissions from the use of food trays and expanded polystyrene [t-NMVOC]

AD : Shipment amounts of polystyrene paper and expanded polystyrene [t]

R : VOC content in polystyrene paper and expanded polystyrene [%]

EF : Atmospheric emission rate [%]

- ***Emission factors***

The VOC content was set to 1.0% and the atmospheric emission rate was set to 100%, based on the value established in the *Expanded VOC Emission Inventory*.

- ***Activity data***

For food trays, shipment amounts of polystyrene paper provided by the Japan Polystyrene Foamed Sheet Industry Association were used. The value of 1991 was used for 1990 due to the lack of the data for 1990, since it was before the establishment of the industry association.

For expanded polystyrene, recovery amounts for recycling (equal to domestic distribution amounts) of expanded polystyrene by the Japan Expanded Polystyrene Association were used. The value of 1991 was used for 1990 due to lack of the data for 1990.

A3.1.2.2.bb. Use of writing utensils, etc

a) Category Description

During the use of writing utensils, etc (ballpoint pens, marking pens, whiteouts), the alcoholic content (benzyl alcohol) or organic solvents in the ink or whiteout are emitted into the atmosphere.

b) Methodological Issues

- ***Estimation Method***

Following the methodology for the *Expanded VOC Emission Inventory* and the *Survey by the Tokyo Metropolitan Government*, emissions are estimated by multiplying the number of ballpoint pens (water-based, oil-based), marking pens, and whiteout sold by solvent content, use rate of ink, VOC content, and by the atmospheric emission rate.

$$E = \sum_i AD_i \times SC_i \times UR_i \times SG \times 10^{-6} \times R_i \times EF_i$$

E	: NMVOC emissions from the use of writing utensils, etc [t-NMVOC]
AD_i	: Number of writing utensils sold
SC_i	: Solvent content in product i [mL/item]
UR_i	: Use rate of ink in product i [%]
SG	: Specific gravity of solvent [1.0 g/mL]
R_i	: VOC content in product i [%]
EF_i	: Atmospheric emission rate [%]
i	: Type of writing utensil, etc

- ***Emission factors***

The solvent content and VOC content were set as in the following table, based on the values established in the *Expanded VOC Emission Inventory*, etc. The atmospheric emission rate was set at 100%. Although emissions for the products still containing ink at disposal are possibly double-counted in the Waste sector, the use rate of ink is set at 100%, since information is not available to estimate the ratio.

Table A 3-62 Solvent content and VOC content of writing utensils, etc

Type	Solvent content [mL/item]	VOC content
ballpoint pens	0.2	Water-based ballpoint pens: 5% Oil-based ballpoint pens: 15%
marking pens	3.0	FY1990 to 1997: Weighted averages were taken of the VOC content for water-based marking pens (15%) and oil-based marking pens (70%) using their respective numbers of pens sold. FY1998 onwards: Similar to FY1990 to 1997, weighted averages were taken of the VOC content, by borrowing the growth rate from FY1997, of the ratio of water-based ballpoint pens to the total number of ballpoint pens, and applying it to marking pens.
whiteout	7.0	45%

- ***Activity data***

The number of ballpoint pens (water-based, oil-based), marking pens, and whiteout sold, provided in the *Yearbook of Current Production Statistics - Textiles and Consumer Goods Statistics* (METI) were used.

For whiteout, since data could not be obtained from the above statistics for 1990 to 1994, the following estimations were made. First, the total expenditures on writing utensils, etc were estimated by multiplying household expenditures on writing utensils, etc (*Survey of Household*

Economy (two-or-more-person households)) by the number of households (*Household Survey*, Ministry of Internal Affairs and Communications) for 1995 to 2020. This was then used to divide the sales revenue of whiteout (*Yearbook of Current Production Statistics*) for 1995-2000 to yield the share of whiteout in total expenditures per year. Then by using linear approximation drawn from the share of whiteout for 1995-2020, the share of whiteout for 1990-1994 was estimated, and by multiplying this by the total expenditures in each year, the sales revenue for whiteout was estimated. Then by using the unit price (sales revenue/sales amount) of whiteout for 1995 and ratios to previous year prices of writing utensils, etc (*Consumer Price Index (2020 standard)*, Ministry of Internal Affairs and Communications), prices for whiteout for 1990-1994 were estimated, and by dividing the sales revenue by this, the number of writing utensils, etc sold were estimated for 1990-1994.

A3.1.2.2.cc. Use of wet wipes

a) Category Description

During the use of disinfecting/sanitizing wet wipes, the alcoholic content (ethyl alcohol) in the wet wipes is emitted into the atmosphere. Since wet wipes for nursing care, miscellaneous items, and makeup hardly use any alcohol, they are excluded from the scope for estimation.

b) Methodological Issues

- ***Estimation Method***

Following the methodology for the *Expanded VOC Emission Inventory*, emissions are estimated by multiplying the number of sheets of wet wipes produced, by the amount of liquid per sheet, the VOC content, and by the atmospheric emission rate.

$$E = AD \times L \times R \times 10^{-6} \times SG \times EF$$

E	: NMVOC emissions from the use of wet wipes [t -NMVOC]
AD	: Number of sheets of wet wipes produced
L	: Amount of liquid per sheet [mL/sheet]
R	: VOC content in wet wipes [%]
SG	: Specific gravity of alcohol (0.8)
EF	: Atmospheric emission rate [%]

- ***Emission factors***

Based on the values established in the *Expanded VOC Emission Inventory,* the amount of liquid per sheet was set at 3 [mL/sheet], the VOC content was set at 10%, and the atmospheric emission rate was set at 100%.

- ***Activity data***

Following the *Expanded VOC Emission Inventory,* the number of sheets of wet wipes produced was estimated by multiplying the number of disinfecting/sanitizing wet wipe packages produced provided by the Japan Hygiene Products Industry Association (JHPIA), by the number of sheets per package, and by the ratio of alcohol-containing products.

$$AD = \sum_i M_i \times S \times R_i$$

AD : Number of sheets of wet wipes produced
M_i : Number of disinfecting/sanitizing wet wipe packages produced
S : Number of sheets per package [sheet/package]
R_i : Ratio of alcohol-containing products [%]
i : Type of wet wipe (disinfecting, sanitizing)

The number of disinfecting/sanitizing wet wipe packages produced were set as in the following tables.

Table A 3-63 Method of establishing activity data for the use of disinfecting wet wipes

FY	Method of establishing activity data
-2007	Number of disinfecting wet wipe packages produced was set at zero.
2008-2012	Based on interview results with JHPIA, it was assumed that wider sales began to the public in 2008, and therefore interpolation was done between packages produced in 2007 and 2013.
2013-	Following the *Expanded VOC Emission Inventory*, *Statistical Data of Wet Wipes* (JHPIA) was used.

Table A 3-64 Method of establishing activity data for the use of sanitizing wet wipes

FY	Method of establishing activity data
-2000	Number of disinfecting wet wipe packages produced was set at zero.
2001-2004	Interpolation was done between packages produced in 2000 and 2005.
2005-2007	Following the *Expanded VOC Emission Inventory*, the *Survey by the Tokyo Metropolitan Government* data was used.
2008-2009	Following the *Expanded VOC Emission Inventory*, the 2007 value was used.
2010-	Following the *Expanded VOC Emission Inventory*, *Statistical Data of Wet Wipes* (JHPIA) was used.

Following the *Expanded VOC Emission Inventory*, the number of sheets per wet wipe package was wet at 50 [sheets/package]. The ratio of alcohol-containing products within disinfecting wet wipes was set at 100%, and 30% for sanitizing wet wipes.

A3.1.2.3. Others – Food and Beverage Industry (2.H.2.) (NMVOCs)

A3.1.2.3.a. Foods (Fermentation)

a) Category Description

NMVOCs are released as a fugitive emission in alcohol in the process of manufacturing foods or beverages. For the estimation of NMVOC emissions from this source category, alcohol which is generated by bread making and alcoholic brewing is included in the calculation; it is considered to be of biogenic-origin.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from manufacturing foods or beverages were estimated by multiplying the production amount of bread and alcohol drinks, by the NMVOC emission factor per production amount of bread and alcoholic drinks.

➢ ***Calculation of NMVOC emissions from bread making***

$$E = AD \times EF$$

E : NMVOC emissions from bread making [t -NMVOC]
AD : Production amount of bread [1000 t]
EF : Emission factor per production amount of bread [kg-NMVOC/t]

➢ ***Calculation of NMVOC emissions from alcohol brewing***

$$E = AD \times ABV \times EF$$

E : NMVOC emissions from alcohol brewing [t -NMVOC]
AD : Production volume of alcoholic drinks [1000 kL]
ABV: Ethyl alcohol content rate [%] (only for Shochu (Japanese distilled spirit), whiskey, spirits, and liqueur)
EF : Emission factor per production amount of alcoholic drinks [kg-NMVOC/kL]

● ***Emission factors***

Emission factor (4.5kg/t) for bread making, provided in the European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*, was used as the emission factor for bread making.

As for emission factor for brewing alcoholic drinks, the ethyl alcohol content provided in European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009* was also used (TableA3-65). The ethyl alcohol contents of the alcoholic drinks were only established for Shochu, whiskey, spirits and liqueurs. The ethyl alcohol contents of Shochu and whiskey were established based on the European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009* (TableA3-66). The ethyl alcohol content provided in the *Study on the VOC Emission Inventory* was used for spirits and liquor. (TableA3-67 and TableA3-68).

Table A 3-65 Emission factors for brewing alcoholic drinks

Alcoholic drinks	Emission factor	Unit
Sake	0.08	kg/100L- volume of brewed alcoholic drinks
Sake compound	0.08	kg/100L- volume of brewed alcoholic drinks
Shochu (Japanese distilled spirit)	0.4	kg/100L- volume of brewed ethyl alcohol
Beer	0.035	kg/100L- volume of brewed alcoholic drinks
Fruit wine	0.08	kg/100L- volume of brewed alcoholic drinks brewed volume
Whiskey	15	kg/100L- volume of brewed ethyl alcohol
Spirits	0.4	kg/100L- volume of ethyl alcohol
Liqueurs	0.4	kg/100L- volume of brewed ethyl alcohol
Other liquors (including low-malt beer)	0.035	kg/100L-volume of brewed alcoholic drinks

Note: The *Study on the VOC Emission Inventory*, established based on the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*

Table A 3-66 Ethyl alcohol content for alcoholic drinks (shochu, whiskey)

Alcoholic drinks	Ethyl alcohol content
Shochu (Japanese distilled spirit)	25%
Whiskey	40%

Note: Based on *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*

Table A 3-67 Methods of establishing ethyl alcohol content of spirits and liquor

Fiscal year (FY)	Methods of establishing ethyl alcohol content of spirits and liquor
1990-1999	The value of ethyl alcohol content for FY2000 provided in the *Study on the VOC Emission Inventory* was used.
2000	The value of ethyl alcohol content provided in the *Study on the VOC Emission Inventory* was used.
2001-2004	Estimated by interpolating between the ethyl alcohol contents for FY2000 and FY2005.
2005-	The value of ethyl alcohol content for each year provided in the *Study on the VOC Emission Inventory* was used.

Table A 3-68 Ethyl alcohol content for alcoholic drinks (spirits, liquor)

Item	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Spirits	25.9%	25.9%	25.9%	12.7%	10.3%	10.1%	10.0%	9.8%	9.7%	9.7%	9.8%	9.9%	9.9%	9.9%	9.9%
Liqueurs	11.7%	11.7%	11.7%	8.5%	7.0%	6.8%	6.7%	6.8%	6.7%	6.5%	6.4%	6.4%	6.4%	6.4%	6.4%

- ***Activity data***

For bread, the production amount of various kinds of bread, provided in *Food Industry Trend Survey* (Ministry of Agriculture, Forestry and Fisheries of Japan), was used for activity data.

For alcoholic drinks, the volume of production of brewed alcoholic drinks, provided in Table of volume of production of brewed alcoholic drinks and volume of stock (The National Tax Administration Agency) was used for activity data.

A3.1.3 Agriculture

A3.1.3.1. Field Burning of Agricultural Residues (3.F: CO, NOx)

a) Methodological Issues

- ***Estimation Method***

CO and NOx emissions were calculated by using the method indicated in the *2006 IPCC Guidelines*, which is the same method as that for CH_4 and N_2O estimation.

$$E = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

E : CO and NOx emissions from field burning of agriculture residues [t-CO or t-NO_X]
A : Area burnt [ha]
M_B : Mass of fuel available for combustion [t/ha]
C_f : Combustion factor
G_{ef} : Emission factor [g-CO/kg or g-NO_X/kg]

- ***Emission factors***

CO : 92 g-CO/kg (dry matter) (default value in the *2006 IPCC Guidelines*)
NOx : 2.5 g-NO_X/kg (dry matter) (default value in the *2006 IPCC Guidelines*)

- ***Activity data***

Activity data are the same as those used for CH_4 and N_2O estimation described in "5.7. Field Burning of Agricultural Residues (3.F.)".

A3.1.4 Land Use, Land-Use Change and Forestry

A3.1.4.1. Biomass burning (4.(V))

a) Methodological Issues

1) Biomass Burning in Forest Land (4(V))

- ***Estimation Method***

For CO and NO_X emissions due to biomass burning from forest fires, the Tier 1 method is used.

- ***CO***

$$bbGHG_f = L_{forest\ fires} \times ER$$

- ***NO_X***

$$bbGHG_f = L_{forest\ fires} \times ER \times NC_{ratio}$$

$bbGHG_f$	: CO and NO_X emissions due to forest biomass burning
$L_{forest\ fires}$	: Carbon released due to forest fires [t-C/yr]
ER	: Emission ratio (CO: 0.06, NO_X: 0.121)
NC_{ratio}	: NC ratio

- ***Emission Factor***

- ***Emission ratio***

The following values are applied to emission ratios for CO and NO_X due to biomass burning.

CO: 0.06, NO_X: 0.121
(default value stated in the *GPG-LULUCF*, Table 3A.1.15)

- ***NC ratio***

The following values are applied to NC ratio of NO_X.

NC ratio: 0.01 (default value stated in the *GPG-LULUCF* p.3.50)

- ***Activity data***

For activity data in Forest land, carbon released by forest fire is used. For detailed information, see the description on the activity data in section 6.16 in Chapter 6.

2) From burning of pruned branches from orchard trees (4(V))

- ***Estimation Method***

For CO and NOx emissions due to biomass burning of pruned branches from orchard trees, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* is applied. The estimation equation is as follows:

$$L_{fire} = W_B \times C_f \times G_{ef} \times 10^{-6}$$

L_{fire} : CO and NOx emissions from fire [kt]
W_B : Amount burnt [t-d.m.]
C_f : Combustion factor
G_{ef} : Emission factor [t/kt-d.m.]

- ***Parameters***

For the combustion factor, a general value (0.9) which has been used generally in field burning of crop residues in agriculture in Japan is applied. The default emission factors (Agricultural residue value) described in the *2006 IPCC Guidelines* are used.

Table A 3-69 Emission factors [t/kt-d.m.]

Category	CO	NOx
Agricultural residue	92	2.5

Reference: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

- ***Activity Data (Amount burned)***

For activity in orchard land, see the description on the activity data in section 6.16 in Chapter 6.

3) Biomass Burning in Grassland (4(V))

- ***Estimation Method***

For CO and NOx emissions due to biomass burning of grassland, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* is applied. The estimation equation is as follows:

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-6}$$

L_{fire} : CO and NOx Emissions from fire [kt]
M_B : Amount burnt [t-d.m.]
C_f : Combustion factor
G_{ef} : Emission factor [t/kt-d.m.]

- ***Parameters***

For the combustion factor, value of 0.9 is applied according to expert judgment that considering survey data on burning of grassland in Japan. The default emission factors (Savanna and grassland) described in the *2006 IPCC Guidelines* are used.

Table A 3-70 Emission factors [t/kt-d.m.]

Category	CO	NOx
Savanna and grassland	65	3.9

Note: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

- ***Activity Data (Amount burned)***

For activity data in grassland, see the description on the activity data in section 6.16 in Chapter 6.

A3.1.5 Waste

A3.1.5.1. Incineration and Open Burning of Waste (5.C.)

A3.1.5.1.a. Municipal Solid Waste Incineration (5.C.1.–)

- ***Estimation Method***

The NO_X, CO, NMVOCs, and SO_X emissions from the specified sources were calculated by multiplying the incineration amount of MSW in each incinerator type (Continuous Incinerators, Semi-continuous Incinerators, Batch type Incinerators, Gasification melting furnaces) by Japan's country-specific emission factors. These emissions are categorized following the methods given in chapter 7 based on incinerations either with or without energy recovery. The former emissions are reported in the Energy sector, while the latter are reported in the Waste sector.

- ***Emission factors***

➢ ***NO_X, SO_X***

For incinerators, emission factors were established for each incinerator type by using the emission amount and amount of treated waste identified in the *General Survey of the Emissions of Air Pollutants*. (The categories of incinerator types included: [1301: Waste incinerator (municipal solid waste; continuous system)] and [1302: Waste incinerator (municipal solid waste; batch system)]). The incineration material was [53: Municipal solid waste].) It is noted that while the *General Survey of the Emissions of Air Pollutants* classified the incinerators into two classes (Continuous and Batch), this report classifies incinerators into three classes ("Continuous", "Semi-continuous", and "Batch type") by dividing the Continuous system and assigning those which operated for less than 3,000 hours to the "Semi-continuous" class.

For gasification melting furnaces, the value for Continuous Incinerators with a similar incineration method was used.

Table A 3-71 NO_X and SO_X emission factors for municipal waste by type of incineration method

Furnace type	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NOx																
Continuous incinerator	kg-NOx/t	1.238	1.213	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127
Semi-continuous incinerator	kg-NOx/t	1.055	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226
Batch type incinerator	kg-NOx/t	1.137	1.918	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850
Gasification melting furnace	kg-NOx/t	1.238	1.213	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127
SOx																
Continuous incinerator	kg-SOx/t	0.555	0.539	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361
Semi-continuous incinerator	kg-SOx/t	0.627	1.141	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712
Batch type incinerator	kg-SOx/t	1.073	1.625	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714
Gasification melting furnace	kg-SOx/t	0.555	0.539	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361

Note: The data for 2000 were used for 2001 and subsequent years.
Reference: *General Survey of the Emissions of Air Pollutants* (MOE)

➢ ***CO***

For incinerators, the emission factors were established for each incinerator class based on the emission factors for individual facilities summarized in Japan Society for Atmospheric Environment (1996) as well as other reports. It is noted that while the Japan Society for Atmospheric Environment report subdivided the facilities by furnace type (e.g., stoker, fluidized bed, etc.), this report determined the emission factors for three classes of "Continuous", "Semi-continuous" and "Batch type" by taking the average weighted by incinerated amount for each furnace.

For gasification melting furnaces, the value for continuous stoker furnaces with a similar incineration method was used.

Table A 3-72 CO emission factors for municipal waste by type of incineration method

Furnace type	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Continuous incinerator	g-CO/t	557	557	555	554	554	553	553	553	553	553	554	554	554	554	554
Semi-continuous incinerator	g-CO/t	548	548	567	591	611	613	609	614	607	600	603	611	603	611	611
Batch type incinerator	g-CO/t	8,237	8,237	8,298	8,341	8,270	8,270	8,274	8,274	8,279	8,281	8,239	8,241	8,241	8,244	8,244
Gasification melting furnace	g-CO/t	567	567	567	567	567	567	567	567	567	567	567	567	567	567	567

Reference: Japan Society for Atmospheric Environment (1996), and others.

➢ ***NMVOCs***

For both incinerators and gasification melting furnaces, NMVOC emission factors were established by multiplying the CH_4 emission factors for each furnace type of each fuel type by "NMVOC/CH_4", the emission ratio for fuel type. The ratio was determined by using the reference materials by Japan Environmental Sanitation Center (1989) and Institute of Behavioral Science (1984), which estimated CH_4 and NMVOC emissions per unit calorific value.

Table A 3-73 NMVOC emission factors for municipal waste by type of incineration method

Furnace type	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Continuous incinerator	g-NMVOC/t	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Semi-continuous incinerator	g-NMVOC/t	7.8	7.8	8.5	2.2	2.4	2.4	2.3	2.4	2.3	2.3	2.3	2.4	2.3	2.4	2.4
Batch type incinerator	g-NMVOC/t	9.1	9.1	9.5	1.5	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2
Gasification melting furnace	g-NMVOC/t	NA	NA	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Reference: Japan Environmental Sanitation Center (1989), Institute of Behavioral Science (1984)

- ***Activity data***

For incinerators, the activity data used was the incineration amount for each facility type as calculated by multiplying the incineration amount of municipal waste by the incineration rate for each facility type. The incineration amount data were extracted from the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes (the Volume on Cyclical Use)* (MOE). The incineration rate was calculated by the data in the *Waste Treatment in Japan* (MOE).

For gasification melting furnaces, the activity data used was the amount incinerated in gasification melting furnaces, calculated from data in the *Waste Treatment in Japan* (MOE).

A3.1.5.1.b. Industrial Wastes Incineration (5.C.1.–)

- ***Estimation Method***

NO_X, CO, NMVOCs, and SO_X emissions from the specified sources were calculated by multiplying the incineration amount of industrial waste for each waste type by Japan's country-specific emission factors. These emissions are categorized following the methods given in chapter 7 based on incinerations either with or without energy recovery. The former emissions are reported in the Energy sector, while the latter are reported in the Waste sector.

- ***Emission factors***

➢ ***NO_X, SO_X***

An emission factor was established for each type of industrial solid waste using the emission amount and amount of treated industrial solid waste identified by the *General Survey of the Emissions of Air Pollutants*. The categories of incinerator types included: [1303: Waste incinerator (industrial solid waste; continuous system)] and [1304: Waste incinerator (industrial solid waste; batch system)]. The incinerator fuel covered the categories [23: Fuel Wood] and [54: Industrial solid waste]). The six types of industrial waste were "Paper/cardboard, wood", "Sludge", "Waste oil", "Plastics", "Textiles", and "Animal and vegetable residues/animal carcasses". Category [23: Sawn Timber] was used for "Paper/cardboard, wood", "Waste textiles", and "Animal and vegetable residues/animal carcasses", while category [54: Industrial waste] was used for "Sludge", "Waste oil", and "Waste plastics". However, no emission factor was set for the mixed burning of multiple waste types.

Table A 3-74 NO_X and SO_X emission factors for industrial waste by waste type

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NOx																
"Fuel Wood 23"	kg-NOx/t	1.545	1.312	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828
"Industrial Waste 54"	kg-NOx/t	0.999	1.158	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415
SOx																
"Fuel Wood 23"	kg-SOx/t	1.528	1.274	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118
"Industrial Waste 54"	kg-SOx/t	1.179	1.882	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352

Note: The data for 2000 were used for 2001 and subsequent years.
Reference: *General Survey of the Emissions of Air Pollutants* (MOE)

➢ ***CO***

Based on the emission factors for individual facilities summarized in Japan Society for Atmospheric Environment (1996) as well as other reports, an emission factor was established for each type of industrial solid waste. The six types of industrial waste were “Paper/cardboard, wood”, “Sludge”, “Waste oil”, “Plastics”, “Textiles”, and “Animal and vegetable residues/animal carcasses”. The emission factor for “Wood” was used for “Waste textiles” and “Animal and vegetable residues/animal carcasses”, for which there are no measurements. No emission factor was set for the mixed burning of multiple waste types.

Table A 3-75 CO emission factors for industrial waste by waste type

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Paper/cardboard, wood	g-CO/t	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334
Waste oil	g-CO/t	127	127	127	127	127	127	127	127	127	127	127	127	127	127	127
Plastics	g-CO/t	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790
Sludge	g-CO/t	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285
Textile	g-CO/t	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334
Animal and vegetable residues/ animal carcasses	g-CO/t	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334

Reference: Japan Society for Atmospheric Environment (1996) and others

➢ ***NMVOCs***

NMVOC emission factors were established by multiplying the CH_4 emission factors for each furnace type of each fuel type by “NMVOC/CH_4”, the emission ratio for fuel type. The ratio was determined by using the reference materials by Japan Environmental Sanitation Center (1986) and Institute of Behavioral Science (1984), which estimated CH_4 and NMVOC emissions per unit calorific value.

Table A 3-76 NMVOC emission factors for industrial waste by waste type

Item	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Paper/cardboard, wood	g-NMVOC/t	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
Waste oil	g-NMVOC/t	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Plastics	g-NMVOC/t	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40
Sludge	g-NMVOC/t	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61
Textile	g-NMVOC/t	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
Animal and vegetable residues/ animal carcasses	g-NMVOC/t	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48

Reference: Japan Environmental Sanitation Center (1989), Institute of Behavioral Science (1984)

- ***Activity data***

The activity data used the incineration amount data for each type of waste extracted from the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes (the Volume on Cyclical Use)* (MOE).

A3.1.5.1.c. Open Burning of Industrial Waste (5.C.2.–)

- ***Estimation Method***

NO_X, CO, NMVOCs, and SO_X emissions from the specified sources were calculated by multiplying the amount of industrial waste burned in the open air for each waste type by Japan’s country-specific emission factors.

- ***Emission factors***

As no knowledge is obtained for making it possible to set emission factors specific to open burning of waste in Japan, the country-specific emission factors for industrial waste incineration were substituted. For detail, the NO_X, CO, NMVOC and SO_X emission factors for plastics incineration as for plastics burned in the open air, and those for wood incineration as for other waste burned in the open air were adopted respectively. See also section "A3.1.5.1.b. Industrial Wastes Incineration (5.C.1.–)".

- ***Activity data***

The amount of industrial waste burned in the open air obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE) was used as the activity data in and after FY1996. As for the past activity data from FY1990 to 1995 for which the survey data is not available, the data of FY1996 was uniformly used as a substitute since there are no other appropriate way to estimate.

A3.1.5.1.d. Incineration in Conjunction with Use of Waste as Fuel and Raw Material (1.A.-)

- ***Estimation Method***

CO and NMVOC emissions from this source were estimated by multiplying the amounts of fuel/raw material burned for each waste type by a Japan-specific emission factor. These emissions are reported in Energy sector (1.A.) following the methodologies given in chapter 7 (Waste).

- ***Emission Factors***

➢ ***CO***

The CO emission factors were established by converting the emission factors (energy unit basis) by furnace type, which are used for estimating emissions from 1.A Stationary Sources, to weight-based emission factors by multiplying the calorific values in the *General Energy Statistics*.

Table A 3-77 CO emission factors from incineration in conjunction with use of waste as fuel and raw material

Application	Units	Waste oil	RDF	RPF	Waste tires (FY2004 and before)	Waste tires (FY2005 and after)	Plastics	Plastics (Liquefaction)	Wood
Simple incineration	kg-CO/t	0.13	1.79	1.79	1.79	1.79	-	-	-
Boilers	kg-CO/t	0.052	0.24	0.39	0.28	0.44	0.39	0.034	3.64
Cement kilns	kg-CO/t	-	19.8	32.2	23.0	36.5	32.2	-	-
Other furnaces	kg-CO/t	0.052	0.24	0.39	0.28	0.44	-	-	-
Pyrolysis furnaces	kg-CO/t	-	-	-	0.021	0.033	-	-	-
Gasification	kg-CO/t	-	-	-	0.015	0.024	-	-	-

➢ ***NMVOCs***

Just as for the incineration of municipal solid waste and industrial waste, emission factors were determined from documents with estimates of emissions of CH_4 and NMVOCs per unit calorific values.

