U.S. Department of the Interior
U.S. Geological Survey

MINERAL COMMODITY SUMMARIES 2022

Abrasives
Aluminum
Antimony
Arsenic
Asbestos
Barite
Bauxite
Beryllium
Bismuth
Boron
Bromine
Cadmium
Cement
Cesium
Chromium
Clays
Cobalt
Copper
Diamond
Diatomite
Feldspar
Fluorspar
Gallium
Garnet
Gemstones
Germanium
Gold
Graphite
Gypsum
Hafnium
Helium
Indium
Iodine
Iron and Steel
Iron Ore
Iron Oxide Pigments
Kyanite
Lead
Lime
Lithium
Magnesium
Manganese
Mercury
Mica
Molybdenum
Nickel
Niobium
Nitrogen
Palladium
Peat
Perlite
Phosphate Rock
Platinum
Potash
Pumice
Quartz Crystal
Rare Earths
Rhenium
Rubidium
Salt
Sand and Gravel
Scandium
Selenium
Silicon
Silver
Soda Ash
Stone
Strontium
Sulfur
Talc
Tantalum
Tellurium
Thallium
Thorium
Tin
Titanium
Tungsten
Vanadium
Vermiculite
Wollastonite
Yttrium
Zeolites
Zinc
Zirconium

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Cover: A photomicrograph showing the four primary phases of cement: alite, belite, aluminate, and ferrite. Clinker is the primary component of cement, which in turn is the key ingredient of concrete. Concrete is a universal construction material, which is used in varying quantities in virtually every construction project in the world. The use of cement and concrete dates to ancient civilizations, and those materials are used for bridges, buildings, highways, and numerous other infrastructure projects. Cement production and consumption trends in developed countries can be useful as national economic indicators and often reflect the transition from emerging economies to industrial economies. (Photograph from fig. 7–15 of the Portland Cement Association's "Microscopical Examination and Interpretation of Portland Cement and Clinker," second edition, 1999, by Donald H. Campbell; used with permission of the Portland Cement Association.)

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Lime
Lithium
Magnesium
Manganese
Mercury
Mica
Molybdenum
Nickel
Niobium
Nitrogen
Palladium
Peat
Perlite
Phosphate Rock
Platinum
Potash
Pumice
Quartz Crystal
Rare Earths
Rhenium
Rubidium
Salt
Sand and Gravel
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This publication has been prepared by the National Minerals Information Center. Information about the Center and its products is available from the internet at https://www.usgs.gov/centers/nmic or by writing to Director, National Minerals Information Center, 988 National Center, Reston, VA 20192.

KEY PUBLICATIONS

Minerals Yearbook—These annual publications review the mineral industries of the United States and of more than 180 other countries. They contain statistical data on minerals and materials and include information on economic and technical trends and developments and are available at https://www.usgs.gov/centers/nmic/publications. The three volumes that make up the Minerals Yearbook are volume I, Metals and Minerals; volume II, Area Reports—Domestic; and volume III, Area Reports—International.

Mineral Commodity Summaries—Published on an annual basis, this report is the earliest Government publication to furnish estimates covering nonfuel mineral industry data and is available at https://www.usgs.gov/centers/nmic/mineral-commodity-summaries. Data sheets contain information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics for more than 90 individual minerals and materials.

Mineral Industry Surveys—These periodic statistical and economic reports are designed to provide timely statistical data on production, shipments, stocks, and consumption of significant mineral commodities and are available at https://www.usgs.gov/centers/nmic/mineral-industry-surveys. The surveys are issued monthly, quarterly, or at other regular intervals.

Materials Flow Studies—These publications describe the flow of minerals and materials from extraction to ultimate disposition to help better understand the economy, manage the use of natural resources, and protect the environment and are available at https://www.usgs.gov/centers/nmic/materials-flow.

Recycling Reports—These studies illustrate the recycling of metal commodities and identify recycling trends and are available at https://www.usgs.gov/centers/nmic/recycling-statistics-and-information.

Historical Statistics for Mineral and Material Commodities in the United States (Data Series 140)—This report provides a compilation of statistics on production, trade, and use of approximately 90 mineral commodities since as far back as 1900 and is available at https://www.usgs.gov/centers/nmic/historical-statistics-mineral-and-material-commodities-united-states.

WHERE TO OBTAIN PUBLICATIONS

- *Mineral Commodity Summaries* and the *Minerals Yearbook* are sold by the U.S. Government Publishing Office. Orders are accepted over the internet at https://bookstore.gpo.gov, by email at ContactCenter@gpo.gov, by telephone toll free (866) 512–1800; Washington, DC, area (202) 512–1800, by fax (202) 512–2104, or through the mail (P.O. Box 979050, St. Louis, MO 63197–9000).

- All current and many past publications are available as downloadable Portable Document Format (PDF) files through https://www.usgs.gov/centers/nmic.

INTRODUCTION

Each mineral commodity chapter of the 2022 edition of the U.S. Geological Survey (USGS) Mineral Commodity Summaries (MCS) includes information on events, trends, and issues for each mineral commodity as well as discussions and tabular presentations on domestic industry structure, Government programs, tariffs, 5-year salient statistics, and world production, reserves, and resources. The MCS is the earliest comprehensive source of 2021 mineral production data for the world. More than 90 individual minerals and materials are covered by 2-page synopses.

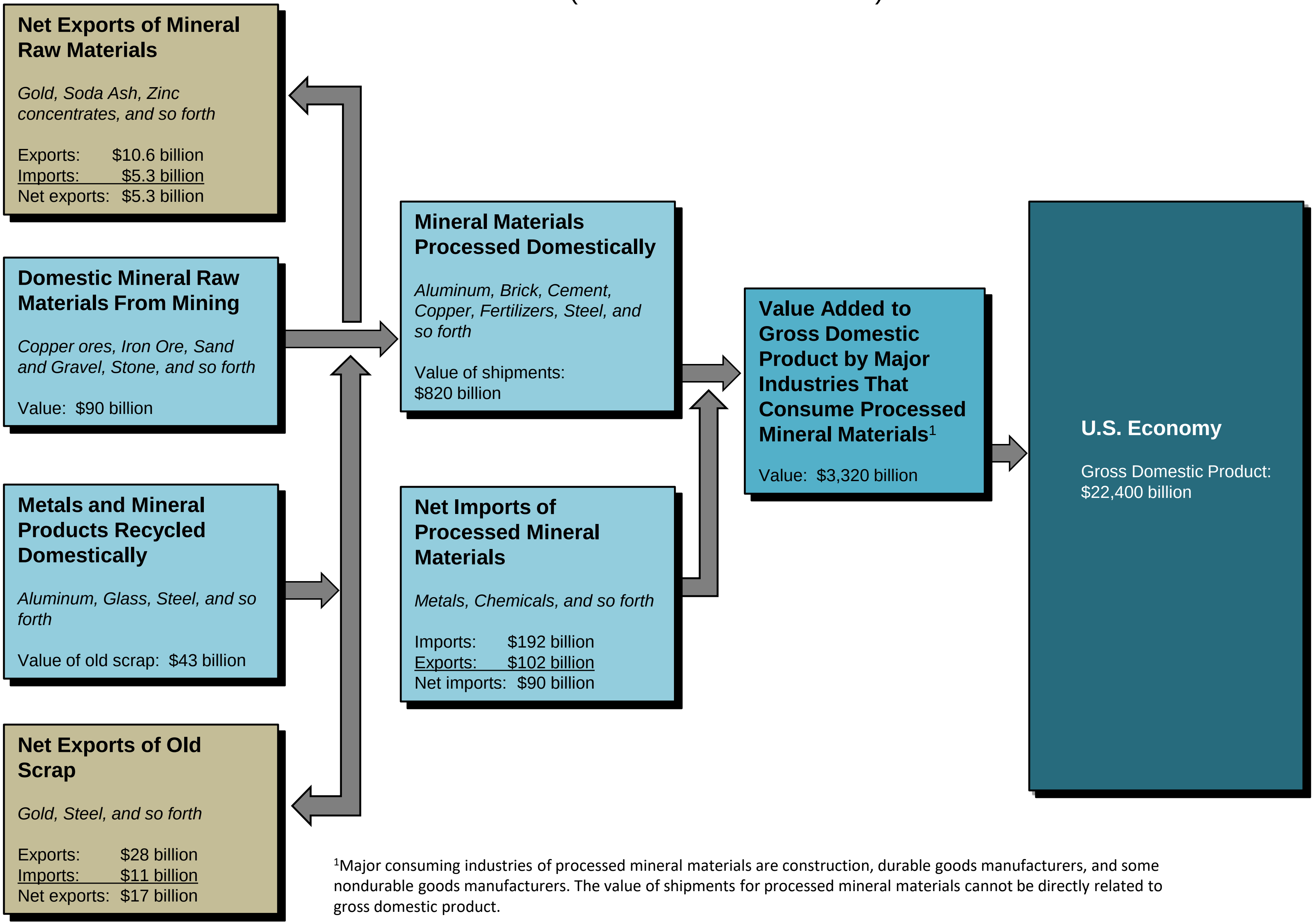
For mineral commodities for which there is a Government stockpile, detailed information concerning the stockpile status is included in the 2-page synopsis.

Abbreviations and units of measure and definitions of selected terms used in the report are in Appendix A and Appendix B, respectively. Reserves and resources information is in Appendix C, which includes “Part A—Resource and Reserve Classification for Minerals” and “Part B—Sources of Reserves Data.” A directory of USGS minerals information country specialists and their responsibilities is in Appendix D.

The USGS continually strives to improve the value of its publications to users. Constructive comments and suggestions by readers of the MCS 2022 are welcomed.

Figure 1.—The Role of Nonfuel Minerals in the U.S. Economy

(Estimated values in 2021)



[1]Major consuming industries of processed mineral materials are construction, durable goods manufacturers, and some nondurable goods manufacturers. The value of shipments for processed mineral materials cannot be directly related to gross domestic product.

Sources: U.S. Geological Survey and U.S. Department of Commerce.

SIGNIFICANT EVENTS, TRENDS, AND ISSUES

In 2021, the estimated total value of nonfuel mineral production in the United States was $90.4 billion, an increase of 12% from the revised total of $80.7 billion in 2020. The estimated value of metals production increased by 23% to $33.8 billion. The increased price for copper, which was projected to be about $4.20 per pound in 2021, an alltime high, contributed to the increased value of metal production. The total value of industrial minerals production was $56.6 billion, a 6% increase from that in 2020. Of this total, $29.2 billion was construction aggregates production (construction sand and gravel and crushed stone). Crushed stone was the leading nonfuel mineral commodity in 2021 with a production value of more than $19.3 billion and accounted for 21% of the total value of U.S. nonfuel mineral production.

Increases in consumption of nonfuel mineral commodities in commercial construction, steel production, and automotive and transportation industry were attributed to the restarting of the economy after closure because of the global COVID-19 pandemic. For the metals sector, the copper, iron ore, steel, and zinc industries were particularly affected by increased demand from manufacturing. For the industrial minerals sector, the largest increases in production were in cement, crushed stone, sand and gravel, and soda ash, commodities that are closely tied to the performance of the construction industry.

Trade Issues

On October 31, 2021, it was announced the additional 10% and 25% ad valorem tariffs under section 232 of the Trade Expansion Act of 1962 (86 FR 64748) on aluminum and steel imports, respectively, from the European Union would be replaced with an import quota effective January 1, 2022. An agreement was reached between the United States and the European Union to remove the ad valorem tariff on aluminum and steel imports that was imposed in 2018 under the authority of section 232 of the Trade Expansion Act of 1962. Effective in January 2022, the tariff would only be applied on imports from countries in the European Union that exceed specified quotas.

The additional 25% ad valorem duty for products imported from China (Lists 1, 2, and 3) and the 7.5% ad valorem duty for products imported from China (List 4) imposed under section 301(b) of the Trade Act of 1974, (19 U.S.C. 2411, as amended) by the United States Trade Representative continued in 2021. Likewise, China imposed additional import duties for certain items originating in the United States.

In 2021, widespread supply chain disruptions were experienced by most industries, particularly in cargo transportation. In March, a large container ship blocked the Suez Canal for 6 days, severely delaying global trade. Delays in offloading ships at docks resulted from the lack of truck drivers to remove cargo containers, and ports ran out of space to store containers. Cargo ships were forced to remain at sea until space was available to unload them. Additionally, ongoing travel- and work-related restrictions put in place to mitigate the effects of the global COVID-19 pandemic continued throughout the year. Lockdowns took place in various countries as COVID-19 and its variants spread throughout the world.

U.S. ports continued to experience lengthy delays, especially at the Ports of Long Beach, CA, Los Angeles, CA, and Savannah, GA. Despite a Presidential order for ports to remain open 24 hours per day, worker, truck, and rail shortages and other logistic issues restricted easing of congestion.

U.S. Production and Consumption

As shown in figure 1, minerals remained fundamental to the U.S. economy, contributing to the real gross domestic product at several levels, including mining, processing, and manufacturing finished products. The estimated value of nonfuel minerals produced at mines in the United States in 2021 was $90.4 billion. The value of net exports of mineral raw materials increased to $5.3 billion from $4.0 billion in 2020. Domestically recycled products totaled $43 billion, and iron and steel scrap contributed $18 billion to that total. Domestic raw materials and domestically recycled materials were used to produce mineral materials worth $820 billion. These mineral materials as well as imports of processed mineral materials, which decreased by 9% in 2021, were, in turn, consumed by downstream industries creating an estimated value of $3.32 trillion in 2021, an 8% increase from that in 2020.

Figure 2 illustrates the reliance of the United States on foreign sources for raw and processed mineral materials. In 2021, imports made up more than one-half of the U.S. apparent consumption for 47 nonfuel mineral commodities, and the United States was 100% net import reliant for 17 of those. Of the 35 minerals or mineral material groups identified as “critical minerals” published in the Federal Register on May 18, 2018 (83 FR 23295), the United States was 100% net import reliant for 14, and an additional 15 critical mineral commodities had a net import reliance greater than 50% of apparent consumption.

Additional information regarding critical minerals in the United States can be found in the “United States Critical Minerals Update” section that begins on page 17.

Figure 3 shows the countries that were sources of nonfuel mineral commodities for which the United States was greater than 50% net import reliant in 2021 and the number of mineral commodities for which each highlighted country was a leading supplier. China, followed by Canada, supplied the largest number of these nonfuel mineral commodities. The countries that were the leading sources of imported mineral commodities with greater than 50% net import reliance were: China, 25 mineral commodities; Canada, 16 mineral commodities; Germany, 11 mineral commodities; South Africa, 10 mineral commodities; and Brazil and Mexico, 9 mineral commodities each.

The estimated value of U.S. metal mine production in 2021 was $33.8 billion, 23% higher than the revised value in 2020 (table 1). Principal contributors to the total value of metal mine production in 2021 were copper, 35%; gold, 31%; iron ore, 13%; and zinc, 7%. The estimated value of U.S. industrial minerals production in 2021, including construction aggregates, was $56.6 billion, about 6% more than the revised value of 2020 (table 1). The value of industrial minerals production in 2021 was dominated by crushed stone, 34%; cement (masonry and portland), 19%; and construction sand and gravel, 17%.

In 2021, U.S. production of 14 mineral commodities was valued at more than $1 billion each. These commodities were, in decreasing order of value, crushed stone, copper, cement, gold, construction sand and gravel, iron ore, salt, lime, industrial sand and gravel, zinc, soda ash, phosphate rock, palladium, and molybdenum.

In 2021, 13 States each produced more than $2 billion worth of nonfuel mineral commodities. These States were, in descending order of production value, Arizona, Nevada, Texas, California, Minnesota, Alaska, Utah, Florida, Missouri, Michigan, Wyoming, Georgia, and Montana (table 3, fig. 4).

The west region was the leading region in the production of the metals and metallic minerals and other industrial minerals production with a value of $28 billion and $10.4 billion, respectively, in 2021 (figs. 5, 6).

In 2021, there were seven States that produced more than $900 million worth of crushed stone. These States were, in descending order of production value, Texas, Pennsylvania, Florida, North Carolina, Georgia, Virginia, and Missouri (fig. 7).

Construction sand and gravel was produced in every State. California and Texas were the only two States that produced more than $1 billion worth of construction sand and gravel in 2021. Arizona, Utah, Washington, Ohio, New York, Colorado, Michigan, and Florida, in descending order of production value, were the other top 10 producing States (fig. 8).

The Defense Logistics Agency Strategic Materials (DLA Strategic Materials) is responsible for the operational oversight of the National Defense Stockpile (NDS) of strategic and critical materials. Managing the security, environmentally sound stewardship, and ensuring the readiness of all NDS stocks is the mission of the DLA Strategic Materials. The NDS currently contains 46 unique commodities stored at 10 locations within the continental United States. In fiscal year 2021, approximately $4.95 million of new stocks were acquired and $75.45 million of excess materials were sold. Revenue from the Stockpile Sales Program fund the operation of the NDS and the acquisition of new stocks. As of September 30, 2021, the NDS inventory had a fair market value of $1.28 billion. For reporting purposes, NDS stocks are categorized as held in reserve or available for sale. The majority of stocks are held in reserve. Additional detailed information can be found in the “Government Stockpile” sections in the mineral commodity chapters that follow. Under the authority of the Defense Production Act of 1950 (Public Law 81–774), the USGS advises the DLA Strategic Materials on acquisitions and disposals of NDS mineral materials.

Figure 2.—2021 U.S. Net Import Reliance[1]

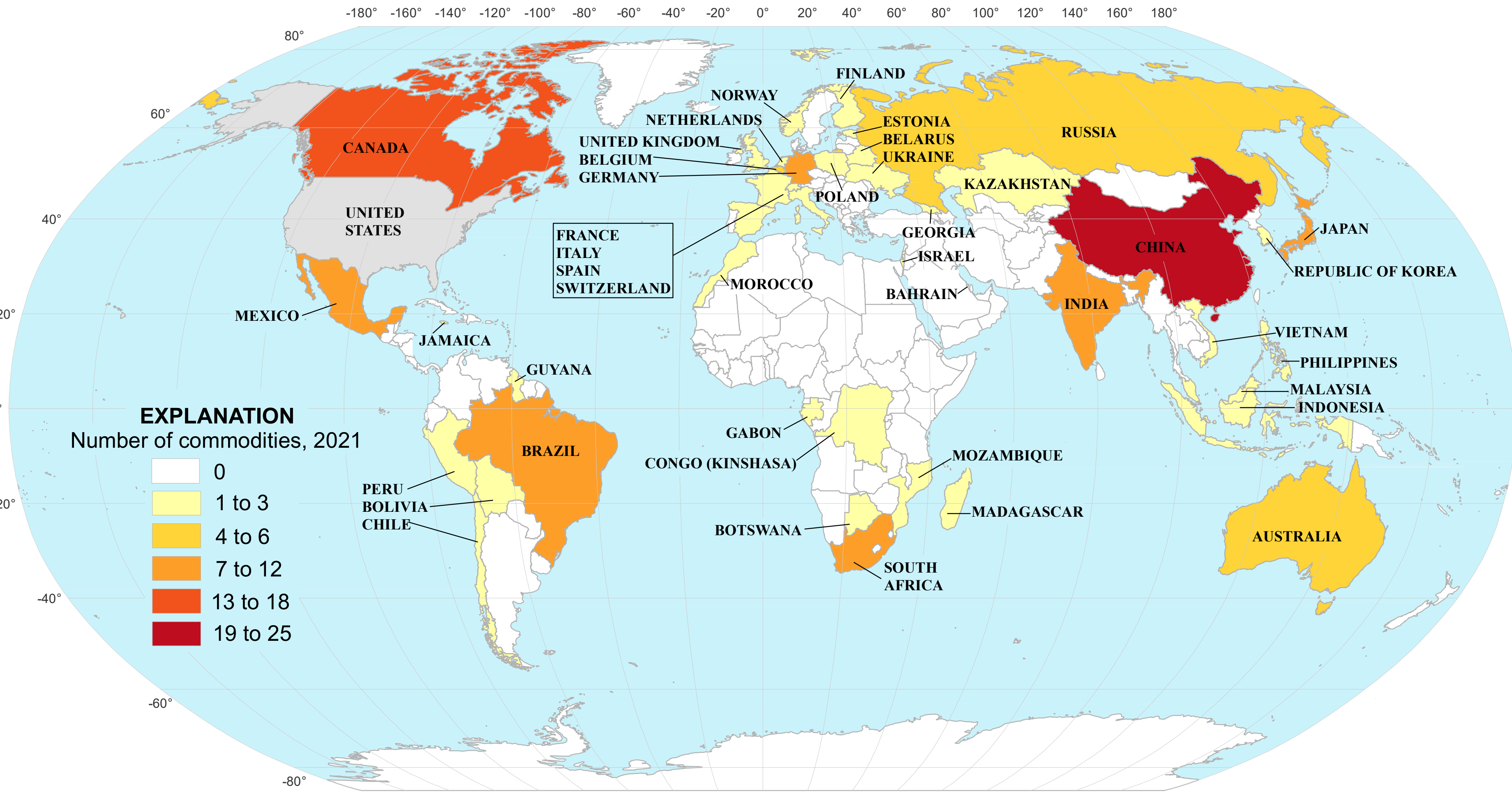
Commodity	Net import reliance as a percentage of apparent consumption	Major import sources (2017–20)[2]
ARSENIC, all forms	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Germany, China
FLUORSPAR	100	Mexico, Vietnam, South Africa, Canada
GALLIUM	100	China, United Kingdom, Germany, Ukraine
GRAPHITE (NATURAL)	100	China, Mexico, Canada, India
INDIUM	100	China, Canada, Republic of Korea, France
MANGANESE	100	Gabon, South Africa, Australia, Georgia
MICA (NATURAL), sheet	100	China, Brazil, Belgium, India
NEPHELINE SYENITE	100	Canada
NIOBIUM (COLUMBIUM)	100	Brazil, Canada
RUBIDIUM	100	Germany
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Germany, Australia, Indonesia
VANADIUM	100	Canada, China, Brazil, South Africa
YTTRIUM	100	China, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
TELLURIUM	>95	Canada, Germany, China, Philippines
POTASH	93	Canada, Russia, Belarus
IRON OXIDE PIGMENTS, natural and synthetic	91	China, Germany, Brazil
RARE EARTHS,[3] compounds and metals	>90	China, Estonia, Malaysia, Japan
TITANIUM, sponge	>90	Japan, Kazakhstan, Ukraine
BISMUTH	90	China, Republic of Korea, Mexico, Belgium
TITANIUM MINERAL CONCENTRATES	90	South Africa, Australia, Madagascar, Mozambique
ANTIMONY, metal and oxide	84	China, Belgium, India
STONE (DIMENSION)	84	China, Brazil, Italy, India
CHROMIUM	80	South Africa, Kazakhstan, Russia, Mexico
PEAT	80	Canada
SILVER	79	Mexico, Canada, Chile, Poland
TIN, refined	78	Indonesia, Peru, Malaysia, Bolivia
COBALT	76	Norway, Canada, Japan, Finland
DIAMOND (INDUSTRIAL), stones	76	South Africa, India, Congo (Kinshasa), Botswana
ZINC, refined	76	Canada, Mexico, Peru, Spain
ABRASIVES, crude fused aluminum oxide	>75	China, France, Bahrain, Russia
BARITE	>75	China, India, Morocco, Mexico
BAUXITE	>75	Jamaica, Brazil, Guyana, Australia
SELENIUM	>75	Philippines, China, Mexico, Germany
RHENIUM	72	Chile, Canada, Kazakhstan, Japan
PLATINUM	70	South Africa, Germany, Switzerland, Italy
ALUMINA	58	Brazil, Australia, Jamaica, Canada
GARNET (INDUSTRIAL)	56	South Africa, China, India, Australia
MAGNESIUM COMPOUNDS	55	China, Brazil, Israel, Canada
ABRASIVES, crude silicon carbide	>50	China, Netherlands, South Africa
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
TUNGSTEN	>50	China, Bolivia, Germany, Canada
CADMIUM	<50	Australia, China, Germany, Peru
MAGNESIUM METAL	<50	Canada, Israel, Mexico
NICKEL	48	Canada, Norway, Finland, Australia
COPPER, refined	45	Chile, Canada, Mexico
ALUMINUM	44	Canada, United Arab Emirates, Russia, China
DIAMOND (INDUSTRIAL), bort, grit, dust, and powder	41	China, Ireland, Republic of Korea, Russia
LEAD, refined	38	Canada, Mexico, Republic of Korea, India
PALLADIUM	37	Russia, South Africa, Germany
FELDSPAR	32	Turkey
SILICON, metal and ferrosilicon	32	Russia, Brazil, Canada, Norway
SALT	29	Chile, Canada, Mexico, Egypt
MICA (NATURAL), scrap and flake	28	Canada, China, India
LITHIUM	>25	Argentina, Chile, China, Russia
BROMINE	<25	Israel, Jordan, China
ZIRCONIUM, ores and concentrates	<25	South Africa, Senegal, Australia, Russia
PERLITE	23	Greece, China, Mexico, Turkey
VERMICULITE	20	South Africa, Brazil

[1]Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (boron; clays; diatomite; gold; helium; iron and steel scrap; iron ore; kyanite; molybdenum; rare earths, mineral concentrates; sand and gravel, industrial; soda ash; titanium dioxide pigment; wollastonite; zeolites; and zinc concentrates) or less than 20% net import reliant (abrasives, metallic; beryllium; cement; gypsum; iron and steel; iron and steel slag; lime; nitrogen (fixed)—ammonia; phosphate rock; pumice; sand and gravel, construction; stone, crushed; sulfur; and talc and pyrophyllite). For some mineral commodities (hafnium; mercury; quartz crystal, industrial; thallium; and thorium), not enough information is available to calculate the exact percentage of import reliance.

[2]Listed in descending order of import share.

[3]Data include lanthanides.

Figure 3.—Major Import Sources of Nonfuel Mineral Commodities for Which the United States was Greater Than 50% Net Import Reliant in 2021



Source: U.S. Geological Survey

Table 1.—U.S. Mineral Industry Trends

	2017	2018	2019	2020	2021[e]
Total mine production (million dollars):					
Metals	26,800	28,000	26,900	27,500	33,800
Industrial minerals	52,800	56,300	55,800	53,200	56,600
Coal	26,100	27,200	25,500	16,800	18,700
Employment (thousands of workers):					
Coal mining, all employees	52	52	51	42	42
Nonfuel mineral mining, all employees	134	140	140	137	140
Chemicals and allied products, production workers	525	546	559	535	530
Stone, clay, and glass products, production workers	305	311	312	294	290
Primary metal industries, production workers	292	295	302	272	270
Average weekly earnings of workers (dollars):					
Coal mining, all employees	1,484	1,546	1,617	1,521	1,590
Chemicals and allied products, production workers	1,010	1,072	1,066	1,065	1,110
Stone, clay, and glass products, production workers	873	945	966	982	1,010
Primary metal industries, production workers	996	1,035	1,025	1,008	1,070

[e]Estimated.

Sources: U.S. Geological Survey, U.S. Department of Energy, and U.S. Department of Labor.

Table 2.—U.S. Mineral-Related Economic Trends

	2017	2018	2019	2020	2021[e]
Gross domestic product (billion dollars)	19,480	20,527	21,373	20,894	22,400
Industrial production (2017=100):					
Total index:	100	103	102	95	100
Manufacturing:	100	101	100	93	99
Nonmetallic mineral products	100	100	98	95	97
Primary metals:	100	103	99	86	97
Iron and steel	100	103	97	81	96
Aluminum	100	106	101	92	106
Nonferrous metals (except aluminum)	100	102	104	92	93
Chemicals	100	99	95	93	98
Mining:	100	113	120	103	105
Coal	100	98	92	69	76
Oil and gas extraction	100	116	129	122	121
Metals	100	99	96	94	91
Nonmetallic minerals	100	104	107	104	109
Capacity utilization (percent):					
Total industry:	76	79	77	72	75
Mining:	78	87	86	72	74
Metals	72	71	68	67	64
Nonmetallic minerals	88	89	89	85	88
Housing starts (thousands)	1,205	1,247	1,292	1,397	1,580
Light vehicle sales (thousands)	17,150	17,225	16,961	14,472	15,170
Highway construction, value, put in place (billion dollars)	90	91	100	101	99

[e]Estimated.

Sources: U.S. Department of Commerce and Federal Reserve Board.

Table 3.—Value of Nonfuel Mineral Production in the United States and Principal Nonfuel Mineral Commodities Produced in 2021[p, 1, 2]

State	Value (millions)	Rank[3]	Percent of U.S. total[4]	Principal nonfuel mineral commodities[5]
Alabama	$1,860	16	2.06	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Alaska	3,890	6	4.30	Gold, lead, sand and gravel (construction), silver, zinc.
Arizona	9,960	1	11.00	Cement (portland), copper, molybdenum mineral concentrates, sand and gravel (construction), stone (crushed).
Arkansas	1,000	28	1.11	Bromine, cement (portland), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
California	5,270	4	5.83	Boron minerals, cement (portland), rare earths, sand and gravel (construction), stone (crushed).
Colorado	1,610	19	1.78	Cement (portland), gold, molybdenum mineral concentrates, sand and gravel (construction), stone (crushed).
Connecticut	183	43	0.20	Sand and gravel (construction), stone (crushed), stone (dimension).
Delaware[6]	22	50	0.02	Magnesium compounds, sand and gravel (construction), stone (crushed).
Florida[6, 7]	2,400	8	2.65	Cement (masonry and portland), phosphate rock, sand and gravel (construction), stone (crushed).
Georgia[6, 7]	2,040	12	2.25	Cement (portland), clay (kaolin and montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Hawaii	134	45	0.15	Sand and gravel (construction), stone (crushed).
Idaho	722	34	0.80	Lead, phosphate rock, sand and gravel (construction), silver, stone (crushed).
Illinois[6]	992	25	1.10	Cement (portland), magnesium compounds, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Indiana	1,160	26	1.28	Cement (portland), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Iowa	959	29	1.06	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Kansas[6]	1,210	24	1.34	Cement (portland), helium (Grade-A), salt, sand and gravel (construction), stone (crushed).
Kentucky[6]	586	30	0.65	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Louisiana	661	35	0.73	Clay (common clay), salt, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Maine[6]	127	44	0.14	Cement (portland), peat, sand and gravel (construction), stone (crushed), stone (dimension).
Maryland[6]	461	32	0.51	Cement (masonry and portland), sand and gravel (construction), stone (crushed), stone (dimension).
Massachusetts[6]	209	42	0.23	Clay (common clay), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Michigan	3,000	10	3.32	Cement (portland), iron ore, nickel sulfide concentrates, sand and gravel (construction), stone (crushed).
Minnesota[6]	4,010	5	4.44	Iron ore, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Mississippi[6]	200	41	0.22	Clay (bentonite and montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Missouri	3,300	9	3.65	Cement (portland), lead, lime, sand and gravel (industrial), stone (crushed).
Montana	2,010	13	2.23	Copper, molybdenum mineral concentrates, palladium, platinum, sand and gravel (construction).

See footnotes at end of table.

Table 3.—Value of Nonfuel Mineral Production in the United States and Principal Nonfuel Mineral Commodities Produced in 2021[p, 1, 2]—Continued

State	Value (millions)	Rank[3]	Percent of U.S. total[4]	Principal nonfuel mineral commodities[5]
Nebraska[6]	$220	39	0.24	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Nevada	9,350	2	10.30	Copper, gold, lime, silver, stone (crushed).
New Hampshire	95	47	0.10	Sand and gravel (construction), stone (crushed), stone (dimension).
New Jersey	396	38	0.44	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
New Mexico	1,290	23	1.43	Cement (portland), copper, potash, sand and gravel (construction), stone (crushed).
New York[6]	1,570	18	1.74	Cement (portland), salt, sand and gravel (construction), stone (crushed), zinc.
North Carolina[6]	1,460	17	1.62	Clay (common clay), phosphate rock, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
North Dakota[6]	65	48	0.07	Clay (common clay), lime, sand and gravel (construction), stone (crushed).
Ohio[6]	1,380	15	1.53	Cement (portland), lime, salt, sand and gravel (construction), stone (crushed).
Oklahoma	916	31	1.01	Cement (portland), iodine, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Oregon	595	36	0.66	Cement (portland), diatomite, perlite (crude), sand and gravel (construction), stone (crushed).
Pennsylvania[6]	1,950	14	2.15	Cement (masonry and portland), lime, sand and gravel (construction), stone (crushed).
Rhode Island[6]	66	49	0.07	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
South Carolina[6]	953	22	1.05	Cement (masonry and portland), gold, sand and gravel (construction), stone (crushed).
South Dakota	495	37	0.55	Cement (portland), gold, lime, sand and gravel (construction), stone (crushed).
Tennessee	1,550	21	1.71	Cement (portland), sand and gravel (construction), sand and gravel (industrial), stone (crushed), zinc.
Texas	5,760	3	6.37	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Utah	3,750	7	4.15	Copper, magnesium metal, molybdenum mineral concentrates, potash, sand and gravel (construction).
Vermont[6]	112	46	0.12	Sand and gravel (construction), stone (crushed), stone (dimension), talc (crude).
Virginia	1,550	20	1.72	Cement (portland), kyanite, lime, sand and gravel (construction), stone (crushed).
Washington	732	33	0.81	Cement (portland), diatomite, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
West Virginia	360	40	0.40	Cement (masonry and portland), lime, sand and gravel (construction), stone (crushed).
Wisconsin[6]	997	27	1.10	Lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Wyoming	2,750	11	3.14	Cement (portland), clay (bentonite), helium (Grade-A), sand and gravel (construction), soda ash.
Undistributed	4,050	XX	4.48	
Total	90,400	XX	100.00	

[p]Preliminary. XX Not applicable.

[1]Includes data available through December 9, 2021.

[2]Data are rounded to no more than three significant digits; may not add to totals shown.

[3]Rank based on total, unadjusted State values.

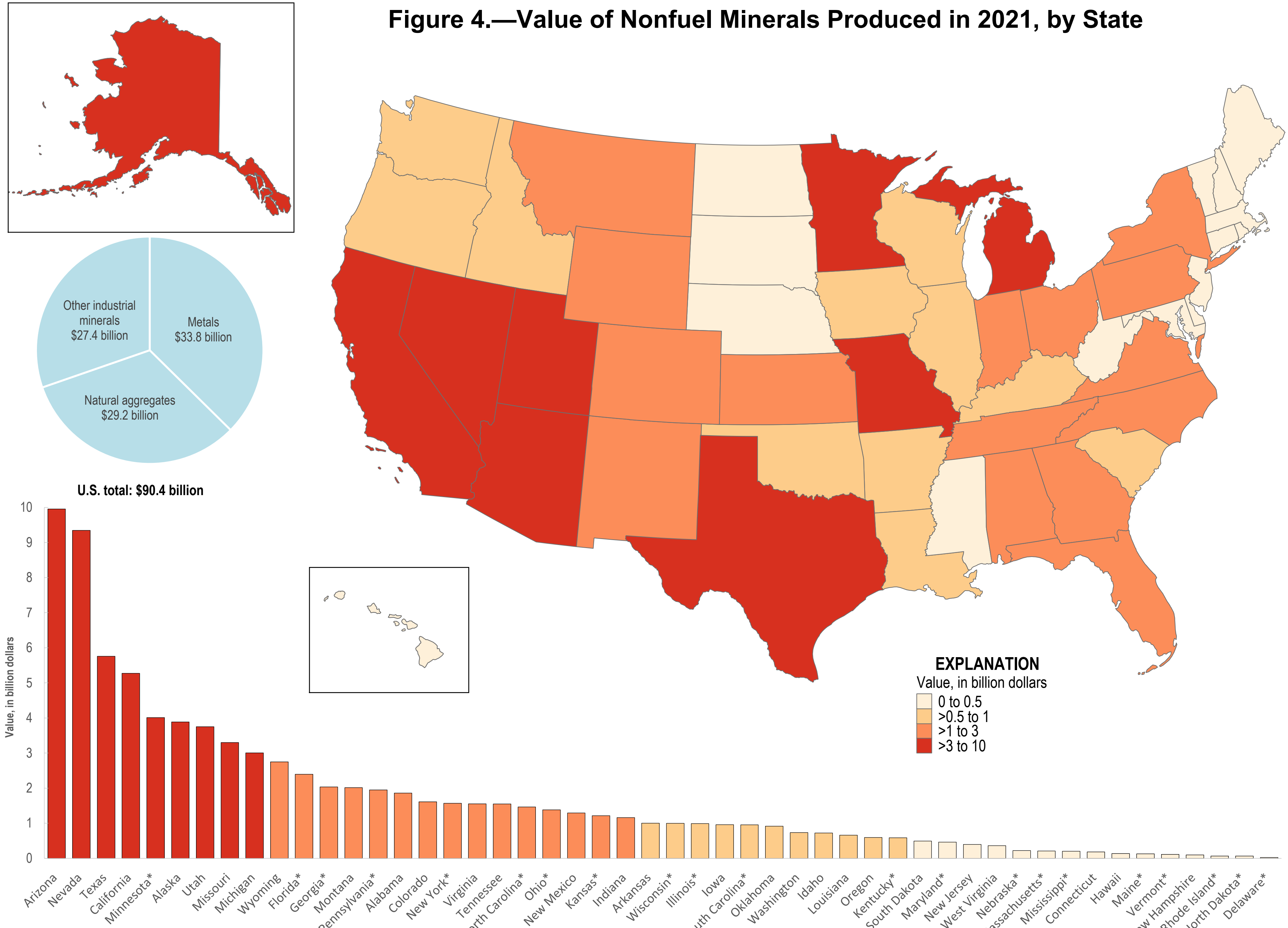
[4]"Percent of U.S. total" calculated to two decimal places.

[5]Listed in alphabetical order.

[6]Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed."

[7]Florida and Georgia also produce significant quantities of titanium and zirconium minerals concentrates, but breakdown by State is not available to avoid disclosing company proprietary data.

Figure 4.—Value of Nonfuel Minerals Produced in 2021, by State



*Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed" in table 3.

