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Nuclear Fuel Cycle Information System

A Directory of Nuclear Fuel Cycle Facilities
2009 Edition

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FOREWORD

In recent years, there have been rising expectations for nuclear power all over the world to meet the ever increasing demand for electricity. Several countries with nuclear power have declared intentions to build new nuclear power plants to replace their existing capacities or to add new capacities. Several other countries without nuclear power are taking an active interest in launching nuclear power programmes. Nuclear power and nuclear fuel cycle go hand in hand. Hence implementations of such nuclear power programmes cannot be considered without parallel development in the nuclear fuel cycle area.

The worldwide nuclear fuel cycle industry comprises several global players which are operating on a commercial basis in more than one country and many other domestic players which are active only in their respective countries. Knowing the current status and the future outlook of the nuclear fuel cycle industry is important not only for meeting the needs of global nuclear power development but also for facilitating the multilateral approach to the nuclear fuel cycle currently being discussed with a focus on ‘assurance of fuel supply’ and ‘non-proliferation of nuclear materials’.

The Nuclear Fuel Cycle Information System (NFCIS) database is an international directory of civilian nuclear fuel cycle facilities worldwide. Its purpose is to provide information mainly on commercial nuclear fuel cycle facilities throughout the world. In addition, some pilot and laboratory scale facilities are included in the database. It contains information on operational and non-operational, planned, and cancelled facilities.

NFCIS covers almost all of the main nuclear fuel cycle activities except transportation, waste management and nuclear power and research reactors. Waste management facilities are covered by the IAEA’s Net Enabled Waste Management Database (NEWMDB), nuclear power reactors are covered by the IAEA’s Power Reactor Information System (PRIS) and nuclear research reactors are covered by the IAEA’s Research Reactor Database (RRDB).

The information has been obtained through questionnaires, directly from some of the IAEA Member States and from authoritative published sources. Every effort has been made to present the most complete and accurate information available but, given the magnitude of the task and the constantly changing conditions of the nuclear industry, it is inevitable that there will be some errors and omissions.

This document and its attached CD-ROM provide information on 650 civilian nuclear fuel cycle facilities in 53 countries. It is hoped that the material presented will provide readers with useful information on the nuclear fuel cycle industry worldwide, and improve the transparency of nuclear energy development in general. The information in this document comes from the database and is updated as of end of 2008 if not stated otherwise.

The IAEA wishes to thank the experts who took part in the preparation of this report for their valuable contribution. The IAEA is also grateful to Member States and individual organizations for their generous support in providing experts and information to assist in this work. The IAEA officer responsible for this publication was M. Ceyhan of the Division of Nuclear Fuel Cycle and Waste Technology.

CONTENTS

1. INTRODUCTION

1.1. Background

The nuclear fuel cycle may be broadly defined as the set of processes and operations needed to manufacture nuclear fuel, its irradiation in nuclear power reactors and storage, reprocessing, recycling or disposal. Several nuclear fuel cycles may be considered depending on the type of reactor and the type of fuel used and whether or not the irradiated fuel is reprocessed and recycled.

The IAEA in 1980 began development of the Nuclear Fuel Cycle Information System (NFCIS) as [1] an international directory of civilian nuclear fuel cycle facilities worldwide. NFCIS has been operated by the IAEA as a computerized database system since 1985. In January 1998, a major upgrade to NFCIS was completed. The NFCIS web site was developed in 2001 to enable users to search and retrieve information on nuclear fuel cycle facilities via the Internet (http://www-nfcis.iaea.org) [2].

NFCIS is a computerized database which became operational in 1985 and was first published as IAEA-TECDOC-408 in February 1987 [3]. The second and third editions prior to the present publication were: The Nuclear Fuel Cycle Information System, published in 1988 [4] and 1996 [5]. The database migrated to a database server and published through the internet since 2001 in http://www-nfcis.iaea.org.

In 1985 NFCIS covered 271 (operational and non-operational) civil nuclear fuel cycle facilities in 32 countries, in 1987 344 facilities in 33 countries, in 1995, 422 facilities in 46 countries, and in 2008, 650 facilities in 53 countries. However, qualitative improvement of the NFCIS database by inclusion of technical information on technological processes is, probably, more important than quantitative growth of the number of facilities covered by the NFCIS. In proportion to these changes, the number of NFCIS users has been growing every year. This demonstrates the necessity of maintaining such database and serving it to IAEA Member States.

1.2. Objective

The Nuclear Fuel Cycle Information System (NFCIS) is an international directory of civilian nuclear fuel cycle facilities. Its purpose is to provide the IAEA, its Member States and public users with current, consistent, and readily accessible information on existing, closed and planned nuclear fuel cycle facilities throughout the world. NFCIS publishes main parameters of the facilities, including capacities, types of the processes, feed and product materials. NFCIS allows obtaining summary/statistical data on all stages of the nuclear fuel cycle services in each country and globally. Providing significant block of data, NFCIS thus offers a better understanding of the nuclear fuel cycle industry worldwide.

This information is of special importance at present time, because of increasing globalization of the nuclear fuel market. The interactions of the nuclear fuel cycle market will become more complex in support of the potential increasing use of nuclear power. No globally comprehensive and publicly available source of such information exists at present. There are private reports and databases which are maintained and published by various companies and organizations such as NAC International Fuel-Trac Status Reports [6] and Nuclear Engineering International World Nuclear Industry Handbook [7]. However, the reports and the information they contain are commercial products and usually requires subscription or purchasing. They do not contain all stages of nuclear fuel cycle or the related industrial activities, like zirconium alloy production, zirconium alloy tubing and heavy water production. And, finally, most of those reports are not structured and published through a queryable web site.

Another purpose of the NFCIS database is to provide support for the Contracting Parties under the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management by the preparation of their National Reports.

In this context, a need was perceived for a compilation of nuclear fuel cycle facilities data in a form which can easily be understood both by experts and by the public, and which should lead to a greater understanding of these activities worldwide. Furthermore, such information would improve the transparency of nuclear energy development in general.

1.3. Scope

As all databases, NFCIS attempts to model the real world. The current NFCIS database considers eight discrete operations of the nuclear fuel cycle (uranium production, conversion, enrichment, fuel fabrication, spent fuel conditioning, spent fuel storage, spent fuel reprocessing and recycling and spent fuel disposal) and related industrial activities (production of nuclear grade zirconium, zirconium alloy tubing and production of heavy water) as shown in TABLE 1. There are 29 Subtypes of facilities in total. NFCIS does not cover the entire nuclear fuel cycle to avoid duplication with other IAEA databases and publications. Information on uranium deposits and mines is included in the IAEA World Distribution of Uranium Deposits (UDEPO) [8], which is a part of the Integrated Nuclear Fuel Cycle Information Systems (iNFCIS) web site [2]. Alongside with UDEPO, Nuclear Fuel Cycle Simulation System (NFCSS) [9][10] supports in part of material balance calculation.

Information on nuclear power reactors can be found in the IAEA Power Reactor Information System (PRIS). PRIS is available online [11]. There are also hardcopy publications from PRIS [12].

Information on waste management facilities is covered by the IAEA Net Enabled Waste Management Database (NEWMDB) including data on research, inventories, facilities and management practices on radioactive wastes [13].

Information on Research Reactors are maintained and published by the IAEA through its Research Reactor Database (RRDB) [14].

So far it has not been possible to include information on at-reactor storage of spent fuel (mainly spent fuel pools in the reactors) in NFCIS because much of the data are not readily available, and because of the nature of these data. Inventory of the reactor pools can easily be changed through the discharge from the reactors or movement from the pools to the interim storage facilities. In future, attempts to collect information on at-reactor spent fuel storage facilities will be undertaken.

Currently NFCIS includes 650 facilities (operational and non-operational) in 53 Countries. Section 3 provides directory of the nuclear fuel cycle facilities by describing capacities of facilities by country and by status for each facility for all stages/components of the nuclear fuel cycle presented in the NFCIS.

NFCIS covers all statuses from ‘planned’ stage to the ‘remediated’ stage including operational and non-operational stages. Non-operational stages include under study, planned or under construction, closed or on stand-by, commissioned, deferred, etc. A nuclear fuel cycle facility has been defined as an installation in which one of the main nuclear fuel cycle operations is being performed. Therefore, a plant in which more than one operation is being carried out is listed in this directory two or more times as separate records to be able to describe the actual fuel cycle activity in the plant.

NFCIS covers laboratory and pilot plant scale facilities in addition to the commercial scale facilities in order to reflect the research and developments in the area of nuclear fuel cycle.

1.4. Description of the database

The NFCIS database was first developed as an electronic database in early 1980s. Since then there were major upgrades or revisions in the system. The current version of NFCIS is a structured database stored in a relational database server which enables users to define the customizable queries to retrieve the information requested. The database has been available online since early 2001 on the internet environment [2]. The visitors of this web site are able to prepare their own queries and get the information they are interested in.

The NFCIS is a structured database with a number of data fields which can have one of the predefined values (lookup fields). The main fields with this characteristic are Facility Type, Facility Status and Scale of Operation. TABLE 1, and TABLE 3 give the possible entries for those three main lookup fields and explanatory information for each of the entries.

TABLE 1 gives the list of facility types which have already been covered by NFCIS and the types which will be covered by NFCIS in future. Some facility types are excluded due to avoid duplication with other IAEA databases.

Facilities are grouped in eight main groups and one related activities group. Each group might have one or more sub facility types. For example, enrichment group has only one sub type whereas uranium fuel fabrication group has five sub types.

Some facilities might have more than one operations carried out. Those facilities are represented either by one-single integrated facility in which the product material is final output material or by multiple facilities each of them has its own output material.

TABLE 2 gives the list of facility statuses including all operational statuses starting from under construction to decommissioned/remediated as well as non-operational statuses such as under study, planned, siting/design, cancelled and deferred.

TABLE 3 gives the list of operational scales of the nuclear fuel cycle facilities which are covered by the NFCIS. The list includes commercial facilities as well as pilot plant and laboratory scale facilities in order to represent all ongoing nuclear fuel cycle activities including research and development.

TABLE 4 gives the list of data fields which are publicly available on the NFCIS internet site and in this publication. A short description of each field is also given in the table.

1.5. Sources of the information

The data stored in the NFCIS database is based mainly on the official data collected from the Member States through the officially nominated contact points. Starting 2003, a questionnaire has been sent to Member States every year. Those questionnaires are the primary data source for the NFCIS database.

TABLE 1. NUCLEAR FUEL CYCLE FACILITY TYPES

Nuclear Fuel Cycle Stage	**NFCIS Facility Subtypes**	**Description**
Uranium Production	Uranium Mine [a]	Uranium mines from which uranium ore is extracted
	Uranium Ore Processing	Facilities in which uranium ore is processed to produce yellowcake (includes in-situ-leach facilities)
	Uranium Recovery from Phosphate	Facilities in which uranium is retrieved as by product of phosphate.
Conversion	Conversion to UO_2	Facilities which convert U_3O_8 to UO_2 to produce PHWR fuel.
	Conversion to UO_3	Facilities which convert U_3O_8 to UO_3 which is used later for conversion to UO_2 or UF_6.
	Conversion to UF_4	Facilities in which U_3O_8 is converted to UF_4 which is later converted to UF_6 for enrichment or to U_{metal} for Magnox fuel.
	Conversion to UF_6	Facilities in which U_3O_8 or UF_4 is converted to UF_6 to be used in enrichment process.
	Conversion to U Metal	Facilities in which UF_4 is converted to U_{metal} for Magnox fuel.
	Re-Conversion to U_3O_8 (Dep U)	Facilities in which depleted UF_6 is converted to U_3O_8 for further storage or processing.
Enrichment	Enrichment	Facilities in which ^{235}U content is increased in comparison to ^{238}U content.
(Fresh) Uranium Fuel Fabrication	Re-conversion to UO2 Powder	Facilities which convert enriched UF_6 to UO_2 powder.
	Fuel Fabrication (U Pellet-Pin)	Facilities which produce fuel pellets and/or pins using UO_2 powder.
	Fuel Fabrication (U Assembly)	Facilities which produce fuel assemblies using the pellets/pins (Sometimes fuel fabrication facilities include all three steps: powder, pellet/pin and assembly in one integrated facility).
	Fuel Fabrication (Research Reactors)	Facilities in which research reactor fuel is produced.
	Fuel Fabrication (Pebble) [a]	Facilities in which fuel pebbles are produced for pebble bed reactors.
Irradiation [b]		Reactors which irradiate the fuel.
Spent Fuel Storage	AR Spent Fuel Storage [a]	Facilities, located in the reactor site, in which spent fuel is stored temporarily, usually reactor pools.
	AFR Wet Spent Fuel Storage	Facilities, located outside the reactor site, in which spent fuel is stored temporarily in pools.
	AFR Dry Spent Fuel Storage	Facilities, located outside the reactor site, in which spent fuel is stored temporarily in dry silos or containers.
Spent Fuel Reprocessing and Recycling	Spent Fuel Reprocessing	Facilities in which spent fuel is reprocessed to retrieve nuclear material.
	Re-conversion to U_3O_8 (Rep. U)	Facilities in which Reprocessed uranium is converted U_3O_8.
	Co-conversion to MOX Powder	Facilities in which Uranium and Plutonium is mixed in the form of MOX powder.
	Fuel Fabrication (MOX Pellet-Pin)	Facilities in which MOX fuel pellets/pins are produced.
	Fuel Fabrication (MOX Assembly)	Facilities in which MOX fuel assemblies are produced.
Spent Fuel Conditioning	Spent Fuel Conditioning [a]	Facilities in which spent fuel is conditioned for longer term interim storage or for disposal.
Spent Fuel Disposal	Spent Fuel Disposal [a]	Facilities in which spent fuel is disposed permanently.
Related Industrial Activities	Heavy Water Production	Facilities in which heavy water is produced for PHWRs.
	Zirconium Alloy Production	Facilities in which zirconium metal sponges are produced.
	Zirconium Alloy Tubing	Facilities in which zirconium alloy tubes are produced.
	Fuel Assembly Component [a]	Facilities in which other fuel structurals are produced.
Transportation [c]		All transportation related to the nuclear fuel cycle.
Waste Management [d]		Facilities in which all kind of radioactive wastes are conditioned, processed, stored or disposed.

[a] New type (will be included in the NFCIS database).

[b] Not covered in the NFCIS (Covered in PRIS and RRDB).

[c] Not covered in the NFCIS.

[d] Not covered in the NFCIS (Covered in NEWMDB).

TABLE 2. FACILITY STATUSES COVERED IN THE NFCIS

Facility Status	**Description**
Under Study/Assessment	Formal feasibility or pre-feasibility studies or assessments are underway.
Planned	A formal commitment has been made to build the facility or process line.
Siting/Design	Site and/or design have been licensed.
Under Construction	The facility or process line is currently being built.
Commissioning	The construction of the facility or process line has been completed and is under commissioning.
In Operation	The facility or process line is currently operational.
Stand by	The facility or process line is not currently in operation but can be restarted in a relatively short time.
Refurbishment	A major modification is underway in the facility or process line.
Shutdown	The facility or process line is not currently in operation and there are no plans to restart it.
Decommissioning	The facility or process line is currently under decommissioning. Dismantling and remediation work is included.
Decommissioned	The facility or process line is decommissioned and dismantled. The facility is not under regulatory control.
Cancelled	The project has been cancelled completely during any stage before operation.
Deferred	The project has been postponed indefinitely.
Not reported	The status of the facility or process line is unknown.

TABLE 3. SCALES OF OPERATION COVERED IN THE NFCIS

Scale of Operation	**Description**
Commercial	The facility or process line is being operated in commercial or industrial scale.
Pilot Plant	The facility or process line is being operated as a precursor of an commercial or industrial facility or process line.
Laboratory	The facility or process line is being operated in a laboratory to examine the applicability of a process.

TABLE 4. THE PUBLICLY AVAILABLE INFORMATION ON THE NFCIS

Data field	**Description**
Facility Name	The mostly used name of the facility
Operator	Name of the current operator company
Ownership	Name of the owner companies and their share
Facility Location	Country, province, site where the facility is located
Facility General Type	Fuel cycle step
Facility Type	Type of the facility
Design Capacity	Design nameplate capacity of the facility
Facility Status	Current operational status of the facility
Facility Scale	Operational scale of the facility.
Start of Operation	Year of start of operation of the facility
Permanent end of Operation	Year of permament end of operation of the facility
Remarks	Any information related to the facility
Process	Short identification of the process applied in the facility
Feed Material	Initial feed material of the facility
Product Material	End product of the facility
	In addition to the information for a selected facility, the web site and this publication provide statistical tables to the readers such as the number of nuclear fuel cycle facilities in the world for each country and for each facility type.

Sometimes it is not possible to get officially reported data. In those cases, there is a need to feed the database by using other authoritative information sources. These authoritative information sources are called secondary data sources. The most important secondary data sources are the other IAEA publications such as IAEA/OECD-NEA publication 'Uranium: Resources, Production and Demand' [15] (Red Book) which is also based on officially reported information. Consultants to IAEA activities, publications of the IAEA conferences, other scientific and technical journals are among the other secondary information sources.

It should be noted that since NFCIS is based mainly on the voluntary declaration of data by the IAEA Member States, the NFCIS does not contain all of the nuclear fuel cycle facilities in the world. The IAEA is aware of many other nuclear fuel cycle facilities through its Safeguard functions. Those facilities are reported in the IAEA Annual Report for safeguarded facilities in States.

Accuracy of the data presented in the database depends directly on completeness/correctness of the datasets provided by the Member States or retrieved by the IAEA from other sources. Sometimes, information on individual facilities might be outdated because of the rapid changes in the nuclear fuel cycle industry, the complexity of the nuclear fuel cycle industry and mutual links inside it.

1.6. The other related IAEA databases

In accordance with its exchange of information function, the IAEA has been maintaining quite large number of databases since the very beginning of the establishment. Some of the databases are related to nuclear fuel cycle in one way or another. Below is the list of IAEA databases which are related to nuclear fuel cycle. Most of them are currently available online.

- Nuclear Fuel Cycle Information Systems (NFCIS): Directory of civilian nuclear fuel cycle facilities.

- World Distribution of Uranium Deposits (UDEPO): Database on geological and technical characteristics of worldwide uranium deposits.

- Post Irradiation Examination Facilities Database (PIEDB): Catalogue of worldwide post irradiation examination facilities (hotcells).

- Minor Actinide Property Database (MADB): Thermomechanical and thermochemical properties of selected materials containing minor actinides.

- Nuclear Fuel Cycle Simulation System (NFCSS) [9][10]: A web based tool for estimation of long term nuclear fuel cycle material and service requirements.

- Power Reactor Information Systems (PRIS) [11][12]: Directory of worldwide commercial nuclear power plants.

- Research Reactor Database (RRDB) [14]: Database on worldwide research and test reactors.

- Net Enabled Waste Management Database (NEWMDB) [13]: Database on all waste management issues covering policies, regulations, facilities, inventories, etc.

- Fast Reactor Database (FR): Catalogue of existing fast reactor designs and developments.
- Accelerator Driven Systems (ADSDB): Database on the research and development in the area of accelerator driven systems for advanced fuel cycles.

2. NUCLEAR FUEL CYCLE

2.1. Nuclear fuel cycle options and developments

For the purposes of the NFCIS, the nuclear fuel cycle may be broadly defined as the set of processes and operations needed to manufacture nuclear fuel, its irradiation in nuclear power reactors and storage, reprocessing or disposal of the irradiated fuel. Several nuclear fuel cycles may be considered, depending on the type of reactor and the fuel used and whether or not the irradiated fuel is reprocessed and the nuclear material is recycled. There are two fuel cycle options: 'open' (or once-through) fuel cycle (without reuse of nuclear materials) and 'closed' fuel cycle (with reuse of nuclear materials extracted from irradiated fuel).

Choosing the 'closed' or 'open' fuel cycle is a matter of national policy. Some countries have adopted the 'closed' fuel cycle solution, and some others have chosen the 'open' fuel cycle. Combination of solutions or on hold (wait and see) is a position of other nuclear power countries. Additional information on the national policies can be found in Technical Rports Series No. 425 [16], which reflects the statuses as of end of 2002. An artistic view of the nuclear fuel cycle with its open and closed variants is presented in Fig. 1 A more detailed scheme of the processes in the open and closed fuel cycle for different reactor types might be seen in Fig. 2.

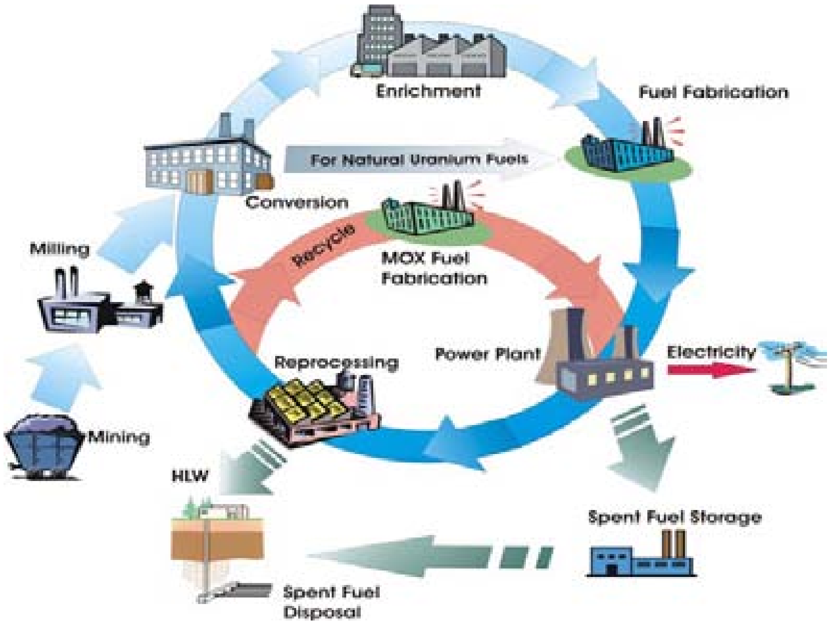


Fig. 1. Simplified artistic view of the typical nuclear fuel cycle.

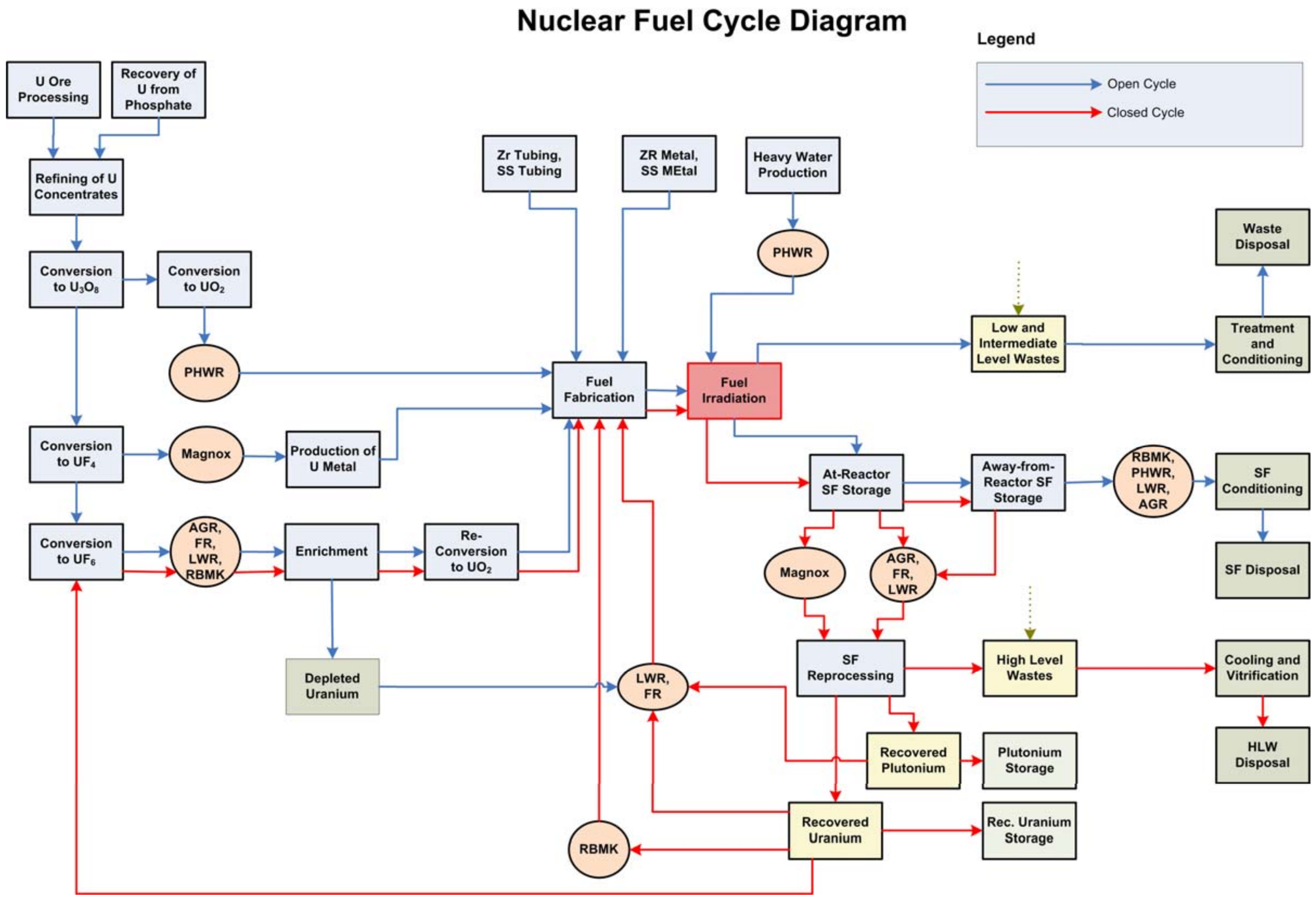


Fig. 2. Flowsheet of processes in the typical nuclear fuel cycle.

In addition to the typical open and closed fuel cycle options, there are research and developments on alternative fuel cycle options such as GNEP [17], DUPIC [18], ADS [19], P&T [20], etc. All of the alternative options focus on the resource utilization and radiotoxicity reduction as well as non-proliferation.

2.1.1. Open fuel cycle

The open fuel cycle is the mode of operation in which the nuclear material passes through the reactor just once. After irradiation, the fuel is kept in at-reactor pools until it is sent to away-from-reactor storage. It is planned that the fuel will be conditioned and put into a final repository in this mode of operation. This fuel cycle strategy is the one currently adopted by many nuclear power countries. However, no final repositories for spent fuel have yet been established. As it can be seen in Fig. 2, this strategy is definitely applied today for pressurized heavy water reactors (PHWR) and graphite moderated light water cooled reactors (RBMK).

2.1.2. Closed fuel cycle

The closed fuel cycle is the mode of operation in which, after a sufficient cooling period, the spent fuel is reprocessed to extract the remaining uranium and plutonium from the fission products and other actinides. The reprocessed uranium and plutonium is then reused in the reactors. This recycle strategy has been adopted by some countries mainly in light water reactors (LWR) in the form of mixed oxide (MOX) fuel.

Apart from the current LWR recycling experience, another closed fuel cycle practice is the recycle of nuclear materials in fast reactors in which, reprocessed uranium and plutonium are used for production of fast reactor (FR) fuel. By suitable operation, such a reactor can produce more fissile plutonium than it consumes.

2.2. Stages of the nuclear fuel cycle

The nuclear fuel cycle starts with uranium exploration and ends with disposal of the materials used and generated during the cycle. For practical reasons the cycle has been further subdivided into two stages: the front-end and the back-end. The nuclear fuel cycle is then completed by the addition of irradiation of nuclear fuel and other related industrial activities to those two main stages. The front-end of the fuel cycle occurs before irradiation and the back-end begins with the discharge of spent fuel from the reactor. The specific steps or processes and the corresponding nuclear fuel cycle facilities can be subdivided on front-end, irradiation/nuclear power reactor operation, back-end, and related industrial activities. The below sections give the list of stages and processes involved (with indication, whether these stages and processes are covered by the NFCIS or not).

2.2.1. Front-end

The front-end processes involve some of the steps below:

- *uranium ore exploration:* activities related to the finding and development of the uranium ores for uranium production; not presented in the NFCIS;

- *uranium ore mining:* activities related to the extracting uranium ore from the ground; will be included in the NFCIS;

- *uranium ore processing:* activities related to the milling and refining of the ore to produce uranium concentrates including in-situ leaching (commonly called yellow cake — ammonium diuranate containing 80 to 90% of U_3O_8); presented in the NFCIS;

- *conversion:* activities related to the refining and conversion to the form which is suitable for any of the other processes; presented in the NFCIS;

- *enrichment:* activities related to the isotopic enrichment of UF_6 to obtain the appropriately enriched ^{235}U concentration; presented in the NFCIS;

- *uranium fuel fabrication:* activities related to the production of nuclear fuel to be inserted in the nuclear reactor; presented in the NFCIS.