Table A 3-78 NMVOC emissions factors from incineration in conjunction with use of waste as fuel and raw material

Application	Units	Waste oil	RDF	RPF	Waste tires (FY2004 and before)	Waste tires (FY2005 and after)	Plastics	Plastics (Liquefaction)	Wood
Boilers	kg-NMVOC/t	0.015	0.00027	0.00043	0.00031	0.00049	0.00043	0.010	0.12
Cement kilns	kg-NMVOC/t	-	-	0.043	0.031	0.049	0.043	-	-
Pyrolysis furnaces	kg-NMVOC/t	-	-	-	0.0051	0.0080	-	-	-
Gasification	kg-NMVOC/t	-	-	-	0.0187	0.0297	-	-	-

- ***Activity data***

Same activity data that were used when estimating CH_4 emissions for the use of waste as fuel and raw material were used.

A3.1.6 Other sectors

A3.1.6.1. Smoking (6.–: CO, NMVOCs)

a) Methodological Issues

1) CO

- ***Estimation Method***

CO emissions were calculated by multiplying the number of cigarettes sold by Japan's country-specific emission factor.

$$E_{CO} = AD \times EF$$

E_{CO} : CO emissions from smoking
AD : Number of cigarettes sold
EF : Emission factor [g-CO/cigarette]

- ***Emission factors***

The emission factor (0.055 [g-CO/cigarette]) was provided by Japan Tobacco Inc.

- ***Activity data***

The number of cigarettes sold published in the *Statistical Data of Cigarettes* on the Tobacco Institute of Japan website (https://www.tioj.or.jp) was used for activity data.

2) NMVOCs

- ***Estimation Method***

NMVOC emissions were calculated by multiplying the number of cigarettes sold by Japan's country-specific emission factor.

$$Enmvoc = \sum_{i,j} AD_{i,j} \times EF_{i,j} \times 10^{-12}$$

Enmvoc	: NMVOC emissions from smoking [t-NMVOC]
$AD_{i,j}$	: Number of cigarettes sold
$EF_{i,j}$	: Emission factor [μg-NMVOC/cigarette]
i	: Type of cigarette (cigarettes, heated cigarettes)
j	: Type of cigarette smoke (mainstream smoke, sidestream smoke)

- ***Emission factors***

For the emission factor for cigarettes, a total of the average amount of chemical substances designated in the *Expanded VOC Emission Inventory* occurring from seven cigarette brands, shown in *FY1999-2000 Component Analysis of Tobacco Smoke (Summary)* (MHLW), was used. (mainstream smoke: 1,287 [μg-NMVOC/cigarette], sidestream smoke: 8,294 [μg-NMVOC/cigarette]).

For the emission factor for heated cigarettes, a total of the average amount of chemical substances designated in the *Expanded VOC Emission Inventory* occurring from six major heated cigarette brands sold domestically was used. (mainstream smoke: 189 [μg-NMVOC/cigarette]).

- ***Activity data***

For cigarettes, the number of cigarettes sold published in the *Statistical Data of Cigarettes* on the

Tobacco Institute of Japan website (https://www.tioj.or.jp) was used for activity data. For heated cigarettes, the activity data was established as follows.

Table A 3-79 Methods of establishing activity data for heated cigarettes

FY	Methods of establishing activity data
1990-2013	Based on interview results with the Tobacco Institute of Japan, it was assumed that there were no sales of heated cigarettes, and therefore activity data was set at zero.
2014-2019	Estimated by interpolating between the number of cigarettes sold in FY2013 and FY2020 from the Statistical Data of Heated Cigarettes (the Tobacco Institute of Japan).
2020-	The number of cigarettes sold in the Statistical Data of Heated Cigarettes (the Tobacco Institute of Japan) was used.

References

1. IPCC, *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, 1997.
2. IPCC, *Good Practice Guidance and Uncertainty Management in national Greenhouse Gas Inventories,* 2000.
3. IPCC, *Good Practice Guidance for Land Use, Land Use Change and Forestry,* 2003.
4. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
5. IPCC, *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2019.
6. European Environment Agency, *EMEP/EEA Air Pollutant Emission Inventory Guidebook.*
7. Agency for Natural Resources and Energy, *Study on the total system for prevention of HC-Vapor in petroleum industries*, 1975.
8. Agency for Natural Resources and Energy, *General Energy Statistics.*
9. Agency for Natural Resources and Energy, *Current Survey of Production Concerning Gas Industry.*
10. Ministry of Economy, Trade and Industry and Ministry of the Environment, *Estimation Methods for Releases from Sources not Required to Report under PRTR (Pollutant Release and Transfer Register)*, 2012.
11. Ministry of Economy, Trade and Industry, *Statistics of Rubber Products.*
12. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics - chemical industry.*
13. Ministry of Economy, Trade and Industry, *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*.
14. Ministry of Economy, Trade and Industry, *Yearbook of Mineral Resources and Petroleum Products Statistics.*
15. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics.*
16. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics - Paper, Printing, Plastics Products and Rubber Products Statistics.*
17. Ministry of Economy, Trade and Industry, Y*earbook of Current Production Statistics - Textiles and Consumer Goods Statistics.*
18. Ministry of Economy, Trade and Industry, *VOC Voluntary Action Plan and Achievement Report.*
19. Ministry of Economy, Trade and Industry, *Census of Manufactures.*
20. Ministry of Economy, Trade and Industry and Ministry of the Environment, *Compilation Results of Emissions and Transfers Reported under PRTR by Chemical Substance.*
21. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Air Transport.*
22. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Motor Vehicle Transport.*
23. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Port.*
24. Ministry of Agriculture, Forestry and Fisheries, *Food Industry Trend Survey.*
25. National Tax Agency, *Liquor Production and Stocks.*

26. Ministry of the Environment, *Development Research of New Testing Methodology for Emission Gas from Vehicle (Motorcycle), FY2002*.
27. Ministry of the Environment, *Development Research of New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle), FY2003*.
28. Ministry of the Environment, *Studies to develop the national emissions inventory for volatile organic compounds (VOC), FY 2011*, (2012).
29. Ministry of the Environment, *The National Emission Inventory for Volatile Organic Compounds (VOC).*
30. Ministry of the Environment, *[Expanded] The National Emission Inventory for Volatile Organic Compounds (VOC)*.
31. Ministry of the Environment, *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes (the Volume on Cyclical Use).*
32. Ministry of the Environment, *Report on Survey of Organizations in Industrial Waste Administration*.
33. Ministry of the Environment, *General Survey of the Emissions of Air Pollutants.*
34. Ministry of the Environment, *Survey for Consideration Estimation of Emission Factors and Total Emissions of Exhaust Gas from Automobiles.*
35. Ministry of the Environment, *Waste Treatment in Japan.*
36. Environmental Agency, Air Quality Management Bureau, *Report of Research on Measures for Emission Sources of Small Facilities*, 1996.
37. Japan Meteorological Agency, *Weather Statistics Information.*
38. Ministry of Health, Labour and Welfare, *The Survey on Usage of Dry-cleaning Solvent.*
39. Ministry of Health, Labour and Welfare, *Statistics of Production by Pharmaceutical Industry.*
40. Ministry of Health, Labour and Welfare, *Japanese Pharmacopoeia.*
41. Ministry of Internal Affairs and Communications, *Survey of Household Economy*.
42. Ministry of Internal Affairs and Communications, *Household Survey*.
43. Ministry of Internal Affairs and Communications, *Population, vital statistics and number of households survey based on the Resident Registration System*.
44. Ministry of Internal Affairs and Communications, *Consumer Price Index (2020 standard)*.
45. National Institute for Environmental Studies, *Survey of Actual Use of Methyl Bromide*, 1998.
46. Energy Data and Modeling Center, *Handbook of Energy & Economic Statistics in Japan.*
47. Institute of Behavioral Science, *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions*, 1984.
48. Institute of Behavioral Science, *Basic Study on HC Sources*, 1987.
49. Institute of Behavioral Science, *Report of the Research on the Indirect Greenhouse Gas Emission Inventory in FY1996*, 1997.
50. Institute of Behavioral Sciences *Business Report on Grid Database on Atmospheric Pollutants Emissions,* 2000.
51. Institute of Behavioral Science, *Research Report on VOC emissions from private sector*, March 2010.

52. Japan Adhesive Industry Association, *Current Survey Report on Adhesive.*
53. Japan Environmental Sanitation Center, *Report on Screening Survey Regarding Measures to Counter Global Warming (Atmospheric Management)*, 1989.
54. Japan Society for Atmospheric Environment, *Report on Emission Factor Results for Combustion Facilities*, 1996. (The English translation was published in 1997.)
55. Tobacco Institute of Japan, *Statistical Data of Cigarettes*. (https://www.tioj.or.jp/).
56. Environmental Research and Control Center, *Regulation of Total NO_X Emission Manual (New Edition)*, 2000.
57. Automobile Inspection and Registration Information Association (AIRIA), *Statistics of AIRIA/ Number of Motor Vehicles.*
58. Ocean Policy Research Foundation, *Survey Report on influence of VOC emissions from vessels in FY2005*, March 2006.
59. Ocean Policy Research Foundation, *Report on Estimation of Improvement Effect of Air Environment by Establishing Emission Control Area in FY2011*, March 2012.
60. Sekiyu Tsushinsha, *Sekiyu shiryo.*
61. Japan Industrial Conference on Cleaning (JICC), *Commission report on manual for promoting voluntary approach for emission control of VOC in FY2005.*
62. Japan Natural Gas Association, *Natural Gas Data Yearbook.*
63. Japan Paint Manufacturers Association, *Summary of estimation for the current status of VOC emissions from painting.*
64. Fuji Keizai CO., Ltd, *Cosmetic Products Marketing Directory.*
65. Japan Auto Chemical Industry Association, *Research report on the current status of auto chemical manufacturing.*
66. Yokota, H., Ueno, H., Ishii, K., Utida, Y. and Akiyama, K., *Volatile organic compound losses during refueling of passenger cars*, Journal of Japan Society for Atmospheric Environment, Vol.47, No.5, pp.231-239, 2012.
67. Yokota, H., Ueno, H., Ishii, K., Uchida, Y., and Akiyama, K., *Characteristics of Gasoline Evaporation Composition and VOCs Emission Estimates from Gasoline Passenger Cars at Refueling*, Yearbook of Tokyo Metropolitan Research Institute for Environmental Protection, 2011.
68. Petroleum Association of Japan, *Petroleum Industry in Japan 2015*, 2015.
69. Petroleum Association of Japan, *Oil Product Sales Summary by Prefecture.*
70. Japan Cleaning Chemicals Association, *Shipping Weight of Solvents*.
71. Aerosols Industry Association of Japan, *Survey of Production Amounts of Aerosols*.
72. Ministry of Economy, Trade and Industry, *Report on the Promotion of Chemical Substance Safety Measures (The Survey on Methods for Emission Estimation for Below-threshold Entities and Methods for Emission Estimation for Ozone-depleting Substances and Low-content Substances)*.
73. Japan Automobile Manufacturers Association, *Monthly Report Statistics of Vehicles.*
74. Japan Automobile Manufacturers Association, *Survey of Motorcycle Market Trends.*
75. United States Environmental Protection Agency, *Compilation of Air Pollutant Emission Factors*

(AP-42), Volume 1, 4th Edition, 1985.

76. Society of Automotive Engineers of Japan, Inc., *Technology of engine in vehicle for environment*, 2008.

Annex 4. The National Energy Balance for the Most Recent Inventory Year

A4.1. Discrepancies between the figures reported in the CRF tables and the IEA statistics

In the report of the individual review of the greenhouse gas inventory of Japan submitted in 2006 (FCCC/ARR/2006/JPN), which was conducted from January to February 2007, the ERT (Expert Review Team) recommended that in the next NIR submission Japan provide a clear explanation for the discrepancies found between the data in the CRF tables and the IEA statistics. In response to this recommendation, Japan has provided the detailed information on the Annex of the NIR regarding the discrepancies of the FY2005 data between the CRF tables and the IEA statistics. Also, in the individual review report of the GHG inventory of Japan submitted in 2010 (FCCC/ARR/2010/JPN), the updating of this information with the latest available inventory year data was recommended by the ERT. In response to this recommendation, the detailed information regarding the discrepancies of the reported value between the CRF and the IEA statistics is hereby updated with the FY2020 actual data. The IEA statistical data used in the explanation were extracted from the *World Energy Statistics*, July 2022 Edition, OECD/IEA.

In summary, these discrepancies occurred; because (a) the CRF tables and the IEA statistics treat international aviation and marine bunker fuels (bonded exports) differently, and (b) fuel oil A is classified in a different way. The figures for imports and exports of fuels reported in the CRF tables include the bonded exports, whereas the figures for imports and exports of fuels in the IEA statistics do not. With respect to fuel oil A, Japan includes it under "heavy fuel oil" in its energy balances but reports it to the IEA under gas/diesel oil according to the classifications used in Europe and the United States.

According to Japanese definition, fuel oil A has a flash point of more than 60 °C, kinematic viscosity of below 20 mm^2/s, carbon residue content of below 4% and sulfur content of below 2.0 %. Fuel oil B has a flash point of more than 60 °C, kinematic viscosity of below 50 mm^2/s, carbon residue content of below 8% and sulfur content of below 3.0 %. Fuel oil B is rarely used nowadays in Japan, for this reason, fuel oil B is treated as "fuel oil B/C" together with fuel oil C in Japanese statistics. Fuel oil C has a flash point of more than 70 °C, kinematic viscosity of less than 1,000 mm^2/s and sulfur content of less than 3.5%.

In addition, the preliminary figures of reporting year (y) based on the *General Energy Statistics* are used for reporting to the IEA in fall of the next fiscal year (y+1), which starts in April and ends in March; on the other hand, the final figures based on the *General Energy Statistics* are used for reporting to the UNFCCC since the final figures are available in the CRF submission period in spring of the next year (y+2). Therefore, there are discrepancies of the reported values between the IEA statistics (preliminary figures) and the CRF tables (final figures) at the time of review under the UNFCCC in summer of the next year (y+2). The preliminary figures reported to the IEA are updated to the final figures in fall of the next year (y+2) and are published in the IEA statistics in summer of the year after next (y+3); the discrepancies between the data in the CRF tables and the IEA statistics are dissolved at the time, except for discrepancies resulted from the definitions or different estimation methods mentioned below.

Further explanations are provided below for each of the discrepancies noted by the ERT.

a) Differences in exports of jet kerosene and residual fuel oil

<ERT findings on FCCC/ARR/2006/JPN>

Exports of liquid fuels are between 40 and 70 per cent lower in the IEA data; the differences are due in particular to differences in the figures for jet kerosene and residual fuel oil, with the largest errors occurring in recent years.

<Explanation 1: Exports of jet kerosene>

The figures for jet kerosene exports reported in the CRF tables are different from those in the IEA statistics because the CRF figures include bonded exports whereas the export figures in the IEA statistics do not. The IEA statistics accounted the consumption of jet kerosene by international aviation bunkers as an aggregate of the bonded exports and imports. (See Chapter 3, for bonded exports and imports.)

Table A 4-1 Exports of jet kerosene in FY2020 (reference)

CRF Table 1.A(b)
Exports: $3,780.03\times10^3$ kL
IEA statistics
Exports: 747.69×10^3 t [$3,780.03\times10^3$ kL (Exports)-$2,825.62\times10^3$ kL (Bonded exports) = 954.41×10^3 kL. 954.41×10^3 kL×0.7834 t/kL (density) = 747.69×10^3 t] <Remarks> International aviation: $2,636.60\times10^3$ t [$2,825.62\times10^3$ kL (bonded exports) + 539.96×10^3 kL (bonded imports) = $3,365.58\times10^3$ kL. $3,365.58\times10^3$ kL × 0.78 t/kL (density) = $2,636.60\times10^3$ t]

<Explanation 2: Exports of residual fuel oil>

The figures for exports of residual fuel oil reported in the CRF tables are different from those in the IEA statistics because the CRF figures for residual fuel oil include the bonded exports, whereas the export figures for fuel oil in the IEA statistics do not. The bonded exports portion of the fuel oil was reported in the IEA statistics as an aggregate of the bonded exports and imports of fuel oil under international marine bunkers. (See Chapter 3, for bonded exports and imports.)

Further, the figures for exports of residual fuel oil reported in the CRF include fuel oil A, whereas the figures reported under fuel oil in the IEA statistics do not. The IEA reports fuel oil A together with gas oil under gas/diesel oil in its statistics. Because fuel oil A, which is treated as a fuel oil that is distinguished from diesel oil in Japan, is grouped together with diesel oil in Europe and the United States, the fuel oil A data have been included in the diesel oil data in Japan’s report to the IEA.

Table A 4-2 Exports of residual fuel oil in FY2020 (reference)

CRF Table 1.A(b)
Exports: 8,052.17×10³ kL [1,292.05×10³ kL (fuel oil A) + 0.00×10³ kL (fuel oil B) + 6,760.13×10³ kL (fuel oil C for general use) + 0.00×10³ kL (fuel oil C for power generation) = 8,052.17×10³ kL]
IEA statistics
Exports: 1,354.08×10³ t [0.00×10³ kL (fuel oil B) +6,760.13×10³ kL (fuel oil C for general use) + 0.00×10³ kL (fuel oil C for power generation) -5,255.60×10³ kL (bonded exports of fuel oils B and C) =1,504.53×10³ kL. 1,504.53×10³ kL × 0.9000 t/kL (density) = 1,354.08×10³ t] <Remarks> International marine bunkers: 5,255.60×10³ t [5,255.60×10³ kL (bonded exports of fuel oils B and C) + 0.00×10³ kL (bonded imports of fuel oils B and C) = 5,255.60×10³ kL. 5,255.60×10³ kL × 0.9000 t/kL (density) = 4, 730.04×10³ t]

b) Differences in imports of jet kerosene and gas/diesel oil

<ERT findings on FCCC/ARR/2006/JPN>

Imports of jet kerosene have been reported to the IEA, but are shown as zero in the CRFs for the years 1990–1997, while imports of gas/diesel oil are systematically about 80 per cent lower in the CRF tables than in the IEA figures.

<Explanation 1: Imports of jet kerosene>

The figures for jet kerosene imports reported in the CRF tables are different from those in the IEA statistics because the CRF figures are the sums of imports including bonded imports and bonded exports while the IEA statistics figures are the imports including bonded imports. (See Chapter 3, for bonded exports and imports.)

Table A 4-3 Imports of jet kerosene in FY2020 (reference)

CRF Table 1.A(b)
Imports: 3,444.20×10³ kL [78.62×10³ kL (imports) +539.96×10³ kL (bonded imports) +2,825.62×10³ kL (bonded exports) =3,444.20×10³ kL]
IEA statistics
Imports: 484.59×10³ t [78.62×10³ kL (imports) + 539.96×10³ kL (bonded imports) =618.58×10³ kL. 618.58×10³ kL × 0.7834 t/kL (density) = 484.59×10³ t]

<Explanation 2: Imports of gas/diesel oil>

The figures for imports of gas/diesel oil reported in the CRF tables are different from those in the IEA statistics, because the CRF figures are the sums of imports (including bonded imports) and bonded exports of diesel oil, which excludes fuel oil A, while the figures for imports of gas/diesel oil in the IEA statistics are the aggregate of imports of diesel oil and fuel oil A, both of which included the bonded imports.

Table A 4-4 Imports of gas/diesel oil in FY2020 (reference)

CRF Table 1.A(b)
Imports: 1,465.53×10^3 kL [1,448.99×10^3 kL (imports of gas/diesel oil) + 5.00×10^3 kL (bonded imports of gas/diesel oil) + 11.54×10^3 kL (bonded exports of gas/diesel oil) = 1,465.53×10^3 kL]
IEA statistics
Imports: 1,322.79×10^3 t [1,448.99×10^3 kL (imports of gas/diesel oil) + 5.00×10^3 kL (bonded imports of gas/diesel oil) + 115.16×10^3 kL (imports of fuel oil A) + 0.00×10^3 kL (bonded imports of fuel oil A) = 1,569.15×10^3 kL. 1,569.15×10^3 kL × 0.8430 t/kL (density) = 1,322.79×10^3 t]

c) Differences in imports of coking coal

<ERT findings on FCCC/ARR/2006/JPN>

Furthermore, the figures for imports of coking coal are systematically lower in the CRF tables than those in the IEA statistics, with the largest discrepancy occurring in 1999.

<Explanation: Imports of coking coal>

The imported amounts of coking coal in the CRF and the IEA statistics in physical units are basically the same.

Table A 4-5 Imports of coking coal in FY2020 (reference)

CRF Table 1.A(b)
Imports: 42,287.64×10^3 t
IEA statistics
Imports: 42,287.64×10^3 t

d) Differences in stock changes in liquid and gaseous fuels

<ERT findings on FCCC/ARR/2006/JPN>

In addition, the data on stock changes are not consistent for liquid and gaseous fuels.

It should be noted that the plus-minus signs of stock changes in the CRF differ from those of the IEA. The changes in the CRF are defined as plus for stock increase and as minus for stock release, while the changes in the IEA are defined as minus for stock increase and as plus for stock release.

<Explanation 1: Changes in crude oil stock>

The difference between the CRF table and the IEA statistics with respect to changes in crude oil stock occurred because the figures reported in the CRF were calculated using the stock of crude oil after customs clearance (or more precisely, after inspection in the presence of customs officers). The stock changes reported in the IEA statistics were calculated based on stock that included crude oil carried by oil tankers in Japanese territorial waters, but which was yet to clear customs as well as the crude oil in the national stockpile. This discrepancy arose because the UNFCCC and the IEA had different objectives.

Table A 4-6 Changes in crude oil stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: -2,442.34×10^3 kL [-(2,621.96×10^3 kL (crude oil for refining) + -179.62×10^3 kL (crude oil for power generation)) = -2,442.34×10^3 kL]
IEA statistics
Stock changes: 3,046.33×10^3 t [(12,195.01×10^3 kL (opening stock) +46,746.00×10^3 kL (opening national stockpile) +1,192.00×10^3 kL (opening stock carried by oil tankers) -687.00×10^3 kL (opening joint stockpile with Abu Dhabi)) - (9,573.05×10^3 kL (closing stock) +46,267.00×10^3 kL (closing national stockpile) +661.00×10^3 kL (closing stock carried by oil tankers) -618.00×10^3 kL (closing joint stockpile with Abu Dhabi)) =3,562.96×10^3 kL. 3,562.96×10^3 kL × 0.8550 t/kL (density) =3,046.33×10^3 t]

<Explanation 2: Changes in NGL stock>

Stock changes concerning NGL in FY2020 were reported as 0 in the CRF and the IEA Statistics. The NGL stock changes reported in the IEA statistics were 0 because the NGL stock figure in the Monthly Oil Statistics (MOS) of the IEA was 0. This discrepancy resulted from the direction given by the IEA that the figures in the IEA statistics must be consistent with the MOS figures. Furthermore, the MOS requires figures for opening stock and closing stock, but Japan does not collect such statistical data for NGL. As a result, Japan reported 0 values to the IEA for both opening stock and closing stock data for the MOS. Due to lack of statistical data for stock changes in NGL, the estimated value calculated as a difference between supply and consumption amount is reported as stock change in the CRF tables. The estimated value is 0 in FY2020.

<Explanation 3: Changes in gasoline stock>

The figures for stock of gasoline reported in the CRF tables are changes of gasoline stock only, whereas the values relating to the stock of gasoline in the IEA statistics are changes of gasoline stock plus national stockpile minus other gasoline stock. Other gasoline stock is reported as stock change of white spirit in the IEA statistics.

Table A 4-7 Changes in gasoline stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: 120.41×10^3 kL
IEA statistics
Stock changes: -91.46×10^3 t [(1,870.44×10^3 kL (opening stock) +585.42×10^3 kL (opening national stockpile) -7.11×10^3 kL (opening gasoline inventories for others (*Monthly Report of Current Production Statistics*, METI)) -7.66×10^3 kL (opening gasoline inventories for others (*Monthly Report of Mineral Resources and Petroleum Products Statistics*, METI)) - (1,990.85×10^3 kL (closing stock) +585.00×10^3 kL (closing national stockpile) -6.99×10^3 kL (closing gasoline inventories for others (*Monthly Report of Current Production Statistics*, METI)) -3.68×10^3 kL (closing gasoline inventories for others (*Monthly Report of Mineral Resources and Petroleum Products Statistics*, METI)) = -124.10×10^3 kL. -124.10×10^3 kL × 0.7370 t/kL (density) = -91.46×10^3 t]

<Explanation 4: Changes in jet kerosene stock>

The figures for changes in jet kerosene stock reported in the CRF tables are basically the same as the figures in the IEA statistics.

Table A 4-8 Changes in jet kerosene stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: -128.59×10^3 kL
IEA statistics
Stock changes: 100.74×10^3 t [815.74×10^3 kL (opening stock) -687.16×10^3 kL (closing stock) =128.59×10^3 kL. 128.59×10^3 kL × 0.7834 t/kL (density) =100.74×10^3 t)]

<Explanation 5: Changes in kerosene stock>

The figures reported in the CRF tables are changes in kerosene stock only, while the figures in the IEA statistics are the sum of the changes in kerosene stock and national stockpile of kerosene.

Table A 4-9 Changes in kerosene stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: 39.34×10^3 kL
IEA statistics
Stock changes: -31.75×10^3 t [(1,445.01×10^3 kL (opening stock) +317.33×10^3 kL (opening national stockpile)) - (1,484.35×10^3 kL (closing stock) +317.00×10^3 kL (closing national stockpile)) = -39.01×10^3 kL. -39.01×10^3 kL × 0.8140 t/kL (density)= -31.75×10^3 t]

<Explanation 6: Changes in gas/diesel oil stock>

The figures for gas/diesel stock reported in the CRF tables did not include stock changes in fuel oil A, while the figures in the IEA statistics included stock changes in fuel oil A and change of national stockpile of gas/diesel oil and fuel oil A.

Table A 4-10 Changes in gas/diesel oil stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: 68.76×10^3 kL
IEA statistics
Stock changes: -68.62×10^3 t [(1,410.07×10^3 kL (gas/diesel oil, opening stock) +712.13×10^3 kL (fuel oil A, opening stock) +374.16×10^3 kL (gas/diesel oil, opening national stockpile) +152.18×10^3 kL (fuel oil A, opening national stockpile)) - (1,478.83×10^3 kL (gas/diesel oil, closing stock) +712.33×10^3 kL (fuel oil A, closing stock) +374.00×10^3 kL (gas/diesel oil, closing national stockpile) +152.00×10^3 kL (fuel oil A, closing national stockpile)) = -68.62×10^3 kL. -68.62×10^3 kL × 0.8430 t/kL (density) =-57.85×10^3 t]

<Explanation 7: Changes in residual fuel oil stock>

The figures for residual fuel oil stock reported in the CRF tables were different from those in the IEA statistics because the CRF figures included changes in fuel oil A stock, whereas stock change data under fuel oil in the IEA statistics did not include fuel oil A. (See the explanation for the gas/diesel oil data above.)