Figure 5.—Value of Metals and Metallic Minerals Produced in 2021, by Region

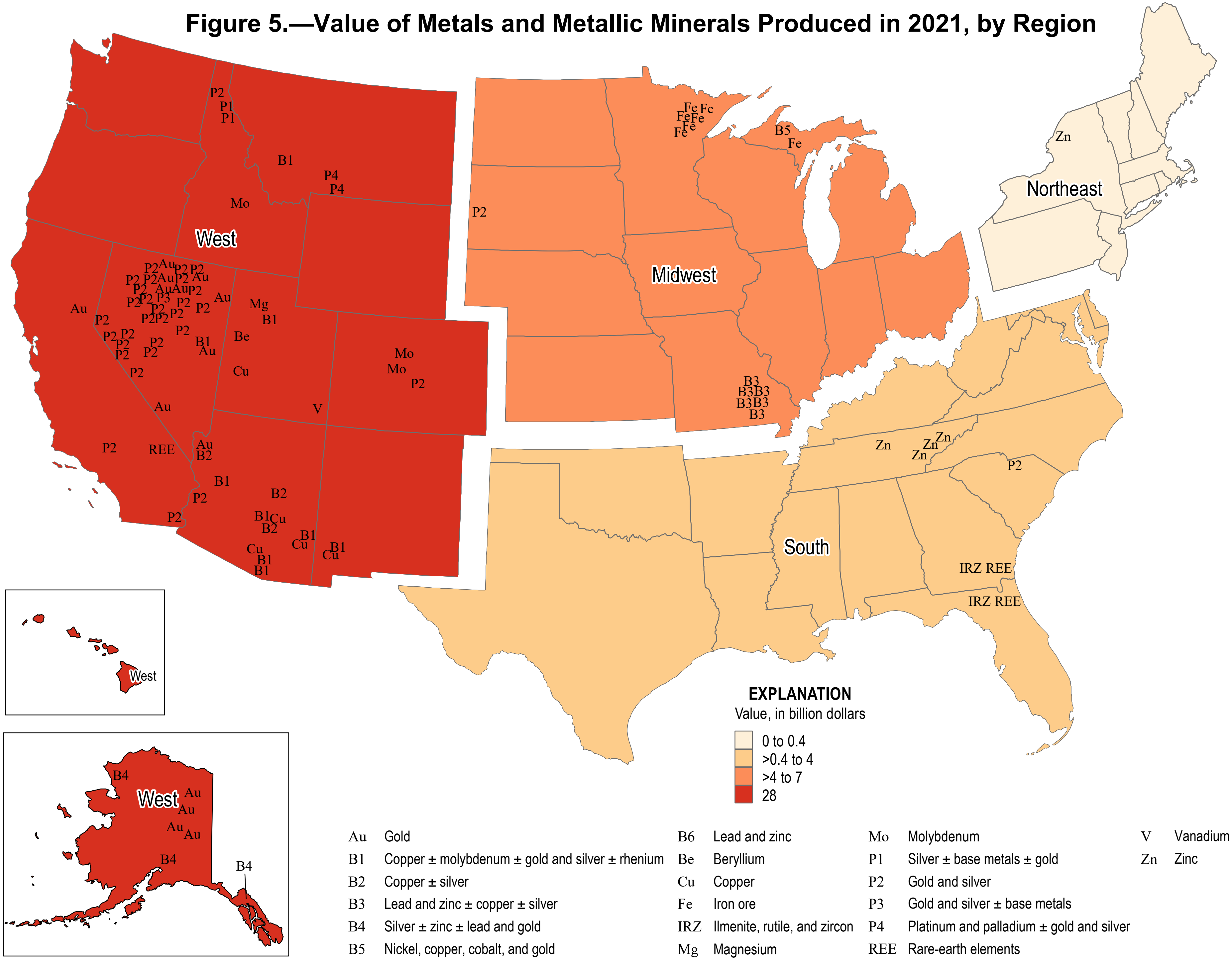


Figure 6.—Value of Other Industrial Minerals Produced in 2021, by Region

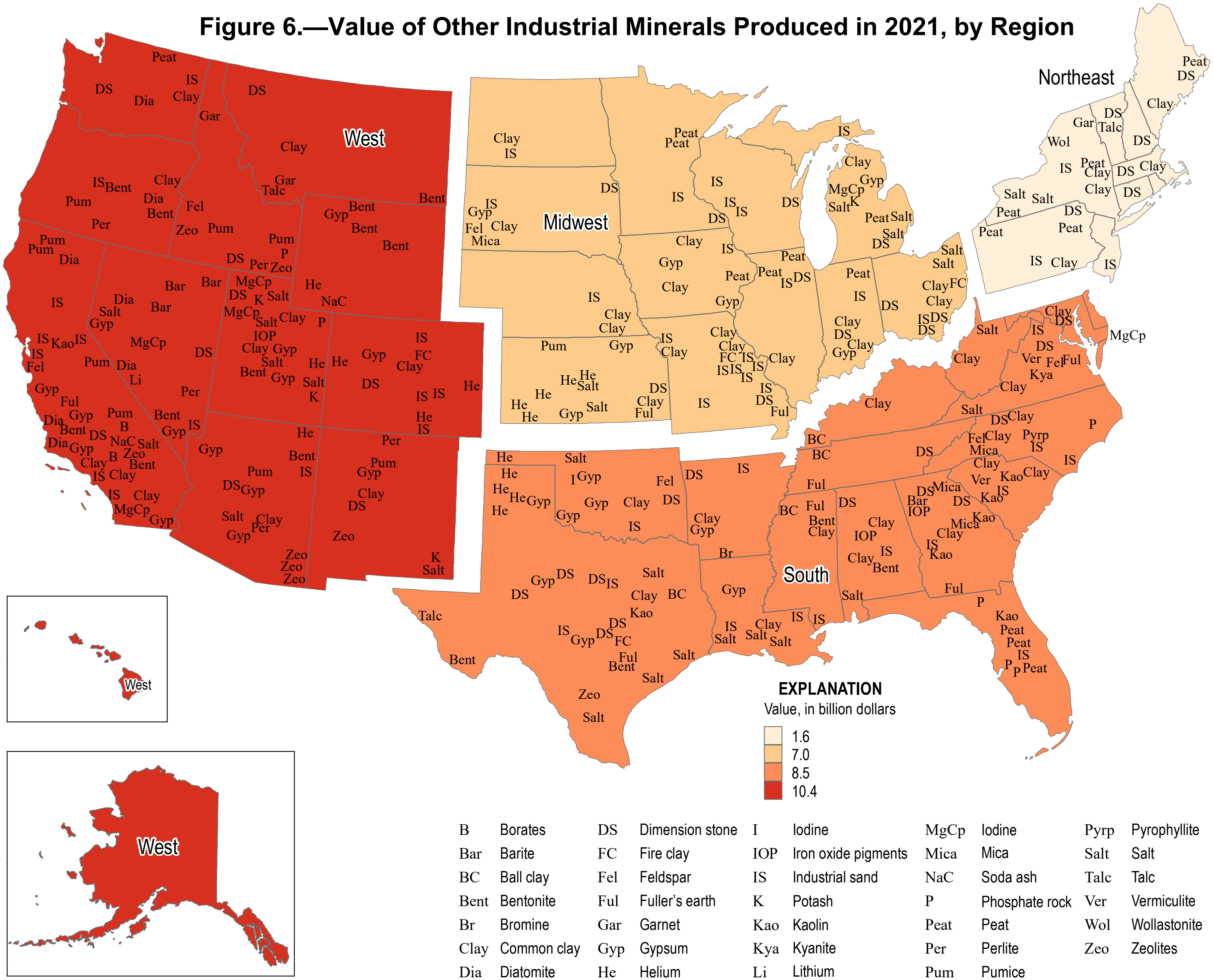


Figure 7.—Value of Crushed Stone Produced in 2021, by State

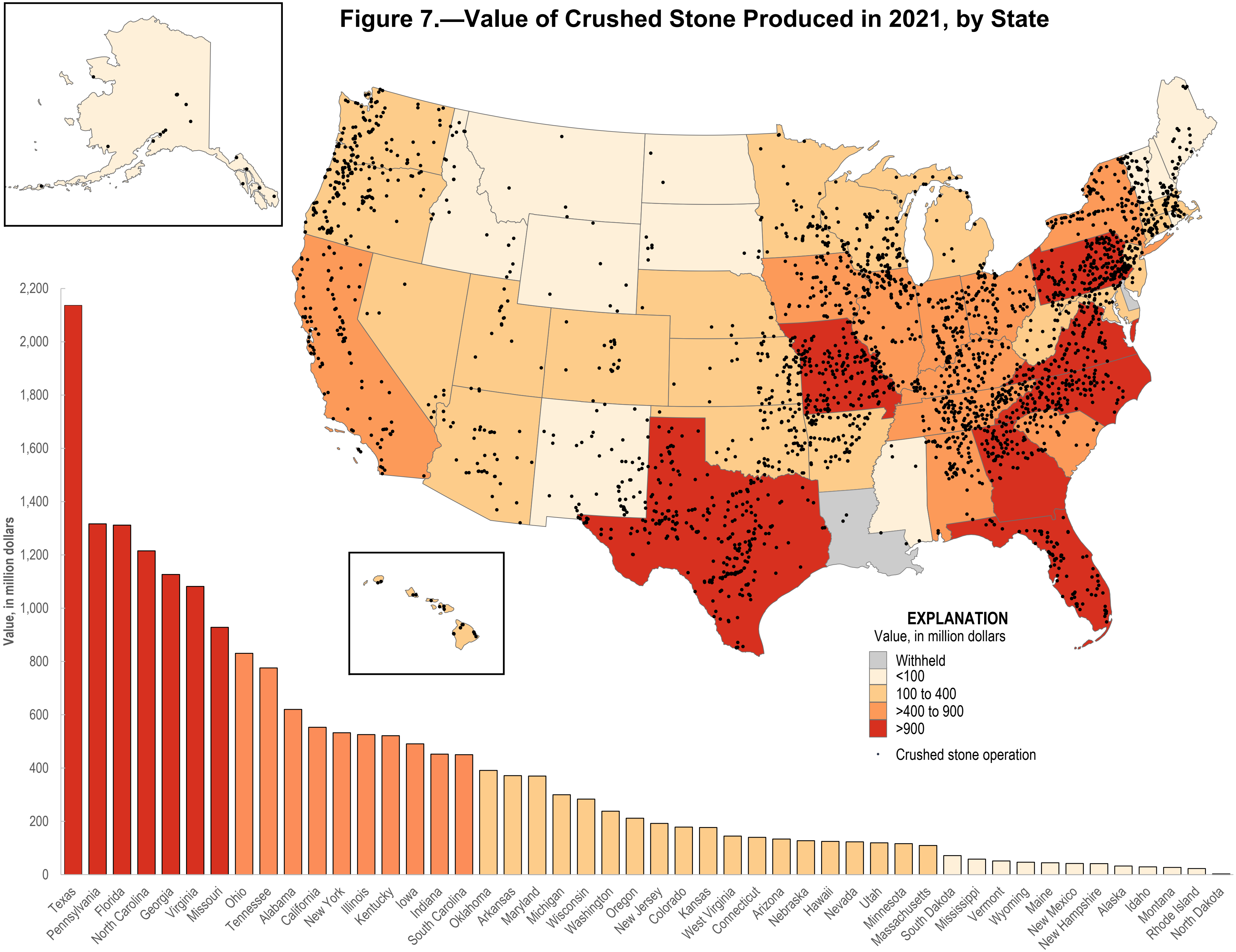
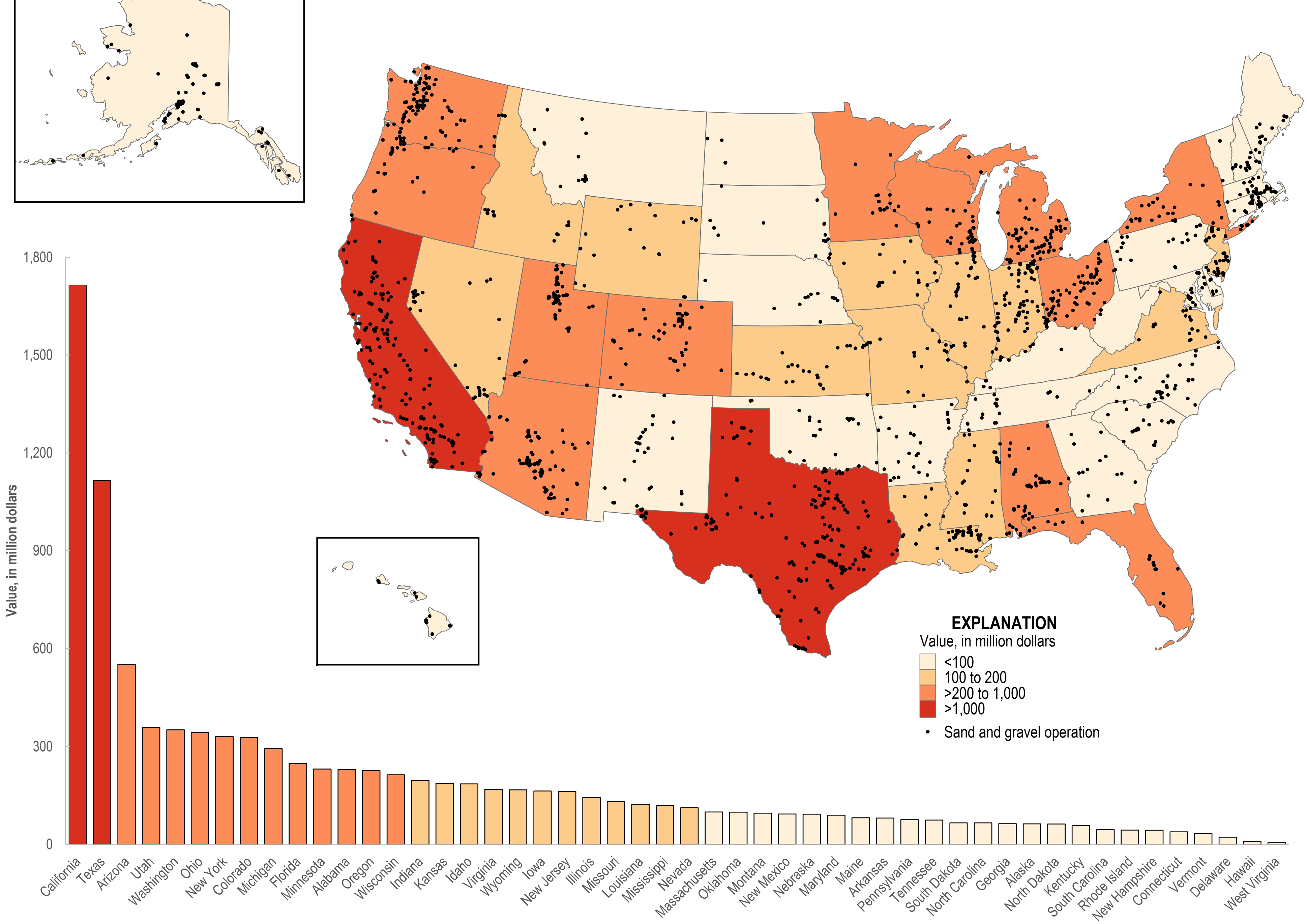


Figure 8.—Value of Construction Sand and Gravel Produced in 2021, by State



UNITED STATES CRITICAL MINERALS UPDATE

Critical Minerals and the U.S. Critical Minerals List

The Energy Act of 2020 (Public Law 116–260, December 27, 2020, 116th Cong.) defined critical minerals as those which are essential to the economic or national security of the United States; have a supply chain that is vulnerable to disruption; and serve an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economic or national security of the United States. The act further specified that critical minerals do not include fuel minerals; water, ice, or snow; or common varieties of sand, gravel, stone, pumice, cinders, and clay.

On May 7, 2021, Open-File Report 2021–1045, "Methodology and Technical Input for the 2021 Review and Revision of the U.S. Critical Minerals List" was published by the U.S. Geological Survey (USGS) as required by section 7002 of title VII of the Energy Act of 2020. The report documented the updated evaluation methodology and the resultant updated draft list of minerals recommended for inclusion in the U.S. critical minerals list (CML). Uranium was excluded by its definition as a fuel mineral in the Mining and Minerals Policy Act of 1970 [30 U.S.C. 21(a)].

On November 9, 2021, a proposed, revised U.S. CML was published in the Federal Register (86 FR 62199). This list contains 50 individual mineral commodities. It differs from the prior 2018 U.S. CML by individually listing the rare-earth elements and platinum-group elements by specific element forms, adding nickel and zinc, and removing helium, potash, rhenium, strontium, and uranium. As of the date of this publication, the proposed, revised U.S. CML has not yet been finalized. Following adjudication of public comments, a final, revised critical minerals list is anticipated to be posted to the Federal Register by the end of February 2022.

Supply Chain Security and U.S. Government Critical Minerals Initiatives

In 2021, several U.S. Government efforts were taken to strengthen U.S. critical mineral supply chains. Some examples of these are presented here. Additional information on specific mineral commodity initiatives may be found in the mineral commodity chapters that follow.

In 2020 and 2021, the U.S. Department of Defense awarded technology investment agreements to establish light-rare-earth-element separation facilities in Texas and California pursuant to section 303 of the Defense Production Act of 1950, as amended (50 U.S.C. 4533).

In April 2021, the U.S. Department of Energy (DOE) awarded $19 million for 13 projects to support production of rare-earth elements and critical minerals vital for the clean energy economy. Many of these awards were made to universities in traditional fossil-fuel-producing communities. In September 2021, the DOE awarded $30 million in funding for 13 national-lab- and university-led research projects focused on developing substitutes for, diversifying the supply of, and improving the reuse and recycling of rare-earth elements and platinum-group elements to support creating cleaner energy.

In September 2021, the U.S. Department of Defense's Office of Industrial Policy announced the kickoff of the "Critical Minerals from Coal Ash" pilot project, which was a 30-month project funded for $4 million to develop next-generation technologies for recovery of critical minerals, including rare-earth elements from domestic coal ash.

U.S. Production and Consumption of Critical Minerals in 2021

The United States was 100% net import reliant for 14 of the listed critical minerals or mineral groups. Despite not having mine production or refining, the United States did have secondary production for four critical minerals and thus net import reliance was less than 100%. Additionally, there was secondary production for another nine critical minerals that supplemented primary production (table 4).

China was the leading producing nation for 16 of the 32 listed critical minerals. The other leading producers of critical minerals were South Africa with four critical minerals; Australia, three critical minerals; Congo (Kinshasa), two critical minerals; and the United States, two critical minerals (table 4).

Figure 9 shows the trends in net import reliance for critical minerals over the past 20 years. For most critical minerals, the United States is heavily reliant on foreign sources for its consumption requirements; exceptions include beryllium, helium, and zirconium.

Trade

In November 2021, the U.S. Department of Commerce issued a notice of its final investigation into the effect of imports of vanadium on the national security of the United States under section 232 of the Trade Expansion Act of 1962 (86 FR 64748). The report concluded that current quantities of vanadium imports did not impair national security and no additional ad valorem duties were recommended.

Table 4.—Salient Critical Minerals Statistics in 2021[1]

(Metric tons, mine production, unless otherwise specified)

Critical mineral	United States: Primary production	Secondary production	Apparent consumption	Net import reliance as a percentage of apparent consumption	Primary import source (2017–20)	World: Leading producing country	Production in leading country	World production total	Percentage of world total
Aluminum (bauxite)	W	—	[2]3,600,000	>75	Jamaica	Australia	110,000,000	[3]390,000,000	28
Antimony	—	4,100	[4]28,000	84	China	China	60,000	110,000	55
Arsenic	—	—	[5]6,800	100	China	Peru	[6]27,000	[6]59,000	46
Barite	W	—	W	>75	China	China	2,800,000	[3]7,300,000	38
Beryllium	170	NA	200	16	Kazakhstan	United States	170	260	65
Bismuth[7]	—	80	810	90	China	China	16,000	19,000	84
Chromium	—	120,000	590,000	80	South Africa	South Africa	18,000,000	41,000,000	44
Cobalt	700	1,600	6,700	76	Norway	Congo (Kinshasa)	120,000	170,000	71
Fluorspar	NA	—	450,000	100	Mexico	China	5,400,000	8,600,000	63
Gallium	—	—	[2]16	100	China	China	420	430	98
Germanium[7]	—	W	[5]30	>50	China	China	95	[3]140	68
Graphite (natural)	—	—	45,000	100	China	China	820,000	1,000,000	82
Helium[8]	71	NA	40	E	Qatar	United States	71	160	44
Indium[7]	—	NA	[5]170	100	China	China	530	920	58
Lithium	W	W	[5]2,000	>25	Argentina	Australia	55,000	[3]100,000	55
Magnesium[7]	W	98,000	[2]50,000	<50	Canada	China	800,000	[3]950,000	84
Manganese	—	—	640,000	100	Gabon	South Africa	7,400,000	20,000,000	37
Niobium	—	NA	7,000	100	Brazil	Brazil	66,000	75,000	88
Palladium (platinum-group metal)	14	42	90	37	Russia	South Africa	80	200	40
Platinum (platinum-group metal)	4	7	37	70	South Africa	South Africa	130	180	72
Potash	480,000	—	7,400,000	93	Canada	Canada	14,000,000	46,000,000	30
Rare-earth elements[9]	43,000	—	[10]6,100	>90	China	China	168,000	280,000	60
Rhenium	9	NA	32	72	Chile	Chile	29	59	49
Scandium	—	—	NA	100	NA	China	NA	NA	NA
Strontium	—	—	4,800	100	Mexico	Spain	150,000	360,000	42
Tantalum	—	NA	710	100	China	Congo (Kinshasa)	700	2,100	33
Tellurium[7]	W	—	W	>95	Canada	China	340	[3]580	59
Tin	—	10,000	45,000	78	Indonesia	China	91,000	300,000	30
Titanium[7]	W	W	[2]W	>90	Japan	China	120,000	[3]210,000	57
Tungsten	—	W	W	>50	China	China	66,000	79,000	84
Vanadium	—	NA	3,600	100	Canada	China	73,000	110,000	66
Zirconium	[11]20,000	—	[11]30,000	<25	South Africa	Australia	400,000	1,200,000	33

E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Critical minerals as published in the Federal Register on May 18, 2018 (83 FR 23295). Not all critical minerals are listed here. Those not shown include mineral commodities for which not enough information is available regarding U.S. or world production. The critical minerals cesium, hafnium, and rubidium are not listed in the table because it is thought there is no U.S. production for these commodities.

[2]Reported consumption.

[3]Excludes U.S. production.

[4]Antimony in oxide and unwrought metal, powder.

[5]Estimated consumption.

[6]Arsenic trioxide.

[7]Refinery production.

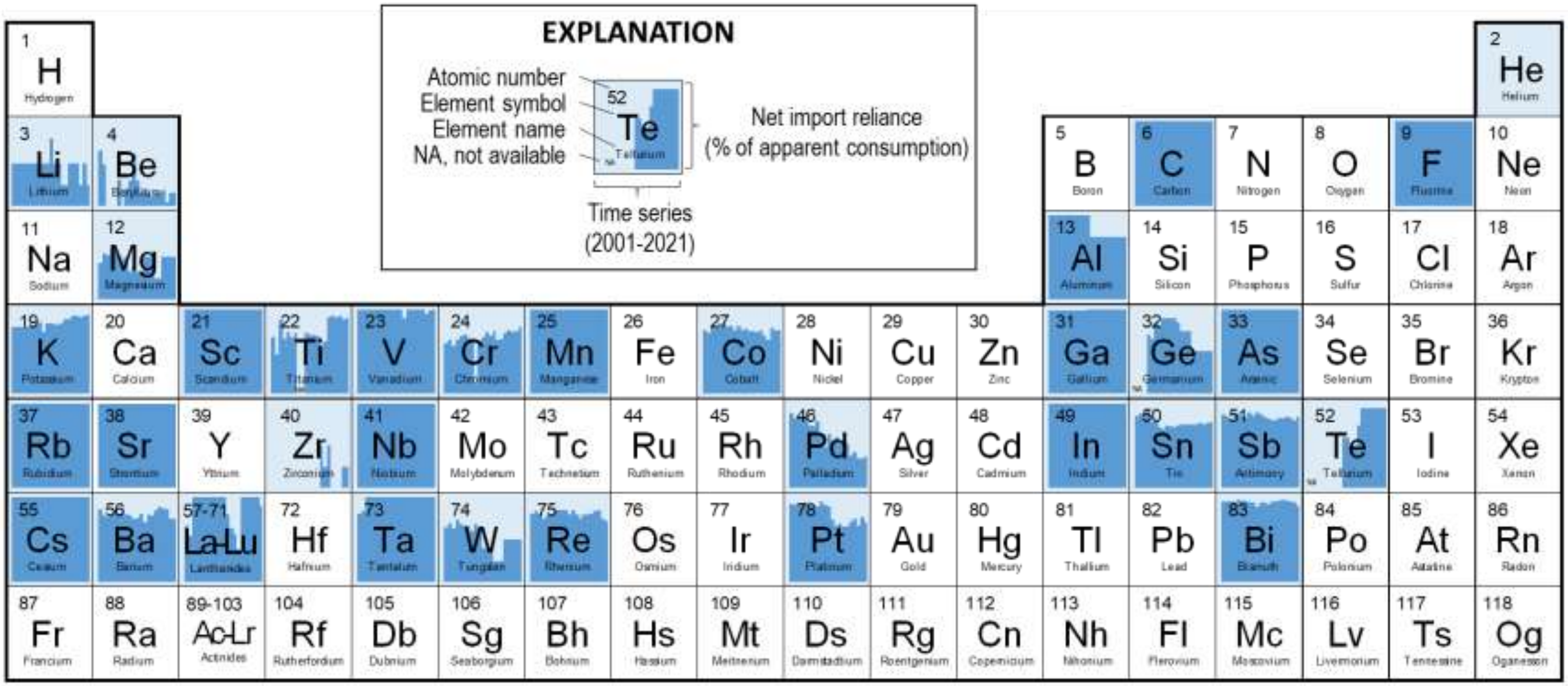
[8]Million cubic meters.

[9]Data include lanthanides and yttrium but exclude most scandium.

[10]Compounds and metals. The United States is a net exporter of mineral concentrates.

[11]Rounded to one significant digit to avoid disclosing company proprietary data.

Figure 9.—20-Year Trend of U.S. Net Import Reliance for Critical Minerals



For elements of the periodic table associated with mineral commodities identified as critical in 2018 (83 FR 23295), the figure displays the U.S. net import reliance (NIR) as a percent of apparent consumption from 2001 through 2021. Barite is listed under barium (Ba). Bauxite is listed under aluminum (Al). Fluorspar is listed under fluorine (F). Graphite (natural) is listed under carbon (C). Potash is listed under potassium (K). Rare earths are listed under lanthanides (La–Lu). Net import reliance data are not available (NA) for hafnium for 2001 through 2021, germanium prior to 2004, tellurium prior to 2010, and titanium for 2008 and 2009. For certain years, the NIR for barite, bauxite, germanium, lithium, magnesium, rare earths, tellurium, tungsten, and zirconium are rounded to avoid disclosing company proprietary data.

ABRASIVES (MANUFACTURED)

(Fused aluminum oxide, silicon carbide, and metallic abrasives)
(Data in metric tons unless otherwise noted)

Domestic Production and Use: Fused aluminum oxide was produced by two companies at three plants in the United States and Canada. Production of crude fused aluminum oxide had an estimated value of $3.0 million. Silicon carbide was produced by two companies at two plants in the United States. Production of crude silicon carbide had an estimated value of about $30 million. Metallic abrasives were produced by 11 companies in eight States. Production of metallic abrasives had an estimated value of about $100 million. Bonded and coated abrasive products accounted for most abrasive uses of fused aluminum oxide and silicon carbide. Metallic abrasives are used primarily for steel shot and grit and cut wire shot, which are used for sandblasting, peening, and stonecutting applications.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Fused aluminum oxide, crude[1, 2]	10,000	10,000	10,000	10,000	10,000
Silicon carbide[2]	35,000	35,000	35,000	35,000	35,000
Metallic abrasives	179,000	180,000	177,000	176,000	180,000
Shipments, metallic abrasives	197,000	196,000	195,000	194,000	200,000
Imports for consumption:					
Fused aluminum oxide	206,000	192,000	184,000	121,000	110,000
Silicon carbide	137,000	146,000	131,000	88,000	90,000
Metallic abrasives	29,600	29,900	27,900	25,800	29,000
Exports:					
Fused aluminum oxide	15,500	20,100	18,400	11,400	11,000
Silicon carbide	6,100	10,100	11,500	8,300	12,000
Metallic abrasives	31,000	33,600	31,200	18,100	20,000
Consumption, apparent:					
Fused aluminum oxide[3]	191,000	172,000	166,000	110,000	100,000
Silicon carbide[4]	166,000	171,000	155,000	115,000	110,000
Metallic abrasives[5]	196,000	192,000	192,000	202,000	200,000
Price, average unit value of imports, dollars per ton:					
Fused aluminum oxide, regular	489	681	716	666	630
Fused aluminum oxide, high-purity	1,220	1,290	1,250	1,180	1,300
Silicon carbide, crude	479	670	701	628	530
Metallic abrasives	1,020	1,180	1,310	1,130	1,300
Net import reliance[6] as a percentage of apparent consumption:					
Fused aluminum oxide	>75	>75	>75	>75	>75
Silicon carbide	>75	>75	>75	>50	>50
Metallic abrasives	E	E	E	4	5

Recycling: Up to 30% of fused aluminum oxide may be recycled, and about 5% of silicon carbide is recycled.

Import Sources (2017–20): Fused aluminum oxide, crude: China,[7] 91%; France, 3%; Bahrain and Russia, 2% each; and other, 2%. Fused aluminum oxide, grain: Canada, 22%; Brazil, 19%; Austria, 15%; China,[7] 12%; and other, 32%. Silicon carbide, crude: China,[7] 88%; the Netherlands and South Africa, 4% each; and other 4%. Silicon carbide, grain: China,[7] 47%; Brazil, 21%; Russia, 9%; Norway, 7%; and other, 16%. Metallic abrasives: Canada, 33%; China,[7] 15%; Turkey, 12%; Germany, 10%; and other, 30%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Artificial corundum, crude	2818.10.1000	Free.
White, pink, ruby artificial corundum, greater than 97.5% aluminum oxide, grain	2818.10.2010	1.3% ad valorem.
Artificial corundum, not elsewhere specified or included, fused aluminum oxide, grain	2818.10.2090	1.3% ad valorem.
Silicon carbide, crude	2849.20.1000	Free.
Silicon carbide, grain	2849.20.2000	0.5% ad valorem.
Iron, pig iron, or steel granules	7205.10.0000	Free.

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ABRASIVES (MANUFACTURED)

Depletion Allowance: None.

Government Stockpile: None.

Events, Trends, and Issues: In 2021, China was the world's leading producer of abrasive fused aluminum oxide and abrasive silicon carbide. Imports, especially from China where operating costs were lower, continued to challenge abrasives producers in the United States and Canada. In recent years, imports of abrasives from Hong Kong have also increased. Foreign competition is expected to persist and continue to limit production in North America. The average unit value of imports had increased every year since 2016 for regular fused aluminum oxide and crude silicon carbide but have decreased since 2020. The average unit values of imports of regular fused aluminum oxide and crude silicon carbide during the first 7 months of 2021 were 6% and 14% lower, respectively, than those in 2020 and 13% and 33% lower, respectively, than those in 2019.

Abrasives consumption in the United States is greatly influenced by activity in the manufacturing sectors, particularly the aerospace, automotive, furniture, housing, and steel industries. Automobile and steel production were greatly affected by the global COVID-19 pandemic as well as a global semiconductor chip shortage, which in turn reduced the demand for metallic abrasives.

Domestic production remains consistent, although foreign trade continues to be negatively affected by the COVID-19 pandemic. Imports and exports showed signs of recovery from 2020, but they remained significantly below pre-pandemic levels. Additionally, a global container shortage arose that greatly delayed shipments and caused container prices to nearly double compared with prices in 2020.

World Production Capacity:

	Fused aluminum oxide[e]		Silicon carbide[e]	
	2020	2021	2020	2021
United States	60,000	60,000	40,000	40,000
Australia	50,000	50,000	—	—
Austria	60,000	60,000	—	—
Brazil	50,000	50,000	40,000	40,000
China	800,000	800,000	450,000	450,000
France	40,000	40,000	20,000	20,000
Germany	80,000	80,000	35,000	35,000
India	40,000	40,000	5,000	5,000
Japan	15,000	15,000	60,000	60,000
Mexico	—	—	45,000	45,000
Norway	—	—	80,000	80,000
Venezuela	—	—	30,000	30,000
Other countries	80,000	80,000	200,000	200,000
World total (rounded)	1,300,000	1,300,000	1,000,000	1,000,000

World Resources:[8] Although domestic resources of raw materials for fused aluminum oxide production are limited, adequate resources are available in the Western Hemisphere. Domestic resources are more than adequate for silicon carbide production.

Substitutes: Natural and manufactured abrasives, such as garnet, emery, or metallic abrasives, can be substituted for fused aluminum oxide and silicon carbide in various applications.

[e]Estimated. E Net exporter. — Zero.

[1]Production data for aluminum oxide are combined production data from the United States and Canada to avoid disclosing company proprietary data.

[2]Rounded to the nearest 5,000 tons to avoid disclosing company proprietary data.

[3]Defined as imports – exports because production includes data from Canada; actual consumption is higher than that shown.

[4]Defined as production + imports – exports.

[5]Defined as shipments + imports – exports.

[6]Defined as imports – exports.

[7]Includes Hong Kong.

[8]See Appendix C for resource and reserve definitions and information concerning data sources.

ALUMINUM[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, three companies operated six primary aluminum smelters in five States. Two smelters operated at full capacity and four smelters operated at reduced capacity throughout the year. Another smelter remained on standby throughout the year, and one that had been on standby since 2015 was permanently shut down in December. Domestic smelters were operating at about 55% of capacity of 1.64 million tons per year at yearend 2021. Estimated primary production decreased by 13% compared with that in 2020 but estimated secondary production from new and old scrap increased by 5% compared with that in 2021. Based on published prices, the value of primary aluminum production was about $2.70 billion, 35% more than the value in 2020. The average annual U.S. market price increased by about 55% from that in 2020. Transportation applications accounted for 35% of domestic consumption; in descending order of consumption, the remainder was used in packaging, 23%; building, 16%; electrical, 9%; consumer durables, 7%; machinery, 7%; and other, 3%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Primary	741	891	1,093	1,012	880
Secondary (from old scrap)	1,590	1,570	1,540	1,420	1,500
Secondary (from new scrap)	2,050	2,140	1,920	1,630	1,700
Imports for consumption:					
Crude and semimanufactures	6,220	5,550	5,280	4,320	4,800
Scrap	700	695	596	542	700
Exports:					
Crude and semimanufactures	1,330	1,310	1,110	905	820
Scrap	1,570	1,760	1,860	1,850	2,000
Consumption, apparent[2]	5,680	4,900	4,980	3,980	4,300
Supply, apparent[3]	7,730	7,040	6,910	5,620	6,000
Price, ingot, average U.S. market (spot), cents per pound	98.3	114.7	99.5	89.7	140
Stocks, yearend:					
Aluminum industry	1,470	1,570	1,600	1,490	1,700
London Metal Exchange (LME), U.S. warehouses[4]	254	186	[e]120	235	100
Employment, number[5]	31,700	31,600	32,900	30,100	30,000
Net import reliance[6] as a percentage of apparent consumption	59	50	47	39	44

Recycling: In 2021, aluminum recovered from purchased scrap in the United States was about 3.2 million tons, of which about 53% came from new (manufacturing) scrap and 47% from old scrap (discarded aluminum products). Aluminum recovered from old scrap was equivalent to about 30% of apparent consumption.

Import Sources (2017–20): Canada, 50%; the United Arab Emirates, 9%; Russia, 6%; China,[7] 4%; and other, 31%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Aluminum, not alloyed:		
Unwrought (in coils)	7601.10.3000	2.6% ad valorem.
Unwrought (other than aluminum alloys)	7601.10.6000	Free.
Aluminum alloys, unwrought (billet)	7601.20.9045	Free.
Aluminum scrap:		
Used beverage container scrap	7602.00.0030	Free.
Industrial process scrap	7602.00.0091	Free.

Depletion Allowance: Not applicable.[1]

Government Stockpile: None.

Events, Trends, and Issues: In March, a primary aluminum smelter in Mount Holly, SC, signed a new power supply contract through the end of 2023. The contract would provide enough power for the 230,000-ton-per-year smelter to restart about 57,000 tons per year of capacity. The smelter had only been producing at a rate of 115,000 tons per year. The restart of the additional capacity was expected to be completed early in 2022 after maintenance was completed. In December, the temporary shutdown of a 146,000-ton-per-year smelter in Wenatchee, WA, was made permanent. The smelter last produced in 2015. Prices for aluminum generally trended upward throughout 2021 in the United States and in world markets. High power prices attributed to higher coal prices and shutdowns of powerplants complying with environmental regulations were cited for increased aluminum prices in China, the world's leading

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producer. Additionally, higher prices for alumina amid shutdowns of alumina refineries in Brazil and China in July and in Jamaica in August added pressure to production costs for smelters.

In June, the U.S. Department of Commerce (DOC) opened the Aluminum Import Monitoring and Analysis (AIM) system (https://www.trade.gov/aluminum) for submitting applications for required licenses to import covered aluminum products. The AIM system is intended to aid in enforcement of trade agreements and circumvent evasion of tariffs and quotas on aluminum and aluminum products. In October, an agreement was reached between the United States and the European Union to remove the 10% ad valorem tariff on aluminum imports that was imposed in 2018 under the authority of section 232 of the Trade Expansion Act of 1964. Effective in January 2022, the tariff would only be applied on imports from countries in the European Union that exceed specified quotas.

In 2021, the DOC issued final determinations of antidumping and countervailing duty investigations for aluminum foil imports and common alloy aluminum sheet imports. Foil imports from China between August 14, 2017, and December 31, 2018, had antidumping duty rates assessed that ranged from 23.62% to 47.57% and countervailing duty rates that ranged from 17.05% to 48.36%. Final countervailing determinations of aluminum foil imports from Oman and Turkey in 2019 were made by the U.S. International Trade Commission in September with countervailing duty rates set at 1.93% for imports from Oman and 2.6% for imports from Turkey. In October, the DOC issued final antidumping duty rates for aluminum foil imported between July 1, 2019, and June 30, 2020, ranging from 29.11% for Armenia, 13.93% to 63.05% for Brazil, 3.89% for Oman, and 62.18% for Russia. In March, the DOC issued its final determinations of an antidumping investigation of common alloy aluminum sheet imports from 18 countries and determined that imports produced in 16 countries were sold below fair market value. The countervailing duty investigation determined that producers in three countries also benefited from Government subsidy programs.

World Smelter Production and Capacity: Capacity data for Bahrain, China, the United Arab Emirates, and the United States were revised based on company and Government data.

	Smelter production		Yearend capacity	
	2020	2021[e]	2020	2021[e]
United States	1,012	880	1,790	1,640
Australia	1,580	1,600	1,720	1,720
Bahrain	1,550	1,500	1,550	1,550
Canada	3,120	3,100	3,270	3,270
China	37,100	39,000	42,300	43,000
Iceland	860	880	890	890
India	3,560	3,900	4,060	4,060
Norway	1,330	1,400	1,430	1,430
Russia	3,640	3,700	4,020	4,020
United Arab Emirates	2,520	2,600	2,700	2,780
Other countries	8,880	9,400	12,300	12,300
World total (rounded)	65,100	68,000	76,000	77,000

World Resources:[8] Global resources of bauxite are estimated to be between 55 billion and 75 billion tons and are sufficient to meet world demand for metal well into the future.

Substitutes: Composites can substitute for aluminum in aircraft fuselages and wings. Glass, paper, plastics, and steel can substitute for aluminum in packaging. Composites, magnesium, steel, and titanium can substitute for aluminum in ground transportation uses. Composites, steel, vinyl, and wood can substitute for aluminum in construction. Copper can replace aluminum in electrical and heat-exchange applications.