2.2.2. Irradiation/Nuclear reactor operation

The fuel is inserted in the reactor and irradiated. Nuclear fission takes place, with the release of energy. The length of irradiation of a fuel load is in general three to five years in LWRs and one year in GCRs and PHWRs. The information about the nuclear power reactors are covered by the IAEA PRIS database and not by the NFCIS.

2.2.3. Back-end

The back-end processes involve some of the steps below:

- *At-reactor (AR) spent fuel storage:* activities related to the storage of spent fuel in at-reactor spent fuel storage facilities (wet type) for interim period. The storage is by definition an interim measure; will be included in the NFCIS ;

- *Away from reactor (AFR) spent fuel storage:* activities related to the storage of spent fuel in away-from-reactor spent fuel storage facilities (wet or dry type) for interim period; presented in the NFCIS;

- *spent fuel reprocessing and recycling:* activities related to the special treatment of spent fuel to be able to extract the usable materials and to recycle them in the reactors; presented in the NFCIS;

- *spent fuel conditioning:* activities related to the production of spent fuel packages suitable for handling, transport, storage and/or disposal; will be included in the NFCIS;

- *disposal of spent fuel:* activities related to the emplacement of spent fuel/wastes in an appropriate facility without the intention of retrieval; will be included in the NFCIS.

2.2.4. Related industrial activities

Related industrial activities include:

- *heavy water production (for PHWRs):* activities related to the production of heavy water which is necessary to run PHWRs; presented in the NFCIS;

- *zirconium alloy production:* activities related to the production of nuclear grade zirconium sponge which will be used to produce zirconium alloy tubing; presented in the NFCIS;

- *zirconium alloy tubing:* activities related to the production of zirconium alloy tubing to be used as cladding material for nuclear fuel; presented in the NFCIS;

- *Stainless steel metal production (for AGRs, FRs):* activities related to the production of nuclear grade stainless steel which will be used to produce stainless steel tubing; will be included in the NFCIS;

- *Stainless steel tubing production (for AGRs, FRs):* activities related to the production of stainless steel tubing to be used as cladding material for nuclear fuel; will be included in the NFCIS;

- *Magnox fuel element cladding fabrication (for Magnox reactors):* activities related to the production of Magnox fuel cladding which is special type of cladding; not presented in the NFCIS;

- *Management of high level and other wastes:* activities related to the management of radioactive waste from all stages of the nuclear fuel cycle and the reactor operation; not presented in the NFCIS;

- *Transportation:* Transportation activities associated with moving materials between each of the above operations; not presented in the NFCIS.

2.3. Steps in the different stages of the nuclear fuel cycle

This section provides a description of the basic nuclear fuel cycle processes mentioned in the Section 2.1.3, including:

- Status of the technologies used in each step;

- Major developments in the area;

- Information on total capacities and, if available, on balance between supply and demand/requirements.

This section is accompanied and supported by tables given in the Section 3. Tables show the capacities of nuclear fuel cycle facilities and their operational status.

2.3.1. Uranium production (uranium ore processing)

Uranium is an element that is widely distributed within the earth's crust. Its principal use is as the primary fuel for nuclear power reactors. Naturally occurring uranium is composed of about 99.3% ^{238}U, 0.7% ^{235}U and traces of ^{234}U. ^{235}U is the fissile isotope of uranium, i.e. its atoms have a high probability of undergoing fission after capture of a thermal neutron. In order to use uranium in the ground, it has to be extracted from the ore and converted into a compound which can be utilized in the further steps of the nuclear fuel cycle. The form of uranium to be used in next step is called uranium concentrate and known as yellowcake due to its colour.

For the sake of NFCIS, there are two major facility types in the database regarding uranium ore processing. One is called uranium ore processing and covers conventional uranium mills and the other is called uranium recovery from phosphates and covers facilities in which uranium is recovered as by-product from phosphate production facilities.

Data on uranium resources and demand are not included in the NFCIS and might be found in the above-mentioned Uranium Red Book published biennially jointly by the IAEA and OECD/NEA. The last publication of the Uranium Red Book was done in 2008 [15]. Also, a lot of data and present status in the area were well presented at the IAEA "International Symposium on Uranium Production and Raw Materials for the Nuclear Fuel Cycle — Supply and Demand, Economics, the Environment and Energy Security" in June 2005 [21]. According to the last issue of the Red Book, the Reasonably Assured Resources and Inferred Resources recoverable at costs US$ 130/kgU are equal to 3.338 and 2.130 million t U, respectively.

The planned growth of nuclear energy in the late 1970s motivated intensive uranium resource exploration and exploitation. In reality, the actual nuclear energy growth and related uranium consumption were much lower than forecast. In the 1980s the production of uranium exceeded the consumption in the civilian nuclear programme and large civilian stockpiles of natural uranium were created. The consequence was the closure of high cost uranium production centres. Present uranium production is sufficient to meet only about 60% of current uranium demand of the world civilian nuclear programme. For example, annual demand of uranium in 2007 was equal to 69 110 t U, while production is 43 328 t U in 2007 [21]. The difference is provided from uranium inventories (natural U in concentrates, enriched U, reprocessed U). In addition to civilian stocks, nuclear grade highly enriched uranium (HEU) from military reserves is diluted and used for LWR fuel. But these two sources inherited from 1970s are of limited character. The use of recycled materials (reprocessed uranium and recovered plutonium) also helped to reduce the uranium demand. Reenriching uranium tails (depleted uranium) is an additional way to reduce the uranium demand.

Uranium prices in the spot market, which had been low and stable for the previous decade and a half, continued their climb — from US$25/kg in 2002 to US$350/kg in July 2007 then reduced to US$122/kg in August 2008 [22]. Uranium production has been well below consumption for about 15 years, and the current price increase reflects the growing perception that secondary sources, which have covered the difference, are becoming exhausted. The pressure on uranium prices is likely to remain strong, as primary production once again becomes the dominant source of supply to satisfy demand, given the heavy investment that will be required over the long term. This increase in production requires increased capacity and an extension of the life of some production facilities, the start of mining operations at new deposits, and rapid resumption of exploration. One of major conclusions of the 2005 IAEA International Symposium [21] was that there is sufficient uranium resource in ground to fuel expanding nuclear power programmes. However, the gap between the uranium in ground and yellow cake (uranium concentrate) availability has to be narrowed by expansion of uranium exploration, mining, milling and production activities.

Most uranium is produced by conventional ore mines and ore processing plants. Uranium ores usually contain 0.1% to 0.5% of uranium although higher grades (up to several per cent) have been found in some cases. Uranium is extracted by several basic processes: underground mining (~38% of total), open pit mining (~23%), in situ leaching-ISL (~28%), with co-product and by-product recovery from copper and gold operations (~8%) and other methods (~3%) [15]. Figure 3 shows the major mining methods and their share in the 2007 total uranium production. Underground mining is used to exploit orebodies lying well below the earth's surface. This is a traditional process of mineral extraction, with shafts sunk into the earth in order to gain access to the uranium ore. Open pit mining is used on ore bodies lying nearer to the surface. With both of these processes, the ore is transported to a processing facility (mill) in which the uranium is separated from the ore. In situ leaching is a process that does not require the removal of solid ore from the ground. Instead the uranium is extracted from the ore in the site by the use of a leaching solution (water with the addition of oxidants and less often with the addition of sulphuric acid). ISL technology is used to extract uranium from sandstone deposits.

Among other process methods, Heap Leaching is the process being used to recover uranium from low grade ore and it is usually associated with a conventional uranium mine and ore processing plant. In-place Leaching involves the extraction of uranium from broken ore without removing it from an underground mine, whereas heap leaching involved the use of a leaching facility on the surface.

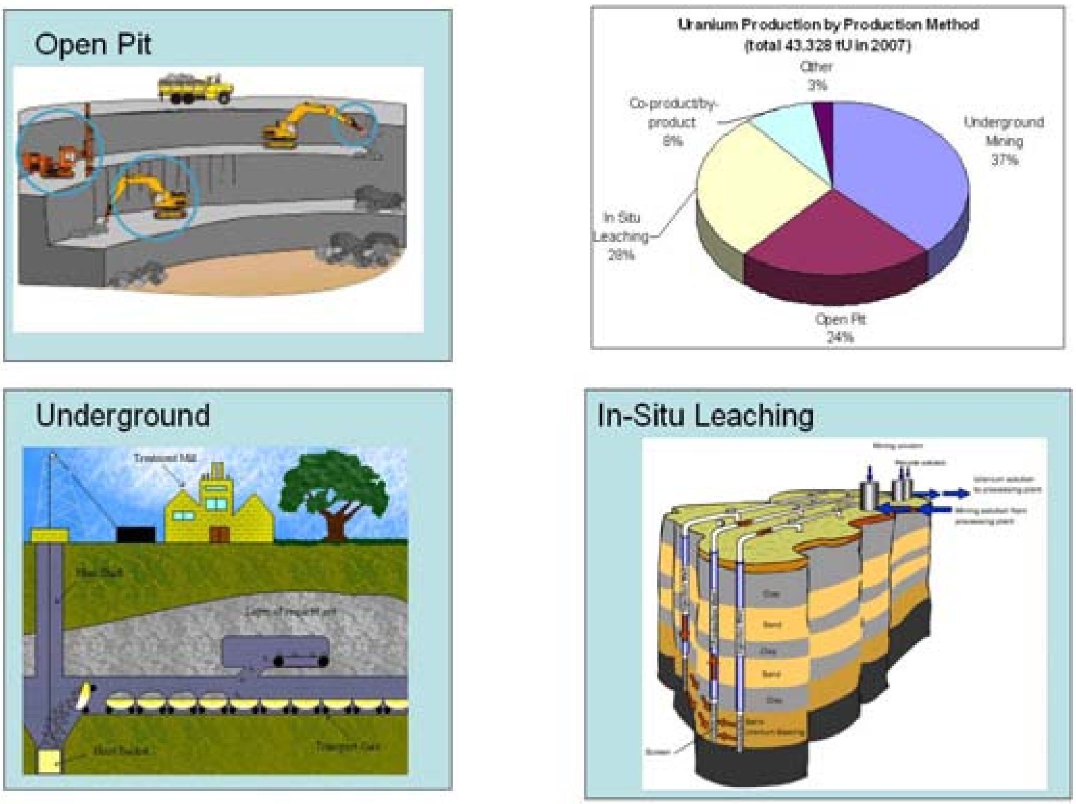


Fig. 3. Major methods of mining uranium and their share in 2007 production [15].

Unconventional methods include recovery of uranium through treatment of mine waters as part of reclamation and decommissioning (present share is ~0.2%), might be seen in more details in [23].

In previous years uranium was also recovered as a by-product of phosphoric acid production by a solvent extraction process. The technology to recover the uranium from phosphates is mature; it has been utilized in Belgium, Canada and USA, but high recovery costs limit the utilization of these resources [23].

Once the uranium ore has been extracted, it is processed in a mill where the uranium is leached from the ore using either an acid or an alkaline leaching solution. The uranium is recovered from this solution, or from ISL solutions, using an ion exchange or solvent extraction process. The usable mill product is a uranium oxide concentrate termed yellowcake. The yellowcake is usually heated to remove impurities, thus increasing the U_3O_8 concentration.

2.3.1.1. Balance (supply-demand-production)

At present, the main uranium producing countries are Australia, Canada, China, Kazakhstan, Namibia, Niger, the Russian Federation, South Africa, the USA and Uzbekistan. The increase in production will be the product of new mines offsetting mine shutdowns contemplated after 2010. The most significant of these projects include Australia, Africa, Canada and Kazakhstan.

According to RedBook 2007 edition [15] the natural uranium demand is about 69 110 t U in 2007. The demand is projected to become between 70 000 and 122 000 in 2030 in the same document. World natural uranium production is about 43 300 t U in 2007. The gap between the production and demand has been supplied by the inventories and the secondary uranium sources such as diluted highly enriched uranium. But those secondary sources and inventories are limited and the natural uranium production has to be increased almost 50% in coming years. These facts are one of the driving factors for the latest huge increase in natural uranium price.

According to the NFCIS records, current total production capacity of uranium processing facilities is 56 946 t U. The new capacities are being added to meet the projected demand in several countries including Kazakhstan, China, Russian Federation, Canada, South Africa, Namibia, Niger and Australia. The breakdown of the commercial operating uranium ore processing facilities is given in Section 3 TABLE 7.

2.3.2. Conversion

In order to use the uranium for the nuclear fuel uranium concentrate has to be converted to other forms which is usable by the further steps in the fuel cycle, i.e. uranium hexafluoride (UF_6) in case of enriched uranium fuel, natural uranium oxide (UO_2) in case of PHWRs, metal uranium in case of fuel based on metallic uranium alloy.

Conversion to UF_6 is a two-stage process. In the first stage, the uranium is converted into uranium tetrafluoride (UF_4), green salt. The UF_4 is a solid with a melting point of 960^oC. This stage involves dissolving the uranium concentrates with acid, obtaining $UO_2(NO_3)_2{\cdot}6H_2O$ (UNH) and purifying and then calcining it to produce UO_3 powder. This product is then hydrofluorinated with hydrofluoric acid, which converts it into UF_4, which is granular and green. In the second stage, the UF_4 is converted into uranium hexafluoride (UF_6) through fluorination. One of the chemical characteristics of UF_6 is that it turns into a gas when heated at relatively low temperature. The fluorine used in this process is produced through electrolysis of hydrofluoric acid. Two stages are usually performed at one plant, but, sometimes, these two stages might be performed at two different plants (one example for separate facilities — hydrofluorination stage with production of UF_4 is carried out at the Comurhex Malvesi plant, Narbonne, France and fluorination stage with production of UF_6 is carried out at the Comurhex Pierrelatte plant in southern France).

The scheme of uranium ore concentrate refining and conversion into UF_6 by conventional 'wet route' is presented in Fig. 4.

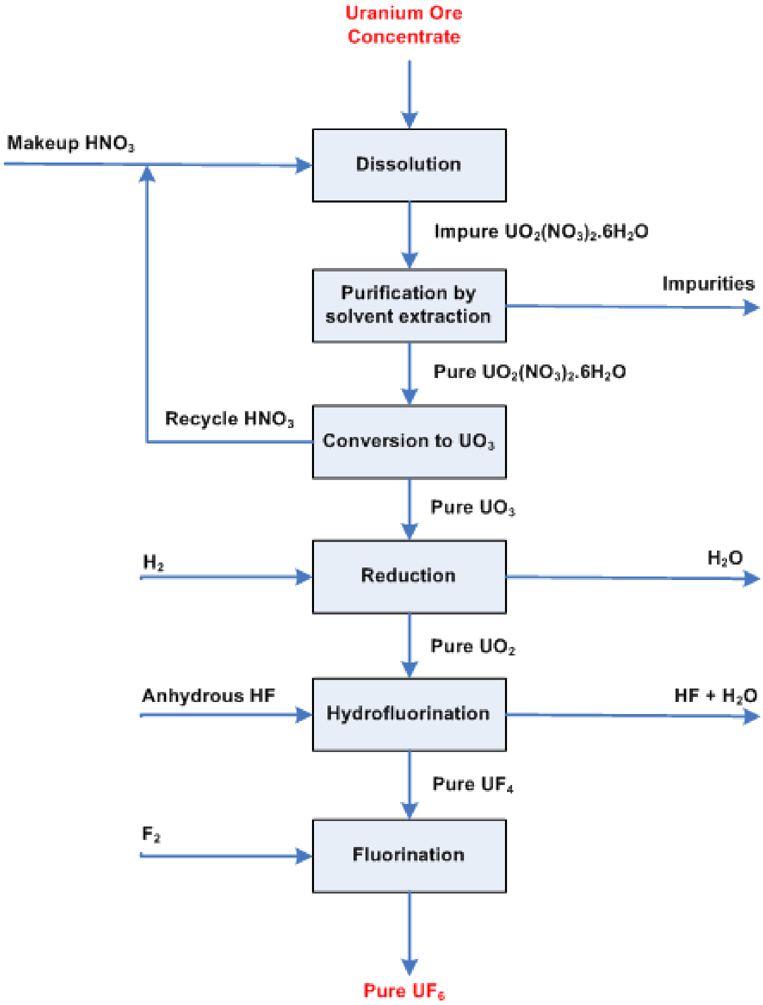


Fig. 4. Stages in conventional (wet route) UF_6 refining-conversion process.

The purified uranium trioxide (UO_3) transformed in uranium dioxide (UO_2) is used for the fabrication of fuel elements for PHWRs, which usually operate with natural UO_2 fuel. For LWRs, using enriched fuel, UO_2 is converted to UF_6 (feed for enrichment process). UF_4 conversion to U metal is used for fabrication of Magnox fuel.

The introduction of reprocessed uranium (RepU) into the fuel cycle has led to plans for the construction of facilities dedicated to the production of UF_6 from RepU. AREVA operates TU2 and TU5 lines in Pierrelatte to convert UNH from reprocessing plant into U_3O_8, stable oxide form for storage purposes. This U_3O_8 can be further converted to UF_6 in Comurhex Pierrelatte facility for re-enrichment purposes. Conversion of RepU was also done by Tomsk (Rosatom, Russia), BNFL (UK) and Japan Atomic Energy Agency (JAEA) (Japan).

The uranium enrichment process generates depleted UF_6, which might be converted into stable, insoluble and non-corrosive U_3O_8 that can be safely stored pending reuse. The AREVA Pierrelatte defluorination (Reconversion to U_3O_8) plant is the only facility in the world to convert depleted uranium hexafluoride into U_3O_8 on a commercial scale. Also, conversion of depleted uranium hexafluoride into an oxide generates an ultra pure 70% hydrofluoric acid.

2.3.2.1. Balance (Supply-Demand-Production)

Regarding NFCIS data, the total capacity of uranium conversion facilities worldwide is about 74 000 t U/a for conversion into UF_6 and 3 400 t U/a for conversion into UO_2 for PHWR fuel. The current demand for UF_6 conversion is about 60 000 t U/a. The projected demand will be between 60 000 and 90 000 t U/a in year 2025. In case the high growth case is realized in nuclear power projections, there will be a need to build new conversion facilities. The existing conversion facilities are also aging and need to be replaced. AREVA has already started the construction of its new conversion facilities (Comurhex II). At present, the world uranium conversion services are characterized by a small oversupply and relatively stable prices.

The breakdown of the commercial conversion facilities is given in TABLE 8 to TABLE 13 of Section 3.

2.3.3. Enrichment

Natural uranium consists of three isotopes: ^{238}U (99.28 % by mass), ^{235}U (0.711 % by mass) and ^{234}U (0.0054% by mass). ^{235}U is fissionable by thermal neutrons and is the only naturally occurring uranium isotope which can be used as nuclear fuel in thermal reactors. While pressurized heavy water reactors (PHWRs) and natural uranium gas cooled graphite reactors (Magnox) use natural uranium as a fuel, LWRs, Advanced Gas Cooled Reactors (AGRs) and Graphite Moderated Light Water Cooled Reactors (RBMKs), which altogether represent more than 90% of the installed nuclear power in the world [11][12], require enriched uranium as a fuel material. For these reactors, ^{235}U has to be enriched to about 2-5% by mass. Some PHWRs are also planned to be fuelled with the Slightly Enriched Uranium fuel with 0.85-1.25% ^{235}U.

The enrichment of uranium is a physical process used to increase the concentration of the ^{235}U isotope. Enrichment is the altering of isotope ratios in an element, and is usually done by isotope separation. Enrichment processes are made up of many stages, both in series and parallel, so it is usual to speak of separation factors per stage of process. When each process stage has only a small separation factor, many stages in series are needed to get the desired enrichment level. Also, when each stage has only a limited throughput, many stages are needed in parallel to get the required production rate. Since it is difficult to achieve both high separation and high throughput in a stage, design compromises are often made. Physical and technological principles of enrichment are very well presented in [24].

To obtain the desired enrichment and quantity, an enrichment plant is designed as a series of cascades, each with multiple units. At each stage, the enriched product feeds a higher enrichment cascade and the depleted product a lower one. Diagram illustrating the concept of enrichment unit, stage and cascade is given in Fig. 5, where enriched streams go to the next stage of the enrichment section and depleted streams are returned to the stripping section. The unit of measurement of enrichment is the Separative Work Unit (SWU). This can be defined in mathematical terms, but is the best thought of as related to the amount of energy required to take 1 kg of material from one enrichment level to another. Million SWU is the most common used unit for enrichment services. However, sometimes, MTSWU which represents 1 000 SWU, is used when large quantities of enrichment are involved. The tails usually contain 0.2-0.3 wt% ^{235}U. NFCIS database was designed to use enrichment capacities in MTSWU terms. The capacities from NFCIS can easily be converted to the other notation by using the relation 1 000 MTSWU = 1 million SWU.

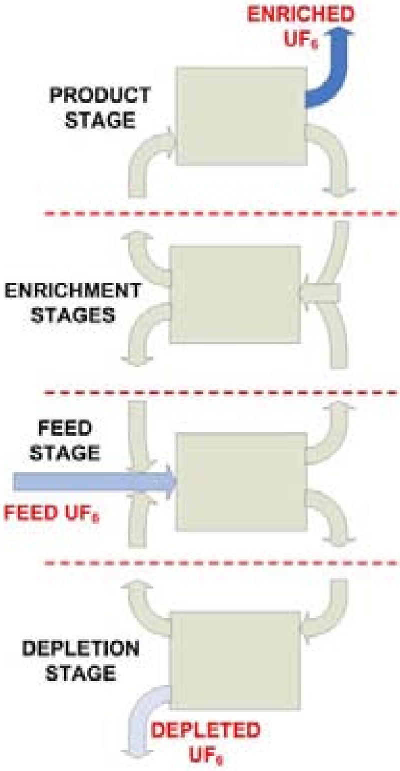


Fig. 5. Illustration of enrichment cascades.

The most common methods for enrichment are gaseous diffusion enrichment and centrifugal enrichment. In both technologies UF_6 is used as feed material. UF_6 is the only gas form suitable for diffusion/centrifuging. It has three main advantages: (1) it is a gas at low temperatures (56.4^oC is its sublimation temperature at normal pressure); (2) fluorine has only one isotope, and (3) fluorine has a low atomic weight. Disadvantages of UF_6 are how it acts with moisture to form UO_2F_2 (uranyl fluoride), which is very corrosive media.

In gaseous diffusion, separation is achieved by virtue of the faster rate of diffusion of $^{235}UF_6$ through a porous membrane relative to $^{238}UF_6$ (Fig. 6). This process is energy intensive and requires very large plants for economically viable operation, because separation factor is very low (1.0043). The number of stages should be very significant, e.g. Eurodif Georges Besse gaseous diffusion plant's cascade includes 1400 diffusion barrier stages.

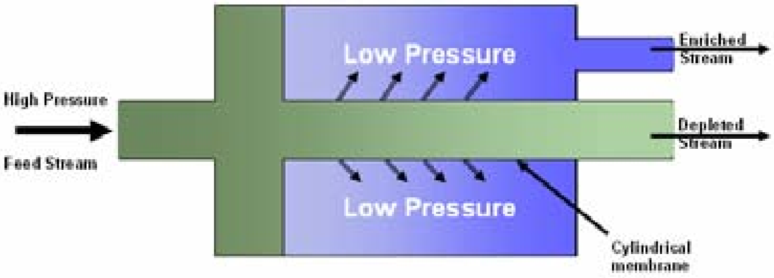


Fig. 6. Principal scheme of gaseous diffusion enrichment process.

The more recent technology is centrifuge enrichment, which relies on the application of extremely high rotational speeds to separate the lighter ^{235}U from the ^{238}U, again present in the form of gaseous UF_6. The separation is effected in cylinders (Fig. 7). Gas centrifuge has two major advantages over gaseous diffusion: (1) it is much more energy efficient; and (2) its plants have much fewer stages to a given enrichment. Although centrifuges have much smaller throughput than diffusion stages, this allows incremental capacity to be put on-line in smaller steps. The capital cost per unit capacity is about the same for both. Typical separation factor is higher than 1.25, up to 2.0 for very advanced units. The electricity consumption of the centrifuge process is relatively low — about 50 kWh for one SWU, which is about 1/50 of that for gaseous diffusion. Also, this technology can be developed in a modular way, allowing expansion of the facility according to demand.

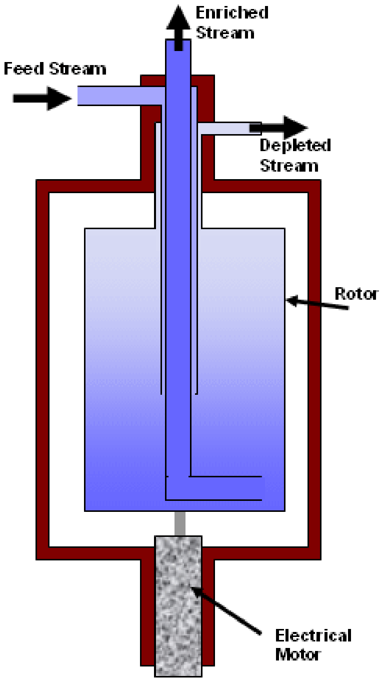


Fig. 7. Principal scheme of centrifuge enrichment process.

Chemical exchange and aerodynamic enrichment processes were developed and implemented on commercial/semi-commercial scale in the past, but no industrial application came to life. Some countries have investigated other isotope separation technologies. Most of these involve separation by atomic and molecular laser excitation. The first one was under development in the USA (by USEC/LLL — 'AVLIS'), France (by CEA – 'SILVA'), Japan ('Laser Jet'); the second one was under development in Australia ('SILEX'). These technologies have not been commercialized and it is unlikely that commercialization will be achieved in the near future. Financing of these projects was either stopped or drastically reduced. Typical stage separation factors over 2.0 were achieved for some of experimental laser devices.

There are plans to replace gaseous diffusion plants by gaseous centrifuge plants in France and USA. Georges Besse II plant using centrifuge technology will replace the current gaseous diffusion plant in in France. Construction and commissioning is expected to span the period from 2006 to about 2018. It is expected that the Georges Besse II plant will start up by 2009. The facility then will gradually reach to its full production capacity in about 2018.

USEC started construction of the American Centrifuge Plant in 2007 in Piketon, which will begin uranium enrichment operations in 2010, and reach an initial annual production capacity of 3.8 million SWU in 2012 [25].

URENCO has started the work for constructing a gasous centrifuge plant in USA. The facility is called National Enrichment Facility (NEF) and located in New Mexico. The final capacity will be 3 million SWU and is expected to be achieved in year 2013.

In case of utilizing the reprocessed uranium as low enriched fuel, it has to be re-enriched to the required level. Since RepU contains isotopes that are difficult to handle at a diffusion plant, the low inventory and modular design of a centrifuge enrichment plant is preferred for its re-enrichment.

2.3.3.1. Balance (Supply-Demand-Production)

World demand of enrichment services in 2007 was estimated about 40 million SWU. Regarding NFCIS, available worldwide enrichment capacity is about 56 million SWU plus 5.5 million SWU from dilution of excessive HEU from Russian defence programme. That is the evidence of some over-capacity in enrichment sector.

The demand for uranium enrichment is projected between 50 and 85 million SWU in year 2025 for low and high growth of nuclear power projection.

The breakdown of the commercial enrichment facilities is given in Section 3 TABLE 14.

2.3.4. Uranium fuel fabrication

The next step in the nuclear fuel cycle after enrichment (after conversion in the case of natural uranium fuel) is manufacturing the nuclear fuel in the form of an assembly in order to be utilized in the nuclear power reactors. The assembly has to be in a certain shape to meet the neutronic and thermalhydraulic design of the reactor and in a certain material form to provide first level of containment of radioactive material including fission products and other actinides which are produced during the irradiation of the nuclear fuel.

Usually, final product of fuel fabrication plant delivered to the electric utilities is a fuel assembly (FA). An LWR fuel assembly is made of cylindrical tubes called ‘fuel rods’ containing sintered uranium oxide pellets — the fissile material — held in place in a metal frame, or ‘skeleton’, usually made of zirconium alloy. An assembly can contain 200 to 500 kilograms of heavy metal, depending on the type of assembly. Figure 8 demonstrates typical fuel assemblies for the most common nuclear power plants in the world including LMFRs.