Table A 4-11 Changes in residual fuel oil stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: 17.32×10^3 kL [-0.21×10^3 kL (fuel oil A) + 0.00×10^3 kL (fuel oil B) +-17.12×10^3 kL (fuel oil C for general use) + 0.00×10^3 kL (fuel oil C for power generation) = 17.32×10^3 kL]
IEA statistics
Stock changes: -15.41×10^3 t [$1,059.71\times10^3$ kL (fuel oil B and C, opening stock) $-1,076.83\times10^3$ kL (fuel oil B and C, opening stock) = -17.12×10^3 kL. -17.12×10^3 kL × 0.9000 t/kL (density) = -15.41×10^3 t]

<Explanation 8: Changes in LPG stock>

The figures for changes in LPG stock reported in the CRF tables differ from those reported in IEA statistics, because the LPG stock in IEA includes the national stock.

Table A 4-12 Changes in LPG stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: -44.45×10^3 t
IEA statistics
Stock changes: 45.45×10^3 t [($1,610.56\times10^3$ t (opening stock) + $1,395.00\times10^3$ t (opening national stockpile) - ($1,566.11\times10^3$ t (closing stock) + $1,394.00\times10^3$ t (closing national stockpile)) = 45.45×10^3 t]

<Explanation 9: Changes in naphtha stock>

The figures for changes in naphtha stock reported in the CRF tables are the same as the figures in the IEA statistics.

Table A 4-13 Changes in naphtha stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: -63.23×10^3 kL
IEA statistics
Stock changes: 46.60×10^3 t [$1,424.28\times10^3$ kL (opening stock) $-1,361.05\times10^3$ kL (closing stock) = 63.23×10^3 kL. 63.23×10^3 kL × 0.7370 t/kL (density) = 46.60×10^3 t]

<Explanation 10: Changes in bitumen stock>

The figures for changes in bitumen stock reported in the CRF tables were slightly different from the figures reported under bitumen in the IEA statistics because the bitumen data in the CRF tables included asphalt and other heavy oil and paraffin products. The IEA statistics reported figures for only asphalt under bitumen, and the figures for other heavy oil and paraffin products reported in the CRF tables under bitumen were included in the figures reported under paraffin waxes in the IEA statistics.

Table A 4-14 Changes in bitumen stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: -61.70×10^3 t
IEA statistics
Stock changes in bitumen: 62.26×10^3 t [223.96×10^3 t (opening stock) -161.70×10^3 t (closing stock) = 62.26×10^3 t]

<Explanation 11: Changes in lubricants stock>

The figures for changes in lubricants stock reported in the CRF tables are basically the same as the figures in the IEA statistics.

Table A 4-15 Changes in lubricants stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: -53.93×10^3 kL
IEA statistics
Stock changes: 48.05×10^3 t [504.52×10^3 kL (opening stock) - 450.60×10^3 kL (closing stock) = 53.93×10^3 kL. 53.93×10^3 kL × 0.8910 t/kL (density) = 48.05×10^3 t]

<Explanation 12: Changes in petroleum coke stock>

The figures for changes in petroleum coke stock reported in the CRF tables are the same as the figures in the IEA statistics.

Table A 4-16 Changes in petroleum coke stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: 0.52×10^3 t
IEA statistics
Stock changes: -0.52×10^3 t [10.09×10^3 t (opening stock) -10.61×10^3 t (closing stock) = -0.52×10^3 t]

<Explanation 13: Changes in refinery feedstock stock>

The figures for changes in refinery feedstock stock reported in the CRF were different from those in the IEA statistics because the IEA statistics included the figures for stock changes in slack wax and slack coke in addition to the semi-refined products reported in the CRF tables.

The changes in slack wax and coke stocks were not reported in the CRF tables because the both items were solids used as raw materials for the production of paraffin and petroleum coke, and unlikely to be returned to oil refining processes. In addition, shipments of paraffin and petroleum coke produced using slack wax and slack coke were separately accounted for.

Table A 4-17 Changes in refinery feedstock stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: -709.57×10^3 kL [39.72×10^3 kL (slack gasoline) + 145.21×10^3 kL (slack kerosene) + 39.24×10^3 kL (slack diesel oil or gas oil) + 485.40×10^3 kL (slack fuel oil) + 0.00×10^3 kL (feedstock oil for refinery and mixing) = -709.57×10^3 kL]
IEA statistics
Stock changes: 608.18×10^3 t [(2,243.84×10^3 kL (slack gasoline, opening stock) - 2,204.12×10^3 kL (slack gasoline, closing stock)) × 0.7370 t/kL (density) + (596.12×10^3 kL (slack kerosene, opening stock) - 450.91×10^3 kL (slack kerosene, closing stock)) × 0.8140 t/kL (density) + (802.25×10^3 kL (slack diesel oil or gas oil, opening stock) -763.00×10^3 kL (slack diesel oil or gas oil, closing stock)) × 0.8430 t/kL (density) + (4,141.55×10^3 kL (slack fuel oil, opening stock) - 3,701.22×10^3 kL (slack fuel oil, closing stock)) × 0.9000 t/kL (density) + (458.17×10^3 kL (slack lubricant, opening stock) -413.10×10^3 kL (slack lubricant, closing stock)) × 0.8910 t/kL (density) + (42.37×10^3 kL (slack wax, opening stock) -33.79×10^3 kL (slack wax, closing stock)) × 0.8160 t/kL (density) + (21.67×10^3 kL (slack coke, opening stock) -38.45×10^3 kL (slack coke, closing stock)) × 0.9436 t/kL (density) = 608.18×10^3 t]

<Explanation 14: Changes in natural gas stock>

The figures for changes in natural gas stock (imported liquefied natural gas (LNG) and domestic natural gas) reported in the CRF tables were different from those in the IEA statistics because of the differences in the methods used for estimation of changes in the imported LNG stock and the treatment of changes in city gas stock. The source figures for the domestic natural gas stock were the same for reporting of the CRF and the IEA statistics because the statistical data existed in Japan. The estimation method for imported LNG were different between the CRF tables and the IEA statistics. The figures for stock changes reported to the CRF tables were the difference between the stock of imported LNG at the end of the previous fiscal year and the stock at the end of the current fiscal year, both from national statistics. On the other hand, the figures for stock changes reported to the IEA includes the inventory change calculated as the difference between the inventory volume at the end of the previous year and the inventory volume at the end of the current year in the *Electric Power Statistics* and the *Current Survey of Production Concerning Gas Industry*. Note that the figures reported to the IEA until FY2019 were the difference between the stock of imported LNG at the end of the previous fiscal year and the stock at the end of the relevant fiscal year, with the former calculated as one-half of the LNG import in March of the previous year, and the latter as one-half of the LNG import in March of the relevant year. One reason for reporting the estimated data to IEA was that the national statistics did not catch stocks of LNG in the past and the stock data have been estimated in this way since then. The figures for stock of natural gas reported in the CRF tables include the city gas stock, whereas the figures for stock of natural gas in the IEA statistics do not.

Table A 4-18 Changes in natural gas stock in FY2020 (reference)

CRF Table 1.A(b)
Stock changes: -3,134.73 TJ [14.55×10^3 t (LNG) ×54.73MJ/kg (GCV) +42.115×10^6 m^3-SATP (indigenous natural gas) × 38.38 MJ/m^3-SATP (GCV) + 18.092×10^6 m^3-SATP (city gas) ×39.91 MJ/m^3-SATP (GCV) = -3,134.73 TJ]
IEA statistics
Stock changes: 17,993.24TJ [{86.71×10^3 t (LNG, opening stock (*Mineral Resources and Petroleum Products Statistics*)) + 2,431.49×10^3 t (LNG, opening stock (*Electric Power Statistics*)) + 2,283.76×10^3 t (LNG, opening stock (*Current Survey of Production Concerning Gas Industry*))} ×54.71 MJ/kg (GCV in previous year) + 211.834×10^6 Sm^3 (natural gas, opening stock) / 1.0759 Sm^3/Nm^3 × 1.1060 m^3-SATP/Nm^3 × 38.38 MJ/m^3-SATP (GCV in previous year) = 271,088.67 TJ (opening stock). {72.16×10^3 t (LNG, closing stock (*Mineral Resources and Petroleum Products Statistics*)) + 3,005.15×10^3 t (LNG, closing stock (*Electric Power Statistics*)) + 1,424.09×10^3 t (LNG, closing stock (*Current Survey of Production Concerning Gas Industry*))} × 54.73 MJ/kg (GCV in current year) + 170.865×10^6 Sm^3 (natural gas, closing stock) / 1.0759 Sm^3/Nm^3 × 1.1060 m^3-SATP/Nm^3 × 38.38 MJ/m^3-SATP (GCV in current year) = 253,095.43 TJ (closing stock). 271,088.67TJ (opening stock) - 253,095.43 TJ (closing stock) = 17,993.24 TJ]

A4.2. General Energy Statistics

A4.2.1 General Energy Statistics Overview

The data given in the *General Energy Statistics* compiled by the Agency for Natural Resources and Energy were used for the activity data of fuel combustion in energy sector.

The *General Energy Statistics* (Energy Balance Table) provides a comprehensive overview of domestic energy supply and demand to grasp what are converted from energy sources, such as coal, oil, natural gas and others, provided in Japan and what are consumed in what sectors. The supply/conversion and consumption data in *General Energy Statistics* use official statistics and are structured with the minimum of estimation and adjustment. (Kainou, 2012)

General Energy Statistics (Energy Balance Table) indicates an overview of domestic energy supply and demand, shows the main energy sources used in Japan as "Columns" and the supply, conversion and consumption sectors as "Rows", in a matrix. Specifically, columns comprise 13 major categories (coal [$0100[1]], coal products [$0200], crude oil [$0300], oil products [$0400], natural gas [$0500], city gas [$0600], renewable energy (excl. hydro) [$0700], hydraulic power generation (excl. pumped) [$0800], pumped storage [$0900], effective recovery use of wasted energy [$1000], nuclear power generation [$1100], electricity [$1200], and heat [$1300]) and the necessary sub-categories and a more detailed breakdown of the sub-categories. The *General Energy Statistics* supply and demand sectors (rows) comprise 3 major sectors — primary energy supply [#01], energy transformation & own use [#08], and final energy consumption [#19] — plus the necessary sub-categories and a more detailed breakdown of the sub-categories. (Refer to the following *General Energy Statistics* simplified table.)

The *General Energy Statistics* (complete Energy Balance Tables) for the years since FY1990 is available on the following internet site:

https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline2

The following is the energy balance simplified table (Table A 4-19 –Table A 4-22).

[1] Code number of the *General Energy Statistics* (Energy Balance Table)

Table A 4-19 Energy balance simplified table (General Energy Statistics, FY1990, 1995)

1990FY	*Row $*	*$0100*	*$0200*	*$0300*	*$0400*	*$0500*	*$0600*	*$0700*	*$0800*	*$0900*	*$1000*	*$1100*	*$1200*	*$1300*	*$1400*	*$1401*	*$1402*
	<< General Energy Statistics >> **Simplified energy unit table** **GCV (gross calorific value) basis** **Display unit: TJ**	Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total
Line #																	
#01	Primary Energy Supply	3,357,112	-39,341	8,981,710	2,026,265	2,056,326	0	267,189	818,519	0	317,978	1,883,500	0	0	19,669,259	18,066,871	1,602,388
#02	Indigenously Produced	193,762	0	24,484	0	89,203	0	266,070	818,519	0	317,978	1,883,500	0	0	3,593,516	0	0
#03	Import	3,161,715	15,352	9,139,187	2,341,006	1,967,475	0	1,119	0	0	0	0	0	0	16,625,854	0	0
#04	Total Primary Energy Supply	3,355,476	15,352	9,163,671	2,341,006	2,056,678	0	267,189	818,519	0	317,978	1,883,500	0	0	20,219,371	18,616,982	1,602,388
#05	Export	-53	-56,644	0	-292,955	0	0	-1	0	0	0	0	0	0	-349,653	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	1,689	1,951	-181,961	-21,786	-352	0	0	0	0	0	0	0	0	-200,458	0	0
#07	Domestic Primary Energy Supply (Supply)	3,357,112	-39,341	8,981,710	2,026,265	2,056,326	0	267,189	818,519	0	317,978	1,883,500	0	0	19,669,259	18,066,871	1,602,388
	(Demand)														19,786,192	18,183,804	1,602,388
#08	Energy Transformation & Own Use	-3,151,561	1,278,447	-8,961,984	5,499,151	-1,980,245	510,901	-210,804	-818,519	0	-317,978	-1,883,500	2,785,372	1,017,841	-6,232,881	-6,170,659	-62,222
#09	Manufacture of Coal Products (+: output/-: input)	-2,142,047	1,934,969	0	-27,085	0	0	0	0	0	0	0	0	0	-234,162	-234,162	0
#10	Oil Products (+: output/-: input)	0	0	-8,073,053	8,125,199	5,121	0	0	0	0	0	0	0	-94,149	-36,882	0	-36,882
#11	Gas Conversion and Production (+: output/-: input)	0	-19,178	0	-161,220	-503,899	683,704	-101	0	0	-445	0	0	0	-1,139	-1,139	0
#12	Power Generation	-673,045	-209,619	-874,209	-1,052,475	-1,529,799	-65	-13,827	-752,524	0	0	-1,882,503	2,679,366	0	-4,308,700	-4,308,700	0
#13	Auto Power Generation	-162,252	-132,541	0	-432,341	-4,367	-27,139	-87,643	-65,995	0	-170,247	-997	407,089	0	-676,433	-676,433	0
#14	Auto Steam Generation	-147,046	-135,509	0	-640,424	-4,241	-61,907	-109,183	0	0	-145,775	0	0	1,106,341	-137,744	-137,744	0
#15	District Heat Supply/ Other Energy Transformation	-3,704	2,880	0	4,949	56,636	-62,805	-37	0	0	-1,511	0	-1,229	8,361	3,541	-4,000	7,541
#16	Own Use and Loss	-3,015	-161,697	-1,017	-319,060	-238	-20,889	0	0	0	0	0	-299,854	-2,712	-808,481	-808,481	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	-20,454	-858	-13,705	1,607	542	0	-13	0	0	0	0	0	0	-32,881	0	-32,881
#18	Statistical Discrepancy (+: excess/-: shortage)	-195,600	12,361	19,725	0	18,443	0	0	0	0	0	0	32,053	-3,916	-116,933	-116,933	0
#19	Final Energy Consumption	401,151	1,226,745	0	7,525,416	57,638	510,901	56,385	0	0	0	0	2,753,319	1,021,756	13,553,311	12,013,145	1,540,166
#20	Industry	401,119	1,223,865	0	3,901,385	57,638	167,823	7,989	0	0	0	0	2,054,311	1,020,472	8,834,602	7,335,187	1,499,414
#21	Agriculture, Fishery, Mining and Construction	133	5,090	0	615,958	1,753	2,182	0	0	0	0	0	83,252	2,276	710,645	521,338	189,306
#22	Manufacturing	400,852	1,218,775	0	2,187,376	55,885	100,469	0	0	0	0	0	1,462,951	935,052	6,361,360	5,166,996	1,194,364
#23	Food, Beverages, Tobacco and Feed	48	0	0	52,848	0	8,102	0	0	0	0	0	56,462	49,454	166,915	166,915	0
#24	Textile Mill Products	544	0	0	50,417	0	4,699	0	0	0	0	0	71,268	92,180	219,108	219,108	0
#25	Pulp, Paper and Paper Products	126	0	0	31,995	2	4,731	0	0	0	0	0	130,845	274,119	441,819	441,819	0
#26	Chemical and Allied Products, Oil and Coal Products	6,633	46,779	0	1,458,730	25,021	9,582	0	0	0	0	0	210,838	234,151	1,991,735	810,784	1,180,951
#27	Ceramic, Stone and Clay Products	236,521	37,016	0	202,577	854	13,546	0	0	0	0	0	111,187	42,437	644,140	631,411	12,728
#28	Iron and Steel	140,959	1,109,711	0	126,640	24,987	11,084	0	0	0	0	0	272,173	110,581	1,796,135	1,795,449	685
#29	Non-Ferrous Metals	15,811	11,378	0	56,332	322	9,162	0	0	0	0	0	62,110	17,411	172,526	172,526	0
#30	Machinery	15	13,891	0	170,851	4,698	33,072	0	0	0	0	0	398,766	76,719	698,012	698,012	0
#31	Miscellaneous	194	0	0	36,985	0	6,489	0	0	0	0	0	149,302	38,000	230,971	230,971	0
#32	Commercial Industry	133	0	0	1,098,051	0	65,172	7,989	0	0	0	0	508,107	83,144	1,762,597	1,646,853	115,744
#33	Residential	0	2,880	0	606,330	0	343,074	48,395	0	0	0	0	638,494	1,284	1,640,458	1,640,458	0
#34	Transportation	33	0	0	3,017,702	0	3	0	0	0	0	0	60,514	0	3,078,252	3,037,500	40,752
#35	Passenger	33	0	0	1,516,269	0	1	0	0	0	0	0	56,610	0	1,572,912	1,540,989	31,923
#36	Freight	0	0	0	1,501,433	0	3	0	0	0	0	0	3,905	0	1,505,340	1,496,511	8,829
#37	Non-energy and Feedstock Use	6,063	26,437	0	1,493,632	13,997	38	0	0	0	0	0	0	0	1,540,166	0	1,540,166

1995FY	*Row $*	*$0100*	*$0200*	*$0300*	*$0400*	*$0500*	*$0600*	*$0700*	*$0800*	*$0900*	*$1000*	*$1100*	*$1200*	*$1300*	*$1400*	*$1401*	*$1402*
	<< General Energy Statistics >> **Simplified energy unit table** **GCV (gross calorific value) basis** **Display unit: TJ**	Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total
Line #																	
#01	Primary Energy Supply	3,725,382	-91,908	10,166,812	1,642,449	2,477,257	0	280,834	728,509	0	380,411	2,693,458	0	0	22,003,203	20,202,409	1,800,794
#02	Indigenously Produced	153,374	0	32,455	0	95,250	0	278,350	728,509	0	380,411	2,693,458	0	0	4,361,806	0	0
#03	Import	3,575,648	18,016	10,171,504	2,226,338	2,382,172	0	2,491	0	0	0	0	0	0	18,376,169	0	0
#04	Total Primary Energy Supply	3,729,022	18,016	10,203,959	2,226,338	2,477,422	0	280,841	728,509	0	380,411	2,693,458	0	0	22,737,975	20,937,181	1,800,794
#05	Export	-75	-103,811	0	-717,045	0	0	-6	0	0	0	0	0	0	-820,938	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	-3,565	-6,113	-37,147	133,156	-165	0	0	0	0	0	0	0	0	86,166	0	0
#07	Domestic Primary Energy Supply (Supply)	3,725,382	-91,908	10,166,812	1,642,449	2,477,257	0	280,834	728,509	0	380,411	2,693,458	0	0	22,003,203	20,202,409	1,800,794
	(Demand)														21,968,302	20,167,508	1,800,794
#08	Energy Transformation & Own Use	-3,316,691	1,148,397	#########	6,946,881	-2,418,050	685,997	-224,089	-728,509	0	-380,411	-2,693,458	3,146,438	1,055,422	-6,841,393	-6,776,341	-65,052
#09	Manufacture of Coal Products (+: output/-: input)	-1,899,695	1,792,057	0	-24,231	0	0	0	0	0	0	0	0	0	-131,869	-131,869	0
#10	Oil Products (+: output/-: input)	0	0	-9,375,750	9,417,456	5,773	0	0	0	0	0	0	0	-103,260	-55,781	0	-55,781
#11	Gas Conversion and Production (+: output/-: input)	0	-12,205	0	-180,538	-723,679	915,060	-37	0	0	0	0	0	0	-1,400	-1,400	0
#12	Power Generation	-1,072,304	-219,914	-669,401	-835,632	-1,750,119	-663	-27,002	-667,399	0	0	-2,691,935	3,054,038	0	-4,880,332	-4,880,332	0
#13	Auto Power Generation	-182,384	-138,015	-539	-439,106	-5,482	-45,424	-97,713	-61,110	0	-202,462	-1,523	440,633	0	-733,126	-733,126	0
#14	Auto Steam Generation	-160,158	-127,828	-669	-672,326	-4,887	-98,261	-99,257	0	0	-174,443	0	0	1,145,850	-191,980	-191,980	0
#15	District Heat Supply/ Other Energy Transformation	-2,274	1,637	0	7,394	54,485	-65,586	-99	0	0	-3,505	0	-2,548	15,823	5,326	-3,669	8,995
#16	Own Use and Loss	-2,978	-139,799	-1,058	-322,242	-86	-19,128	0	0	0	0	0	-345,686	-2,990	-833,968	-833,968	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	3,103	-7,537	-15,903	-3,893	5,944	0	20	0	0	0	0	0	0	-18,265	0	-18,265
#18	Statistical Discrepancy (+: excess/-: shortage)	-45,916	425	103,492	0	991	0	0	0	0	0	0	8,299	-32,390	34,901	34,901	0
#19	Final Energy Consumption	454,606	1,056,064	0	8,589,329	58,216	685,997	56,745	0	0	0	0	3,138,139	1,087,812	15,126,909	13,391,167	1,735,742
#20	Industry	454,575	1,054,427	0	4,275,478	58,216	286,618	7,099	0	0	0	0	2,251,832	1,086,444	9,474,690	7,771,448	1,703,242
#21	Agriculture, Fishery, Mining and Construction	82	1,590	0	581,369	1,571	2,963	0	0	0	0	0	79,742	1,944	669,260	497,671	171,589
#22	Manufacturing	454,325	1,052,837	0	2,523,875	56,645	160,422	36	0	0	0	0	1,407,011	969,692	6,624,844	5,209,813	1,415,031
#23	Food, Beverages, Tobacco and Feed	82	0	0	63,054	0	14,756	0	0	0	0	0	65,038	70,106	213,037	213,037	0
#24	Textile Mill Products	823	0	0	46,242	14	6,320	0	0	0	0	0	64,730	92,448	210,577	210,577	0
#25	Pulp, Paper and Paper Products	0	0	0	35,625	5	10,330	36	0	0	0	0	132,158	274,405	452,559	452,559	0
#26	Chemical and Allied Products, Oil and Coal Products	6,103	31,971	0	1,779,429	21,427	16,674	0	0	0	0	0	210,026	248,201	2,313,831	914,655	1,399,176
#27	Ceramic, Stone and Clay Products	236,215	34,354	0	216,168	1,758	15,743	0	0	0	0	0	104,387	43,204	651,829	636,182	15,647
#28	Iron and Steel	200,658	962,201	0	123,546	26,217	23,652	0	0	0	0	0	257,704	112,652	1,706,629	1,706,422	208
#29	Non-Ferrous Metals	10,236	9,869	0	54,938	96	10,237	0	0	0	0	0	51,307	14,066	150,749	150,749	0
#30	Machinery	4	14,444	0	166,069	7,128	54,690	0	0	0	0	0	393,787	73,276	709,398	709,398	0
#31	Miscellaneous	203	0	0	38,803	0	8,020	0	0	0	0	0	127,874	41,334	216,234	216,234	0
#32	Commercial Industry	168	0	0	1,170,234	0	123,233	7,063	0	0	0	0	765,079	114,808	2,180,586	2,063,964	116,622
#33	Residential	0	1,637	0	706,407	0	399,238	49,646	0	0	0	0	818,788	1,368	1,977,084	1,977,084	0
#34	Transportation	31	0	0	3,607,445	0	141	0	0	0	0	0	67,518	0	3,675,135	3,642,635	32,500
#35	Passenger	31	0	0	1,952,379	0	20	0	0	0	0	0	63,676	0	2,016,106	1,991,138	24,968
#36	Freight	0	0	0	1,655,066	0	121	0	0	0	0	0	3,842	0	1,659,029	1,651,497	7,532
#37	Non-energy and Feedstock Use	5,446	25,104	0	1,693,158	12,033	0	0	0	0	0	0	0	0	1,735,742	0	1,735,742

Table A 4-20 Energy balance simplified table (General Energy Statistics, FY2000, 2005)

2000FY	Row $	$0100 Coal	$0200 Coal Products	$0300 Crude Oil	$0400 Oil Products	$0500 Natural Gas	$0600 City Gas	$0700 Renewable (excl. hydro)	$0800 Hydraulic Power Generation (excl. pumped)	$0900 Pumped Storage	$1000 Effective Recovery Use of Wasted Energy	$1100 Nuclear Power Generation	$1200 Electricity	$1300 Heat	$1400 Total	$1401 Energy Use Total	$1402 Non-Energy Use Total
	<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ																
Line #																	
#01	Primary Energy Supply	4,203,202	-3,821	9,634,832	1,528,928	3,058,878	0	273,860	745,903	0	409,621	2,858,092	0	0	22,709,495	20,834,947	1,874,549
#02	Indigenously Produced	66,912	0	28,034	0	106,340	0	269,127	745,903	0	409,621	2,858,092	0	0	4,484,028	0	0
#03	Import	4,139,375	76,219	9,733,303	2,252,207	2,952,403	0	4,746	0	0	0	0	0	0	19,158,252	0	0
#04	Total Primary Energy Supply	4,206,287	76,219	9,761,337	2,252,207	3,058,742	0	273,873	745,903	0	409,621	2,858,092	0	0	23,642,280	21,767,731	1,874,549
#05	Export	-112	-78,077	0	-617,396	0	0	-13	0	0	0	0	0	0	-695,597	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	-2,972	-1,963	-126,505	-105,883	136	0	0	0	0	0	0	0	0	-237,187	0	0
#07	Domestic Primary Energy Supply (Supply)	4,203,202	-3,821	9,634,832	1,528,928	3,058,878	0	273,860	745,903	0	409,621	2,858,092	0	0	22,709,495	20,834,947	1,874,549
	(Demand)														22,729,352	20,854,803	1,874,549
#08	Energy Transformation & Own Use	-3,705,208	1,114,629	-9,622,842	7,213,548	-3,022,830	806,834	-223,800	-745,903	0	-403,364	-2,858,092	3,414,115	1,158,073	-6,874,841	-6,769,290	-105,551
#09	Manufacture of Coal Products (+: output/-: input)	-1,738,478	1,664,686	0	-33,697	0	0	0	0	0	0	0	0	0	-107,489	-107,489	0
#10	Oil Products (+: output/-: input)	0	0	-9,331,059	9,412,940	6,972	0	0	0	0	0	0	0	-137,327	-48,474	0	-48,474
#11	Gas Conversion and Production (+: output/-: input)	0	-9,573	0	-150,046	-925,341	1,084,614	-31	0	0	0	0	0	0	-377	-377	0
#12	Power Generation	-1,513,154	-219,155	-301,245	-544,697	-2,130,517	-1,632	-27,676	-679,439	0	0	-2,851,772	3,320,803	0	-4,948,485	-4,948,485	0
#13	Auto Power Generation	-222,305	-114,011	-83	-431,513	-9,034	-71,592	-99,374	-66,464	0	-178,038	-6,320	457,645	0	-741,088	-741,088	0
#14	Auto Steam Generation	-198,902	-69,828	-135	-672,981	-7,845	-128,034	-96,581	0	0	-220,572	0	0	1,276,053	-118,825	-118,825	0
#15	District Heat Supply/ Other Energy Transformation	-708	0	0	-34,671	48,869	-63,384	-116	0	0	-4,755	0	-3,940	22,648	-36,057	-3,078	-32,978
#16	Own Use and Loss	-4,240	-132,502	-518	-335,337	-519	-13,139	0	0	0	0	0	-360,392	-3,302	-849,949	-849,949	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	-27,422	-4,989	10,199	3,549	-5,414	0	-22	0	0	1	0	0	0	-24,098	0	-24,098
#18	Statistical Discrepancy (+: excess/-: shortage)	76,007	60,164	11,990	0	-14,343	0	0	0	0	0	0	-87,528	-66,148	-19,857	-19,857	0
#19	Final Energy Consumption	421,987	1,050,644	0	8,742,476	50,391	806,834	50,059	0	0	6,256	0	3,501,643	1,224,220	15,854,510	14,085,513	1,768,998
#20	Industry	421,941	1,050,644	0	4,211,861	50,391	386,796	17,219	0	0	6,256	0	2,531,853	1,222,914	9,899,876	8,165,041	1,734,835
#21	Agriculture, Fishery, Mining and Construction	47	1,744	0	533,670	1,930	2,959	0	0	0	0	0	75,049	1,530	616,930	463,427	153,503
#22	Manufacturing	421,754	1,048,900	0	2,495,178	48,461	178,337	12,142	0	0	6,256	0	1,441,577	1,076,657	6,729,262	5,235,834	1,493,428
#23	Food, Beverages, Tobacco and Feed	34	0	0	66,373	0	21,171	0	0	0	0	0	75,932	79,504	243,015	243,015	0
#24	Textile Mill Products	257	0	0	34,473	1	5,858	0	0	0	0	0	56,816	79,810	177,214	177,214	0
#25	Pulp, Paper and Paper Products	0	0	0	26,153	71	8,250	12,142	0	0	0	0	140,731	287,154	474,501	474,501	0
#26	Chemical and Allied Products, Oil and Coal Products	556	36,239	0	1,880,427	23,397	22,408	0	0	0	0	0	212,761	352,672	2,528,459	1,036,347	1,492,113
#27	Ceramic, Stone and Clay Products	185,818	24,256	0	170,732	1,681	19,036	0	0	0	6,235	0	96,376	33,996	538,130	536,966	1,164
#28	Iron and Steel	230,744	973,938	0	109,213	22,154	36,208	0	0	0	0	0	261,809	109,404	1,743,470	1,743,318	152
#29	Non-Ferrous Metals	4,209	10,185	0	49,230	238	14,836	0	0	0	19	0	56,982	23,072	158,770	158,770	0
#30	Machinery	0	4,282	0	122,206	919	37,437	0	0	0	2	0	389,189	65,343	619,377	619,377	0
#31	Miscellaneous	137	0	0	36,370	0	13,133	0	0	0	0	0	150,982	45,703	246,325	246,325	0
#32	Commercial Industry	140	0	0	1,183,013	0	205,500	5,078	0	0	0	0	1,015,227	144,727	2,553,685	2,465,781	87,904
#33	Residential	0	0	0	768,778	0	418,897	32,840	0	0	0	0	902,926	1,306	2,124,747	2,124,747	0
#34	Transportation	46	0	0	3,761,837	0	1,141	0	0	0	0	0	66,864	0	3,829,887	3,795,725	34,162
#35	Passenger	46	0	0	2,190,118	0	172	0	0	0	0	0	63,385	0	2,253,720	2,227,912	25,808
#36	Freight	0	0	0	1,571,719	0	969	0	0	0	0	0	3,479	0	1,576,167	1,567,813	8,354
#37	Non-energy and Feedstock Use	19	19,641	0	1,740,814	8,523	0	0	0	0	0	0	0	0	1,768,998	0	1,768,998