[e]Estimated.
[1]See also Bauxite and Alumina.
[2]Defined as primary production + secondary production from old scrap + imports – exports + adjustments for stock changes; excludes imported scrap.
[3]Defined as primary production + secondary production + imports – exports + adjustments for stock changes; excludes imported scrap.
[4]Includes aluminum alloy. Starting with 2019, also includes off-warrant stocks of primary and alloyed aluminum; estimated for 2019.
[5]Alumina and aluminum production workers (North American Industry Classification System—3313). Source: U.S. Department of Labor, Bureau of Labor Statistics.
[6]Defined as imports – exports + adjustments for industry stock changes; excludes imported scrap.
[7]Includes Hong Kong.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.

ANTIMONY

(Data in metric tons of contained antimony unless otherwise noted)

Domestic Production and Use: In 2021, no marketable antimony was mined in the United States. A mine in Nevada that had extracted about 800 tons of stibnite ore from 2013 through 2014 was placed on care-and-maintenance status in 2015 and had no reported production in 2021. Primary antimony metal and oxide were produced by one company in Montana using imported feedstock. Secondary antimony production was derived mostly from antimonial lead recovered from spent lead-acid batteries. The estimated value of secondary antimony produced in 2021 was about $47 million. Recycling supplied about 15% of estimated domestic consumption, and the remainder came mostly from imports. The value of antimony consumption in 2021 was about $320 million. In the United States, the leading uses of antimony were as follows: flame retardants, 40%; metal products, including antimonial lead and ammunition, 36%; and nonmetal products, including ceramics and glass and rubber products, 24%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine (recoverable antimony)	—	—	—	—	—
Smelter:					
Primary	621	331	377	254	460
Secondary	4,370	4,090	4,140	4,250	4,100
Imports for consumption:					
Ore and concentrates	61	96	121	105	29
Oxide	17,800	19,200	17,300	15,000	18,000
Unwrought, powder	6,810	6,320	6,670	5,520	7,700
Waste and scrap[1]	16	202	17	6	11
Exports:					
Ore and concentrates[1]	46	38	9	10	11
Oxide	1,600	1,750	1,570	1,230	1,600
Unwrought, powder	643	497	370	393	770
Waste and scrap[1]	11	9	14	11	130
Consumption, apparent[2]	27,400	27,700	26,400	23,400	28,000
Price, metal, average, dollars per pound[3]	3.77	3.81	3.04	2.67	5.20
Net import reliance[4] as a percentage of apparent consumption	82	84	83	81	84

Recycling: The bulk of secondary antimony is recovered at secondary lead smelters as antimonial lead, most of which was generated by, and then consumed by, the lead-acid battery industry.

Import Sources (2017–20): Ore and concentrates: China, 42%; Italy, 36%; India, 11%; Mexico, 4%; and other, 7%. Oxide: China,[5] 71%; Belgium, 10%; Bolivia, 6%; Thailand, 5%; and other, 8%. Unwrought metal and powder: China,[5] 37%; India, 24%; Vietnam, 11%; Burma, 9%; and other, 19%. Total metal and oxide: China,[5] 63%; Belgium, 7%; India, 6%; and other, 24%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Ore and concentrates	2617.10.0000	Free.
Antimony oxide	2825.80.0000	Free.
Antimony and articles thereof:		
Unwrought antimony; powder	8110.10.0000	Free.
Waste and scrap	8110.20.0000	Free.
Other	8110.90.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[6]

		FY 2021		**FY 2022**	
Material	**Inventory as of 9–30–21**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Antimony	90.12	1,100	—	1,100	—

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ANTIMONY

Events, Trends, and Issues: China continued to be the leading global antimony producer in 2021 and accounted for 55% of global mine production, followed by Russia, 23%, and Tajikistan, 12%. The supply of antimony raw materials and downstream production of antimony products was constrained in 2021 as a result of environmental audits in China and various temporary mine shutdowns to mitigate the spread of the global COVID-19 pandemic. The raw material shortage combined with the worldwide shipping delays caused a supply shortage of refined antimony on the market, and the antimony price reached a high of $6.65 per pound in October 2021 compared with the annual average price of $2.67 per pound in 2020.

World Mine Production and Reserves: Reserves for Australia and Burma were revised based on Government and industry reports.

	Mine production		Reserves[7]
	2020	2021[e]	
United States	—	—	[8]60,000
Australia	3,900	3,400	[9]100,000
Bolivia	2,600	2,700	310,000
Burma	2,200	2,000	140,000
Canada	2	2	78,000
China	61,000	60,000	480,000
Guatemala	80	80	NA
Iran	400	400	NA
Kazakhstan	100	100	NA
Kyrgyzstan	—	—	260,000
Mexico	700	700	18,000
Pakistan	17	20	26,000
Russia (recoverable)	25,000	25,000	350,000
Tajikistan	13,000	13,000	50,000
Turkey	1,330	1,300	100,000
Vietnam	390	400	NA
World total (rounded)	111,000	110,000	>2,000,000

World Resources:[7] U.S. resources of antimony are mainly in Alaska, Idaho, Montana, and Nevada. Principal identified world resources are in Australia, Bolivia, Burma, China, Mexico, Russia, South Africa, and Tajikistan. Additional antimony resources may occur in Mississippi Valley-type lead deposits in the Eastern United States.

Substitutes: Selected organic compounds and hydrated aluminum oxide are substitutes as flame retardants. Chromium, tin, titanium, zinc, and zirconium compounds substitute for antimony chemicals in enamels, paint, and pigments. Combinations of calcium, copper, selenium, sulfur, and tin are substitutes for alloys in lead-acid batteries.

[e]Estimated. NA Not available. — Zero.
[1]Gross weight.
[2]Defined as primary production + secondary production from old scrap + imports of antimony in oxide and unwrought metal, powder – exports of antimony in oxide and unwrought metal, powder + adjustments for Government stock changes.
[3]Antimony minimum 99.65%, cost, insurance, and freight. Source: Argus Media group—Argus Metals International.
[4]Defined as imports of antimony in oxide and unwrought metal, powder – exports of antimony in oxide and unwrought metal, powder + adjustments for Government stock changes.
[5]Includes Hong Kong.
[6]See Appendix B for definitions.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]Company-reported probable reserves for the Stibnite Gold Project in Idaho.
[9]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 18,000 tons.

ARSENIC

(Data in metric tons of contained arsenic[1] unless otherwise noted)

Domestic Production and Use: Arsenic trioxide and primary arsenic metal have not been produced in the United States since 1985. The principal use for arsenic trioxide was for the production of arsenic acid used in the formulation of chromated copper arsenate (CCA) preservatives for the pressure treating of lumber used primarily in nonresidential applications. Seven companies produced CCA-treated wood in the United States in 2021. The grids in lead-acid storage batteries were strengthened by the addition of arsenic metal. Arsenic metal also was used as an antifriction additive for bearings, to harden lead shot, and in clip-on wheel weights. Arsenic compounds were used in herbicides and insecticides. High-purity (99.9999%) arsenic metal was used to produce gallium-arsenide (GaAs) semiconductors for solar cells, space research, and telecommunications. Arsenic also was used for germanium-arsenide-selenide specialty optical materials. Indium-gallium-arsenide (InGaAs) was used for short-wave infrared technology. The value of arsenic compounds and metal imported domestically in 2021 was estimated to be about $8 million. Given that arsenic metal has not been produced domestically since 1985, it is likely that only a small portion of the material reported by the U.S. Census Bureau as arsenic exports was pure arsenic metal, and most of the material that was reported under this category reflects the gross weight of alloys, compounds, residues, scrap, and waste containing arsenic. Therefore, the estimated consumption reported under U.S. salient statistics reflects only imports of arsenic products.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Imports for consumption:					
Arsenic metal	942	929	391	522	750
Compounds	5,980	5,540	7,090	7,780	6,000
Exports, all forms of arsenic (gross weight)	698	107	56	29	40
Consumption, estimated, all forms of arsenic[2]	6,920	6,470	7,480	8,300	6,800
Price, average unit value of imports (free alongside ship),[3] dollars per kilogram:					
Arsenic metal (China)	1.56	1.43	1.93	1.51	1.28
Trioxide (China)	0.45	0.44	0.46	0.43	0.43
Trioxide (Morocco)	0.68	0.75	0.78	0.83	0.84
Net import reliance[4] as a percentage of estimated consumption, all forms of arsenic	100	100	100	100	100

Recycling: Arsenic metal was contained in new scrap recycled during GaAs semiconductor manufacturing. Arsenic-containing process water was internally recycled at wood treatment plants where CCA was used. Although scrap electronic circuit boards, relays, and switches may contain arsenic, no arsenic was known to have been recovered during the recycling process to recover other contained metals. No arsenic was recovered domestically from arsenic-containing residues and dusts generated at nonferrous smelters in the United States.

Import Sources (2017–20): Arsenic metal: China,[5] 95%; Japan, 4%; and other, 1%. Arsenic trioxide: China, 57%; Morocco, 38%; Belgium, 4%; and other, 1%. All forms of arsenic: China,[5] 60%; Morocco, 34%; Belgium, 3%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Arsenic metal	2804.80.0000	Free.
Arsenic acid	2811.19.1000	2.3% ad valorem.
Arsenic trioxide	2811.29.1000	Free.
Arsenic sulfide	2813.90.1000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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ARSENIC

Events, Trends, and Issues: Peru, China, and Morocco, in descending order, were the leading global producers of arsenic trioxide, accounting for about 98% of estimated world production. China and Morocco continued to supply about 90% of United States imports of arsenic trioxide in 2021. China was the leading world producer of arsenic metal and supplied about 94% of United States arsenic metal imports in 2021.

High-purity arsenic metal was used to produce GaAs, indium-arsenide, and InGaAs semiconductors that were used in biomedical, communications, computer, electronics, and photovoltaic applications. Total revenues from GaAs devices increased in 2021 because of fifth-generation (5G) technology that became standard for broadband cellular 5G networks and consumer devices. A variety of GaAs wafer manufacturers ranging from large, multinational corporations to small, privately owned companies competed in this industry, but the top six producers accounted for more than 75% of the market. China and Japan each produced about 30% of global GaAs, followed by Europe (20%), North America (15%), and the rest of the world (5%). See the Gallium chapter for additional details.

World Production and Reserves (gross weight):

	Production[e, 6] (arsenic trioxide) 2020	2021	Reserves[7]
United States	—	—	World reserves data are unavailable but are thought to be more than 20 times world production.
Belgium	1,000	1,000	
Bolivia	100	160	
China	24,000	24,000	
Japan	40	40	
Morocco	7,700	7,000	
Peru	27,000	27,000	
Russia	120	100	
World total (rounded)	60,000	59,000	

World Resources:[7] Arsenic may be obtained from copper, gold, and lead smelter flue dust, as well as from roasting arsenopyrite, the most abundant ore mineral of arsenic. Arsenic has been recovered from orpiment and realgar in China, Peru, and the Philippines and from copper-gold ores in Chile, and arsenic was associated with gold occurrences in Canada. Orpiment and realgar from gold mines in Sichuan Province, China, were stockpiled for later recovery of arsenic. Arsenic also may be recovered from enargite, a copper mineral. Arsenic trioxide was produced at the hydrometallurgical complex of Guemassa, near Marrakech, Morocco, from cobalt-arsenide ore from the Bou Azzer Mine.

Substitutes: Substitutes for CCA in wood treatment include alkaline copper quaternary, ammoniacal copper quaternary, ammoniacal copper zinc arsenate, alkaline copper quaternary boron-based preservatives, copper azole, copper citrate, and copper naphthenate. Treated wood substitutes include concrete, plastic composite material, plasticized wood scrap, or steel. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier third-generation cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. In many defense-related applications, GaAs-based integrated circuits are used because of their unique properties, and no effective substitutes exist for GaAs in these applications. In heterojunction bipolar transistors, GaAs is being replaced in some applications by silicon-germanium.

[e]Estimated. — Zero.
[1]Arsenic content of arsenic metal is 100%; arsenic content of arsenic compounds is 77.7% for arsenic acids, 60.7% for arsenic sulfides, and 75.71% for arsenic trioxide.
[2]Estimated to be the same as imports.
[3]Calculated from U.S. Census Bureau import data.
[4]Defined as imports.
[5]Includes Hong Kong.
[6]Includes calculated arsenic trioxide equivalent of output of elemental arsenic compounds other than arsenic trioxide; inclusion of such materials would not duplicate reported arsenic trioxide production. Chile and Mexico were thought to be significant producers of commercial-grade arsenic trioxide but have reported no production in recent years.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.

ASBESTOS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: The last U.S. producer of asbestos ceased operations in 2002 as a result of the decline in domestic and international asbestos markets associated with health and liability issues. The United States has since been wholly dependent on imports to meet manufacturing needs. All the asbestos fiber currently imported into and used within the United States consists of chrysotile. In 2021, domestic consumption of chrysotile was estimated to be 320 tons, and all imports originated from Brazil, based on data available through July. The chloralkali industry, which uses chrysotile to manufacture nonreactive semipermeable diaphragms that prevent chlorine generated at the anode of an electrolytic cell from reacting with sodium hydroxide generated at the cathode, has accounted for 100% of asbestos fiber consumption since at least 2015. In addition to asbestos fiber, a small, but unknown, quantity of asbestos is imported annually within manufactured products. According to the U.S. Environmental Protection Agency (EPA), the only imported items known to contain asbestos are brake blocks for use in the oil industry, preformed gaskets used in the exhaust system of a specific type of utility vehicle, rubber sheets for gasket fabrication (primarily used to create a chemical containment seal in the production of titanium dioxide), and some vehicle friction products.[1]

Salient Statistics—United States:[2]	2017	2018	2019	2020	2021[e]
Imports for consumption[3]	332	681	172	305	[4]100
Exports[5]	—	—	—	—	—
Consumption, estimated[6]	520	500	450	450	320
Price, average U.S. customs unit value, dollars per ton	1,870	1,670	1,570	2,110	2,000
Net import reliance[7] as a percentage of estimated consumption	100	100	100	100	100

Recycling: None.

Import Sources (2017–20): Brazil, 80%; and Russia, 20%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Crocidolite	2524.10.0000	Free.
Amosite	2524.90.0010	Free.
Chrysotile:		
Crudes	2524.90.0030	Free.
Milled fibers, group 3 grades	2524.90.0040	Free.
Milled fibers, group 4 and 5 grades	2524.90.0045	Free.
Other	2524.90.0055	Free.
Other, asbestos	2524.90.0060	Free.

Depletion Allowance: 22% (domestic), 10% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of asbestos fiber in the United States has decreased during the past several decades, falling from a record high of 803,000 tons in 1973 to approximately 520 tons or less in each year since 2017. This decline has taken place as a result of health and liability issues associated with asbestos use, leading to the displacement of asbestos from traditional domestic markets by substitutes, alternative materials, and new technology. The chloralkali industry is the only remaining domestic consumer of asbestos in mineral form. Asbestos diaphragms are used in at least 11 chloralkali plants in the United States and account for about one-third of domestic chlorine production.

The Frank R. Lautenberg Chemical Safety for the 21st Century Act, which amended the Toxic Substances Control Act of 1976 (TSCA), was signed into law in 2016. The legislation granted the EPA greater authority to evaluate the hazards posed by new chemicals as well as those already in the marketplace. The EPA issued the final risk evaluation report for chrysotile in 2020. The agency determined that the disposal, processing, and (or) use of chrysotile in the chloralkali industry and in all chrysotile-containing manufactured products that are currently imported into the United States (oil industry brake blocks, sheet and other gaskets, and some vehicle friction products) present unreasonable risks to human health. As required by the TSCA, the EPA will propose and finalize actions to address these risks by yearend 2022. The new regulations could include limitations or prohibitions on the disposal, distribution in commerce, manufacture, processing, or use of chrysotile.[1]

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ASBESTOS

Estimated worldwide consumption of asbestos fiber decreased from approximately 2 million tons in 2010 to roughly 1.2 million tons per year in the past several years. Asbestos-cement products, such as corrugated roofing tiles, pipes, and wall panels, are expected to continue to be the leading global market for asbestos.

In Brazil, a comprehensive national ban on asbestos was enacted in November 2017. A judicial injunction allowed the only asbestos producer in the country to continue operating until February 2019, when production ceased. In July 2019, the government of the State of Goias passed a law that authorized the extraction of asbestos in the State for export purposes, and ore processing was restarted in February 2020. In August 2021, the Federal Court of Uruacu ruled that the company must immediately suspend mining, processing, and export of asbestos.

At the former King Mine in Mashava, Zimbabwe, asbestos production from old tailings commenced in 2019. As of March 2020, the company had completed dewatering of the mining shafts and was in the process of selling real estate assets to fund the restart of mining operations and dewatering an additional asbestos mine in Zvishavane. At full capacity, the King Mine was expected to produce 75,000 tons per year of asbestos. Updates on the status of these projects were not available as of September 2021.

World Mine Production and Reserves:

	Mine production[e]		
	2020	**2021**	**Reserves[8]**
United States	—	—	Small
Brazil	[9]71,200	110,000	11,000,000
China	120,000	120,000	95,000,000
Kazakhstan	[10]227,000	250,000	Large
Russia	720,000	700,000	110,000,000
Zimbabwe	8,000	10,000	Large
World total (rounded)	1,100,000	1,200,000	Large

World Resources:[8] Reliable evaluations of global asbestos resources have not been published recently, and available information was insufficient to make accurate estimates for many countries. However, world resources are large and more than adequate to meet anticipated demand in the foreseeable future. Resources in the United States are composed mostly of short-fiber asbestos for which use in asbestos-based products is more limited than long-fiber asbestos.

Substitutes: Numerous materials substitute for asbestos. Substitutes include calcium silicate, carbon fiber, cellulose fiber, ceramic fiber, glass fiber, steel fiber, wollastonite, and several organic fibers, such as aramid, polyethylene, polypropylene, and polytetrafluoroethylene. Several nonfibrous minerals or rocks, such as perlite, serpentine, silica, and talc, are also considered to be possible asbestos substitutes for products in which the reinforcement properties of fibers are not required. Membrane cells and mercury cells are alternatives to asbestos diaphragms used in the chloralkali industry.

[e]Estimated. — Zero.
[1]Source: U.S. Environmental Protection Agency, 2020, Risk evaluation for asbestos, part I—Chrysotile asbestos: Washington, DC, EPA Document # EPA-740-R1-8012, December, 352 p.
[2]Includes asbestos fiber (chrysotile) only; excludes asbestos contained in manufactured products.
[3]Additional chrysotile imports were reported by the U.S. Census Bureau in some years, but existing asbestos bans and bill of lading information from a commercial trade database suggest that some shipments were misclassified.
[4]According to the U.S. Census Bureau, imports of chrysotile totaled 41 tons through July. Final 2021 imports may differ significantly from the provided estimate because chrysotile imports typically do not follow a predictable pattern throughout the year.
[5]Exports of asbestos reported by the U.S. Census Bureau were 143 tons in 2017, 235 tons in 2018, 2 tons in 2019, 1 ton in 2020, and 127 tons through July in 2021. These shipments likely consisted of materials misclassified as asbestos, reexports, and (or) waste products because the United States no longer mines asbestos.
[6]To account for year-to-year fluctuations in chrysotile imports owing to cycles of companies replenishing and drawing down stockpiles, consumption is estimated as a 5-year rolling average of imports for consumption. Information regarding the quantity of industry stocks was unavailable.
[7]Defined as imports – exports. The United States has been 100% net import reliant since 2002. All consumption of asbestos was from imports and unreported inventories.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]Asbestos production permitted for export purposes only. Value shown is reported country exports.
[10]Reported.

BARITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, one company in Nevada mined barite from two mines that operated intermittently, but mine production data were withheld to avoid disclosing company proprietary data. Another company in Nevada processed domestically mined barite from material that had been previously stockpiled. A third company's mining and processing assets in Nevada were reportedly idled and put up for sale. An estimated 1.5 million tons of barite (from domestic production and imports) was sold by crushers and grinders operating in eight States. Typically, more than 90% of the barite sold in the United States is used as a weighting agent in fluids used in the drilling of oil and natural gas wells. The majority of Nevada crude barite was ground in Nevada and then sold to companies drilling in the Central and Western United States. Because of the higher cost of rail and truck transportation compared to ocean freight, offshore drilling operations in the Gulf of Mexico and onshore drilling operations in other regions primarily used imported barite.

Barite also is used as a filler, extender, or weighting agent in products such as paints, plastics, and rubber. Some specific applications include use in automobile brake and clutch pads, in automobile paint primer for metal protection and gloss, as a weighting agent in rubber, and in the cement jacket around underwater petroleum pipelines. In the metal-casting industry, barite is part of the mold-release compounds. Because barite significantly blocks X-ray and gamma-ray emissions, it is used as aggregate in high-density concrete for radiation shielding around X-ray units in hospitals, nuclear powerplants, and university nuclear research facilities. Ultrapure barite is used as a contrast medium in X-ray and computed tomography examinations of the gastrointestinal tract.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Sold or used, mine	334	366	414	W	W
Ground and crushed[1]	2,030	2,420	2,350	1,410	1,500
Imports for consumption[2]	2,470	2,460	2,500	1,480	1,700
Exports[3]	116	67	38	48	45
Consumption, apparent (crude and ground)[4]	2,680	2,760	2,880	W	W
Price, average value, ground, ex-works, dollars per ton	179	176	179	183	180
Employment, mine and mill, number[e]	450	520	480	330	310
Net import reliance[5] as a percentage of apparent consumption	88	87	86	>75	>75

Recycling: None.

Import Sources (2017–20): China,[6] 41%; India, 28%; Morocco, 14%; Mexico, 13%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Ground barite	2511.10.1000	Free.
Crude barite	2511.10.5000	$1.25 per metric ton.
Barium compounds:		
Barium oxide, hydroxide, and peroxide	2816.40.2000	2% ad valorem.
Barium chloride	2827.39.4500	4.2% ad valorem.
Barium sulfate, precipitated	2833.27.0000	0.6% ad valorem.
Barium carbonate, precipitated	2836.60.0000	2.3% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic and global drilling rig counts, which have historically been a good barometer of barite consumption, generally increased throughout 2021. This trend was reflected in domestic sales of ground barite, which were estimated to have increased by 6% in 2021, attributed primarily to increased sales in Texas. World mine production was estimated to have increased by 8%. Despite modest increases in 2021, domestic and global production and consumption of barite were estimated to have remained well below the quantities attained prior to the global COVID-19 pandemic. Production in most leading barite-producing countries was estimated to have remained essentially unchanged compared with that in 2020 with the exception of Morocco. According to some domestic consumers, barite suppliers in Morocco were able to offer smaller shipments and shorter lead times than suppliers in China and India, which supported increased production. This allowed domestic consumers increased flexibility in responding to uncertainty in anticipated future consumption levels.

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BARITE

Barite trade was negatively affected by ongoing logistics issues. In addition to contributing to reduced consumption of transport fuels, which directly affected barite consumption, continued travel restrictions were a factor in some areas. For example, prior to the COVID-19 pandemic, production in Laos had begun to emerge as a potentially significant new source of global supply. In 2020 and 2021, barite exports from Laos, a landlocked country, were reportedly inhibited by border closures with neighboring countries. Domestic importers also noted cost increases per ton of barite because of increased land- and ocean-based freight rates. As a bulk commodity used primarily for its weight, transportation expenses are a substantial component of the final cost of barite used on a per ton basis. However, it is unclear if these cost increases affected sales prices.

In 2021, researchers at Purdue University filed a patent application for a barium sulfate (barite)-based formulation for white paint that had a higher reflectivity compared with all other white paints. The new formulation, which used a higher concentration of barite with a broader range of particle sizes, had an ambient-cooling effect when used on exterior surfaces.

World Mine Production and Reserves: In response to concerns about dwindling global reserves of 4.2-specific-gravity barite used by the oil and gas drilling industry, the American Petroleum Institute issued an alternate specification for 4.1-specific-gravity weighting agents in 2010. Estimated reserves data are included only if developed since the adoption of the 4.1-specific-gravity standard.

	Mine production		Reserves[7]
	2020	2021[e]	
United States	W	W	NA
China	[8]2,800	[8]2,800	36,000
India	1,600	1,600	51,000
Iran	202	200	100,000
Kazakhstan	445	450	85,000
Laos	180	110	NA
Mexico	323	320	NA
Morocco	410	1,100	NA
Pakistan	86	50	40,000
Russia	287	150	12,000
Turkey	180	180	35,000
Other countries	329	370	30,000
World total (rounded)	[9]6,840	[9]7,300	NA

World Resources:[7] In the United States, identified resources of barite are estimated to be 150 million tons, and undiscovered resources contribute an additional 150 million tons. The world's barite resources in all categories are about 2 billion tons, but only about 740 million tons are identified resources

Substitutes: In the oil- and gas-drilling industry, alternatives to barite include celestite, ilmenite, iron ore, and synthetic hematite that is manufactured in Germany. However, the use of substitutes has been in relatively small amounts, and barite remains the preferred choice for drilling applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Imported and domestic barite, crushed and ground, sold or used by domestic grinding establishments.
[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2511.10.1000, 2511.10.5000, and 2833.27.0000.
[3]Includes data for the following Schedule B codes: 2511.10.1000 and 2833.27.0000.
[4]Defined as sold or used by domestic mines + imports – exports.
[5]Defined as imports – exports.
[6]Includes Hong Kong.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]The China Industrial Minerals Yearbook estimated that production was closer to 4 million tons.
[9]Excludes U.S. production.

BAUXITE AND ALUMINA[1]

(Data in thousand metric dry tons unless otherwise noted)

Domestic Production and Use: In 2021, the reported quantity of bauxite consumed was estimated to be 3.6 million tons, 8% more than that reported in 2020, with an estimated value of about $115 million. About 70% of the bauxite was refined by the Bayer process for alumina or aluminum hydroxide, and the remainder went to products such as abrasives, cement, chemicals, proppants, and refractories, and as a slag adjuster in steel mills. Alumina production was estimated to be 1 million tons, 25% less than that in 2020. One domestic alumina refinery with production capacity of 1.2 million tons per year accounted for all the production in 2021. Another alumina refinery with 500,000 tons per year of capacity was on care-and-maintenance status the entire year. About 55% of the alumina produced went to primary aluminum smelters, and the remainder went to nonmetallurgical products, such as abrasives, ceramics, chemicals, and refractories.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Bauxite:					
Production, mine	W	W	W	W	W
Imports for consumption[2]	4,350	3,980	4,620	3,760	3,600
Exports[2]	29	16	15	15	12
Stocks, industry, yearend[e, 2]	880	600	300	250	200
Consumption:					
Apparent[3]	W	W	W	W	W
Reported	4,330	4,460	3,680	3,330	3,600
Price, average value of imports, free alongside ship (f.a.s.), dollars per ton	31	31	32	26	32
Net import reliance[4] as a percentage of apparent consumption	>75	>75	>75	>75	>75
Alumina:					
Production, refinery[5]	1,430	1,570	1,410	1,340	1,000
Imports for consumption[5]	1,330	1,530	1,930	1,340	1,500
Exports[5]	481	288	200	162	190
Stocks, industry, yearend[5]	264	275	275	234	150
Consumption, apparent[3]	2,340	2,800	3,140	2,560	2,400
Price, average value of imports, f.a.s., dollars per ton	486	592	480	412	450
Net import reliance[4] as a percentage of apparent consumption	39	44	55	48	58

Recycling: None.

Import Sources (2017–20): Bauxite:[2] Jamaica, 62%; Brazil, 13%; Guyana, 8%; Australia, 6%; and other, 11%. Alumina:[5] Brazil, 54%; Australia, 20%; Jamaica, 12%; Canada, 5%; and other, 9%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Bauxite, calcined (refractory grade)	2606.00.0030	Free.
Bauxite, calcined (other)	2606.00.0060	Free.
Bauxite, crude dry (metallurgical grade)	2606.00.0090	Free.
Aluminum oxide (alumina)	2818.20.0000	Free.
Aluminum hydroxide	2818.30.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, one domestic alumina refinery produced alumina from imported bauxite. A 1.2-million-ton-per-year alumina refinery in Gramercy, LA, produced alumina for aluminum smelting and specialty-grade alumina. The Gramercy alumina refinery stopped production for about 1 week at the end of August as a precaution when Hurricane Ida approached the region, but restarted production soon afterwards. A 500,000-ton-per-year alumina refinery in Burnside, LA, was temporarily shut down in August 2020, and no plans have been announced regarding reopening. The average prices, f.a.s., for U.S. imports for consumption of crude dry bauxite and metallurgical-grade alumina during the first 9 months of 2021 were $32 per ton, 19% more than that in the same period in 2020, and $450 per ton, 18% more than that in the same period of 2020, respectively.

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BAUXITE AND ALUMINA[1]

In April 2021, a 2.8-million-ton-per-year alumina refinery in Shanxi Province, China, restarted production after being shut down in May 2019 after a spill from its red mud disposal impoundment. Flooding in Henan Province, China, was cited for several alumina refineries shutting down production for about 2 weeks in July. Environmental and safety audits were cited for several alumina refineries and bauxite mines shutting down production in several locations in China throughout the year, and production was not expected to restart at some locations until 2022. In Indonesia, a new 1-million-ton-per-year alumina refinery started production and shipped its first product in July. In July, a 3.5-million-ton-per-year alumina refinery in Brazil temporarily shut down about one-third of its capacity citing damage to equipment used to unload bauxite, but production was restarted in early October. In August, a 1.42-million-ton-per-year alumina refinery in Jamaica temporarily shut down after a fire caused major damage to its powerhouse.

World Alumina Refinery and Bauxite Mine Production and Bauxite Reserves: Reserves for Australia, Saudi Arabia, Vietnam, and some listed in "Other countries" were revised based on information from Government and other sources.

	Refinery and mine production				Bauxite reserves[6]
	Alumina[5]		Bauxite		
	2020	2021[e]	2020	2021[e]	
United States	1,340	1,000	W	W	20,000
Australia	20,800	21,000	104,000	110,000	[7]5,300,000
Brazil	10,300	11,000	31,000	32,000	2,700,000
Canada	1,520	1,500	—	—	—
China	73,100	74,000	92,700	86,000	1,000,000
Germany	1,900	1,900	—	—	—
Guinea	439	400	86,000	85,000	7,400,000
India	6,560	6,800	20,200	22,000	660,000
Indonesia	1,200	1,500	20,800	18,000	1,200,000
Ireland	1,880	1,900	—	—	—
Jamaica	1,620	1,200	7,550	5,800	2,000,000
Kazakhstan	1,400	1,500	5,000	5,200	160,000
Russia	2,870	3,100	5,570	6,200	500,000
Saudi Arabia	1,810	1,800	4,310	4,300	180,000
Spain	1,550	1,600	—	—	—
Ukraine	1,730	1,700	—	—	—
United Arab Emirates	1,920	2,000	—	—	—
Vietnam	1,400	1,400	3,500	3,500	5,800,000
Other countries	2,700	3,000	10,500	12,000	5,100,000
World total (rounded)	136,000	140,000	[8]391,000	[8]390,000	32,000,000

World Resources:[6] Bauxite resources are estimated to be between 55 billion and 75 billion tons, distributed in Africa (32%), Oceania (23%), South America and the Caribbean (21%), Asia (18%), and elsewhere (6%). Domestic resources of bauxite are inadequate to meet long-term U.S. demand, but the United States and most other major aluminum-producing countries have essentially inexhaustible subeconomic resources of aluminum in materials other than bauxite.

Substitutes: Bauxite is the only raw material used in the production of alumina on a commercial scale in the United States. Although currently not economically competitive with bauxite, vast resources of clay are technically feasible sources of alumina. Other raw materials, such as alunite, anorthosite, coal wastes, and oil shales, offer additional potential alumina sources. Synthetic mullite, produced from kaolin, bauxitic kaolin, kyanite, and sillimanite, substitutes for bauxite-based refractories. Silicon carbide and alumina zirconia can substitute for alumina and bauxite in abrasives but cost more.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]See also Aluminum. As a general rule, 4 tons of dried bauxite is required to produce 2 tons of alumina, which, in turn, produces 1 ton of aluminum.
[2]Includes all forms of bauxite, expressed as dry equivalent weights.
[3]Defined as production + imports – exports + adjustments for industry stock changes.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]Calcined equivalent weights.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 2.0 billion tons.
[8]Excludes U.S. production.

BERYLLIUM

(Data in metric tons of contained beryllium unless otherwise noted)

Domestic Production and Use: One company in Utah mined bertrandite ore and converted it, along with imported beryl, into beryllium hydroxide. Some of the beryllium hydroxide was shipped to the company's plant in Ohio, where it was converted into metal, oxide, and downstream beryllium-copper master alloy, and some was sold. Based on the estimated unit value for beryllium in imported beryllium-copper master alloy, beryllium apparent consumption of 200 tons was valued at about $120 million. Based on sales revenues, approximately 23% of beryllium products were used in industrial components; 17% each in aerospace and defense applications and in automotive electronics; 12% in consumer electronics; 11% in telecommunications infrastructure; 5% in energy applications; 1% in semiconductor applications; and 14% in other applications. Beryllium alloy strip and bulk products, the most common forms of processed beryllium, were used in all application areas. Most unalloyed beryllium metal and beryllium composite products were used in defense and scientific applications.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, mine shipments	150	165	160	165	170
Imports for consumption[1]	60	67	49	48	52
Exports[2]	38	30	37	25	27
Shipments from Government stockpile[3]	2	—	—	3	7
Consumption:					
Apparent[4]	179	202	167	196	200
Reported, ore	160	170	160	170	170
Price, annual average unit value, beryllium-copper master alloy,[5] dollars per kilogram of contained beryllium	640	590	620	620	610
Stocks, ore, consumer, yearend	30	30	35	30	30
Net import reliance[6] as a percentage of apparent consumption	16	18	4	16	16

Recycling: Beryllium was recovered from new scrap generated during the manufacture of beryllium products and from old scrap. Detailed data on the quantities of beryllium recycled are not available but may account for as much as 20% to 25% of total beryllium consumption. The leading U.S. beryllium producer established a comprehensive recycling program for all of its beryllium products, recovering approximately 40% of the beryllium content of the new and old beryllium alloy scrap.

Import Sources (2017–20):[1] Kazakhstan, 41%; Japan, 16%; Brazil, 11%; Latvia, 10%; and other, 22%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Beryllium ores and concentrates	2617.90.0030	Free.
Beryllium oxide and hydroxide	2825.90.1000	3.7% ad valorem.
Beryllium-copper master alloy	7405.00.6030	Free.
Beryllium-copper plates, sheets, and strip:		
Thickness of 5 millimeters (mm) or more	7409.90.1030	3.0% ad valorem.
Thickness of less than 5 mm:		
Width of 500 mm or more	7409.90.5030	1.7% ad valorem.
Width of less than 500 mm	7409.90.9030	3.0% ad valorem.
Beryllium:		
Unwrought, including powders	8112.12.0000	8.5% ad valorem.
Waste and scrap	8112.13.0000	Free.
Other	8112.19.0000	5.5% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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BERYLLIUM

Government Stockpile:[7] The Defense Logistics Agency Strategic Materials had a goal of retaining 47 tons of beryllium metal in the National Defense Stockpile.

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Beryl ore (gross weight)	1	—	—	—	—
Metal (all types)	57	—	7	—	7
Structured powder	7	—	—	—	—

Events, Trends, and Issues: Domestic beryllium consumption in 2021 was estimated to be about the same as that of 2020. During the first 6 months of 2021, the leading U.S. beryllium producer reported that net sales of its beryllium alloy strip and bulk products and beryllium metal and composite products were 19% higher than those during the first 6 months of 2020. Net sales of beryllium products increased primarily in the aerospace and defense, automotive, and industrial components markets. As various COVID-19 restrictions were lifted in 2021, it was reported that customer demand increased.

Because of the toxic nature of beryllium, various international, national, and State guidelines and regulations have been established regarding beryllium in air, water, and other media. Industry is required to carefully control the quantity of beryllium dust, fumes, and mists in the workplace.

World Mine Production and Reserves:

	Mine production[8, 9] 2020	2021[e]	Reserves[10]
United States	165	170	The United States has very little beryl that can be economically hand sorted from pegmatite deposits. The Spor Mountain area in Utah, an epithermal deposit, contains a large bertrandite resource, which is being mined. Proven and probable bertrandite reserves in Utah total about 20,000 tons of contained beryllium. World beryllium reserves are not available.
Brazil	[e]3	3	
China	70	70	
Madagascar	[e]1	1	
Mozambique	[e]3	3	
Nigeria	[e]1	1	
Rwanda	[e]1	1	
Uganda	7	7	
World total (rounded)	250	260	

World Resources:[10] The world's identified resources of beryllium have been estimated to be more than 100,000 tons. About 60% of these resources are in the United States; by tonnage, the Spor Mountain area in Utah, the McCullough Butte area in Nevada, the Black Hills area in South Dakota, the Sierra Blanca area in Texas, the Seward Peninsula in Alaska, and the Gold Hill area in Utah account for most of the total.

Substitutes: Because the cost of beryllium is high compared with that of other materials, it is used in applications in which its properties are crucial. In some applications, certain metal matrix or organic composites, high-strength grades of aluminum, pyrolytic graphite, silicon carbide, steel, or titanium may be substituted for beryllium metal or beryllium composites. Copper alloys containing nickel and silicon, tin, titanium, or other alloying elements or phosphor bronze alloys (copper-tin-phosphorus) may be substituted for beryllium-copper alloys, but these substitutions can result in substantially reduced performance. Aluminum nitride or boron nitride may be substituted for beryllium oxide.

[e]Estimated. — Zero.
[1]Includes estimated beryllium content of imported ores and concentrates, oxide and hydroxide, unwrought metal (including powders), beryllium articles, waste and scrap, beryllium-copper master alloy, and beryllium-copper plates, sheets, and strip.
[2]Includes estimated beryllium content of exported unwrought metal (including powders), beryllium articles, and waste and scrap.
[3]Change in total inventory level from prior yearend inventory.
[4]Defined as production + imports – exports + adjustments for Government and industry stock changes.
[5]Calculated from gross weight and customs value of imports; beryllium content estimated to be 4%. Rounded to two significant figures.
[6]Defined as imports – exports + adjustments for Government and industry stock changes.
[7]See Appendix B for definitions.
[8]In addition to the countries listed, Kazakhstan and Portugal may have produced beryl ore, but available information was inadequate to make reliable estimates of output. Other nations that produced gemstone beryl ore may also have produced some industrial beryl ore.
[9]Based on a beryllium content of 4% from bertrandite and beryl sources.
[10]See Appendix C for resource and reserve definitions and information concerning data sources.

BISMUTH

(Data in metric tons, gross weight, unless otherwise noted)

Domestic Production and Use: The United States ceased production of primary refined bismuth in 1997 and is highly import reliant. Bismuth is contained in some lead ores mined domestically. However, the last domestic primary lead smelter closed at yearend 2013; since then, all lead concentrates have been exported for smelting.