Main stages in FA fabrication are shown in Fig. 9. They include re-conversion of UF_6 to UO_2 powder, pellet fabrication, cladding fabrication, fuel rod fabrication, and skeleton fabrication (in case of LWRs; guide tubes, grids and end pieces) and, finally assembly fabrication. There are facilities which produce powder, pellets, rods and assembly. However, there are facilities which produce powder, pellets or rods as final products to feed other facilities.

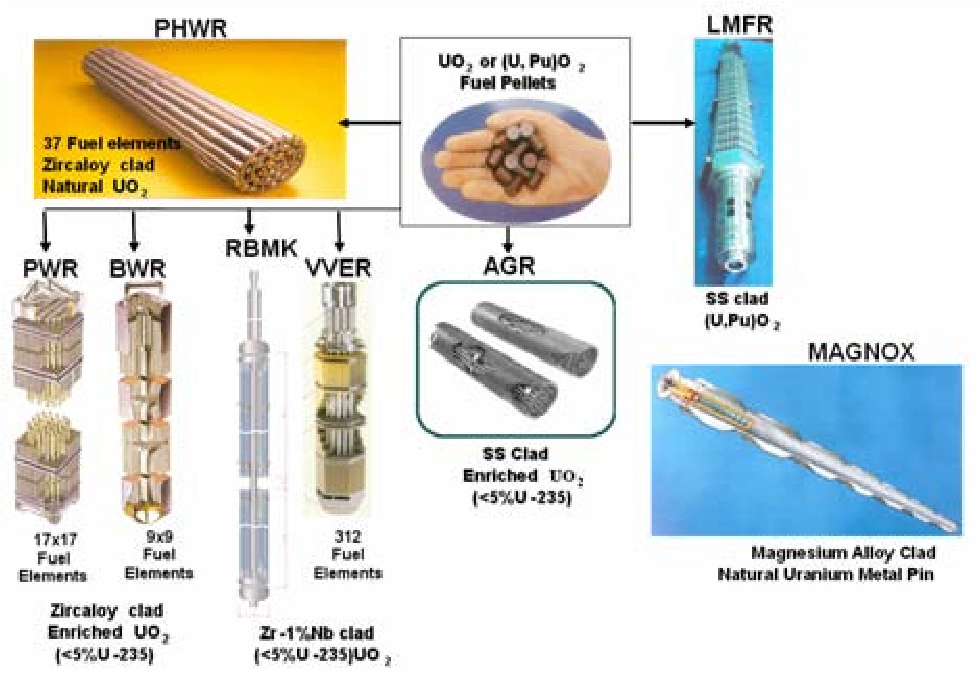


Fig. 8. Various typical fuel assemblies.

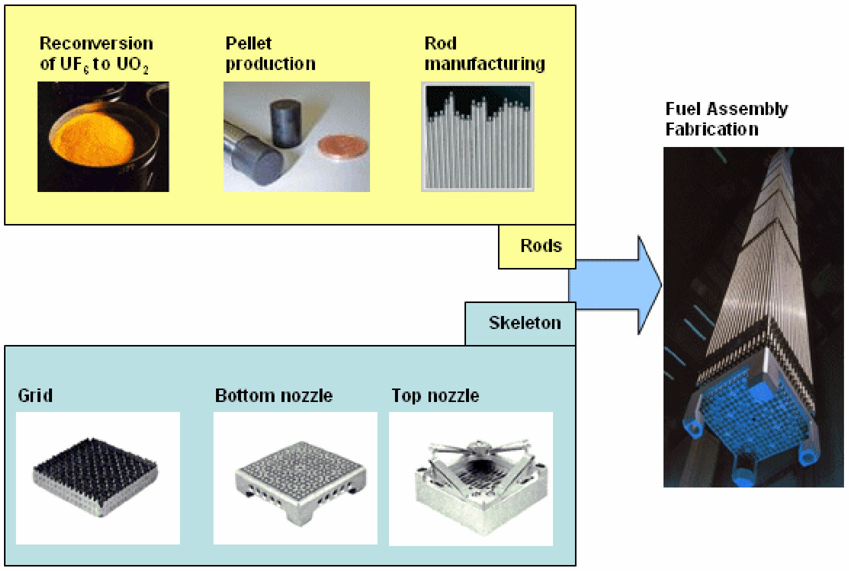


Fig. 9. Main stages in LWR fuel assembly fabrication.

2.3.4.1. Re-conversion of UF_6 to UO_2 powder

In order to manufacture enriched uranium fuel, enriched UF_6 has to be re-converted into UO_2 powder. This is the first step in the enriched fuel fabrication. It is called re-conversion. There are several dry or wet processes for re-conversion (or deconversion) of UF_6 to UO_2 powder. The first commercially introduced dry process so-called IDR (Integrated Dry Route Powder Process) was developed by BNFL [26] and licensed in many countries. Two wet processes, namely ADU (ammonium di-uranate) and AUC (ammonium uranyl carbonate), are the most frequently used wet processes worldwide.

Flow sheet of ADU and AUC reconversion processes and some reaction data are given in Fig. 10. Usually, independently on the type of main reconversion process used, large capacity fuel fabrication plant operates separate ADU line for own UO_2 scrap recycling and purification and or RepU conversion. High industrial maturity is the distinctive feature of the ADU process. The shortage is insufficient powder flowability and the need for intermediate granulation stage.

Flow sheet of IDR process is given in Fig. 11. The IDR technique consists, in brief, of feeding UF_6 vapour with steam through a jet to form a plume of UO_2F_2 powder which is then ejected into a rotating kiln where it meets a counter-current flow of hydrogen and steam. The product UO_2 of high reactivity and fine particle size is discharged from the end of the kiln through check-hoppers into product containers.

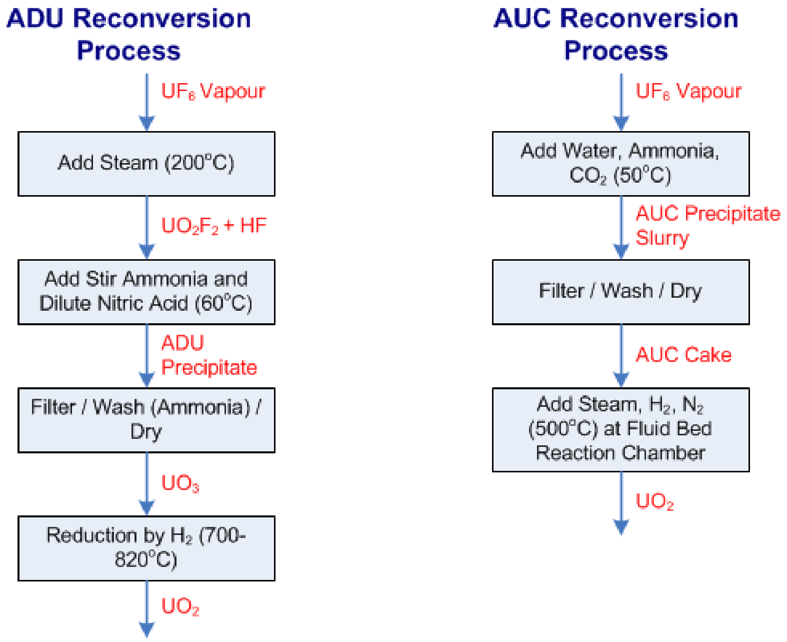


Fig. 10. Flow sheet of ADU and AUC reconversion processes and some reaction data.

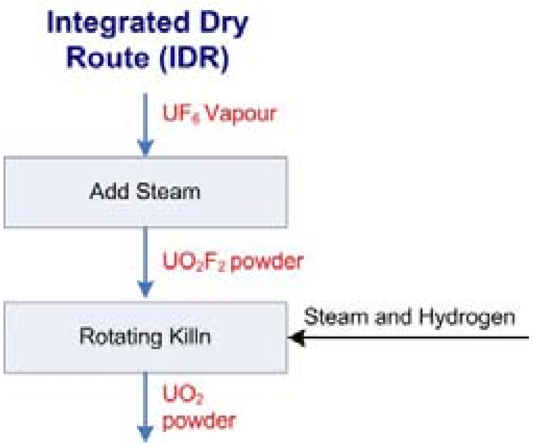


Fig. 11. Flow sheet of Integrated Dry Route for reconversion to UO_2 powder [26].

2.3.4.2. *Fuel pellet production*

Characteristics of UO_2 powders obtained by different routes might be found in [26], and information on powder/pelletizing technologies in [27][28] in more details. Flow sheet of pellet manufacturing is given in Fig. 12, [29]. Depending on characteristics of the initial powder, mainly flowability and bulk density, and requirements on finished pellet characteristics, press feed preparation stage (pre-pressing and granulation) might be omitted. Addition of fine U_3O_8 powder increases mechanical strength of green (before sintering) pellets and impacts on pore structure, (i.e. on densification behaviour). Pore former agent assists to obtaining desirable porosity level and pore's distribution. Addition of lubricant provides for better pressing behaviour and lower green density gradient.

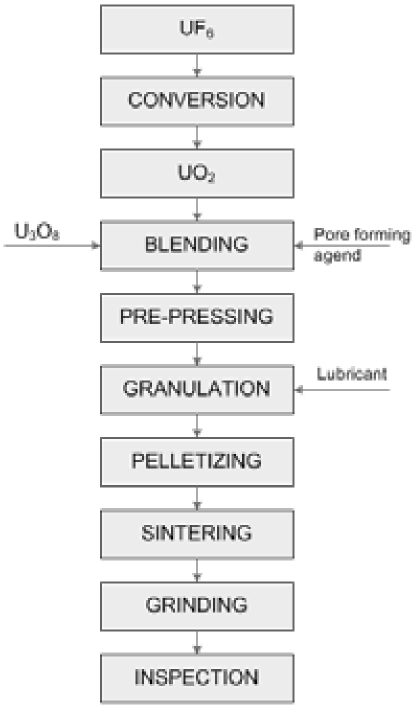


Fig. 12. Flow sheet of LWR pellet manufacturing starting from UF_6 [29].

The green pellet density is about 60% of theoretical density (5.9-6.3 g/cm^3). Sintering is usually done in furnaces with different temperature/cover gas zones (preheat, densification and high temperature zones) divided by a gas barrier (nitrogen jet) to provide the required physical and chemical characteristics such as mechanical strength, porosity and grain size, etc. The pellets are subjected to grinding, cleaning and drying to achieve necessary geometrical and quality requirements.

In detail, fuel pellet technology was considered at the IAEA Technical Meetings on Advanced Methods of Process/Quality Control in Nuclear Reactor Fuel Manufacture held in 1999 [27] and on Advanced Fuel Pellet Materials and Designs for Water Cooled Reactors held in 2003 [28].

2.3.4.3. *Rod manufacturing*

Fabrication of rods includes insertion of fuel pellets in the cladding and, in some case, blanket pellets in the end of fuel column, then springs and welding of the lower end plug. LWR fuel rods are filled in with helium. Helium pressure depends on rod design and varies from about 15 to 30 bars. Fabrication and inspection (fuel column weight, column continuity, cladding integrity and others) operations are maximally automated.

PHWR fuel rods are of different in comparison to LWR rods design, because cladding (sheath) is thin (~0.35 mm thickness) and collapses during the operation of power reactor. Before pellet loading, a thin layer of graphite is applied to reduce pellet-cladding interaction (PCI). Inside rod, like in PWR rods, there is helium-inert gas mixture atmosphere.

2.3.4.4. *Assembly manufacturing*

The final step in the fuel fabrication is to assemble all components in one structure. This final product is called fuel assembly.

LWR fuel assembly components include spacer grids, usually made of zirconium alloy plates with welded Inconel springs (more than 500 welding points and more than 200 welding seams per grid [25]), top and bottom nozzles made of stainless steel, and guide tubes. First, the skeleton assembly is made, which is the assembly of the guide tubes and the instrumentation tube to the spacer grids and bottom nozzle. On the assembly bench, the rods are driven by traction equipment. Then the top nozzle is mounted. The nozzles are mounted on the guide tubes by screws which heads are crimped by machining, which ensures blocking during rotation [29]. The screws can be taken out to dismantle the nozzles and, if needed, to replace defective rod/rods with zirconium alloy dummy/dummies (FA repair). After replacement, new screws are inserted.

In PHWR fuel assembly fuel rods (configuration of spacer elements on rods is different for inner and outer rods) are welded with end plates at both ends.

2.3.4.5. *Balance (Supply-Demand-Production)*

Worldwide requirement on LWR fuel was about 7 500 t HM in 2007 and total capacity, regarding NFCIS, constituted about 11 500 t HM/a in fuel assemblies. MOX fuel fabrication capacities were equal about 315 t HM/a, and the production is about 150-200 t HM/a. Worldwide capacity for PHWR fuel manufacture constituted of about 4 250 t HM/a. The demand for PWHR fuel was about 2 750 t HM in 2007.

The projections for LWR fuel fabrication shows that the demand will be between 6 000 and 12 000 t HM/a in year 2025 for the low and high nuclear power growth projections.

The breakdown of the commercial uranium fuel fabrication facilities is given in TABLE 15 to TABLE 23 of Section 3.

2.3.5. Irradiation / Nuclear reactor operation

The finished fuel is loaded into nuclear reactors and irradiated, i.e. nuclear fission reactions are allowed to take place, thereby releasing energy which is used to generate electricity. The amount of energy that can be obtained from a given amount of uranium depends on the type of reactor used, the degree of burnup achieved and other variables. One metric tonne of natural uranium dioxide, at the present level of nuclear fuel cycle technology, can produce approximately 3 × 10^7 kWh of the electricity, which is equivalent about to 11 000 tonnes of crude oil. TABLE 5 shows basic characteristics of presently operating nuclear power reactors and their fuels. According to the IAEA PRIS database, there are 439 reactors in operation and the total installed capacity of those is about 372 GWe as of September 2008 [11][12]. PRIS show also that 35 reactors with total capacity of 29.3 GWe is under construction as of September 2008.

TABLE 5. TYPICAL BASIC CHARACTERISTICS OF PRESENTLY OPERATING NUCLEAR POWER REACTORS AND THEIR FUELS

Reactor Type	**PWR/WWER**	**BWR**	**PHWR**	**RBMK**	**AGR**	**MAGNOX**	**FR**
Neutron spectrum	Thermal	Thermal	Thermal	Thermal	Thermal	Thermal	Fast
Moderator	H_2O	H_2O	D_2O	Graphite	Graphite	Graphite	–
Coolant:							
type	Press. H_2O	Boiling H_2O	Pr. D_2O	Boil. H_2O	CO_2	CO_2	Na
pressure, bar	155	70	110	70	40	19	5
temperature, outlet, ^{0}C	320	286	310	284	630	400	550
Fuel:							
type	UO_2 or MOX	UO_2 or MOX	UO_2	UO_2	UO_2	U metal	UO_2*
enrichment	up to 5% ^{235}U eff.	Up to 5% ^{235}U eff.	Nat. U	Up to 3% ^{235}U	2.5-3.8% ^{235}U	Nat. U	17-26% ^{235}U*
Cladding	Zr alloy	Zr alloy	Zr alloy	Zr alloy	SS**	MgO-Al	SS**
Burnup, GWD/t HM	Up to 60	Up to 55	7	Up to 25	Up to 30	4	Up to 100*
Number of operating reactors	229	93	39	16	14	8	1
Total power, GWe	240.6	82.6	20	11.4	8.4	2.3	0.6*

*-data for Russian BN-600.
**-SS-stainless steel.

Types of presently operating nuclear power reactors include Pressurized Water Reactors (PWRs and WWERs), Boiling Water Reactors (BWRs), Pressurized Heavy Water Reactors (PHWRs), Graphite Moderated Light Water Cooled Reactors (RBMKs), Advanced Gas Reactors (AGRs), Magnox Reactors and Fast Reactors (FRs). Prototype High Temperature Gas Cooled Reactors (HTGRs) which were operated earlier are shutdown. There are continuous studies on the development of HTGRs and on the other new designs including new type of fast reactors.

2.3.6. *Spent fuel management options*

The nuclear fuel, which has been irradiated in the nuclear reactor, has to be removed (discharged) from the reactor after the irradiation period. Discharged fuel is called spent fuel, used fuel or irradiated fuel. After discharge the spent fuel is usually stored at At-Reactor (AR) pools for a certain period of time. Following the AR storage the nuclear fuel goes to the next step of the nuclear fuel cycle.

Figure 13 shows the main paths of fuel after discharge from the reactor for different fuel cycle options. In the *open fuel cycle option*, the next fuel cycle step is the storage of nuclear fuel in Away From Reactor (AFR) storage facilities. AFR facilities can be wet type (pools) or dry types. The storage solutions available on the market allow nuclear power utility to manage its own spent fuel for several decades. The long-term challenge will be the final disposal of the utility's inventory of spent fuel, often in connection with the national nuclear waste disposal programs.

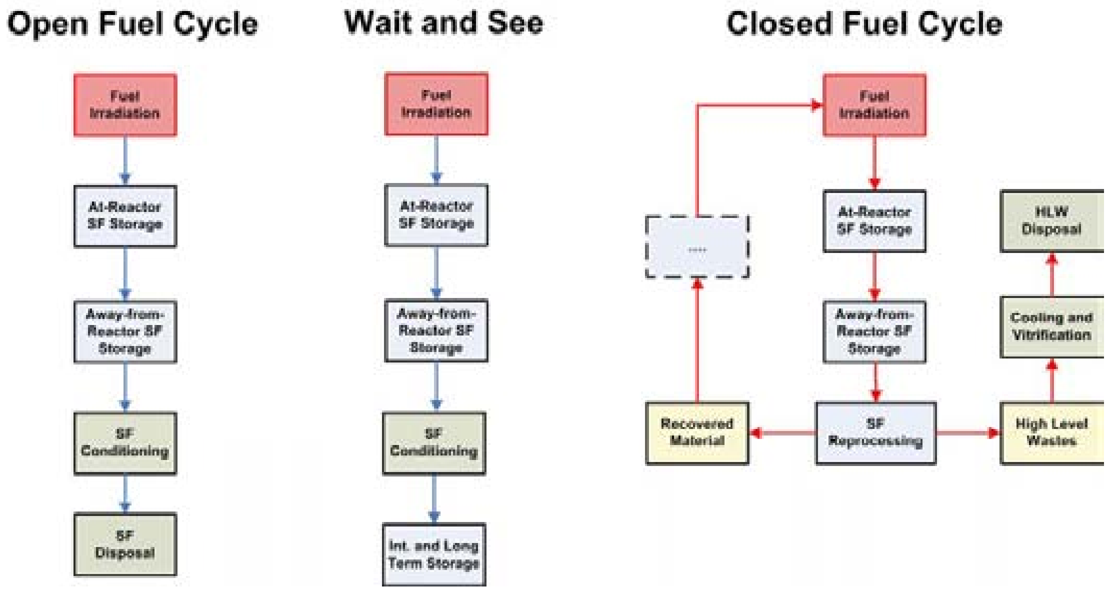


Fig. 13. Different spent fuel management options.

In the *closed fuel cycle option*, the next fuel cycle step is the reprocessing of the spent nuclear fuel. In *wait-and-see option*, the spent fuel is stored at AFR facilities for uncertain period after at-reactor storage period. Spent fuel is conditioned if the longer term storage is planned.

In LWR, spent fuel is discharged from the core during regular reactor refuelling outage, with primary circuit depressurized and the vessel open. Fuel assembly first goes to the at-reactor (AR) pool and then to the away-from-reactor (AFR) spent fuel storage facility or to reprocessing facility depending on the fuel cycle option. Spent PHWR, RBMK and some AGR fuel are discharged on-power and assemblies are stored in water pools, at least, for heat removal period of time. FR spent fuel assemblies are stored in internal sodium storage for heat removal before transport to water pool.

Magnox spent fuel elements have to be reprocessed because they cannot be stored for long periods of time without serious degradation of the cladding. The Magnox system was designed with a wet discharge routes and interim pool storage of fuel in anticipation of early reprocessing. Wylfa NPP, which utilizes a wet discharge route also, has an at-reactor dry storage facility built to guard against any interruption to reprocessing activities at Sellafield. Magnox fuel is reprocessed after about 6 month's storage.

AGRs have very small AR spent fuel storage pools, as early reprocessing was envisaged during the design of the reactors, and hence all spent AGR fuel is sent to Sellafield where it is stored underwater. The contractual relationship between BNFL & BE covers the lifetime arisings of AGR fuel. It provides for a near maximum commitment to reprocessing over the first two decades of Thorp operation. There are options for further reprocessing following the first 20 years of Thorp operation or long term storage [30].

2.3.7. Spent fuel storage

The spent fuel has to be stored for certain period after discharge from the reactor regardless of the spent fuel management route. However, the duration of the storage period depends on the spent fuel management route and the type of the fuel. Spent fuel can be stored in either wet storage facilities or dry storage facilities.

The wet storage of spent LWR fuel has been in use for rather more than 30 years. Spent FAs are stored in vertical racks, usually done of borated SS in order to avoid criticality, in water at temperatures below 40°C. Water is constantly purified and activity is maintained below 10^7 Bq/m^3.

The dry storage is possible in air, nitrogen or in inert gas. The present conclusions for air storage are that the maximum cladding temperature should not exceed 140-150°C [29][31][32]. At these conditions the additional oxidation of a Zircaloy cladding, as estimated, to be less than 10 µm over 50 years [29]. Regarding storage in inert gas, experiments and calculations have led to the recommendation on maintaining 350-400°C as maximum cladding temperature to avoid creep risk and cladding oxidation [29][31][32]. There are several types of dry storage designs based on different cask types or vault type facilities.

Wet fuel storage is now considered to be a mature technology. Dry storage has been developed over the past 25-30 years and can also be regarded as an established industrial technology.

Figure 14 shows the trends in spent fuel discharge, reprocessing and storage estimated by the NFCSS [9] based on the nuclear power projection which is given in the IAEA RDS-1 [33]. In this estimation, the arithmetic median of the low and high projection of RDS-1 was used.

Regarding the NFCSS estimation, the spent fuel generation rate worldwide was about 11 000 t HM/year in 2007 and expected to increase to about 13 00 t HM/year by 2030. As less than one third of the fuel inventory is reprocessed in current practice, about 8 500 t HM/year was needed to be placed into interim storage facilities in 2007. At the beginning of 2008, slightly more than 200 000 t HM of spent fuel were stored in storage facilities of various types. This will reach to about 400 000 t HM-in 2030 if the current trend in reprocessing is maintained. Total capacity of existing spent fuel storage (SFS) facilities in 2003 was 243 800 t HM and total capacity of the facilities under construction is about 24 000 t HM [34]. Most of this fuel was under water, but dry storage was becoming a commonly used technology with more than 12 000 t HM stored in dry storage facilities worldwide. Consequently, a storage shortage is not expected globally. On a national level however, a shortage may occur if construction or expansion cannot be completed in time. The breakdown of AFR spent fuel storage facilities is given in TABLE 24 and TABLE 25 of Section 3.

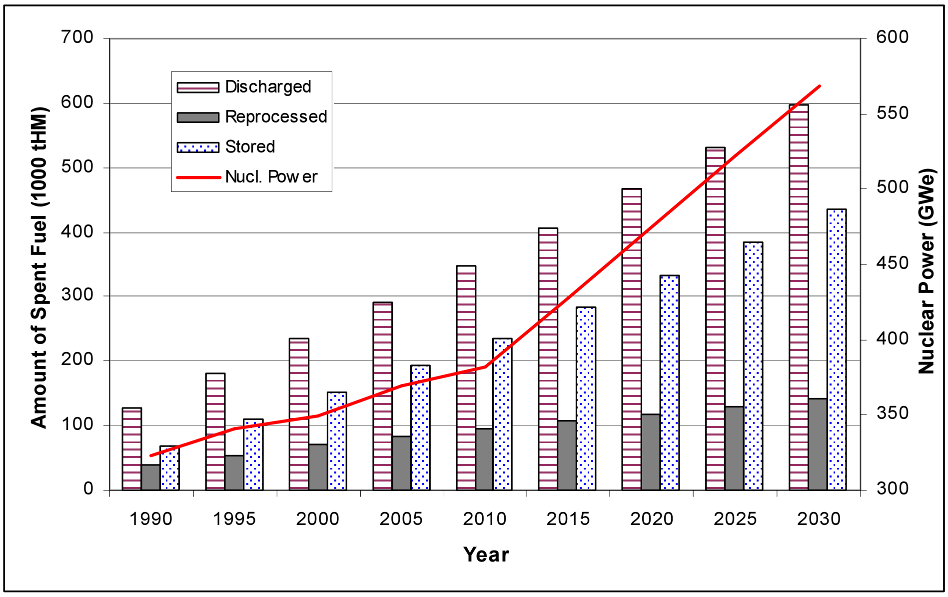


Fig. 14. Cumulative spent fuel discharged, stored and reprocessed from 1990 to 2030.

2.3.8. Spent fuel conditioning

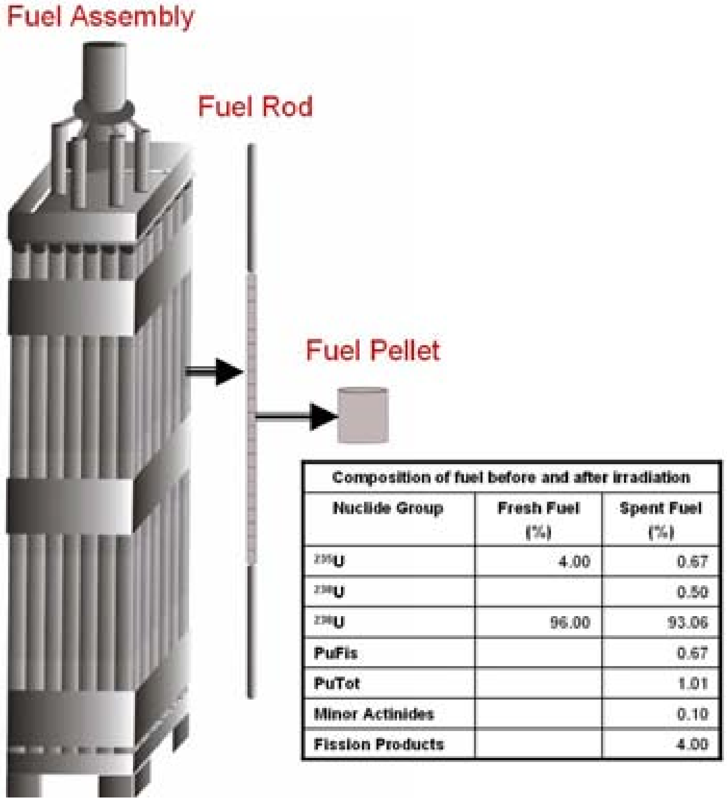
After a storage period in interim storage facilities (AR or AFR type), spent fuel will be prepared for reprocessing or conditioned for further storage or disposal. Depending on the disposal concept, spent fuel is generally placed first in a primary metallic (usually iron or steel) container that is then placed inside an overpack or canister (usually mild steel, cast iron, stainless steel, concrete, copper and titanium) [35][36]. Normally, only the overpack/canister is intended to have a barrier function once emplaced in the repository. One of the functions of the primary or inner container is to facilitate handling by providing the required mechanical strength. In regard to spent fuel, fuel assemblies might be placed individually into slots in a composite disposal canister (i.e. one without an inner container).

Overpacks/canisters are usually designed to contribute to the containment capacity of the engineered barrier system (EBS). Two conceptual approaches are possible: corrosion allowance and corrosion resistance. The first involves the use of readily corrodible metals (e.g. mild steel and cast iron) with sufficient thickness to delay container failure for some thousands of years, i.e. until the short lived fission products in the spent fuel have decayed. Thereafter, the corrosion products may have some chemical barrier role. The second involves the use of corrosion resistant materials (e.g. copper and titanium alloys) that are intended to prevent water access for much longer periods (up to 100 000 years), possibly even until all the most mobile radionuclides have decayed and the waste hazard has declined to levels similar to those of natural uranium ore. There is no commercial spent fuel conditioning facility in operation yet.

2.3.9. Spent fuel reprocessing and recycling

One of the important steps in the closed nuclear fuel cycle is the reprocessing of spent fuel. The spent nuclear fuel still consists of significant amount of fissile material that can be used to produce energy. The considerable amount of ^{235}U is still contained in the spent fuel and there are new fissile nuclides that were produced during the operation of nuclear power reactor such as ^{239}Pu. Closed nuclear fuel cycle considers taking out those fissile material from the spent fuel, refabricating it as fuel and burning in the reactor. MOX fuel and ERU fuels are the most common fuels that use reprocessed material. Reprocessed uranium from WWER fuel is also used in RBMK by blending with fresh materials and with other reprocessed uranium with higher content of fissile material (reprocessed research reactor fuel). Reprocessing process is based on chemical and physical processes to separate the required material from spent nuclear fuel. The feed of this process is spent fuel and the products are reusable material and high level waste. Reprocessing not only utilizes nuclear materials more effectively but also reduces the volume and the radiotoxicity of the material requiring deep geological disposal.