2005FY	Row $	$0100 Coal	$0200 Coal Products	$0300 Crude Oil	$0400 Oil Products	$0500 Natural Gas	$0600 City Gas	$0700 Renewable (excl. hydro)	$0800 Hydraulic Power Generation (excl. pumped)	$0900 Pumped Storage	$1000 Effective Recovery Use of Wasted Energy	$1100 Nuclear Power Generation	$1200 Electricity	$1300 Heat	$1400 Total	$1401 Energy Use Total	$1402 Non-Energy Use Total
	<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ																
Line #																	
#01	Primary Energy Supply	4,765,771	15,805	9,517,554	1,173,834	3,291,376	0	380,850	671,487	0	428,091	2,660,242	0	0	22,905,011	20,957,082	1,947,930
#02	Indigenously Produced	28,110	0	33,051	0	134,612	0	375,440	671,487	0	428,091	2,660,242	0	0	4,331,033	0	0
#03	Import	4,737,747	81,303	9,473,040	2,127,563	3,156,903	0	5,461	0	0	0	0	0	0	19,582,017	0	0
#04	Total Primary Energy Supply	4,765,856	81,303	9,506,092	2,127,563	3,291,515	0	380,901	671,487	0	428,091	2,660,242	0	0	23,913,050	21,965,120	1,947,930
#05	Export	-85	-49,269	-4	-880,259	0	0	-51	0	0	0	0	0	0	-929,668	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	0	-16,228	11,466	-73,470	-138	0	0	0	0	0	0	0	0	-78,371	0	0
#07	Domestic Primary Energy Supply (Supply)	4,765,771	15,805	9,517,554	1,173,834	3,291,376	0	380,850	671,487	0	428,091	2,660,242	0	0	22,905,011	20,957,082	1,947,930
	(Demand)														22,954,613	21,006,684	1,947,930
#08	Energy Transformation & Own Use	-4,310,565	1,121,057	-9,510,672	7,253,909	-3,227,280	966,321	-354,038	-671,487	0	-421,786	-2,660,242	3,561,797	1,199,658	-7,053,329	-6,930,529	-122,800
#09	Manufacture of Coal Products (+: output/-: input)	-1,730,636	1,633,464	0	-18,801	0	0	0	0	0	0	0	0	0	-115,974	-115,974	0
#10	Oil Products (+: output/-: input)	0	0	-9,209,723	9,278,313	8,203	0	0	0	0	0	0	0	-139,784	-62,992	0	-62,992
#11	Gas Conversion and Production (+: output/-: input)	0	-1,994	0	-99,300	-1,315,246	1,414,464	-46	0	0	0	0	0	0	-2,121	-2,121	0
#12	Power Generation	-2,146,038	-189,378	-301,537	-546,895	-1,910,075	-58,869	-52,804	-614,127	0	0	-2,660,242	3,440,790	0	-5,039,177	-5,039,177	0
#13	Auto Power Generation	-250,929	-106,559	-20	-400,617	-16,206	-115,803	-132,042	-57,360	0	-178,129	0	502,550	0	-755,114	-755,114	0
#14	Auto Steam Generation	-215,125	-66,543	-37	-572,779	-12,856	-183,042	-168,956	0	0	-238,466	0	0	1,317,573	-140,231	-140,231	0
#15	District Heat Supply/ Other Energy Transformation	-633	0	0	-54,980	63,151	-81,254	-146	0	0	-5,124	0	-4,129	25,072	-58,042	-4,085	-53,958
#16	Own Use and Loss	-6,994	-129,554	-91	-331,117	-16,279	-9,176	0	0	0	0	0	-377,413	-3,203	-873,827	-873,827	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	39,791	-18,378	736	86	-27,972	0	-44	0	0	-68	0	0	0	-5,850	0	-5,850
#18	Statistical Discrepancy (+: excess/-: shortage)	33,648	93,728	6,882	0	-566	0	0	0	0	0	0	-127,656	-55,638	-49,602	-49,602	0
#19	Final Energy Consumption	421,558	1,043,135	0	8,427,743	64,662	966,321	26,812	0	0	6,305	0	3,689,453	1,255,296	15,901,284	14,076,155	1,825,130
#20	Industry	421,521	1,043,135	0	4,155,720	64,662	526,270	4,278	0	0	6,305	0	2,624,065	1,253,971	10,099,926	8,310,469	1,789,456
#21	Agriculture, Fishery, Mining and Construction	34	524	0	458,565	2,758	3,115	0	0	0	0	0	60,986	1,350	527,331	426,504	100,828
#22	Manufacturing	421,249	1,042,611	0	2,443,486	61,905	259,987	25	0	0	6,305	0	1,416,001	1,115,783	6,767,351	5,161,986	1,605,364
#23	Food, Beverages, Tobacco and Feed	39	0	0	61,918	0	32,399	0	0	0	0	0	88,551	88,379	271,285	271,285	0
#24	Textile Mill Products	231	0	0	26,382	0	6,957	0	0	0	0	0	45,906	64,926	144,403	144,403	0
#25	Pulp, Paper and Paper Products	506	0	0	23,810	119	10,603	25	0	0	0	0	134,442	282,635	452,138	452,138	0
#26	Chemical and Allied Products, Oil and Coal Products	971	39,347	0	1,944,659	31,470	31,462	0	0	0	0	0	211,479	392,864	2,652,253	1,047,426	1,604,828
#27	Ceramic, Stone and Clay Products	163,358	21,640	0	132,156	2,541	22,808	0	0	0	6,300	0	80,915	29,084	458,803	458,395	408
#28	Iron and Steel	252,942	968,364	0	93,093	25,126	54,384	0	0	0	0	0	263,940	113,867	1,771,715	1,771,587	129
#29	Non-Ferrous Metals	2,993	9,518	0	41,262	315	19,808	0	0	0	0	0	54,697	26,351	154,944	154,944	0
#30	Machinery	1	3,742	0	89,291	2,334	63,972	0	0	0	5	0	394,749	65,339	619,434	619,434	0
#31	Miscellaneous	206	0	0	30,915	0	17,593	0	0	0	0	0	141,322	52,339	242,376	242,376	0
#32	Commercial Industry	238	0	0	1,253,669	0	263,168	4,253	0	0	0	0	1,147,078	136,838	2,805,244	2,721,979	83,264
#33	Residential	0	0	0	729,070	0	436,076	22,534	0	0	0	0	997,357	1,326	2,186,363	2,186,363	0
#34	Transportation	37	0	0	3,542,953	0	3,974	0	0	0	0	0	68,031	0	3,614,996	3,579,323	35,674
#35	Passenger	37	0	0	2,079,246	0	591	0	0	0	0	0	64,483	0	2,144,357	2,117,707	26,651
#36	Freight	0	0	0	1,463,707	0	3,383	0	0	0	0	0	3,548	0	1,470,639	1,461,616	9,023
#37	Non-energy and Feedstock Use	32	18,343	0	1,790,501	16,254	0	0	0	0	0	0	0	0	1,825,130	0	1,825,130

Table A 4-21 Energy balance simplified table (General Energy Statistics, FY2010, 2015)

2010FY Row $		$0100 Coal	$0200 Coal Products	$0300 Crude Oil	$0400 Oil Products	$0500 Natural Gas	$0600 City Gas	$0700 Renewable (excl. hydro)	$0800 Hydraulic Power Generation (excl. pumped)	$0900 Pumped Storage	$1000 Effective Recovery Use of Wasted Energy	$1100 Nuclear Power Generation	$1200 Electricity	$1300 Heat	$1400 Total	$1401 Energy Use Total	$1402 Non-Energy Use Total
	<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ																
Line #																	
#01	Primary Energy Supply	4,983,144	14,115	8,127,286	730,774	3,994,127	1,105	436,391	715,871	0	529,798	2,462,243	0	0	21,994,855	20,126,593	1,868,262
#02	Indigenously Produced	25,764	0	30,637	0	149,324	0	421,586	715,871	0	529,798	2,462,243	0	0	4,335,224	0	0
#03	Import	4,957,466	29,909	8,140,499	1,946,768	3,844,997	0	14,857	0	0	0	0	0	0	18,934,496	0	0
#04	Total Primary Energy Supply	4,983,230	29,909	8,171,136	1,946,768	3,994,321	0	436,443	715,871	0	529,798	2,462,243	0	0	23,269,720	21,401,458	1,868,262
#05	Export	-87	-19,695	0	-1,187,778	0	0	-51	0	0	0	0	0	0	-1,207,611	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	0	3,901	-43,851	-28,216	-194	1,105	0	0	0	0	0	0	0	-67,255	0	0
#07	Domestic Primary Energy Supply (Supply)	4,983,144	14,115	8,127,286	730,774	3,994,127	1,105	436,391	715,871	0	529,798	2,462,243	0	0	21,994,855	20,126,593	1,868,262
	(Demand)														21,931,664	20,063,402	1,868,262
#08	Energy Transformation & Own Use	-4,523,260	1,090,966	-8,133,969	6,532,803	-3,960,650	1,087,984	-415,108	-715,871	0	-522,602	-2,462,243	3,799,519	1,003,399	-7,219,031	-7,081,798	-137,233
#09	Manufacture of Coal Products (+: output/-: input)	-1,704,578	1,611,327	0	-20,407	0	0	0	0	0	-87	0	0	0	-113,745	-113,745	0
#10	Oil Products (+: output/-: input)	0	0	-7,949,128	8,038,382	5,579	0	-8,588	0	0	0	0	0	-146,978	-60,732	0	-60,732
#11	Gas Conversion and Production (+: output/-: input)	0	0	0	-73,311	-1,646,183	1,719,690	0	0	0	0	0	0	0	196	196	0
#12	Power Generation	-2,087,400	-207,076	-189,297	-374,290	-2,342,899	-59,859	-49,324	-574,862	0	-5,678	-2,462,243	3,474,987	0	-4,877,940	-4,877,940	0
#13	Auto Power Generation	-440,814	-104,816	-46	-309,172	-149,028	-133,884	-172,142	-141,010	0	-282,311	0	704,765	0	-1,028,457	-1,028,457	0
#14	Auto Steam Generation	-240,628	-76,411	-90	-378,618	-27,268	-168,223	-184,754	0	0	-229,472	0	0	1,130,683	-174,781	-174,781	0
#15	District Heat Supply/ Other Energy Transformation	0	0	0	-46,256	202,348	-219,351	-577	0	0	-4,068	0	-4,126	24,418	-47,613	-1,932	-45,681
#16	Own Use and Loss	-20,471	-134,613	-62	-293,998	-4,773	-50,390	0	0	0	0	0	-376,108	-4,724	-885,138	-885,138	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	-29,368	2,555	4,654	-9,526	1,573	0	278	0	0	-987	0	0	0	-30,821	0	-30,821
#18	Statistical Discrepancy (+: excess/-: shortage)	68,210	49,980	-6,683	-133	-34,148	0	0	0	0	0	0	72,012	-86,048	63,191	63,191	0
#19	Final Energy Consumption	391,674	1,055,101	0	7,263,710	67,624	1,089,088	21,284	0	0	7,196	0	3,727,507	1,089,447	14,712,632	12,981,604	1,731,028
#20	Industry	391,630	1,055,101	0	3,300,853	67,624	657,371	4,834	0	0	7,196	0	2,588,231	1,088,165	9,161,006	7,465,453	1,695,552
#21	Agriculture, Fishery, Mining and Construction	87	140	0	388,845	5,064	2,672	0	0	0	0	0	45,746	1,392	443,947	370,579	73,368
#22	Manufacturing	391,306	1,052,992	0	2,203,042	62,560	281,280	350	0	0	7,196	0	1,329,670	976,583	6,304,979	4,747,258	1,557,722
#23	Food, Beverages, Tobacco and Feed	28	91	0	49,050	0	39,753	0	0	0	0	0	91,205	99,108	279,235	279,235	0
#24	Textile Mill Products	153	0	0	13,306	0	7,678	0	0	0	0	0	35,686	49,765	106,588	106,588	0
#25	Pulp, Paper and Paper Products	322	0	0	19,946	333	5,171	344	0	0	89	0	123,818	228,675	378,697	378,697	0
#26	Chemical and Allied Products, Oil and Coal Products	1,051	49,884	0	1,854,151	34,826	27,260	0	0	0	0	0	204,863	365,869	2,537,905	980,551	1,557,354
#27	Ceramic, Stone and Clay Products	128,254	17,780	0	96,373	4,255	28,179	6	0	0	6,582	0	72,152	19,889	373,471	373,290	181
#28	Iron and Steel	258,193	972,911	0	77,186	20,273	76,514	0	0	0	387	0	258,516	118,085	1,782,065	1,781,879	186
#29	Non-Ferrous Metals	2,314	8,661	0	23,718	1,024	16,292	0	0	0	137	0	52,542	10,665	115,353	115,353	0
#30	Machinery	76	3,587	0	50,855	1,849	65,643	0	0	0	0	0	373,471	58,690	554,171	554,171	0
#31	Miscellaneous	915	78	0	18,457	0	14,790	0	0	0	0	0	117,417	25,837	177,494	177,494	0
#32	Commercial Industry	237	1,970	0	708,965	0	373,418	4,485	0	0	0	0	1,212,816	110,189	2,412,079	2,347,616	64,463
#33	Residential	0	0	0	646,431	0	427,050	16,449	0	0	0	0	1,073,597	1,282	2,164,810	2,164,810	0
#34	Transportation	43	0	0	3,316,427	0	4,667	0	0	0	0	0	65,679	0	3,386,816	3,351,340	35,476
#35	Passenger	43	0	0	1,962,870	0	640	0	0	0	0	0	62,568	0	2,026,122	1,999,526	26,596
#36	Freight	0	0	0	1,353,557	0	4,027	0	0	0	0	0	3,111	0	1,360,695	1,351,815	8,880
#37	Non-energy and Feedstock Use	16	17,902	0	1,696,536	16,575	0	0	0	0	0	0	0	0	1,731,028	0	1,731,028

2015FY Row $		$0100 Coal	$0200 Coal Products	$0300 Crude Oil	$0400 Oil Products	$0500 Natural Gas	$0600 City Gas	$0700 Renewable (excl. hydro)	$0800 Hydraulic Power Generation (excl. pumped)	$0900 Pumped Storage	$1000 Effective Recovery Use of Wasted Energy	$1100 Nuclear Power Generation	$1200 Electricity	$1300 Heat	$1400 Total	$1401 Energy Use Total	$1402 Non-Energy Use Total
	<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ																
Line #																	
#01	Primary Energy Supply	5,096,871	57,471	7,406,284	731,279	4,658,056	-833	726,484	725,930	0	535,685	78,638	0	0	20,015,863	18,217,801	1,798,062
#02	Indigenously Produced	31,982	0	20,896	0	110,598	0	694,411	725,930	0	535,685	78,638	0	0	2,198,141	0	0
#03	Import	5,064,950	80,375	7,414,496	1,952,126	4,551,428	0	32,118	0	0	0	0	0	0	19,095,492	0	0
#04	Total Primary Energy Supply	5,096,932	80,375	7,435,391	1,952,126	4,662,026	0	726,529	725,930	0	535,685	78,638	0	0	21,293,632	19,495,571	1,798,062
#05	Export	-62	-22,999	0	-1,265,963	0	0	-45	0	0	0	0	0	0	-1,289,068	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	0	95	-29,108	45,115	-3,970	-833	0	0	0	0	0	0	0	11,299	0	0
#07	Domestic Primary Energy Supply (Supply)	5,096,871	57,471	7,406,284	731,279	4,658,056	-833	726,484	725,930	0	535,685	78,638	0	0	20,015,863	18,217,801	1,798,062
	(Demand)														20,043,654	18,245,593	1,798,062
#08	Energy Transformation & Own Use	-4,717,988	946,675	-7,406,973	5,870,508	-4,603,419	1,072,604	-711,325	-725,930	0	-510,425	-78,638	3,464,390	883,439	-6,517,082	-6,401,239	-115,843
#09	Manufacture of Coal Products (+: output/-: input)	-1,523,216	1,436,363	0	-19,673	0	0	0	0	0	-4,893	0	0	0	-111,419	-111,419	0
#10	Oil Products (+: output/-: input)	0	0	-7,191,157	7,208,201	4,204	0	-14,525	0	0	0	0	0	-119,254	-112,532	0	-112,532
#11	Gas Conversion and Production (+: output/-: input)	0	0	0	-68,503	-1,669,358	1,738,071	-116	0	0	0	0	0	0	95	95	0
#12	Power Generation	-2,375,953	-201,063	-226,562	-382,134	-2,924,727	-121,063	-52,323	-588,695	0	-5,484	-78,638	2,945,950	0	-4,010,691	-4,010,691	0
#13	Auto Power Generation	-502,927	-101,086	-39	-262,099	-159,588	-136,847	-472,130	-137,236	0	-297,981	0	843,721	0	-1,226,213	-1,226,213	0
#14	Auto Steam Generation	-243,912	-70,119	-74	-317,268	-24,529	-181,391	-171,077	0	0	-199,185	0	0	986,116	-221,438	-221,438	0
#15	District Heat Supply/ Other Energy Transformation	0	0	0	5,100	165,482	-179,577	-1,026	0	0	-2,631	0	-3,609	21,309	5,046	169	4,877
#16	Own Use and Loss	-20,270	-120,506	-83	-304,499	-13,393	-46,590	0	0	0	0	0	-321,672	-4,730	-831,743	-831,743	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	-51,710	3,085	10,941	11,383	18,491	0	-128	0	0	-250	0	0	0	-8,188	0	-8,188
#18	Statistical Discrepancy (+: excess/-: shortage)	-52,944	48,096	-690	-440	-7,176	0	0	0	0	0	0	46,221	-60,858	-27,791	-27,791	0
#19	Final Energy Consumption	431,827	956,049	0	6,602,227	61,813	1,071,770	15,159	0	0	25,260	0	3,418,170	944,297	13,526,572	11,844,353	1,682,219
#20	Industry	431,788	956,049	0	2,988,944	61,813	668,128	5,229	0	0	25,260	0	2,389,850	943,195	8,470,256	6,824,470	1,645,786
#21	Agriculture, Fishery, Mining and Construction	28	291	0	363,295	4,695	3,082	0	0	0	0	0	38,140	1,095	410,626	355,900	54,726
#22	Manufacturing	431,413	952,800	0	2,065,504	57,118	248,435	390	0	0	25,260	0	1,214,517	878,520	5,873,957	4,331,718	1,542,239
#23	Food, Beverages, Tobacco and Feed	245	80	0	32,811	0	31,205	0	0	0	0	0	91,746	83,786	239,874	239,874	0
#24	Textile Mill Products	112	0	0	7,149	10	5,463	0	0	0	0	0	33,417	50,873	97,022	97,022	0
#25	Pulp, Paper and Paper Products	1,793	0	0	15,758	534	4,531	324	0	0	1,018	0	112,140	205,821	341,918	341,918	0
#26	Chemical and Allied Products, Oil and Coal Products	4,215	49,754	0	1,797,179	27,107	21,360	0	0	0	2,008	0	188,334	332,954	2,422,911	880,925	1,541,985
#27	Ceramic, Stone and Clay Products	130,671	12,652	0	84,461	5,002	25,789	67	0	0	19,110	0	61,848	19,240	358,839	358,700	139
#28	Iron and Steel	291,655	879,851	0	60,409	21,522	80,046	0	0	0	1,707	0	250,808	99,610	1,685,609	1,685,494	114
#29	Non-Ferrous Metals	2,283	7,412	0	16,339	1,317	12,808	0	0	0	1,417	0	43,123	10,152	94,851	94,851	0
#30	Machinery	77	2,994	0	39,581	1,627	55,813	0	0	0	0	0	325,304	42,832	468,228	468,228	0
#31	Miscellaneous	363	56	0	11,816	0	11,421	0	0	0	0	0	107,797	33,253	164,705	164,705	0
#32	Commercial Industry	348	2,958	0	560,146	0	416,611	4,838	0	0	0	0	1,137,193	63,579	2,185,673	2,136,852	48,821
#33	Residential	0	0	0	531,546	0	400,326	9,930	0	0	0	0	965,137	1,102	1,908,040	1,908,040	0
#34	Transportation	39	0	0	3,081,737	0	3,317	0	0	0	0	0	63,183	0	3,148,275	3,111,843	36,433
#35	Passenger	39	0	0	1,794,236	0	320	0	0	0	0	0	60,289	0	1,854,884	1,827,225	27,659
#36	Freight	0	0	0	1,287,501	0	2,996	0	0	0	0	0	2,894	0	1,293,392	1,284,617	8,774
#37	Non-energy and Feedstock Use	9	17,701	0	1,652,935	11,574	0	0	0	0	0	0	0	0	1,682,219	0	1,682,219

Table A 4-22 Energy balance simplified table (General Energy Statistics, FY2020, 2021)

2020FY	Row $	$0100	$0200	$0300	$0400	$0500	$0600	$0700	$0800	$0900	$1000	$1100	$1200	$1300	$1400	$1401	$1402
	<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ	Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total
Line #																	
#01	Primary Energy Supply	4,488,175	-68,861	5,293,990	1,238,093	4,271,624	723	1,186,060	662,732	0	543,425	325,883	0	0	17,941,843	16,506,315	1,435,528
#02	Indigenously Produced	18,136	0	18,636	0	90,329	0	1,097,085	662,732	0	543,425	325,883	0	0	2,756,224	0	0
#03	Import	4,470,131	25,693	5,196,524	1,933,350	4,178,883	0	89,007	0	0	0	0	0	0	15,893,589	0	0
#04	Total Primary Energy Supply	4,488,267	25,693	5,215,160	1,933,350	4,269,212	0	1,186,092	662,732	0	543,425	325,883	0	0	18,649,813	17,214,285	1,435,528
#05	Export	-92	-94,390	0	-744,068	0	0	-32	0	0	0	0	0	0	-838,582	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	0	-164	78,829	48,811	2,413	723	0	0	0	0	0	0	0	130,612	0	0
#07	Domestic Primary Energy Supply (Supply)	4,488,175	-68,861	5,293,990	1,238,093	4,271,624	723	1,186,060	662,732	0	543,425	325,883	0	0	17,941,843	16,506,315	1,435,528
	(Demand)														18,006,786	16,571,258	1,435,528
#08	Energy Transformation & Own Use	-4,157,767	887,393	-5,307,574	4,496,031	-4,220,768	991,699	-1,175,774	-662,732	0	-513,576	-325,883	3,252,123	816,300	-5,920,529	-5,914,497	-6,032
#09	Manufacture of Coal Products (+: output/-: input)	-1,337,102	1,261,810	0	-13,474	0	0	0	0	0	-5,165	0	0	0	-93,930	-93,930	0
#10	Oil Products (+: output/-: input)	0	0	-5,301,697	5,256,534	1,502	0	-19,630	0	0	0	0	0	-112,550	-175,840	0	-175,840
#11	Gas Conversion and Production (+: output/-: input)	0	0	0	-77,530	-1,603,662	1,679,649	-66	0	0	0	0	0	0	-1,609	-1,609	0
#12	Power Generation	-2,457,503	-112,324	-12,359	-212,036	-2,673,009	-196,375	-378,535	-637,510	0	-130,836	-325,883	3,043,355	0	-4,093,016	-4,093,016	0
#13	Auto Power Generation	-171,702	-95,717	-31	-155,927	-42,433	-111,309	-614,821	-25,221	0	-193,107	0	572,536	0	-837,733	-837,733	0
#14	Auto Steam Generation	-212,003	-58,276	-55	-276,054	-21,689	-188,235	-159,807	0	0	-180,653	0	0	913,861	-182,911	-182,911	0
#15	District Heat Supply/ Other Energy Transformation	0	0	0	130,760	162,308	-168,778	-771	0	0	-3,066	0	-3,243	21,261	138,472	1,519	136,953
#16	Own Use and Loss	-12,903	-107,198	-1	-183,521	-13,115	-23,253	-27	0	0	0	0	-360,525	-6,273	-706,817	-706,817	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	33,446	-902	6,568	27,279	-30,670	0	-2,117	0	0	-749	0	0	0	32,854	0	32,854
#18	Statistical Discrepancy (+: excess/-: shortage)	-4,774	35,245	-13,585	153	-4,252	0	0	0	0	0	0	-36,233	-41,497	-64,943	-64,943	0
#19	Final Energy Consumption	335,182	783,286	0	5,733,972	55,108	992,422	10,286	0	0	29,848	0	3,288,356	857,797	12,086,257	10,656,761	1,429,496
#20	Industry	335,166	783,286	0	2,606,390	55,108	558,002	3,962	0	0	29,848	0	2,272,186	856,702	7,500,650	6,106,135	1,394,514
#21	Agriculture, Fishery, Mining and Construction	0	18	0	347,509	4,490	2,926	0	0	0	0	0	37,752	849	393,544	342,597	50,947
#22	Manufacturing	335,161	774,756	0	1,738,916	50,619	242,587	146	0	0	29,848	0	1,137,648	790,810	5,100,490	3,784,542	1,315,948
#23	Food, Beverages, Tobacco and Feed	17	0	0	26,564	0	31,605	0	0	0	0	0	88,205	91,530	237,921	237,921	0
#24	Textile Mill Products	0	0	0	4,555	39	5,409	0	0	0	0	0	26,002	37,777	73,781	73,781	0
#25	Pulp, Paper and Paper Products	0	0	0	12,814	400	4,580	113	0	0	760	0	96,394	175,512	290,573	290,573	0
#26	Chemical and Allied Products, Oil and Coal Products	1,860	48,209	0	1,518,826	26,214	22,564	0	0	0	2,000	0	179,155	302,327	2,101,155	785,785	1,315,369
#27	Ceramic, Stone and Clay Products	120,170	12,481	0	74,276	4,641	26,243	32	0	0	24,621	0	60,008	19,520	341,993	341,536	456
#28	Iron and Steel	211,670	705,801	0	37,817	16,216	69,226	0	0	0	1,290	0	218,176	84,793	1,344,989	1,344,867	122
#29	Non-Ferrous Metals	1,426	6,654	0	13,950	1,312	12,663	0	0	0	1,177	0	43,062	9,485	89,730	89,730	0
#30	Machinery	1	1,611	0	37,808	1,797	58,232	0	0	0	0	0	321,793	34,298	455,540	455,540	0
#31	Miscellaneous	17	0	0	12,306	0	12,066	0	0	0	0	0	104,852	35,567	164,808	164,808	0
#32	Commercial Industry	5	8,512	0	519,964	0	312,489	3,816	0	0	0	0	1,096,786	65,043	2,006,616	1,978,996	27,619
#33	Residential	0	0	0	514,467	0	433,238	6,324	0	0	0	0	956,663	1,095	1,911,787	1,911,787	0
#34	Transportation	16	0	0	2,613,115	0	1,182	0	0	0	0	0	59,507	0	2,673,820	2,638,838	34,982
#35	Passenger	16	0	0	1,455,913	0	52	0	0	0	0	0	57,063	0	1,513,044	1,486,818	26,226
#36	Freight	0	0	0	1,157,203	0	1,129	0	0	0	0	0	2,444	0	1,160,776	1,152,020	8,756
#37	Non-energy and Feedstock Use	22	18,552	0	1,400,384	10,538	0	0	0	0	0	0	0	0	1,429,496	0	1,429,496