About 60% of domestic bismuth consumption was for chemicals used in cosmetic, industrial, laboratory, and pharmaceutical applications. Bismuth use in pharmaceuticals included bismuth subsalicylate (the active ingredient in over-the-counter stomach remedies) and other compounds used to treat burns, intestinal disorders, and stomach ulcers. Bismuth is also used in industrial applications for the manufacture of ceramic glazes, crystalware, and pearlescent pigments.

Bismuth has a wide variety of metallurgical applications, including use as an additive to improve metal integrity of malleable cast iron in the foundry industry and as a nontoxic replacement for lead in brass, free-machining steels, and solders. The use of bismuth in brass for pipe fittings, fixtures, and water meters increased after 2014 when the definition of “lead-free” under the Safe Drinking Water Act was modified to reduce the maximum lead content of “lead-free” pipes and plumbing fixtures to 0.25% from 8%. The melting point of bismuth is relatively low at 271 degrees Celsius, and it is an important component of various fusible alloys, some of which have melting points below that of boiling water. These bismuth-containing alloys can be used in holding devices for grinding optical lenses, as plugs for abandoned oil wells, as a temporary filler to prevent damage to tubes in bending operations, as a triggering mechanism for fire sprinklers, and in other applications in which a low melting point is ideal. Bismuth-tellurium-oxide alloy film paste is used in the manufacture of semiconductor devices.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Refinery	—	—	—	—	—
Secondary (scrap)[e]	80	80	80	80	80
Imports for consumption, metal, alloys, and scrap	2,820	2,470	2,340	1,650	1,500
Exports, metal, alloys, and scrap	392	653	636	699	840
Consumption:					
Apparent[1]	2,530	2,040	1,690	1,200	810
Reported	694	570	548	513	500
Price, average,[2] dollars per pound	4.94	4.61	3.18	2.72	3.65
Stocks, yearend, consumer	489	346	443	271	200
Net import reliance[3] as a percentage of apparent consumption	97	96	95	93	90

Recycling: Bismuth-containing alloy scrap was recycled and thought to compose between 5% and 10% of U.S. bismuth apparent consumption.

Import Sources (2017–20): China,[4] 67%; the Republic of Korea, 16%; Mexico, 6%; Belgium, 5%; and other, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Bismuth and articles thereof, including waste and scrap	8106.00.0000	Free.

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BISMUTH

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: The estimated annual average domestic dealer price for bismuth in 2021 was an estimated $3.65 per pound and increased for the first time since 2017. The price was an estimated 34% higher than that in 2020 and the highest price since 2018. Globally, excess stocks continued to keep prices low compared with those in 2007 through 2014 when the average annual dealer price traded above $7.84 per pound. Primary production tightened in early 2021 as mines continued to feel effects from shutdowns that began during the first of half of 2020 resulting from the global COVID-19 pandemic. Trade data through August 2021 were mixed when compared with the same period in 2020—whereas bismuth exports increased, imports for consumption decreased. Foreign buyers were reportedly stockpiling bismuth while prices were relatively low compared with previous higher prices.

World Refinery Production and Reserves: Available information was inadequate to make reliable estimates of reserves.

	Refinery production[e] 2020	Refinery production[e] 2021	Reserves[5]
United States	—	—	Quantitative estimates of reserves were not available.
Bolivia	30	60	
Bulgaria	50	50	
Canada	35	30	
China	16,000	16,000	
Japan	570	600	
Kazakhstan	230	240	
Korea, Republic of	970	1,000	
Laos	1,000	1,000	
Mexico	10	10	
World total (rounded)	19,000	19,000	

World Resources:[5] World reserves of bismuth are usually estimated based on the bismuth content of lead resources because bismuth production is most often a byproduct of processing lead ores. In China and Vietnam, bismuth production is a byproduct or coproduct of tungsten and other metal ore processing. Bismuth minerals rarely occur in sufficient quantities to be mined as principal products; the Tasna Mine in Bolivia and a mine in China are the only mines where bismuth has been the primary product. The Tasna Mine has been inactive since 1996.

Substitutes: Bismuth compounds can be replaced in pharmaceutical applications by alumina, antibiotics, calcium carbonate, and magnesia. Titanium dioxide-coated mica flakes and fish-scale extracts are substitutes in pigment uses. Cadmium, indium, lead, and tin can partially replace bismuth in low-temperature solders. Resins can replace bismuth alloys for holding metal shapes during machining, and glycerine-filled glass bulbs can replace bismuth alloys in triggering devices for fire sprinklers. Free-machining alloys can contain lead, selenium, or tellurium as a replacement for bismuth. Bismuth is an environmentally friendly substitute for lead in plumbing and many other applications, including fishing weights, hunting ammunition, lubricating greases, and soldering alloys.

[e]Estimated. — Zero.
[1]Defined as secondary production + imports – exports + adjustments for industry stock changes.
[2]Prices are based on 99.99%-purity metal at warehouse (Rotterdam) in minimum lots of 1 ton; source: Fastmarkets AMM.
[3]Defined as imports – exports + adjustments for industry stock changes.
[4]Includes Hong Kong.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.

BORON

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies in southern California produced borates in 2021, and most of the boron products consumed in the United States were manufactured domestically. Estimated boron production decreased slightly in 2021 compared with 2020 production. U.S. boron production and consumption data were withheld to avoid disclosing company proprietary data. The leading boron producer mined borate ores, which contain the minerals kernite, tincal, and ulexite, by open pit methods and operated associated compound plants. Kernite was used to produce boric acid, tincal was used to produce sodium borate, and ulexite was used as a primary ingredient in the manufacture of a variety of specialty glasses and ceramics. A second company produced borates from brines extracted through solution-mining techniques. Boron minerals and chemicals were principally consumed in the north-central and eastern United States. In 2021, the glass and ceramics industries remained the leading domestic users of boron products, accounting for an estimated 65% of total borates consumption. Boron also was used as a component in abrasives, cleaning products, insecticides, and insulation and in the production of semiconductors.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production	W	W	W	W	W
Imports for consumption:					
Refined borax	158	133	161	174	230
Boric acid	40	51	41	39	50
Colemanite (calcium borates)	58	73	42	18	5
Ulexite (sodium borates)	24	34	38	41	55
Exports:					
Boric acid	216	251	251	257	290
Refined borax	572	610	598	594	600
Consumption, apparent[1]	W	W	W	W	W
Price, average value of imports, cost, insurance, and freight, dollars per ton	392	404	373	380	390
Employment, number	1,300	1,350	1,350	1,330	1,330
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2017–20): All forms: Turkey, 88%; Bolivia, 5%; Chile, 3%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Natural borates:		
Sodium (ulexite)	2528.00.0005	Free.
Calcium (colemanite)	2528.00.0010	Free.
Boric acids	2810.00.0000	1.5% ad valorem.
Borates, refined borax:		
Anhydrous	2840.11.0000	0.3% ad valorem.
Non-anhydrous	2840.19.0000	0.1% ad valorem.

Depletion Allowance: Borax, 14% (domestic and foreign).

Government Stockpile: None.

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BORON

Events, Trends, and Issues: Elemental boron is a metalloid with limited commercial applications. Although the term "boron" is commonly referenced, it does not occur in nature in an elemental state. Boron combines with oxygen and other elements to form boric acid or inorganic salts called borates. Boron compounds, chiefly borates, are commercially important; therefore, boron products are priced and sold based on their boric oxide (B_2O_3) content, varying by ore and compound and by the absence or presence of calcium and sodium. Four borate minerals—colemanite, kernite, tincal, and ulexite—account for 90% of the borate minerals used by industry worldwide. Although borates were used in more than 300 applications, more than three-quarters of world consumption was used in ceramics, detergents, fertilizers, and glass.

China, India, the Netherlands, Malaysia, and Mexico, in decreasing order of tonnage, are the countries that imported the largest quantities of refined borates from the United States in 2021. Because China has low-grade boron reserves and demand for boron is anticipated to rise in that country, imports to China from Chile, Russia, Turkey, and the United States were expected to remain steady during the next several years.

Continued investment in new borate refineries and the continued rise in demand were expected to fuel growth in world production for the next few years. Two Australia-based mine developers previously confirmed that production of high-quality boron products would be possible from their projects in California and Nevada, respectively. These companies continued to make progress on their respective projects by acquiring some of the permits necessary to begin and continue construction. The project in California was expected to begin production in 2021. However, construction was postponed to focus on expanding the company's boron production and product selection by adding additional specialty products for industries related to global decarbonization and food security. The Nevada project was expected to begin production by mid-2023. These companies have the potential to become substantial boron producers when their projects are fully developed.

World Production and Reserves: Reserves for Turkey were revised based on industry information.

	Production—All forms		Reserves[3]
	2020	2021[e]	
United States	W	W	40,000
Argentina, crude ore	71	71	NA
Bolivia, ulexite	200	210	NA
Chile, ulexite	350	300	35,000
China, boric oxide equivalent	380	380	24,000
Germany, compounds	120	120	NA
Peru, crude borates	110	50	4,000
Russia, datolite ore	80	80	40,000
Turkey, refined borates	2,000	1,700	1,200,000
World total[4]	XX	XX	XX

World Resources:[3] Deposits of borates are associated with volcanic activity and arid climates, with the largest economically viable deposits in the Mojave Desert of the United States, the Alpide belt along the southern margin of Eurasia, and the Andean belt of South America. U.S. deposits consist primarily of tincal, kernite, and borates contained in brines, and to a lesser extent, ulexite and colemanite. About 70% of all deposits in Turkey are colemanite, primarily used in the production of heat-resistant glass. At current levels of consumption, world resources are adequate for the foreseeable future.

Substitutes: The substitution of other materials for boron is possible in detergents, enamels, insulation, and soaps. Sodium percarbonate can replace borates in detergents and requires lower temperatures to undergo hydrolysis, which is an environmental consideration. Some enamels can use other glass-producing substances, such as phosphates. Insulation substitutes include cellulose, foams, and mineral wools. In soaps, sodium and potassium salts of fatty acids can act as cleaning and emulsifying agents.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable.

[1]Defined as production + imports – exports.

[2]Defined as imports – exports.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]World totals cannot be calculated because production and reserves are not reported in a consistent manner by all countries.

BROMINE

(Data in metric tons of contained bromine unless otherwise noted)

Domestic Production and Use: Bromine was recovered from underground brines by two companies in Arkansas. Bromine is one of the leading mineral commodities, in terms of value, produced in Arkansas. The two bromine companies in the United States account for a large percentage of world production capacity.

The leading global applications of bromine are for the production of brominated flame retardants (BFRs) and clear brine drilling fluids. Bromine compounds are also used in a variety of other applications, including industrial uses, as intermediates, and for water treatment. U.S. apparent consumption of bromine in 2021 was estimated to be greater than that in 2020.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production	W	W	W	W	W
Imports for consumption, elemental bromine and compounds[1]	52,700	56,200	56,300	28,700	32,000
Exports, elemental bromine and compounds[2]	32,600	21,900	29,300	36,800	25,000
Consumption, apparent[3]	W	W	W	W	W
Price, average unit value of imports (cost, insurance, and freight), dollars per kilogram	2.30	2.21	2.31	2.73	2.66
Employment, number[e]	1,050	1,050	1,050	1,050	1,050
Net import reliance[4] as a percentage of apparent consumption	<25	<25	<25	E	<25

Recycling: Some bromide solutions were recycled to obtain elemental bromine and to prevent the solutions from being disposed of as hazardous waste. For example, hydrogen bromide is emitted as a byproduct in many organic reactions. This byproduct waste can be recycled with virgin bromine brines and used as a source of bromine production. Bromine contained in plastics can be incinerated as solid organic waste and the bromine can be recovered.

Import Sources (2017–20):[5] Israel, 78%; Jordan, 13%; China, 6%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Bromine	2801.30.2000	5.5% ad valorem.
Hydrobromic acid	2811.19.3000	Free.
Potassium or sodium bromide	2827.51.0000	Free.
Ammonium, calcium, or zinc bromide	2827.59.2500	Free.
Potassium bromate	2829.90.0500	Free.
Sodium bromate	2829.90.2500	Free.
Ethylene dibromide	2903.31.0000	5.4% ad valorem.
Methyl bromide	2903.39.1520	Free.
Dibromoneopentylglycol	2905.59.3000	Free.
Tetrabromobisphenol A	2908.19.2500	5.5% ad valorem.
Decabromodiphenyl and octabromodiphenyl oxide	2909.30.0700	5.5% ad valorem.

Depletion Allowance: Brine wells, 5% (domestic and foreign).

Government Stockpile: None.

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BROMINE

Events, Trends, and Issues: The United States maintained its position as one of the leading bromine producers in the world along with China, Israel, and Jordan. In 2021, the leading source of imports of bromine and bromide compounds (gross weight) was Israel. The average import value of bromine and bromine compounds decreased by about 3% in 2021 compared with that in 2020. Together, the leading imported bromine products in terms of both gross weight and bromine content were bromides and bromide oxides of ammonium, calcium, or zinc and bromides of sodium or potassium (over 90%). Total imports of bromine and bromine compounds (bromine content) increased by about 10% whereas total exports decreased by about 30% compared with that in 2020.

Global sales of bromine and bromine compounds increased in 2021 compared with those in 2020. Sales volumes increased for BFRs and clear brine fluids, the leading applications of bromine, compared with the previous year. Sales were driven, in particular, by strong demand in electronic, automotive, and construction industries, the leading consumers of BFRs. Although sales of clear brine drilling fluids increased compared with the previous year, demand had yet to return to pre-pandemic levels. In February 2021, Texas suffered a major power crisis, which resulted from three severe winter storms sweeping across the United States on February 10–11, 13–17, and 15–20. The storms caused a massive electricity generation failure in Texas, leading to shortages of water, food, and heat. Additionally, the winter storms adversely affected drilling production, drew down inventory stocks, and disrupted supply-chain logistics.

World Production and Reserves:

	Production		Reserves[6]
	2020	2021[e]	
United States	W	W	11,000,000
Azerbaijan	—	—	300,000
China	70,000	75,000	NA
India	3,300	3,000	NA
Israel	170,000	180,000	Large
Japan	20,000	20,000	NA
Jordan	84,000	110,000	Large
Ukraine	4,500	4,500	NA
World total (rounded)	[7]352,000	[7]390,000	Large

World Resources:[6] Bromine is found principally in seawater, evaporitic (salt) lakes, and underground brines associated with petroleum deposits. The Dead Sea, in the Middle East, is estimated to contain 1 billion tons of bromine. Seawater contains about 65 parts per million bromine, or an estimated 100 trillion tons. Bromine is also recovered from seawater as a coproduct during evaporation to produce salt.

Substitutes: Chlorine and iodine may be substituted for bromine in a few chemical reactions and for sanitation purposes. There are no comparable substitutes for bromine in various oil- and gas-well-completion and packer applications. Because plastics have a low ignition temperature, aluminum hydroxide, magnesium hydroxide, organic chlorine compounds, and phosphorus compounds can be substituted for bromine as fire retardants in some uses.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Includes data for the Harmonized Tariff Schedule of the United States codes shown in the "Tariff" section.
[2]Includes data for the following Schedule B numbers: 2801.30.2000, 2827.51.0000, 2827.59.0000, 2903.31.0000, and 2903.39.1520.
[3]Defined as production (sold or used) + imports – exports.
[4]Defined as imports – exports.
[5]Calculated using the gross weight of imports.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]Excludes U.S. production.

CADMIUM

(Data in metric tons of contained cadmium unless otherwise noted)

Domestic Production and Use: Two companies in the United States produced refined cadmium in 2021. One company, operating in Tennessee, recovered primary refined cadmium as a byproduct of zinc leaching from roasted sulfide concentrates. The other company, operating in Ohio, recovered secondary cadmium metal from spent nickel cadmium (NiCd) batteries. A cadmium concentrate was produced by one company in North Carolina that produced zinc from recycled electric-arc-furnace dust obtained from steel mills. Domestic production and consumption of cadmium were withheld to avoid disclosing company proprietary data. Cadmium metal and compounds are mainly consumed for alloys, coatings, NiCd batteries, pigments, and plastic stabilizers. For the past 5 years, the United States has been a net importer of unwrought cadmium metal and cadmium metal powders and a net exporter of wrought cadmium products and of cadmium pigments and preparations based on cadmium compounds.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, refined[1]	W	W	W	W	W
Imports for consumption:					
Unwrought cadmium and powders	274	273	385	282	140
Wrought cadmium and other articles (gross weight)	2	1	21	3	1
Cadmium waste and scrap (gross weight)	20	20	86	90	150
Cadmium pigments and preparations based on cadmium compounds (gross weight)	158	310	108	69	90
Exports:					
Unwrought cadmium and powders	223	40	32	4	80
Wrought cadmium and other articles (gross weight)	205	99	84	480	210
Cadmium waste and scrap (gross weight)	([2])	([2])	6	([2])	([2])
Cadmium pigments and preparations based on cadmium compounds (gross weight)	617	565	795	2,120	560
Consumption, reported, refined	W	W	W	W	W
Price, metal, annual average,[3] dollars per kilogram	1.75	2.89	2.67	2.29	2.49
Net import reliance[4] as a percentage of apparent consumption	<25	<50	<50	<50	<50

Recycling: Secondary cadmium is mainly recovered from spent consumer and industrial NiCd batteries. Other waste and scrap from which cadmium can be recycled includes copper-cadmium alloy scrap, some complex nonferrous alloy scrap, cadmium-containing dust from electric arc furnaces, and cadmium telluride (CdTe) solar panels.

Import Sources (2017–20):[5] Australia, 29%; China,[6] 20%; Germany, 19%; Peru, 11%; and other, 21%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Cadmium oxide	2825.90.7500	Free.
Cadmium sulfide	2830.90.2000	3.1% ad valorem.
Pigments and preparations based on cadmium compounds	3206.49.6010	3.1% ad valorem.
Unwrought cadmium and powders	8107.20.0000	Free.
Cadmium waste and scrap	8107.30.0000	Free.
Wrought cadmium and other articles	8107.90.0000	4.4% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Most of the world's primary cadmium metal was produced in Asia, and leading global producers, in descending order of production, were China and the Republic of Korea, followed by Japan and Canada. A smaller amount of secondary cadmium metal was recovered from recycling NiCd batteries. Although detailed data on the global consumption of primary cadmium were not available, NiCd battery production was thought to have continued to account for most global cadmium consumption. Other end uses for cadmium and cadmium compounds included alloys, anticorrosive coatings, pigments, polyvinyl chloride (PVC) stabilizers, and semiconductors for solar cells and for radiation-detecting imaging equipment.

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CADMIUM

The average monthly cadmium price began 2021 averaging $2.12 per kilogram in January and trended upward to about $2.85 per kilogram in April and May before decreasing to $2.13 per kilogram in August. The resurgence of the delta variant of the COVID-19 virus in April through July in India affected economic activity and was likely a factor in the decrease in price. As a major consumer of cadmium but without significant production, India was an important determinant of cadmium prices in the spot market.

In March 2021, the U.S. Department of Energy Solar Energy Technologies Office initiated the Cadmium Telluride Photovoltaics (PV) Accelerator program, intended to enhance U.S. technology leadership and competitiveness in the CdTe PV industry. Program goals included achieving cell efficiencies above 26%, decreasing module costs to below $0.15 per watt before 2030, and increasing domestic CdTe PV material and module production. The National Renewable Energy Laboratory would provide resources and support for a consortium to bring together academic institutions, industry, and government to accomplish the program goals.

A major United States-based CdTe thin-film solar-cell producer began building a third manufacturing facility in Ohio. The new facility, to be completed in 2023, would add 3.3 gigawatts (GW) to the company's annual production capacity for a total of 6 GW and make it the largest vertically integrated solar manufacturing complex outside of China.

World Refinery Production and Reserves:

	Refinery production[e] 2020	Refinery production[e] 2021	Reserves[7]
United States[1]	W	W	Quantitative estimates of reserves are not available. The cadmium content of typical zinc ores averages about 0.03%. See the Zinc chapter for zinc reserves.
Australia	348	300	
Canada	1,800	1,800	
China	10,000	10,000	
Germany	450	500	
Japan	1,880	1,900	
Kazakhstan	1,500	1,500	
Korea, Republic of	3,000	3,000	
Mexico	978	800	
Netherlands	880	900	
Norway	400	400	
Peru	700	600	
Russia	1,000	1,000	
Uzbekistan	400	400	
Other countries	520	600	
World total (rounded)[8]	24,000	24,000	

World Resources:[7] Cadmium is generally recovered from zinc ores and concentrates. Sphalerite, the most economically significant zinc ore mineral, commonly contains minor amounts of cadmium, which shares certain similar chemical properties with zinc and often substitutes for zinc in the sphalerite crystal lattice. The cadmium mineral greenockite is frequently associated with weathered sphalerite and wurtzite.

Substitutes: Lithium-ion and nickel-metal hydride batteries can replace NiCd batteries in many applications. Except where the surface characteristics of a coating are critical (for example, fasteners for aircraft), coatings of zinc, zinc nickel, aluminum, or tin can be substituted for cadmium in many plating applications. Cerium sulfide is used as a replacement for cadmium pigments, mostly in plastics. Barium-zinc or calcium-zinc stabilizers can replace barium-cadmium stabilizers in flexible PVC applications. Amorphous silicon and copper-indium-gallium-selenide photovoltaic cells compete with CdTe in the thin-film solar-cell market. Research efforts continued to advance new thin-film technology based on perovskite material as a potential substitute.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]Cadmium metal produced as a byproduct of zinc refining plus metal from recycling.
[2]Less than ½ unit.
[3]Average free market price for 99.95% purity in 10-ton lots; cost, insurance, and freight; global ports. Source: Fastmarkets MB.
[4]Defined as imports of unwrought metal and metal powders – exports of unwrought metal and metal powders.
[5]Includes data for the following Harmonized Tariff Schedule of the United States code: 8107.20.0000.
[6]Includes Hong Kong.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]Excludes U.S. production.

CEMENT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, U.S. portland cement production increased slightly to an estimated 90 million tons, and masonry cement production continued to remain steady at 2.4 million tons. Cement was produced at 96 plants in 34 States, and at 2 plants in Puerto Rico. Texas, Missouri, California, and Florida were, in descending order of production, the four leading cement-producing States and accounted for nearly 44% of U.S. production. Overall, the U.S. cement industry's growth continued to be constrained by closed or idle plants, underutilized capacity at others, production disruptions from plant upgrades, and relatively inexpensive imports. In 2021, shipments of cement were estimated to have increased slightly from those of 2020 and were valued at $13.4 billion. In 2021, an estimated 70% to 75% of sales were to ready-mixed concrete producers, 11% to concrete product manufacturers, 8% to 10% to contractors, and 5% to 12% to other customer types.

Salient Statistics—United States:[1]	**2017**	**2018**	**2019**	**2020**	**2021**[e]
Production:					
Portland and masonry cement[2]	86,356	86,368	87,233	[e]89,000	92,000
Clinker	76,678	77,112	78,858	79,000	79,000
Shipments to final customers, includes exports	97,935	99,419	102,823	105,000	107,000
Imports for consumption:					
Hydraulic cement	12,288	13,693	14,674	15,201	19,000
Clinker	1,209	967	1,160	1,534	2,000
Exports of hydraulic cement and clinker	1,035	919	1,024	888	1,000
Consumption, apparent[3]	97,160	98,400	101,600	[e]103,000	109,000
Price, average mill value, dollars per ton	117	121	123	[e]124	125
Stocks, cement, yearend	7,870	8,580	7,890	[e]7,750	8,000
Employment, mine and mill, number[e]	12,500	12,300	12,500	12,200	12,300
Net import reliance[4] as a percentage of apparent consumption	13	14	15	15	18

Recycling: Cement is not recycled, but significant quantities of concrete are recycled for use as a construction aggregate. Cement kilns can use waste fuels, recycled cement kiln dust, and recycled raw materials such as slags and fly ash. Various secondary materials can be incorporated as supplementary cementitious materials (SCMs) in blended cements and in the cement paste in concrete.

Import Sources (2017–20):[5] Canada, 32%; Turkey, 20%; Greece, 13%; China,[6] 8%; and other, 27%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Cement clinker	2523.10.0000	Free.
White portland cement	2523.21.0000	Free.
Other portland cement	2523.29.0000	Free.
Aluminous cement	2523.30.0000	Free.
Other hydraulic cement	2523.90.0000	Free.

Depletion Allowance: Not applicable. Certain raw materials for cement production have depletion allowances.

Government Stockpile: None.

Events, Trends, and Issues: The value of total construction put in place in the United States increased by about 7% during the first 9 months of 2021 compared with that in the same period in 2020. Residential construction spending increased, but nonresidential construction spending decreased. Despite weather-related declines in the beginning of the year, cement shipments increased slightly during the first 9 months of 2021 compared with those in the same period in 2020. The leading cement-consuming States continued to be Texas, California, and Florida, in descending order by tonnage.

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CEMENT

The increase in cement shipments was attributed to economic recovery from the global COVID-19 pandemic. However, growth continued to be constrained by increased costs for material and service inputs, labor and production shortages, ongoing logistical and shipping issues, and supply chain disruptions. The November 2021 passage of the Infrastructure Investment and Jobs Act was projected to support increased cement consumption.

Company merger-and-acquisition activity continued in 2021, with the final approval to combine the North American cement operations of a Brazilian cement company and a Canadian cement company into a joint venture. One United States cement company completed its purchase of a European cement company's western United States operations, and a Swiss cement company acquired a United States building products company. In 2019, one European cement company entered into an agreement to purchase a Mexican cement company's plant in Pennsylvania, but the transaction was abandoned after being challenged by regulatory authorities in 2021.

Cement plant upgrades were well underway at cement plants in Alabama and Indiana, with completion expected in 2022 and 2023, respectively. Several minor upgrades were ongoing at some other domestic plants, and upgrades also were announced for a few cement terminals. Numerous companies continued to make announcements aligned with the industry's commitment to sustainability, such as new blended cement product lines, renewable energy plans, decarbonization research initiatives, and other innovations. Many plants have installed emissions-reduction equipment to comply with the 2010 National Emissions Standards for Hazardous Air Pollutants (NESHAP). It remains possible that some kilns could be shut, idled, or used in a reduced capacity to comply with NESHAP, which would constrain U.S. clinker capacity.

World Production and Capacity:

	Cement production[e]		Clinker capacity[e]	
	2020	2021	2020	2021
United States (includes Puerto Rico)	89,000	92,000	100,000	100,000
Brazil	61,000	65,000	60,000	60,000
China	2,400,000	2,500,000	2,000,000	2,000,000
Egypt	42,000	40,000	48,000	48,000
India	295,000	330,000	280,000	280,000
Indonesia	65,000	66,000	78,000	79,000
Iran	68,000	62,000	81,000	81,000
Japan	51,000	52,000	53,000	54,000
Korea, Republic of	48,000	48,000	50,000	60,000
Mexico	48,000	50,000	42,000	42,000
Russia	56,000	56,000	80,000	80,000
Saudi Arabia	53,000	55,000	75,000	75,000
Turkey	72,000	76,000	92,000	92,000
Vietnam	98,000	100,000	90,000	90,000
Other countries (rounded)	760,000	810,000	600,000	600,000
World total (rounded)	4,200,000	4,400,000	3,700,000	3,700,000

World Resources: Not applicable. See Crushed Stone for cement raw-material resources.

Substitutes: Most portland cement is used to make concrete, mortars, or stuccos, and competes in the construction sector with concrete substitutes, such as aluminum, asphalt, clay brick, fiberglass, glass, gypsum (plaster), steel, stone, and wood. Certain materials, especially fly ash and ground granulated blast furnace slag, develop good hydraulic cementitious properties by reacting with lime, such as that released by the hydration of portland cement. Where readily available (including as imports), these SCMs are increasingly being used as partial substitutes for portland cement in many concrete applications and are components of finished blended cements.

[e]Estimated.

[1]Portland cement plus masonry cement unless otherwise noted; excludes Puerto Rico unless otherwise noted.

[2]Includes cement made from imported clinker.

[3]Defined as production of cement (including from imported clinker) + imports (excluding clinker) – exports + adjustments for stock changes.

[4]Defined as imports (cement and clinker) – exports.

[5]Hydraulic cement and clinker; includes imports into Puerto Rico.

[6]Includes Hong Kong.

CESIUM

(Data in metric tons of cesium oxide unless otherwise noted)

Domestic Production and Use: In 2021, no cesium was mined domestically, and the United States was 100% net import reliant for cesium minerals. Pollucite, mainly found in association with lithium-rich, lepidolite-bearing or petalite-bearing zoned granite pegmatites, is the principal cesium ore mineral. Cesium minerals are used as feedstocks to produce a variety of cesium compounds and cesium metal. The primary application for cesium, by gross weight, is in cesium formate brines used for high-pressure, high-temperature well drilling for oil and gas exploration and production. With the exception of cesium formate, cesium is used in relatively small-scale applications, using only a few grams for most applications. Owing to the lack of global availability of cesium, many applications have used mineral substitutes and the use of cesium in any particular application may no longer be viable.

Cesium metal is used in the production of cesium compounds and potentially in photoelectric cells. Cesium bromide is used in infrared detectors, optics, photoelectric cells, scintillation counters, and spectrophotometers. Cesium carbonate is used in the alkylation of organic compounds and in energy conversion devices, such as fuel cells, magneto-hydrodynamic generators, and polymer solar cells. Cesium chloride is used in analytical chemistry applications as a reagent, in high-temperature solders, as an intermediate in cesium metal production, in isopycnic centrifugation, as a radioisotope in nuclear medicine, as an insect repellent in agricultural applications, and in specialty glasses. Cesium hydroxide is used as an electrolyte in alkaline storage batteries. Cesium iodide is used in fluoroscopy equipment—Fourier-transform infrared spectrometers—as the input phosphor of X-ray image intensifier tubes, and in scintillators. Cesium nitrate is used as a colorant and oxidizer in the pyrotechnic industry, in petroleum cracking, in scintillation counters, and in X-ray phosphors. Cesium sulfates are soluble in water and are thought to be used primarily in water treatment, fuel cells, and to improve optical quality for scientific instruments.

Cesium isotopes, which are obtained as a byproduct in nuclear fission or formed from other isotopes, such as barium-131, are used in electronic, medical, metallurgical, and research applications. Cesium isotopes are used as an atomic resonance frequency standard in atomic clocks, playing a vital role in aircraft guidance systems, global positioning satellites, and internet and cellular telephone transmissions. Cesium clocks monitor the cycles of microwave radiation emitted by cesium's electrons and use these cycles as a time reference. Owing to the high accuracy of the cesium atomic clock, the international definition of 1 second is based on the cesium atom. The U.S. civilian time and frequency standard is based on a cesium fountain clock at the National Institute of Standards and Technology in Boulder, CO. The U.S. military frequency standard, the United States Naval Observatory (USNO) timescale, is based on 48 weighted atomic clocks, including 25 USNO cesium fountain clocks.

A company in Richland, WA, produced a range of cesium-131 medical products for treatment of various cancers. Cesium-137 may be used in industrial gauges, in mining and geophysical instruments, and for sterilization of food, sewage, and surgical equipment. Because of the danger posed by the radiological properties of cesium-137, efforts to find substitutes in its applications continued.

Salient Statistics—United States: Consumption, import, and export data for cesium have not been available since the late 1980s. Because cesium metal is not traded in commercial quantities, a market price is unavailable. Only a few thousand kilograms of cesium chemicals are thought to be consumed in the United States every year. The United States was 100% net import reliant for its cesium needs.

In 2021, one company offered 1-gram ampoules of 99.8% (metal basis) cesium for $69.90, a 7.2% increase from $65.20 in 2020, and 99.98% (metal basis) cesium for $88.90, a 5.0% increase from $84.70 in 2020. In 2021, the prices for 50 grams of 99.9% (metal basis) cesium acetate, cesium bromide, cesium carbonate, cesium chloride, and cesium iodide were $131.20, $75.90, $110.20, $112.00, and $127.60, respectively, with increases ranging from 4.1% to 9.3% from prices in 2020. The price for a cesium-plasma standard solution (10,000 micrograms per milliliter) was $78.60 for 50 milliliters and $120.00 for 100 milliliters, and the price for 25 grams of cesium formate, 98% (metal basis), was $42.60. In 2020, the price for a cesium-plasma standard solution (10,000 micrograms per milliliter) was $77.80 for 50 milliliters and $119.00 for 100 milliliters, and the price for 25 grams of cesium formate, 98% (metal basis), was $41.40.

Recycling: Cesium formate brines are typically rented by oil and gas exploration clients. After completion of the well, the used cesium formate brine is returned and reprocessed for subsequent drilling operations. Cesium formate brines are recycled, recovering nearly 85% of the brines for recycling to be reprocessed for further use.

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CESIUM

Import Sources (2017–20): No reliable data have been available to determine the source of cesium ore imported by the United States since 1988. Prior to 2016, Canada was thought to be the primary supplier of cesium ore.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Alkali metals, other	2805.19.9000	5.5% ad valorem.
Chlorides, other	2827.39.9000	3.7% ad valorem.
Bromides, other	2827.59.5100	3.6% ad valorem.
Iodides, other	2827.60.5100	4.2% ad valorem.
Sulfates, other	2833.29.5100	3.7% ad valorem.
Nitrates, other	2834.29.5100	3.5% ad valorem.
Carbonates, other	2836.99.5000	3.7% ad valorem.
Cesium-137, other	2844.40.0021	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic cesium occurrences will likely remain uneconomic unless market conditions change. No known human health issues are associated with naturally occurring cesium, and its use has minimal environmental impact. Manufactured radioactive isotopes of cesium have been known to cause adverse health effects. Certain cesium compounds may be toxic if consumed. Food that has been irradiated using the radioisotope cesium-137 has been found to be safe by the U.S. Food and Drug Administration.

During 2021, no primary cesium mine production was reported globally but cesium was thought to have been mined in China. Mine production of cesium from all countries, excluding China, ceased within the past two decades. Production in Namibia ceased in the early 2000s, followed by the Tanco Mine in Canada shutting down and later being sold after a mine collapse in 2015. The Bikita Mine in Zimbabwe was depleted of pollucite ore reserves in 2018, and the Sinclair Mine in Australia completed the mining and shipments of all economically recoverable pollucite ore in 2019. Recent reports indicate that with current processing rates for the only operating intermediate refinery in Germany, the world's stockpiles of cesium ore, excluding those in China, will be depleted within a few years.

A company completed an updated mineral resource estimate for the Karibib project in Namibia, reporting 8.9 million metric tons of measured and indicated resources containing 0.23% rubidium and 303 parts per million cesium. The company also reported 6.72 million metric tons of proven and probable reserves containing 2.26% rubidium and 320 parts per million cesium. Located in the Karibib Pegmatite Belt, lithium would be the primary product, with cesium, potassium, and rubidium as potential byproducts. Development of the Karibib project continued in 2021.

World Mine Production and Reserves:[1] There were no official sources for cesium production data in 2021. Cesium reserves are, therefore, estimated based on the occurrence of pollucite, a primary lithium-cesium-rubidium mineral. Most pollucite contains 5% to 32% cesium oxide. No reliable data are available to determine reserves for specific countries; however, Australia, Canada, China, and Namibia were thought to have reserves totaling less than 200,000 tons. Existing stockpiles at multiple former mine sites have continued feeding downstream refineries, though recent reports have indicated stockpiles will be depleted within a few years.

World Resources:[1] Cesium is associated with lithium-bearing pegmatites worldwide, and cesium resources have been identified in Australia, Canada, Namibia, the United States, and Zimbabwe. In the United States, pollucite occurs in pegmatites in Alaska, Maine, and South Dakota. Lower concentrations occur in brines in Chile and China and in geothermal systems in Germany, India, and China. China was thought to have cesium-rich deposits of geyserite, lepidolite, and pollucite, with concentrations highest in Yichun, Jiangxi Province, although no resource, reserve, or production estimates were available.

Substitutes: Cesium and rubidium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material for some applications. However, rubidium is mined from similar deposits, in relatively smaller quantities, as a byproduct of cesium production in pegmatites and as a byproduct of lithium production from lepidolite (hard-rock) mining and processing, making it no more readily available than cesium.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

CHROMIUM

(Data in thousand metric tons of contained chromium unless otherwise noted)

Domestic Production and Use: In 2021, the United States was expected to consume 5% of world chromite ore production in various forms of imported materials, such as chromite ore, chromium chemicals, chromium ferroalloys, chromium metal, and stainless steel. Imported chromite ore was consumed by one chemical company to produce chromium chemicals. Stainless-steel and heat-resisting-steel producers were the leading consumers of ferrochromium. Stainless steels and superalloys require the addition of chromium via ferrochromium or chromium-containing scrap. The value of chromium material consumption was expected to be about $850 million in 2021, as measured by the value of net imports, excluding stainless steel, and was a fourfold increase from $201 million in 2020.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Mine	—	—	—	—	—
Recycling[1]	152	139	135	116	120
Imports for consumption[2]	634	651	530	457	590
Exports	256	212	149	111	120
Shipments from Government stockpile	8	4	4	5	5
Consumption (includes recycling):					
Reported	516	459	480	379	360
Apparent[3]	541	583	520	465	590
Price, average annual unit value of imports, dollars per ton:					
Chromite ore (gross weight)	259	279	248	179	210
Ferrochromium (chromium content)[4]	2,547	2,549	2,094	1,878	2,400
Chromium metal (gross weight)	9,675	11,344	10,393	7,931	7,500
Stocks, consumer, yearend	6	5	5	6	6
Net import reliance[5] as a percentage of apparent consumption	72	76	73	75	80

Recycling: In 2021, recycled chromium (contained in reported stainless-steel scrap receipts) accounted for 20% of apparent consumption.

Import Sources (2017–20): Chromite (ores and concentrates): South Africa, 99%; and Canada, 1%.
Chromium-containing scrap:[6] United Kingdom, 53%; Canada, 28%; Japan, 9%; and other, 10%.
Chromium (primary metal):[7] Russia, 36%; United Kingdom, 23%; France, 21%; China,[8] 15%; and other, 5%.
Total imports: South Africa, 38%; Kazakhstan, 9%; Russia, 7%; Mexico, 6%; and other, 40%.

Tariff:[9] **Item**	**Number**	**Normal Trade Relations 12–31–21**
Chromium ores and concentrates:		
Cr_2O_3 not more than 40%	2610.00.0020	Free.
Cr_2O_3 more than 40% and less than 46%	2610.00.0040	Free.
Cr_2O_3 more than or equal to 46%	2610.00.0060	Free.
Ferrochromium:		
Carbon more than 4%	7202.41.0000	1.9% ad valorem.
Carbon more than 3%	7202.49.1000	1.9% ad valorem.
Carbon more than 0.5%	7202.49.5010	3.1% ad valorem.
Other	7202.49.5090	3.1% ad valorem.
Ferrosilicon chromium	7202.50.0000	10% ad valorem.
Chromium metal:		
Unwrought, powder	8112.21.0000	3% ad valorem.
Waste and scrap	8112.22.0000	Free.
Other	8112.29.0000	3% ad valorem.