Reprocessing has been carried out on a commercial scale for over four decades in several countries. Reprocessing strategy considers spent fuel as an energy resource which is recovered through reprocessing. As it is displayed in Fig. 15, spent fuel contains, (for 4% initial enrichment and 45 GWd/t discharge burnup), about 0.67% unburned ^{235}U, about 0.5% ^{236}U, about 93% ^{238}U, about 1% plutonium (0.67% is Fissile Pu), 0.1% Minor Actinides, 4% of fission products and small amounts of other actinides. After cooling in a pool for a few years, the fuel can be reprocessed. Reprocessing of irradiated nuclear fuel separates plutonium and uranium from the intensely radioactive fission products and other actinides.



Composition of fuel before and after irradiation		
Nuclide Group	Fresh Fuel (%)	Spent Fuel (%)
^{235}U	4.00	0.67
^{236}U		0.50
^{238}U	96.00	93.06
PuFis		0.67
PuTot		1.01
Minor Actinides		0.10
Fission Products		4.00

Fig. 15. Illustration of a typical PWR fuel assembly and approxiomate composition of fresh fuel and spent fuel after irradiation after 45 GWd/t burnup.

Different technical processes can be used to accomplish this separation. However, over the years Purex (Fig. 16) has become the most commonly accepted process. The Purex process has a number of advantages including lower solvent volatility and flammability, higher chemical and radiation stability of the solvent and lower operating costs. Purex involves the shearing of irradiated nuclear fuel and its dissolution in nitric acid, followed by separation of uranium, plutonium and fission products by solvent extraction using an organic diluent — the extractant tributyl phosphate (TBP) mixed in a largely inert hydrocarbon solvent [24].

In order to increase proliferation resistance features of the fuel cycles, the studies are going on to develop and commercialize other reprocessing techniques which will retrieve uranium and plutonium together from the spent fuel.

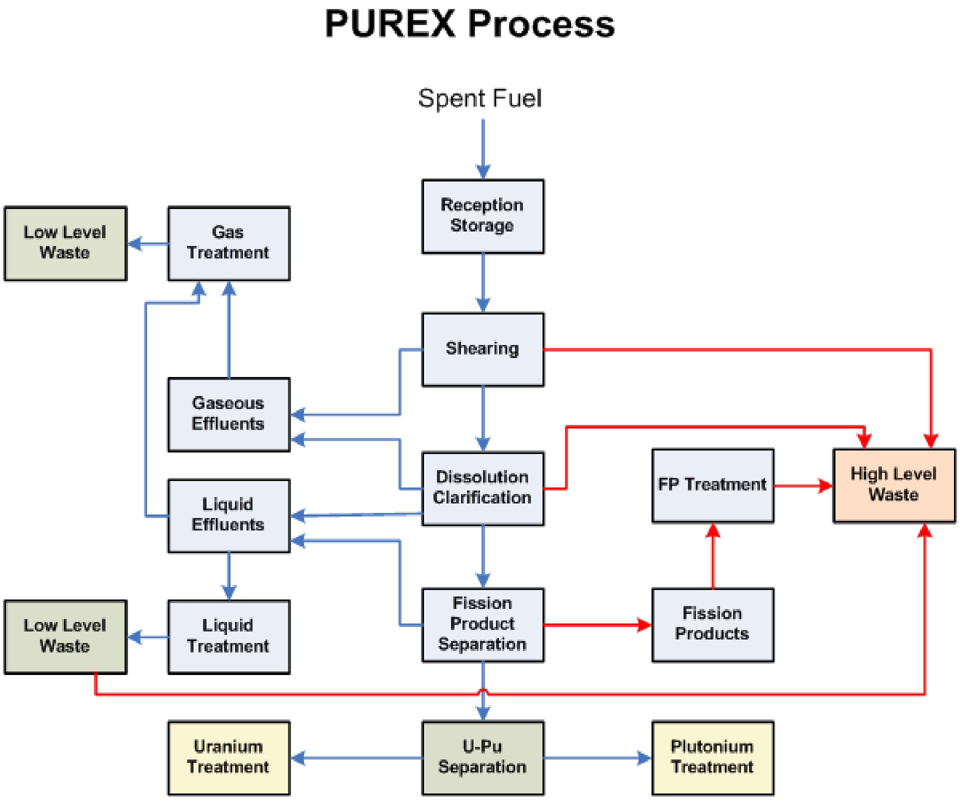


Fig. 16. Flowsheet of a typical PUREX reprocessing.

The fission products are stored temporarily in stainless steel tanks fitted with continuous cooling and agitating devices. After a decay period of about one year, the fission product solutions can be solidified usually by vitrification. Glass containing the high level nuclear waste is poured into stainless steel canisters which are stored in an interim monitored storage where they are cooled by ventilation. After sufficient cooling, the canisters could be sent to an underground repository for disposal.

Recovered uranium is converted into oxide powder and stored prior to further use. It is then re-enriched or blended with HEU and fabricated into new fuel. It could also be used as a matrix for MOX fuel to replace the depleted uranium. Since reprocessed uranium contains artificial isotopes not present in natural uranium, the fuel fabrication requires special shielding and processing lines. The additional measures include protection against radiation due to the presence of the ^{232}U isotope and its by-products and require over enrichment in ^{235}U compensating for ^{236}U neutron absorption effects.

Separated plutonium is converted into an oxide powder, packed in leak tight cans and transported to plutonium fuel fabrication facilities for the production of MOX fuels for

LWRs and FRs. Because of the fissile isotopes ^{239}Pu and ^{241}Pu, plutonium is used as substitute for ^{235}U. But ^{241}Pu decays into the non-fissile and highly radioactive ^{241}Am. For this reason the utilization of plutonium for MOX fuel should ideally take place shortly after its separation from the spent fuel.

In general MOX fuel pellets are produced from UO2 and PuO2 powders in a similar way to the uranium fuel. Details for the MOX fuel pellet production can be found in IAEA Technical Reports Series 415 “Status and Advances in MOX fuel Technology [37].

Balance (supply-demand-production)

As of the end of 2007, about 90 000 t HM of commercial spent fuel has been reprocessed, mostly at the two commercial plants at La Hague and Sellafield [38] and in Mayak. Activities range from the small scale reprocessing of fuel from research or experimental reactors to large-scale industrial plants offering an international service for standard oxide LWR, WWER and AGR fuel. The total reprocessing capacity will increase with the new plant, Rokkasho-mura of 800 t HM/a nominal capacities, currently under commissioning test in Japan, which is expected to come on line soon.

Only operating MOX fuel assembly fabrication facility is MELOX in France with nominal capacity of 145 t HM. Sellafield MOX facility is under commissioning tests (capacity will be 120 t HM). There is also a planned MOX fabrication facility in Rokkasho with nominal capacity of 130 t HM.

The breakdown of commercial reprocessing facilities is given in Section 3 TABLE 26. The breakdown of commercial MOX fuel fabrication facilities is given in Section 3 TABLE 27 and TABLE 28.

2.3.10. Spent fuel disposal

After being properly conditioned, spent fuel can be disposed in deep geological formations for an indefinite period of time until a non-hazardous level of radioactivity from the actinides and fission products is reached by decay. The term ‘Spent Nuclear Fuel’ includes whole or dismantled fuel assemblies or consolidated fuel rods, containing the original metallic uranium, uranium dioxide or mixed oxide (MOX) fuel matrices and the fission products and transuranics that were formed while the fuel was in the reactor. Spent fuel can easily withstand the elevated temperatures that will be reached during its early phase in the repository, since the temperatures experienced in reactors are very much higher. The repository EBS may, however, be much more sensitive to elevated temperatures, and its long term performance in the context of the thermal evolution of the repository will need to be estimated with care. In this respect, MOX fuels generate more heat, and for a longer period, than normal uranium oxide fuel.

Various repository concepts are under consideration. Some are based on underground engineered galleries several hundred meters below the surface, where conditioned fuel packed into canisters would be loaded into tunnels and then backfilled with a material impervious to water such as bentonite. The siting of such a repository requires special geological and seismic conditions in order to provide a physically and chemically stable environment preventing eventual migration of actinides and fission products into the environment. Several geological formations are under investigation for underground repository siting, including granite, schists, salt deposits and clay beds.

At present there is no operating repository for spent nuclear fuel, although several are under study. The fuel is at present kept in at-reactor pools or in monitored and retrievable interim spent fuel storage. Scientific and technical basis for the geological disposal of spent fuel and radioactive wastes are considered in [35].

2.3.11. Related Industrial Activities

2.3.11.1. Zirconium alloy (nuclear grade) production

Zirconium is a very important metal in nuclear power industry. With atomic number 40, 6.5 g/cm^3 density, 1875 °C melting point, good mechanical properties and thermal conductivity and very low macroscopic cross-section for thermal neutrons, Zirconium is the best material for water reactor claddings and fuel assembly components. Zr is among the most abundant (0.28%) elements in the Earth's crust. It occurs in the form of Zr-sand (mineral with the formula $ZrSiO_4$) and usually contains up to 3% Hf which is a neutron poison and should be separated from Zr. The production of zirconium alloy from Zr-sand to the alloyed metallic ingot is based on a Zr-tetrachloride ($ZrCl_4$) technology for basic manufacturers.

The zirconium alloys in use for nuclear fuel fabrication are: Zircaloy-2 (BWR FR cladding), Zircaloy-4 (PWR/PHWR FR cladding and BWR and PWR FA structure), M5 and ZIRLO^{TM} (PWR fuel rod cladding and FA structure), E-110 and E-635 (WWER/RBMK fuel rod cladding and FA structure), Zr-2.5Nb or E-125 (respectively, PHWR and RBMK pressure tubes). Chemical compositions for Zr-based alloys (wt %) are: Zircaloy -2 (Sn: 1.2-1.7%; Fe: 0.07-0.2%; Ni: 0.03-0.08%; Cr: 0.05-0.15% plus Zr); Zircaloy-4 (Sn: 1.2-1.7%; Fe: 0.18- 0.24%; Ni: 0.007%; Cr: 0.07-0.15% plus Zr). The zirconium alloy (Zr + 1 % Nb) is used for WWER fuel. The zirconium alloy (Zr + 2.5% Nb) is mainly used as pressure tube material for RBMKs and PHWRs.

To reduce the fuel-cycle costs the nuclear industry strives to extend the discharge burnup of the fuel and to prolong the operating cycles. In PWRs this trend is accompanied by new operating regimes, including higher B and Li levels in the primary coolant. Similar changes are carried out in WWERs. Under these operating conditions, corrosion, hydriding and irradiation induced growth of Zr-based materials are important factors for the performance of LWR fuel. R&D work resulted in development and introduction of modified or new advanced cladding materials.

The breakdown of commercial zirconium alloy production facilities is given in Section 3 TABLE 29.

2.3.11.2. Zirconium Alloy tubing

As mentioned in previous part, Zr-alloy metal is used as feed material for fabrication of final products, like FR claddings, pressure tubes, FA components (spacer grids, springs) and guide tubes. Zr-alloy products must meet very rigorous quality requirements for dimensional tolerances and mechanical properties, material condition, surface state and direction of residual stresses in order to minimize fuel failures.

More detailed information on zirconium alloy tubing technology might be found in [39]. Technology of fabrication of PHWR/RBMK pressure tubes and zirconium alloy sheets has own peculiarities and might be found in appropriate literature, e.g. in the Proceedings of the ASTM Zirconium Conferences and also in ‘Zr Handbook’ to be published by the IAEA presumably in 2008.

The breakdown of commercial Zirconium alloy tubing facilities is given in Section 3 TABLE 30.

2.3.11.3. Heavy Water production

Heavy water is the common name for D_2O, deuterium oxide. Heavy water is required as a moderator and coolant for PHWRs loaded with natural UO_2 fuel. Heavy water represents about 10% of the operational cost of PHWRs. Several chemical exchange processes are available for the commercial production of heavy water. For bulk commercial production, the primary extraction process to date, the bithermal 'Girdler-Sulphide (G-S)' process, exploits the temperature-dependence of the exchange of deuterium between water and hydrogen-sulphide gas (H_2S). Exchange reaction is fast and occurs without a catalyst to produce 'reactor-grade' heavy water with 99.75 wt% deuterium content. The G-S process is expensive and requires large quantities of toxic H_2S gas and the last G-S plant in Canada was shutdown in 1997. There are still operating G-S plants in China, India, and Romania.

Another chemical exchange process used for commercial heavy water production is monothermal ammonia-hydrogen processes depends on ammoniacal alkali metal salts to catalyse the reaction (KNH_2 in ammonia). Even with these, the reaction is still rather slow and complex mechanical agitation is needed to provide adequate transfer rates. To exploit the effect of temperature on separation factors, refrigeration is needed and the energy demands of the process are significant. Plants using this process are in operation in Argentina and India.

AECL is currently working on more efficient heavy-water production processes based on monothermal water-hydrogen exchange wet-proofed catalyst technology. These technologies abbreviated CECE (Combined Electrolysis and Catalytic Exchange) and CIRCE (Combined Industrial Reforming and Catalytic Exchange) are based on electrolytic hydrogen and reformed hydrogen, respectively. AECL currently has a prototype CIRCE unit operating at a small hydrogen-production plant in Hamilton, Ontario [40]. Another prototype plant at AECL's Chalk River Laboratories completed qualification of the CECE process for use as a heavy-water upgrader (at around half the cost of water distillation) and for tritium removal from heavy water [40].

The breakdown of commercial heavy water production facilities is given in Section 3 TABLE 31.

2.4.Economic aspects of nuclear fuel cycle steps

Economics is not, of course, a part of the NFCIS. However, information on the price of nuclear fuel cycle components/stages may help understanding the role of each stage in the nuclear fuel cycle as a whole.

In order to asses the economic aspects of the nuclear fuel cycle, we need to know the components of the overall nuclear fuel cycle cost. These are (typical for enriched uranium fuel cycle):

- Front-end componets
    - Natural uranium purchase
    - Conversion
    - Enrichment
    - Fuel fabrication

- Back-end components
    - Open-cycle
        - Spent fuel storage and transport
        - Spent fuel conditioning and disposal
    - Closed-cycle
        - Spent fuel transport and storage
        - Spent fuel reprocessing
        - Disposal of LLW, ILW and HLW

The OECD/NEA published a comprehensive report on the economics of fuel cycle in 1994 [41]. Details about the contribution of each fuel cycle stage to the total fuel cycle cost can be found in this report for different type of reactors and fuel cycle options. Although the prices levels of each stage changed significantly nowadays (especially the price for natural uranium) the report provides a good overview of the fuel cycle cost calculation.

3. DIRECTORY OF NUCLEAR FUEL CYCLE FACILITIES

3.1. NFCIS CDROM

A CDROM has been prepared to help readers of this TECDOC to provide detailed information on the worldwide civilian nuclear fuel cycle facilities as a supplementary tool. The CDROM has been formulated so that any internet browser is capable of showing the content of the CDROM. However, the CD has been fully tested only on MS Internet Explorer Version 6 and 7. Other browsers might show some differences in the operation of the CDROM.

The home page to the NFCIS CDROM is NFCISMain.html. The home page will be opened automatically by the system if Autorun feature of CDROM device is enabled in the computer. Otherwise the users can open the NFCISMain.html page easily by double clicking on the name of the file in Windows Explorer. The home page of the NFCIS CDROM shows a very brief introduction to the nuclear fuel cycle (Fig. 17).

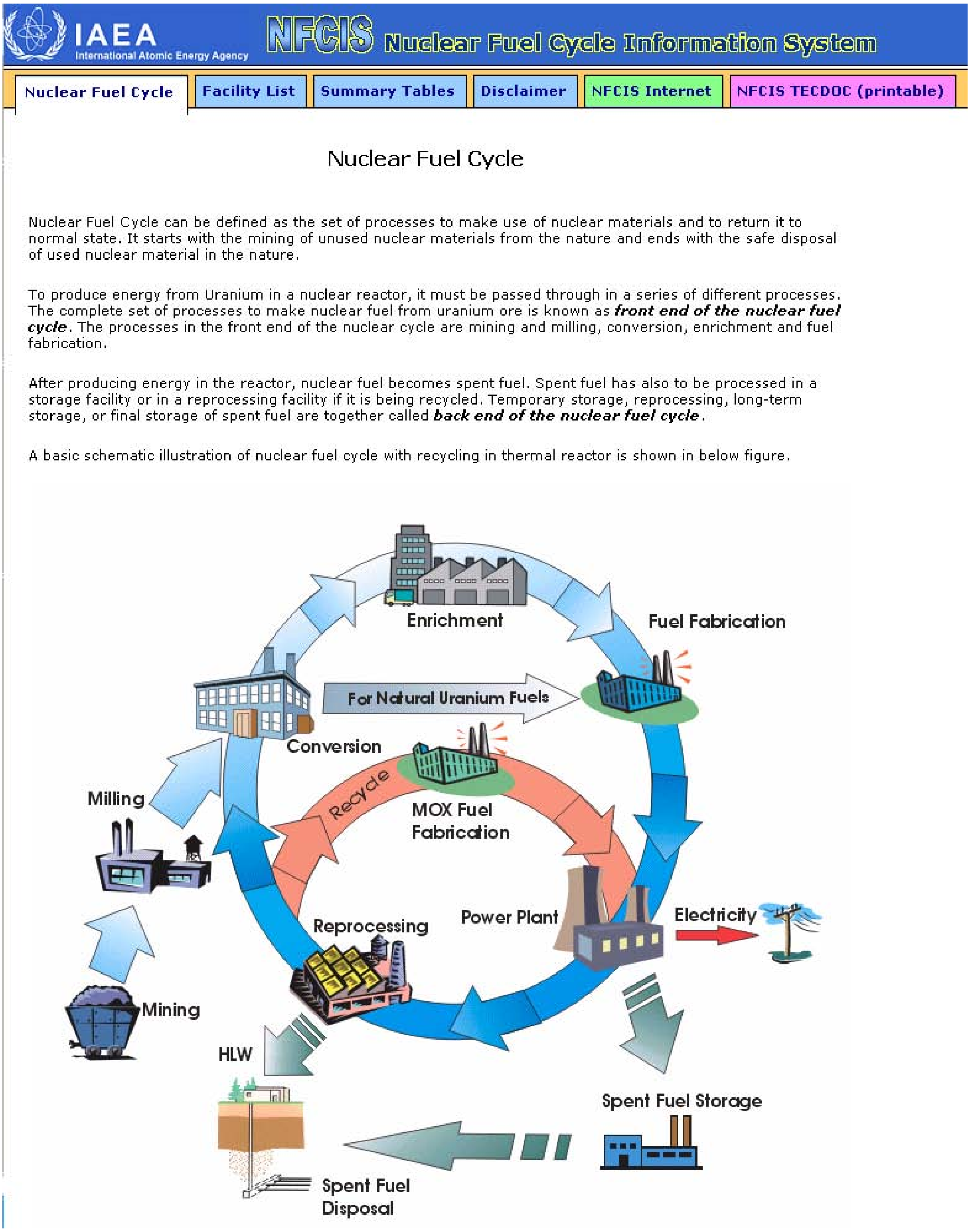
In addition to the information provided in NFCIS CDROM, more details, summary tables with the recent updates can be found at the NFCIS internet site at http://www-nfcis.iaea.org.

3.1.1. Facility list

Facility list can be accessed by clicking Facility List tab in the tabnavigation bar (Fig. 18). The complete list includes 650 deposits. The list can be filtered by using the filters in the upper part of the table. The list can also be sorted by any of the fields by clicking the column headings of the table. By default the paging is enabled and set to 20 facilities per page. However, paging can be disabled by pressing ‘Show All Rows’ button in the top of the table. The footer part of the table shows the total number of facilities and the number of facilities which match the selected filters (the number is displayed in red colour). The footer also hosts the paging information and links to go to the next or previous page.

3.1.2. Facility report

Facility report is opened when link over the FacilityID or Facility Name is clicked. As it can be seen in Fig. 19, detailed catalogue information about the selected facility is displayed in the facility report page.



Nuclear Fuel Cycle

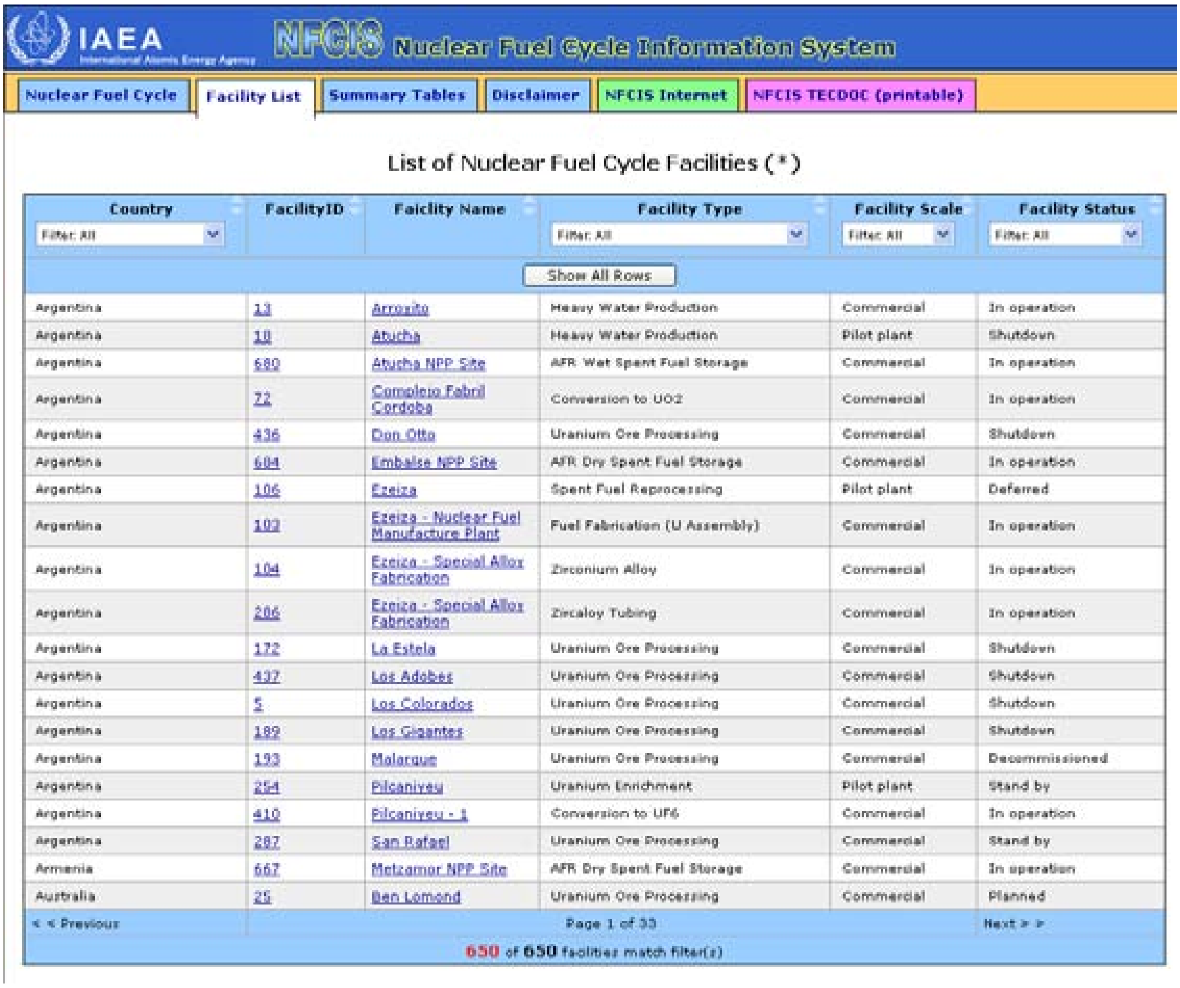
Nuclear Fuel Cycle can be defined as the set of processes to make use of nuclear materials and to return it to normal state. It starts with the mining of unused nuclear materials from the nature and ends with the safe disposal of used nuclear material in the nature.

To produce energy from Uranium in a nuclear reactor, it must be passed through in a series of different processes. The complete set of processes to make nuclear fuel from uranium ore is known as ***front end of the nuclear fuel cycle***. The processes in the front end of the nuclear cycle are mining and milling, conversion, enrichment and fuel fabrication.

After producing energy in the reactor, nuclear fuel becomes spent fuel. Spent fuel has also to be processed in a storage facility or in a reprocessing facility if it is being recycled. Temporary storage, reprocessing, long-term storage, or final storage of spent fuel are together called ***back end of the nuclear fuel cycle***.

A basic schematic illustration of nuclear fuel cycle with recycling in thermal reactor is shown in below figure.

Fig. 17. Home page of the NFCIS CDROM.



List of Nuclear Fuel Cycle Facilities (*)

Country	FacilityID	Faiclity Name	Facility Type	Facility Scale	Facility Status
Argentina	13	Arroyito	Heavy Water Production	Commercial	In operation
Argentina	18	Atucha	Heavy Water Production	Pilot plant	Shutdown
Argentina	680	Atucha NPP Site	AFR Wet Spent Fuel Storage	Commercial	In operation
Argentina	72	Complejo Fabril Cordoba	Conversion to UO2	Commercial	In operation
Argentina	436	Don Otto	Uranium Ore Processing	Commercial	Shutdown
Argentina	604	Embalse NPP Site	AFR Dry Spent Fuel Storage	Commercial	In operation
Argentina	106	Ezeiza	Spent Fuel Reprocessing	Pilot plant	Deferred
Argentina	103	Ezeiza - Nuclear Fuel Manufacture Plant	Fuel Fabrication (U Assembly)	Commercial	In operation
Argentina	104	Ezeiza - Special Alloy Fabrication	Zirconium Alloy	Commercial	In operation
Argentina	206	Ezeiza - Special Alloy Fabrication	Zircaloy Tubing	Commercial	In operation
Argentina	172	La Estela	Uranium Ore Processing	Commercial	Shutdown
Argentina	437	Los Adobes	Uranium Ore Processing	Commercial	Shutdown
Argentina	5	Los Colorados	Uranium Ore Processing	Commercial	Shutdown
Argentina	189	Los Gigantes	Uranium Ore Processing	Commercial	Shutdown
Argentina	193	Malargue	Uranium Ore Processing	Commercial	Decommissioned
Argentina	254	Pilcaniyeu	Uranium Enrichment	Pilot plant	Stand by
Argentina	410	Pilcaniyeu - 1	Conversion to UF6	Commercial	In operation
Argentina	287	San Rafael	Uranium Ore Processing	Commercial	Stand by
Armenia	667	Metzamor NPP Site	AFR Dry Spent Fuel Storage	Commercial	In operation
Australia	25	Ben Lomond	Uranium Ore Processing	Commercial	Planned

< < Previous Page 1 of 33 Next > >

650 of 650 facilties match filter(s)

Fig. 18. List of nuclear fuel cycle facilities from NFCIS CDROM.