2021FY	Row $	$0100	$0200	$0300	$0400	$0500	$0600	$0700	$0800	$0900	$1000	$1100	$1200	$1300	$1400	$1401	$1402
	<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ	Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total
Line #																	
#01	Primary Energy Supply	4,812,955	-4,692	5,656,731	1,063,316	3,997,511	943	1,324,585	673,120	0	541,056	604,886	0	0	18,670,410	17,228,574	1,441,836
#02	Indigenously Produced	15,990	0	17,145	0	89,230	0	1,219,635	673,120	0	541,056	604,886	0	0	3,161,062	0	0
#03	Import	4,797,109	63,192	5,676,187	1,953,929	3,910,636	0	104,975	0	0	0	0	0	0	16,506,027	0	0
#04	Total Primary Energy Supply	4,813,099	63,192	5,693,331	1,953,929	3,999,866	0	1,324,610	673,120	0	541,056	604,886	0	0	19,667,089	18,225,253	1,441,836
#05	Export	-144	-66,167	0	-938,715	0	0	-26	0	0	0	0	0	0	-1,005,051	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	0	-1,716	-36,601	48,102	-2,356	943	0	0	0	0	0	0	0	8,372	0	0
#07	Domestic Primary Energy Supply (Supply)	4,812,955	-4,692	5,656,731	1,063,316	3,997,511	943	1,324,585	673,120	0	541,056	604,886	0	0	18,670,410	17,228,574	1,441,836
	(Demand)														18,571,954	17,130,118	1,441,836
#08	Energy Transformation & Own Use	-4,393,997	920,195	-5,628,513	4,619,595	-3,912,446	1,034,569	-1,314,947	-673,120	0	-508,857	-604,886	3,348,729	818,045	-6,295,634	-6,285,093	-10,541
#09	Manufacture of Coal Products (+: output/-: input)	-1,426,802	1,330,276	0	-14,614	0	0	0	0	0	-5,555	0	0	0	-116,695	-116,695	0
#10	Oil Products (+: output/-: input)	0	0	-5,623,033	5,605,003	1,573	0	-19,958	0	0	0	0	0	-105,130	-141,544	0	-141,544
#11	Gas Conversion and Production (+: output/-: input)	0	0	0	-88,107	-1,661,472	1,747,481	-59	0	0	0	0	0	0	-2,156	-2,156	0
#12	Power Generation	-2,572,829	-128,635	-9,317	-282,017	-2,388,659	-201,185	-434,796	-647,142	0	-131,536	-604,886	3,103,692	0	-4,297,309	-4,297,309	0
#13	Auto Power Generation	-174,267	-103,406	0	-165,550	-45,669	-115,451	-684,459	-25,978	0	-199,669	0	623,609	0	-890,841	-890,841	0
#14	Auto Steam Generation	-219,365	-63,504	0	-276,121	-22,426	-200,366	-171,325	0	0	-168,983	0	0	908,338	-213,753	-213,753	0
#15	District Heat Supply/ Other Energy Transformation	0	0	0	44,916	169,305	-175,834	-845	0	0	-3,145	0	-3,219	21,574	52,753	1,599	51,154
#16	Own Use and Loss	-33,148	-110,610	-5	-207,713	-12,013	-20,077	-282	0	0	0	0	-375,353	-6,738	-765,938	-765,938	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	32,414	-3,927	3,842	3,797	46,915	0	-3,223	0	0	31	0	0	0	79,849	0	79,849
#18	Statistical Discrepancy (+: excess/-: shortage)	32,783	71,583	28,217	-266	27,763	0	0	0	0	0	0	23,302	-84,926	98,456	98,456	0
#19	Final Energy Consumption	386,175	843,919	1	5,683,177	57,302	1,035,512	9,637	0	0	32,199	0	3,325,427	902,971	12,276,320	10,845,025	1,431,295
#20	Industry	386,159	843,919	1	2,598,368	57,302	606,028	3,886	0	0	32,199	0	2,367,417	901,908	7,797,188	6,400,181	1,397,006
#21	Agriculture, Fishery, Mining and Construction	0	1	0	349,136	4,734	2,800	0	0	0	0	0	39,870	692	397,233	352,370	44,864
#22	Manufacturing	386,156	837,546	1	1,780,083	52,568	252,106	126	0	0	32,199	0	1,165,944	839,822	5,346,550	4,015,730	1,330,820
#23	Food, Beverages, Tobacco and Feed	19	0	0	26,846	0	28,043	0	0	0	0	0	89,934	106,537	251,378	251,378	0
#24	Textile Mill Products	0	0	0	4,559	41	5,555	0	0	0	0	0	27,507	40,313	77,975	77,975	0
#25	Pulp, Paper and Paper Products	0	0	0	13,244	1,029	4,501	95	0	0	704	0	99,816	183,862	303,250	303,250	0
#26	Chemical and Allied Products, Oil and Coal Products	852	48,300	1	1,563,575	25,274	24,768	0	0	0	2,010	0	180,564	303,160	2,148,503	817,961	1,330,542
#27	Ceramic, Stone and Clay Products	117,320	13,040	0	71,280	4,262	23,950	31	0	0	26,938	0	58,413	16,007	331,240	331,071	169
#28	Iron and Steel	266,280	768,093	0	38,105	18,845	78,811	0	0	0	1,255	0	238,034	92,529	1,501,953	1,501,844	109
#29	Non-Ferrous Metals	1,395	6,461	0	14,300	1,415	17,543	0	0	0	1,292	0	42,467	10,074	94,947	94,947	0
#30	Machinery	0	1,652	0	36,645	1,703	57,358	0	0	0	0	0	327,606	45,846	470,809	470,809	0
#31	Miscellaneous	289	0	0	11,529	0	11,578	0	0	0	0	0	101,603	41,495	166,494	166,494	0
#32	Commercial Industry	3	6,372	0	469,148	0	351,122	3,760	0	0	0	0	1,161,604	61,394	2,053,404	2,032,081	21,323
#33	Residential	0	0	0	453,774	0	428,538	5,751	0	0	0	0	898,503	1,063	1,787,629	1,787,629	0
#34	Transportation	16	0	0	2,631,035	0	946	0	0	0	0	0	59,507	0	2,691,504	2,657,215	34,289
#35	Passenger	16	0	0	1,439,763	0	36	0	0	0	0	0	57,063	0	1,496,878	1,471,388	25,489
#36	Freight	0	0	0	1,191,272	0	910	0	0	0	0	0	2,444	0	1,194,626	1,185,827	8,799
#37	Non-energy and Feedstock Use	13	19,536	1	1,400,847	10,898	0	0	0	0	0	0	0	0	1,431,295	0	1,431,295

A4.2.2 General Energy Statistics and CRF

In order to report CO_2 emissions in CRF, emissions reported under the sectors in *General Energy Statistics* (Energy Balance Table) were reported under each sector in CRF. The correspondence of categories between *General Energy Statistics* and CRF table 1.A(a) 'sectoral approach' is indicated in Table A 4-23.

Values subtracting energy consumption reported under 'non-energy and feedstock use' [#950000] from energy consumption reported under 'energy transformation & own use' [#200000], 'industry' [#600000], 'residential' [#700000], and 'transportation' [#800000] in *General Energy Statistics* (Energy Balance Table) are used for activity data. Because energy consumption reported under 'non-energy and feedstock use' [#950000] was used for the purposes other than combustion and was considered not emitting CO_2, these values were deducted. However, out of this amount deducted as feedstock and non-energy use, the emissions from what is used or collected as energy during waste incineration are separately estimated and reported.

The *2006 IPCC Guidelines* requires carbon dioxide emitted from auto power generation, etc., to be counted in the corresponding sector. In Japan's Energy Balance Table (*General Energy Statistics*), fuel consumption used for auto power generation and auto steam generation are presented under 'auto power generation' [#250000], 'auto steam generation' [#260000] in the energy transformation sector. However, auto power generation and auto steam generation actually belong to industry sector. Hence, carbon dioxide emissions from "auto power generation" and "auto steam generation" are allocated to each section of '1.A.2 Manufacturing industries and construction' and '1.A.4 Other sectors'.

In 'energy transformation & own use', 'manufacture of coal products' [#210000], 'oil products' [#220000], 'gas conversion and production' [#230000], 'power generation' [#240000], 'auto power generation' [#250000], 'auto steam generation' [#260000], 'district heat supply' [#270000], and 'own use & loss' [#300000] are calculated, and other sectors ('other energy transformation' and 'transformation and consumption stockpile change') are excluded from calculations.

The category 'manufacture of coal products' [#210000] corresponds to the balance between input amount of feedstock and output amount of coal products under coke manufacturing process. The difference between the coke-making carbon input and carbon output is considered to be the portion that is oxidized in the atmosphere (burned) from the time that red-hot coke is extruded from a coke oven until it enters the coke dry quenching facility. It was considered appropriate to count this as CO_2 emissions, and it was calculated as carbon emissions from this category. (Ministry of the Environment, 2006)

The category 'oil products' [#220000] corresponds to the balance between input amount of feedstock and output amount of oil products under oil refining process. The difference between the carbon input and carbon output is considered to be the burned carbon precipitated on catalysts in fluid catalytic cracking facilities (so-called FCC coke). The burning is aimed at recovering the catalytic activities lowered by the cracking reaction of slack fuel oil. The difference is also considered to be heat recovery at boilers of the off-gas, mainly consisting of CO, generated in the fluid catalytic cracking facilities. The difference is also regarded as CO_2 as by-product of hydrogen generating facilities. It was considered appropriate to count the difference as CO_2 emissions, and it was calculated as carbon emissions from this category. (Ministry of the Environment, 2015)

Table A 4-23 Correspondence between sectors of General Energy Statistics (Detailed Sector) and of the CRF table 1.A(a)

CRF			General Energy Statistics	
1.A.1		Energy industries		
	1.A.1.a	Public electricity and heat production	Public Power generation	#240000
			Own use; Public Power generation	#301400
			District heat supply	#270000
			Own use; District heat supply	#301500
			Auto power generation; Production, transmission and distribution of electricity (until 2015)	#255330
	1.A.1.b	Petroleum refining	Oil products	#220000
			Own use; Oil products	#301200
			Auto power generation; Manufacture of petroleum products	#253171
			Auto steam generation, Manufacture of petroleum products	#263171
			Final energy consumption, Manufacture of petroleum products	#626510
			Non-energy and feedstock use; Manufacture of petroleum products	#951540
	1.A.1.c	Manufacture of solid fuels and other energy industries	Manufacture of coal products	#210000
			Own use; Coal products	#301100
			Auto power generation; Manufacture of coal products and miscellaneous	#253175
			Auto steam generation, Manufacture of coal products and miscellaneous	#263175
			Final energy consumption; Manufacture of coal products and miscellaneous	#626550
			Gas conversion and production	#230000
			Own use; Gas conversion and production	#301300
1.A.2		Manufacturing industries and construction		
	1.A.2.a	Iron and steel	Auto power generation; Manufacture of iron and steel	#253250
			Auto steam generation; Manufacture of iron and steel	#263220
			Final energy consumption; Manufacture of iron and steel	#629100
			Non-energy and feedstock use; Manufacture of iron, steel and steel products	#951560
	1.A.2.b	Non-ferrous metals	Auto power generation; Manufacture of non-ferrous metals and products	#253230
			Auto steam generation; Manufacture of non-ferrous metals and products	#263260
			Final energy consumption; Manufacture of non-ferrous metals and products	#629300
			Non-energy and feedstock use; Primary smelting and refining of copper, lead, zinc and aluminium	#951570
	1.A.2.c	Chemicals	Auto power generation; Manufacture of chemical and allied products	#253160
			Auto steam generation; Manufacture of chemical and allied products	#263160
			Final energy consumption; Manufacture of chemical and allied products	#626100
			Non-energy and feedstock use; Manufacture of petrochemical, ammonia, soda products	#951530
	1.A.2.d	Pulp, paper and print	Auto power generation; Manufacture of pulp, paper and paper products	#253140
			Auto power generation; Printing and allied industries	#253150
			Auto steam generation; Manufacture of pulp, paper and paper products	#263140
			Auto steam generation; Printing and allied industries	#263150
			Final energy consumption; Manufacture of pulp, paper and paper products	#624000
			Final energy consumption; Printing and allied industries	#625000
			Non-energy and feedstock use; Manufacture of pulp, paper and paper products, large scale	#951520
	1.A.2.e	Food processing, beverages and tobacco	Auto power generation; Manufacture of food	#253090
			Auto power generation; Manufacture of beverages, tobacco and feed	#253100
			Auto steam generation; Manufacture of food	#263090
			Auto steam generation; Manufacture of beverages, tobacco and feed	#263100
			Final energy consumption; Manufacture of food, beverages, tobacco and feed	#621000
	1.A.2.f	Non-metallic minerals	Auto power generation; Manufacture of ceramic, stone and clay products	#253210
			Auto steam generation; Manufacture of ceramic, stone and clay products	#263210
			Final energy consumption; Manufacture of ceramic, stone and clay products	#628100
			Non-energy and feedstock use; Manufacture of ceramic, stone and clay products	#951550
	1.A.2.g	Other	Auto power generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#251010-#251040])	#251000
			Auto power generation; Manufacturing (except for the industries listed in 1.A.1.b, 1.A.1.c, 1.A.2.a through 1.A.2.f)	#252000
			Auto steam generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#261010-#261040])	#261000
			Auto steam generation; Manufacturing (except for the industries listed in 1.A.1.b, 1.A.1.c, 1.A.2.a through 1.A.2.f)	#262000
			Final energy consumption; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#611000])	#610000
			Final energy consumption; Manufacturing (except for the industries listed in 1.A.1.b, 1.A.1.c, 1.A.2.a through 1.A.2.f)	#620000
			Non-energy and feedstock use; Agriculture, fishery, mining and construction (except for agriculture, forestry and fishery)	#951100
			Non-energy and feedstock use; Manufacturing industry, large scale (except for the industries listed in 1.A.1.b, 1.A.1.c, 1.A.2.a through 1.A.2.f)	#951500
			Non-energy and feedstock use; Manufacturing industry, small and medium scale	#951700

Table A 4-23 Correspondence between sectors of General Energy Statistics (Detailed Sector) and of the CRF table 1.A(a) (cont.)

CRF			General Energy Statistics	
1.A.3	Transport			
1.A.3.a	Domestic aviation		Final energy consumption; Passenger; Air passenger transport	#815000
			Final energy consumption; Freight; Air freight transport	#854000
			Non-energy and feedstock use; Transportation (air)	#953000
1.A.3.b	Road transportation			
	i	Cars	Final energy consumption; Passenger; Passenger vehicle	#811000
			Non-energy and feedstock use; Transportation (passenger vehicle)	#953000
	ii	Light duty trucks	IE (1.A.3.b.iii)	-
	iii	Heavy duty trucks and buses	Final energy consumption; Passenger; Bus	#811500
			Final energy consumption, Freight; Freight truck and lorry	#851000
			Non-energy and feedstock use; Transportation (bus, freight truck and lorry)	#953000
	iv	Motorcycles	Final energy consumption; Passenger; Motorcycles	#812000
			Non-energy and feedstock use; Transportation (Motorcycles)	#953000
	v	Other	IE (1.A.3.b.iii)	-
1.A.3.c	Railways		Final energy consumption; Passenger; Railway passenger transport	#813000
			Final energy consumption; Freight; Railway freight transport	#852000
			Non-energy and feedstock use; Transportation (railways)	#953000
1.A.3.d	Domestic navigation		Final energy consumption; Passenger; Water passenger transport	#814000
			Final energy consumption; Freight; Water freight transport	#853000
			Non-energy and feedstock use; Transportation (water)	#953000
1.A.3.e	Other transportation		NO	-
1.A.4	Other sectors			
1.A.4.a	Commercial/institutional		Auto power generation (except for Production, transmission and distribution of electricity [#255330] (until 2015), Agriculture, fishery, mining and construction [#251000] and Manufacturing [#252000])	#250000
			Auto steam generation (except for Agriculture, fishery, mining and construction [#261000] and Manufacturing [#262000])	#260000
			Final energy consumption; Commercial industry	#650000
			Non-energy and feedstock use; Commercial	#951800
1.A.4.b	Residential		Final energy consumption; Residential	#700000
			Non-energy and feedstock use; Household	#952000
1.A.4.c	Agriculture/forestry/fishing			
	i	Stationary	Auto power generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#251000
			Auto steam generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#261000
			Final energy consumption; Agriculture, forestry and fishery [#610000]; stationary sources (estimates)	
			Non-energy and feedstock use; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#951100
	ii	Off-road vehicles and other machinery	Final energy consumption; Agriculture [#611100]; mobile sources (estimates)	
			Final energy consumption; Forestry [#611200]; mobile sources (estimates)	
	iii	Fishing	Final energy consumption; Fishery, except aquaculture [#611300]; mobile sources (estimates)	
			Final energy consumption; Aquaculture [#611400]; mobile sources (estimates)	
1.A.5	Other		NO	-

Note: #9xxxxx items are subtracted as a Non-energy use activity.

The ERT recommended that Japan provide a table in the NIR mapping the various types of fuels as reported in the energy balance with the corresponding fuels as reported in CRF table 1.A(d) (FCCC/ARR/2014/JPN). Table A 4-24 shows the correspondence of fuels among *General Energy Statistics*, CRF table 1.A(b) 'reference approach' and CRF table 1.A(d) 'non-energy use of fuels'.

Table A 4-24 Correspondence of fuels among *General Energy Statistics*, CRF table 1.A(b) and (d)

Fuel in CRF table 1.A(b) and (d)			Fuel in General Energy Statistics	Code
Liquid fossil	Primary fuels	Crude oil	Crude oil for refinery use	$0310
			Crude oil for power generation use	$0320
		Orimulsion	Bituminous mixture fuel	$0321
		Natural gas liquids	Natural gas liquid (NGL) & condensate	$0330
	Secondary fuels	Gasoline	Gasoline	$0431
		Jet kerosene	Jet fuel oil	$0432
		Other kerosene	Kerosene	$0433
		Gas/diesel oil	Gas oil or diesel oil	$0434
		Residual fuel oil	Fuel oil A	$0436
			Fuel oil B	$0438
			Fuel oil C for general use	$0439
			Fuel oil C for power generation use	$0440
		Liquefied petroleum gas	Liquefied petroleum gas (LPG)	$0458
		Naphtha	Pure naphtha	$0420
			Reformate	$0421
		Bitumen	Other heavy oil products	$0452
		Lubricants	Lubricant oil	$0451
		Petroleum coke	Oil coke	$0455
		Refinery feedstocks	Slack gasoline	$0412
			Slack kerosene	$0413
			Slack diesel oil or gas oil	$0414
			Slack fuel oil	$0415
			Cracked gasoline	$0416
			Cracked diesel oil or gas oil	$0417
			Feedstock oil for refinery and mixing	$0418
		Other oil	Refinery gas	$0457
Solid fossil	Primary fuels	Anthracite	Hard coal, anthracite & lignite	$0130
		Coking coal	Steel making coal	$0110
		Other bituminous coal	Imported steam coal for general use	$0121
			Imported steam coal for power generation use	$0123
		Sub-bituminous coal	Indigenous produced steam coal	$0124
	Secondary fuels	BKB and patent fuel	Coal briquette	$0213
		Coke oven/gas coke	Coke	$0211
			Coke oven gas	$0221
			Blast furnace gas	$0222
			Converter furnace gas	$0225
		Coal tar	Coal tar	$0212
Gaseous fossil		Natural gas	Liquefied natural gas (LNG)	$0510
			Indigenous natural gas	$0521
			Coal mining gas	$0522
			Boil off gas from crude oil	$0523
			City gas	$0610
			Small scale community gas	$0620
Biomass		Solid biomass	Woods	$N131
			Waste Woods	$N132
			Thermal Use of Black Liquor	$N136
		Liquid biomass	Bioethanol	$N134
			Biodiesel	$N135
		Gas biomass	Gas Biomass	$N137

A4.3. Quality Standard for Diesel Oil

The carbon emission factor for liquid fuels (diesel oil) in 1.A.3.b (Road transportation) is the lowest in Annex I Parties for two reasons. One is because the quality standard for diesel oil in Japan is different from other countries. Crude oil with high sulfur content imported from the Middle East must be decomposed and go through ultra-deep desulfurization to become low-sulfur diesel oil (<10 ppm) according to Japanese automobile exhaust gas regulations. The other reason is because gas oil used for purposes other than road transport is called "fuel oil A" to distinguish it from diesel oil. The carbon balance of Japanese petroleum refineries including diesel oil and fuel oil A nearly matches according to statistics, so these carbon emission factors are not irregular.

In the individual review on Japanese greenhouse gas inventory conducted in September 2012, the ERT (Expert Review Team) asked Japan for the possibility of involving the information on Japanese quality standard of diesel oil in the future NIR. In correspondence to the question, Japan has provided the information on Japanese quality requirement of diesel oil mainly used for automobile engine in the Table A 4-25 below. In this standard, the diesel oil is classified into five types based on the pour point difference. Also, the standard meets with the Japanese law “Act on the Quality Control of Gasoline and Other Fuel” as a matter of course.

Table A 4-25 Required quality of diesel oil in Japan

Test item	Unit	Type				
		S1	1	2	3	S3
Flash point	°C	50 or more			45 or more	
90 % distilling temperature	°C	360 or less		350 or less	330 or less 1)	330 or less
Pour point	°C	+5 or less	-2.5 or less	-7.5 or less	-20 or less	-30 or less
Cold filter plugging point	°C	−	-1 or less	-5 or less	-12 or less	-19 or less
Residual carbon ratio in 10 % residual oil	% in weight	0.1 or less				
Cetane index 2)	−	50 or more		45 or more		
Kinetic viscosity at 30 °C	mm^2/s	2.7 or more		2.5 or more	2.0 or more	1.7 or more
Sulfur ratio	% in weight	0.0010 or less				
Density at 15 °C	g/cm^3	0.86 or less				

1) 350 or less, if the kinetic viscosity at 30 °C is 4.7 mm^2/s or less.
2) Cetane number is also available for cetane index.
Reference: Japanese Industrial Standards, Diesel Fuel (JIS K 2204:2007)

A4.4. Conversion factors of calorific values

The ERT recommended that Japan include in the NIR detailed information on the conversion factors used to convert gross calorific values (GCV) to net calorific values (NCV) for all fuels (FCCC/ARR/2014/JPN). For reference, the following table provides the ratio of NCV to GCV, which are derived from GCV and NCV obtained from the standard values of FY2018.

Table A 4-26 Ratio of NCV to GCV (for reference)

Fuel	NCV/GCV	Fuel	NCV/GCV
Coal		Oil	
Imported steel making coal	0.92	Crude oil	0.94
Coking coal	0.92	NGL/condensate	0.94
PCI coal	0.92	Crude Oil - Power Generation Use	0.94
Imported steam coal	0.95	Bituminous Mixture Fuel / Orimulsion	0.95
Indigenous Produced Steam Coal	0.94	Oil Products	
Imported anthracite	0.97	LPG	0.93
Coal products		Propane	0.93
Coke	0.98	Butane	0.93
Coal Tar	0.95	Naphtha	0.94
Coke oven gas	0.90	Reformate	0.94
Blast furnace gas	0.98	Gasoline	0.94
Blast Furnace Gas - Power Generation Use	0.98	Premium Gasoline	0.94
Converter furnace gas	1.00	Regular Gasoline	0.94
Combustible natural gas		Jet fuel oil	0.94
Imported natural gas (LNG)	0.91	Jet fuel oil -Gasoline based	0.94
Indigenous natural gas	0.91	Jet fuel oil -Kerosene based	0.94
Imported natural gas (Vaporized LNG)	0.91	Kerosene	0.94
Indigenous Natural Gas	0.91	Diesel oil	0.94
Boil Off Gas from Crude Oil	0.91	Fuel oil A	0.94
City gas	0.91	Fuel oil C	0.95
Direct Supply LPG	0.93	Fuel oil B	0.94
Renewable Energy		Fuel Oil C - Power Generation Use	0.95
Black Liquor	0.87	Lubricants	0.94
Waste Woods	0.90	Other heavy oil products	0.95
Woods	0.95	Asphalt	0.95
Bioethanol	0.91	Petroleum coke	0.98
Biodiesel	0.91	Galvanic Furnace Gas	1.00
Gas Biomass	0.92	Refinery gas	0.92

Reference: Calculated from Agency for Natural Resources and Energy (2020). *2006 IPCC Guidelines* (Vol. 2, page 1.16) for Coal tar and Bituminous mixture fuel/Orimulsion.