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CHROMIUM

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[10, 11]

Material	Inventory as of 8–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Ferrochromium:					
High-carbon	25.6	—	[12]21.8	—	[12]21.8
Low-carbon	27.4	—	—	—	—
Chromium metal	3.62	—	0.454	—	0.454

Events, Trends, and Issues: Chromium is consumed in the form of ferrochromium to produce stainless steel. South Africa was the leading chromite ore producer. Ore production was estimated to increase in 2021 owing to recovery of the market following the COVID-19 pandemic. China was the leading ferrochromium- and stainless-steel-producing country, and the leading chromium-consuming country. Ferrochromium production is electrical-energy intensive, so stricter environmental standards could affect ferrochromium production in China.

From October 2020 to October 2021, the monthly average high-carbon ferrochromium price more than doubled. The price of chromium metal increased by 85% in October 2021 compared with the monthly average price in October 2020.

World Mine Production and Reserves:

	Mine production[13] 2020	Mine production[13] 2021[e]	Reserves[14] (shipping grade)[15]
United States	—	—	620
Finland	2,290	2,300	13,000
India	2,500	3,000	100,000
Kazakhstan	7,000	7,000	230,000
South Africa	13,200	18,000	200,000
Turkey	8,000	7,000	26,000
Other countries	3,980	4,100	NA
World total (rounded)	37,000	41,000	570,000

World Resources:[14] World resources are greater than 12 billion tons of shipping-grade chromite, sufficient to meet conceivable demand for centuries. World chromium resources are heavily geographically concentrated (95%) in Kazakhstan and southern Africa; United States chromium resources are mostly in the Stillwater Complex in Montana.

Substitutes: Chromium has no substitute in stainless steel, the leading end use, or in superalloys, the major strategic end use. Chromium-containing scrap can substitute for ferrochromium in some metallurgical uses.

[e]Estimated. NA Not available. — Zero.
[1]Recycling production is based on reported receipts of all types of stainless-steel scrap.
[2]Includes chromite ores, ferrochromium, chromium metal, and chromium chemicals.
[3]Defined as production (from mines and recycling) + imports – exports + adjustments for Government and industry stock changes.
[4]Excludes ferrochromium silicon.
[5]Defined as imports – exports + adjustments for Government and industry stock changes.
[6]Includes chromium metal scrap and stainless-steel scrap.
[7]Includes chromium metal, ferrochromium, and stainless steel.
[8]Includes Hong Kong.
[9]In addition to the tariff items listed, certain imported chromium materials (see 26 U.S.C., sec. 4661, 4662, and 4672) are subject to excise tax.
[10]See Appendix B for definitions.
[11]Units are thousand metric tons of material by gross weight.
[12]High-carbon and low-carbon ferrochromium, combined.
[13]Mine production units are thousand metric tons, gross weight, of marketable chromite ore.
[14]See Appendix C for resource and reserve definitions and information concerning data sources.
[15]Reserves units are thousand metric tons of shipping-grade chromite ore, which is deposit quantity and grade normalized to 45% Cr_2O_3, except for the United States where grade is normalized to 7% Cr_2O_3 and Finland where grade is normalized to 26% Cr_2O_3.

CLAYS

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Production of clays (sold or used) in the United States was estimated to be 25 million tons valued at $1.5 billion in 2021, with about 120 companies operating clay and shale mines in 38 States. The leading 20 companies produced approximately 65% of the U.S. tonnage and 84% of the value for all types of clay. Principal domestic uses for specific clays were estimated to be as follows: ball clay—50% floor and wall tile and 18% sanitaryware; bentonite—50% pet waste absorbents and 22% drilling mud; common clay—45% brick, 28% lightweight aggregate, and 22% cement; fire clay—82% heavy clay and lightweight aggregates products (for example, brick, cement, and concrete) and 14% refractory products and miscellaneous uses; fuller's earth—81% absorbents (includes oil and grease absorbents, pet waste absorbents, and miscellaneous absorbents); and kaolin—30% paper coating and filling, 15% miscellaneous ceramics, and 15% refractory products.

Exports of clay and shale were estimated have increased by 16% in 2021 after decreasing by 13% in 2020. In 2021, the United States exported an estimated 800,000 tons of bentonite with Canada, Japan, and China, in decreasing order, being the leading destinations. About 2.3 million tons of kaolin was exported mainly as a paper coating and filler; a component in ceramic bodies; and fillers and extenders in paint, plastic, and rubber products, with China, Mexico, and Japan, in decreasing order, being the leading destinations. Lesser quantities of ball clay, fire clay, and fuller's earth were exported for ceramic, refractory, and absorbent uses, respectively.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production (sold or used):					
Ball clay[e]	1,270	1,110	1,060	1,080	1,100
Bentonite	4,450	4,570	4,520	4,240	4,300
Common clay	13,600	12,900	12,800	12,600	13,000
Fire clay	575	567	603	635	650
Fuller's earth[e, 1]	1,840	1,880	1,990	1,980	2,000
Kaolin[e]	5,450	5,350	5,060	4,570	4,100
Total[1, 2]	27,200	26,400	26,100	25,100	25,000
Imports for consumption:					
Artificially activated clays and earths	28	23	31	31	40
Kaolin	316	330	293	224	190
Other	86	68	66	28	40
Total[2]	430	421	389	284	270
Exports:					
Artificially activated clays and earths	147	149	138	127	140
Ball clay	83	90	85	68	130
Bentonite	961	845	906	728	800
Clays, not elsewhere classified	244	244	204	185	170
Fire clay[3]	225	250	194	190	190
Fuller's earth	78	70	73	77	80
Kaolin	2,310	2,390	2,280	1,980	2,300
Total[2]	4,040	4,030	3,880	3,360	3,900
Consumption, apparent[4]	23,600	22,800	22,600	22,100	21,000
Price, ex-works, average unit value, dollars per ton:					
Ball clay	49	55	56	58	64
Bentonite	99	98	98	96	94
Common clay	15	16	17	16	16
Fire clay	13	12	14	13	13
Fuller's earth[1]	93	88	88	89	88
Kaolin	158	160	162	160	160
Employment (excludes office workers), number:[e]					
Mine (may not include contract workers)	1,220	1,110	1,110	1,060	1,060
Mill	4,370	4,310	4,310	4,260	4,240
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2017–20): All clay types combined: Brazil, 70%; Mexico, 9%; China, 7%; and other, 14%.

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CLAYS

Tariff: Item	Number	Normal Trade Relations 12–31–21
Kaolin and other kaolinic clays, whether or not calcined	2507.00.0000	Free.
Bentonite	2508.10.0000	Free.
Fire clay	2508.30.0000	Free.
Common blue clay and other ball clays	2508.40.0110	Free.
Decolorizing earths and fuller's earth	2508.40.0120	Free.
Other clays	2508.40.0150	Free.
Chamotte or dinas earth	2508.70.0000	Free.
Activated clays and activated earths	3802.90.2000	2.5% ad valorem.
Expanded clays and other mixtures	6806.20.0000	Free.

Depletion Allowance: Ball clay, bentonite, fire clay, fuller's earth, and kaolin, 14% (domestic and foreign); clay used in the manufacture of common brick, lightweight aggregate, and sewer pipe, 7.5% (domestic and foreign); clay used in the manufacture of drain and roofing tile, flowerpots, and kindred products, 5% (domestic and foreign); clay from which alumina and aluminum compounds are extracted, 22% (domestic).

Government Stockpile: None.

Events, Trends, and Issues: In October 2021, a common clay producer headquartered in Tennessee finalized the acquisition of another common clay company headquartered in Georgia, which operated 20 plants throughout North America. In July 2021, a Georgia kaolin producer announced an agreement to purchase central Georgia assets that support the paper and board industry from another kaolin producer with North American headquarters in Georgia.

World Mine Production and Reserves:[6] Global reserves are large, but country-specific data were not available.

	Mine production					
	Bentonite		Fuller's earth		Kaolin	
	2020	2021[e]	2020	2021[e]	2020	2021[e]
United States	4,240	4,300	[1]1,980	[1]2,000	4,570	4,100
Brazil (beneficiated)	217	200	—	—	1,240	1,200
China	2,500	2,500	—	—	6,500	6,400
Czechia	226	230	—	—	[7]3,070	[7]3,100
Germany	360	350	—	—	870	800
Greece	[7]1,300	[7]1,300	34	30	—	—
India	3,500	3,500	730	730	[7]7,600	[7]7,600
Iran	425	420	—	—	1,800	1,800
Mexico	25	20	110	110	120	120
Senegal	—	—	117	120	—	—
Spain	221	220	590	590	[7]450	[7]450
Turkey	1,500	1,700	60	60	1,200	1,200
Ukraine	180	180	—	—	1,680	1,600
Uzbekistan	25	20	—	—	5,900	5,500
Other countries	3,480	3,500	313	310	11,400	11,000
World total (rounded)	18,200	18,000	[1]3,930	[1]4,000	46,400	45,000

World Resources:[6] Resources of all clays are extremely large.

Substitutes: Clays compete with calcium carbonate in filler and extender applications; diatomite, organic pet litters, polymers, silica gel, and zeolites as absorbents; and various siding and roofing types in building construction.

[e]Estimated. E Net exporter. — Zero.
[1]Does not include U.S. production of attapulgite.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes refractory-grade kaolin.
[4]Defined as production (sold or used) + imports – exports.
[5]Defined as imports – exports.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]Includes production of crude ore.

COBALT

(Data in metric tons of contained cobalt unless otherwise noted)

Domestic Production and Use: In 2021, the nickel-copper Eagle Mine in Michigan produced cobalt-bearing nickel concentrate, which was exported to Canada or overseas for processing. In Missouri, a company produced nickel-copper-cobalt concentrate from historic mine tailings and was building a hydrometallurgical processing plant near the mine site. Most U.S. cobalt supply consisted of imports and secondary (scrap) materials. Approximately six companies in the United States produced cobalt chemicals. An estimated 42% of the cobalt consumed in the United States was used in superalloys, mainly in aircraft gas turbine engines; 9% in cemented carbides for cutting and wear-resistant applications; 16% in various other metallic applications; and 33% in a variety of chemical applications. The total estimated value of cobalt consumed in 2021 was $340 million.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:[e]					
Mine	640	480	500	600	700
Secondary[1]	2,750	2,750	2,750	2,000	1,600
Imports for consumption	11,900	11,900	13,900	9,740	9,900
Exports	5,690	6,980	4,080	3,440	4,800
Consumption (includes secondary):					
Estimated[2]	9,240	9,290	9,050	7,300	6,600
Apparent[3]	8,950	7,680	12,500	8,500	6,700
Price, average, dollars per pound:					
U.S. spot, cathode[4]	26.97	37.43	16.95	15.70	23
London Metal Exchange (LME), cash	25.28	32.94	14.88	14.21	22
Stocks, yearend:					
Industry[e, 2, 5]	1,020	1,060	1,090	950	950
LME, U.S. warehouse	160	130	102	82	50
Net import reliance[6] as a percentage of apparent consumption	69	64	78	76	76

Recycling: In 2021, cobalt contained in purchased scrap represented an estimated 24% of cobalt estimated consumption.

Import Sources (2017–20): Cobalt contained in metal, oxide, and salts: Norway, 20%; Canada, 16%; Japan, 13%; Finland, 11%; and other, 40%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Cobalt ores and concentrates	2605.00.0000	Free.
Chemical compounds:		
Cobalt oxides and hydroxides	2822.00.0000	0.1% ad valorem.
Cobalt chlorides	2827.39.6000	4.2% ad valorem.
Cobalt sulfates	2833.29.1000	1.4% ad valorem.
Cobalt carbonates	2836.99.1000	4.2% ad valorem.
Cobalt acetates	2915.29.3000	4.2% ad valorem.
Unwrought cobalt, alloys	8105.20.3000	4.4% ad valorem.
Unwrought cobalt, other	8105.20.6000	Free.
Cobalt mattes and other intermediate products; cobalt powders	8105.20.9000	Free.
Cobalt waste and scrap	8105.30.0000	Free.
Wrought cobalt and cobalt articles	8105.90.0000	3.7% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7] See Lithium for statistics on lithium-cobalt oxide and lithium-nickel-cobalt-aluminum oxide.

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Cobalt	302	—	—	—	—
Cobalt alloys, gross weight[8]	11	50	—	50	—

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COBALT

Events, Trends, and Issues: Global cobalt mine and refinery production were forecast to increase to record high levels in 2021. The increase in raw materials feed was mainly from increased production at existing operations, although new production and restarts at suspended operations also contributed to supply. Congo (Kinshasa) continued to be the world's leading source of mined cobalt, supplying more than 70% of world cobalt mine production. With the exception of production in Morocco and artisanally mined cobalt in Congo (Kinshasa), most cobalt is mined as a byproduct of copper or nickel. China was the world's leading producer of refined cobalt, most of which was produced from partially refined cobalt imported from Congo (Kinshasa). China was the world's leading consumer of cobalt, with more than 80% of its consumption being used by the rechargeable battery industry.

World Mine Production and Reserves: Reserves for multiple countries were revised based on Government or industry reports.

	Mine production		Reserves[9]
	2020	2021[e]	
United States	600	700	69,000
Australia	5,630	5,600	[10]1,400,000
Canada	3,690	4,300	220,000
China	2,200	2,200	80,000
Congo (Kinshasa)	98,000	120,000	3,500,000
Cuba	3,800	3,900	500,000
Indonesia	1,100	2,100	600,000
Madagascar	850	2,500	100,000
Morocco	2,300	2,300	13,000
Papua New Guinea	2,940	3,000	47,000
Philippines	4,500	4,500	260,000
Russia	9,000	7,600	250,000
Other countries	7,640	6,600	610,000
World total (rounded)	142,000	170,000	7,600,000

World Resources:[9] Identified cobalt resources of the United States are estimated to be about 1 million tons. Most of these resources are in Minnesota, but other important occurrences are in Alaska, California, Idaho, Michigan, Missouri, Montana, Oregon, and Pennsylvania. With the exception of resources in Idaho and Missouri, any future cobalt production from these deposits would be as a byproduct of another metal. Identified world terrestrial cobalt resources are about 25 million tons. The vast majority of these resources are in sediment-hosted stratiform copper deposits in Congo (Kinshasa) and Zambia; nickel-bearing laterite deposits in Australia and nearby island countries and Cuba; and magmatic nickel-copper sulfide deposits hosted in mafic and ultramafic rocks in Australia, Canada, Russia, and the United States. More than 120 million tons of cobalt resources have been identified in polymetallic nodules and crusts on the floor of the Atlantic, Indian, and Pacific Oceans.

Substitutes: Depending on the application, substitution for cobalt could result in a loss in product performance or an increase in cost. The cobalt contents of lithium-ion batteries, the leading global use for cobalt, are being reduced; potential commercially available cobalt-free substitutes use iron and phosphorus. Potential substitutes in other applications include barium or strontium ferrites, neodymium-iron-boron alloys, or nickel-iron alloys in magnets; cerium, iron, lead, manganese, or vanadium in paints; cobalt-iron-copper or iron-copper in diamond tools; copper-iron-manganese for curing unsaturated polyester resins; iron, iron-cobalt-nickel, nickel, ceramic-metallic composites (cermets), or ceramics in cutting and wear-resistant materials; nickel-base alloys or ceramics in jet engines; nickel in petroleum catalysts; rhodium in hydroformylation catalysts; and titanium-base alloys in prosthetics.

[e]Estimated. — Zero.
[1]Estimated from consumption of purchased scrap.
[2]Includes reported data and U.S. Geological Survey estimates.
[3]Defined as secondary production + imports – exports + adjustments for Government and industry stock changes for refined cobalt.
[4]Source: Platts Metals Week. Cobalt cathode is refined cobalt metal produced by an electrolytic process.
[5]Stocks held by consumers and processors; excludes stocks held by trading companies and held for investment purposes.
[6]Defined as imports – exports + adjustments for Government and industry stock changes for refined cobalt.
[7]See Appendix B for definitions.
[8]Inventory is cobalt alloys; potential acquisitions are samarium-cobalt alloy; excludes potential disposals of aerospace alloys.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.
[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 560,000 tons.

COPPER

(Data in thousand metric tons of contained copper unless otherwise noted)

Domestic Production and Use: In 2021, the recoverable copper content of U.S. mine production was an estimated 1.2 million tons, unchanged from that in 2020, and was valued at an estimated $12 billion, 58% greater than $7.61 billion in 2020. Arizona was the leading copper-producing State and accounted for an estimated 71% of domestic output; copper was also mined in Michigan, Missouri, Montana, Nevada, New Mexico, and Utah. Copper was recovered or processed at 25 mines (19 of which accounted for 99% of mine production), 2 smelters, 2 electrolytic refineries, and 14 electrowinning facilities. An additional smelter and electrolytic refinery have been temporarily closed since October 2019. Refined copper and scrap were used at about 30 brass mills, 14 rod mills, and 500 foundries and miscellaneous consumers. Copper and copper alloy products were used in building construction, 46%; electrical and electronic products, 21%; transportation equipment, 16%; consumer and general products, 10%; and industrial machinery and equipment, 7%.[1]

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine, recoverable copper content	1,260	1,220	1,260	1,200	1,200
Refinery:					
Primary (from ore)	1,040	1,070	985	874	950
Secondary (from scrap)	40	41	44	43	50
Copper recovered from old (post-consumer) scrap[2]	146	149	[e]150	[e]150	160
Imports for consumption:					
Ore and concentrates	14	32	27	2	13
Refined	813	778	663	676	920
Exports:					
Ore and concentrates	237	253	353	383	360
Refined	94	190	125	41	50
Consumption:					
Reported, refined metal	1,800	1,820	1,830	1,710	1,800
Apparent, primary refined and old scrap[3]	1,860	1,830	1,810	1,650	2,000
Price, annual average, cents per pound:					
U.S. producer, cathode (COMEX + premium)	285.4	298.7	279.6	286.7	430.0
COMEX, high-grade, first position	280.4	292.6	272.3	279.9	420.0
London Metal Exchange, grade A, cash	279.5	296.0	272.4	279.8	420.0
Stocks, refined, held by U.S. producers, consumers, and metal exchanges, yearend	265	244	111	118	80
Employment, mine and plant, number	10,500	11,700	12,000	11,000	11,000
Net import reliance[4] as a percentage of apparent consumption	36	33	37	38	45

Recycling: Old (post-consumer) scrap, converted to refined metal and alloys, provided an estimated 160,000 tons of copper. Purchased new (manufacturing) scrap, derived from fabricating operations, yielded an estimated 710,000 tons. Of the total copper recovered from scrap (including non-copper-base scrap), brass and wire-rod mills accounted for about 80%; smelters, refiners, and ingot makers, 15%; and miscellaneous chemical plants, foundries, and manufacturers, 5%. Copper recovered from scrap contributed about 32% of the U.S. copper supply.[5]

Import Sources (2017–20): Copper content of blister and anodes: Finland, 81%; Malaysia, 13%; and other, 6%. Copper content of matte, ash, and precipitates: Canada, 28%; Mexico, 20%; Belgium, 14%; Spain, 11%; and other, 27%. Copper content of ore and concentrates: Mexico, 97%; and other, 3%. Copper content of scrap: Canada, 54%; Mexico, 34%; and other, 12%. Refined copper: Chile, 62%; Canada, 23%; Mexico, 11%; and other, 4%. Refined copper accounted for 85% of all unmanufactured copper imports.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Copper ore and concentrates, copper content	2603.00.0010	1.7¢/kg on lead content.
Unrefined copper anodes	7402.00.0000	Free.
Refined copper and alloys, unwrought	7403.00.0000	1.0% ad valorem.
Copper wire rod	7408.11.0000	1.0% or 3.0% ad valorem.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: None.

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COPPER

Events, Trends, and Issues: In the United States, mined copper production remained unchanged in 2021 from that in 2020. Production increased significantly at the Safford Mine in Arizona owing to the rampup of the Lone Star expansion that was completed in the second half of 2020. Operations at the Chino Mine in New Mexico, which had been suspended since April 2020 after multiple workers tested positive for COVID-19, restarted in the first quarter of 2021. At the Pinto Valley Mine in Arizona, optimization projects completed in 2020 and 2021 resulted in higher copper recovery and throughput rates. Production also increased at other domestic copper mines because of higher ore grades, but the increases were offset by significant decreases in output at several major mines in Arizona. The rampup of the Gunnison Mine in Arizona, which commenced production in late 2020, was delayed because of technical complications with the injection wells. Production at the Pumpkin Hollow Mine in Nevada, which started in late 2019 and was halted for several months in 2020 because of the COVID-19 pandemic, was expected to reach capacity in the third quarter of 2022. Refined copper production in the United States increased by an estimated 9% in 2021 compared with that in 2020, when operations at the smelter in Utah were affected by a rebuild of the flash converting furnace after an earthquake and a delayed restart following planned maintenance.

Based on data through October, the annual average COMEX copper price was projected to be about $4.20 per pound in 2021, an increase of 50% from that in 2020 and 5% greater than the previous alltime high of $4.01 per pound in 2011. Strong global manufacturing activity, constrained growth in world copper production, low stockpiles, and supply constraints owing to shipping delays contributed to the increased copper price.

World Mine and Refinery Production and Reserves: Reserves for multiple countries were revised based on company and (or) Government information.

	Mine production		Refinery production		Reserves[6]
	2020	2021[e]	2020	2021[e]	
United States	1,200	1,200	918	1,000	48,000
Australia	885	900	427	450	[7]93,000
Canada	585	590	[e]290	300	9,800
Chile	5,730	5,600	2,330	2,200	200,000
China	1,720	1,800	10,000	10,000	26,000
Congo (Kinshasa)	1,600	1,800	1,350	1,500	31,000
Germany	—	—	643	630	—
Indonesia	505	810	269	270	24,000
Japan	—	—	1,580	1,500	—
Kazakhstan	552	520	515	470	20,000
Korea, Republic of	—	—	671	650	—
Mexico	733	720	492	470	53,000
Peru	2,150	2,200	324	350	77,000
Poland	393	390	560	590	31,000
Russia	[e]810	820	1,040	920	62,000
Zambia	853	830	378	350	21,000
Other countries	2,840	2,800	3,450	4,300	180,000
World total (rounded)	20,600	21,000	25,300	26,000	880,000

World Resources:[6] A U.S. Geological Survey study of global copper deposits indicated that, as of 2015, identified resources contained 2.1 billion tons of copper, and undiscovered resources contained an estimated 3.5 billion tons.[8]

Substitutes: Aluminum substitutes for copper in automobile radiators, cooling and refrigeration tube, electrical equipment, and power cable. Titanium and steel are used in heat exchangers. Optical fiber substitutes for copper in telecommunications applications, and plastics substitute for copper in drain pipe, plumbing fixtures, and water pipe.

[e]Estimated. — Zero.
[1]Distribution reported by the Copper Development Association. Some electrical components are included in each end use.
[2]Copper converted to refined metal and alloys by brass and wire-rod mills, foundries, refineries, and other manufacturers.
[3]Primary refined production + copper in old scrap converted to refined metal and alloys + refined imports – refined exports ± refined stock changes.
[4]Defined as refined imports – refined exports ± adjustments for refined copper stock changes.
[5]Primary refined production + copper recovered from old and new scrap + refined imports – refined exports ± refined stock changes.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 23 million tons.
[8]Hammarstrom, J.M., Zientek, M.L., Parks, H.L., Dicken, C.L., and the U.S. Geological Survey Global Copper Mineral Resource Assessment Team, 2019, Assessment of undiscovered copper resources of the world, 2015 (ver.1.1, May 24, 2019): U.S. Geological Survey Scientific Investigations Report 2018–5160, 619 p., https://doi.org/10.3133/sir20185160.

DIAMOND (INDUSTRIAL)[1]

(Data in million carats unless otherwise noted)

Domestic Production and Use: In 2021, total domestic primary production of manufactured industrial diamond bort, grit, and dust and powder was estimated to be 140 million carats with a value of $42 million, a 7% increase compared with that in 2020. No industrial diamond stone was produced domestically. One company with facilities in Florida and Ohio and a second company in Pennsylvania accounted for all domestic primary production. At least four companies produced polycrystalline diamond from diamond powder. At least two companies recovered used industrial diamond material from used diamond drill bits, diamond tools, and other diamond-containing wastes for recycling. The major consuming sectors of industrial diamond are computer chip production; construction; drilling for minerals, natural gas, and oil; machinery manufacturing; stone cutting and polishing; and transportation (infrastructure and vehicles). Highway building, milling, and repair and stone cutting consumed most of the industrial diamond stone. About 94% of U.S. industrial diamond apparent consumption was synthetic industrial diamond because its quality can be controlled and its properties can be customized.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Bort, grit, and dust and powder; natural and synthetic:					
Production:					
Manufactured diamond[e]	41	184	114	130	140
Secondary	11	32	36	35	34
Imports for consumption	362	574	310	191	220
Exports	161	139	114	91	100
Consumption, apparent[2]	253	652	346	265	290
Price, unit value of imports, dollars per carat	0.16	0.12	0.14	0.19	0.21
Net import reliance[3] as a percentage of apparent consumption	79	67	57	38	41
Stones, natural and synthetic:					
Production:					
Manufactured diamond[e]	87	—	—	—	—
Secondary	0.39	0.13	0.10	0.10	0.10
Imports for consumption	1.23	2.52	1.07	0.51	0.32
Exports	—	—	([4])	0.02	—
Consumption, apparent[2]	89.0	2.7	1.2	0.6	0.4
Price, unit value of imports, dollars per carat	12.9	2.9	5.8	8.4	12.0
Net import reliance[3] as a percentage of apparent consumption	1	95	91	83	76

Recycling: In 2021, the amount of diamond bort, grit, and dust and powder recycled was estimated to be 34 million carats with an estimated value of $5.4 million. It was estimated that 98,000 carats of diamond stone were recycled with an estimated value of $150,000.

Import Sources (2017–20): Bort, grit, and dust and powder; natural and synthetic: China,[5] 81%; Ireland, 6%; the Republic of Korea, 6%; Russia, 4%; and other, 3%. Stones, primarily natural: South Africa, 24%; India, 18%; Congo (Kinshasa), 17%; Botswana, 10%; and other, 31%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Industrial Miners' diamonds, carbonados	7102.21.1010	Free.
Industrial Miners' diamonds, other	7102.21.1020	Free.
Industrial diamonds, simply sawn, cleaved, or bruted	7102.21.3000	Free.
Industrial diamonds, not worked	7102.21.4000	Free.
Grit or dust and powder of natural diamonds, 80 mesh or finer	7105.10.0011	Free.
Grit or dust and powder of natural diamonds, over 80 mesh	7105.10.0015	Free.
Grit or dust and powder of synthetic diamonds, coated with metal	7105.10.0020	Free.
Grit or dust and powder of synthetic diamonds, not coated with metal, 80 mesh or finer	7105.10.0030	Free.
Grit or dust and powder of synthetic diamonds, not coated with metal, over 80 mesh	7105.10.0050	Free.

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DIAMOND (INDUSTRIAL)

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Most natural industrial diamond is produced as a byproduct of mining gem-quality diamond. Global natural industrial diamond production increased slightly during 2021. This increase was the result of mines returning to normal operation after the global COVID-19 pandemic caused reduced production in 2020. The most significant recoveries in rough diamond production were in Angola, Botswana, and Canada. Recovery from the effects of the pandemic have been hampered by mine closures and lower output as mines approach the ends of their lives. The world's largest diamond mines have matured and are past their peak production levels, and several of the largest diamond mines are expected to close by the end of 2025. As these mines are depleted, global production is expected to decline in quantity and the global supply of crude natural diamond (including gem-quality and industrial diamond) is forecasted to steadily decrease to about 120 million carats in 2030.

In 2021, U.S. synthetic-industrial-diamond producers did not manufacture any diamond stone and the combined apparent consumption of all types of industrial diamond decreased. Domestic and global demand for synthetic diamond grit and powder is expected to remain greater than that for natural diamond material. The average unit value of all types of natural and synthetic industrial diamond imports increased by 6%. In 2021, China was the leading producing country of synthetic industrial diamond, followed by the United States, Russia, Ireland, and South Africa, in descending order of quantity. These five countries produced about 99% of the world's synthetic industrial diamond. Synthetic diamond accounted for more than 99% of global industrial diamond production and consumption. Worldwide production of manufactured industrial diamond totaled more than 14.7 billion carats.

The United States is likely to continue to be one of the world's leading markets for industrial diamond into the next decade and is expected to remain a significant producer and exporter of synthetic industrial diamond as well. U.S. demand for industrial diamond is likely to be strong in the construction sector as the United States continues building, milling, and repairing the Nation's highway system. Industrial diamond coats the cutting edge of saws used to cut concrete in highway construction and repair work.

World Natural Industrial Diamond Mine Production and Reserves: Reserves for Australia, Botswana, Russia, and South Africa were revised based on Government and company information.

	Mine production		Reserves[6]
	2020	2021[e]	
United States	—	—	NA
Australia	11	8	[7]11
Botswana	5	6	300
Congo (Kinshasa)	10	11	150
Russia	14	15	1,100
South Africa	2	2	120
Zimbabwe	2	2	NA
Other countries	1	1	120
World total (rounded)	45	45	1,800

World Resources:[6] Natural diamond deposits have been discovered in more than 35 countries. Natural diamond accounts for about 4% of all industrial diamond used, synthetic diamond accounts for the remainder. At least 15 countries have the technology to produce synthetic diamond.

Substitutes: Materials that can compete with industrial diamond in some applications include manufactured abrasives, such as cubic boron nitride, fused aluminum oxide, and silicon carbide. Globally, synthetic diamond, rather than natural diamond, is used for about 99% of industrial applications.

[e]Estimated. NA Not available. — Zero.
[1]See Gemstones for information on gem-quality diamond.
[2]Defined as manufactured diamond production + secondary diamond production + imports – exports.
[3]Defined as imports – exports.
[4]Less than 500 carats.
[5]Includes Hong Kong.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 10 million carats.

DIATOMITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, production of diatomite, also known as diatomaceous earth, was estimated to be 830,000 tons with an estimated processed value of $274 million, free on board (f.o.b.) plant. Six companies produced diatomite at 12 mining areas and 9 processing facilities in California, Nevada, Oregon, and Washington. Approximately 55% of diatomite is used in filtration products. The remaining 45% is used in absorbents, fillers, lightweight aggregates, and other applications. A small amount, less than 1%, is used for specialized pharmaceutical and biomedical purposes. The unit value of diatomite varied widely in 2021, from approximately $10 per ton when used as a lightweight aggregate in portland cement concrete to more than $1,000 per ton for limited specialty markets, including art supplies, cosmetics, and deoxyribonucleic acid (DNA) extraction.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production[1]	768	957	768	822	830
Imports for consumption	9	9	10	14	14
Exports	87	68	68	66	70
Consumption, apparent[2]	690	898	710	770	770
Price, average value, f.o.b. plant, dollars per ton	360	330	340	330	330
Employment, mine and plant, number[e]	360	370	370	370	370
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None.

Import Sources (2017–20): Canada, 68%; Mexico, 12%; Germany, 10%; Argentina, 4%; and other, 6%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Siliceous fossil meals, including diatomite	2512.00.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The amount of domestically produced diatomite sold or used by producers in 2021 was essentially unchanged compared with that in 2020. Apparent domestic consumption in 2021 was the same at an estimated 770,000 tons; exports were estimated to have increased by 6%. The United States remained the leading global producer and consumer of diatomite. Filtration (including the purification of beer, liquors, and wine and the cleansing of greases and oils) continued to be the leading end use for diatomite. An important application for diatomite is the removal of microbial contaminants, such as bacteria, protozoa, and viruses in public water systems. Other applications for diatomite include filtration of human blood plasma, pharmaceutical processing, and use as a nontoxic insecticide. Domestically, diatomite used in the production of cement was the second-ranked use. Despite disruptions caused by the global COVID-19 pandemic, the production of diatomite through 2021 remained about the same as that in 2020.

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DIATOMITE

In 2021, the United States accounted for an estimated 36% of total world production; followed by Denmark with 17%; Turkey with 9%; China with 6%; and Argentina, Mexico, and Peru, each with 4%. Smaller quantities of diatomite were mined in 21 additional countries.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States[1]	822	830	250,000
Argentina	94	90	NA
China	140	140	110,000
Denmark[5] (processed)	400	400	NA
France	75	75	NA
Germany	52	50	NA
Japan	40	40	NA
Korea, Republic of	26	50	NA
Mexico	96	100	NA
New Zealand	40	40	NA
Peru	91	90	NA
Russia	51	50	NA
Spain	50	50	NA
Turkey	220	200	44,000
Other countries	120	120	NA
World total (rounded)	2,320	2,300	Large

World Resources:[4] Diatomite deposits form from an accumulation of amorphous hydrous silica cell walls of dead diatoms in oceanic and fresh waters. Diatomite is also known as kieselguhr (Germany), tripolite (after an occurrence near Tripoli, Libya), and moler (an impure Danish form). Because U.S. diatomite occurrences are at or near Earth's surface, recovery from most deposits is achieved through low-cost, open pit mining. Outside the United States, however, underground mining is fairly common owing to deposit location and topographic constraints. World resources of crude diatomite are adequate for the foreseeable future.

Substitutes: Many materials can be substituted for diatomite. However, the unique properties of diatomite assure its continued use in many applications. Expanded perlite and silica sand compete for filtration. Filters made from manufactured materials, notably ceramic, polymeric, or carbon membrane filters and filters made with cellulose fibers, are becoming competitive as filter media. Alternate filler materials include clay, ground limestone, ground mica, ground silica sand, perlite, talc, and vermiculite. For thermal insulation, materials such as various clays, exfoliated vermiculite, expanded perlite, mineral wool, and special brick can be used. Transportation costs will continue to determine the maximum economic distance that most forms of diatomite may be shipped and still remain competitive with alternative materials.

[e]Estimated. E Net exporter. NA Not available.
[1]Processed ore sold or used by producers.
[2]Defined as production + imports – exports.
[3]Defined as imports – exports.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]Includes sales of moler production.

FELDSPAR AND NEPHELINE SYENITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: U.S. feldspar production in 2021 had an estimated value of $43 million. Two leading companies mined and processed about 60% of production; five other companies supplied the remainder. The five leading producing States were California, North Carolina, Oklahoma, South Dakota, and Virginia. Feldspar processors reported joint product recovery of mica and silica sand. Nepheline syenite produced in the United States was not included in production figures because the material was not considered to be marketable as a flux and was mostly used in construction applications.

Feldspar is ground to about 20 mesh for glassmaking and to 200 mesh or finer for most ceramic and filler applications. It was estimated that domestically produced feldspar was transported by ship, rail, or truck to at least 30 States and to foreign destinations, including Canada and Mexico. In pottery and glass, feldspar and nepheline syenite function as a flux. The estimated 2021 end-use distribution of domestic feldspar and nepheline syenite was glass, 65%, and ceramic tile, pottery, and other uses, 35%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, feldspar, marketable[1]	440	550	450	430	400
Imports for consumption:					
Feldspar	290	181	64	43	190
Nepheline syenite	1,460	1,070	508	503	520
Exports, feldspar	5	4	4	3	4
Consumption, apparent:[1, 2]					
Feldspar only	730	730	510	470	590
Feldspar and nepheline syenite	2,200	1,800	1,000	980	1,100
Price, average value, dollars per ton:					
Feldspar only, marketable production	62	97	107	108	110
Nepheline syenite, average unit value of imports	61	76	156	163	170
Employment, mine, preparation plant, and office, number[e]	240	240	240	240	220
Net import reliance[3] as a percentage of apparent consumption:					
Feldspar	39	24	12	8	32
Nepheline syenite	100	100	100	100	100

Recycling: Feldspar and nepheline syenite are not recycled by producers; however, glass container producers use cullet (recycled container glass), thereby reducing feldspar and nepheline syenite consumption.

Import Sources (2017–20): Feldspar: Turkey, 98%; and other, 2%. Nepheline syenite: Canada, 100%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Feldspar	2529.10.0000	Free.
Nepheline syenite	2529.30.0010	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, estimated domestic production and sales of feldspar decreased by about 6%, and the average unit value of sales slightly increased compared with that in 2020. Estimated imports of feldspar were more than fourfold those in 2020, and nepheline syenite imports increased by an estimated 3% in 2021. Imports of nepheline syenite reported by the U.S. Census Bureau in 2017 and 2018 were unusually high.

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FELDSPAR AND NEPHELINE SYENITE

Domestic feldspar consumption has been gradually shifting toward glass from ceramics. A growing segment in the glass industry was solar glass, used in the production of solar panels. Glass—including beverage containers (more than one-half of the feldspar consumed by the glass industry), plate glass, and fiberglass insulation for housing and building construction—continued to be the leading end use of feldspar in the United States.

In the United States, residential construction, in which feldspar is a raw material commonly used in the manufacture of plate glass, ceramic tiles and sanitaryware, and insulation, increased by 17% during the first 10 months of 2021 compared with that in the same period in 2020. Production and sales of feldspar are expected to increase into 2022, owing in part to low mortgage interest rates, increased demand for single-family homes as the global COVID-19 pandemic made multifamily homes less desirable, and supply shortages of materials needed in new residential construction.

A company based in Canada continued development of a feldspar-quartz-kaolin project in Idaho that contained high-grade potassium feldspar. Production was expected to be about 30,000 tons per year of potassium feldspar during a 25-year mine life. For several years, the operation has produced a low-iron and trace-element feldspathic sand product from old mine tailings, which was sold to ceramic tile producers.

World Mine Production and Reserves:[4] Reserves data for Czechia and Thailand were revised based on industry and Government information.

	Mine production		Reserves[5]
	2020	2021[e]	
United States[1]	430	400	NA
Brazil (beneficiated, marketable)	300	300	150,000
China	2,500	2,600	NA
Czechia	419	420	22,000
India	6,000	6,200	320,000
Iran	2,400	2,400	630,000
Italy	2,200	2,200	NA
Korea, Republic of	415	420	180,000
Mexico	300	500	NA
Poland	405	350	NA
Russia	300	350	NA
Spain (includes pegmatites)	650	800	NA
Thailand	1,200	1,300	220,000
Turkey	5,000	7,800	240,000
Other countries	1,920	1,900	NA
World total (rounded)	24,400	28,000	Large

World Resources:[5] Identified and undiscovered resources of feldspar are more than adequate to meet anticipated world demand. Quantitative data on resources of feldspar existing in feldspathic sands, granites, and pegmatites generally have not been compiled. Ample geologic evidence indicates that resources are large, although not always conveniently accessible to the principal centers of consumption.

Substitutes: Imported nepheline syenite was the major alternative material for feldspar. Feldspar can be replaced in some of its end uses by clays, electric furnace slag, feldspar-silica mixtures, pyrophyllite, spodumene, or talc.

[e]Estimated. NA Not available.
[1]Rounded to two significant digits to avoid disclosing company proprietary data.
[2]Defined as production + imports – exports.
[3]Defined as imports – exports.
[4]Feldspar only.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.