]

NFCIS Facility Report

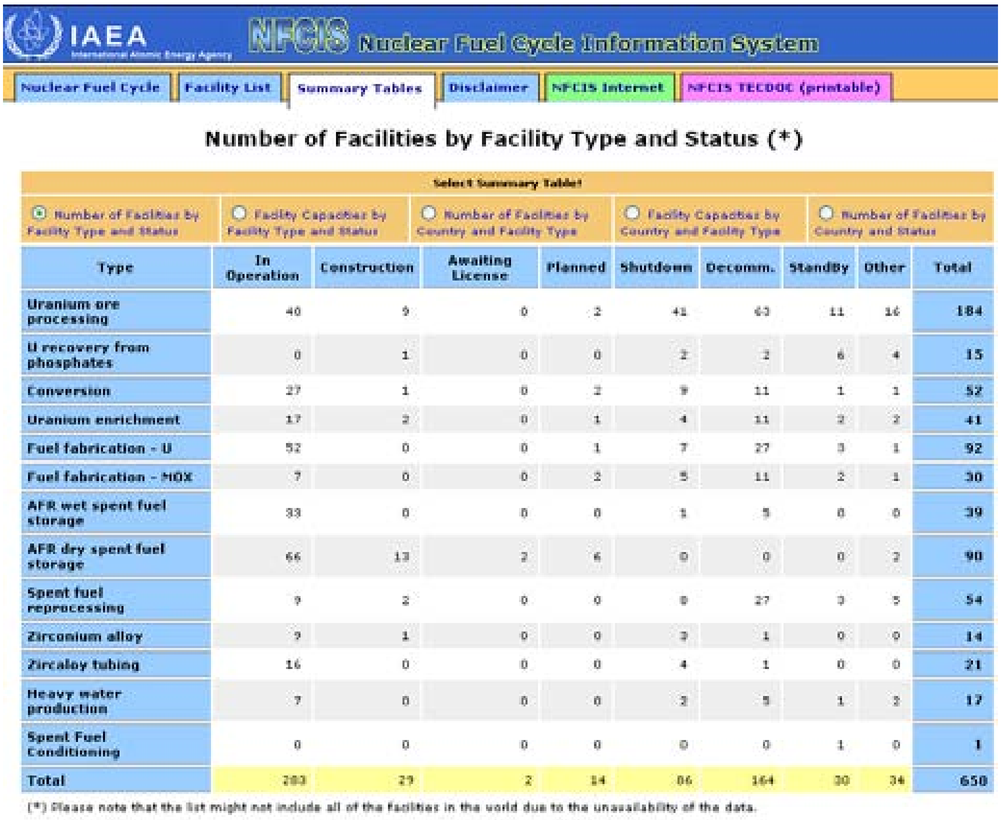
Facility : Belgonucleaire PO Plant

General Information			
Country	Belgium	IAEA Ref #	23 - SPRA
Facility Location	Dessel	Last Update	4/12/2007
Province	Antwerpen		
Data Source	IAEA Questionnaire to Member States, 2006	Last Source Date	3/31/2007
Activity			
Facility Type	Fuel Fabrication (MOX Assembly)		
Design Capacity (*)	40 t HM/year		
Status	Shutdown		
Scale	Commercial		
Start of Operation	1973		
Permanent end of Operation	2006		
Remarks			
Process			

Fig. 19. Facility report page from NFCIS CDROM.

3.1.3. *Worldwide summary tables*

The third page in the NFCIS CDROM is the Summary Tables page which hosts a number of statistical or summary tables to illustrate the worldwide overview of the nuclear fuel cycle facilities (Fig. 20). There are a number of different tables and they can be selected by clicking on the radio button which resides on the left part of the table caption.



Number of Facilities by Facility Type and Status (*)

Select Summary Table!

● Number of Facilities by Facility Type and Status ○ Facility Capacities by Facility Type and Status ○ Number of Facilities by Country and Facility Type ○ Facility Capacities by Country and Facility Type ○ Number of Facilities by Country and Status

Type	In Operation	Construction	Awaiting License	Planned	Shutdown	Decomm.	StandBy	Other	Total
Uranium ore processing	40	9	0	2	41	63	11	16	184
U recovery from phosphates	0	1	0	0	2	2	6	4	15
Conversion	27	1	0	2	9	11	1	1	52
Uranium enrichment	17	2	0	1	4	11	2	2	41
Fuel fabrication - U	52	0	0	1	7	27	3	1	92
Fuel fabrication - MOX	7	0	0	2	5	11	2	1	30
AFR wet spent fuel storage	33	0	0	0	1	5	0	0	39
AFR dry spent fuel storage	66	13	2	6	0	0	0	2	90
Spent fuel reprocessing	9	2	0	0	8	27	3	5	54
Zirconium alloy	9	1	0	0	3	1	0	0	14
Zircaloy tubing	16	0	0	0	4	1	0	0	21
Heavy water production	7	0	0	0	2	5	1	2	17
Spent Fuel Conditioning	0	0	0	0	0	0	1	0	1
Total	283	29	2	14	86	164	30	34	650

(*) Please note that the list might not include all of the facilities in the world due to the unavailability of the data.

Fig. 20. Summary table from NFCIS CDROM.

3.2. Directory of nuclear fuel cycle facilities

TABLE 6. LIST OF ALL NUCLEAR FUEL CYCLE FACILITIES: SORTED BY NFCIS FACILITY NAME

Facility Name	Country	Facility Type	Status	Scale
Actinide Packaging and Storage Fac. (APSF)	United States of America	AFR Dry Spent Fuel Storage	Planned	Laboratory
Advanced Fuel Laboratory	United States of America	Fuel Fabrication (MOX Assembly)	Decommissioned	Laboratory
Advanced Nuclear Fuels GmbH Duisburg Plant	Germany	Zirconium Alloy Tubing	In operation	Commercial
Advanced Nuclear Fuels GmbH Karlstein Plant	Germany	Fuel Assembly Component	In operation	Commercial
Advanced Nuclear Fuels GmbH Lingen Plant	Germany	Fuel Fabrication (U Assembly)	In operation	Commercial
Advanced Spent Fuel Conditioning Process Facility	Korea, Republic of	Spent Fuel Conditioning	Stand by	Laboratory
Agnew Lake	Canada	Uranium Ore Processing	Decommissioned	Commercial
Ahaus Central Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
Akouta	Niger	Uranium Ore Processing	In operation	Commercial
ALKEM Fuel Fabrication Plant	Germany	Fuel Fabrication (MOX Assembly)	Decommissioned	Pilot plant
Allens Park	United States of America	Zirconium Alloy Tubing	In operation	Commercial
Alta Mesa	United States of America	Uranium Ore Processing	Deferred	Commercial
Ambrosia Lake	United States of America	Uranium Ore Processing	Stand by	Commercial
American Centrifuge Demonstration Facility	United States of America	Uranium Enrichment	Commissioning	Pilot plant
American Centrifuge Plant	United States of America	Uranium Enrichment	Planned	Commercial
Andujar	Spain	Uranium Ore Processing	Decommissioned	Commercial
Angarsk	Russian Federation	Uranium Enrichment	In operation	Commercial
Angarsk	Russian Federation	Conversion to UF6	In operation	Commercial
Apollo	United States of America	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Appak	Kazakhstan	Uranium Ore Processing	Under Construction	Commercial
AREVA NC, MOX	France	Fuel Fabrication (MOX Assembly)	Shutdown	Commercial
Arkansas Nuclear No:1 and No:2 NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Arlit	Niger	Uranium Ore Processing	In operation	Commercial
Arroyito HW Production Facility	Argentina	Heavy Water Production	In operation	Commercial
Asahi U Enrichment Laboratory	Japan	Uranium Enrichment	Shutdown	Pilot plant
Atelier Pilote	France	Spent Fuel Reprocessing	Shutdown	Pilot plant
ATTILA	France	Spent Fuel Reprocessing	Decommissioned	Pilot plant
Atucha HW Production Facility	Argentina	Heavy Water Production	Shutdown	Pilot plant
Atucha SF Storage Facility	Argentina	AFR Wet Spent Fuel Storage	In operation	Commercial
B212 Plutonium Glovebox	United States of America	Fuel Fabrication (MOX Assembly)	Decommissioned	Laboratory
Baimadong	China	Uranium Ore Processing	Shutdown	Commercial
Barnwell	United States of America	Re-conversion to UO2 Powder	Deferred	Commercial
Barnwell	United States of America	Spent Fuel Reprocessing	Deferred	Commercial
Baroda	India	Heavy Water Production	In operation	Commercial
Bartow Module	United States of America	U Recovery from Phosphates	Decommissioned	Commercial
BC-1	Pakistan	Uranium Ore Processing	In operation	Pilot plant
Bear Creek	United States of America	Uranium Ore Processing	Decommissioned	Laboratory
Beaverlodge	Canada	Uranium Ore Processing	Decommissioned	Commercial

Facility Name	Country	Facility Type	Status	Scale
Beisa	South Africa	Uranium Ore Processing	Shutdown	Commercial
Belgonucleaire PO Plant	Belgium	Fuel Fabrication (MOX Pellet-Pin)	Shutdown	Commercial
Ben Lomond	Australia	Uranium Ore Processing	Deferred	Commercial
Benxi	China	Uranium Ore Processing	In operation	Commercial
Bertholene (Les Ballaures)	France	Uranium Ore Processing	Shutdown	Commercial
Bessines	France	Uranium Ore Processing	Decommissioned	Commercial
Beva	South Africa	Fuel Fabrication (U Assembly)	Shutdown	Commercial
Beverley	Australia	Uranium Ore Processing	In operation	Commercial
BHWP — A	Canada	Heavy Water Production	Decommissioned	Commercial
BHWP — B	Canada	Heavy Water Production	Decommissioning	Commercial
BHWP — C	Canada	Heavy Water Production	Cancelled	Commercial
BHWP — D	Canada	Heavy Water Production	Deferred	Commercial
Biblis NPP On-Site Interim Storage Facility (Temporary)	Germany	AFR Dry Spent Fuel Storage	Shutdown	Commercial
Biblis NPP On-Site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
Big Rock Point NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Bluewater	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Blyvooruitzicht	South Africa	Uranium Ore Processing	Decommissioned	Commercial
Bohunice NPP Site SFSF	Slovakia	AFR Wet Spent Fuel Storage	In operation	Commercial
BRF Enrichment	Brazil	Uranium Enrichment	In operation	Pilot plant
BRN Enrichment	Brazil	Uranium Enrichment	In operation	Laboratory
Brokdorf NPP On-Site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
Browns Ferry NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
BRQ Pellet Production	Brazil	Fuel Fabrication (U Pellet-Pin)	In operation	Laboratory
BRTG Fuel Fabrication	Brazil	Fuel Fabrication (U Pellet-Pin)	In operation	Laboratory
Bruni	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Brunsbuettel NPP On-Site Interim Storage Facility (Temporary)	Germany	AFR Dry Spent Fuel Storage	Cancelled	Commercial
Brunsbuettel NPP On-site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
BRW Conversion	Brazil	Conversion to UF6	Under construction	Pilot plant
Buffelsfontein	South Africa	Uranium Ore Processing	Under construction	Commercial
Building 18	France	Spent Fuel Reprocessing	Decommissioning	Laboratory
Building 19	France	Spent Fuel Reprocessing	Decommissioned	Laboratory
Bukhovo	Bulgaria	Uranium Ore Processing	Shutdown	Commercial
Burns	United States of America	Uranium Ore Processing	Decommissioned	Commercial
BWXT	United States of America	Fuel Fabrication (Research Reactors)	In operation	Commercial
Calgary	Canada	U Recovery from Phosphates	Stand by	Commercial
Calvert Cliffs NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Cameco — Blind River (UO3)	Canada	Conversion to UO3	In operation	Commercial
Cameco — Port Hope (U)	Canada	Conversion to U Metal	In operation	Commercial
Cameco — Port Hope (UF6)	Canada	Conversion to UF6	In operation	Commercial
Cameco — Port Hope (UO2)	Canada	Conversion to UO2	In operation	Commercial
Candu Fuel Fabrication Plant (1)	Korea, Republic of	Fuel Fabrication (U Assembly)	Shutdown	Commercial
CANDU Fuel Fabrication Plant (2)	Korea, Republic of	Fuel Fabrication (U Assembly)	In operation	Commercial
Candu Fuel Plant	China	Fuel Fabrication (U Assembly)	In operation	Commercial
Canon City-I	United States of America	Uranium Ore Processing	Decommissioned	Commercial

Facility Name	Country	Facility Type	Status	Scale
Canon City-II	United States of America	Uranium Ore Processing	In operation	Commercial
Central Processing Plant	South Africa	Uranium Ore Processing	Shutdown	Commercial
Centralized Wet Storage Facility (CWSF)	China	AFR Wet Spent Fuel Storage	In operation	Commercial
Centralnoye (Taukent)	Kazakhstan	Uranium Ore Processing	In operation	Commercial
CEZUS — Jarrie	France	Zirconium Alloy Production	In operation	Commercial
CEZUS — Montreuil Juigné	France	Zirconium Alloy Tubing	In operation	Commercial
Cezus — Nagahama	Japan	Zirconium Alloy Production	Shutdown	Commercial
CEZUS — Paimboeuf	France	Zirconium Alloy Tubing	In operation	Commercial
CEZUS — Rugles	France	Zirconium Alloy Production	In operation	Commercial
CEZUS — Ugine	France	Zirconium Alloy Production	In operation	Commercial
Chalk River Laboratories, NFFF	Canada	Fuel Fabrication (Research Reactors)	In operation	Commercial
Chashma	Pakistan	Fuel Fabrication (U Assembly)	In operation	Commercial
Chepetski Machine Plant — Zircaloy	Russian Federation	Zirconium Alloy Tubing	In operation	Commercial
Chepetski Machine Plant- Zirconium	Russian Federation	Zirconium Alloy Production	In operation	Commercial
Chernobyl NPP Site	Ukraine	AFR Dry Spent Fuel Storage	Planned	Commercial
Chernobyl NPP Site	Ukraine	AFR Wet Spent Fuel Storage	In operation	Commercial
Chkalovsk (Vostok-Redmet)	Tajikistan	Uranium Ore Processing	Shutdown	Commercial
Chongyi	China	Uranium Ore Processing	In operation	Commercial
Christensen Ranch	United States of America	Uranium Ore Processing	Decommissioning	Commercial
Clab ISF	Sweden	AFR Wet Spent Fuel Storage	In operation	Commercial
Claiborne Enrichment Center	United States of America	Uranium Enrichment	Deferred	Commercial
Clay West	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Cluff Lake	Canada	Uranium Ore Processing	Decommissioning	Commercial
CNRC Nuclear Fuel Pilot Plant — Conversion	Turkey	Conversion to UO2	In operation	Pilot plant
CNRC Nuclear Fuel Pilot Plant — Pellet Production	Turkey	Fuel Fabrication (U Pellet-Pin)	In operation	Pilot plant
Columbia (Westinghouse)	United States of America	Fuel Fabrication (U Assembly)	In operation	Commercial
Columbia Generating Station NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Comurhex II — Malvesi (UF4)	France	Conversion to UF4	Under construction	Commercial
Comurhex II — Pierrelatte (RepU)	France	Conversion to UF6	Under study-Assessment	Commercial
Comurhex II — Pierrelatte (UF6)	France	Conversion to UF6	Under construction	Commercial
Comurhex Malvesi (UF4)	France	Conversion to UF4	In operation	Commercial
Comurhex Pierrelatte (Rep. U)	France	Conversion to UF6	Shutdown	Commercial
Comurhex Pierrelatte (UF6)	France	Conversion to UF6	In operation	Commercial
CONU Magnox Fuel Fabrication Plant	Italy	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Coral	India	Spent Fuel Reprocessing	In operation	Pilot plant
Cordoba Conversion Facility	Argentina	Conversion to UO2	In operation	Commercial
Crossen Uranium Ore Processing Plant	Germany	Uranium Ore Processing	Decommissioned	Commercial
Crow Butte	United States of America	Uranium Ore Processing	In operation	Commercial
Crown Point	United States of America	Uranium Ore Processing	Under study	Commercial
Cserkut (Mecsekuran LLC)	Hungary	Uranium Ore Processing	Shutdown	Commercial
Dalur	Russian Federation	Uranium Ore Processing	In operation	Commercial
Danish Decommissioning	Denmark	Fuel Fabrication (Research Reactors)	Shutdown	Pilot plant
Davis Besse NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
DeMOX — ToMOX	United States of America	Fuel Fabrication (MOX Assembly)	Planned	Commercial
Denison	Canada	Uranium Ore Processing	Decommissioned	Commercial

Facility Name	Country	Facility Type	Status	Scale
Dnieprodzerzynsk	Ukraine	Uranium Ore Processing	Decommissioned	Commercial
Doel NPP Site	Belgium	AFR Dry Spent Fuel Storage	In operation	Commercial
Don Otto	Argentina	Uranium Ore Processing	Shutdown	Commercial
Dornod / Erdes	Mongolia	Uranium Ore Processing	Stand by	Commercial
Douglas Point NPP Site	Canada	AFR Dry Spent Fuel Storage	In operation	Commercial
DP West Plutonium Facility	United States of America	Fuel Fabrication (MOX Assembly)	Decommissioning	Commercial
Dresden NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Driefontein	South Africa	Uranium Ore Processing	Decommissioned	Commercial
Dry Storage Facility (ROG)	Romania	AFR Dry Spent Fuel Storage	In operation	Commercial
Duane Arnold NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
DUPIC Fuel Dev. Fac. (DFDF)	Korea, Republic of	Fuel Fabrication (U Assembly)	In operation	Laboratory
DUPIC Pilot Scale Facility	Korea, Republic of	Fuel Fabrication (U Assembly)	Cancelled	Pilot plant
East Rand	South Africa	Uranium Ore Processing	Decommissioned	Commercial
Ekaterinburg (Sverdlovsk-44)	Russian Federation	Uranium Enrichment	In operation	Commercial
Ekaterinburg (Sverdlovsk-44)	Russian Federation	Conversion to UF6	In operation	Commercial
Eleshnitza	Bulgaria	Uranium Ore Processing	Shutdown	Commercial
Ellweiler Uranium Ore Processing Plant	Germany	Uranium Ore Processing	Shutdown	Commercial
Embalse SF Storage Facility	Argentina	AFR Dry Spent Fuel Storage	In operation	Commercial
Engis	Belgium	U Recovery from Phosphates	Decommissioned	Commercial
Enrichment Technology Company Ltd. Zweigniederlassung Deutschland	Germany	Uranium Enrichment	In operation	Laboratory
Eurex SFRE (MTR)	Italy	Spent Fuel Reprocessing	Decommissioning	Pilot plant
Eurex SFRE (Oxide)	Italy	Spent Fuel Reprocessing	Decommissioning	Pilot plant
Eurex SFRE (Pu Nitrate Line)	Italy	Spent Fuel Reprocessing	Decommissioning	Pilot plant
Eurochemic (Belgoprocess Site)	Belgium	Spent Fuel Reprocessing	Decommissioning	Pilot plant
Eurochemic (Belgoprocess Site) Storage Pools	Belgium	AFR Wet Spent Fuel Storage	Decommissioning	Commercial
Eurodif (Georges Besse)	France	Uranium Enrichment	In operation	Commercial
Existing Dry Spent Fuel Storage Facility — Ignalina	Lithuania	AFR Dry Spent Fuel Storage	In operation	Commercial
Experimental Fuel Element Facility	Indonesia	Fuel Fabrication (Research Reactors)	In operation	Laboratory
Experimental Reprocessing Facility (Building 211)	France	Spent Fuel Reprocessing	Shutdown	Pilot plant
Ezeiza — Nuclear Fuel Manufacture Plant	Argentina	Fuel Fabrication (U Assembly)	In operation	Commercial
Ezeiza — SF Reprocessing Facility	Argentina	Spent Fuel Reprocessing	Deferred	Pilot plant
Ezeiza — Special Alloy Fabrication	Argentina	Zirconium Alloy Tubing	In operation	Commercial
Ezeiza — Special Alloy Fabrication	Argentina	Zirconium Alloy Production	In operation	Commercial
Fabrica de combustible	Spain	Fuel Fabrication (U Assembly)	In operation	Commercial
Fabrica de Combustivel Nuclear	Brazil	Conversion to UO2	In operation	Commercial
Fabricazioni Nucleari SPA	Italy	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Falls City	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Farley NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Faustina (Agrico)	United States of America	U Recovery from Phosphates	Stand by	Commercial
FBFC — Pierrelatte	France	Fuel Fabrication (U Assembly)	Shutdown	Commercial
FBFC — Romans	France	Fuel Fabrication (U Assembly)	In operation	Commercial
FBFC International — LWR	Belgium	Fuel Fabrication (U Assembly)	In operation	Commercial

Facility Name	Country	Facility Type	Status	Scale
FBFC International — MOX	Belgium	Fuel Fabrication (MOX Assembly)	In operation	Commercial
FCN Resende — Unit 1	Brazil	Fuel Fabrication (U Assembly)	In operation	Commercial
Feldioara Branch	Romania	Uranium Ore Processing	In operation	Commercial
FitzPatrick NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Fiuminero	Italy	Uranium Ore Processing	Deferred	Commercial
Fort St. Vrain NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Four Mile	Australia	Uranium Mining	Planned	Commercial
Freegold	South Africa	Uranium Ore Processing	Decommissioned	Commercial
Fuel Element Fabrication Plant	Egypt	Fuel Fabrication (Research Reactors)	In operation	Pilot plant
Fuel Fabrication Facility Attleboro	United States of America	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Fuel Fabrication Plant	Norway	Fuel Fabrication (U Pellet-Pin)	In operation	Pilot plant
Fuels and Materials Examination Fac. (FMEF)	United States of America	Fuel Fabrication (MOX Assembly)	Stand by	Laboratory
Fukushima Daiichi NPP Site SFSF	Japan	AFR Dry Spent Fuel Storage	In operation	Commercial
Fukushima Daiichi NPP Site SFSF	Japan	AFR Wet Spent Fuel Storage	In operation	Commercial
Fuzhou	China	Uranium Ore Processing	In operation	Commercial
Gabes	Tunisia	U Recovery from Phosphates	Under study	Commercial
Gas Hills / American Nuclear	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Gas Hills / Umetco	United States of America	Uranium Ore Processing	Decommissioned	Commercial
GEAM Dolni Rozinka	Czech Republic	Uranium Ore Processing	In operation	Commercial
General Electric Canada Inc. — Arnprior	Canada	Zirconium Alloy Tubing	In operation	Commercial
Gentilly 1 NPP Site	Canada	AFR Dry Spent Fuel Storage	In operation	Commercial
Gentilly 2 NPP Site	Canada	AFR Dry Spent Fuel Storage	In operation	Commercial
Georges Besse II	France	Uranium Enrichment	Under construction	Commercial
Glace Bay	Canada	Heavy Water Production	Decommissioned	Commercial
Global Nuclear Fuel-Japan Co. Ltd. (GNF-J)	Japan	Fuel Fabrication (U Assembly)	In operation	Commercial
Gore	United States of America	Conversion to UF6	Decommissioning	Commercial
Gorleben Central Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
Gorleben Pilot Conditioning Plant	Germany	Spent Fuel Conditioning	Stand by	Pilot plant
Grafenrheinfeld NPP On-site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
Grants	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Green River	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Greifswald Interim Storage Facility North	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
Greifswald NPP On-Site Interim Storage Facility (temporary)	Germany	AFR Wet Spent Fuel Storage	Decommissioning	Commercial
Grohnde NPP On-site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
Gruy Ranch (Satellite)	United States of America	Uranium Ore Processing	Shutdown	Commercial
Gundremmingen NPP On-site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
H.B. Robinson NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Haddam Neck NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Hanford	United States of America	Fuel Fabrication (U Assembly)	Shutdown	Laboratory
Hanford	United States of America	Conversion to UO3	Shutdown	Laboratory
Hanford — B Plant	United States of America	Spent Fuel Reprocessing	Decommissioning	Laboratory
Hanford — Canister Storage Building	United States of America	AFR Dry Spent Fuel Storage	Under construction	Laboratory
Hanford — K Basins	United States of America	AFR Wet Spent Fuel Storage	In operation	Laboratory

Facility Name	Country	Facility Type	Status	Scale
Hanford — Plutonium Finishing Plant	United States of America	Fuel Fabrication (MOX Assembly)	Shutdown	Laboratory
Hanford Redox Facility	United States of America	Spent Fuel Reprocessing	Decommissioning	Pilot plant
Hanford T Plant Complex	United States of America	Spent Fuel Reprocessing	Decommissioning	Commercial
Hansen	United States of America	Uranium Ore Processing	Deferred	Commercial
Harmony (Merriespruit)	South Africa	Uranium Ore Processing	Decommissioned	Commercial
Hartebeestfontein	South Africa	Uranium Ore Processing	Shutdown	Commercial
Hatch NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Hazira	India	Heavy Water Production	In operation	Commercial
Hematite (ABB-CE)	United States of America	Fuel Fabrication (U Assembly)	Decommissioning	Commercial
Hengyang	China	Uranium Ore Processing	Stand by	Commercial
Highland	United States of America	Uranium Ore Processing	Stand by	Commercial
Hobeg Fuel Fabrication Plant	Germany	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Hobson	United States of America	Uranium Ore Processing	Stand by	Commercial
Holiday / El Mesquite	United States of America	Uranium Ore Processing	Decommissioning	Commercial
Honeymoon	Australia	Uranium Ore Processing	In operation	Commercial
Idaho Chemical Processing Plant	United States of America	Spent Fuel Reprocessing	Shutdown	Laboratory
Idaho CPP-603 IFSF, CPP-749	United States of America	AFR Dry Spent Fuel Storage	In operation	Laboratory
Idaho CPP-603, CPP-666	United States of America	AFR Wet Spent Fuel Storage	In operation	Laboratory
Idaho TAN-607 demonstration	United States of America	AFR Dry Spent Fuel Storage	In operation	Laboratory
IFEC FABR — High Enrich. Line	Italy	Fuel Fabrication (Research Reactors)	Decommissioned	Pilot plant
IFEC FABR — HWR — CIRENE Line	Italy	Fuel Fabrication (U Assembly)	Decommissioned	Pilot plant
IFEC FABR — MTR Line	Italy	Fuel Fabrication (Research Reactors)	Decommissioned	Pilot plant
Inchas Nuclear Fuel Laboratory	Egypt	Fuel Fabrication (U Assembly)	In operation	Laboratory
Irigaray	United States of America	Uranium Ore Processing	Decommissioning	Commercial
Isar NPP On-site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
ISFSF Dukovany	Czech Republic	AFR Dry Spent Fuel Storage	In operation	Commercial
Islamabad	Pakistan	Conversion to UO2	In operation	Commercial
Issa Khel / Kubul Kel	Pakistan	Uranium Ore Processing	In operation	Pilot plant
ITREC	Italy	Spent Fuel Reprocessing	Decommissioning	Pilot plant
JAEA Ningyo — Toge Enrichment Demo. Plant (DOP)	Japan	Uranium Enrichment	Shutdown	Pilot plant
JAEA Tokai (Enrichment Tests)	Japan	Uranium Enrichment	Shutdown	Laboratory
JAEA Tokai (PCDF)	Japan	Co-conversion to MOX Powder	In operation	Pilot plant
JAEA Tokai (PFDF-MOX)	Japan	Fuel Fabrication (MOX Assembly)	In operation	Laboratory
JAEA Tokai (PFFF-ATR)	Japan	Fuel Fabrication (MOX Assembly)	In operation	Pilot plant
JAEA Tokai (PFFF-FBR)	Japan	Fuel Fabrication (MOX Assembly)	Shutdown	Pilot plant
JAEA Tokai (PFPF-FBR)	Japan	Fuel Fabrication (MOX Assembly)	In operation	Pilot plant
JAEA Tokai Reprocessing Plant	Japan	Spent Fuel Reprocessing	In operation	Pilot plant
JAEA Tokai Reprocessing Plant — Spent Fuel Storage	Japan	AFR Wet Spent Fuel Storage	In operation	Pilot plant
Japan Nuclear Fuel Conversion (JCO)	Japan	Re-conversion to UO2 Powder	Shutdown	Commercial
Jorf Lasfar — Khouribga	Morocco	U Recovery from Phosphates	Deferred	Commercial
JV Betpak-Dala	Kazakhstan	Uranium Ore Processing	Under Construction	Commercial