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
2. UNFCCC, *Report of the individual review of the greenhouse gas inventory of Japan submitted in 2006*, FCCC/ARR/2006/JPN, 2007.
3. UNFCCC, *Report of the individual review of the annual submission of Japan submitted in 2010*, FCCC/ARR/2010/JPN, 2011.
4. UNFCCC, *Report of the individual review of the annual submission of Japan submitted in 2012*, FCCC/ARR/2012/JPN, 2013.
5. UNFCCC, *Report on the individual review of the annual submission of Japan submitted in 2014*, FCCC/ARR/2014/JPN, 2015.
6. OECD/IEA, *World Energy Statistics.*
7. Agency for Natural Resources and Energy, *General Energy Statistics.*
8. Agency for Natural Resources and Energy, *Explanation on Standard Calorific Values and Carbon Emission Factors for Fuel Combustion Revised in FY2018*, 2020.
9. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 1*, August 2006.
10. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report FY2014*, 2015.
11. Japanese Industrial Standards, Diesel Fuel (JIS K 2204:2007).
12. Kainou, K., *Explanation of General Energy Statistics*, 2012.

Annex 5. Assessment of Completeness, Definition of Notation Keys, and Sources and Sinks Reported as "NE"

A5.1. Assessment of Completeness

The current inventory is submitted in accordance with the common reporting format (CRF), which requires entering emissions/removals data or a notation key such as "NO", "NE", or "NA" for all sources/sinks. Japan reviewed the definition of notation keys provided in the *UNFCCC reporting guidelines*, etc and established decision trees for their application by Committee for Greenhouse Gas Emissions Estimation Methods in FY2002, 2012, and 2014.

This chapter indicates the decision trees described above and classification of source/sink categories of Japan reported as "NE".

A5.2. Definition of Notation Keys

In Japan, notation keys are used in accordance with the *UNFCCC reporting guidelines* (Decision 24/CP.19). The following table A5-1 indicates definitions of notation keys provided in the *UNFCCC reporting guidelines*.

Table A 5-1 Definitions of notation keys indicated in the *UNFCCC reporting guidelines*

Notation Key	Explanation
NO (Not Occurring)	"NO" (not occurring) for categories or processes, including recovery, under a particular source or sink category that do not occur within an Annex I Party.
NE (Not Estimated)	"NE" (not estimated) for AD and/or emissions by sources and removals by sinks of GHGs which have not been estimated but for which a corresponding activity may occur within a Party. Where "NE" is used in an inventory to report emissions or removals of CO_2, N_2O, CH_4, HFCs, PFCs, SF_6 and NF_3, the Annex I Party shall indicate in both the NIR and the CRF completeness table why such emissions or removals have not been estimated. Furthermore, a Party may consider that a disproportionate amount of effort would be required to collect data for a gas from a specific category that would be insignificant in terms of the overall level and trend in national emissions and in such cases use the notation key "NE". The Party should in the NIR provide justifications for exclusion in terms of the likely level of emissions. An emission should only be considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions, and does not exceed 500 kt CO_2 eq. The total national aggregate of estimated emissions for all gases and categories considered insignificant shall remain below 0.1 per cent of the national total GHG emissions. Parties should use approximated AD and default IPCC EFs to derive a likely level of emissions for the respective category. Once emissions from a specific category have been reported in a previous submission, emissions from this specific category shall be reported in subsequent GHG inventory submissions.
NA (Not Applicable)	"NA" (not applicable) for activities under a given source/sink category that do occur within the Party but do not result in emissions or removals of a specific gas. If the cells for categories in the CRF tables for which "NA" is applicable are shaded, they do not need to be filled in.
IE (Included Elsewhere)	"IE" (included elsewhere) for emissions by sources and removals by sinks of GHGs estimated but included elsewhere in the inventory instead of under the expected source/sink category. Where "IE" is used in an inventory, the Annex I Party should indicate, in the CRF completeness table, where in the inventory the emissions or removals for the displaced source/sink category have been included, and the Annex I Party should explain such a deviation from the inclusion under the expected category, especially if it is due to confidentiality.
C (Confidential)	"C" (confidential) for emissions by sources and removals by sinks of GHGs of which the reporting could lead to the disclosure of confidential information, given the provisions of paragraph 36. (Paragraph 36: Emissions and removals should be reported at the most disaggregated level of each source/sink category, taking into account that a minimum level of aggregation may be required to protect confidential business and military information.)

Reference : *UNFCCC reporting guidelines on annual greenhouse gas inventories* (Decision 24/CP.19)

Applicability criteria for "NE" when the emissions are considered insignificant was stipulated by the Committee for the Greenhouse Gas Emissions Estimation Methods in FY2012 and FY2014.

If the *UNFCCC reporting guidelines* are revised in the future, the definition of notation keys and their application will be reviewed.

A5.3. Decision Tree for Application of Notation Keys

A decision tree for the application of notation keys and that for applicability criteria for "NE" when the emissions are considered insignificant for Japan's inventory are shown in Figure A5-1 and A5-2.

When emissions by sources and removals by sinks of GHGs could be confidential information, they are reported as "C".

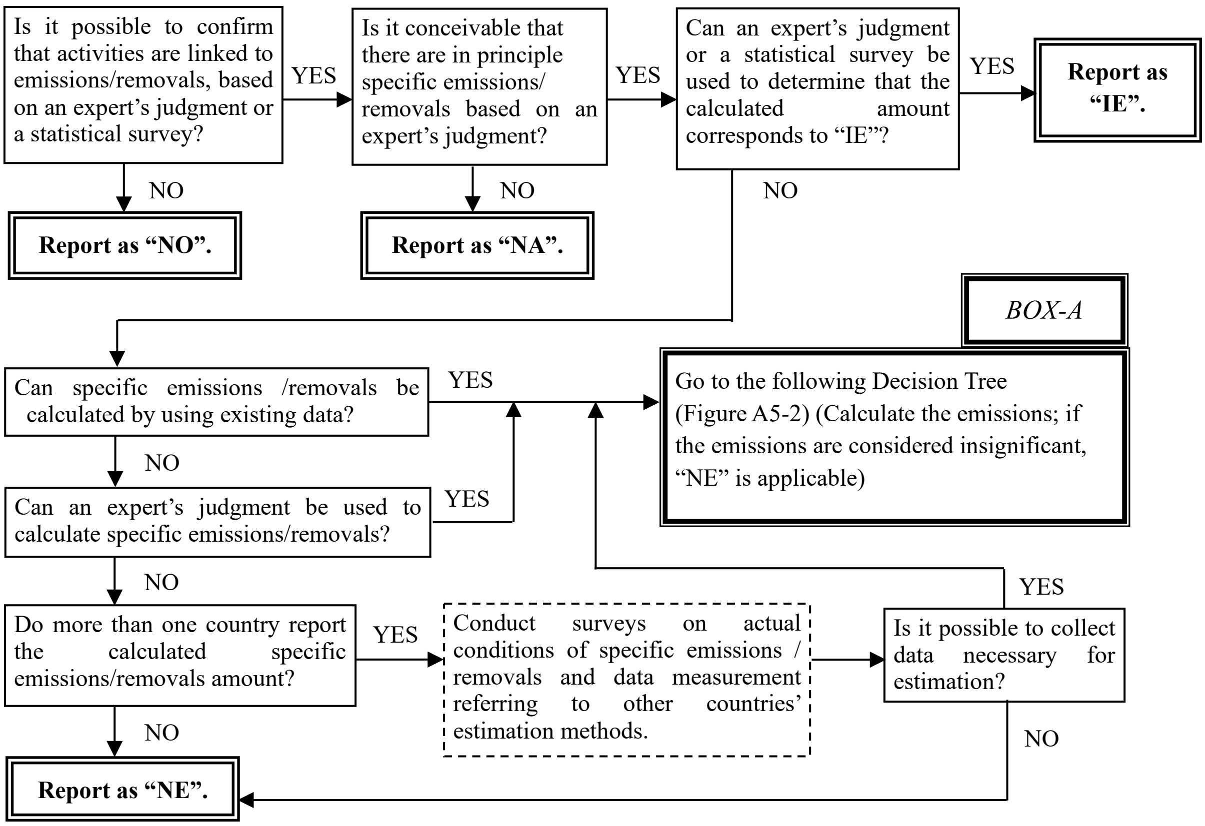


Figure A 5-1 Decision tree for application of notation keys

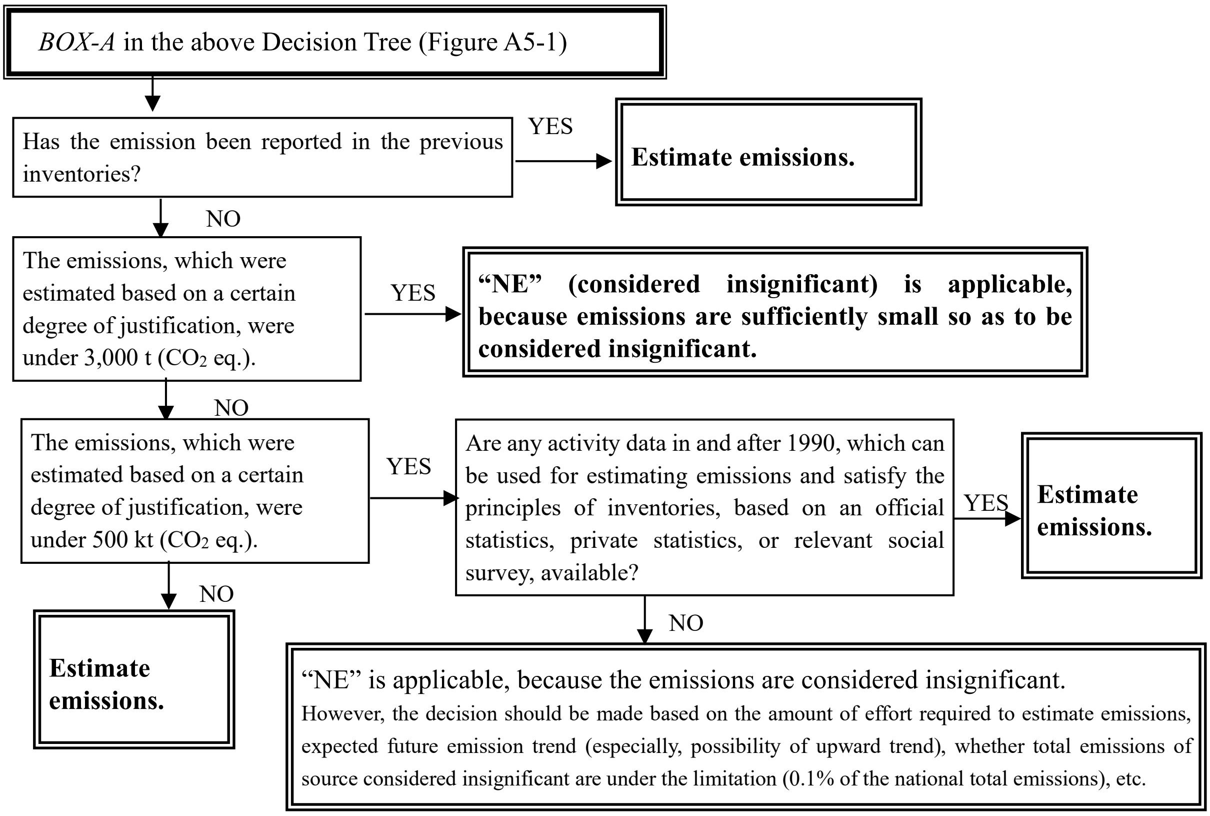


Figure A 5-2 Decision tree for determining applicability of "NE" when the emissions are considered insignificant

A5.4. Emission sources reported as "NE" (considered insignificant) in Japan

The notation key "NE" (considered insignificant) was used for the source categories indicated in the following Table A5-2, because the emissions are sufficiently small so as to be considered insignificant. Since the approximate total amount of emissions from these emission sources (excluding removals) is 123 kt (in CO_2 eq.) at maximum, it is not expected to exceed 0.1% of the national total emissions (approximately 1.17 Mt in CO_2 eq. for Japan), which is stipulated in paragraph 37(b) in the *UNFCCC reporting guidelines* (Decision 24/CP.19) as the upper limit of applicability of "NE" for being considered insignificant.

Table A 5-2 Emission sources reported as "NE" (considered insignificant)

	Code	Sector and Category			Gas	Likely Level of Emissions* [kt-CO_2eq]
#1	1.B.2.b.iv.	Energy	Fugitive emissions from fuels (Natural gas)	Transmission and storage	CO_2	<0.5
#2	1.B.2.b.v.	Energy	Fugitive emissions from fuels (Natural gas)	Distribution	CO_2	
#3	1.C.	Energy	CO_2 transport and storage		CO_2	<0.007
#4	2.C.7.	IPPU	Rare Earths Production		CO_2	<0.6
#5	2.C.7.	IPPU	Rare Earths Production		PFCs	<0.4
#6	2.D.3.	IPPU	NMVOC incineration		CH_4	<0.2
#7	2.D.3.	IPPU	NMVOC incineration		N_2O	<1
#8	2.F.1.	IPPU	Refrigeration and Air Conditioning Equipment	Fugitive emissions from refrigerant containers	HFCs	<63
#9	2.F.4.	IPPU	Product uses as substitutes for ODS	Aerosols	HFCs	<1.8
#10	2.G.2.	IPPU	SF_6 and PFCs from other product use	Soundproof windows	SF_6	<0.3
#11	3.A.4.-	Agriculture	Enteric Fermentation	Deer	CH_4	<2.3
#12	3.A.4.-	Agriculture	Enteric Fermentation	Alpaca	CH_4	<0.07
#13	3.B.4.-	Agriculture	Manure Management	Deer	CH_4	<0.03
#14	3.B.4.-	Agriculture	Manure Management	Reindeer	CH_4	<0.01
#15	3.B.4.-	Agriculture	Manure Management	Fox	CH_4	<0.04
#16	3.B.4.-	Agriculture	Manure Management	Other poultries (duck, turkey, etc.)	CH_4	<0.8
#17	3.B.4.-	Agriculture	Manure Management	Deer	N_2O	<0.6
#18	3.B.4.-	Agriculture	Manure Management	Reindeer	N_2O	<0.02
#19	3.B.4.-	Agriculture	Manure Management	Fox	N_2O	<0.01
#20	3.B.4.-	Agriculture	Manure Management	Other poultries (duck, turkey, etc.)	N_2O	<0.3
#21	4.D.1.	LULUCF	Wetlands	Peat extraction	CO_2	<50
#22	4.D.	LULUCF	Wetlands	Biomass Burning	CH_4	<0.14
#23	4.D.	LULUCF	Wetlands	Biomass Burning	N_2O	<0.16
#24	5.B.2.	Waste	Anaerobic digestion at biogas facilities		CH_4	<1.4
Total						**<123**

Note: Maximum possible amount of emissions between FY 1990 and the latest year, under certain assumptions and based on simple estimation methods such as Tier 1

A5.5. Other Source and sink categories not estimated in Japan's inventory

Based on consideration of availability of activity data and estimation methods provided in the *2006 IPCC Guidelines*, etc, the following table A5-3 indicates source and sink categories which were reported as "NE" for emissions/removals, excluding "NE" categories for being "considered insignificant" as described above.

Table A 5-3 Other Source and sink categories which were not estimated in Japan's inventory

	Code	Sector	Source and sink category				GHG
#1	1.A.3.	Energy	Fuel Combustion	Transport	Lubricants		CH_4
#2	1.A.3.	Energy	Fuel Combustion	Transport	Lubricants		N_2O
#3	1.B.1.a.	Energy	Fugitive Emissions from Fuels	Solid Fuels	Coal Mining and Handling		N_2O
#4	1.B.1.c.	Energy	Fugitive Emissions from Fuels	Solid Fuels	Others (Uncontrolled Combustion) (FY1999 only)		CO_2
#5	1.B.2.a.iv.	Energy	Fugitive Emissions from Fuels	Oil and Natural Gas	Oil	Refining/Storage	CO_2
#6	1.B.2.a.v.	Energy	Fugitive Emissions from Fuels	Oil and Natural Gas	Oil	Distribution of Oil Products	CO_2
#7	1.B.2.a.v.	Energy	Fugitive Emissions from Fuels	Oil and Natural Gas	Oil	Distribution of Oil Products	CH_4
#8	2.B.1.	IPPU	Chemical Industry	Ammonia Production			CH_4
#9	2.D.2.	IPPU	Non-energy Products from Fuels and Solvent Use	Lubricant Use			CH_4
#10	2.D.2.	IPPU	Non-energy Products from Fuels and Solvent Use	Lubricant Use			N_2O
#11	2.D.2.	IPPU	Non-energy Products from Fuels and Solvent Use	Paraffin Wax Use			CH_4
#12	2.D.2.	IPPU	Non-energy Products from Fuels and Solvent Use	Paraffin Wax Use			N_2O
#13	2.E.5.	IPPU	Electronics Industry	Microelectromechanical systems			HFCs
#14	2.E.5.	IPPU	Electronics Industry	Microelectromechanical systems			PFCs
#15	4.D.2.	LULUCF	Wetlands	Land converted to Wetlands	Cropland converted to Wetlands	Soil	Carbon Stock Change
#16	4.D.2.	LULUCF	Wetlands	Land converted to Wetlands	Grassland converted to Wetlands	Soil	Carbon Stock Change
#17	4.D.2.	LULUCF	Wetlands	Land converted to Wetlands	Settlements converted to Wetlands	Soil	Carbon Stock Change
#18	4.D.2.	LULUCF	Wetlands	Land converted to Wetlands	Other Land converted to Wetlands	Soil	Carbon Stock Change

Note: This table does not include sources with recovery reported as "NE", because recovery not estimated does not lead to underestimation of emissions. See related sections of each sector for more details of each item listed in this table.

Annex 6. Hierarchical Structure of Japan's National GHG Inventory File System

Multiple MS Excel files have been used when estimating the Japanese inventory. The explanation of each MS Excel file and the hierarchical structure of the Japanese National GHGs Inventory (JNGI) file system are shown below.

Table A6-1 Explanation of each MS Excel file

Category	Excel file name	Contents
	JPN_20xx_1990 - JPN_20xx_20yy	Common reporting format generated by CRF reporter
1. Energy	1A-L3-CO2-1990-20xx - 1A-L3-CO2-20yy-20xx	CO_2 emissions from fuel combustions
	1A-L3-CRF-20xx	CRF format data of GHG emissions from fuel combustion (including emissions by energy use of waste)
	1A-L3-timeseries-20xx	Time-series data of GHG emissions from fuel combustion
	1A-L2-MAP_EB-1990-20xx - 1A-L2-MAP_EB-20yy-20xx	Activity data for furnaces
	1A-L3-Biomass-20xx	GHG emissions from biomass combustion
	1A-L3-CO-20xx	CO emissions from furnace and off-road vehicle
	1A-L3-HC-20xx	CH_4, NMVOC emissions from furnace and off-road vehicle
	1A-L3-N2O-20xx	N_2O emissions from furnace and off-road vehicle
	1A-L3-NOxSO2-20xx	NOx, SO_2 emissions from fuel combustion (except transport sector)
	1A-L2-nonCO2-ADEF-20xx	Activity data and emission factors of non-CO_2 from fuel combustion (except transport sector)
	1A-L2-NOxSO2-ADEF-20xx	Activity data and emission factors of NOx, SO_2 from fuel combustion (except transport sector)
	1A-L3-Lub-20xx	CO_2 emissions from lubricant
	1A-L2-EBEF-20xx	Emission factors for CO_2 from fuel combustion
	1A-L1-EB-20xx	Data of the *General Energy Statistics* using in categories other than stationary combustion
	1A3-L3-CH4N2O-20xx	GHG emissions from mobile combustion (transport sector) (except CO_2)
	1A3-L2-ADEF-20xx	Activity data and emission factors for mobile combustion (transport sector)
	1A3-L2-2wADEF-20xx	Activity data and emission factors for motorcycles
	1B-L3-20xx	Fugitive GHG emissions from fuels
	1B-L2-ADEF-20xx	Activity data and emission factors for fugitive emissions from fuels
2. Industrial processes and other product use (IPPU)	2-L2-ADEF-20xx	Activity data and emission factors of IPPU sector (except F-gases)
	2-L3-20xx	GHG emissions from IPPU sector (except F-gases)
	2-L3-Fgas-20xx	F-gas (HFCs, PFCs, SF_6, NF_3) emissions
	2-L3-NMVOC-20xx	NMVOC emissions from the IPPU sector
	2-L2-NMVOC-20xx	Activity data and emission factors for NMVOC emissions from the IPPU sector
3. Agriculture	3A-L3-CH4-20xx	CH_4 emissions from enteric fermentation
	3B-L3-CH4N2O-20xx	GHG emissions from manure management
	3C-L3-CH4-20xx	CH_4 emissions from rice cultivation
	3D-L3-N2O-20xx	N_2O emissions from agricultural soils
	3F-L3-CH4N2OCO-20xx	GHG emissions from field burning of agricultural residues
	3GH-L3-CO2-20xx	CO_2 emissions from lime application and urine application to agricultural soil
	3AB-L2-ADEF-20xx	Activity data and emission factors of livestock
	3CDFGH-L2-ADEF-20xx	Activity data and emission factors of rice cultivation and agricultural soils, etc
4. LULUCF	4-L3-nonCSC-20xx	GHG emissions excluding carbon stock change
	4-L3-4A-CO2-20xx	CO_2 emissions and removals from forest land
	4-L3-4B-CO2-20xx	CO_2 emissions and removals from cropland
	4-L3-4C-CO2-20xx	CO_2 emissions and removals from grassland
	4-L3-4D-CO2-20xx	CO_2 emissions and removals from wetlands
	4-L3-4E-CO2-20xx	CO_2 emissions and removals from settlements
	4-L3-4F-CO2-20xx	CO_2 emissions and removals from other land
	4-L3-4G-CO2-20xx	CO_2 emissions and removals from HWP
	4-L2-Area(Pref.)-20xx	Area of mineral and organic soils
	4-L2-LandArea-20xx	Land area for each land use category
	4-L2-LandArea-Matrix-20xx	Land-use matrix
	4-L2-Mangrove-20xx	Carbon stock changes in mangroves
	4-L2-Orchard-20xx	Carbon stock changes in orchard
	4-L2-Parameter-20xx	Parameters for each land use category
	4-L2-Soil-20xx	Land area and carbon stock changes in cropland and grassland
	4-L2-Biochar-20xx	Organic carbon stocks from biochar amendments in mineral soil in cropland
5. Waste	5A3-L2-AD-20xx	Activity data of solid waste disposal (uncategorized waste disposal sites)
	5A-L3-20xx	GHG emissions from solid waste disposal
	5A-L2-AD-20xx	Activity data of solid waste disposal (managed waste disposal sites)
	5B-L3-20xx	GHG emissions from biological treatment of solid waste
	5B-L2-AD-20xx	Activity data of biological treatment of solid waste
	5C-L2-AD-20xx	Activity data of incineration and open burning of waste
	5C-L3-20xx	GHG emissions from incineration and open burning of waste
	5C-L3-Energy-20xx	GHG emissions from waste incineration and energy use (reported on energy sector)
	5D-L3-20xx	GHG emissions from wastewater treatment and discharge
	5D-L2-AD-20xx	Activity data of wastewater treatment and discharge
	5E-L3-20xx	GHG emissions from other
	5E-L2-AD-20xx	Activity data of other
	5-L2-EF-20xx	Emission factors of waste sector
6. Other	6-L3-20xx	CO emissions from smoking
7. Indirect CO_2	7-L3-Indi7-L3-Indirect CO2-20xx	Indirect CO_2 emissions
Memo item	1D-L3-bunker-20xx	GHG emissions from international bunker fuels
NDC-LULUCF	4KP-2-AR-20xx	GHG emissions and removals from afforestation/reforestation
	4KP-2-CM-20xx	GHG emissions and removals from cropland management
	4KP-2-D-20xx	GHG emissions and removals from deforestation
	4KP-2-FM-20xx	GHG emissions and removals from forest management
	4KP-2-HWP-20xx	CO_2 emissions and removals from HWP in forest management
	4KP-2-GM-20xx	GHG emissions and removals from grazing land management
	4NDC-2-UG-20xx	GHG emissions and removals from urban greening

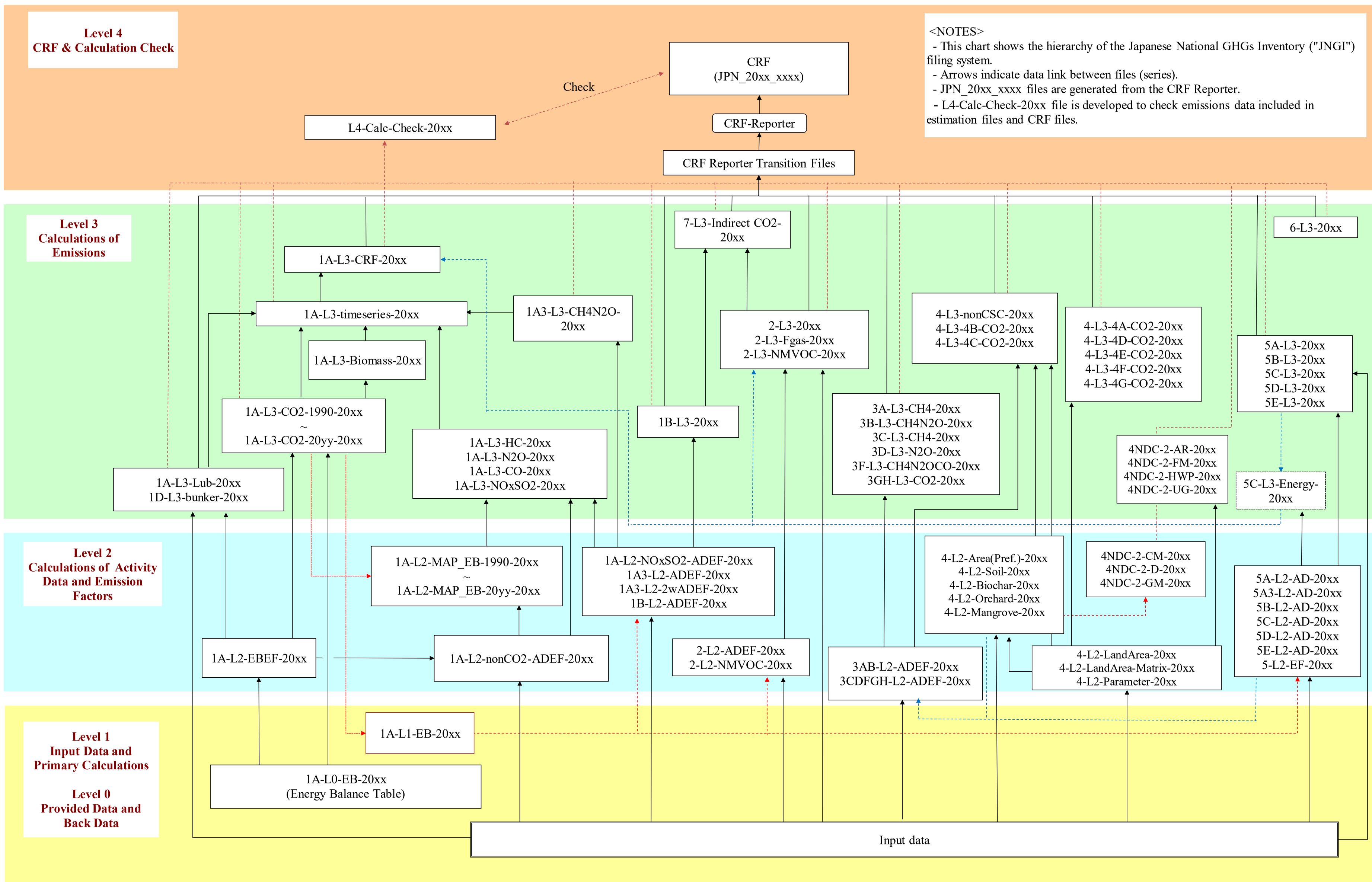


Figure A 6-1 Hierarchical structure of Japan's National GHG Inventory File System

Annex 7. Methodological Details of the LULUCF Sector Accounting in the NDC

A7.1. Summary of Greenhouse Gas (GHG) Emissions by Sources and Removals by Sinks in the LULUCF Sector in the NDC

A7.1.1 Activities Subject to GHG Emissions and Removals Estimation, Their Scope, and Estimation Methodology Tiers in the LULUCF Sector in the NDC

This annex chapter, based on Decision 4/CMA.1, describes the activities subject to estimation of GHG emissions by sources and removals by sinks in the LULUCF sector in Japan's NDC, their scope, and the methodologies for accounting and estimation. This Annex is intended to be a supplemental explanation of GHG emissions and removals in the LULUCF sector in the NDC to be reported in “4. Structured summary” of Common Tabular Formats (CTF) in the Biennial Transparency Report (BTR).