FLUORSPAR

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, minimal fluorspar (calcium fluoride, CaF_2) was produced in the United States. One company sold fluorspar from stockpiles produced as a byproduct of its limestone quarrying operation in Cave-in-Rock, IL, and continued development of its fluorspar mine in Kentucky. In May, a second company, in Utah, began site preparations for the construction of a plant to produce metallurgical-grade fluorspar briquets. An estimated 22,000 tons of fluorosilicic acid (FSA), equivalent to about 36,000 tons of fluorspar grading 100% CaF_2, was recovered from three phosphoric acid plants processing phosphate rock and was primarily used in water fluoridation. A company in Aurora, NC, continued construction on a plant to produce hydrofluoric acid (HF) from FSA which was expected to begin operation in 2022. The U.S. Department of Energy continued to produce aqueous HF as a byproduct of the conversion of depleted uranium hexafluoride to depleted uranium oxide at plants in Paducah, KY, and Portsmouth, OH.

U.S. fluorspar consumption was satisfied by imports. Domestically, production of HF in Louisiana and Texas was by far the leading use for acid-grade fluorspar. Hydrofluoric acid is the primary feedstock for the manufacture of virtually all fluorine-bearing chemicals, particularly refrigerants and fluoropolymers, and is also a key ingredient in the processing of aluminum and uranium. Fluorspar was also used in cement production, in enamels, as a flux in steelmaking, in glass manufacture, in iron and steel casting, and in welding rod coatings.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Finished, metallurgical grade	NA	NA	NA	NA	NA
Fluorosilicic acid from phosphate rock	40	33	29	22	22
Imports for consumption:					
Acid grade	331	381	346	414	430
Metallurgical grade	70	78	59	65	40
Total fluorspar imports	401	459	405	480	470
Hydrofluoric acid	123	122	124	103	110
Aluminum fluoride	21	26	38	21	20
Cryolite	10	17	21	26	46
Exports, fluorspar, all grades[1]	11	9	8	9	17
Consumption, apparent[2]	390	450	398	470	450
Price, average unit value of imports, cost, insurance, and freight, dollars per ton:					
Acid grade	267	276	304	310	330
Metallurgical grade	237	258	292	149	160
Employment, mine, number[e]	19	16	14	14	14
Net import reliance[2] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Synthetic fluorspar may be produced from neutralization of waste in the enrichment of uranium, petroleum alkylation, and stainless-steel pickling; however, undesirable impurities constrain use. Primary aluminum producers recycle HF and fluorides from smelting operations.

Import Sources (2017–20):[3] Mexico, 66%; Vietnam, 16%; South Africa, 7%; Canada, 4%; and other, 7%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Metallurgical grade (less than 97% CaF_2)	2529.21.0000	Free.
Acid grade (97% or more CaF_2)	2529.22.0000	Free.
Natural cryolite	2530.90.1000	Free.
Hydrogen fluoride (hydrofluoric acid)	2811.11.0000	Free.
Aluminum fluoride	2826.12.0000	Free.
Sodium hexafluoroaluminate (synthetic cryolite)	2826.30.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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FLUORSPAR

Events, Trends, and Issues: Global mine production was estimated to have increased in 2021 primarily owing to the continued rampup of production at mines in Canada, Mongolia, and South Africa. Globally, several projects to produce HF from FSA also continued to progress.

Some countries continued to phase down production, consumption, and imports of non-feedstock hydrofluorocarbons (HFCs) used as aerosols, propellants, and refrigerants owing to HFCs' high global warming potential. Consumption of fluorspar in Europe decreased since the European Union's fluorinated greenhouse gas (also known as F-Gas) regulation went into effect in 2015 and several producers discontinued production of HFCs. Subsequent price increases and lack of availability have reportedly led to a resurgence in illegal imports and sales of these materials. Previous phasedowns of chlorofluorocarbons and hydrochlorofluorocarbons led to similar activity.

In response to the American Innovation and Manufacturing Act, in October, the U.S. Environmental Protection Agency established the Allowance Allocation and Trading Program as part of its final rule to phase down the production and consumption of non-feedstock HFCs by 85% over the next 15 years. The rule set baseline production and consumption levels from which reductions will be made and established a methodology for allocating and trading HFC allowances. In a related action, the White House established an interagency task force on illegal HFC trade.

The State Intellectual Property Office of China invalidated a U.S. company's patent on a manufacturing process used to produce hydrofluoroolefins (HFOs). HFOs have increasingly been adopted as low-global-warming-potential alternatives to HFCs.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States	NA	NA	4,000
Canada	100	140	NA
China	[5]5,400	[5]5,400	42,000
Germany	80	80	NA
Iran	56	56	3,400
Kazakhstan	77	77	NA
Mexico	915	990	68,000
Mongolia	685	800	22,000
Morocco	82	80	210
Pakistan	55	70	NA
South Africa	330	420	41,000
Spain	131	130	10,000
Vietnam	220	220	5,000
Other countries	110	110	120,000
World total (rounded)	8,240	8,600	320,000

World Resources:[4, 6] Large quantities of fluorine are present in phosphate rock. Current U.S. reserves of phosphate rock are estimated to be 1 billion tons, containing about 72 million tons of 100% fluorspar equivalent assuming an average fluorine content of 3.5% in the phosphate rock. World reserves of phosphate rock are estimated to be 71 billion tons, containing about 5 billion tons of 100% fluorspar equivalent.

Substitutes: FSA is used to produce aluminum fluoride (AlF_3) and HF. Because of differing physical properties, AlF_3 produced from FSA is not readily substituted for AlF_3 produced from fluorspar. Aluminum smelting dross, borax, calcium chloride, iron oxides, manganese ore, silica sand, and titanium dioxide have been used as substitutes for fluorspar fluxes.

[e]Estimated. NA Not available.
[1]Includes data for the following Schedule B codes: 2529.21.0000 and 2529.22.0000.
[2]Defined as total fluorspar imports – exports.
[3]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2529.21.0000 and 2529.22.0000.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]As reported by China's Ministry of Natural Resources. Likely excludes production from operations that did not meet the Government's minimum mining and processing requirements. The China Non-Metallic Minerals Industry Association estimated that actual production was closer to 6 million tons.
[6]Measured as 100% CaF_2.

GALLIUM

(Data in kilograms of contained gallium unless otherwise noted)

Domestic Production and Use: No domestic primary (low-purity, unrefined) gallium has been recovered since 1987. Globally, primary gallium is recovered as a byproduct of processing bauxite and zinc ores. One company in Utah recovered and refined high-purity gallium from imported primary low-purity gallium metal and new scrap. Imports of gallium metal and gallium arsenide (GaAs) wafers were valued at about $3 million and $200 million, respectively. GaAs was used to manufacture compound semiconductor wafers used in integrated circuits (ICs) and optoelectronic devices, which include laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells. Gallium nitride (GaN) principally was used to manufacture optoelectronic devices. ICs accounted for 77% of domestic gallium consumption, optoelectronic devices accounted for 21%, and research and development accounted for 2%. About 81% of the gallium consumed in the United States was contained in GaAs, GaN, and gallium phosphide (GaP) wafers. Gallium metal, triethyl gallium, and trimethyl gallium, used in the epitaxial layering process to fabricate epiwafers for the production of ICs and LEDs, accounted for most of the remainder. Optoelectronic devices were used in aerospace applications, consumer goods, industrial equipment, medical equipment, and telecommunications equipment. Uses of ICs included defense applications, high-performance computers, and telecommunications equipment.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, primary	—	—	—	—	—
Imports for consumption:					
Metal	20,200	32,000	5,740	4,460	10,600
Gallium arsenide wafers (gross weight)	803,000	444,000	272,000	178,000	270,000
Exports	NA	NA	NA	NA	NA
Consumption, reported	17,900	15,000	14,900	15,700	16,000
Price, imports, dollars per kilogram:					
High-purity, refined[1]	477	508	573	596	570
Low-purity, primary[2]	124	185	153	163	200
Stocks, consumer, yearend	2,840	2,920	2,850	2,920	2,800
Net import reliance[3] as a percentage of reported consumption	100	100	100	100	100

Recycling: Old scrap, none. Substantial quantities of new scrap generated in the manufacture of GaAs-based devices were reprocessed to recover high-purity gallium at one facility in Utah.

Import Sources (2017–20): Metal: China,[4] 53%; the United Kingdom, 11%; Germany, 9%; Ukraine, 7%; and other, 20%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Gallium arsenide wafers, doped	3818.00.0010	Free.
Gallium metal	8112.92.1000	3.0% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Imports of gallium metal and GaAs wafers continued to account for all U.S. consumption of gallium. In 2021, gallium metal imports increased by an estimated 140% from those of 2020 owing to increased imports from Canada, Japan, and Singapore. Beginning in 2019, U.S. gallium metal imports decreased substantially from previous years when higher tariffs were placed on China's gallium exports to the United States.

Primary low-purity (99.99%-pure) gallium prices in China increased by an estimated 25% in 2021, to $345 per kilogram in October from approximately $275 per kilogram at yearend 2020. This followed a 96% increase in China's primary low-purity gallium prices in 2020, to $275 per kilogram in December from $140 per kilogram in January. The increases in China's gallium prices resulted from several issues. Environmental restrictions placed on Chinese bauxite production in 2019 compelled the country's alumina refineries to import bauxite with lower gallium content from abroad, which increased gallium extraction costs. When the global COVID-19 pandemic reduced gallium demand in early to mid-2020, Chinese gallium producers slowed or shut down operations. Chinese gallium supply was scarce when gallium demand resumed in the second half of 2020, and gallium prices increased significantly in the last quarter of 2020, continuing through 2021.

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GALLIUM

China's primary low-purity gallium production capacity has been approximately 650,000 kilograms per year since 2020, following an expansion from 140,000 kilograms per year in 2010. China accounted for approximately 84% of worldwide low-purity gallium capacity.

The remaining primary low-purity gallium producers outside of China most likely restricted output owing to a large surplus of primary gallium that began in 2012. These producers included Japan, the Republic of Korea, and Russia. Germany and Kazakhstan ceased primary production in 2016 and 2013, respectively. However, owing to the increase in gallium prices in 2020 and 2021, Germany announced that it would restart primary gallium production by the end of 2021. Hungary and Ukraine were thought to have ceased primary production in 2015 and 2019, respectively. High-purity refined gallium production in 2021 was estimated to be about 225,000 kilograms, a 5% increase from that in 2020. China, Japan, Slovakia, and the United States were the known principal producers of high-purity refined gallium. The United Kingdom ceased high-purity refined gallium production in 2018. Gallium was recovered from new scrap in Canada, China, Germany, Japan, Slovakia, and the United States. World primary low-purity gallium production capacity in 2021 was estimated to be 774,000 kilograms per year; high-purity refined gallium production capacity, 325,000 kilograms per year; and secondary high-purity gallium production capacity, 273,000 kilograms per year.

World Production and Reserves:

	Primary production		**Reserves**[5]
	2020	**2021**[e]	
United States	—	—	Quantitative estimates of reserves are not available.
China	317,000	420,000	
Japan	3,000	3,000	
Korea, Republic of	2,000	2,000	
Russia	5,000	5,000	
World total (rounded)	327,000	430,000	

World Resources:[5] Gallium occurs in very small concentrations in ores of other metals. Most gallium is produced as a byproduct of processing bauxite, and the remainder is produced from zinc-processing residues. The average gallium content of bauxite is 50 parts per million. U.S. bauxite deposits consist mainly of subeconomic resources that are not generally suitable for alumina production owing to their high silica content. Some domestic zinc ores contain up to 50 parts per million gallium and could be a significant resource, although no gallium is currently recovered from domestic ores. Gallium contained in world resources of bauxite is estimated to exceed 1 million tons, and a considerable quantity could be contained in world zinc resources. However, less than 10% of the gallium in bauxite and zinc resources is potentially recoverable.

Substitutes: Liquid crystals made from organic compounds are used in visual displays as substitutes for LEDs. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier third generation (3G) cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. In many defense-related applications, GaAs-based ICs are used because of their unique properties, and no effective substitutes exist for GaAs in these applications. In heterojunction bipolar transistors, GaAs is being replaced in some applications by silicon-germanium.

[e]Estimated. NA Not available. — Zero.
[1]Estimated based on the average unit values of U.S. imports for 99.999%- and 99.99999%-pure gallium.
[2]Estimated based on the average unit values of U.S. imports for 99.99%-pure gallium.
[3]Defined as imports – exports. Excludes gallium arsenide wafers.
[4]Includes Hong Kong.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.

GARNET (INDUSTRIAL)[1]

(Data in metric tons of garnet unless otherwise noted)

Domestic Production and Use: In 2021, garnet for industrial use was mined by four firms—one in Idaho, one in Montana, and two in New York. One processing facility operated in Oregon and another operated in Pennsylvania. The estimated value of crude garnet production was about $15 million, and refined material sold or used had an estimated value of $53 million. The major end uses of garnet were, in descending percentage of consumption, for abrasive blasting, water-filtration media, water-jet-assisted cutting, and other end uses, such as in abrasive powders, nonslip coatings, and sandpaper. Domestic industries that consume garnet include aircraft and motor vehicle manufacturers, ceramics and glass producers, electronic component manufacturers, filtration plants, glass polishing, the petroleum industry, shipbuilders, textile stonewashing, and wood-furniture-finishing operations.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Crude	92,900	101,000	104,000	101,000	75,000
Refined, sold or used	84,100	166,000	147,000	146,000	120,000
Imports for consumption[2]	50,400	265,000	208,000	115,000	110,000
Exports	17,700	14,200	12,600	13,600	15,000
Consumption, apparent[3]	126,000	352,000	300,000	202,000	170,000
Price, average import unit value, dollars per ton	306	215	214	250	325
Employment, mine and mill, number[e]	140	170	160	130	120
Net import reliance[4] as a percentage of apparent consumption	26	71	65	50	56

Recycling: Garnet was recycled at a plant in Oregon with a recycling capacity of 16,000 tons per year and at a plant in Pennsylvania with a recycling capacity of 25,000 tons per year. Garnet can be recycled multiple times without degradation of its quality. Most recycled garnet is from blast cleaning and water-jet-assisted cutting operations.

Import Sources (2017–20):[e] South Africa, 43%; China,[5] 22%; India, 20%; Australia, 12%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Emery, natural corundum, natural garnet, and other natural abrasives, crude	2513.20.1000	Free.
Emery, natural corundum, natural garnet, and other natural abrasives, other than crude	2513.20.9000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: During 2021, estimated domestic production of crude garnet concentrates decreased by 26% compared with production in 2020. This decrease was due to lower production levels from a mine in Montana, although most other U.S. garnet mines also produced less compared with that in 2020. U.S. garnet production was estimated to be about 7% of total global garnet production. The 2021 estimated domestic sales or use of refined garnet decreased by about 16% compared with sales in 2020.

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GARNET (INDUSTRIAL)

Garnet imports in 2021 were estimated to have decreased slightly compared with those in 2020. This decrease was attributed to lower imports of garnet from Australia, China, and India. In 2021, the average unit value of garnet imports was $325 per ton, an increase of 30% compared with the average unit value in 2020. In the United States, most domestically produced crude garnet concentrate was priced at about $206 per ton. U.S. exports in 2021 were estimated to have increased by 11%.

During 2021, the United States consumed about 170,000 tons of garnet. This was a 16% decrease from that of 2020.

The U.S. natural gas and petroleum industry is one of the leading garnet-consuming industries, using garnet for cleaning drill pipes and well casings. Natural gas and petroleum producers also use garnet as a reservoir-fracturing proppant, alone or mixed with other proppants. During 2021, the number of drill rigs operating in the United States was 339 rigs at the beginning of the year, increasing through the year to 508 rigs at the end of September, likely indicating that more garnet was consumed in well drilling.

The garnet market is very competitive. To increase profitability and remain competitive with imported material, production may be restricted to only high-grade garnet ores or as a byproduct of other salable mineral products that occur with garnet, such as kyanite, marble, metallic ore minerals, mica minerals, sillimanite, staurolite, or wollastonite.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States	101,000	75,000	5,000,000
Australia	360,000	360,000	Moderate to large
China	310,000	310,000	Moderate to large
India	130,000	130,000	13,000,000
South Africa	140,000	140,000	NA
Other countries	60,000	60,000	6,500,000
World total (rounded)	1,100,000	1,100,000	Moderate to large

World Resources:[6] World resources of garnet are large and occur in a wide variety of rocks, particularly gneisses and schists. Garnet also occurs in contact-metamorphic deposits in crystalline limestones, pegmatites, and serpentinites and in vein deposits. In addition, alluvial garnet is present in many heavy-mineral sand and gravel deposits throughout the world. Large domestic resources of garnet also are concentrated in coarsely crystalline gneiss near North Creek, NY; other significant domestic resources of garnet occur in Idaho, Maine, Montana, New Hampshire, North Carolina, and Oregon. In addition to those in the United States, major garnet deposits exist in Australia, Canada, China, India, and South Africa, where they are mined for foreign and domestic markets; deposits in Russia and Turkey also have been mined in recent years, primarily for internal markets. Additional garnet resources are in Chile, Czechia, Pakistan, Spain, Thailand, and Ukraine; small mining operations have been reported in most of these countries.

Substitutes: Other natural and manufactured abrasives can substitute to some extent for all major end uses of garnet. In many cases, however, using the substitutes would entail sacrifices in quality or cost. Fused aluminum oxide and staurolite compete with garnet as a sandblasting material. Ilmenite, magnetite, and plastics compete as filtration media. Corundum, diamond, and fused aluminum oxide compete for lens grinding and for many lapping operations. Emery is a substitute in nonskid surfaces. Fused aluminum oxide, quartz sand, and silicon carbide compete for the finishing of plastics, wood furniture, and other products.

[e]Estimated. NA Not available.
[1]Excludes gem and synthetic garnet.
[2]Sources: U.S. Census Bureau and Trade Mining, LLC; data adjusted by the U.S. Geological Survey.
[3]Defined as crude production + imports – exports.
[4]Defined as imports – exports.
[5]Includes Hong Kong.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.

GEMSTONES[1]

(Data in million dollars unless otherwise noted)

Domestic Production and Use: The combined value of U.S. natural and synthetic gemstone output in 2021 was an estimated $95 million, a 25% increase compared with that in 2020. Domestic gemstone production included agate, beryl, coral, diamond, garnet, jade, jasper, opal, pearl, quartz, sapphire, shell, topaz, tourmaline, turquoise, and many other gem materials. In descending order of production value, Arizona led the Nation in natural gemstone production and Oregon was second. The other top producing States were Arkansas, California, Colorado, Idaho, Maine, Montana, Nevada, New York, North Carolina, Tennessee, and Utah. These 13 States produced 96% of U.S. natural gemstones. Synthetic gemstones were manufactured by five companies in California, North Carolina, New York, Maryland, and Arizona, in decreasing order of production value. U.S. synthetic gemstone production increased by 29% compared with that in 2020. Major gemstone end uses were carvings, gem and mineral collections, and jewelry.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:[2]					
Natural[3]	9.2	9.5	9.2	9.8	10
Laboratory-created (synthetic)	55	65	94	66	85
Imports for consumption	24,900	27,700	24,400	16,300	24,000
Exports, excluding reexports	2,440	1,850	1,020	1,320	900
Consumption, apparent[4]	22,500	25,900	23,500	15,100	23,000
Price	Variable, depending on size, type, and quality				
Employment, mine, number[e]	1,120	1,120	1,120	1,100	1,100
Net import reliance[5] as a percentage of apparent consumption	99	99	99	99	99

Recycling: Gemstones are often recycled by being resold as estate jewelry, reset, or recut, but this report does not account for those stones.

Import Sources (2017–20, by value): Diamond: India, 41%; Israel, 31%; Belgium, 12%; South Africa, 4%; and other, 12%. Diamond imports accounted for an average of 90% of the total value of gem imports.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Coral and similar materials, unworked	0508.00.0000	Free.
Imitation gemstones	3926.90.4000	2.8% ad valorem.
Pearls, imitation, pearl beads, not strung	7018.10.1000	4.0% ad valorem.
Imitation gemstones, glass beads	7018.10.2000	Free.
Pearls, natural, graded and temporarily strung	7101.10.3000	Free.
Pearls, natural, other	7101.10.6000	Free.
Pearls, cultured	7101.21.0000	Free.
Diamonds, unworked or sawn	7102.31.0000	Free.
Diamonds, ½ carat or less	7102.39.0010	Free.
Diamonds, cut, more than ½ carat	7102.39.0050	Free.
Other nondiamond gemstones, unworked	7103.10.2000	Free.
Other nondiamond gemstones, uncut	7103.10.4000	10.5% ad valorem.
Rubies, cut	7103.91.0010	Free.
Sapphires, cut	7103.91.0020	Free.
Emeralds, cut	7103.91.0030	Free.
Other nondiamond gemstones, cut	7103.99.1000	Free.
Other nondiamond gemstones, worked	7103.99.5000	10.5% ad valorem.
Synthetic gemstones, cut but not set	7104.90.1000	Free.
Synthetic gemstones, other	7104.90.5000	6.4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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GEMSTONES

Events, Trends, and Issues: During 2021, the U.S. and global gemstone and jewelry industries began recovering from the effects of the COVID-19 pandemic restrictions, lockdowns, and temporary mine and store closings. The largest production decreases in 2020 were from Australia, Botswana, Canada, and Russia. Total world diamond production during 2021 increased slightly from 2020 levels and was driven by the reopening of profitable mines that were suspended in 2020. Production would need to increase by up to 2% per year during the next 3 to 5 years to allow the market to fully rebalance.

New sales platforms were established during 2020 and remained in place during 2021 in the rough diamond market to overcome travel constraints and streamline the journey from the mine to the jeweler. Online auctions gained a higher share of rough diamond sales and offset deficits in traditional sales channels. Many jewelry stores successfully shifted sales to their websites. Global gemstone sales are expected to increase at a steady rate over the next 5 years.

In 2021, U.S. imports for consumption of gemstones were about $24 billion, which was a 49% increase compared with $16.3 billion in 2020. These imports consisted of about $21 billion in gem-quality diamonds, which was a 49% increase compared with $14.3 billion in 2020, and about $2.9 billion in nondiamond gemstones, which was a 51% increase compared with $1.9 billion in 2020. The increase in U.S. gem production combined with the growth in U.S. gem imports and the decrease in gem exports produced a 52% increase in apparent consumption to a value of $23 billion. The United States was the leading global market in terms of sales. The United States is expected to continue to dominate global gemstone demand.

World Gem Diamond Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2020	2021[e]	
United States	—	—	World reserves of diamond-bearing deposits are substantial. No reserves data are available for other gemstones.
Angola	6,960	7,100	
Australia	219	220	
Botswana	11,900	12,000	
Brazil	125	130	
Canada	13,100	13,000	
Congo (Kinshasa)	2,550	2,600	
Guinea	103	100	
Lesotho	481	490	
Namibia	1,550	1,600	
Russia	17,500	18,000	
Sierra Leone	513	520	
South Africa	6,780	6,900	
Tanzania	110	110	
Zimbabwe	267	270	
Other countries	142	140	
World total (rounded)	62,300	63,000	

World Resources:[7] Most diamond ore bodies have a diamond content that ranges from less than 1 carat per ton to about 6 carats per ton of ore. The major diamond reserves are in southern Africa, Australia, Canada, and Russia.

Substitutes: Glass, plastics, and other materials are substituted for natural gemstones. Synthetic gemstones (manufactured materials that have the same chemical and physical properties as natural gemstones) are common substitutes. Simulants (materials that appear to be gems but differ in chemical and physical characteristics) also are frequently substituted for natural gemstones.

[e]Estimated.
[1]Excludes industrial diamond and industrial garnet. See Diamond (Industrial) and Garnet (Industrial).
[2]Estimated minimum production.
[3]Includes production of freshwater shell.
[4]Defined as production (natural and synthetic) + imports – exports (excluding reexports).
[5]Defined as imports – exports (excluding reexports).
[6]Data in thousands of carats of gem diamond.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.

GERMANIUM

(Data in kilograms of contained germanium unless otherwise noted)

Domestic Production and Use: In 2021, zinc concentrates containing germanium were produced at mines in Alaska and Tennessee. Germanium-containing concentrates in Alaska were exported to a refinery in Canada for processing and germanium recovery. A zinc smelter in Clarksville, TN, produced and exported germanium leach concentrates recovered from processing zinc concentrates from the Middle Tennessee mine complex. Germanium in the form of compounds and metal was imported into the United States for further processing by industry. A company in Utah produced germanium wafers for solar cells used in satellites from imported and recycled germanium. A refinery in Oklahoma recovered germanium from industry-generated scrap and produced germanium tetrachloride for the production of fiber optics. The estimated value of germanium consumed in 2021, based on the annual average germanium metal price, was $36 million, 15% more than that in 2020.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, refinery:					
Primary	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Germanium metal	11,100	11,900	14,000	18,300	13,000
Germanium dioxide[e, 1]	12,000	12,200	21,000	12,000	17,000
Exports[e, 2]	3,670	4,880	4,600	7,100	6,600
Shipments from Government stockpile	—	—	—	—	—
Consumption, estimated[3]	30,000	30,000	30,000	30,000	30,000
Price, annual average, dollars per kilogram:[4]					
Germanium metal	1,082	1,543	1,236	1,046	1,200
Germanium dioxide	731	1,084	913	724	770
Net import reliance[5] as a percentage of estimated consumption	>50%	>50%	>50%	>50%	>50%

Recycling: Worldwide, it has been estimated that about 30% of the total germanium consumed is produced from recycled materials. During the manufacture of most optical devices, more than 60% of the germanium metal used is routinely recycled as new scrap. Germanium scrap is also recovered from the windows in decommissioned tanks and other military vehicles. The United States has the capability to recycle new and old scrap.

Import Sources (2017–20):[6] Germanium metal: China, 53%; Belgium, 22%; Germany, 11%; Russia, 9%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Germanium oxides and zirconium dioxide	2825.60.0000	3.7% ad valorem.
Metal, unwrought	8112.92.6000	2.6% ad valorem.
Metal, powder	8112.92.6500	4.4% ad valorem.
Metal, wrought	8112.99.1000	4.4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile:[7]

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Germanium metal	14,000	—	—	—	5,000
Germanium scrap (gross weight)	6,170	—	3,000	—	—
Germanium wafers (each)	68,700	—	—	—	—

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GERMANIUM

Events, Trends, and Issues: The major global end uses for germanium were electronics and solar applications, fiber-optic systems, infrared optics, polymerization catalysts, and other uses (such as chemotherapy, metallurgy, and phosphors).

Prices for germanium dioxide and metal trended upward during 2021. During the first 10 months of the year, the price for germanium metal (minimum 99.999% purity) increased by 21% to $1,315 per kilogram from $1,090 per kilogram, and the price for germanium dioxide (minimum 99.999% purity) increased by 15% to $825 per kilogram from $720 per kilogram.

In 2021, a high-purity metals and compounds producer with a germanium wafer production facility in Utah acquired a Germany-based manufacturer of multijunction germanium solar cells for space and terrestrial applications. An advanced materials producer with a germanium production facility in Oklahoma announced that a new generation of solar arrays using germanium substrates were produced for the International Space Station to replace the existing silicon-based solar arrays. Similar germanium solar cell technology would also be used to power the National Aeronautics and Space Administration’s Gateway space station currently under development.

China was a leading global exporter of germanium in 2021. Exports of unwrought germanium, germanium powders, and germanium waste and scrap (China’s export code 8112.99.10) for the year through September were 27,800 kilograms, 24% more than exports in the same period in 2020. Nearly all exports were sent to Russia, Germany, Hong Kong, Belgium, Japan, and the United States, in descending order of quantity.

World Refinery Production and Reserves:

	Refinery production[e, 8] 2020	Refinery production[e, 8] 2021	Reserves[9]
United States	W	W	Data on the recoverable germanium content of zinc ores are not available.
China	95,000	95,000	
Russia	5,000	5,000	
Other countries[10]	40,000	40,000	
World total (rounded)[11]	140,000	140,000	

World Resources:[9] The available resources of germanium are associated with certain zinc and lead-zinc-copper sulfide ores. Substantial U.S. reserves of recoverable germanium are contained in zinc deposits in Alaska, Tennessee, and Washington. Based on an analysis of zinc concentrates, U.S. reserves of zinc may contain as much as 2,500 tons of germanium. Because zinc concentrates are shipped globally and blended at smelters, however, the recoverable germanium in zinc reserves cannot be determined. On a global scale, as little as 3% of the germanium contained in zinc concentrates is recovered. Significant amounts of germanium are contained in ash and flue dust generated in the combustion of certain coals for power generation.

Substitutes: Silicon can be a less-expensive substitute for germanium in certain electronic applications. Some metallic compounds can be substituted in high-frequency electronics applications and in some light-emitting-diode applications. Zinc selenide and germanium glass substitute for germanium metal in infrared applications systems, but often at the expense of performance. Antimony and titanium are substitutes for use as polymerization catalysts.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Data have been adjusted to exclude low-value shipments, then multiplied by 69% to account for germanium content.
[2]Includes Schedule B numbers: 8112.92.6100, 8112.99.1000, and 2825.60.0000. Data have been adjusted to exclude low-value shipments. Oxide data have been multiplied by 69% to account for germanium content.
[3]Estimated consumption of germanium contained in metal and germanium dioxide.
[4]Average European price for minimum 99.999% purity. Source: Argus Media group—Argus Metals International.
[5]Defined as imports – exports + adjustments for Government stock changes.
[6]Import sources are based on gross weight of wrought and unwrought germanium metal and germanium metal powders.
[7]See Appendix B for definitions.
[8]Includes primary and secondary production.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.
[10]Includes Belgium, Canada, Germany, Japan, and Ukraine.
[11]Excludes U.S. production.

GOLD

(Data in metric tons[1] of contained gold unless otherwise noted)

Domestic Production and Use: In 2021, domestic gold mine production was estimated to be 180 tons, 7% less than that in 2020, and the value was estimated to be about $10 billion. Gold was produced at more than 40 lode mines in 11 States, at several large placer mines in Alaska, and at numerous smaller placer mines (mostly in Alaska and in the Western States). Nevada was the leading gold-producing State, accounting for about 74% of total domestic production. About 6% of domestic gold was recovered as a byproduct of processing domestic base-metal ores, chiefly copper ores. The top 26 operations yielded about 98% of the mined gold produced in the United States. Commercial-grade gold was produced at about 15 refineries. A few dozen companies, out of several thousand companies and artisans, dominated the fabrication of gold into commercial products. U.S. jewelry manufacturing was heavily concentrated in the New York, NY, and Providence, RI, areas, with lesser concentrations in California, Florida, and Texas. Estimated global gold consumption was jewelry, 47%; physical bar, 21%; central banks and other institutions, 14%; official coins and medals and imitation coins, 10%; electrical and electronics, 7%; and other, 1%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine	237	226	200	193	180
Refinery:					
Primary	207	205	205	181	180
Secondary (new and old scrap)	119	117	116	92	90
Imports for consumption[2]	255	213	199	545	190
Exports[2]	461	474	360	297	400
Consumption, reported[3]	159	154	151	185	250
Stocks, Treasury, yearend[4]	8,130	8,130	8,130	8,130	8,130
Price, dollars per troy ounce[5]	1,261	1,272	1,395	1,774	1,800
Employment, mine and mill, number[6]	11,900	12,200	12,400	12,500	12,400
Net import reliance[7] as a percentage of apparent consumption[8]	E	E	E	47	E

Recycling: In 2021, an estimated 90 tons of new and old scrap was recycled, equivalent to about 36% of reported consumption. The domestic supply of gold from recycling decreased slightly compared with that of 2020.

Import Sources (2017–20): Ores and concentrates: Greece, 48%; Ireland, 37%; Canada, 11%; and Germany, 4%. Dore: Mexico, 45%; Colombia and Peru, 11% each; Canada, 7%; and other, 26%. Bullion: Switzerland, 34%; Canada, 24%; Singapore, 7%; and other, 35%. Combined total: Mexico, 22%; Switzerland, 21%; Canada, 17%; Peru, 8%; and other, 32%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Precious metal ore and concentrates:		
Gold content of silver ores	2616.10.0080	0.8 ¢/kg on lead content.
Gold content of other ores	2616.90.0040	1.7 ¢/kg on lead content.
Gold bullion	7108.12.1013	Free.
Gold dore	7108.12.1020	Free.
Gold scrap	7112.91.0000	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: The U.S. Department of the Treasury maintains stocks of gold (see salient statistics above), and the U.S. Department of Defense administers a Governmentwide secondary precious-metals recovery program.

Events, Trends, and Issues: The estimated gold price in 2021 was slightly higher than the previous record-high annual price in 2020.The Engelhard daily price of gold in 2021 fluctuated in the first and second quarters. Early in the year, the gold price was about $1,840 per troy ounce before decreasing in March and increasing through May. Several factors were reported to have caused the increase in price: gold demand for safe-haven buying increased owing to the continued global COVID-19 pandemic, global investor uncertainty, and the U.S. Federal Reserve Board low interest rates. The price decreased slightly from June through October and then increased in November.

In 2021, worldwide gold mine production was estimated to be slightly less than that in 2020. Decreased gold mine production in Papua New Guinea, Russia, and the United States more than offset production increases in China, Ghana, Indonesia, South Africa, and Tanzania.

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GOLD

In the first 9 months of 2021, global consumption of gold in physical bars increased by about 58%, in jewelry by 49%, in industrial applications by 16%, in electronics by about 13%, and in official coins and medals and imitation coins by about 6% compared with that in the first 9 months of 2020. Global investments in gold-based exchange-traded funds decreased by almost 116%, while gold holdings in central banks doubled during the same period.

World Mine Production and Reserves: Reserves for Australia, Papua New Guinea, Peru, Russia, and South Africa were revised based on Government and (or) industry reports

	Mine production		Reserves[9]
	2020	2021[e]	
United States	193	180	3,000
Argentina	59	60	1,600
Australia	328	330	[10]11,000
Brazil	78	80	2,400
Burkina Faso	58	60	NA
Canada	170	170	2,200
China	365	370	2,000
Colombia	48	50	NA
Ghana	125	130	1,000
Indonesia	86	90	2,600
Kazakhstan	63	60	1,000
Mexico	102	100	1,400
Papua New Guinea	54	50	1,100
Peru	87	90	2,000
Russia	305	300	6,800
South Africa	96	100	5,000
Sudan	90	90	NA
Tanzania	47	50	NA
Uzbekistan	101	100	1,800
Other countries	572	570	9,200
World total (rounded)	3,030	3,000	54,000

World Resources:[9] An assessment of U.S. gold resources indicated 33,000 tons of gold in identified (15,000 tons) and undiscovered (18,000 tons) resources.[11] Nearly one-quarter of the gold in undiscovered resources was estimated to be contained in porphyry copper deposits. The gold resources in the United States, however, are only a small portion of global gold resources.

Substitutes: Base metals clad with gold alloys are widely used to economize on gold in electrical and electronic products and in jewelry; many of these products are continually redesigned to maintain high-utility standards with lower gold content. Generally, palladium, platinum, and silver may substitute for gold.

[e]Estimated. E Net exporter. NA Not available.

[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.

[2]Includes refined bullion, dore, ores, concentrates, and precipitates. Excludes waste and scrap, official monetary gold, gold in fabricated items, gold in coins, and net bullion flow (in tons) to market from foreign stocks at the New York Federal Reserve Bank.

[3]Includes gold used in the production of consumer purchased bar, coins, and jewelry. Excludes gold as an investment (except consumer purchased bar and coins). Source: World Gold Council.

[4]Includes gold in Exchange Stabilization Fund. Stocks were valued at the official price of $42.22 per troy ounce.

[5]Engelhard's average gold price quotation for the year. In 2021, the price was estimated by the U.S. Geological Survey based on data from January through November.

[6]Data from the Mine Safety and Health Administration.

[7]Defined as imports – exports.

[8]Defined as mine production + secondary production + imports – exports.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 4,000 tons.

[11]U.S. Geological Survey National Mineral Resource Assessment Team, 2000, 1998 assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Circular 1178, 21 p.

GRAPHITE (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2021, natural graphite was not produced in the United States; however, approximately 95 U.S. companies, primarily in the Great Lakes and Northeastern regions and Alabama and Tennessee, consumed 45,000 tons valued at an estimated $41 million. The major uses of natural graphite were batteries, brake linings, lubricants, powdered metals, refractory applications, and steelmaking. During 2021, U.S. natural graphite imports were an estimated 53,000 tons, which were about 57% flake and high-purity, 42% amorphous, and 1% lump and chip graphite.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, mine	—	—	—	—	—
Imports for consumption	51,900	70,700	50,300	36,000	53,000
Exports	13,900	9,950	5,890	5,930	8,400
Consumption, apparent[1]	38,000	60,700	44,400	30,000	45,000
Price, average value of imports, dollars per ton at foreign ports:					
Flake	1,390	1,520	1,350	1,540	1,600
Lump and chip (Sri Lanka)	1,900	1,890	2,380	2,940	2,700
Amorphous	451	319	498	687	630
Net import reliance[1] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Refractory brick and linings, alumina-graphite refractories for continuous metal castings, magnesia-graphite refractory brick for basic oxygen and electric arc furnaces, and insulation brick led the way in the recycling of graphite products. Recycling of refractory graphite material is increasing, with material being recycled into products such as brake linings and thermal insulation. Recovering high-quality flake graphite from steelmaking kish is technically feasible, but currently not practiced. The abundance of graphite in the world market inhibits increased recycling efforts. Information on the quantity and value of recycled graphite is not available.

Import Sources (2017–20): China, 33%; Mexico, 21%; Canada, 17%; India, 9%; and other, 20%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Crystalline flake (not including flake dust)	2504.10.1000	Free.
Powder	2504.10.5000	Free.
Other	2504.90.0000	Free.

Depletion Allowance: Lump and amorphous, 22% (domestic) and flake, 14% (domestic); 14% (foreign).

Government Stockpile:[2]

		FY 2021		**FY 2022**	
Material	**Inventory as of 9–30–21**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Graphite	—	—	—	900	—

Events, Trends, and Issues: U.S. natural graphite exports decreased each year from 2017 to 2019, remained essentially unchanged in 2020, and then increased by 41% in 2021. This was still an overall 40% decline for the 5-year period of 2017 to 2021. U.S. imports for consumption and apparent consumption peaked in 2018, and imports and apparent consumption declined during 2019 and 2020. During 2021, U.S. imports for consumption and apparent consumption increased by 48% and 50%, respectively, as recovery from the COVID-19 pandemic began.

During 2021, China was the world's leading graphite producer, producing an estimated 79% of total world output. Approximately 24% of production in China was amorphous graphite and about 76% was flake. China produced some large flake graphite, but much of its flake graphite production was very small, in the +200-mesh range. China also processed most of the world's spherical graphite. Globally, during 2021, graphite supplies began recovering from the effects that the global COVID-19 pandemic had during 2020. In 2021, global graphite production was estimated to have increased by 7.6% from 2020 production. In China, the recovery was quick, which was demonstrated by China's pattern of exports. Chinese producers quickly increased production after a few months of closures in 2020. This allowed China to gain a more dominant position in the market for 2021 and slowed down the diversification of the supply chain.

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GRAPHITE (NATURAL)

North America produced only 1.2% of the world's graphite supply with production in Canada and Mexico. Two companies were developing graphite mining projects in the United States—one in Alabama and one in Alaska.