Facility Name	**Country**	**Facility Type**	**Status**	**Scale**
JV Inkai	Kazakhstan	Uranium Ore Processing	In operation	Commercial
JV Katco (Moynkum)	Kazakhstan	Uranium Ore Processing	In operation	Commercial
JV Zarechnoye	Kazakhstan	Uranium Ore Processing	Under Construction	Commercial
Kahuta	Pakistan	Uranium Enrichment	In operation	Commercial
KALNA Mine	Serbia	Uranium Ore Processing	Shutdown	Pilot plant
Kara Balta	Kyrgyzstan	Uranium Ore Processing	In operation	Commercial
Karamurun — Mining Company	Kazakhstan	Uranium Ore Processing	In operation	Commercial
Karatau	Kazakhstan	Uranium Ore Processing	Under Construction	Commercial
Karlsruhe Enrichment, Research Centre Karlsruhe, Institute for Nuclear Process Engineering	Germany	Uranium Enrichment	Decommissioned	Pilot plant
Karlsruhe Reprocessing Plant	Germany	Spent Fuel Reprocessing	Decommissioned	Pilot plant
Kaskor (Prikaspisky)	Kazakhstan	U Recovery from Phosphates	Stand by	Commercial
Kaskor Mill	Kazakhstan	Uranium Ore Processing	Stand by	Commercial
Ken-Dala	Kazakhstan	Uranium Ore Processing	Under Construction	Commercial
Kennewick	United States of America	Zirconium Alloy Tubing	In operation	Commercial
Key Lake/McArthur River	Canada	Uranium Ore Processing	In operation	Commercial
Khiagda	Russian Federation	Uranium Ore Processing	Under construction	Commercial
Kiggavik	Canada	Uranium Ore Processing	Deferred	Commercial
Kingsville Dome	United States of America	Uranium Ore Processing	Stand by	Commercial
Kintyre	Australia	Uranium Ore Processing	Deferred	Commercial
Kizilkum	Kazakhstan	Uranium Ore Processing	Under Construction	Commercial
Kobe Special Tube Chofu-Kita	Japan	Zirconium Alloy Tubing	Shutdown	Commercial
Koenigstein Uranium Ore Processing Plant	Germany	Uranium Ore Processing	Shutdown	Commercial
Koongarra	Australia	Uranium Ore Processing	Deferred	Commercial
Koprubasi Pilot Plant	Turkey	Uranium Ore Processing	Shutdown	Pilot plant
Kota	India	Heavy Water Production	In operation	Commercial
Kozloduy NPP Site	Bulgaria	AFR Wet Spent Fuel Storage	In operation	Commercial
KPM	India	Uranium Ore Processing	Under study	Commercial
Krasnoyarsk	Russian Federation	Uranium Enrichment	In operation	Commercial
Kruemmel NPP On- Site Interim Storage Facility (Temporary)	Germany	AFR Dry Spent Fuel Storage	Shutdown	Commercial
Kruemmel NPP On-site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
Kursk NPP Site	Russian Federation	AFR Wet Spent Fuel Storage	In operation	Commercial
La Estela	Argentina	Uranium Ore Processing	Shutdown	Commercial
La Hague — AT1	France	Spent Fuel Reprocessing	Decommissioning	Pilot plant
La Hague — C	France	AFR Wet Spent Fuel Storage	In operation	Commercial
La Hague — D	France	AFR Wet Spent Fuel Storage	In operation	Commercial
La Hague — E	France	AFR Wet Spent Fuel Storage	In operation	Commercial
La Hague — HAO	France	AFR Wet Spent Fuel Storage	In operation	Commercial
La Hague — NPH	France	AFR Wet Spent Fuel Storage	In operation	Commercial
La Hague — UP2-400	France	Spent Fuel Reprocessing	Shutdown	Commercial
La Hague — UP2-800	France	Spent Fuel Reprocessing	In operation	Commercial
La Hague — UP3	France	Spent Fuel Reprocessing	In operation	Commercial
Laboratory RM2	France	Spent Fuel Reprocessing	Decommissioned	Laboratory
Lagoa Real	Brazil	Uranium Ore Processing	In operation	Commercial
Lake Way	Australia	Uranium Ore Processing	Under Study	Commercial
Lamprecht	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Langer Heinrich Uranium	Namibia	Uranium Ore Processing	In operation	Commercial
LANL TA-21	United States of America	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Lantian	China	Uranium Ore Processing	In operation	Commercial

Facility Name	**Country**	**Facility Type**	**Status**	**Scale**
Lanzhou Conversion Facility	China	Conversion to UF6	In operation	Commercial
Lanzhou (RPP)	China	Spent Fuel Reprocessing	Under construction	Pilot plant
Lanzhou 2	China	Uranium Enrichment	In operation	Commercial
Las Palmas	United States of America	Uranium Ore Processing	Decommissioning	Commercial
Lawrence Livermore National Laboratory	United States of America	Uranium Enrichment	Decommissioned	Laboratory
L-Bar	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Le Bernardan (Jouac)	France	Uranium Ore Processing	Decommissioned	Commercial
Le Cellier	France	Uranium Ore Processing	Decommissioned	Commercial
L'Ecarpiere	France	Uranium Ore Processing	Decommissioned	Commercial
Lemajung Pilot U Processing	Indonesia	Uranium Ore Processing	Shutdown	Pilot plant
Leningrad NPP Site	Russian Federation	AFR Wet Spent Fuel Storage	In operation	Commercial
Lingen NPP On-site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
Lisbon	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Los Adobes	Argentina	Uranium Ore Processing	Shutdown	Commercial
Los Alamos Plutonium Facility	United States of America	Spent Fuel Reprocessing	In operation	Laboratory
Los Colorados	Argentina	Uranium Ore Processing	Shutdown	Commercial
Los Gigantes	Argentina	Uranium Ore Processing	Decommissioned	Commercial
Loviisa NPP Site (Spent Fuel Storage 1)	Finland	AFR Wet Spent Fuel Storage	In operation	Commercial
Loviisa NPP Site (Spent Fuel Storage 2)	Finland	AFR Wet Spent Fuel Storage	In operation	Commercial
Lucky Mc (Pathfinder)	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Lynchburg — FC Fuels	United States of America	Fuel Fabrication (U Assembly)	In operation	Commercial
Machine — Building Plant (FBR)	Russian Federation	Fuel Fabrication (U Assembly)	In operation	Commercial
Machine — Building Plant (RBMK)	Russian Federation	Fuel Fabrication (U Assembly)	In operation	Commercial
Machine — Building Plant (WWER)	Russian Federation	Fuel Fabrication (U Assembly)	In operation	Commercial
Machine Building Plant (Pellets)	Russian Federation	Fuel Fabrication (U Pellet-Pin)	In operation	Commercial
Madawaska (Faraday)	Canada	Uranium Ore Processing	Decommissioned	Commercial
Maine Yankee NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Malargue	Argentina	Uranium Ore Processing	Shutdown	Commercial
Mannesmann Röhrenwerke AG Hellenthal	Germany	Zirconium Alloy Tubing	Decommissioned	Commercial
Manuguru	India	Heavy Water Production	In operation	Commercial
MAPE Mydlovary Processing Plant	Czech Republic	Uranium Ore Processing	Decommissioned	Commercial
Marcoule — UP1	France	Spent Fuel Reprocessing	Decommissioning	Commercial
Marquez	United States of America	Uranium Ore Processing	Deferred	Commercial
Mayak — Paket	Russian Federation	Fuel Fabrication (MOX Assembly)	In operation	Pilot plant
McBryde	United States of America	Uranium Ore Processing	Decommissioned	Commercial
McClean Lake	Canada	Uranium Ore Processing	In operation	Commercial
McGuire NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Melox	France	Fuel Fabrication (MOX Assembly)	In operation	Commercial
Metropolis / Converdyn	United States of America	Conversion to UF6	In operation	Commercial
Metzamor NPP Site	Armenia	AFR Dry Spent Fuel Storage	In operation	Commercial
Midnite	United States of America	Uranium Ore Processing	Stand by	Commercial
MILLI Reprocessing Test Facility	Germany	Spent Fuel Reprocessing	Decommissioned	Pilot plant
Millstone NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Mina Cunha Baixa	Portugal	Uranium Ore Processing	Shutdown	Commercial
Mina Da Bica	Portugal	Uranium Ore Processing	Shutdown	Commercial

Facility Name	**Country**	**Facility Type**	**Status**	**Scale**
Mina Da Quinta Do Bispo	Portugal	Uranium Ore Processing	Shutdown	Commercial
Mina De Castelejo	Portugal	Uranium Ore Processing	Shutdown	Commercial
Mina De Sevilha	Portugal	Uranium Ore Processing	Shutdown	Commercial
Mina Senhora Das Fontes	Portugal	Uranium Ore Processing	Shutdown	Pilot plant
Mining and Chemical Complex Site	Russian Federation	AFR Dry Spent Fuel Storage	Planned	Commercial
Mitsubishi Materials Corporation — Okegawa Plant	Japan	Zirconium Alloy Tubing	In operation	Commercial
Mitsubishi Nuclear Fuel Ltd. (MNF)	Japan	Fuel Fabrication (U Assembly)	In operation	Commercial
Mitsubushi Nuclear Fuel Ltd. (MNF)	Japan	Re-conversion to UO2 Powder	In operation	Commercial
Moab	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Mochovce NPP Site SFSF	Slovakia	AFR Dry Spent Fuel Storage	Planned	Commercial
Moncton	Canada	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Morris	United States of America	Spent Fuel Reprocessing	Shutdown	Commercial
Morris Reprocessing Plant Site	United States of America	AFR Wet Spent Fuel Storage	In operation	Commercial
Mosaboni, Rakha, Surda	India	Uranium Ore Processing	Stand by	Commercial
Mounana	Gabon	Uranium Ore Processing	Decommissioned	Commercial
Mt. Lucas	United States of America	Uranium Ore Processing	Decommissioning	Commercial
MTA Technology Lab — ThO2 Recovery	Turkey	Uranium Ore Processing	Shutdown	Laboratory
MTA Technology Lab.	Turkey	U Recovery from Phosphates	Shutdown	Pilot plant
N. Fuel PLLT. OP. — Toronto	Canada	Fuel Fabrication (U Pellet-Pin)	In operation	Commercial
Nabarlek	Australia	Uranium Ore Processing	Decommissioned	Commercial
Nangal	India	Heavy Water Production	Decommissioned	Commercial
National Enrichment Facility (NEF)	United States of America	Uranium Enrichment	Under construction	Commercial
Navoi Hydrometallurgical C.	Uzbekistan	Uranium Ore Processing	In operation	Commercial
NDA A58 Pellet Plant	United Kingdom	Fuel Fabrication (U Pellet-Pin)	Decommissioning	Commercial
NDA B203 Pu Residues Recovery Plant	United Kingdom	Spent Fuel Reprocessing	Decommissioning	Commercial
NDA B204 Reprocessing Plant	United Kingdom	Spent Fuel Reprocessing	Decommissioning	Commercial
NDA B205 Magnox Reprocessing	United Kingdom	Spent Fuel Reprocessing	In operation	Commercial
NDA B205 Magnox Reprocessing Pilot Plant	United Kingdom	Spent Fuel Reprocessing	Decommissioning	Pilot plant
NDA B205 Plutonium Operating Corridors	United Kingdom	Spent Fuel Reprocessing	Decommissioning	Commercial
NDA B206 Solvent Regeneration Plant	United Kingdom	Spent Fuel Reprocessing	Decommissioning	Commercial
NDA B207 Uranium Purification Plant	United Kingdom	Spent Fuel Reprocessing	Decommissioning	Commercial
NDA B209N Plutonium Finishing Line III	United Kingdom	Co-conversion to MOX Powder	Decommissioning	Commercial
NDA B209S Dry Granulation Production	United Kingdom	Fuel Fabrication (U Assembly)	Decommissioning	Commercial
NDA Capenhurst (GD)	United Kingdom	Uranium Enrichment	Decommissioned	Commercial
NDA Coprecipitation Plant	United Kingdom	Fuel Fabrication (MOX Assembly)	Decommissioning	Commercial
NDA Dry Recovery Plant	United Kingdom	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
NDA MOX For FBR	United Kingdom	Fuel Fabrication (MOX Assembly)	Shutdown	Commercial
NDA Sellafield B27 Pond	United Kingdom	AFR Wet Spent Fuel Storage	In operation	Commercial
NDA Sellafield B29 Pond	United Kingdom	AFR Wet Spent Fuel Storage	Decommissioning	Commercial
NDA Sellafield B30 Pond	United Kingdom	AFR Wet Spent Fuel Storage	Decommissioning	Commercial
NDA Sellafield Fuel Handling Plant	United Kingdom	AFR Wet Spent Fuel Storage	In operation	Commercial

Facility Name	Country	Facility Type	Status	Scale
NDA Sellafield MDF (MOX Demonstration Facility)	United Kingdom	Fuel Fabrication (MOX Assembly)	Stand by	Pilot plant
NDA Sellafield MOX Plant (SMP)	United Kingdom	Fuel Fabrication (MOX Assembly)	Commissioning	Commercial
NDA Sellafield North Group Facilities	United Kingdom	Spent Fuel Reprocessing	Decommissioned	Commercial
NDA Sellafield Pond 4	United Kingdom	AFR Wet Spent Fuel Storage	In operation	Commercial
NDA Springfields (PWR)	United Kingdom	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
NDA Springfields AGR Fuel Canning Plant	United Kingdom	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
NDA Springfields Enr. U Residue Recovery Plant	United Kingdom	Conversion to UO2	In operation	Commercial
NDA Springfields IDR Plant	United Kingdom	Conversion to UO2	Decommissioning	Commercial
NDA Springfields Line 2 Hex Plant	United Kingdom	Conversion to UF6	Decommissioned	Commercial
NDA Springfields Line 3 Hex Plant	United Kingdom	Conversion to UF6	Decommissioned	Commercial
NDA Springfields Line 4 Hex Plant	United Kingdom	Conversion to UF6	In operation	Commercial
NDA Springfields Magnox Canning Plant	United Kingdom	Fuel Fabrication (U Assembly)	In operation	Commercial
NDA Springfields Main Line Chemical Plant	United Kingdom	Conversion to UF4	In operation	Commercial
NDA Springfields OFC AGR Line	United Kingdom	Fuel Fabrication (U Assembly)	In operation	Commercial
NDA Springfields OFC IDR UO2 Line	United Kingdom	Conversion to UO2	In operation	Commercial
NDA Springfields OFC LWR Line	United Kingdom	Fuel Fabrication (U Assembly)	In operation	Commercial
NDA Springfields U Metal Plant	United Kingdom	Conversion to U Metal	In operation	Commercial
NDA Thorp	United Kingdom	Spent Fuel Reprocessing	In operation	Commercial
NDA Thorp Miniature Pilot Plant (TMPP)	United Kingdom	Spent Fuel Reprocessing	Decommissioning	Pilot plant
NDA Thorp RT and ST-1,2	United Kingdom	AFR Wet Spent Fuel Storage	In operation	Commercial
NDA UKAEA Conversion Plant	United Kingdom	Conversion to U Metal	Stand by	Commercial
NDA UKAEA Fuel Fabrication Plant	United Kingdom	Fuel Fabrication (Research Reactors)	Shutdown	Commercial
NDA UKAEA Fuel Manufacturing Facility (Winfrith)	United Kingdom	Fuel Fabrication (MOX Assembly)	Decommissioned	Pilot plant
NDA UKAEA Reprocessing Plant, MOX	United Kingdom	Spent Fuel Reprocessing	Stand by	Commercial
NDA UKAEA Reprocessing Plant, MTR	United Kingdom	Spent Fuel Reprocessing	Decommissioning	Commercial
NDA Wylfa NPP Site	United Kingdom	AFR Dry Spent Fuel Storage	In operation	Commercial
Neckarwestheim NPP On-Site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
New Dry Spent Fuel Storage Facility — Ignalina	Lithuania	AFR Dry Spent Fuel Storage	Planned	Commercial
New Wales Plant	United States of America	U Recovery from Phosphates	Stand by	Commercial
NFC — Hyderabad (BWR)	India	Fuel Fabrication (U Assembly)	In operation	Commercial
NFC — Hyderabad (NZFP)	India	Zirconium Alloy Tubing	In operation	Commercial
NFC — Hyderabad (NZSP)	India	Zirconium Alloy Production	In operation	Commercial
NFC — Hyderabad (PELLET)	India	Fuel Fabrication (U Pellet-Pin)	In operation	Commercial
NFC — Hyderabad (PHWR)	India	Fuel Fabrication (U Assembly)	In operation	Commercial
NFC — Hyderabad (PHWR)-2	India	Fuel Fabrication (U Assembly)	In operation	Commercial
NFC — Hyderabad (UOP)	India	Conversion to UO2	In operation	Commercial
NFC — Hyderabad (ZFP)	India	Zirconium Alloy Tubing	In operation	Commercial
NFC — Hyderabad (ZIR)	India	Zirconium Alloy Production	In operation	Commercial

Facility Name	Country	Facility Type	Status	Scale
NFC — Hyderabad (ZSP)	India	Zirconium Alloy Tubing	In operation	Commercial
NFC, Palayakayal	India	Zirconium Alloy Production	Under construction	Commercial
Ningyo — Toge Milling Plant	Japan	Uranium Ore Processing	Decommissioned	Pilot plant
Ningyo — Toge Ref. Conv. Plant (Dry Process)	Japan	Conversion to UF6	Shutdown	Pilot plant
Ningyo — Toge Ref. Conv. Plant (Wet Process)	Japan	Conversion to UF6	Shutdown	Pilot plant
Ningyo — Toge Uranium Pilot Plant	Japan	Uranium Enrichment	Shutdown	Pilot plant
NISA	Portugal	Uranium Ore Processing	Cancelled	Commercial
North Anna NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Novosibirsk Chemical Concentrates Plant (Assembly)	Russian Federation	Fuel Fabrication (U Assembly)	In operation	Commercial
Novosibirsk Chemical Concentrates Plant (Pellets)	Russian Federation	Fuel Fabrication (U Pellet-Pin)	Planned	Commercial
Novovoronezh NPP Site	Russian Federation	AFR Wet Spent Fuel Storage	In operation	Commercial
NPD Spent Fuel Storage	Canada	AFR Dry Spent Fuel Storage	In operation	Commercial
Nuclear Fuel Fabrication Plant	Dem. P.R. of Korea	Fuel Fabrication (Research Reactors)	Stand by	Commercial
Nuclear Fuel Industry Ltd. (NFI Kumatori)	Japan	Fuel Fabrication (U Assembly)	In operation	Commercial
Nuclear Fuel Industry Ltd. (NFI Tokai)	Japan	Fuel Fabrication (U Assembly)	In operation	Commercial
Nuclear Fuel Services	United States of America	Fuel Fabrication (MOX Assembly)	Decommissioned	Commercial
Nuclear Material Development Facility	United States of America	Fuel Fabrication (MOX Assembly)	Decommissioned	Laboratory
Nuclear Product Department — Cobourgh	Canada	Zirconium Alloy Tubing	In operation	Commercial
Nukem Fuel Fabrication Plant	Germany	Fuel Fabrication (Research Reactors)	Decommissioned	Commercial
Oak Ridge	United States of America	Spent Fuel Reprocessing	Cancelled	Commercial
Oak Ridge K-25, Y-12	United States of America	Uranium Enrichment	Decommissioning	Commercial
Obrigheim NPP On-Site Interim Storage Facility (temporary)	Germany	AFR Wet Spent Fuel Storage	In operation	Commercial
Obrigheim NPP On-Site Storage Facility	Germany	AFR Dry Spent Fuel Storage	Planned	Commercial
Oconee NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Oficina De Tratamento Quim.	Portugal	Uranium Ore Processing	Shutdown	Commercial
Olkiluoto NPP Site, TVO KPA	Finland	AFR Wet Spent Fuel Storage	In operation	Commercial
Olympic Dam	Australia	Uranium Ore Processing	In operation	Commercial
Ore Treatment Plant Geugnon	France	Conversion to U Metal	Decommissioned	Commercial
Ore Treatment Plant Le Bouchet	France	Conversion to U Metal	Decommissioned	Commercial
Owl Creek NPP Site	United States of America	AFR Dry Spent Fuel Storage	Deferred	Commercial
Oyster Creek NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Paducah	United States of America	Re-conversion to UO2 Powder	Planned	Commercial
Paducah Gaseous Diffusion	United States of America	Uranium Enrichment	In operation	Commercial
Paks NPP Site ISFSF	Hungary	AFR Dry Spent Fuel Storage	In operation	Commercial
Palabora	South Africa	Uranium Ore Processing	Shutdown	Commercial
Palangana	United States of America	Uranium Ore Processing	Shutdown	Commercial
Palisades NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Palo Verde NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Panel	Canada	Uranium Ore Processing	Decommissioned	Commercial
Panna Maria	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Peach Bottom NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Pelindaba Fuel Fabrication	South Africa	Fuel Fabrication (Research Reactors)	In operation	Pilot plant

Facility Name	**Country**	**Facility Type**	**Status**	**Scale**
Pelindaba Zircaloy Tubing	South Africa	Zirconium Alloy Tubing	Shutdown	Commercial
Peterborough Facility	Canada	Fuel Fabrication (U Assembly)	In operation	Commercial
Philippsburg NPP On-Site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
Pilcaniyeu Conversion Facility	Argentina	Conversion to UF6	In operation	Commercial
Pilcaniyeu Enrichment Facility	Argentina	Uranium Enrichment	In operation	Pilot plant
Pilot Uranium Enrichment Plant	Brazil	Uranium Enrichment	Decommissioned	Pilot plant
Pilot Uranium Reprocessing Plant	Norway	Spent Fuel Reprocessing	Decommissioned	Pilot plant
Pitesti Fuel Fabrication Plant (FCN)	Romania	Fuel Fabrication (U Assembly)	In operation	Commercial
PL4	France	Uranium Enrichment	Decommissioned	Laboratory
Plant 7 (Hex Reduction Plant)	United States of America	Conversion to UF4	Decommissioned	Commercial
Plant City Module	United States of America	U Recovery from Phosphates	Stand by	Commercial
Planta de Beneficio de Uranio de Villa Aldama Chi.	Mexico	Uranium Ore Processing	Decommissioned	Commercial
Planta Elefante	Spain	Uranium Ore Processing	Decommissioned	Commercial
Planta Lobo-G	Spain	Uranium Ore Processing	Decommissioned	Commercial
Planta Piloto de Fabrication de Combustible (PPFC)	Mexico	Fuel Fabrication (U Assembly)	Stand by	Pilot plant
Planta Provisional de Fabricacion de Combustible	Mexico	Fuel Fabrication (U Assembly)	Decommissioned	Laboratory
Planta Quercus	Spain	Uranium Ore Processing	Shutdown	Commercial
Plovdiv (Rosen)	Bulgaria	Uranium Ore Processing	Shutdown	Commercial
Plutonium Fabrication Facility (Building 350)	United States of America	Fuel Fabrication (MOX Assembly)	Decommissioned	Pilot plant
Plutonium Laboratory	Italy	Fuel Fabrication (MOX Assembly)	Decommissioning	Pilot plant
Plutonium Test Extraction Facility	Germany	Spent Fuel Reprocessing	Decommissioned	Pilot plant
Pocos De Caldas — CIPC	Brazil	Uranium Ore Processing	Shutdown	Commercial
Point Beach NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Point Lepreau NPP Site	Canada	AFR Dry Spent Fuel Storage	In operation	Commercial
Port Hawkesbury, Point Tupper	Canada	Heavy Water Production	Decommissioned	Commercial
Port Hope Eldorado	Canada	Zirconium Alloy Production	Decommissioned	Commercial
Portsmouth	United States of America	Re-conversion to UO2 Powder	Planned	Commercial
Portsmouth Gaseous Diffusion	United States of America	Uranium Enrichment	Stand By	Commercial
Prairie Island NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Priargunski / Krasnokamensk	Russian Federation	Uranium Ore Processing	In operation	Commercial
Private Fuel Storage LLC	United States of America	AFR Dry Spent Fuel Storage	Awaiting license	Commercial
Pu and Thorium Processing Facility	Canada	Fuel Fabrication (MOX Assembly)	Decommissioning	Laboratory
PWR Fuel Fabrication Plant	Korea, Republic of	Fuel Fabrication (U Assembly)	In operation	Commercial
Quad Cities NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Quirke	Canada	Uranium Ore Processing	Decommissioned	Commercial
Rabbit Lake	Canada	Uranium Ore Processing	In operation	Commercial
Radiochemical Laboratory	Dem. P.R. of Korea	Spent Fuel Reprocessing	Stand by	Laboratory
Rajasthan NPP Site	India	AFR Dry Spent Fuel Storage	In operation	Commercial
Rancho Seco NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Rancho Seco NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Randfontein (Cooke)	South Africa	Uranium Ore Processing	Decommissioned	Commercial
Ranger	Australia	Uranium Ore Processing	In operation	Commercial
Ranstad Mineral AB	Sweden	Uranium Ore Processing	In operation	Commercial

Facility Name	Country	Facility Type	Status	Scale
Recycle Fuel Fabr. Lab. (RFFL)	Canada	Fuel Fabrication (MOX Assembly)	In operation	Laboratory
Reproccesing Plant Karlsruhe (pool for storage of spent fuel assemblies)	Germany	AFR Wet Spent Fuel Storage	Decommissioned	Pilot plant
Reprocessing Test Facility (JRTF)	Japan	Spent Fuel Reprocessing	Decommissioning	Laboratory
Resende Enrichment	Brazil	Uranium Enrichment	Commissioning	Commercial
Resende Pilot Plant	Brazil	Uranium Enrichment	Decommissioned	Pilot plant
Rhone Poulenc, Inc.	United States of America	Uranium Ore Processing	Shutdown	Commercial
RIAR (Research Institute of Atomic Reactors)	Russian Federation	Fuel Fabrication (MOX Assembly)	In operation	Pilot plant
RIAR (Research Institute of Atomic Reactors)	Russian Federation	Spent Fuel Reprocessing	In operation	Pilot plant
Richland (ANF)	United States of America	Fuel Fabrication (U Assembly)	In operation	Commercial
River Bend NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Rjukan	Norway	Heavy Water Production	Shutdown	Commercial
RMI Extrusion Plant	United States of America	Fuel Fabrication (U Assembly)	Decommissioning	Commercial
Rokkasho MOX Fuel Fabrication Plant	Japan	Fuel Fabrication (MOX Assembly)	Planned	Commercial
Rokkasho Reprocessing Plant	Japan	Spent Fuel Reprocessing	Under construction	Commercial
Rokkasho Spent Fuel Storage	Japan	AFR Wet Spent Fuel Storage	In operation	Commercial
Rokkasho Uranium Enrichment Plant	Japan	Uranium Enrichment	In operation	Commercial
Rosita	United States of America	Uranium Ore Processing	Shutdown	Commercial
Rössing	Namibia	Uranium Ore Processing	In operation	Commercial
Rotem fertilizers plant	Israel	U Recovery from Phosphates	Shutdown	Pilot plant
RR Fuel Element Production Installation (IFEBRR)	Indonesia	Fuel Fabrication (Research Reactors)	In operation	Pilot plant
RT-1, Combined Mayak	Russian Federation	Spent Fuel Reprocessing	In operation	Commercial
RT-1, Mayak, Reprocessing Plant Site	Russian Federation	AFR Wet Spent Fuel Storage	In operation	Commercial
RT-2, Krasnoyarsk, 1st Line	Russian Federation	Spent Fuel Reprocessing	Deferred	Commercial
RT-2, Krasnoyarsk, Reprocessing Plant Site	Russian Federation	AFR Wet Spent Fuel Storage	In operation	Commercial
Rudnik Zirovski VRH	Slovenia	Uranium Ore Processing	Decommissioning	Commercial
Rum Jungle	Australia	Uranium Ore Processing	Under study-Assessment	Commercial
Safi — Youssoufia	Morocco	U Recovery from Phosphates	Deferred	Commercial
San Onofre NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
San Rafael	Argentina	Uranium Ore Processing	Stand by	Commercial
Sandvik Materials Technology	Sweden	Zirconium Alloy Tubing	In operation	Commercial
Santa Quitéria	Brazil	U Recovery from Phosphates	Deferred	Commercial
Sao Jose dos Campos	Brazil	Uranium Enrichment	In operation	Laboratory
Sao Paulo — Conversion Unit	Brazil	Conversion to UF6	Shutdown	Pilot plant
Sao Paulo — Fuel Element Fabrication Plant for Research Reactors	Brazil	Fuel Fabrication (Research Reactors)	In operation	Pilot plant
Sao Paulo — Reprocessing	Brazil	Spent Fuel Reprocessing	Shutdown	Laboratory
Sao Paulo — U Reduction Unit	Brazil	Conversion to U Metal	Shutdown	Pilot plant
Sao Paulo — Zirconium Metal	Brazil	Zirconium Alloy Production	Shutdown	Pilot plant
Sao Paulo — Zirconium Oxide	Brazil	Zirconium Alloy Production	Shutdown	Pilot plant
Savannah River (SRS)	United States of America	Fuel Fabrication (U Assembly)	Decommissioned	Pilot plant
Savannah River (SRS)	United States of America	AFR Wet Spent Fuel Storage	In operation	Laboratory
Seelingstaedt Uranium Ore Processing Plant	Germany	Uranium Ore Processing	Decommissioned	Commercial
Sequoyah NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Serpong Conversion Facility	Indonesia	Conversion to UO2	Shutdown	Pilot plant