GHG emissions and removals in the LULUCF sector in Japan’s NDC are calculated based on removals by measures for forest and other carbon sinks by adopting activity-based accounting. The scope is basically the same as the LULUCF activities under the second commitment period of the Kyoto Protocol: afforestation and reforestation (AR), deforestation (D), forest management (FM), cropland management (CM) and grazing management (GM), as well as urban greening (UG) whose scope has been expanded from revegetation (RV). These activities are collectively referred to as NDC-LULUCF activities. Table A 7-1 shows the status of estimations of carbon pools and gases reported for each activity. The tiers of the methodology used for the estimations are shown in Table A 7-2.

Table A 7-1 Reporting status of each carbon pool and gas for NDC-LULUCF activities

NDC-LULUCF Activity	Change in carbon pool reported						Greenhouse gas sources reported						
	Living biomass	Litter	Dead wood	Soil		HWP	Fertili-zation	Drainage of organic soils		N mineralization in mineral soils	Biomass burning		
				Mineral	Organic		N_2O	CH_4	N_2O	N_2O	CO_2	CH_4	N_2O
Afforestation and reforestation	R	R	R	R	NO	IE	IE	NO	NO	NA	IE	IE	IE
Deforestation	R	R	R	R	NO	IO	NO	NO	NO	R	NO	NO	NO
Forest management	R	R	R	R	NO	R	R	NO	NO	R	IE	R	R
Cropland management	R	NR	NR	R	R			R		R	R	R	R
Grazing land management	R	NR	NR	R	R			R		R	R	R	R
Urban greening	R	R	IE	R	NO		IE	NO	NO	NA	NO	NO	NO

R: Reported, NR: Not Reported, NO: Not Occurring, IE: Included Elsewhere, IO: Instantaneous Oxidation

Table A 7-2 Methodological tiers used to calculate each NDC-LULUCF activity

NDC-LULUCF Activity	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
Afforestation and reforestation	T2	CS	T1	D	T1	D
Deforestation	T2	CS,D			T1,T2	CS,D
Forest management	T2,T3	CS,D	T1	D	T1,T2	CS,D
Cropland management	T2,T3	CS,D	T1	CS,D	T2,CS	CS,D
Grazing land management	T2,T3	CS,D	T1	CS,D	T2,CS	CS,D
Urban greening	T2	CS,D				

T1: IPCC Tier 1, T2: IPCC Tier 2, T3: IPCC Tier 3, D: IPCC default, CS: country-specific method or emissions factor

A7.1.2 Accounting Approach and Accounting Quantity for each NDC-LULUCF Activity

The accounting approach used for each NDC-LULUCF activity is established in accordance with Article 4.14 of the Paris Agreement, taking into account the existing methodology and guidance based on the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (hereinafter referred to as *KP Supplement*), which was applied to each LULUCF activity in the second commitment period of the Kyoto Protocol. The gross-net approach was applied to afforestation and reforestation (AR) and deforestation (D) activities, which covered only lands with activities since 1990, as in the second commitment period of the Kyoto Protocol. The reference level approach was applied for forest management (FM). The reference level was set as zero for the forest carbon pools under FM, as in the second commitment period of the Kyoto Protocol, by only accounting for lands where additional anthropogenic activities (e.g., thinning) have been reliably conducted since 1990, while future projections were applied to the reference level for the Harvested Wood Products (HWP) pool. The sum of the reference levels for the forest carbon pools and HWP pool was used as the reference level for the entire FM. For CM and GM activities, as in the second commitment period of the Kyoto Protocol, the net-net approach was applied, using 1990 as the base year. In UG activities, the area of urban green space that have been established, serviced, or conserved is subject to calculation. In such net sink activities, it is important to maintain and enhance removals as an absolute amount in each year, so the net removals for the relevant fiscal year from the UG activity were directly accounted for as the amount of removals. This is equivalent to the gross-net accounting approach. The amount of those activities in FY2021 (after applying the accounting approaches) was 47,643 kt-CO_2eq. removal.

The annual accounted values before the target year, 2030, provided in this Annex chapter are presented only as a reference to indicate where Japan currently stands. Since our NDC target for 2030 was set as a single year net GHG emissions and removals target, the NDC-LULUCF removals will be accounted for only in the target year (2030). Values up to FY2020 are historical achievements which had already been accounted for in the 2020 target, while values from FY2021 indicate the status during the NDC period (Table A 7-3).

Table A 7-3 Accounting quantities for NDC-LULUCF activities

NDC-LULUCF activity	Accounting quantities [kt CO_2 eq.]							
	Archives							NDC period
	2014	2015	2016	2017	2018	2019	2020	2021
Afforestation/reforestation	-1,685	-1,664	-1,362	-1,301	-1,158	-1,439	-1,363	-1,293
Deforestation	3,170	3,371	3,335	2,890	2,852	2,953	2,935	2,555
Forest management	-56,820	-53,346	-51,512	-51,020	-49,888	-45,602	-43,112	-43,862
Cropland management	-1,521	-2,004	-2,231	-3,047	-3,624	-2,997	-3,014	-3,335
Grazing land management	1,100	817	533	371	141	272	140	-158
Urban greening	-1,776	-1,747	-1,728	-1,704	-1,667	-1,640	-1,593	-1,551
Total accounting quantity	-57,531	-54,574	-52,964	-53,811	-53,343	-48,452	-46,007	-47,643

(CO_2) +: Emissions, -: Removals

A7.2. Scope of Estimations for each NDC-LULUCF Activity

A7.2.1 Afforestation/Reforestation (AR)

For AR activity, annual GHG emissions and removals associated with growth and forest management practices were estimated for land that was not forested at the end of 1989, but was converted to forest through afforestation or other human activities after 1990. This activity is similar to “land converted to forest land (4.A.2.)” in the Convention inventory, but the starting point for counting the area covered is different (1990 for AR activity). The loss of carbon stocks of living biomass from lands prior to conversion to forest land is to be accounted for under the activities before the conversions. The carbon stock changes in HWP from AR activity are difficult to distinguish from HWP from FM activity, and therefore all the amount is collectively estimated under FM activity.

A7.2.2 Deforestation (D)

For D activity, annual GHG emissions from deforestation and site preparation were estimated for the land that was anthropogenically converted from forest to non-forest land use after 1990. The increase in carbon stocks due to growth on the converted land is to be accounted for under the post-conversion activities.

A7.2.3 Forest Management (FM)

For FM activity, GHG emissions and removals from the following activities (excluding AR activities) of forests with standing trees in “forest land remaining forest land (4.A.1.)” in the Convention inventory were estimated.

- Ikusei-rin forests: forest practices conducted since 1990 to maintain forests in appropriate conditions, including regeneration (land preparation, soil scarification, planting, etc.), tending (weeding, pre-commercial cutting, etc.), thinning and harvesting
- Tennensei-rin forests: protection or conservation of forests, including regulating logging activities and restrictions on land-use changes, which have been carried out by law

Carbon stock changes in HWP from the above-mentioned forests are also included in the estimation of this activity.

A7.2.4 Cropland Management (CM)

For CM activity, GHG emissions and removals resulting from the practices of cultivating and other activities in rice fields, upland fields, and orchards in cropland (4.B.) in the Convention inventory were estimated. Dilapidated farmland which is included in the Convention inventory is not included in CM because the land is not being properly managed.

A7.2.5 Grazing land Management (GM)

For GM activity, GHG emissions and removals resulting from grazing in pasture land under grassland (4.C.) in the Convention inventory were estimated.

"Grazed Meadow land" which has no change in management practices and "wild land" which is not land dedicated for grazing, are not included in GM, although they are reported under grassland in the Convention inventory.

A7.2.6 Urban Greening (UG)

For UG activity, GHG emissions and removals from urban green areas under settlements (4.E.) of the Convention inventory were included in the estimation. The scope of activities includes urban green areas with an area of less than 0.05 ha as well as those that were established or serviced before 1990, which were not subject to reporting and estimation under Revegetation (RV) activity of the Kyoto

Protocol, and green spaces conserved by zoning.

A7.3. Methods for Estimating and Accounting for GHG Emissions and Removals for each NDC-LULUCF Activity

A7.3.1 Afforestation and Reforestation Activities

A7.3.1.1. Method of Identifying Areas of Activity

As described in Section 6.2.2.1, the change from non-forest to forest detected by interpretation of satellite images was considered as an AR activity, and the AR cumulative occurrence area for the fiscal year *i* was calculated by multiplying the AR cumulative occurrence rate from 1990 to the end of the most recent year (year *i*) by the national land area. When interpreting satellite images, the area subject to AR activities and the forest restoration area due to natural succession are distinguished by judging whether each forest cover change is human-induced or not. This judgement is based on whether any signs of human activities, such as uniform tree species and uniform tree height, artificial forestation blocks, or work roads for forestation, are observed or not.

Table A 7-4 Area subject to AR activity

	Unit	1990-2014	1990-2015	1990-2016	1990-2017	1990-2018	1990-2019	1990-2020	1990-2021
AR accumulated occurrence area	[kha]	98.9	99.7	100.5	100.5	100.5	100.3	100.1	100

A7.3.1.2. Methods for Calculating for Carbon Stock Changes and GHG Emissions

a) Living Biomass

■ **Methodology**

The annual stock of living biomass that accumulates after conversion from other land uses to forests are to be included in this estimation. The calculation was based on the Tier 2 stock-change method which is the same method used for “forest land remaining forest land (4.A.1.)”. Since it is difficult to directly obtain the area where AR activities occur by tree species and by forest age, the carbon stock of living biomass ($C_{AR\_LB,\,i}$) of the area subject to AR activities in fiscal year *i* was calculated, by multiplying the cumulative area of AR occurrence since 1990 in fiscal year *i* ($A_{AR,\,i}$) with the carbon stock per unit area, which is calculated by dividing the total carbon stock ($C_{IM,\,i}$) by the total area ($A_{IM,\,i}$) of intensively managed forests at the end of fiscal year *i*, using the data extracted from the National Forest Resources Database, assuming that the composition of tree species and age class in intensively managed forests is the same as that of AR area.

$$\Delta C_{AR\_LB,i} = (C_{AR\_LB,i} - C_{AR\_LB,i-1})/(t_i - t_{i-1})$$

$$C_{AR\_LB,i} = A_{AR,i} \times \frac{C_{IM\_LB,i}}{A_{IM,i}}$$

$\Delta C_{AR\_LB,\,i}$: Carbon stock changes in living biomass in the area subject to AR activity in fiscal year *i* [t-C/yr]
t_i, t_{i-1} : At the time of the carbon stock survey: year *i* and year *i-1* (both at the end of fiscal year)
$C_{AR\_LB,\,i}$: Carbon stocks in living biomass in the area subject to AR activity at the end of fiscal year *i* [t-C]
$C_{IM\_LB,\,i}$: Carbon stock in living biomass in intensively managed forests at the end of fiscal year *i* [t-C]
$A_{AR,i}$: Cumulative area of AR occurrence since 1990 in fiscal year *i* [ha]
$A_{IM,i}$: Area of intensively managed forests at the end of fiscal year *i* [ha]

■ **Activity Data**

The cumulative area of AR occurrence since 1990 was used.

b) Dead wood, Litter and Soils

■ **Methodology**

The carbon stock changes in dead wood, litter and mineral soils in areas subject to AR activities were calculated by using the same method used for "land converted to forest land (4.A.2.)" in Section 6.4.2.2.b)2) for forests less than 20 years old, and the same method as "forest land remaining forest land (4.A.1.)" in Section 6.4.2.1.b)2) for forests of 21 years old and older.

As mentioned in Section 6.4.1.b).2), the emissions from organic soils were reported as "NO".

■ **Activity Data**

The cumulative area of AR occurrence since 1990 was used for dead wood and mineral soils estimation, and the cumulative area of AR occurrence within 20 years was used for litter estimation.

c) Harvested Wood Products (HWP)

As the amount of HWP from AR activities cannot be distinguished from that from FM activities, it was reported collectively in FM activities and reported as "IE" in this category.

d) Other gases

1) N_2O emissions from N fertilization

As the amount of nitrogen-based fertilizer applied in Forest land cannot be separated between those in AR activities and in FM activities, N_2O emissions from N fertilization are reported collectively in FM activities , and reported as "IE" in this category.

2) N_2O and CH_4 emissions from drainage of organic soils

As described in Section 6.12, drainage activities in forest land with organic soils are not implemented in Japan. Therefore, N_2O and CH_4 emissions were reported as "NO" in this category.

3) N_2O Emissions from N mineralization due to carbon loss associated with land-use conversions and management change in mineral soils

According to the Tier 1 or Tier 2 methods described in *the 2006 IPCC Guidelines*, N_2O emissions from N immobilization associated with gain of soil organic matter are not subject to estimation. Therefore, N_2O emissions were reported as "NA", since soil carbon stock changes in AR are reported to be on the increase.

4) Emissions from Biomass Burning

As the area of forest fire occurrence cannot be distinguished by whether it is from AR activities or FM activities, associated emissions were reported collectively in FM activities and reported as "IE" in this category.

A7.3.1.3. Method of Accounting and Calculation Results

The accounting quantity was calculated by gross-net approach with 1990 as the base year. The net removals of area subject to AR activities in Table A 7-5 were used as the accounting quantity as is. The calculation results are as follows.

Table A 7-5 Emissions and removals and the accounting quantity from AR activity

	2014	2015	2016	2017	2018	2019	2020	2021
	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]
AR net removals and accounting quantity	-1685.35	-1663.99	-1362.28	-1301.41	-1157.60	-1439.10	-1362.95	-1292.71
Living biomass	-1495.63	-1478.42	-1180.11	-1125.20	-993.54	-1282.81	-1213.01	-1148.25
Dead wood	-59.48	-59.90	-60.40	-59.87	-59.83	-59.63	-59.51	-59.57
Litter	-100.89	-96.09	-91.26	-84.74	-71.54	-63.92	-58.33	-54.15
Mineral soils	-29.35	-29.58	-30.52	-31.60	-32.68	-32.75	-32.10	-30.74
Organic soils	NO	NO	NO	NO	NO	NO	NO	NO
Harvested wood products (HWP)	IE	IE	IE	IE	IE	IE	IE	IE
Other gases	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA
Fertilization (N_2O)	IE	IE	IE	IE	IE	IE	IE	IE
Organic soil drainage (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO
N mineralization in mineral soil (N_2O)	NA	NA	NA	NA	NA	NA	NA	NA
Biomass burning (CH_4, N_2O)	IE	IE	IE	IE	IE	IE	IE	IE

(CO_2) +: Emissions, -: Removals

A7.3.2 Deforestation Activity

A7.3.2.1. Method of Identifying Area of Activity

As described in section 6.2.2.1, the change from forest to non-forest detected by the interpretation of satellite images was identified as a D activity, and the national land area was multiplied by the D occurrence rate for a single year to calculate the D occurrence area for a single fiscal year, and the cumulative D occurrence area was calculated by multiplying the national land area by the total D occurrence rate from 1990 to the most recent fiscal year. In Japan, land conversion from forest land to other land uses means an exclusion of the land from forest plans. Therefore, as far as the area of harvested forest would remain included in forest plans, the area would not be regarded as D activity but as temporary loss of biomass stock, and would be distinguished from area subject to D activity which means conversion to other land uses, in the Forest Registers.

Japan identifies forest change as D activity only in the cases when lands undergo transformation or artificial construction are observed, or obvious conversion to non-forest land such as cropland are detected through imagery interpretation using aerial photos and satellite images. By this methodology, D activity is distinguished from temporary loss of biomass stock in forest land such as clear-cut under ongoing forestry activities.

Sample field surveys are conducted at plots which are interpreted as D areas in several prefectures every year, and the accuracy of D interpretation is approximately 90% on average.

Under the system based on the Forest Law, regeneration is expected to be done within around two years after a harvest event. If natural regeneration is selected as a means of regeneration, trees are expected to be established within five years after a harvest event.

Table A 7-6 Area subject to D activity

	Unit	1990-2014	1990-2015	1990-2016	1990-2017	1990-2018	1990-2019	1990-2020	1990-2021
D Accumulated occurrence area	[kha]	277.5	285.2	294	302.7	309.7	316.7	321.8	326.9
Area of occurrence in a single year	[kha]	7.7	8.8	8.8	7.0	7.0	5.1	5.1	4.1

A7.3.2.2. Methods for Calculating for Carbon Stock Change and GHG Emissions

a) Living Biomass

■ **Methodology**

As with the area subject to AR activities, it is difficult to directly obtain the area subject to D activities by species and by forest age. Therefore the forest biomass stock lost due to D activities was calculated assuming that the average forest biomass stock in the forests with standing trees at the beginning of the fiscal year subject to calculation is lost due to D activities. Specifically, the average carbon stock per unit area of the forests with standing trees at the beginning of the fiscal year extracted from the National

Forest Resources Database was multiplied by the D area occurred in the single fiscal year subject to calculation. All emissions resulting from deforestation were accounted for in the year in which deforestation occurred.

■ **Activity Data**

The area of D occurrence in a single fiscal year was used.

b) Dead Wood, Litter and Soils

■ **Methodology**

The carbon stock changes in dead wood, litter and mineral soils associated with D activities were calculated in the same way as for the conversion from forest to other land uses, as described in Section 6.6.2.b)2). Since there is no drainage treatment during D activities in organic soil areas, the relevant emissions in this category were reported as “NO”.

■ **Activity Data**

For the estimation of dead wood and litter, the area of D activities that occurred in a single fiscal year was used. For the estimation of mineral soils, the cumulative area of D activities occurred since 1990 was used in the case of conversions to upland fields and to orchards, whereas that of D activities occurred within 20 years was used in the case of conversion to land-uses other than upland fields or orchards.

c) Harvested Wood Products (HWP)

The carbon stock changes in the HWP pool were reported as “IO” because HWP from the area subject to D activity was accounted for by instantaneous oxidization when the wood was harvested in accordance with the methodology described in Section 2.8.2 of the *KP supplement*.

d) Other Gases

1) N_2O Emissions from N Fertilization

As no fertilization was conducted during the D activities, the emissions in this category were reported as “NO”.

2) N_2O and CH_4 Emissions from Drainage of Organic Soils

As there is no drainage treatment during D activities, the emissions in this category were reported as “NO”.

3) N_2O Emissions from N Mineralization due to Carbon Loss Associated with Land-Use Conversions and Management Changes in Mineral Soils

N_2O emissions from nitrogen mineralization associated with land-use changes and management were calculated using Tier 2 estimation method described in the *2006 IPCC Guidelines*. The estimation equation and parameters used are the same as those used in section 6.13, “land Converted to Other Land (4.F.2.)” calculation. Soil carbon loss data from D activities were used for the amount of soil carbon mineralized by land conversion on the area subject to D activities.

4) Emissions from Biomass burning

In Japan, controlled burning activities are not carried out in deforestation activities because of severe restrictions imposed by the “Waste Management and Public Cleansing Law” and the “Fire Defense

Law". Therefore, CH_4, N_2O emissions from biomass burning in D land are reported as "NO".

A7.3.2.3. Method of Accounting and Calculation Results

The accounting quantity was calculated using the gross-net approach with 1990 as the base year. The net emissions in the D activities of Table A 7-7 are directly used as the accounting quantity. The calculation results are as follows.

Table A 7-7 Emissions from D activity and the accounting quantity

	2014	2015	2016	2017	2018	2019	2020	2021
	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]
D Emissions and accounting quantity	3170.46	3370.76	3335.45	2890.44	2851.83	2953.31	2934.82	2555.07
Living biomass	1308.50	1498.21	1496.79	1186.69	1180.33	1425.64	1435.66	1163.08
Dead wood	281.09	321.85	321.85	255.01	255.01	188.65	188.65	151.68
Litter	137.73	157.71	157.70	124.96	124.96	92.44	92.44	74.32
Mineral soils	1344.26	1297.55	1265.97	1233.07	1203.02	1161.16	1134.61	1086.10
Organic soils	NO	NO	NO	NO	NO	NO	NO	NO
Harvested wood products (HWP)	IO	IO	IO	IO	IO	IO	IO	IO
Other gases	98.89	95.45	93.13	90.71	88.50	85.42	83.46	79.90
Fertilization (N_2O)	NO	NO	NO	NO	NO	NO	NO	NO
Organic soil drainage (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO
N mineralization in mineral soil (N_2O)	98.89	95.45	93.13	90.71	88.50	85.42	83.46	79.90
Biomass burning (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO

(CO_2) +: Emissions, -: Removals

A7.3.3 Forest Management

A7.3.3.1. Method of Identifying Area of Activity

Japan estimates the area subject to FM activity for Ikusei-rin forests and Tennensei-rin forests according to the following procedures.

a) Ikusei-rin Forests

1. [Planning of the FM Forest Survey]

   To estimate the percentage of forests subject to FM activities (FM rate), approximately 20,000 survey plots were randomly selected from the National Forest Resources Database in 2007 considering the distribution of private and national forests, as well as the distribution of tree species and regions for planted forests. Forests under the age where AR activities possibly happened after 1990 were excluded from the survey plots.

2. [Conducting the FM Forest Survey]

   The following FM Forest survey was conducted at the survey plots mentioned in the previous paragraph to determine whether the forests were subject to FM activities or not.

   ・FM Forest survey items: Current status of the forest (tree species, forest age, number of standing trees, etc.), existence and details of operations since 1990, etc.

   ・FM Forest survey method: Field surveys, interviews with forestry cooperatives, etc. and literature review of administrative documents and other documents related to subsidized afforestation projects

3. [Calculation of FM rate]

   The FM rate for FY2021 was calculated using the cumulative number of plots surveyed from the first year of the survey to the end of FY2021. This means that the FM activities implemented from 1990 to the end of the FY2021 are subject to the calculation.

4. [Calculation of FM area]

The area of forests subject to FM activities was calculated by excluding AR area from the area of Ikuseirin-forests at the end of FY2021, and applying FM rates for each tree species, region, and age class to the remaining area. Since the total forest area in FY2021 from the Forest Registers and the satellite images were used, the area of D activities that occurred in 2021 was already subtracted from the area.

Table A 7-8 FM ratio of Ikusei-rin forests by private and national forests (applicable to the calculation of the area of FM for FY2021)

Sub-category / Tree species		Region	Private forest	National forest
Intensively managed forest	Japanese cedar	Tohoku, Kita-kanto, Hokuriku, Tosan	0.89	0.92
		Minami-kanto, Tokai	0.75	0.88
		Kinki, Chugoku, Shikoku, Kyusyu	0.80	0.91
	Hinoki cypress	Tohoku, Kanto, Chubu	0.85	0.92
		Kinki, Chugoku, Shikoku, Kyusyu	0.88	0.94
	Japanese larch	All	0.89	0.85
	Other	All	0.74	0.84
Semi-natural forest / All		All	0.48	0.68

Note:
1) Approximately 22,400 surveyed points nationwide as of the end of FY2021
2) Region is a division of several prefectures commonly used in Japan.
3) The values listed here are area-weighted averages of FM rates by age class.
4) The uncertainty estimated for the FM rate listed here is 5% for Japan as a whole.

b) Tennensei-rin Forests

For Tennensei-rin forests, forest lands subject to legal measures of protection or conservation such as regulating logging activities and land-use change using data extracted from the NFRDB are subject to FM activities. Tennensei-rin forests consist of Protection Forests, Special Zones and Special Protection Zones of National Parks and other protected forests/zones as shown in Table A 7-9 below. The Protection Forests are designated under Article 25 of the Forest Law (legislation No. 249 of 26th June 1951) for the purpose of fulfilling multiple functions of forests (such as headwater conservation and disaster prevention). In the Protection Forests, cutting stands, changing land characteristics and related activities without prior approval are prohibited. In addition, placing signs which show the Protection Forest area, conducting field inspection and monitoring by utilizing satellite images are implemented. With respect to the National Parks, the parks are protected by restricting development and changing the characteristics of land, prohibiting hunting animals and harvesting plants, limiting people's and vehicles' accesses, based on the Natural Parks Law (legislation No.161 of 1st June, 1957). These measures have been applied to the Tennensei-rin forests continuously since 1990.

Table A 7-9 Area of protected/conserved Tennensei-rin forests (FY2021) [kha]

Protected / Conserved forest type	Private forest	National forest	Total
Protection forest	2,898	4,563	7,461
Area for conservation facility installation project	1	0	1
Protected forest	0	624	624
Special protected zones in national parks	43	115	158
Class I special zones in national parks	42	168	210
Class II special zones in national parks	141	202	344
Special protected zones in quasi-national parks	9	37	47
Class I special zones in quasi-national parks	31	106	137
Class II special zones in quasi-national parks	97	88	185
Special zone in national environment conservation area	2	9	11
Special seed forest	1	1	1
Total （excluding duplicate designations）	3,266 (2,790)	5,912 (4,320)	9,178 (7,109)

Reference: NFRDB (1st April 2022)
Note: This table includes forests with less standing trees.

Table A 7-10 Area subject to FM activity

		2014	2015	2016	2017	2018	2019	2020	2021
Area subject to FM	［kha］	15,543.6	15,595.7	15,688.4	15,833.4	15,951.7	16,030.6	16,098.2	16,161.7
Ikusei-rin forest	［kha］	8,518.0	8,619.0	8,693.1	8,821.1	8,904.1	8,928.3	8,993.5	9,050.3
Tennensei-rin forest	［kha］	7,025.6	6,976.7	6,995.3	7,012.3	7,047.6	7,102.3	7,104.8	7,111.4

A7.3.3.2. Methods for Calculating Carbon Stock Changes and GHG Emissions

a) Living Biomass

1) Ikusei-rin Forest

1. Carbon stock changes were determined from the forest stock of all Ikusei-rin forests in each year using the stock-difference method.

2. As the carbon stock changes for all Ikusei-rin forests determined in 1. includes changes due to AR activities, the amount of change in carbon stocks caused by AR activities was excluded from the amount of change in carbon stocks determined in 1. In addition, as the calculation in 1. also includes carbon stock changes caused by D activities, the impact was eliminated by adding the amount of changes caused by the D activity.