Large graphite deposits were being developed in Madagascar, northern Mozambique, Namibia, and south-central Tanzania. A graphite mine in Mozambique in a high-grade graphite deposit was reportedly the largest natural graphite mine globally. The mine was expected to operate for about 50 years.

A U.S. automaker continued building a large plant to manufacture lithium-ion electric vehicle batteries. The completed portion of the plant was operational, and it produced battery cells, battery packs, drive units, and energy storage products. At full capacity, the plant was expected to require 35,200 tons per year of spherical graphite for use as anode material for lithium-ion batteries.

An Australian company was producing purified coated spherical graphite for use as lithium-ion battery anode material from its plant in Vidalia, LA, challenging China's hold on global production of purified coated spherical graphite.

New thermal technology and acid-leaching techniques have enabled the production of higher purity graphite powders that are likely to lead to development of new applications for graphite in high-technology fields. Innovative refining techniques have made the use of graphite possible in carbon-graphite composites, electronics, foils, friction materials, and specialty lubricant applications. Flexible graphite product lines are likely to be the fastest growing market. Large-scale fuel-cell applications are being developed that could consume as much graphite as all other uses combined.

World Mine Production and Reserves: Reserves for Tanzania were revised based on information reported by graphite-producing companies and Government reports.

	Mine production		Reserves[3]
	2020	2021[e]	
United States	—	—	([4])
Austria	500	500	([4])
Brazil	63,600	68,000	70,000,000
Canada	8,000	8,600	([4])
China	762,000	820,000	73,000,000
Germany	300	300	([4])
India	6,000	6,500	8,000,000
Korea, North	8,100	8,700	2,000,000
Madagascar	20,900	22,000	26,000,000
Mexico	3,300	3,500	3,100,000
Mozambique	28,000	30,000	25,000,000
Norway	12,000	13,000	600,000
Russia	25,000	27,000	([4])
Sri Lanka	4,000	4,300	1,500,000
Tanzania	—	150	18,000,000
Turkey	2,500	2,700	90,000,000
Ukraine	16,000	17,000	([4])
Uzbekistan	100	110	7,600,000
Vietnam	5,000	5,400	([4])
World total (rounded)	966,000	1,000,000	320,000,000

World Resources:[3] Domestic resources of graphite are relatively small, but the rest of the world's identified resources exceed 800 million tons of recoverable graphite.

Substitutes: Synthetic graphite powder, scrap from discarded machined shapes, and calcined petroleum coke compete for use in iron and steel production. Synthetic graphite powder and secondary synthetic graphite from machining graphite shapes compete for use in battery applications. Finely ground coke with olivine is a potential competitor in foundry-facing applications. Molybdenum disulfide competes as a dry lubricant but is more sensitive to oxidizing conditions.

[e]Estimated. — Zero.
[1]Defined as imports – exports.
[2]See Appendix B for definitions.
[3]See Appendix C for resource and reserve definitions and information concerning data sources.
[4]Included with "World total."

GYPSUM

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, domestic production of crude gypsum was estimated to be 23 million tons with a value of about $210 million. The leading crude gypsum-producing States were estimated to be California, Iowa, Kansas, Nevada, Oklahoma, Texas, and Utah. Overall, 47 companies produced or processed gypsum in the United States at 52 mines in 16 States. The majority of domestic consumption, which totaled approximately 43 million tons, was used by agriculture, cement production, and manufacturers of wallboard and plaster products. Small quantities of high-purity gypsum, used in a wide range of industrial processes, accounted for the remaining tonnage. At the beginning of 2021, the production capacity of 63 operating gypsum panel manufacturing plants in the United States was about 34.1 billion square feet[1] per year. Total wallboard sales in 2021 were estimated to be 28.0 billion square feet.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Crude	20,700	21,100	21,700	21,200	23,000
Synthetic[2]	20,700	16,600	14,400	13,000	13,000
Calcined[3]	17,800	17,500	17,900	17,900	19,000
Wallboard products sold, million square feet[1]	25,000	23,700	25,900	26,200	28,000
Imports, crude, including anhydrite	4,800	5,210	6,140	6,030	6,900
Exports, crude, not ground or calcined	36	36	37	32	35
Consumption, apparent[4]	46,200	42,900	42,200	40,200	43,000
Price, average, dollars per metric ton:					
Crude, free on board (f.o.b.) mine	7.5	8.3	8.6	8.6	9
Calcined, f.o.b. plant	30	32	34	5	37
Employment, mine and calcining plant, number[e]	4,500	4,500	4,500	4,500	4,500
Net import reliance[5] as a percentage of apparent consumption	10	12	15	15	16

Recycling: Approximately 700,000 tons of gypsum scrap that was generated by wallboard manufacturing was recycled onsite. The recycling of wallboard from new construction and demolition sources also took place, although those amounts are unknown. Recycled gypsum was used primarily for agricultural purposes and feedstock for the manufacture of new wallboard. Other potential markets for recycled gypsum include athletic-field marking, cement production (as a stucco additive), grease absorption, sludge drying, and water treatment.

Import Sources (2017–20): Mexico, 36%; Spain, 32%; Canada, 29%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Gypsum; anhydrite	2520.10.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. crude gypsum production increased by an estimated 8%, and apparent consumption increased by 7% compared with that in 2020. U.S. gypsum imports increased by an estimated 14% compared with those in 2020. Exports, although very low compared with imports and often subject to wide fluctuations, increased by an estimated 9%.

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GYPSUM

Demand for gypsum depends principally on construction industry activity, particularly in the United States, where the majority of gypsum consumed is used for agriculture, building plasters, the manufacture of portland cement, and wallboard products. Despite disruptions caused by the global COVID-19 pandemic, the production of gypsum was not affected.

The United States, the world's leading crude gypsum producer, produced an estimated 23 million tons. Iran was the second-leading producer with an estimated 16 million tons of crude production, followed by China with 13 million tons. Increased use of wallboard in Asia, coupled with new gypsum product plants, spurred increased production in the region. As wallboard becomes more widely used, worldwide gypsum production is expected to increase.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	**2021[e]**	
United States	21,200	23,000	700,000
Algeria	2,500	2,500	NA
Brazil	2,000	2,000	450,000
Canada	2,400	2,900	450,000
China	12,600	13,000	NA
France	1,890	1,900	350,000
Germany	4,500	4,500	NA
India	1,500	1,500	37,000
Iran	16,000	16,000	NA
Japan	4,300	4,300	NA
Mexico	5,400	5,400	NA
Oman	10,200	10,000	NA
Pakistan	2,210	2,200	6,000
Russia	4,200	4,200	NA
Saudi Arabia	3,300	3,300	NA
Spain	11,000	11,000	NA
Thailand	9,800	9,800	1,700
Turkey	7,500	9,300	200,000
Other countries	21,700	22,000	NA
World total (rounded)	144,000	150,000	Large

World Resources:[6] Reserves are large in major producing countries, but data for most are not available. Domestic gypsum resources are adequate but unevenly distributed. Large imports from Canada augment domestic supplies for wallboard manufacturing in the United States, particularly in the eastern and southern coastal regions. Imports from Mexico supplement domestic supplies for wallboard manufacturing along portions of the United States western seaboard. Large gypsum deposits occur in the Great Lakes region, the midcontinent region, and several Western States. Foreign resources are large and widely distributed; 78 countries were thought to produce gypsum in 2021.

Substitutes: In such applications as stucco and plaster, cement and lime may be substituted for gypsum; brick, glass, metallic or plastic panels, and wood may be substituted for wallboard. Gypsum has no practical substitute in the manufacturing of portland cement. Synthetic gypsum generated by various industrial processes, including flue gas desulfurization of smokestack emissions, is very important as a substitute for mined gypsum in wallboard manufacturing, cement production, and agricultural applications (in descending order by tonnage). In 2021, synthetic gypsum was estimated to account for about 30% of the total domestic gypsum supply.

[e]Estimated. NA Not available.

[1]The standard unit used in the U.S. wallboard industry is square feet; multiply square feet by 9.29×10^{-2} to convert to square meters. Source: The Gypsum Association.

[2]Synthetic gypsum used; the majority of these data were obtained from the American Coal Ash Association.

[3]From domestic crude and synthetic gypsum.

[4]Defined as domestic crude production + synthetic used + imports – exports.

[5]Defined as imports – exports.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

HELIUM

(Data in million cubic meters of contained helium gas[1] unless otherwise noted)

Domestic Production and Use: The estimated value of Grade-A helium (99.997% or greater) extracted during 2021 by private industry was about $540 million. Fifteen plants (one in Arizona, two in Colorado, five in Kansas, one in New Mexico, one in Oklahoma, four in Texas, and one in Utah) extracted helium from natural gas and produced crude helium that ranged from 50% to 99% helium. One plant in Colorado and another in Wyoming extracted helium from natural gas and produced Grade-A helium. Three plants in Kansas and one in Oklahoma accepted crude helium from other producers and the Bureau of Land Management (BLM) pipeline and purified it to Grade-A helium. In 2021, estimated domestic apparent consumption of Grade-A helium was 40 million cubic meters (1.4 billion cubic feet), and it was used for, in descending order by estimated quantity, magnetic resonance imaging, lifting gas, analytical and laboratory applications, electronics and semiconductor manufacturing, welding, engineering and scientific applications, and various other minor applications.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Helium extracted from natural gas[2]	81	76	72	76	71
Withdrawn from storage[3]	22	22	17	7	6
Grade-A helium sales	103	98	89	83	77
Imports for consumption	19	8	7	7	9
Exports[e, 4]	74	66	56	50	46
Consumption, apparent[5]	48	40	40	40	40
Net import reliance[6] as a percentage of apparent consumption	E	E	E	E	E

In fiscal year (FY) 2021, the price for crude helium to Government users was $3.61 per cubic meter ($100.00 per thousand cubic feet). The BLM does not post a conservation helium price; conservation helium prices were last posted by the Federal Government in 2018. The estimated price for private industry's Grade-A helium was about $7.57 per cubic meter ($210 per thousand cubic feet), with some producers posting surcharges to this price.

Recycling: In the United States, helium used in large-volume applications is seldom recycled. Some low-volume or liquid boil-off recovery systems are used. In the rest of the world, helium recycling is more common.

Import Sources (2017–20): Qatar, 65%; Algeria, 12%; Canada, 11%; Portugal, 7%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Helium	2804.29.0010	3.7% ad valorem.

Depletion Allowance: Allowances are applicable to natural gas from which helium is extracted, but no allowance is granted directly to helium.

Government Stockpile:[7] Under the Helium Stewardship Act of 2013, the BLM manages the Federal Helium Program, which includes all operations of the Cliffside Field helium storage reservoir, in Potter County, TX, and the Government's crude helium pipeline system. Private firms that sell Grade-A helium to Federal agencies are required to purchase a like amount of (in-kind) crude helium from the BLM. The law mandated that the BLM sell at auction Federal Conservation helium stored in Bush Dome at the Cliffside Field. The last auction was completed in summer 2018. The remaining conservation helium is about 85.7 million cubic meters (3.09 billion cubic feet). The Helium Stewardship Act requires that the BLM dispose of all helium assets including the Cliffside Field helium storage reservoir and pipeline system. The BLM will continue to make in-kind helium available to Federal customers until summer 2022. In FY 2021, privately owned companies purchased about 5.88 million cubic meters (0.212 billion cubic feet) of in-kind crude helium. During FY 2021, the BLM's Amarillo Field Office, Helium Operations, accepted about 8.0 million cubic meters (0.288 billion cubic feet) of private helium for storage and redelivered nearly 18.7 million cubic meters (0.674 billion cubic feet). As of September 30, 2021, about 82.1 million cubic meters (2.96 billion cubic feet) of privately owned helium remained in storage at Cliffside Field.

Material	Inventory as of 9–30–21	Authorized for disposal	Disposal plan FY 2022	FY 2023
Helium	85.7	85.7	5.88	79.2

Events, Trends, and Issues: Helium production in 2021 decreased in the United States owing to several unplanned shutdowns taking place, including the BLM Crude Helium Enrichment Unit. As of September 2021, the BLM completed sales of the remaining Federal helium inventory and transferred responsibility for the sale of the remaining assets to the General Services Administration. Federal in-kind users were to have access to helium until

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HELIUM

September 30, 2022. In Russia, a 60-million-cubic-meter-per-year helium-processing plant was commissioned. The first of three 20-million-cubic-meter-per-year trains started production in fall 2021; the next train was scheduled to be completed in February 2022.

On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

World Mine Production and Reserves:[9] Reserves for the United States and Poland were revised based on Government information.

	Mine production		Reserves[10]
	2020	2021[e]	
United States (extracted from natural gas)	76	71	8,500
United States (from Cliffside Field)	7	6	86
Algeria	14	14	1,800
Australia	4	4	NA
Canada	<1	<1	NA
China	1	1	NA
Poland	1	1	24
Qatar	51	51	Large
Russia	5	9	1,700
World total (rounded)	160	160	NA

World Resources:[10] Section 16 of Public Law 113–40 required the U.S. Geological Survey (USGS) to complete a national helium gas assessment. The USGS and the BLM coordinated efforts to complete this assessment, which was published by the USGS in fall 2021.[11] The mean volume of recoverable helium within the known geologic natural gas reservoirs in the United States was estimated to be 8,490 million cubic meters (306 billion cubic feet). This does not include the remaining 85.7 million cubic meters (3 billion cubic feet) in the Federal helium inventory. The estimated mean for the Alaska region was 1.11 million cubic meters (0.04 billion cubic feet); the Gulf Coast region, 12.5 million cubic meters (0.45 billion cubic feet); the Midcontinent region, 4,330 million cubic meters (156 billion cubic feet); the North Central region, 52.7 million cubic meters (1.9 billion cubic feet); and the Rocky Mountain region 4,110 million cubic meters (148 billion cubic feet).

Helium resources of the world, exclusive of the United States, were estimated to be about 31.3 billion cubic meters (1.13 trillion cubic feet). The locations and volumes of the major deposits, in billion cubic meters, are Qatar, 10.1; Algeria, 8.2; Russia, 6.8; Canada, 2.0; and China, 1.1. As of December 31, 2021, the BLM had analyzed about 22,720 gas samples from the United States and 26 other countries in a program to identify world helium resources.

Substitutes: Nothing substitutes for helium in cryogenic applications if temperatures below −429 degrees Fahrenheit are required. Argon can be substituted for helium in welding, and hydrogen can be substituted for helium in some lighter-than-air applications in which the flammable nature of hydrogen is not objectionable. Hydrogen is also being investigated as a substitute for helium in deep-sea diving applications below 305 meters (1,000 feet).

[e]Estimated. E Net exporter. NA Not available.

[1]Measured at 101.325 kilopascals absolute (14.696 psia) and 15 degrees Celsius (°C) [59 degrees Fahrenheit (°F)]; 27.737 cubic meters of helium = 1,000 cubic feet of helium at 101.325 kilopascals absolute (14.696 psia) and 21.1 °C (70 °F).

[2]Both Grade-A and crude helium.

[3]Extracted from natural gas in prior years.

[4]Substantial increases in exports reported in recent years suggested that the data may be incorrect. The Census Bureau was reviewing the export data. Exports were estimated to result in an apparent consumption of 40 million cubic meters for 2018–2021.

[5]Grade-A helium. Defined as sales + imports – exports.

[6]Defined as imports – exports.

[7]See Appendix B for definitions.

[8]Supervisory General Engineer, Helium Resources Division, Bureau of Land Management, Amarillo Field Office, Helium Operations, Amarillo, TX.

[9]Production and reserves outside of the United States were estimated.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]Brennan, S.T., Rivera, J.L., Varela, B.A., and Park, A.J., 2021, National assessment of helium resource within known natural gas reservoirs: U.S. Geological Survey Scientific Investigations Report 2021–5085, 5 p., https://doi.org/10.3133/sir20215085.

INDIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Indium was not recovered from ores in the United States in 2021. Several companies produced indium products—including alloys, compounds, high-purity metal, and solders—from imported indium metal. Production of indium tin oxide (ITO) continued to account for most global indium consumption. ITO thin-film coatings were primarily used for electrically conductive purposes in a variety of flat-panel displays—most commonly liquid crystal displays (LCDs). Other indium end uses included alloys and solders, compounds, electrical components and semiconductors, and research. Estimated domestic consumption of refined indium was 170 tons in 2021. The estimated value of refined indium consumed domestically in 2021, based on the average free on board U.S. warehouse price, was about $37 million.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, refinery	—	—	—	—	—
Imports for consumption	127	125	95	115	170
Exports	NA	NA	NA	NA	NA
Consumption, estimated[1]	127	125	95	115	170
Price, annual average, dollars per kilogram:					
New York dealer[2]	363	375	390	395	NA
Free on board U.S. warehouse[3]	206	285	182	161	220
Duties unpaid in warehouse, Rotterdam[4]	205	281	177	158	210
Net import reliance[5] as a percentage of estimated consumption	100	100	100	100	100

Recycling: Indium is most commonly recovered from ITO scrap in Japan and the Republic of Korea. A significant quantity of scrap was recycled domestically; however, data on the quantity of secondary indium recovered from scrap were not available.

Import Sources (2017–20): China,[6] 31%; Canada, 23%; Republic of Korea, 20%; France, 9%; and other, 17%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Unwrought indium, including powders, waste, and scrap	8112.92.3000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The New York dealer price of indium from the listed source was discontinued in 2021. In 2021, the average annual free on board U.S. warehouse price was an estimated $220 per kilogram, 37% greater than in 2020. The average monthly price was $187 per kilogram in January and increased throughout most of the year to a weekly average price of $270 per kilogram at the beginning of October. The 2021 estimated annual average Rotterdam price of indium (duties unpaid in the warehouse) was $210 per kilogram, 33% greater than that in 2020. The average monthly Rotterdam price of indium (duties unpaid in the warehouse) price began the year at $184 per kilogram in January then generally increased throughout the remainder of the year to a daily average of $235 per kilogram at the beginning of October.

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INDIUM

Demand for indium in Europe has been reduced during the global COVID-19 pandemic restrictions, but demand began to increase in May, when China's exports of indium to Europe increased sharply. Several European buyers started to build up indium stocks to ensure they had enough supply, owing to the prevalence of shipping delays in 2021.

The leading producer of tin in China announced that it produced 34.88 tons of indium in the first 6 months of 2021, with a reported capacity of 60 tons per year of indium. Other producers in China also announced the resumption of production of indium, accounting for an additional 50 to 60 tons per year of capacity, after shutting down to perform maintenance in the beginning of July.

World Refinery Production and Reserves:

	Refinery production[e]		Reserves[7]
	2020	2021	
United States	—	—	Quantitative estimates of reserves are not available.
Belgium	20	20	
Canada	66	60	
China	540	530	
France	38	35	
Japan	66	60	
Korea, Republic of	210	200	
Peru	12	10	
Russia	5	5	
World total (rounded)	960	920	

World Resources:[7] Indium is most commonly recovered from the zinc-sulfide ore mineral sphalerite. The indium content of zinc deposits from which it is recovered ranges from less than 1 part per million to 100 parts per million. Although the geochemical properties of indium are such that it occurs in trace amounts in other base-metal sulfides—particularly chalcopyrite and stannite—most deposits of these minerals are subeconomic for indium recovery.

Substitutes: Antimony tin oxide coatings have been developed as an alternative to ITO coatings in LCDs and have been successfully annealed to LCD glass; carbon nanotube coatings have been developed as an alternative to ITO coatings in flexible displays, solar cells, and touch screens; poly(3,4-ethylene dioxythiophene) (PEDOT) has also been developed as a substitute for ITO in flexible displays and organic light-emitting diodes; and copper or silver nanowires have been explored as a substitute for ITO in touch screens. Graphene has been developed to replace ITO electrodes in solar cells and also has been explored as a replacement for ITO in flexible touch screens. Researchers have developed a more adhesive zinc oxide nanopowder to replace ITO in LCDs. Hafnium can replace indium in nuclear reactor control rod alloys.

[e]Estimated. NA Not available. — Zero.
[1]Estimated to equal imports.
[2]Price is based on 99.99%-minimum-purity indium; delivered duty paid U.S. buyers; in minimum lots of 50 kilograms. Source: S&P Global Platts Metals Week; price was discontinued as of September 11, 2020.
[3]Price is based on 99.99%-minimum-purity indium, free on board U.S. warehouse. Source: Argus Media group—Argus Metals International.
[4]Price is based on 99.99%-minimum-purity indium, duties unpaid in warehouse (Rotterdam). Source: Argus Media group—Argus Metals International.
[5]Defined as imports – exports.
[6]Includes Hong Kong.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.

IODINE

(Data in metric tons of elemental iodine unless otherwise noted)

Domestic Production and Use: Iodine was produced from brines in 2021 by three companies operating in Oklahoma. U.S. iodine production in 2021 was withheld to avoid disclosing company proprietary data but was estimated to have been less than that in 2020. The average annual cost, insurance, and freight unit value of iodine imports in 2021 was estimated to be $32 per kilogram, a slight increase from that of 2020.

Because domestic and imported iodine was used by downstream manufacturers to produce many intermediate iodine compounds, it was difficult to establish an accurate end-use pattern. Crude iodine and inorganic iodine compounds were thought to account for more than 50% of domestic iodine consumption in 2021. Worldwide, the leading uses of iodine and its compounds were X-ray contrast media, pharmaceuticals, liquid crystal displays (LCDs), and iodophors, in descending order of quantity consumed. Other applications of iodine included animal feed, biocides, fluoride derivatives, food supplements, and nylon.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production	W	W	W	W	W
Imports for consumption	4,170	4,930	4,300	4,570	4,100
Exports	1,230	1,190	1,230	1,130	1,200
Consumption:					
Apparent[1]	W	W	W	W	W
Reported	4,500	4,620	4,000	3,750	4,000
Price, crude iodine, average unit value of imports (cost, insurance, and freight), dollars per kilogram	19.55	22.46	26.38	31.57	32
Employment, number[e]	60	60	60	60	60
Net import reliance[2] as a percentage of reported consumption	>50	>50	>50	>50	>50

Recycling: Small amounts of iodine were recycled.

Import Sources (2017–20): Chile, 89%; Japan, 10%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Iodine, crude	2801.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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IODINE

Events, Trends, and Issues: According to trade publications, spot prices for iodine crystal averaged about $36 per kilogram during the first 9 months of 2021. This was slightly less than the 2020 annual average of $36.49 per kilogram. Prices were still considerably less than the historically high levels of $65 to $85 per kilogram in late 2012 and early 2013.

As in recent years, Chile was the world's leading producer of iodine, followed by Japan and the United States. Excluding production in the United States, Chile accounted for about two-thirds of world production in 2021. Most of the world's iodine supply comes from three areas: the Chilean desert nitrate mines, the gasfields and oilfields in Japan, and the iodine-rich brine wells in northwestern Oklahoma.

Following the global COVID-19 pandemic in 2020, global demand for iodine applications increased throughout 2021. One U.S. company was in negotiations with partners to build a new iodine plant with construction expected to begin by the end of 2021.

World Mine Production and Reserves: China and Iran also produce crude iodine, but output is not officially reported, and available information was inadequate to make reliable estimates of output.

	Mine production		Reserves[3]
	2020	2021[e]	
United States	W	W	250,000
Azerbaijan	180	200	170,000
Chile	20,200	22,000	610,000
Indonesia	31	30	100,000
Japan	8,880	9,000	4,900,000
Russia	3	3	120,000
Turkmenistan	600	600	70,000
World total (rounded)	[4]29,900	[4]32,000	6,200,000

World Resources:[3] Seawater contains 0.06 part per million iodine, and the oceans are estimated to contain approximately 90 billion tons of iodine. Seaweeds of the Laminaria family are able to extract and accumulate up to 0.45% iodine on a dry basis. Although not as economical as the production of iodine as a byproduct of gas, nitrates, and oil, the seaweed industry represented a major source of iodine prior to 1959 and remains a large resource.

Substitutes: No comparable substitutes exist for iodine in many of its principal applications, such as in animal feed, catalytic, nutritional, pharmaceutical, and photographic uses. Bromine and chlorine could be substituted for iodine in biocide, colorant, and ink, although they are usually considered less desirable than iodine. Antibiotics can be used as a substitute for iodine biocides.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]Defined as production + imports – exports.
[2]Defined as imports – exports.
[3]See Appendix C for resource and reserve definitions and information concerning data sources.
[4]Excludes U.S. production.

IRON ORE[1]

(Data in thousand metric tons of usable ore unless otherwise noted)

Domestic Production and Use: In 2021, mines in Michigan and Minnesota shipped 98% of the domestic usable iron ore products, which were consumed in the steel industry in the United States, with an estimated value of $4.3 billion, a 23% increase from $3.5 billion in 2020. The remaining 2% of domestic iron ore was produced for nonsteel end uses. Seven open pit iron ore mines (each with associated concentration and pelletizing plants) and four iron metallic plants—one direct-reduced iron (DRI) plant in Louisiana and three hot-briquetted iron (HBI) plants in Indiana, Ohio, and Texas—operated during the year to supply steelmaking raw materials. The United States was estimated to have produced 1.8% and consumed 1.4% of the world's iron ore output.

Salient Statistics—United States:[2]	**2017**	**2018**	**2019**	**2020**	**2021**[e]
Production:					
Iron ore	47,900	49,500	46,900	38,100	46,000
Iron metallics	3,250	3,560	3,660	3,500	3,800
Shipments	46,900	50,400	47,000	38,000	44,000
Imports for consumption	3,720	3,790	3,980	3,240	3,900
Exports	10,600	12,700	11,400	10,400	13,000
Consumption:					
Reported	34,400	36,600	34,800	NA	NA
Apparent[3]	40,100	41,400	39,100	31,100	36,000
Price, average value reported by mines, dollars per ton	78.54	93.00	92.94	91.27	94.00
Stocks, mine, dock, and consuming plant, yearend	3,930	3,100	3,470	3,290	4,000
Employment, mine, concentrating and pelletizing plant, number	4,630	4,860	4,960	4,300	4,200
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None. See Iron and Steel Scrap.

Import Sources (2017–20): Brazil, 55%; Canada, 22%; Sweden, 8%; Russia, 4%; and other, 11%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Iron ores and concentrates:		
Concentrates	2601.11.0030	Free.
Coarse ores	2601.11.0060	Free.
Other ores	2601.11.0090	Free.
Pellets	2601.12.0030	Free.
Briquettes	2601.12.0060	Free.
Sinter	2601.12.0090	Free.
Roasted iron pyrites	2601.20.0000	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Significant increases in production, shipments, and trade in 2021 were due to recovery from the effects of the global COVID-19 pandemic, which lowered steel production and consumption globally in 2020. Domestic iron ore production was estimated to be 46 million tons in 2021, a 21% increase from 38.1 million tons in 2020. Total raw steel production was estimated to have increased to 87 million tons in 2021 from 72.7 million tons in 2020. The share of steel produced by basic oxygen furnaces, the process that uses iron ore, continued to decline from 37.3% in 2015 to an estimated 28% in 2021 owing to increased use of electric arc furnaces because of their energy efficiency, reduced environmental impacts, and the ready supply of scrap.

Overall, global prices trended upward to an average unit value of $178.27 per ton in the first 9 months of 2021, a 64% increase from the 2020 annual average of $108.92 per ton and a 90% increase from the 2019 annual average of $93.85 per ton. Based on reported prices for iron ore fines (62% iron content) imported into China (cost, insurance, and freight into Tianjin Port), the highest monthly average price during the first 9 months of 2021 was $214.43 per ton in June compared with the high of $155.43 per ton in December 2020. The lowest monthly average price during the same period in 2021 was $124.52 per ton in September compared with the low of $84.73 per ton in April 2020. The prices trended upward owing to a reduced supply of higher grade iron ore products and demand for higher grade ore to reduce greenhouse gas emissions in steel production.

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IRON ORE

One company commenced production at a HBI plant in Ohio in late 2020, making it the fourth iron metallics facility operating in the United States. From 2009 to 2013, no iron metallics plants operated domestically. In December 2020, one iron ore mining company acquired all the domestic iron and steel operations from another company, consolidating all domestic iron ore mines, blast furnaces, and basic oxygen furnace steelmaking mills under the control of two companies. Globally, estimated iron ore production in 2021 increased by 4% from that of 2020. Global finished steel consumption was forecast by the World Steel Association[5] to increase by 4.5% in 2021 and increase by 2.2% in 2022.

World Mine Production and Reserves: Reserves for Australia, Peru, and Turkey were revised based on Government and public sources.

	Mine production				Reserves[6] (million metric tons)	
	Usable ore		Iron content			
	2020	2021[e]	2020	2021[e]	Crude ore	Iron content
United States	38,100	46,000	24,100	29,000	3,000	1,000
Australia	912,000	900,000	565,000	560,000	[7]51,000	[7]25,000
Brazil	388,000	380,000	247,000	240,000	34,000	15,000
Canada	60,100	68,000	36,100	41,000	6,000	2,300
Chile	15,600	19,000	9,890	12,000	NA	NA
China	360,000	360,000	225,000	220,000	20,000	6,900
India	204,000	240,000	127,000	150,000	5,500	3,400
Iran	49,500	50,000	32,500	33,000	2,700	1,500
Kazakhstan	62,900	64,000	12,700	13,000	2,500	900
Mexico	14,900	17,000	9,380	11,000	NA	NA
Peru	13,300	16,000	8,890	11,000	2,600	1,500
Russia	100,000	100,000	69,500	71,000	25,000	14,000
South Africa	55,600	61,000	35,400	39,000	1,000	670
Sweden	35,800	40,000	25,400	28,000	1,300	600
Turkey	15,400	16,000	8,570	8,900	130	38
Ukraine	78,800	81,000	49,300	51,000	[8]6,500	[8]2,300
Other countries	69,500	90,000	40,000	58,000	18,000	9,500
World total (rounded)	2,470,000	2,600,000	1,520,000	1,600,000	180,000	85,000

World Resources:[6] U.S. resources are estimated to be 110 billion tons of iron ore containing about 27 billion tons of iron. U.S. resources are mainly low-grade taconite-type ores from the Lake Superior district that require beneficiation and agglomeration prior to commercial use. World resources are estimated to be greater than 800 billion tons of crude ore containing more than 230 billion tons of iron.

Substitutes: The only source of primary iron is iron ore, used directly as direct-shipping ore or converted to briquettes, concentrates, DRI, iron nuggets, pellets, or sinter. DRI, iron nuggets, and scrap are extensively used for steelmaking in electric arc furnaces and in iron and steel foundries. Technological advancements have been made that allow hematite to be recovered from tailings basins and pelletized.

[e]Estimated. E Net exporter. NA Not available.

[1]Data are for iron ore used as a raw material in steelmaking unless otherwise noted. See also Iron and Steel and Iron and Steel Scrap.

[2]Except where noted, salient statistics are for all forms of iron ore used in steelmaking and do not include iron metallics, which include DRI, HBI, and iron nuggets.

[3]Defined as production + imports – exports + adjustments for industry stock changes.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]World Steel Association, 2021, Short range outlook October 2021: Brussels, Belgium, World Steel Association press release, October 14, 8 p.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 24 billion tons of crude ore and 11 billion tons of contained iron.

[8]For Ukraine, reserves consist of the A and B categories of the Soviet reserves classification system.

IRON OXIDE PIGMENTS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Iron oxide pigments (IOPs) were mined domestically by two companies in Alabama and Georgia. Mine production, which was withheld to avoid disclosing company proprietary data, remained about the same in 2021 as that in 2020. Five companies, including the two producers of natural IOPs, processed and sold about 18,000 tons of finished natural and synthetic IOPs with an estimated value of $13 million. About 48% of natural and synthetic finished IOPs were used in concrete and other construction materials; 17% in industrial chemicals; 14% in foundry sands and other foundry uses; 5% each in animal feed and paint and coatings; 3% each in plastics and glass and ceramics; and the remaining 5% in other uses.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Mine production, crude	W	W	W	W	W
Sold or used, finished natural and synthetic IOPs	47,300	48,200	19,200	18,300	18,000
Imports for consumption	179,000	179,000	159,000	173,000	190,000
Exports, pigment grade	13,500	11,100	11,200	9,300	9,400
Consumption, apparent[1]	213,000	216,000	167,000	182,000	200,000
Price, average value, dollars per kilogram[2]	1.46	1.58	0.69	0.72	0.70
Employment, mine and mill, number	60	60	55	47	47
Net import reliance[3] as a percentage of apparent consumption	78	78	89	90	91

Recycling: None.

Import Sources (2017–20): Natural: Cyprus, 40%; Spain, 31%; France, 14%; Austria, 13%; and other, 2%. Synthetic: China, 46%; Germany, 33%; Brazil, 7%; and other, 14%. Total: China, 45%; Germany, 32%; Brazil, 7%; and other, 16%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Natural:		
Micaceous iron oxides	2530.90.2000	2.9% ad valorem.
Earth colors	2530.90.8015	Free.
Iron oxides and hydroxides containing 70% or more by weight Fe_2O_3:		
Synthetic:		
Black	2821.10.0010	3.7% ad valorem.
Red	2821.10.0020	3.7% ad valorem.
Yellow	2821.10.0030	3.7% ad valorem.
Other	2821.10.0040	3.7% ad valorem.
Earth colors	2821.20.0000	5.5% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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IRON OXIDE PIGMENTS

Events, Trends, and Issues: In 2021, domestic mine production of crude and finished natural IOPs remained approximately the same as 2020 production. Imports of natural and synthetic pigments were estimated to have increased by 10% in 2021, owing in part to low mortgage interest rates and increased demand for single-family homes as the global COVID-19 pandemic made multifamily homes less desirable. In the United States, residential construction, in which IOPs are commonly used to color concrete block and brick, ready-mixed concrete, and roofing tiles, increased during the first 9 months of 2021 compared with that in the same period in 2020. Housing starts increased by about 20% in 2021 compared with those in 2020.

Exports of pigment-grade IOPs increased by 3% during the first 9 months of 2021 compared with those during the same period in 2020, mostly owing to an increase in exports to Argentina, Poland, and South Africa. Approximately 80% of pigment-grade IOPs exports went to Mexico, China, Germany, Thailand, Belgium, and Brazil, in descending order of quantity. Exports of other grades of iron oxides and hydroxides decreased by 25% during the first 9 months of 2021 compared with those in the same period in 2020. About 89% of exports of other grades of iron oxides and hydroxides went to Mexico, Canada, Ireland, Belgium, and the Republic of Korea, in descending order of quantity.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States	W	W	Moderate
Cyprus (umber)	3,500	3,500	Moderate
France	6,000	6,000	NA
Germany[5]	400,000	400,000	Moderate
India (ocher)	2,500,000	2,500,000	37,000,000
Italy	30,000	30,000	NA
Pakistan (ocher)	120,000	120,000	100,000
Spain (ocher and red iron oxide)	9,000	9,000	Large
World total (rounded)	[6]NA	[6]NA	Large

World Resources:[4] Domestic and world resources for production of IOPs are adequate. Adequate resources are available worldwide for the manufacture of synthetic IOPs.

Substitutes: Milled IOPs are thought to be the most commonly used natural minerals for pigments. Because IOPs are color stable, low cost, and nontoxic, they can be economically used for imparting black, brown, red, and yellow coloring in large and relatively low-value applications. Other minerals may be used as colorants, but they generally cannot compete with IOPs because of their higher costs and more limited availability. Synthetic IOPs are widely used as colorants and compete with natural IOPs in many color applications. Organic colorants are used for some colorant applications, but many of the organic compounds fade over time from exposure to sunlight.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Defined as sold or used finished natural and synthetic iron oxide pigments + imports – exports.
[2]Average unit value for finished iron oxide pigments sold or used by U.S. producers.
[3]Defined as imports – exports.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]Includes natural and synthetic iron oxide pigments.
[6]A significant number of other countries, including Austria, Azerbaijan, Brazil, China, Honduras, Iran, Kazakhstan, Lithuania, Paraguay, Russia, South Africa, Turkey, Ukraine, and the United Kingdom, are thought to produce iron oxide pigments, but output was not reported, and no basis was available to make reliable estimates of production.

IRON AND STEEL[1]

(Data in million metric tons of metal unless otherwise noted)

Domestic Production and Use: The U.S. iron and steel industry produced raw steel in 2021 with an estimated value of about $110 billion, a 21% increase from $91 billion in 2020. Pig iron and raw steel was produced by three companies operating integrated steel mills in 11 locations. Raw steel was produced by 50 companies at 101 minimills. Combined production capacity was about 106 million tons. Indiana accounted for an estimated 27% of total raw steel production, followed by Ohio, 11%; Pennsylvania, 5%; Illinois and Texas, 4% each; and Michigan, 3%; with no other State having more than 3% of total domestic raw steel production. Construction accounted for an estimated 47% of total domestic shipments by market classification, followed by transportation (predominantly automotive), 25%; machinery and equipment, 9%; appliances and energy, 5% each; and other applications, 9%.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Pig iron production[2]	22.4	24.1	22.3	18.3	22
Raw steel production	81.6	86.6	87.8	72.7	87
Distribution of raw steel production, percent:					
Basic oxygen furnaces	32	32	30	29	29
Electric arc furnaces	68	68	70	71	71
Continuously cast steel, percent	99.6	98.2	99.8	99.8	99.8
Shipments, steel mill products	82.5	86.4	87.3	73.5	88
Imports, steel mill products:					
Finished	26.8	23.3	19.1	14.6	18
Semifinished	7.8	7.3	6.2	5.3	6.7
Total	34.6	30.6	25.3	20.0	25
Exports, steel mill products:					
Finished	9.4	7.9	6.6	6.7	8.1
Semifinished	0.1	0.1	0.1	0.1	0.1
Total	9.5	8.0	6.7	6.8	8.3
Stocks, service centers, yearend[3]	7.0	7.3	7.4	5.8	5.8
Consumption, apparent (steel)[4]	99.4	101	99.6	82.9	98
Producer price index for steel mill products (1982=100)[5]	187.4	211.1	204.0	184.4	348.5
Employment, average, number:					
Iron and steel mills[5]	80,600	82,100	85,700	83,200	86,000
Steel product manufacturing[6]	54,300	56,700	57,800	54,900	57,000
Net import reliance[7] as a percentage of apparent consumption	18	15	12	8	10

Recycling: See Iron and Steel Scrap and Iron and Steel Slag.

Import Sources (2017–20): Canada, 19%; Brazil, 15%; Mexico, 12%; the Republic of Korea, 9%; and other, 45%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Carbon steel:		
Semifinished	7207.00.0000	Free.
Flat, hot-rolled	7208.00.0000	Free.
Flat, cold-rolled	7209.00.0000	Free.
Galvanized	7210.00.0000	Free.
Bars and rods, hot-rolled	7213.00.0000	Free.
Structural shapes	7216.00.0000	Free.
Stainless steel:		
Semifinished	7218.00.0000	Free.
Flat-rolled sheets	7219.00.0000	Free.
Bars and rods	7222.00.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

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IRON AND STEEL

Events, Trends, and Issues: The World Steel Association[8] forecast global finished steel consumption to increase by 4.5% in 2021 and by 2.2% in 2022 owing to rebounding demand from the effects of the global COVID-19 pandemic. Global recovery started in late 2020, as manufacturing ramped up in developed countries, through the second half of 2021, when supply chain disruptions affected delivery and demand. In 2021, U.S. apparent consumption of iron and steel increased by 22% from that in 2020. The automotive sector drove domestic increases in steel consumption and there were increases in demand in the construction sector. The potential for infrastructure stimulus programs could speed economic recovery and increase steel demand; however, the effects would take months to years before they become fully realized.