Facility Name	Country	Facility Type	Status	Scale
SFSF Dukovany	Czech Republic	AFR Dry Spent Fuel Storage	Commissioning	Commercial
SFSF Temelin	Czech Republic	AFR Dry Spent Fuel Storage	Under study	Commercial
Shaanxi Uranium Enrichment Plant	China	Uranium Enrichment	In operation	Commercial
Shirley Basin / Pathfinder	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Shirley Basin / Petromics	United States of America	Uranium Ore Processing	Shutdown	Commercial
Shootering Canyon	United States of America	Uranium Ore Processing	Stand by	Commercial
Siberian Chemical Combine (Seversk)	Russian Federation	Uranium Enrichment	In operation	Commercial
SICN	France	Fuel Fabrication (U Assembly)	Decommissioning	Commercial
SICN GCR Fuel Fabrication	France	Fuel Fabrication (U Assembly)	Decommissioning	Commercial
Siemens Fuel Fabrication Plant Hanau, Section MOX new	Germany	Fuel Fabrication (MOX Assembly)	Cancelled	Commercial
Siemens Fuel Fabrication Plant Hanau, Section MOX old	Germany	Fuel Fabrication (MOX Assembly)	Decommissioned	Commercial
Siemens Fuel Fabrication Plant Hanau, Section Uranium	Germany	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Siemens Fuel Fabrication Plant Karlstein	Germany	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Silex	Australia	Uranium Enrichment	Decommissioning	Laboratory
Sillamae	Estonia	Uranium Ore Processing	Shutdown	Commercial
Smith Ranch	United States of America	Uranium Ore Processing	In operation	Commercial
Smolensk NPP Site	Russian Federation	AFR Wet Spent Fuel Storage	In operation	Commercial
Special Metallurgical Facility	United States of America	Spent Fuel Reprocessing	Decommissioned	Commercial
Split Rock	United States of America	Uranium Ore Processing	Decommissioned	Laboratory
St. Martin Du Bosc (Lodeve)	France	Uranium Ore Processing	Decommissioned	Commercial
Stanleigh	Canada	Uranium Ore Processing	Decommissioned	Commercial
Stanrock	Canada	Uranium Ore Processing	Decommissioned	Commercial
Stepnogorsky Mining and Chemical Complex (SMCC)	Kazakhstan	Uranium Ore Processing	In operation	Commercial
Stepnoye — Mining Company	Kazakhstan	Uranium Ore Processing	In operation	Commercial
Stilfontein	South Africa	Uranium Ore Processing	Decommissioned	Commercial
SUMITOMO Tube Production Plant	Japan	Zirconium Alloy Tubing	Shutdown	Commercial
Surry NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Susquehanna NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Sweetwater (Green Mountain)	United States of America	Uranium Ore Processing	In operation	Commercial
Syrian fertilizers plant	Syrian Arab Republic	U Recovery from Phosphates	Under construction	Pilot plant
Takeyama	Japan	Fuel Fabrication (MOX Assembly)	Decommissioned	Commercial
Talcher	India	Heavy Water Production	Stand by	Commercial
Tarapur (AFR)	India	AFR Wet Spent Fuel Storage	In operation	Commercial
Tarapur NPP Site	India	AFR Dry Spent Fuel Storage	In operation	Commercial
Tengchong	China	Uranium Ore Processing	In operation	Pilot plant
Thal — Vaishet	India	Heavy Water Production	In operation	Commercial
Tihange NPP Site	Belgium	AFR Wet Spent Fuel Storage	In operation	Commercial
TMI-2, Debris at Idaho	United States of America	AFR Dry Spent Fuel Storage	In operation	Laboratory
Tokai II NPP Site SFSF	Japan	AFR Dry Spent Fuel Storage	In operation	Commercial
Tokai Test Facility	Japan	Uranium Enrichment	Decommissioned	Laboratory
Tomsk — Siberian Chemical Combine (Seversk)	Russian Federation	Conversion to UF6	Shutdown	Commercial
Trevino	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Trillo NPP Site SFSF	Spain	AFR Dry Spent Fuel Storage	In operation	Commercial
Trojan NPP Site ISFSI	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Trombay — FBTR	India	Fuel Fabrication (U Assembly)	In operation	Laboratory

Facility Name	**Country**	**Facility Type**	**Status**	**Scale**
Trombay, Fuel Fabrication	India	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
TU2 Cogema	France	Conversion to UO2	In operation	Commercial
TU2 Cogema Reprocessing Line	France	Re-Conversion to U3O8 (Rep. U)	In operation	Commercial
TU5 Cogema Reprocessing Line	France	Re-Conversion to U3O8 (Rep. U)	In operation	Commercial
Tuticorin	India	Heavy Water Production	In operation	Commercial
TUU Straz pod Ralskem: Processing Plant and ISL Plan	Czech Republic	Uranium Ore Processing	Decommissioning	Commercial
UCIL-Jaduguda	India	Uranium Ore Processing	In operation	Commercial
UCIL-Turamdih	India	Uranium Ore Processing	Under construction	Commercial
Ulba Metalurgical Plant (UMP)	Kazakhstan	Fuel Fabrication (U Pellet-Pin)	In operation	Commercial
Uncle Sam	United States of America	U Recovery from Phosphates	Stand by	Commercial
Unterweser NPP On-Site Storage Facility	Germany	AFR Dry Spent Fuel Storage	In operation	Commercial
Uranium — Sea Water Recovery	Japan	Uranium Ore Processing	Decommissioned	Pilot plant
Uranium Concentrates Refining Pilot Plant (PPRCU)	Mexico	Conversion to UO2	Decommissioned	Pilot plant
Uranium Conversion Facility	Korea, Republic of	Conversion to UO2	Decommissioning	Pilot plant
Uranium Fuel Fabrication Plant	United States of America	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Uranium Fuel Fabrication Plant — San Jose	United States of America	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Uranium Manufacturing Facility — Compton	United States of America	Fuel Fabrication (U Assembly)	Decommissioned	Commercial
Uranium One	South Africa	Uranium Ore Processing	In operation	Commercial
Uravan	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Urenco Capenhurst	United Kingdom	Uranium Enrichment	In operation	Commercial
Urenco Germany GmbH	Germany	Uranium Enrichment	In operation	Commercial
Urenco Nederland	Netherlands	Uranium Enrichment	In operation	Commercial
Urgeirica	Portugal	Uranium Ore Processing	Shutdown	Commercial
Vaal Reefs — 1	South Africa	Uranium Ore Processing	Shutdown	Commercial
Vaal Reefs — 2	South Africa	Uranium Ore Processing	In operation	Commercial
Valindaba (Laser)	South Africa	Uranium Enrichment	Deferred	Pilot plant
Valindaba (UF6)	South Africa	Conversion to UF6	Shutdown	Commercial
Valindaba Y — Plant	South Africa	Uranium Enrichment	Decommissioning	Pilot plant
Valindaba Z — Plant	South Africa	Uranium Enrichment	Decommissioning	Commercial
Vasquez	United States of America	Uranium Ore Processing	In operation	Commercial
W Defluorinat (Depl. UF6)	France	Re-Conversion to U3O8 (Dep. U)	In operation	Commercial
Wackersdorf Reprocessing Plant	Germany	Spent Fuel Reprocessing	Cancelled	Commercial
Wah Chang — Albany	United States of America	Zirconium Alloy Production	In operation	Commercial
Weldon Spring Site	United States of America	Conversion to UO2	Decommissioned	Commercial
Wellpinit	United States of America	Uranium Ore Processing	Decommissioned	Commercial
West Cole	United States of America	Uranium Ore Processing	Decommissioned	Commercial
West Rand Consolidated	South Africa	Uranium Ore Processing	Decommissioned	Commercial
West Valley	United States of America	Spent Fuel Reprocessing	Decommissioning	Commercial
West Valley Reprocessing Plant Site	United States of America	AFR Wet Spent Fuel Storage	Decommissioning	Commercial
Western Areas	South Africa	Uranium Ore Processing	Shutdown	Commercial
Western Deep Levels	South Africa	Uranium Ore Processing	Shutdown	Commercial
Western Zirconium	United States of America	Zirconium Alloy Production	In operation	Commercial
Westinghouse Electric Sweden AB	Sweden	Fuel Fabrication (U Assembly)	In operation	Commercial

Facility Name	Country	Facility Type	Status	Scale
White Mesa	United States of America	Uranium Ore Processing	In operation	Commercial
Whiteshell Laboratories	Canada	AFR Dry Spent Fuel Storage	In operation	Commercial
Wilmington	United States of America	Zirconium Alloy Tubing	In operation	Commercial
Wilmington (GNF)	United States of America	Fuel Fabrication (U Assembly)	In operation	Commercial
Wolsong Dry Storage	Korea, Republic of	AFR Dry Spent Fuel Storage	In operation	Commercial
Yankee Rowe NPP Site	United States of America	AFR Dry Spent Fuel Storage	In operation	Commercial
Yeelirrie	Australia	Uranium Ore Processing	Deferred	Commercial
Yibin Nuclear Fuel Element Plant	China	Fuel Fabrication (U Assembly)	In operation	Commercial
Yining	China	Uranium Ore Processing	In operation	Commercial
Zamzow	United States of America	Uranium Ore Processing	Decommissioned	Commercial
Zaporozhe NPP Site	Ukraine	AFR Dry Spent Fuel Storage	In operation	Commercial
Zheltiye Vody	Ukraine	Uranium Ore Processing	In operation	Commercial
Zircatec Precision Ind. — Port Hope	Canada	Fuel Fabrication (U Assembly)	In operation	Commercial
Zirco Products Amagasaki	Japan	Zirconium Alloy Tubing	Shutdown	Commercial
Zirco Products Chofu-kita	Japan	Zirconium Alloy Tubing	In operation	Commercial
ZWIBEZ	Switzerland	AFR Dry Spent Fuel Storage	Under construction	Commercial
ZWILAG	Switzerland	AFR Dry Spent Fuel Storage	In operation	Commercial

3.3. List of operating commercial nuclear fuel cycle facilities

TABLE 7. OPERATING COMMERCIAL URANIUM ORE PROCESSING FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
27	Australia	Beverley	2001	848.0	t U/year
135	Australia	Honeymoon	2008	340.0	t U/year
239	Australia	Olympic Dam	1988	3 930.0	t U/year
266	Australia	Ranger	1981	4 660.0	t U/year
180	Brazil	Lagoa Real	1999	340.0	t U/year
162	Canada	Key Lake/McArthur River	1983	7 200.0	t U/year
398	Canada	McClean Lake	1999	3 075.0	t U/year
92	Canada	Rabbit Lake	1975	4 615.0	t U/year
711	China	Benxi	1996	120.0	t U/year
698	China	Chongyi	1979	120.0	t U/year
499	China	Fuzhou	1966	300.0	t U/year
710	China	Lantian	1993	100.0	t U/year
505	China	Yining	1993	200.0	t U/year
552	Czech Republic	GEAM Dolni Rozinka	1957	400.0	t U/year
146	India	UCIL-Jaduguda	1968	175.0	t U/year
700	Kazakhstan	Centralnoye (Taukent)	1982	1 000.0	t U/year
596	Kazakhstan	JV Inkai	2001	700.0	t U/year
597	Kazakhstan	JV Katco (Moynkum)	2001	700.0	t U/year
594	Kazakhstan	Karamurun — Mining Company	1985	600.0	t U/year
536	Kazakhstan	Stepnogorsky Mining and Chemical Complex (SMCC)	1958	3 000.0	t U/year
562	Kazakhstan	Stepnoye — Mining Company	1978	1 000.0	t U/year
538	Kyrgyzstan	Kara Balta	1956	2 000.0	t U/year
895	Namibia	Langer Heinrich Uranium	2007	1 000.0	t U/year
282	Namibia	Rössing	1976	4 000.0	t U/year
3	Niger	Akouta	1978	2 300.0	t U/year
10	Niger	Arlit	1970	1 500.0	t U/year
564	Romania	Feldioara Branch	1978	300.0	t U/year
686	Russian Federation	Dalur	2002	800.0	t U/year
509	Russian Federation	Priargunski / Krasnokamensk	1968	3 500.0	t U/year
839	South Africa	Uranium One	2007	1 200.0	t U/year
814	South Africa	Vaal Reefs — 2	1977	1 272.0	t U/year
435	Sweden	Ranstad Mineral AB	1965	120.0	t U/year
508	Ukraine	Zheltiye Vody	1959	1 000.0	t U/year
575	United States of America	Canon City-II	1979	210.0	t U/year
450	United States of America	Crow Butte	1991	380.0	t U/year
298	United States of America	Smith Ranch	1996	770.0	t U/year
267	United States of America	Sweetwater (Green Mountain)	1981	350.0	t U/year
829	United States of America	Vasquez	2004	310.0	t U/year
363	United States of America	White Mesa	1980	2 000.0	t U/year
537	Uzbekistan	Navoi Hydrometallurgical C.	1964	3 000.0	t U/year
			Total	**59 435**	t U/year

TABLE 8. OPERATING COMMERCIAL CONVERSION TO URANIUM METAL FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
94	Canada	Cameco — Port Hope (U)	1985	2 000.0	t HM/year
38	United Kingdom	NDA Springfields U Metal Plant	1960	2 000.0	t HM/year
			Total	**4 000.0**	t HM/year

TABLE 9. OPERATING COMMERCIAL RE-CONVERSION TO U_3O_8 (DEP. U) FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
78	France	W Defluorinat (Depl. UF_6)	1984	14 000.0	t HM/year
			Total	**14 000.0**	t HM/year

TABLE 10. OPERATING COMMERCIAL CONVERSION TO UF_4 FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
194	France	Comurhex Malvesi (UF_4)	1959	14 000.0	t HM/year
33	United Kingdom	BNFL Springfields Main Line Chemical Plant	1960	10 000.0	t HM/year
			Total	**24 000.0**	t HM/year

TABLE 11. OPERATING COMMERCIAL CONVERSION TO UF_6 FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
410	Argentina	Pilcaniyeu Conversion Facility	1984	62.0	t HM/year
95	Canada	Cameco — Port Hope (UF6)	1984	12 500.0	t HM/year
182	China	Lanzhou Conversion Facility	1980	400.0	t HM/year
69	France	Comurhex Pierrelatte (UF_6)	1961	14 000.0	t HM/year
545	Russian Federation	Angarsk	1954	20 000.0	t HM/year
701	Russian Federation	Ekaterinburg (Sverdlovsk-44)	1949	4 000.0	t HM/year
583	United Kingdom	NDA Springfields Line 4 Hex Plant	1994	6 000.0	t HM/year
201	United States of America	Metropolis / Converdyn	1959	17 600.0	t HM/year
			Total	**74 562.0**	t HM/year

TABLE 12. OPERATING COMMERCIAL CONVERSION TO UO_2 FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
72	Argentina	Cordoba Conversion Facility	1982	175.0	t HM/year
784	Brazil	Fabrica de Combustivel Nuclear	2000	120.0	t HM/year
96	Canada	Cameco — Port Hope (UO_2)	1980	2 800.0	t HM/year
324	France	TU2 Cogema	1988	350.0	t HM/year
217	India	NFC — Hyderabad (UOP)	1972	450.0	t HM/year
141	Pakistan	Islamabad	1986	0.0	t HM/year
589	United Kingdom	NDA Springfields Enr. U Residue Recovery Plant	1985	65.0	t HM/year
585	United Kingdom	NDA Springfields OFC IDR UO_2 Line	1995	550.0	t HM/year
			Total	**4 510.0**	t HM/year

TABLE 13. OPERATING COMMERCIAL CONVERSION TO UO_3 FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
93	Canada	Cameco — Blind River (UO_3)	1983	18 000.0	t HM/year
			Total	**18 000.0**	t HM/year

TABLE 14. OPERATING COMMERCIAL URANIUM ENRICHMENT FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
712	China	Lanzhou 2	2005	500.0	MTSWU/year
590	China	Shaanxi Uranium Enrichment Plant	1997	500.0	MTSWU/year
117	France	Eurodif (Georges Besse)	1979	10 800.0	MTSWU/year
122	Germany	Urenco Deutschland	1985	1 800.0	MTSWU/year
150	Japan	Rokkasho Uranium Enrichment Plant	1992	1 050.0	MTSWU/year
421	Netherlands	Urenco Nederland	1973	3 500.0	MTSWU/year
156	Pakistan	Kahuta	1984	5.0	MTSWU/year
544	Russian Federation	Angarsk	1954	1 000.0	MTSWU/year
402	Russian Federation	Ekaterinburg (Sverdlovsk-44)	1949	7 000.0	MTSWU/year
541	Russian Federation	Krasnoyarsk	1964	3 000.0	MTSWU/year
542	Russian Federation	Siberian Chemical Combine (Seversk)	1950	4 000.0	MTSWU/year
341	United Kingdom	Urenco Capenhurst	1972	4 000.0	MTSWU/year
243	United States of America	Paducah Gaseous Diffusion	1954	11 300.0	MTSWU/year
			Total	**48 455.0**	MTSWU/year

TABLE 15. OPERATING COMMERCIAL RE-CONVERSION TO UO_2 POWDER FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
709	Japan	Mitsubushi Nuclear Fuel Ltd. (MNF)	1972	450.0	t HM/year
			Total	**450.0**	t HM/year

TABLE 16. OPERATING COMMERCIAL URANIUM FUEL FABRICATION (PELLET-PIN) FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
213	Canada	N. Fuel PLLT. OP. — Toronto	1967	1 300.0	t HM/year
533	India	NFC — Hyderabad (PELLET)	1998	335.0	t HM/year
543	Kazakhstan	Ulba Metalurgical Plant (UMP)	1949	2 800.0	t HM/year
713	Russian Federation	Machine Building Plant (Pellets)	1953	800.0	t HM/year
			Total	**5 235.0**	t HM/year

TABLE 17. OPERATING COMMERCIAL URANIUM FUEL FABRICATION (AGR) FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
584	United Kingdom	BNFL Springfields OFC AGR Line	1996	290.0	t HM/year
			Total	**290.0**	t HM/year

TABLE 18. OPERATING COMMERCIAL URANIUM FUEL FABRICATION (GCR) FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
35	United Kingdom	BNFL Springfields Magnox Canning Plant	1960	1 300.0	t HM/year
			Total	**1 300.0**	t HM/year

TABLE 19. OPERATING COMMERCIAL URANIUM FUEL FABRICATION (FBR) FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
296	Russian Federation	Machine — Building Plant (FBR)	1953	50.0	t HM/year
			Total	**50.0**	t HM/year

TABLE 20. OPERATING COMMERCIAL URANIUM FUEL FABRICATION (RBMK) FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
546	Russian Federation	Machine — Building Plant (RBMK)	1953	900.0	t HM/year
			Total	**900.0**	t HM/year

TABLE 21. OPERATING COMMERCIAL URANIUM FUEL FABRICATION (PHWR) FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
103	Argentina	Ezeiza — Nuclear Fuel Manufacture Plant	1982	270.0	t HM/year
251	Canada	Peterborough Facility	1956	1 200.0	t HM/year
235	Canada	Zircatec Precision Ind. — Port Hope	1964	1 200.0	t HM/year
731	China	Candu Fuel Plant	2003	200.0	t HM/year
222	India	NFC — Hyderabad (PHWR)	1974	270.0	t HM/year
534	India	NFC — Hyderabad (PHWR)-2	1997	300.0	t HM/year
794	Korea, Republic of	CANDU Fuel Fabrication Plant (2)	1998	400.0	t HM/year
58	Pakistan	Chashma	1986	20.0	t HM/year
526	Romania	Pitesti Fuel Fabrication Plant (FCN)	1983	200.0	t HM/year
			Total	**4 060.0**	t HM/year

TABLE 22. OPERATING COMMERCIAL URANIUM FUEL FABRICATION (LWR) FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
110	Belgium	FBFC International — LWR	1961	500.0	t HM/year
268	Brazil	FCN Resende — Unit 1	1982	240.0	t HM/year
369	China	Yibin Nuclear Fuel Element Plant	1998	200.0	t HM/year
280	France	FBFC — Romans	1979	1 400.0	t HM/year
186	Germany	Advanced Nuclear Fuels GmbH Lingen Plant	1979	650.0	t HM/year
223	India	NFC — Hyderabad (BWR)	1974	24.0	t HM/year
371	Japan	Global Nuclear Fuel-Japan Co. Ltd. (GNF-J)	1970	750.0	t HM/year
203	Japan	Mitsubishi Nuclear Fuel Ltd. (MNF)	1972	440.0	t HM/year
170	Japan	Nuclear Fuel Industry Ltd. (NFI Kumatori)	1972	284.0	t HM/year
224	Japan	Nuclear Fuel Industry Ltd. (NFI Tokai)	1980	250.0	t HM/year
166	Korea, Republic of	PWR Fuel Fabrication Plant	1989	400.0	t HM/year
17	Russian Federation	Machine — Building Plant (WWER)	1953	620.0	t HM/year
559	Russian Federation	Novosibirsk Chemical Concentrates Plant (Assembly)	1949	1 000.0	t HM/year
154	Spain	Fabrica de combustible	1985	400.0	t HM/year
350	Sweden	Vasteras Fuel Fabrication Plant	1971	600.0	t HM/year
586	United Kingdom	BNFL Springfilds OFC LWR Line	1996	330.0	t HM/year
68	United States of America	Columbia (Westinghouse)	1986	1 150.0	t HM/year
191	United States of America	Lynchburg — FC Fuels	1982	400.0	t HM/year
275	United States of America	Richland (ANF)	1970	700.0	t HM/year
364	United States of America	Wilmington (GNF)	1982	1 200.0	t HM/year
			Total	**11 538.0**	t HM/year

TABLE 23. OPERATING COMMERCIAL URANIUM FUEL FABRICATION (RESEARCH REACTORS) FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
512	Canada	Chalk River Laboratories, NFFF	1990		t HM/year
861	United States of America	BWXT	1982	100.0	t HM/year
			Total	**100.0**	t HM/year

TABLE 24. OPERATING COMMERCIAL WET TYPE AFR SPENT FUEL STORAGE FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
680	Argentina	Atucha SF Storage Facility	1988	986.0	t HM
681	Belgium	Tihange NPP Site	1997	1 760.0	t HM
169	Bulgaria	Kozloduy NPP Site	1984	600.0	t HM
627	China	Centralized Wet Storage Facility (CWSF)	2003	500.0	t HM
630	Finland	Loviisa NPP Site (Spent Fuel Storage 1)	1980	57.0	t HM
631	Finland	Loviisa NPP Site (Spent Fuel Storage 2)	1985	485.0	t HM
326	Finland	Olkiluoto NPP Site, TVO KPA	1987	1 200.0	t HM
675	France	La Hague — C	1984	4 800.0	t HM
676	France	La Hague — D	1986	4 600.0	t HM
677	France	La Hague — E	1988	6 200.0	t HM
674	France	La Hague — HAO	1976	400.0	t HM
177	France	La Hague — NPH	1981	2 000.0	t HM
901	Germany	Obrigheim NPP On-Site Interim Storage Facility (temporary)	1985	560.0	t HM
678	India	Tarapur (AFR)	1990	275.0	t HM
679	Japan	Fukushima Daiichi NPP Site SFSF	1997	6 840.0	Cask-Bund.
278	Japan	Rokkasho Spent Fuel Storage	1999	3 000.0	t HM
485	Russian Federation	Kursk NPP Site	1986	2 000.0	t HM
185	Russian Federation	Leningrad NPP Site	1984	4 000.0	t HM
233	Russian Federation	Novovoronezh NPP Site	1986	400.0	t HM
636	Russian Federation	RT-1, Mayak, Reprocessing Plant Site	1975	560.0	t HM
496	Russian Federation	RT-2, Krasnoyarsk, Reprocessing Plant Site	1985	6 000.0	t HM
487	Russian Federation	Smolensk NPP Site	1996	2 000.0	t HM
147	Slovakia	Bohunice NPP Site SFSF	1987	1 690.0	t HM
64	Sweden	Clab ISF	1985	8 000.0	t HM
486	Ukraine	Chernobyl NPP Site	1986	2 518.0	t HM
47	United Kingdom	BNFL Sellafield B27 Pond	1964	2 300.0	t HM
114	United Kingdom	BNFL Sellafield Fuel Handling Plant	1986	2 700.0	t HM
257	United Kingdom	BNFL Sellafield Pond 4	1981	1 500.0	t HM
310	United Kingdom	BNFL Thorp RT and ST-1,2	1988	3 800.0	t HM
209	United States of America	West Valley Reprocessing Plant Site	1984	750.0	t HM
			Total	**65 641.0**	t HM
			and	**6 840.0**	Cask-bundle

TABLE 25. OPERATING COMMERCIAL DRY TYPE AFR SPENT FUEL STORAGE FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
684	Argentina	Embalse SF Storage Facility	1993	2000	t HM
667	Armenia	Metzamor NPP Site	2000	74	t HM
664	Belgium	Doel NPP Site	1995	2100	t HM
478	Canada	Douglas Point NPP Site	1987	0	t HM
477	Canada	Gentilly 1 NPP Site	1985	0	t HM
614	Canada	Gentilly 2 NPP Site	1995	0	t HM
494	Canada	NPD Spent Fuel Storage	1987	75	t HM
367	Canada	Point Lepreau NPP Site	1991	0	t HM
493	Canada	Whiteshell Laboratories	1977	0	t HM
605	Czech Republic	ISFSF Dukovany	1995	600	t HM
2	Germany	Ahaus Central Storage Facility	1997	3960	t HM
803	Germany	Biblis NPP On-Site Storage Facility	2005	1400	t HM
797	Germany	Brokdorf NPP On-Site Storage Facility	2007	100	Cask-Bund.
805	Germany	Brunsbuettel NPP On-site Storage Facility	2006	450	t HM
120	Germany	Gorleben Central Storage Facility	1995	3800	t HM
798	Germany	Grafenrheinfeld NPP On-site Storage Facility	2005	88	Cask-Bund.
604	Germany	Greifswald Interim Storage Facility North	1999	585	t HM
800	Germany	Grohnde NPP On-site Storage Facility	2005	1000	t HM
801	Germany	Gundremmingen NPP On-site Storage Facility	2006	1850	t HM
799	Germany	Isar NPP On-site Storage Facility	2007	1500	Cask-Bund.
807	Germany	Kruemmel NPP On-site Storage Facility	2006	800	t HM
802	Germany	Lingen NPP On-site Storage Facility	2002	1250	t HM
717	Germany	Neckarwestheim NPP On-Site Storage Facility	2006	1600	t HM
796	Germany	Philippsburg NPP On-Site Storage Facility	2006	1600	t HM
900	Germany	Unterweser NPP On-Site Storage Facility	2007	800	t HM
571	Hungary	Paks NPP Site ISFSF	1997	850	t HM
724	India	Rajasthan NPP Site	1994	570	t HM
683	India	Tarapur NPP Site	1990	20	t HM
615	Japan	Fukushima Daiichi NPP Site SFSF	1995	408	Cask-Bund.
825	Japan	Tokai II NPP Site SFSF	2001	915	Cask-Bund.
616	Korea, Republic of	Wolsong Dry Storage	1992	6250	t HM
608	Lithuania	Existing Dry Spent Fuel Storage Facility — Ignalina	1998	98	Cask-Bund.
793	Romania	Dry Storage Facility (ROG)	2003	300000	Cask-Bund.
606	Spain	Trillo NPP Site SFSF	2002	1680	Cask-Bund.
0	Switzerland	ZWILAG	2001	2500	t HM
607	Ukraine	Zaporozhe NPP Site	2001	9120	Cask-Bund.
682	United Kingdom	NDA Wylfa NPP Site	1979	700	t HM
593	United States of America	Arkansas Nuclear No:1 and No:2 NPP Site ISFSI	1997	150	t HM
641	United States of America	Big Rock Point NPP Site		0	t HM
846	United States of America	Browns Ferry NPP Site	2004	190	t HM
621	United States of America	Calvert Cliffs NPP Site	1992	1112	t HM
847	United States of America	Columbia Generating Station NPP Site	2000	190	t HM
620	United States of America	Davis Besse NPP Site ISFSI	1995	360	t HM
725	United States of America	Dresden NPP Site	2001	70	t HM
730	United States of America	Duane Arnold NPP Site	2004	0	t HM
848	United States of America	Farley NPP Site	2006	190	t HM
849	United States of America	FitzPatrick NPP Site	2002	190	t HM
617	United States of America	Fort St. Vrain NPP Site ISFSI	1992	15.4	t HM
623	United States of America	H.B. Robinson NPP Site ISFSI	1986	26	t HM

Fac. ID	Country	Facility Name	Start	Capacity	Unit
850	United States of America	Haddam Neck NPP Site	1996	190	t HM
851	United States of America	Hatch NPP Site	1998	190	t HM
852	United States of America	Maine Yankee NPP Site	1997	190	t HM
643	United States of America	McGuire NPP Site	2000	0	t HM
853	United States of America	Millstone NPP Site	2004	190	t HM
696	United States of America	North Anna NPP Site ISFSI	1998	840	t HM
624	United States of America	Oconee NPP Site ISFSI	1990	380	t HM
726	United States of America	Oyster Creek NPP Site	2000	190	t HM
619	United States of America	Palisades NPP Site ISFSI	1993	233	t HM
854	United States of America	Palo Verde NPP Site	2003	190	t HM
611	United States of America	Peach Bottom NPP Site	2000	0	t HM
618	United States of America	Point Beach NPP Site ISFSI	1995	447	t HM
613	United States of America	Prairie Island NPP Site ISFSI	1994	724	t HM
855	United States of America	Quad Cities NPP Site	2004	190	t HM
856	United States of America	Rancho Seco NPP Site	1989	190	t HM
727	United States of America	Rancho Seco NPP Site ISFSI	1989	202	t HM
857	United States of America	River Bend NPP Site	2006	190	t HM
858	United States of America	San Onofre NPP Site	2007	190	t HM
859	United States of America	Sequoyah NPP Site	2004	190	t HM
622	United States of America	Surry NPP Site ISFSI	1986	808	t HM
728	United States of America	Susquehanna NPP Site	1998	343	t HM
642	United States of America	Trojan NPP Site ISFSI		359	t HM
860	United States of America	Yankee Rowe NPP Site	1991	190	t HM
			Total	**313 909.0**	Cask/bundle
			and	**43 943.4**	t HM