3. Carbon stock changes in forests subject to FM activities were calculated by applying the FM rates for each tree species, region, and age class, after eliminating the effects of AR and D activities from the total stock change in Ikusei-rin forests as determined in 2.

2) Tennensei-rin Forest

Carbon stock changes were calculated using the forest area shown in Section A7.3.3.1.

b) Dead wood, Litter and Soils

Carbon stock changes in dead wood, litter and mineral soil pools were estimated by using the same Tier 3 method as "forest land remaining forest land (4.A.1.)". It was estimated by multiplying carbon emissions/removals per unit area in each pool, which were calculated by the CENTURY-jfos model for each forest management type, tree species, region and age class, by the FM area by forest management type, tree species, region and age class. See section 6.4.1.b)2) for estimation equations, key assumptions and parameters applied for the calculation by CENTURY-jfos model.

As described in section 6.4.1.b)2), no drainage of organic soils in forest land is practiced in Japan. Under the Tier 1 and Tier 2 estimation methods provided in the *2006 IPCC Guidelines*, emissions from drainage of organic soils are estimated only if the soil is drained. Therefore, it is considered that emissions do not occur in undrained organic soils, and the emissions were reported as "NO".

c) Harvested Wood Products (HWP)

Carbon stock changes in HWP under FM activities, including those under AR activities, are calculated using the same equations, parameters and activity data in the categories of buildings, wood for other uses than buildings, and paper and paperboards as for HWP (4.G.) under the Convention inventory 4.G, described in section 6.10.

For reporting under FM activities, HWP derived from D activities were excluded from the figures reported in the Convention inventory. The inflow of logs derived from D activities is estimated by multiplying the total national log production ($Harvest_{RW,i}$) by the percentage of harvested standing trees derived from D activities among the total harvested volume $\left((Stock_{i,D,ST} \cdot D_i)/Harvest_{ST,i}\right)$, according to the following equation.

$$Inflow_{i,D,RW} = \mathrm{Harvest}_{RW,i} \times \left\{(\mathrm{Stock}_{i,D,ST} \times D_i)/\mathrm{Harvest}_{ST,i}\right\}$$

$Inflow_{i,D,RW}$	: D-derived inflow (logs) in year *i* [m^3]
$Harvest_{RW,i}$	: Material (logs) production in year *i* [m^3]
$Stock_{i,D,ST}$	: Average volume per ha of the entire standing trees (trunk volume) [m^3/ha]
D_i	: Area of D occurrence in year *i* [ha]
$Harvest_{ST,i}$	: Harvested standing trees (trunk volume) in year *i* [ha]

d) Other Gases

1) Direct and Indirect N_2O Emissions from N Fertilization

As the amount of nitrogen-based fertilizer applied in Forest land cannot be separated between those in AR activities and in FM activities, N_2O emissions from N fertilization are reported collectively in FM activities. With respect to the methodology and parameters applied to this category, see section 6.11.

2) N_2O and CH_4 Emissions from Drainage of Soils

As soil drainage activity for organic soils in forest land does not occur in Japan, N_2O and CH_4 emissions were reported as "NO".

3) N_2O Emissions from N Mineralization due to Carbon Loss associated with Land-Use Conversions and Management Change in Mineral Soils

N_2O emissions from N mineralization associated with loss of soil organic matter is estimated by using the Tier 2 method described in the *2006 IPCC Guidelines*. The estimation method and parameters are the same as section 6.13 and section 6.14 in Chapter 6. The activity data is gross loss of soil carbon in FM which was extracted from land where soil carbon has decreased, by each forest age, tree species, and prefecture.

4) Emissions from Biomass Burning

As forest fire area cannot be separated between those in AR activities and in FM activities, GHG emissions associated with forest fires (wildfires) are reported collectively in FM activities . Calculations are performed only for non-CO_2 emissions since CO_2 emissions are already included in the calculation of carbon stock change and reported as "IE". Emissions due to biomass burning are estimated by multiplying GHG emissions due to fire for all forests calculated in section 6.15 by the ratio of total area subject to FM and AR activities to all forest land area. Moreover, controlled burning activities in forests are not implemented in Japan because of severe restrictions imposed by the "Waste Management and Public Cleansing Law" and the "Fire Defense Law".

A7.3.3.3. Method of Accounting and Calculation Results

As in the second commitment period of the Kyoto Protocol, the reference level approach was used to calculate the accounting quantities. The details of the reference level and the amount recorded are as follows.

a) Forest Management Reference Level for forest carbon pools

In accounting for forest management, a reference level of zero was set for the five forest carbon pools. Since a narrow approach is used in Japan to identify forests subject to forest management, the reference level is set to zero in order to calculate removals using the gross-net method and the only lands where activities have been reliably conducted since 1990 are subject to removals calculation.

b) Forest Management Reference Level for HWP pool

For the HWP pool, the reference level is set as follows, using future projections based on historical trends until 2012, in accordance with the methodology of the *KP supplement*.

The prediction of activity data after 2013 were estimated: for the floor area of buildings by exponentially extrapolating the trend over 20 years from 1993 to 2012; for the production of plywood and wooden board, by linearly extrapolating the trend over 20 years from 1993 to 2012; and for the production of paper and paperboards, by linearly extrapolating the trend over 10 years from 2003 to 2012, respectively. As for the calculation parameter of the ratio of domestic wood, the average values of 10 years from 2003 to 2012 were applied. The periods referenced for the past trend for prediction vary among the activity data and parameters, because the trend which showed a high correlation was applied for each activity data and parameter. The average values for 10 years were also applied where the past trend was not clear. For the projection of the HWP inflow resulting from D activities, the average value of area of D occurrence in a single fiscal year from 2008 to 2012 was used. In order to ensure consistency with the methodology used for estimating FM emissions and removals, the reference level is recalculated when updating the statistics or revising the estimation method used in line with the provisions set out in decision 4/CMA.1.

c) Calculation Results

The total of the value after applying the reference level to net removals in FM is the accounting quantity from FM activity.

Table A 7-11 Emissions and removals from FM activity and the accounting quantity

	2014	2015	2016	2017	2018	2019	2020	2021
	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]
FM accounting quantity	-56,819.62	-53,346.48	-51,511.87	-51,019.52	-49,887.68	-45,601.97	-43,112.05	-43,861.76
FMRL	1,548.16	1,599.12	1,640.35	1,673.16	1,708.12	1,747.23	1,785.31	1,828.58
(Forest)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(HWP)	1,548.16	1,599.12	1,640.35	1,673.16	1,708.12	1,747.23	1,785.31	1,828.58
FM net removals	-55,271.46	-51,747.36	-49,871.52	-49,346.36	-48,179.56	-43,854.74	-41,326.74	-42,033.18
Living biomass	-55,338.57	-51,777.58	-50,021.02	-49,113.45	-47,701.65	-43,334.94	-41,719.29	-41,310.81
Dead wood	2,088.74	2,140.75	2,174.52	2,140.83	2,069.29	1,961.15	1,883.68	1,889.82
Litter	-197.97	-186.60	-166.36	-162.77	-152.54	-130.25	-114.43	-86.61
Mineral soils	-1,452.53	-1,390.62	-1,328.03	-1,275.00	-1,209.48	-1,145.42	-1,096.42	-1,044.80
Organic soils	NO	NO	NO	NO	NO	NO	NO	NO
Harvested wood products (HWP)	-438.10	-589.31	-584.48	-1,006.77	-1,241.72	-1,264.72	-338.20	-1,544.49
Other gases	66.97	56.00	53.86	70.78	56.55	59.45	57.92	63.71
Fertilization (N_2O)	0.90	0.85	0.86	0.86	0.86	0.86	0.86	0.86
Organic soil drainage (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO
N mineralization in mineral soil (N_2O)	49.72	50.75	52.02	52.85	53.89	54.82	55.12	55.82
Biomass burning (CH_4, N_2O)	16.34	4.40	0.98	17.08	1.80	3.77	1.94	7.03

(CO_2) +: Emissions, -: Removals

A7.3.4 Cropland Management

A7.3.4.1. Method of Identifying Area of Activity

As with the Cropland in the Convention inventory, the CM area is based on the area of rice fields, upland fields, and orchards in the "Statistics on Arable Land and Cropland Area" of the Ministry of Agriculture, Forestry and Fisheries, shown in Table 6-2 of Chapter 6. In the calculation of N_2O emissions from mineral soil carbon pools and mineralized nitrogen associated with land use change and management, cropland converted from forest land is included in D activities, and therefore, the land area converted from forest to cropland since 1990 was ascertained from the D survey and subtracted from the current area of rice fields, upland fields and orchards.

Table A 7-12 Area subject to CM activity

	Unit	1990	2014	2015	2016	2017	2018	2019	2020	2021
Area subject to CM	［kha］	4596.52	3909.72	3889.30	3867.09	3842.68	3820.92	3800.65	3777.99	3755.15
Area of mineral soils (excluding area subject to D)	［kha］	4443.00	3746.00	3725.30	3702.92	3678.27	3656.22	3635.51	3612.45	3588.42

A7.3.4.2. Methods for Calculating for Carbon Stock Change and GHG Emissions

a) Living Biomass

The carbon stock changes in living biomass under CM (ΔC_{CM_LB}) was calculated from the annual carbon stock increase accumulated by growth ($\Delta C_{orchard\_LB\_SC}$ and $\Delta C_{annualcrop\_LB\_SC}$) as well as the loss of carbon stock due to conversion from cropland ($\Delta C_{LB\_conversion\_to\_others}$). Carbon stock changes in living biomass in orchards ($\Delta C_{orchard\_LB\_SC}$) were estimated including the loss due to conversion, by using the same method of Tier 2 stock-difference method as "cropland remaining cropland (4.B.1.)" described in section 6.5.1b)1). The carbon stock changes in annual crops are calculated as the increase to the average carbon stock associated with the growth obtained in the current year at the time of land conversion to cropland, as described in section 6.5.1b)1), " land converted to cropland (4.B.2.)". The estimation equations were described below and see Table 6-9, Table 6-11 and section 6.5.1.b)1) of the report for the parameters and activity data used.

$$\Delta C_{CM\_LB} = \Delta C_{orchard\_LB\_SC} + \Delta C_{annualcrop\_LB\_SC} - \Delta C_{LB\_conversion\_to\_others}$$

$$\Delta C_{annualcrop\_LB\_SC} = \Delta A_{others-annualcrop} \times C_{annualcrop\_LB}$$

$$\Delta C_{LB\_conversion\_to\_others} = \Delta A_{annualcrop-others} \times C_{annualcrop\_LB}$$

ΔC_{CM-LB} : Carbon stock change in living biomass subject to CM activities [t-C/yr]

$\Delta C_{orchard\_LB\_SC}$: Carbon stock change in living biomass in orchards [t-C/yr]

$\Delta C_{annualcrop\_LB\_SC}$	: Carbon stock change (gain) in living biomass of annual crops in rice fields and upland fields [t-C/yr]
$\Delta C_{LB\_conversion\_to\_others}$	: Carbon stock change (loss) due to land conversion from cropland [t-C/yr]
$\Delta A_{others-annualcrop}$	: Annual area converted from other land-use category to cropland (rice fields or upland fields) [ha/yr]
$\Delta A_{annualcrop-others}$	: Annual area converted from rice fields and upland fields to other non-forest land-use Categories [ha/yr]
$C_{annualcrop\_LB}$	: Carbon stocks in living biomass of annual crops per unit area in rice fields and upland fields [t-C/ha]

b) Dead Wood, Litter

Since no carbon stock change occurred as described in Section 6.5.1.b) 2), the carbon stock changes for this category were reported as “NA”.

c) Soils

1) Mineral Soils

Carbon stock changes in mineral soils in CM were estimated by applying the Tier 3 model (Roth C) estimation method, as described in section 6.5.1.b) 3). The activity area used for the estimation excluded the area of land subject to D activities.

For mineral soils, in addition to the above, soil carbon sequestration due to biochar application were calculated separately. As described in Section 6.5.1.b) 3), the methodology of the calculations, parameters and activities are the same as those reported in the Convention inventory.

2) Organic Soils

The relevant emissions reported in cropland (4.B.) in the Convention inventory were reported. The methodology of the calculations, parameters and activities used are as described in Section 6.5.1.b) 2) .

d) Other Gases

1) CH_4 Emissions from Drainage of Organic Soils

CH_4 emissions from drainage of organic soils (4.(II)) reported in cropland in the Convention Inventory were reported. The methodology of the calculations, parameters and activities used are described as section 6.12 of Chapter 6.

2) N_2O Emissions from N Mineralization due to Carbon Loss associated with Land-Use Conversions and Management Change in Mineral Soils

N_2O emissions generated from land converted to cropland were calculated using the same methodology, estimation equation and parameters as in section 6.13. The activity area used for the calculation excludes the area subject to D activities.

3) Emissions from Biomass Burning

The relevant emissions reported in cropland under Biomas Burning (4.(V)) in the Convention Inventory were reported, since the emissions are from activities on Cropland. The estimation method and parameters are as described in section.

A7.3.4.3. Method of Accounting and Calculation Results

The accounting quantity was calculated using the net-net approach with 1990 as the base year. The results of the calculations are as follows.

Table A 7-13 Emissions and removals and the accounting quantity from CM activity

	1990 (base year)	2014	2015	2016	2017	2018	2019	2020	2021
	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]
CM accounting quantity	-	-1,520.62	-2,004.39	-2,231.03	-3,046.91	-3,623.58	-2,996.55	-3,013.53	-3,335.15
Base year emissions	7,744.77	7,744.77	7,744.77	7,744.77	7,744.77	7,744.77	7,744.77	7,744.77	7,744.77
CM net emissions	7,744.77	6,224.15	5,740.38	5,513.74	4,697.86	4,121.19	4,748.22	4,731.24	4,409.62
Living biomass	478.77	242.59	299.25	325.11	301.98	334.13	298.37	360.85	326.34
Dead wood	NA	NA	NA	NA	NA	NA	NA	NA	NA
Litter	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mineral soils	5,926.11	4,761.29	4,224.38	3,976.06	3,183.75	2,574.35	3,236.48	3,156.91	2,871.67
Organic soils	1,249.79	1,170.08	1,167.05	1,163.32	1,162.48	1,162.48	1,162.82	1,162.66	1,160.41
Other gases	90.11	50.20	49.70	49.26	49.66	50.24	50.55	50.83	51.21
Organic soil drainage (CH_4)	24.27	23.78	23.60	23.42	23.33	23.31	23.32	23.32	23.19
N mineralization in mineral soil (N_2O)	33.71	4.38	4.43	4.52	5.37	6.39	7.04	7.73	8.60
Biomass burning (CH_4, N_2O)	32.13	22.04	21.67	21.31	20.96	20.54	20.19	19.78	19.42

(CO_2) +: Emissions, -: Removals

A7.3.5 Grazing Land Management

A7.3.5.1. Method of Identifying Area of Activity

The area subject to GM activity is the area of pasture land under Grassland (4.C.) in the Convention inventory, obtained by the *Statistics of Cultivated and Planted Area*, MAFF, shown in Table 6-2. As with GM activity, in the calculation of N_2O from the carbon pool of mineral soils and mineralized nitrogen from land-use change and management, pastureland established through forest conversion is included in the D activity, and therefore the land area converted from forest to cropland after 1990 was ascertained from the D survey and subtracted from the current area of pastureland.

Table A 7-14 Area subject to GM activity

	Unit	1990	2014	2015	2016	2017	2018	2019	2020	2021
Area subject to GM	[kha]	646.6	607.8	606.5	603.4	601	598.6	596.8	595.1	593.4
Area of mineral soils (excluding area subject to D)	[kha]	605.7	552.9	551.1	547.5	544.9	542.2	540.1	538.4	535.9

A7.3.5.2. Methods for Calculating for Carbon Stock Change and GHG Emissions

a) Living Biomass

The carbon stock change in living biomass in the area subject to GM activities was calculated from the carbon stock change that occurred after conversion and the loss of carbon stock in living biomass due to conversion from pastureland Carbon stock change was assumed to be zero in Grazing land remaining Grazing land. The estimation equation, parameters and activity data used were the same as Table 6-9, Table 6-11 and Section 6.6.2.b) 1).

b) Dead Wood, Litter

As carbon stock change in dead wood and litter in grassland do not occur as described in Section 6.6.1.a), the carbon stock change for this category was reported as “NA”.

c) Soils

1) Mineral Soils

Carbon stock changes in mineral soils in GM were estimated by applying the Tier 3 model (Roth C) estimation method as described in section 6.5.1.b)3). The activity area used for the estimation excludes the D area.

2) Organic Soils

The relevant emissions reported in grassland (4.C.) in the Convention Inventory were reported. The methodology of the calculations, parameters and activities used are as described in section 6.5.1.b) 3).

d) Other Gases

1) CH_4 Emissions from Drainage of Organic Soils

CH_4 emissions from drainage of organic soils (4.(II)) reported in pastureland in the Convention Inventory were reported. The estimation equation, parameters and the activity data used are as described in section 6.12.

2) N_2O Emissions from Mineralized N Associated with Land Use Change and Management

Estimation equation, parameters used and activity data are the same as section 6.13.

3) Enmissions from Biomass Burning

As open burning in pastureland does not occur in Japan, emissions from biomass burning in GM were reported as "NO".

A7.3.5.3. Method of Accounting and Calculation Results

The amounts of emissions were calculated using the net-net approach with 1990 as the base year. The calculation results are as follows.

Table A 7-15 Emissions and removals and the accounting quantity from GM Activity

	1990 (base year)	2014	2015	2016	2017	2018	2019	2020	2021
	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]	[kt-CO_2 eq.]
GM accounting quantity	-	1,099.86	816.56	532.92	371.11	141.47	272.29	140.27	-158.11
Base year emissions	460.37	460.37	460.37	460.37	460.37	460.37	460.37	460.37	460.37
GM net emissions/removals	460.37	1,560.24	1,276.93	993.29	831.48	601.85	732.66	600.64	302.26
Living biomass	-34.79	76.18	69.38	77.39	91.15	89.81	79.82	77.72	66.26
Dead wood	NA	NA	NA	NA	NA	NA	NA	NA	NA
Litter	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mineral soils	463.55	1,441.84	1,163.56	883.96	708.44	480.19	621.03	491.12	204.27
Organic soils	27.28	36.31	38.03	27.74	27.71	27.67	27.65	27.64	27.59
Other gases	4.32	5.90	5.96	4.20	4.19	4.18	4.17	4.16	4.15
Organic soil drainage (CH_4)	2.13	2.84	2.97	2.17	2.17	2.16	2.16	2.16	2.16
N mineralization in mineral soil (N_2O)	2.19	3.06	2.98	2.03	2.02	2.01	2.01	2.00	1.99
Biomass burning (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO

(CO_2) +: Emissions, -: Removals

A7.3.6 Urban Greening Activity

A7.3.6.1. Method of Identifying Area of Activity

The area subject to urban greening activities is the same as the area of urban green spaces under Settlements (4.E.) in the Convention inventory. Specifically, the total area of green spaces conserved by zoning and urban green facilities under Settlements remaining Settlements (4.E.1) is subject to the calculation of this activity. See section 6.8.1 of Chapter 6 in this report for details of the methods of identifying the area subject to this activity.

Table A 7-16 Area subject to UG activity

		Unit	2014	2015	2016	2017	2018	2019	2020	2021
Area subject to UG		［kha］	132.2	128.6	126.1	123.9	121.1	117.4	113.8	110.6
	Green spaces conserved by zoning	［kha］	4.5	4.6	4.6	4.6	4.6	4.7	4.7	4.7
	Facility green space	［kha］	127.7	124.0	121.5	119.3	116.5	112.7	109.1	106.0

A7.3.6.2. Methods for Calculating Carbon Stock Change and GHG Emissions

a) Carbon stock changes

The carbon stock changes in the living biomass, dead wood, litter, and soil carbon pools were the same as the values for urban green space reported as settlements remaining settlements (4.E.) in the Convention inventory. The methodology for the calculation, parameters and activities are as described in section 6.8.1.

b) Other Gases

1) N_2O Emissions from N Fertilization

Although fertilizer is applied in urban parks in Japan, it is assumed that the amount of nitrogen-based fertilizer applied to urban parks is included in the demand of nitrogen-based fertilizers calculated for in the Agriculture sector. Therefore, it was reported as “IE”.

2) N_2O and CH_4 Emissions from Drainage of Organic Soils

As soil drainage activity for organic soils in settlements subject to UG activity is not conducted in Japan, this category is reported as “NO”.

3) N_2O Emissions due to nitrogen mineralization from land use conversion and management changes

As soil carbon stock changes in settlements subject to UG activity are reported to be on the increases, according to Tier 1 or Tier 2 methods described in *the 2006 IPCC Guidelines*, it is not necessary to estimate N_2O emissions from N immobilization associated with gain of soil organic matter were not estimated. Therefore, N_2O emissions in this subcategory is reported as “NA”.

4) Emissions from Biomass Burning

In settlements subject to these activities, burning of residues is strictly restricted by the “Waste Management and Public Cleansing Law” and the “Fire Defense Law”. In addition, wildfires do not usually occur in lands subject to UG activity because these lands are managed as a part of urban area. Therefore, biomass burning activities which lead to carbon emissions do not occur and Japan reports this category as “NO”.

A7.3.6.3. Method of Accounting and Calculation Results

The accounting quantity was calculated using the gross-net approach. The calculation results are as follows.

Table A 7-17 Emissions and removals from UG Activity and the accounting quantity

	2014	2015	2016	2017	2018	2019	2020	2021
	[kt-CO_2]	[kt-CO_2]	[kt-CO_2]	[kt-CO_2]	[kt-CO_2]	[kt-CO_2]	[kt-CO_2]	[kt-CO_2]
UG net removals and accounting quantity	-1,776.13	-1,746.81	-1,727.65	-1,704.38	-1,667.46	-1,640.38	-1,593.43	-1,550.62
Living biomass	-1,407.37	-1,382.13	-1,368.05	-1,351.07	-1,321.05	-1,302.76	-1,264.67	-1,230.28
Dead wood	IE	IE	IE	IE	IE	IE	IE	IE
Litter	-19.96	-19.87	-19.78	-19.62	-19.48	-19.20	-18.92	-18.79
Mineral soils	-348.80	-344.81	-339.81	-333.69	-326.92	-318.42	-309.83	-301.55
Organic soils	NO	NO	NO	NO	NO	NO	NO	NO
Other gases	IE,NA,NO	IE	IE	IE	IE	IE	IE	IE
Fertilization (N_2O)	IE	NO	NO	NO	NO	NO	NO	NO
Organic soil drainage (CH_4, N_2O)	NO	NA	NA	NA	NA	NA	NA	NA
N mineralization in mineral soil (N_2O)	NA	NO	NO	NO	NO	NO	NO	NO
Biomass burning (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO

(CO_2) +: Emissions, -: Removals

A7.4. Other Information

A7.4.1 Recalculation and Improvements

N/A since this is the first year of submission.

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
2. IPCC, *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*, 2014.
3. Ministry of Agriculture, Forestry and Fisheries, *Statistics of Cultivated and Planted Area* (Survey of Cropland area)
4. Forestry Agency, *National Forest Resources Database*.
5. Forestry Agency, *"FY2022 Report on Forest GHG Inventory Information Development Project (FM Forests Survey)" (in Japanese)*, 2023
6. Coleman, K. & Jenkinson D. S., *"Roth C-26.3 - A model for the turnover of carbon in soil. In Evaluation of Soil Organic Matter Models: Using Existing Long-Term Datasets"*, Ed. D. S. Powlson, P. Smith & J. U. Smith, p. 237-246, Springer, Berlin, (1996)

Abbreviations

1. Greenhouse Gases

Table AB-1 Greenhouse Gases

Term	Gas
CO_2	Carbon dioxide
CH_4	Methane
N_2O	Nitrous oxide
HFCs	Hydrofluorocarbons
PFCs	Perfluorocarbons
SF_6	Sulfur hexafluoride
NF_3	Nitrogen trifluoride

Table AB-2 Precursors and SO_x

Term	Gas
NO_x	Nitrogen oxides
CO	Carbon monoxide
NMVOC	Non-methane volatile organic compounds
SO_x	Sulfur oxide

2. Prefixes and Units

Table AB-3 Prefixes

Term	Prefix	Definition
P	peta	10^{15}
T	tera	10^{12}
G	giga	10^{9}
M	mega	10^{6}
k	kilo	10^{3}
h	hecto	10^{2}
da	deca	10^{1}
d	deci	10^{-1}
c	centi	10^{-2}
m	milli	10^{-3}
µ	micro	10^{-6}

Table AB-4 Units

Term	Definition
m^3	cubic metre
L	litter
a	are
ha	hectare
g	gram
t	tonne
J	joule
°C	degree Celsius
yr	year
cap	capita
d.m.	dry matter

3. Notation Keys

Table AB-5 Notation keys (See Annex 5 for details)

Notation Key	Definition
NO	Not Occurring
NE	Not Estimated
NA	Not Applicable
IE	Included Elsewhere
C	Confidential

4. Other Abbreviations

Table AB-6 Abbreviations

	Terms	Definition
A	AD	Activity Data
	ARD	Afforestation, Reforestation and Deforestation
B	BFG	Blast Furnace Gas
	BOD	Biochemical Oxygen Demand
C	CFG	Converter Furnace Gas
	CGER	Center for Global Environmental Research
	CM	Cropland Management
	CO_2 eq.	Gas Emission in CO_2 equivalent
	COD	Chemical Oxygen Demand
	COG	Coke Oven Gas
	CRF	Common Reporting Format
	CS-EF	Country-Specific Emission Factor
	CY	Calendar Year
E	EEA	European Environment Agency
	EF	Emission Factor
	EMEP	European Monitoring and Evaluation Programme
F	FM	Forest Management
	FY	Fiscal Year
G	GCV	Gross Calorific Value
	GHG	Greenhouse Gas
	GIO	Greenhouse Gas Inventory Office
	GM	Grazing Land Management
	GPG	Good Practice Guidance
	GPG (2000)	*Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)*
	GPG-LULUCF	*Good Practice Guidance for Land Use, Land-Use Change and Forestry*
	GWP	Global Warming Potential
I	IEA	International Energy Agency
	IEF	Implied Emission Factor
	IPCC	Intergovernmental Panel on Climate Change
J	JNGI	Japanese National GHG Inventory
K	KP	Kyoto Protocol
L	LNG	Liquefied Natural Gas
	LPG	Liquefied Petroleum Gas
	LTO	Landing and Take-off
	LULUCF	Land Use, Land-Use Change and Forestry
M	MAFF	Ministry of Agriculture, Forestry and Fisheries
	MDI	Metered Dose Inhalers
	METI	Ministry of Economy, Trade and Industry
	MOE	Ministry of the Environment
	MIC	Ministry of Internal Affairs and Communications
	MLIT	Ministry of Land, Infrastructure and Transport and Tourism
	MSW	Municipal Solid Waste
N	NCV	Net Calorific Value
	NDC	Nationally Determined Contribution
	NFRDB	National Forest Resource Data Base
	NGL	Natural Gas Liquids
	NIES	National Institute for Environmental Studies
	NIR	National Inventory Report
Q	QA/QC	Quality Assurance / Quality Control
	QAWG	Quality Assurance Working Group

Table AB-6 Abbreviations (Continued)

	Terms	Definition
R	RDF	Refuse Derived Fuel
	RPF	Refuse Paper and Plastic Fuel
	RV	Revegetation
T	THC	Total Hydrocarbon
U	UG	Urban Greening
	UNFCCC	United Nations Framework Convention on Climate Change