TABLE 26. OPERATING COMMERCIAL SPENT FUEL REPROCESSING FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
336	France	La Hague — UP2-800	1967	1 000.0	t HM/year
339	France	La Hague — UP3	1990	1 000.0	t HM/year
475	Russian Federation	RT-1, Combined Mayak	1971	400.0	t HM/year
46	United Kingdom	BNFL B205 Magnox Reprocessing	1964	1 500.0	t HM/year
312	United Kingdom	BNFL Thorp	1994	900.0	t HM/year
			Total	**4 800.0**	t HM/year

TABLE 27. OPERATING COMMERCIAL RE-CONVERSION TO U_3O_8 (REP. U) FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
325	France	TU2 Cogema Reprocessing Line	1988	1 200.0	t HM/year
582	France	TU5 Cogema Reprocessing Line	1995	1 600.0	t HM/year
			Total	**16 800.0**	t HM/year

TABLE 28. OPERATING COMMERCIAL MOX FUEL FABRICATION FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
823	Belgium	FBFC International — MOX	1997	100.0	t HM/year
200	France	Melox	1995	195.0	t HM/year
			Total	**285.0**	t HM/year

TABLE 29. OPERATING COMMERCIAL ZIRCONIUM ALLOY PRODUCTION FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
104	Argentina	Ezeiza — Special Alloy Fabrication	1987	10.0	t/year
57+863	France	CEZUS — (Jarrie+Ugine)	1981	2 200.0	t/year
816	France	CEZUS — Rugles	1981	400.0	t/year
219	India	NFC — Hyderabad (NZSP)		250.0	t/year
218	India	NFC — Hyderabad (ZIR)	1980	250.0	t/year
557	Russian Federation	Chepetski Machine Plant- Zirconium	1951	2 000.0	t/year
306	United States of America	Wah Chang — Albany	1956	2 000.0	t/year
362	United States of America	Western Zirconium	1980	1 350.0	t/year
			Total	**8 460.0**	t/year

TABLE 30. OPERATING COMMERCIAL ZIRCONIUM ALLOY TUBING FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
286	Argentina	Ezeiza — Special Alloy Fabrication	1987	300.0	km/year
116	Canada	General Electric Canada Inc. — Arnprior	1981	1 350.0	km/year
234	Canada	Nuclear Product Department — Cobourgh	1976	950.0	km/year
244+864	France	CEZUS — (Paimboeuf+Montreuil Juigne)	1981	5 000.0	km/year
89	Germany	Advanced Nuclear Fuels GmbH Duisburg Plant	1981	2 100.0	km/year
220	India	NFC — Hyderabad (NZFP)	1987	59.0	t/year
221	India	NFC — Hyderabad (ZFP)	1973	80.0	t/year
822	India	NFC — Hyderabad (ZSP)	1971	180.0	t/year
238	Japan	Mitsubishi Materials Corporation — Okegawa Plant	1973	800.0	km/year
810	Japan	Zirco Products Chofu-kita	2000	1 400.0	km/year
558	Russian Federation	Chepetski Machine Plant — Zircaloy	1951	6 000.0	km/year
289	Sweden	Sandviken	1958	1 000.0	km/year
7	United States of America	Allens Park	1981	500.0	km/year
161	United States of America	Kennewick	1981	2 200.0	km/year
365	United States of America	Wilmington	1981	2 200.0	km/year
			Total	**23 800.0**	km/year
			and	**319**	t/year

TABLE 31. OPERATING COMMERCIAL HEAVY WATER PRODUCTION FACILITIES

Fac. ID	Country	Facility Name	Start	Capacity	Unit
13	Argentina	Arroyito	1993	200.0	t/year
19	India	Baroda	1977	17.0	t/year
129	India	Hazira	1991	80.0	t/year
168	India	Kota	1985	85.0	t/year
196	India	Manuguru	1991	185.0	t/year
309	India	Thal — Vaishet	1987	78.0	t/year
323	India	Tuticorin	1978	49.0	t/year
			Total	**694.0**	t/year

3.4. Worldwide operating commercial nuclear fuel cycle facilities: Total capacities

TABLE 32. WORLDWIDE OPERATING COMMERCIAL NUCLEAR FUEL CYCLE FACILITIES: TOTAL CAPACITIES (*)(**)

Country	Uranium Production (t U/year)	Conversion to UF6 (t HM/year)	Enrichment (t HM/year)	LWR Fuel Assembly Fabrication (t HM/year)	PHWR Fuel Assembly Fabrication (t HM/year)	MOX Fuel Assembly Fabrication (t HM/year)	SF Storage (Wet) (t HM)	SF Storage (Dry) (t HM)	SF Reprocessing (t HM/year)	Zirc. Alloy Production (t/yr)	Zirc. Alloy Tubing (km/yr)	Heavy Water (t/yr)
Australia	9 778											
Argentina		62			270		986	2 000		10	300	200
Armenia								74				
Belgium				500		100	1 760	2 100				
Brazil	340			240								
Bulgaria							600					
Canada	14 890	12 500			2 400			75			2 300	
China	840	400	1 000	200	200		500					
Czech Republic	400							600				
Finland							1 742					
France		14 000	10 800	1 400		195	18 000		2 000	4 800	5 000 (2 200 t/yr)	
Germany			1 800	650			286	19 095 (+1 688 Cask-Bund)			2 100	
Hungary								850				
India	175			24	570		275	590	0	500	319 (t/yr)	494
Japan			1 050	1 724			3 000 (+6 840 Cask-Bund)	1 323 (Cask-Bund)			2 200	
Kazakhstan	7 000											
Republic of Korea				400	400			6 250				
Lithuania								98 (Cask-Bund)				
Kyrgyzstan	2 000											
Namibia	5 000											
Netherlands			3 500									
Niger	3 800											
Pakistan			5		20							
Romania	300				200			300 000 (Cask-Bund)				

Country	Uranium Production (t U/year)	Conversion to UF6 (t HM/year)	Enrichment (t HM/year)	LWR Fuel Assembly Fabrication (t HM/year)	PHWR Fuel Assembly Fabrication (t HM/year)	MOX Fuel Assembly Fabrication (t HM/year)	SF Storage (Wet) (t HM)	SF Storage (Dry) (t HM)	SF Reprocessing (t HM/year)	Zirc. Alloy Production (t/yr)	Zirc. Alloy Tubing (km/yr)	Heavy Water (t/yr)
Russian Federation	4 300	24 000	15 000	1 620			14 960		400	2 000	6 000	
Slovakia							1 690					
Spain				400				1 680 (Cask-Bund)				
Sweden				600			8 000				1 000	
Switzerland								2 500				
South Africa	2 472											
Ukraine	1 000						2 518	9 120 (Cask-Bund)				
United Kingdom		6 000	4 000	330			10 320	700	2 400			
United States of America	4 020	17 600	11 300	3 450			750	9109.4		3 350	4 900	
Uzbekistan	3 000											
Total	59 435	74 562	48 455	11538	4 060	295	65 641 (+6 840 Cask-Bund)	43 943 (+313 909 Cask-Bund)	4 800	10 660	23 800 (+2 519 t/yr)	694

(*) Please note that the list might not include all of the facilities in the world due to the unavailability of the data.

(**) The total capacities listed here might not reflect the actual figures due to lack of exact figures for some individual facilities!

3.5. Worldwide operating commercial nuclear fuel cycle facilities: Numbers

TABLE 33. WORLDWIDE OPERATING COMMERCIAL NUCLEAR FUEL CYCLE FACILITIES: NUMBERS (*)

Country	Uranium Production	Conversion	Enrichment	Fuel Fabr. (Uranium)	Fuel Fabr. (MOX)	SF Storage	SF Repro.	Zirc. Alloy and Tubing	Heavy Water Prod.	Total
Argentina	0	2	0	1	0	2	0	2	1	**8**
Armenia	0	0	0	0	0	1	0	0	0	**1**
Australia	4	0	0	0	0	0	0	0	0	**4**
Belgium	0	0	0	1	1	2	0	0	0	**4**
Brazil	1	1	0	1	0	0	0	0	0	**3**
Bulgaria	0	0	0	0	0	1	0	0	0	**1**
Canada	3	4	0	4	0	6	0	2	0	**19**
China	5	1	2	2	0	1	0	0	0	**11**
Czech Republic	1	0	0	0	0	1	0	0	0	**2**
Finland	0	0	0	0	0	3	0	0	0	**3**
France	0	4	1	1	3	5	2	5	0	**21**
Germany	0	0	1	1	0	16	0	1	1	**20**
Hungary	0	0	0	0	0	1	0	0	0	**1**
India	1	1	0	4	0	3	0	5	6	**20**
Japan	0	0	1	5	0	4	0	2	0	**12**
Kazakhstan	6	0	0	1	0	0	0	0	0	**7**
Korea, Republic of	0	0	0	2	0	1	0	0	0	**3**
Kyrgyzstan	1	0	0	0	0	0	0	0	0	**1**
Lithuania	0	0	0	0	0	1	0	0	0	**1**
Namibia	2	0	0	0	0	0	0	0	0	**2**
Netherlands	0	0	1	0	0	0	0	0	0	**1**
Niger	2	0	0	0	0	0	0	0	0	**2**
Pakistan	0	1	1	1	0	0	0	0	0	**3**
Romania	1	0	0	1	0	1	0	0	0	**3**
Russian Federation	2	2	4	5	0	6	1	2	0	**22**
Slovakia	0	0	0	0	0	1	0	0	0	**1**
South Africa	2	0	0	0	0	0	0	0	0	**2**
Spain	0	0	0	1	0	1	0	0	0	**2**
Sweden	1	0	0	1	0	1	0	1	0	**4**
Switzerland	0	0	0	0	0	1	0	0	0	**1**
Ukraine	1	0	0	0	0	2	0	0	0	**3**
United Kingdom	0	5	1	3	0	5	2	0	0	**16**
United States of America	6	1	1	5	0	36	0	5	0	**54**
Uzbekistan	1	0	0	0	0	0	0	0	0	**1**
Total	40	22	13	40	4	102	5	25	8	**259**

(*) Please note that the list might not include all of the facilities in the world due to the unavailability of the data.

3.6. Total number of nuclear fuel cycle facilities

TABLE 34. TOTAL NUMBER OF ALL NUCLEAR FUEL CYCLE FACILITIES: TYPE BY STATUS (*)

Status Facility Type	In Oper.	Shut.	StandBy+	Decomm.+	Under Constr.	Planned+	Commis.	Other +	Total
Uranium Mining and Milling	43	43	17	69	10	2	0	13	**201**
Conversion	23	9	1	10	3	1	0	0	**47**
Enrichment	18	4	1	11	2	1	2	2	**41**
Fuel Fabrication	52	7	2	28	0	3	0	2	**94**
Spent Fuel Storage	109	2	0	6	2	7	1	2	**130**
Spent Fuel Reprocessing and Recycling	20	11	4	44	2	2	1	6	**90**
Spent Fuel Conditioning	0	0	2	0	0	0	0	0	**2**
Spent Fuel Disposal	0	0	0	0	0	0	0	0	**0**
Related Industrial Activities	33	9	1	7	1	0	0	2	**53**
Total	**298**	**85**	**28**	**175**	**20**	**16**	**4**	**27**	**658**

(*) Please note that the list might not include all of the facilities in the world due to the unavailability of the data.
(+) ***Planned*** includes: Planned, Under Study-Assessment, Siting-Design phases.
(+) ***StandBy*** includes: Stand by, Refurbishment phases.
(+) ***Decomm.*** includes: Decommissioning, Decommissioned phases.
(+) ***Other*** includes: Cancelled, Deferred, Unknownn phases.

TABLE 35. TOTAL NUMBER OF COMMERCIAL NUCLEAR FUEL CYCLE FACILITIES: TYPE BY STATUS (*).

Status Facility Type	In Oper.	Shut.	StandBy+	Decomm.+	Under Constr.	Planned+	Commis.	Other+	Total
Uranium Mining and Milling	40	36	17	65	9	2	0	10	**186**
Conversion	22	3	1	8	2	1	0	0	**37**
Enrichment	13	0	1	3	2	1	1	1	**22**
Fuel Fabrication	40	5	1	23	0	3	0	1	**73**
Spent Fuel Storage	102	20	0	5	1	6	1	1	**120**
Spent Fuel Reprocessing and Recycling	9	5	1	17	1	2	1	5	**41**
Spent Fuel Conditioning	0	0	0	0	0	0	0	0	**0**
Spent Fuel Disposal	0	0	0	0	0	0	0	0	**0**
Related Industrial Activities	33	6	1	7	1	0	0	2	**50**
Total	**259**	**57**	**22**	**128**	**16**	**15**	**3**	**20**	**529**

(*) Please note that the list might not include all of the facilities in the world due to the unavailability of the data.
(+) ***Planned*** includes: Planned, Under Study-Assessment, Siting-Design phases.
(+) ***StandBy*** includes: Stand by, Refurbishment phases.
(+) ***Decomm.*** includes: Decommissioning, Decommissioned phases.
(+) ***Other*** includes: Cancelled, Deferred, Unknownn phases.

TABLE 36. TOTAL NUMBER OF NON-COMMERCIAL NUCLEAR FUEL CYCLE FACILITIES: TYPE BY STATUS (*)

Status Facility Type	In Oper.	Shut.	StandBy$^+$	Decomm.$^+$	Under Constr.	Planned$^+$	Commis.	Other+	Total
Uranium Mining and Milling	3	7	0	4	1	0	0	0	**15**
Conversion	1	6	0	2	1	0	0	0	**10**
Enrichment	5	4	0	8	0	0	1	1	**19**
Fuel Fabrication	12	2	1	5	0	0	0	1	**21**
Spent Fuel Storage	7	0	0	1	1	1	0	0	**10**
Spent Fuel Reprocessing and Recycling	11	6	3	27	1	0	0	1	**49**
Spent Fuel Conditioning	0	0	2	0	0	0	0	0	**2**
Spent Fuel Disposal	0	0	0	0	0	0	0	0	**0**
Related Industrial Activities	0	3	0	0	0	0	0	0	**3**
Total	**39**	**28**	**6**	**47**	**4**	**1**	**1**	**3**	**129**

(*) Please note that the list might not include all of the facilities in the world due to the unavailability of the data.

($^+$) ***Planned*** includes: Planned, Under Study-Assessment, Siting-Design phases.
($^+$) ***StandBy*** includes: Stand by, Refurbishment phases.
($^+$) ***Decomm.*** includes: Decommissioning, Decommissioned phases.
($^+$) ***Other*** includes: Cancelled, Deferred, Unknownn phases.

3.7. Total number of nuclear fuel cycle facilities: Country by status

TABLE 37. TOTAL NUMBER OF ALL NUCLEAR FUEL CYCLE FACILITIES: COUNTRY BY STATUS

Country	Planned	Under Const.	Commiss.	In Opera.	Stand By	Shut.	Decomm.	Other	Total
Argentina	0	0	0	9	1	6	1	1	**18**
Armenia	0	0	0	1	0	0	0	0	**1**
Australia	2	0	0	4	0	0	2	4	**13**
Belgium	0	0	0	4	0	1	3	0	**8**
Brazil	0	1	1	9	0	6	2	1	**20**
Bulgaria	0	0	0	1	0	3	0	0	**4**
Canada	0	0	0	20	1	0	16	3	**40**
China	0	1	0	12	1	1	0	0	**15**
Czech Republic	0	0	1	2	0	0	2	0	**6**
Dem. P.R. of Korea	0	0	0	0	2	0	0	0	**2**
Denmark	0	0	0	0	0	1	0	0	**1**
Egypt	0	0	0	2	0	0	0	0	**2**
Estonia	0	0	0	0	0	1	0	0	**1**
Finland	0	0	0	3	0	0	0	0	**3**
France	1	3	0	21	0	7	16	0	**48**
Gabon	0	0	0	0	0	0	1	0	**1**
Germany	1	0	0	21	1	4	15	3	**45**
Hungary	0	0	0	1	0	1	0	0	**2**
India	0	2	0	22	2	0	2	0	**29**
Indonesia	0	0	0	2	0	2	0	0	**4**

Country	Planned	Under Const.	Commiss.	In Opera.	Stand By	Shut.	Decomm.	Other	Total
Israel	0	0	0	0	0	1	0	0	**1**
Italy	0	0	0	0	0	0	10	1	**11**
Japan	1	1	0	18	0	12	5	0	**37**
Kazakhstan	0	6	0	7	2	0	0	0	**15**
Korea, Republic of	0	0	0	4	1	1	1	1	**8**
Kyrgyzstan	0	0	0	1	0	0	0	0	**1**
Lithuania	1	0	0	1	0	0	0	0	**2**
Mexico	0	0	0	0	1	0	3	0	**4**
Mongolia	0	0	0	0	1	0	0	0	**1**
Morocco	0	0	0	0	0	0	0	2	**2**
Namibia	0	0	0	2	0	0	0	0	**2**
Netherlands	0	0	0	1	0	0	0	0	**1**
Niger	0	0	0	2	0	0	0	0	**2**
Norway	0	0	0	1	0	1	1	0	**3**
Pakistan	0	0	0	5	0	0	0	0	**5**
Portugal	0	0	0	0	0	8	0	1	**9**
Romania	0	0	0	3	0	0	0	0	**3**
Russian Federation	2	1	0	25	0	1	0	1	**30**
Serbia	0	0	0	0	0	1	0	0	**1**
Slovakia	1	0	0	1	0	0	0	0	**2**
Slovenia	0	0	0	0	0	0	1	0	**1**
South Africa	0	1	0	3	0	10	10	1	**25**
Spain	0	0	0	2	0	1	3	0	**6**
Sweden	0	0	0	4	0	0	0	0	**4**
Switzerland	0	1	0	1	0	0	0	0	**2**
Syrian Arab Republic	0	1	0	0	0	0	0	0	**1**
Tajikistan	0	0	0	0	0	1	0	0	**1**
Tunisia	0	0	0	0	0	0	0	0	**1**
Turkey	0	0	0	2	0	3	0	0	**5**
Ukraine	1	0	0	3	0	0	1	0	**5**
United Kingdom	0	0	1	16	3	2	23	0	**45**
United States of America	6	2	1	61	12	10	57	8	**158**
Uzbekistan	0	0	0	1	0	0	0	0	**1**
Total	**16**	**20**	**4**	**298**	**28**	**85**	**175**	**27**	**658**

TABLE 38. TOTAL NUMBER OF COMMERCIAL NUCLEAR FUEL CYCLE FACILITIES: COUNTRY BY STATUS

Country	Planned	Under Constr.	Commiss.	In Opera.	Stand By	Shut.	Decomm.	Other	Total
Argentina	0	0	0	8	1	5	1	0	**15**
Armenia	0	0	0	1	0	0	0	0	**1**
Australia	2	0	0	4	0	0	1	4	**12**
Belgium	0	0	0	4	0	1	2	0	**7**
Brazil	0	0	1	3	0	1	0	1	**6**
Bulgaria	0	0	0	1	0	3	0	0	**4**
Canada	0	0	0	19	1	0	15	3	**38**
China	0	0	0	11	1	1	0	0	**13**
Czech Republic	0	0	1	2	0	0	2	0	**6**
Dem. P.R. of Korea	0	0	0	0	1	0	0	0	**1**
Estonia	0	0	0	0	0	1	0	0	**1**
Finland	0	0	0	3	0	0	0	0	**3**
France	1	3	0	21	0	5	10	0	**40**
Gabon	0	0	0	0	0	0	1	0	**1**
Germany	1	0	0	20	0	4	9	3	**37**
Hungary	0	0	0	1	0	1	0	0	**2**
India	0	2	0	20	2	0	2	0	**27**
Italy	0	0	0	0	0	0	2	1	**3**
Japan	1	1	0	12	0	5	1	0	**20**
Kazakhstan	0	6	0	7	2	0	0	0	**15**
Korea, Republic of	0	0	0	3	0	1	0	0	**4**
Kyrgyzstan	0	0	0	1	0	0	0	0	**1**
Lithuania	1	0	0	1	0	0	0	0	**2**
Mexico	0	0	0	0	0	0	1	0	**1**
Mongolia	0	0	0	0	1	0	0	0	**1**
Morocco	0	0	0	0	0	0	0	2	**2**
Namibia	0	0	0	2	0	0	0	0	**2**
Netherlands	0	0	0	1	0	0	0	0	**1**
Niger	0	0	0	2	0	0	0	0	**2**
Norway	0	0	0	0	0	1	0	0	**1**
Pakistan	0	0	0	3	0	0	0	0	**3**
Portugal	0	0	0	0	0	7	0	1	**8**
Romania	0	0	0	3	0	0	0	0	**3**
Russian Federation	2	1	0	22	0	1	0	1	**27**
Slovakia	1	0	0	1	0	0	0	0	**2**
Slovenia	0	0	0	0	0	0	1	0	**1**
South Africa	0	1	0	2	0	10	9	0	**22**
Spain	0	0	0	2	0	1	3	0	**6**
Sweden	0	0	0	4	0	0	0	0	**4**
Switzerland	0	1	0	1	0	0	0	0	**2**
Tajikistan	0	0	0	0	0	1	0	0	**1**
Tunisia	0	0	0	0	0	0	0	0	**1**
Ukraine	1	0	0	3	0	0	1	0	**5**
United Kingdom	0	0	1	16	2	2	20	0	**41**
United States of America	5	1	0	54	11	6	47	8	**133**
Uzbekistan	0	0	0	1	0	0	0	0	**1**
Total	15	16	3	259	22	57	128	24	**529**

TABLE 39. TOTAL NUMBER OF NON-COMMERCIAL NUCLEAR FUEL CYCLE FACILITIES: COUNTRY BY STATUS

Country	Planned	Under Constr.	Commiss.	In Opera.	Stand By	Shut.	Decomm.	Other	Total
Argentina	0	0	0	1	0	1	0	1	**3**
Australia	0	0	0	0	0	0	1	0	**1**
Belgium	0	0	0	0	0	0	1	0	**1**
Brazil	0	1	0	6	0	5	2	0	**14**
Canada	0	0	0	1	0	0	1	0	**2**
China	0	1	0	1	0	0	0	0	**2**
Denmark	0	0	0	0	0	1	0	0	**1**
Dem. P.R. of Korea	0	0	0	0	1	0	0	0	**1**
Egypt	0	0	0	2	0	0	0	0	**2**
France	0	0	0	0	0	2	6	0	**8**
Germany	0	0	0	1	1	0	6	0	**8**
India	0	0	0	2	0	0	0	0	**2**
Indonesia	0	0	0	2	0	2	0	0	**4**
Israel	0	0	0	0	0	1	0	0	**1**
Italy	0	0	0	0	0	0	8	0	**8**
Japan	0	0	0	6	0	7	4	0	**17**
Korea, Republic of	0	0	0	1	1	0	1	1	**4**
Mexico	0	0	0	0	1	0	2	0	**3**
Norway	0	0	0	1	0	0	1	0	**2**
Pakistan	0	0	0	2	0	0	0	0	**2**
Portugal	0	0	0	0	0	1	0	0	**1**
Russian Federation	0	0	0	3	0	0	0	0	**3**
Serbia	0	0	0	0	0	1	0	0	**1**
South Africa	0	0	0	1	0	0	1	1	**3**
Syrian Arab Republic	0	1	0	0	0	0	0	0	**1**
Turkey	0	0	0	2	0	3	0	0	**5**
United Kingdom	0	0	0	0	1	0	3	0	**4**
United States of America	1	1	1	7	1	4	10	0	**25**
Total	1	4	1	39	6	28	47	3	**129**

4. CONCLUSIONS

IAEA Nuclear Fuel Cycle Information System (NFCIS) database provides general and technical information, including references, on nuclear fuel cycle facilities. Facilities dealing with waste management are covered by other IAEA database and not included in the NFCIS. NFCIS also covers related nuclear industrial activities such as production of Zr metal and Zr alloy tubes, and heavy water. Technical information indicates type, status, scale, process, design capacity, feed and product material of the facility. General information includes facility name, facility location, owner(s) and operators.

NFCIS has been published on the internet which allows the users to register freely and to work with datasets (http://www-nfcis.iaea.org). The web site provides filtering and navigation to the data from the database. It has also a statistical tool which provides summary information on number of facilities and capacities by type and status, and by country and status. In this respect and with regard to the data presented, the NFCIS database is a unique database which provides freely accessible information on worldwide nuclear fuel cycle activities.

Accuracy and completeness of the datasets presented in the NFCIS, like in every database, directly depends on the information either provided by the Member States or retrieved by the IAEA from other sources. Member States' co-operation is of crucial importance to keep the database up-to-date and complete. The contribution from Member States is believed to be enhanced with the increased use of the database hence this document, as an additional path for dissemination of the data, is expected to help the improvement of the database in terms of accuracy and completeness.

Although a great effort is spent to have complete and accurate database, the users should take into consideration that there still might be missing or outdated data for individual facilities due to the rapid changes in the nuclear fuel cycle industry, the complexity of the nuclear fuel cycle industry and mutual links inside it.

The feedback from the users of the database is very important and welcome to improve the usability and the usefulness of the database and its web site.

This document and its supplementary CD-ROM represent a snapshot of the status of the database as of the end of 2008. However, the database is being continuously updated and the latest updates and additions can be accessed from the database web site (http://www-nfcis.iaea.org).

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ABBREVIATIONS

ADU — Ammonium di-Uranate

AECL — Atomic Energy of Canada Limited

AFR — Away-from-Reactor (spent fuel storage)

AR — at-Reactor (spent fuel storage)

ASTM — American Society for Testing and Materials Standards

AUC — Ammonium Uranyl Carbonate

BNFL — British Nuclear Fuel Limited

BWR — Boiling Water Reactor

CANDU — Canadian deuterium uranium (reactor)

CECE — Combined Electrolysis and Catalytic Exchange

ChMZ — Chepetsky Mechanical Zavod (plant in Glazov, Russia)

CIRCE — Combined Industrial Reforming and Catalytic Exchange

CNNC — China National Nuclear Corporation

DEPA — di-Ethilgexil Phosphoric Acid

EBS — Engineered Barrier System

ERU — Enriched Reprocessed Uranium

FA — Fuel Assembly

FR — Fast Reactor

GIF — Generation IV International Forum

G-S — Girdler-sulphide

HEU — High Enriched Uranium

HM — Heavy Metal

HTGR — High Temperature Gas-cooled Reactor

IDR — Integrated Dry Route (powder process)

INPRO — (IAEA) International Project on Innovative Nuclear Reactors and Fuel Cycles

ISL — In-Situ Leaching

JNFL — Japan Nuclear Fuel Limited

LTP — Low Temperature Process

LWR — Light Water Reactor

LMFR — Liquid Metal Fast Breeding Reactor

MADB — (IAEA) Minor Actinide Property Database

MAGNOX — (Magnesium non-oxidising) UK type Gas Cooled Reactors

MIMAS — Micronized Master Blend

MTR — Material Test Reactor

MOX — Mixed OXide (fuel)

NAC — Nuclear Assurance Corporation (International)

NEWMDB — (IAEA) Net Enabled Waste Management Database

NFCIS — (IAEA) Nuclear Fuel Cycle Information System

OECD/NEA — Nuclear Energy Agency of the Organization for Economic Co-operation and Development

PCI — Pellet-Cladding Interaction

PRIS — (IAEA) Power Reactor Information System

Purex — Plutonium Uranium Extraction

RCCA — Rod Cluster Control Assembly

RepU — Reprocessed Uranium

SS — Stainless Steel

SF — Spent Fuel

SFS — Spent Fuel Storage

SWU — Separative Work Unit

TOPO — tri-m-Octyl Phosphorine Oxide

UDEPO — (IAEA) World Distribution of Uranium Deposits

UNH — Uranyl Nitrate Hydrate — $UO_2(NO_3)_2 \cdot 6H_2O$

USEC — The United States Enrichment Corporation

NFCSS — (IAEA) Nuclear Fuel Cycle Simulation System

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