China's steel demand decreased in June 2021 owing to a variety of factors including pandemic closures and other effects, weak real estate activity, poor weather conditions, reduced investment infrastructure, and reduced exports. Steel consumption in the European Union continued to increase throughout the year owing to increased exports from Germany and increasing construction activity in Italy. Despite worsening pandemic conditions in Asia, steel demand remained unchanged owing to increases in Japan's automotive and machinery sectors and an increase in construction activity in the Republic of Korea. Generally, South America experienced a significant decrease in steel demand owing to pandemic conditions in 2020; however, the increased activity in the construction and automotive sectors led to a recovery in steel consumption to pre-pandemic levels.

World Production:

	Pig iron		Raw steel	
	2020	2021[e]	2020	2021[e]
United States[1]	18	22	73	87
Brazil	25	30	31	39
China	888	880	1,060	1,100
Germany	22	25	40	44
India	68	79	100	120
Iran	3	3	29	30
Italy	3	4	20	23
Japan	62	68	83	92
Korea, Republic of	45	50	67	73
Mexico	2	3	17	19
Russia	52	53	72	73
Taiwan	13	14	21	21
Turkey	10	12	36	42
Ukraine	20	21	21	21
Vietnam	10	10	17	17
Other countries	71	99	108	120
World total (rounded)	1,310	1,400	1,790	1,900

World Resources: Not applicable. See Iron Ore and Iron and Steel Scrap for steelmaking raw-material resources.

Substitutes: Iron is the least expensive and most widely used metal. In most applications, iron and steel compete either with less expensive nonmetallic materials or with more expensive materials that have a performance advantage. Iron and steel compete with lighter materials, such as aluminum and plastics in the automotive industry; aluminum, concrete, and wood in construction; and aluminum, glass, paper, and plastics in containers.

[e]Estimated.
[1]Production and shipments data source is the American Iron and Steel Institute; see also Iron and Steel Scrap and Iron Ore.
[2]More than 95% of pig iron production is transported in molten form to steelmaking furnaces at the same site.
[3]Steel mill products. Source: Metals Service Center Institute.
[4]Defined as steel shipments + imports of finished steel mill products – exports of steel mill products + adjustments for industry stock changes.
[5]Source: U.S. Department of Labor, Bureau of Labor Statistics, North American Industry Classification System Code 331200.
[6]Source: U.S. Department of Labor, Bureau of Labor Statistics, North American Industry Classification System Code 331100.
[7]Defined as imports of finished steel mill products – total exports + adjustments for industry stock changes.
[8]World Steel Association, 2021, Short range outlook October 2021: Brussels, Belgium, World Steel Association press release, October 14, 8 p.

IRON AND STEEL SCRAP[1]

(Data in million metric tons of metal unless otherwise noted)

Domestic Production and Use: In 2021, the total value of domestic purchases of iron and steel scrap (receipts of ferrous scrap by all domestic consumers from brokers, dealers, and other outside sources) and exports was estimated to be $27 billion, nearly double the $14.0 billion in 2020 and 68% more than the $15.8 billion in 2019. U.S. apparent consumption of steel, the leading end use for iron and steel scrap, was estimated to have increased by 18% to 98 million tons in 2021 from 82.9 million tons in 2020. Manufacturers of pig iron, raw steel, and steel castings accounted for almost all scrap consumption by the domestic steel industry, using scrap together with pig iron and direct-reduced iron to produce steel products for the appliance, construction, container, machinery, oil and gas, transportation, and various other consumer industries. The ferrous castings industry consumed most of the remaining scrap to produce cast iron and steel products. Relatively small quantities of steel scrap were used for producing ferroalloys, for the precipitation of copper, and by the chemical industry; these uses collectively totaled less than 1 million tons.

During 2021, estimated raw steel production increased by 19% to 87 million tons, from 72.7 million tons in 2020, and net shipments of steel mill products were an estimated 88 million tons, up by 20% from 73.5 million tons in 2020.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Home scrap	5.6	5.8	5.3	4.8	4.2
Purchased scrap[2]	55	59	55	53	55
Imports for consumption[3]	4.6	5.0	4.3	4.5	6.2
Exports[3]	15	17	18	17	19
Consumption:					
Reported	50	52	48	45	46
Apparent[4]	50	52	49	45	46
Price, average, delivered, No. 1 heavy melting composite price, dollars per ton[5]	265	326	249	228	435
Stocks, consumer, yearend	4.5	5.1	4.0	4.0	4.4
Employment, dealers, brokers, processors, number[e]	27,000	27,000	26,000	24,000	25,000
Net import reliance[6] as a percentage of reported consumption	E	E	E	E	E

Recycling: Recycled iron and steel scrap is a vital raw material for the production of new steel and cast iron products. The steel and foundry industries in the United States have been structured to recycle scrap and, as a result, are highly dependent upon scrap. Recycling 1 ton of steel conserves 1.1 tons of iron ore, 0.6 ton of coking coal, and 0.05 ton of limestone. Recycling of scrap also conserves energy because the remelting of scrap requires much less energy than the production of iron or steel products from iron ore.

Overall, the scrap recycling rate in the United States has averaged between 80% and 90% during the past decade, with automobiles making up the primary source of old steel scrap. Recycling of automobiles is nearly 100% each year, with rates fluctuating slightly owing to the rate of new vehicle production and general economic trends. More than 15 million tons of steel is recycled from automobiles annually, the equivalent of approximately 12 million cars, from more than 7,000 vehicle dismantlers and 350 car shredders in North America. The recycling of steel from automobiles is estimated to save the equivalent energy necessary to power 18 million homes every year.

Recycling rates, which fluctuate annually, were estimated to be 98% for structural steel from construction, 88% for appliances, 71% for rebar and reinforcement steel, and 70% for steel packaging. The recycling rates for appliance, can, and construction steel are expected to increase in the United States and in emerging industrial countries at an even greater rate. Public interest in recycling continues, and recycling is becoming more profitable and convenient as environmental regulations for primary production increase. Also, consumption of iron and steel scrap by remelting reduces the burden on landfill disposal facilities and prevents the accumulation of abandoned steel products in the environment

Recycled scrap consists of approximately 58% post-consumer (old, obsolete) scrap, 24% new scrap (produced in steel-product manufacturing plants), and 18% home scrap (recirculating scrap from current operations).

Import Sources (2017–20): Canada, 70%; Mexico, 11%; the United Kingdom, 6%; Sweden, 5%; and other, 8%.

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IRON AND STEEL SCRAP

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Ferrous waste and scrap:		
Stainless steel	7204.21.0000	Free.
Turnings, shavings, chips, milling waste, sawdust, filings, trimmings, and stampings:		
No. 1 bundles	7204.41.0020	Free.
No. 2 bundles	7204.41.0040	Free.
Borings, shovelings, and turnings	7204.41.0060	Free.
Other	7204.41.0080	Free.
Other:		
No. 1 heavy melting	7204.49.0020	Free.
No. 2 heavy melting	7204.49.0040	Free.
Cut plate and structural	7204.49.0060	Free.
Shredded	7204.49.0070	Free.
Remelting scrap ingots	7204.50.0000	Free.
Powders, of pig iron, spiegeleisen, iron, or steel:		
Alloy steel	7205.21.0000	Free.
Other	7205.29.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: In 2021, steel mill production capacity utilization rebounded from the lowest monthly rate since July 2009, reaching 54.6% in May 2020, into the normal historical range for operating rates reaching 76.6% in January and continuing to increase to 84.8% in the second half of 2021. Composite prices published for No. 1 heavy melting steel scrap increased significantly in 2021, rising from $194.01 per ton in July 2020 to a peak of $454.38 per ton in July 2021. The annual average price delivered in the first 8 months of 2021 increased to $408.54 per ton compared with the full-year annual average of $227.62 per ton in 2020, contributing to the significant increase in the total estimated value of domestic purchases and exports of iron and steel scrap in 2021.

In the first 8 months of 2021, Mexico and Turkey were the primary destinations for exports of ferrous scrap, by tonnage, accounting for 18% of total exports each, followed by Malaysia, 10%; Vietnam, 9%; and Bangladesh and Taiwan, 8% each. The value of exported scrap increased to an estimated $8.1 billion in 2021 from $4.8 billion in 2020. In the first 8 months of 2021, Canada was the leading source of imports of ferrous scrap, by tonnage, accounting for 67% of total imports, following by Mexico, 10%; the United Kingdom, 7%; the Netherlands, 6%; and Sweden, 3%.

The World Steel Association[7] forecast global finished steel consumption to increase by 4.5% in 2021 and by 2.2% in 2022 owing to rebounding demand from the effects of the global COVID-19 pandemic. Global recovery started in late 2020, as manufacturing ramped up in developed countries, through the second half of 2021, when supply chain disruptions affected delivery and demand. These factors are expected to be relieved in 2022 and increase recovery momentum. The automotive sector was the leading cause of domestic increases in steel consumption.

World Mine Production and Reserves: Not applicable. See Iron and Steel and Iron Ore.

World Resources: Not applicable. See Iron and Steel and Iron Ore.

Substitutes: An estimated 3.5 million tons of direct-reduced iron was consumed in the United States in 2021 as a substitute for iron and steel scrap, up from 3.3 million tons in 2020.

[e]Estimated. E Net exporter.
[1]See also Iron and Steel and Iron Ore.
[2]Defined as net receipts + exports – imports.
[3]Excludes used rails for rerolling and other uses, and ships, boats, and other vessels for scrapping.
[4]Defined as home scrap + purchased scrap + imports – exports + adjustments for industry stock changes.
[5]Source: Fastmarkets AMM
[6]Defined as imports – exports + adjustments for industry stock changes.
[7]World Steel Association, 2021, Short range outlook October 2021: Brussels, Belgium, World Steel Association press release, October 14, 8 p.

IRON AND STEEL SLAG

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: Iron and steel (ferrous) slags are formed by the combination of slagging agents and impurities during the production of crude (or pig) iron and crude steel. The slags are tapped separately from the metals, then cooled and processed, and are primarily used in the construction industry. Data are unavailable on actual U.S. ferrous slag production, but domestic slag sales[1] in 2021 were estimated to be 17 million tons valued at about $460 million. Blast furnace slag was about 49% of the tonnage sold and accounted for 87% of the total value of slag, most of which was granulated. Steel slag produced from basic oxygen and electric arc furnaces accounted for the remainder of sales. Slag was processed by 28 companies servicing active iron and steel facilities or reprocessing old slag piles at about 124 processing plants (including some iron and steel plants with more than one slag-processing facility) in 33 States, including facilities that import and grind unground slag to sell as ground granulated blast furnace slag (GGBFS).

Air-cooled iron slag and steel slag are used primarily as aggregates in concrete (air-cooled iron slag only); asphaltic paving, fill, and road bases; both slag types also can be used as a feed for cement kilns. Almost all GGBFS is used as a partial substitute for portland cement in concrete mixes or in blended cements. Pelletized slag is generally used for lightweight aggregate but can be ground into material similar to GGBFS. Actual prices per ton ranged from a few cents for some steel slags at a few locations to about $120 or more for some GGBFS in 2021. Owing to low unit values, most slag types can be shipped only short distances by truck, but rail and waterborne transportation allow for greater travel distances. Because much higher unit values make it economical to ship GGBFS longer distances, much of the GGBFS consumed in the United States is imported.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production (sales)[1, 2]	16.2	16.8	[e]16	[e]13	17
Imports for consumption[3]	2.1	2.2	1.8	2.3	2.2
Exports	([4])	([4])	([4])	([4])	([4])
Consumption, apparent[5]	16.2	16.8	[e]16	[e]13	17
Price, average value, free on board plant, dollars per ton[6]	24.50	26.50	27.50	25.50	27.00
Employment, number[e]	1,500	1,500	1,500	1,500	1,500
Net import reliance[7] as a percentage of apparent consumption	13	13	10	14	11

Recycling: Following removal of entrained metal, slag can be returned to the blast and steel furnaces as ferrous and flux feed, but data on these returns are incomplete. Entrained metal, particularly in steel slag, is routinely recovered during slag processing for return to the furnaces and is an important revenue source for slag processors; data on metal returns are unavailable.

Import Sources (2017–20): Japan, 42%; Brazil, 18%; China, 11%; Italy, 10%; and other, 19%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Granulated slag	2618.00.0000	Free.
Slag, dross, scalings, and other waste from manufacture of iron and steel:		
Ferrous scale	2619.00.3000	Free.
Other	2619.00.9000	Free.

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IRON AND STEEL SLAG

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: The availability of steel slag is tied closely to the rates of raw steel production and the cost consideration of recovering slag for use in low-value downstream applications. The majority of U.S. steel slag production is from electric arc furnaces, which accounted for approximately 71% of U.S. steel production in 2021 owing to the overall cost benefits of environmental factors, such as feedstock and power consumption, and the price and availability of ferrous scrap feedstock. In recent years, the percentage of basic oxygen furnace steel production has continued to decline as capacity has idled or closed; however, slag stockpiling at furnaces allow for processing of slag for years after closures. The World Steel Association[8] forecast global finished steel consumption to increase by 4.5% in 2021 and by 2.2% in 2022 owing to rebounding demand from the effects of the global COVID-19 pandemic.

During 2021, domestic GGBFS remained in limited supply because granulation cooling was known to be available at only two active U.S. blast furnaces while, elsewhere, only one domestic plant produced pelletized slag in limited supply. Grinding of granulated blast furnace slag was only done domestically by cement companies. Supply constraints appear to have limited domestic consumption of GGBFS in recent years. Following declines in value and production in 2020, owing to the effects and availability caused by closures related to the COVID-19 pandemic, steel production rates increased through 2021 leading to increased availability of steel slag.

The domestic supply of fly ash, which is used as an additive in concrete production, continues to decrease, owing to restrictions of mercury and carbon dioxide (CO_2) emissions at coal-fired powerplants, powerplant closures, and conversion of powerplants to natural gas. Mercury emission restrictions on cement plants, enacted in 2015, may reduce the demand for fly ash as a raw material in clinker manufacture, and air-cooled and steel slags are used as substitute raw materials. Demand for GGBFS is likely to increase because its use in cement yields a beneficial product in many applications and reduces the unit CO_2 emissions in the production of the cement.

World Production and Reserves: Because slag is not mined, the concept of reserves does not apply. World production data for slag were unavailable, but iron slag from blast furnaces may be estimated to be 25% to 30% of crude (pig) iron production and steel furnace slag may be estimated to be 10% to 15% of raw steel production. In 2021, world iron slag production was estimated to be between 340 million and 410 million tons, and steel slag production was estimated to be between 190 million and 280 million tons.

World Resources: Not applicable.

Substitutes: In the construction sector, ferrous slags compete with natural aggregates (crushed stone and construction sand and gravel) but are far less widely available than the natural materials. As a cementitious additive in blended cements and concrete, GGBFS mainly competes with fly ash, metakaolin, and volcanic ash pozzolans. In this respect, GGBFS reduces the amount of portland cement per ton of concrete, thus allowing more concrete to be made per ton of portland cement. Slags (especially steel slag) can be used as a partial substitute for limestone and some other natural raw materials for clinker (cement) manufacture and compete in this use with fly ash and bottom ash. Some other metallurgical slags, such as copper slag, can compete with ferrous slags in some specialty markets, such as a ferrous feed in clinker manufacture, but are generally in much more restricted supply than ferrous slags.

[e]Estimated.
[1]Processed slag sold during the year, excluding entrained metal.
[2]Data include sales of domestic and imported granulated blast furnace slag and exclude sales of pelletized slag.
[3]U.S. Census Bureau data adjusted by the U.S. Geological Survey to remove nonslag materials (such as cenospheres, fly ash, and silica fume) and slags or other residues of other metallurgical industries (especially copper slag), whose unit values are outside the range expected for granulated slag. In some years, tonnages may be underreported.
[4]Less than 50,000 tons.
[5]Defined as sales – exports.
[6]Rounded to the nearest $0.50 per ton.
[7]Defined as imports – exports.
[8]World Steel Association, 2021, Short range outlook October 2021: Brussels, Belgium, World Steel Association press release, October 14, 8 p.

KYANITE AND RELATED MINERALS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In Virginia, one firm with integrated mining and processing operations produced an estimated 81,000 tons of kyanite worth $30 million from two hard-rock open pit mines and synthetic mullite by calcining kyanite. Two other companies, one in Alabama and another in Georgia, produced synthetic mullite from materials mined from four sites; each company sourced materials from one site in Alabama and one site in Georgia. Synthetic mullite production data are withheld to avoid disclosing company proprietary data. Commercially produced synthetic mullite is made by sintering or fusing such feedstock materials as kyanite, kaolin, bauxite, or bauxitic kaolin. Natural mullite occurrences typically are rare and not economical to mine.

Of the kyanite-mullite output, 90% was estimated to have been used in refractories and 10% in other uses, including abrasive products, such as motor vehicle brake shoes and pads and grinding and cutting wheels; ceramic products, such as electrical insulating porcelains, sanitaryware, and whiteware; foundry products and precision casting molds; and other products. An estimated 60% to 70% of the refractory use was by the iron and steel industries, and the remainder was by industries that manufacture cement, chemicals, glass, nonferrous metals, and other materials.

Andalusite was commercially mined from an andalusite-pyrophyllite-sericite deposit in North Carolina and processed as a blend of primarily andalusite for use by producers of refractories in making firebrick. Another company mined mineral sands within the southeastern United States; product blends that included kyanite and (or) sillimanite were marketed to the abrasive, foundry, and refractory industries.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Kyanite, mine	[1]91,300	[1]89,200	[1]91,300	[1]67,100	81,000
Synthetic mullite	W	W	W	W	W
Imports for consumption (andalusite)	7,420	8,590	6,960	710	1,000
Exports (kyanite)	42,400	43,000	40,100	37,400	45,000
Consumption, apparent[2]	W	W	W	W	W
Price, average value of exports (free alongside ship),[3, 4] dollars per metric ton	350	347	358	369	369
Employment, number:[e]					
Kyanite, mine, office, and plant	140	150	150	140	140
Synthetic mullite, office and plant	200	200	200	200	200
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2017–20):[4] South Africa, 77%; Peru, 12%; France, 7%; United Kingdom, 3%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Andalusite, kyanite, and sillimanite	2508.50.0000	Free.
Mullite	2508.60.0000	Free.

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KYANITE AND RELATED MINERALS

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Crude steel production in the United States, which ranked fourth in the world, increased by about 20% in the first 8 months of 2021 compared with that of the same period in 2020, indicating a similar change in consumption of kyanite-mullite refractories. Total world steel production increased by about 11% during the first 8 months of 2021 compared with that of the same period in 2020. The increase in world steel production during the first 8 months of 2021 was the result of economic recovery from the global COVID-19 pandemic. The steel industry continued to be the largest market for refractories.

In January 2021, a company in South Africa that accounted for nearly one-third of global andalusite output announced that a new investor and owner had been approved. In mid-2019, the company entered into business rescue proceedings attributed to financial problems but was expected to emerge from business rescue status and be transferred to the new owner.

Despite strong demand, andalusite output was hindered by several challenges that contributed to a prolonged and uneven recovery period from the pandemic. Although many countries declared mining essential, production efforts were constrained by ongoing logistical and shipping issues, renewed COVID-19 outbreaks, and supply chain disruptions. If andalusite producers are unable to meet demand, market participants may consider alternatives such as bauxite and mullite, although these materials experienced similarly problematic market conditions in 2021.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States (kyanite)	[1]67,100	81,000	Large
India (kyanite and sillimanite)	61,000	70,000	7,200,000
Peru (andalusite)	[e]40,000	40,000	NA
South Africa (andalusite)	180,000	190,000	NA
World total (rounded)	[7]NA	[7]NA	NA

World Resources:[6] Large resources of kyanite and related minerals are known to exist in the United States. The chief resources are in deposits of micaceous schist and gneiss, mostly in the Appalachian Mountains and in Idaho. Other resources are in aluminous gneiss in southern California. These resources are not economical to mine at present. The characteristics of kyanite resources in the rest of the world are thought to be similar to those in the United States. Significant resources of andalusite are known to exist in China, France, Peru, and South Africa; kyanite resources have been identified in Brazil, India, and Russia; and sillimanite has been identified in India.

Substitutes: Two types of synthetic mullite (fused and sintered), superduty fire clays, and high-alumina materials are substitutes for kyanite in refractories. Principal raw materials for synthetic mullite are bauxite, kaolin and other clays, and silica sand.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Source: Virginia Department of Mines, Minerals and Energy.
[2]Defined as production + imports – exports.
[3]Calculated from U.S. Census Bureau export data.
[4]Includes data for the following Harmonized Tariff Schedule of the United States code: 2508.50.0000.
[5]Defined as imports – exports.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]In addition to the countries listed, France continued production of andalusite, and Cameroon and China produced kyanite and related minerals. Output was not reported quantitatively, and no reliable basis was available for estimation of output levels.

LEAD

(Data in thousand metric tons of contained lead unless otherwise noted)

Domestic Production and Use: Lead was produced domestically by five lead mines in Missouri plus as a byproduct at two zinc mines in Alaska and two silver mines in Idaho. The value of the lead in concentrates of ore mined in 2021 was an estimated $750 million, 21% more than that in 2020. Nearly all lead concentrate production has been exported since the last primary lead refinery closed in 2013. The value of the secondary lead produced in 2021 was $2.4 billion, 17% more than that in 2020. The lead-acid battery industry accounted for an estimated 92% of reported U.S. lead consumption during 2021. Lead-acid batteries were primarily used as starting-lighting-ignition (SLI) batteries for automobiles, as industrial-type batteries for standby power for computer and telecommunications networks, and for motive power. During the first 9 months of 2021, 107 million lead-acid automotive batteries were shipped by North American producers, 8% more than those shipped in the same period of 2020.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine, lead in concentrates	310	280	274	306	300
Primary refinery	—	—	—	—	—
Secondary refinery, old scrap	1,140	1,140	1,070	1,030	990
Imports for consumption:					
Lead in concentrates	([1])	—	([1])	([1])	—
Refined metal, unwrought (gross weight)	658	563	501	382	620
Exports:					
Lead in concentrates	269	251	259	265	250
Refined metal, unwrought (gross weight)	24	70	25	17	22
Consumption, apparent[2]	1,770	1,640	1,550	1,400	1,600
Price, average, cents per pound:[3]					
North American market	114.5	110.9	99.9	91.3	110
London Metal Exchange (LME), cash	105.1	101.8	91.0	82.7	99
Employment, mine and mill (average), number[4]	1,890	1,860	1,690	1,810	1,900
Net import reliance[5] as a percentage of apparent consumption, refined metal	36	30	31	26	38

Recycling: In 2021, about 990,000 tons of secondary lead was produced, an amount equivalent to 62% of apparent domestic consumption. Nearly all secondary lead was recovered from old scrap, mostly lead-acid batteries.

Import Sources (2017–20): Refined metal: Canada, 43%; Mexico, 19%; the Republic of Korea, 17%; India, 4%; and other, 17%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Lead ores and concentrates, lead content	2607.00.0020	1.1¢/kg on lead content.
Refined lead	7801.10.0000	2.5% on the value of the lead content.
Antimonial lead	7801.91.0000	2.5% on the value of the lead content.
Alloys of lead	7801.99.9030	2.5% on the value of the lead content.
Other unwrought lead	7801.99.9050	2.5% on the value of the lead content.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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LEAD

Events, Trends, and Issues: During the first 10 months of 2021, the average LME cash price for lead was 98.9 cents per pound, 20% more than the average price in 2020, owing to the worldwide shipping delays and decreased supply of the refined lead available on the market. The average monthly LME cash price peaked in August at 110.2 cents per pound and declined through November. Global stocks of lead in LME-approved warehouses were 57,800 tons in November 2021, which was 57% less than those at yearend 2020.

In 2021, domestic mine production was estimated to have decreased slightly from that in the previous year. Domestic production of secondary lead decreased by 4% from that in the previous year owing to a reduction in production of several secondary lead smelters and a closure of one secondary lead smelter in South Carolina in 2021. U.S. apparent consumption of refined lead increased by 14% from that in the previous year, and the net import reliance increased from 26% to 38%, owing to the forementioned domestic secondary plants' closures and subsequent 62% increase in the imports of the refined lead. In the first 9 months of 2021, 25.5 million spent SLI lead-acid batteries were exported, 29% more than that in the same time period in 2020.

According to the International Lead and Zinc Study Group,[6] global refined lead production in 2021 was forecast to increase by 4.4% to 12.4 million tons and metal consumption to increase by 5.5% to 12.4 million tons.

World Mine Production and Reserves: Reserves estimates for Australia and Peru were revised based on new information from Government reports.

	Mine production		Reserves[7]
	2020	2021[e]	
United States	306	300	5,000
Australia	494	500	[8]37,000
Bolivia	65	90	1,600
China	1,900	2,000	18,000
India	204	210	2,500
Kazakhstan	30	40	2,000
Mexico	260	270	5,600
Peru	242	280	6,400
Russia	210	210	4,000
Sweden	70	70	1,100
Tajikistan	46	46	NA
Turkey	63	60	860
Other countries	490	220	5,900
World total (rounded)	4,380	4,300	90,000

World Resources:[7] Identified world lead resources total more than 2 billion tons. In recent years, significant lead resources have been identified in association with zinc and (or) silver or copper deposits in Australia, China, Ireland, Mexico, Peru, Portugal, Russia, and the United States (Alaska).

Substitutes: Substitution by plastics has reduced the use of lead in cable covering and cans. Tin has replaced lead in solder for potable water systems. The electronics industry has moved toward lead-free solders and flat-panel displays that do not require lead shielding. Steel and zinc are common substitutes for lead in wheel weights.

[e]Estimated. NA Not available. — Zero.
[1]Less than ½ unit.
[2]Defined as primary refined production + secondary refined production from old scrap + refined imports – refined exports.
[3]Source: S&P Global Platts Metals Week.
[4]Includes lead and zinc-lead mines for which lead was either a principal product or significant byproduct. Data from the Mine Safety and Health Administration.
[5]Defined as imports – exports.
[6]International Lead and Zinc Study Group, 2021, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 12, [5] p.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 12 million tons.

LIME[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, an estimated 17 million tons of quicklime and hydrated was produced (excluding independent commercial hydrators[2]), valued at about $2.3 billion. Twenty-eight companies produced lime, which included 18 companies with commercial sales and 10 companies that produced lime strictly for internal use (for example, sugar companies). These companies had 73 primary lime plants (plants operating quicklime kilns) in 28 States and Puerto Rico. One primary lime plant was idle in 2021. Five of the 28 companies operated only hydrating plants in nine States. In 2021, the five leading U.S. lime companies produced quicklime or hydrated in 22 States and accounted for about 78% of U.S. lime production. Principal producing States were, in alphabetical order, Alabama, Kentucky, Missouri, Ohio, and Texas. Major markets for lime were, in descending order of consumption, steelmaking, chemical and industrial applications (such as the manufacture of fertilizer, glass, paper and pulp, and precipitated calcium carbonate, and in sugar refining), flue gas treatment, construction, water treatment, and nonferrous-metal mining.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production[2, 3]	17,600	18,000	16,900	15,800	17,000
Imports for consumption	367	370	342	308	330
Exports	391	424	347	266	310
Consumption, apparent[4]	17,600	18,000	16,900	15,900	17,000
Price, average value, dollars per ton at plant:					
Quicklime	120.8	125.2	128.3	132.1	140
Hydrated	147.1	151.6	154.6	156.4	160
Net import reliance[5] as a percentage of apparent consumption	E	E	E	<1	<1

Recycling: Large quantities of lime are regenerated by paper mills. Some municipal water-treatment plants regenerate lime from softening sludge. Quicklime is regenerated from waste hydrated lime in the carbide industry. Data for these sources were not included as production in order to avoid duplication.

Import Sources (2017–20): Canada, 90%; Mexico, 7%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Calcined dolomite	2518.20.0000	3% ad valorem.
Quicklime	2522.10.0000	Free.
Slaked lime	2522.20.0000	Free.
Hydraulic lime	2522.30.0000	Free.

Depletion Allowance: Limestone produced and used for lime production, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, domestic lime production was estimated to have increased by 8% from that in 2020. In 2020, a decline in lime production was a result of plants temporarily closing as a result of the global COVID-19 pandemic. As the economy continues to rebound from the effects of the pandemic, so does the lime industry. In Michigan, one sugar company announced plans to construct a desugarization facility to produce an additional 40,000 tons of refined sugar annually. The San Bernardino County, CA, government approved plans to build a lime plant near a limestone quarry at Trona, CA. In 2021, a total of 73 quicklime plants were in operation along with 10 hydrating plants. Hydrated lime is a dry calcium hydroxide powder made from reacting quicklime with a controlled amount of water in a hydrator. It is used in chemical and industrial, construction, and environmental applications.

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LIME

World Lime Production and Limestone Reserves:

	Production[6] 2020	Production[6] 2021[e]	Reserves[7]
United States	15,800	17,000	Adequate for all countries listed.
Australia	1,980	2,000	
Belgium[8]	1,500	1,500	
Brazil	8,000	8,100	
Bulgaria	1,280	1,400	
Canada (shipments)	2,060	2,000	
China	310,000	310,000	
France	2,600	2,600	
Germany	7,100	7,100	
India	15,000	16,000	
Iran	3,600	3,600	
Italy[8]	3,400	3,500	
Japan (quicklime only)	5,820	7,000	
Korea, Republic of	5,100	5,200	
Malaysia	1,480	1,500	
Poland (hydrated and quicklime)	1,680	1,700	
Romania	1,280	1,500	
Russia (industrial and construction)	11,400	11,000	
Slovenia	1,200	1,200	
South Africa	1,200	1,200	
Spain	1,700	1,800	
Turkey	4,700	4,700	
Ukraine	2,340	2,300	
United Kingdom	1,500	1,500	
Other countries	15,000	15,000	
World total (rounded)	427,000	430,000	

World Resources:[7] Domestic and world resources of limestone and dolomite suitable for lime manufacture are very large.

Substitutes: Limestone is a substitute for lime in many applications, such as agriculture, fluxing, and sulfur removal. Limestone, which contains less reactive material, is slower to react and may have other disadvantages compared with lime, depending on the application; however, limestone is considerably less expensive than lime. Calcined gypsum is an alternative material in industrial plasters and mortars. Cement, cement kiln dust, fly ash, and lime kiln dust are potential substitutes for some construction uses of lime. Magnesium hydroxide is a substitute for lime in pH control, and magnesium oxide is a substitute for dolomitic lime as a flux in steelmaking.

[e]Estimated. E Net exporter.
[1]Data are for quicklime, hydrated lime, and refractory dead-burned dolomite. Includes Puerto Rico.
[2]To avoid double counting quicklime production, excludes independent commercial hydrators that purchase quicklime for hydration.
[3]Sold or used by producers.
[4]Defined as production + imports – exports. Includes some double counting based on nominal, undifferentiated reporting of company export sales as U.S. production.
[5]Defined as imports – exports.
[6]Only countries that produced 1 million tons of lime or more are listed separately.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]Includes hydraulic lime.

LITHIUM

(Data in metric tons of contained lithium unless otherwise noted)

Domestic Production and Use: The only lithium production in the United States was from one brine operation in Nevada. Two companies produced a wide range of downstream lithium compounds in the United States from domestic or imported lithium carbonate, lithium chloride, and lithium hydroxide. Domestic production data were withheld to avoid disclosing company proprietary data.

Although lithium markets vary by location, global end-use markets are estimated as follows: batteries, 74%; ceramics and glass, 14%; lubricating greases, 3%; continuous casting mold flux powders, 2%; polymer production, 2%; air treatment, 1%; and other uses, 4%. Lithium consumption for batteries has increased significantly in recent years because rechargeable lithium batteries are used extensively in the growing market for electric vehicles and portable electronic devices, and increasingly are used in electric tools, and grid storage applications. Lithium minerals were used directly as ore concentrates in ceramics and glass applications.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production	W	W	W	W	W
Imports for consumption	3,330	3,420	2,620	2,460	2,500
Exports	1,960	1,660	1,660	1,170	1,900
Consumption, estimated[1]	3,000	3,000	2,000	2,000	2,000
Price, annual average, battery-grade lithium carbonate, dollars per metric ton[2]	15,000	17,000	12,700	8,000	17,000
Employment, mine and mill, number	70	70	70	70	70
Net import reliance[3] as a percentage of estimated consumption	>50	>50	>25	>50	>25

Recycling: One domestic company has recycled lithium metal and lithium-ion batteries since 1992 at its facility in British Columbia, Canada. In 2015, the company began operating the first U.S. recycling facility for lithium-ion vehicle batteries in Lancaster, OH. About 25 companies in North America and Europe recycle lithium batteries or plan to do so. Partnerships between automobile companies and battery recyclers have been made to supply the automobile industry with a source of battery materials.

Import Sources (2017–20): Argentina, 54%; Chile, 37%; China, 5%; Russia, 3%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Lithium oxide and hydroxide	2825.20.0000	3.7% ad valorem.
Lithium carbonate:		
U.S. pharmaceutical grade	2836.91.0010	3.7% ad valorem.
Other	2836.91.0050	3.7% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[4, 5]

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Lithium-cobalt oxide	752	—	—	—	—
Lithium-nickel-cobalt-aluminum oxide	2,698	—	—	—	—

Events, Trends, and Issues: Excluding U.S. production, worldwide lithium production in 2021 increased by 21% to approximately 100,000 tons from 82,500 tons in 2020 in response to strong demand from the lithium-ion battery market and increased prices of lithium. Global consumption of lithium in 2021 was estimated to be 93,000 tons, a 33% increase from 70,000 tons in 2020.

Spot lithium carbonate prices in China (cost, insurance, and freight [c.i.f.] North Asia) increased from approximately $7,000 per ton in January to about $26,200 per ton in November. For fixed contracts, the annual average U.S. lithium carbonate price was $17,000 per ton in 2021, more than double that in 2020. Spot lithium hydroxide prices in China (c.i.f. North Asia) increased from approximately $9,000 per ton in January to about $27,400 per ton in November. Spot spodumene (6% lithium oxide) prices in China (c.i.f. China) increased from approximately $450 per ton in January to about $2,300 per ton in November. Spot lithium metal (99.9% lithium) prices in China increased from approximately $77,000 per ton in January to about $97,000 per ton in July.

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LITHIUM

Four mineral operations in Australia, two brine operations each in Argentina and Chile, and two brine and one mineral operation in China accounted for the majority of world lithium production. Additionally, smaller operations in Brazil, China, Portugal, the United States, and Zimbabwe also contributed to world lithium production. Owing to the resurgence in demand and increased prices of lithium in 2021, established lithium operations worldwide resumed capacity expansion plans which were postponed in 2020 in response to the global COVID-19 pandemic.

Lithium supply security has become a top priority for technology companies in Asia, Europe, and the United States. Strategic alliances and joint ventures among technology companies and exploration companies continued to be established to ensure a reliable, diversified supply of lithium for battery suppliers and vehicle manufacturers. Brine-based lithium sources were in various stages of development in Argentina, Bolivia, Chile, China, and the United States; mineral-based lithium sources were in various stages of development in Australia, Austria, Brazil, Canada, China, Congo (Kinshasa), Czechia, Finland, Germany, Mali, Namibia, Peru, Portugal, Serbia, Spain, the United States, and Zimbabwe; lithium-clay sources were in various stages of development in Mexico and the United States; and a searlesite source was in development in the United States.

World Mine Production and Reserves: Reserves for Argentina, Australia, and "Other countries" were revised based on new information from Government and industry sources.

	Mine production		Reserves[6]
	2020	2021[e]	
United States	W	W	750,000
Argentina	5,900	6,200	2,200,000
Australia	39,700	55,000	[7]5,700,000
Brazil	1,420	1,500	95,000
Chile	21,500	26,000	9,200,000
China	13,300	14,000	1,500,000
Portugal	348	900	60,000
Zimbabwe	417	1,200	220,000
Other countries[8]	—	—	2,700,000
World total (rounded)	[9]82,500	[9]100,000	22,000,000

World Resources:[6] Owing to continuing exploration, identified lithium resources have increased substantially worldwide and total about 89 million tons. Identified lithium resources in the United States—from continental brines, geothermal brines, hectorite, oilfield brines, pegmatites, and searlesite—are 9.1 million tons. Identified lithium resources in other countries have been revised to 80 million tons. Identified lithium resources are distributed as follows: Bolivia, 21 million tons; Argentina, 19 million tons; Chile, 9.8 million tons; Australia, 7.3 million tons; China, 5.1 million tons; Congo (Kinshasa), 3 million tons; Canada, 2.9 million tons; Germany, 2.7 million tons; Mexico, 1.7 million tons; Czechia, 1.3 million tons; Serbia, 1.2 million tons; Russia, 1 million tons; Peru, 880,000 tons; Mali, 700,000 tons; Zimbabwe, 500,000 tons; Brazil, 470,000 tons; Spain, 300,000 tons; Portugal, 270,000 tons; Ghana, 130,000 tons; Austria, 60,000 tons; and Finland, Kazakhstan, and Namibia, 50,000 tons each.

Substitutes: Substitution for lithium compounds is possible in batteries, ceramics, greases, and manufactured glass. Examples are calcium, magnesium, mercury, and zinc as anode material in primary batteries; calcium and aluminum soaps as substitutes for stearates in greases; and sodic and potassic fluxes in ceramics and glass manufacture.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Defined as production + imports – exports + adjustments for Government and industry stock changes. Rounded to one significant digit to avoid disclosing company proprietary data.

[2]Lithium carbonate, contract price, delivered Europe and United States. Source: Fastmarkets IM.

[3]Defined as imports – exports + adjustments for Government and industry stock changes.

[4]See Appendix B for definitions.

[5]Units are kilograms, gross weight.

[6]See Appendix C for resource and reserve definitions and information concerning data sources.

[7]For Australia, Joint Ore Reserves Committee or equivalent reserves were 3.8 million tons.

[8]Other countries with reported reserves include Austria, Canada, Congo (Kinshasa), Czechia, Finland, Germany, Mali, Mexico, and Serbia.

[9]Excludes U.S. production.

MAGNESIUM COMPOUNDS[1]

[Data in thousand metric tons of contained magnesium oxide (MgO) unless otherwise noted][2]

Domestic Production and Use: Seawater and natural brines accounted for about 64% of U.S. magnesium compound production in 2021. The value of shipments of all types of magnesium compounds was estimated to be $390 million, a 7% increase from the revised value in 2020. Magnesium oxide and other compounds were recovered from seawater by one company in California and another company in Delaware, from well brines by one company in Michigan, and from lake brines by two companies in Utah. Magnesite was mined by one company in Nevada.

In the United States, about 78% of magnesium compounds were consumed in the form of caustic-calcined magnesia, magnesium chloride, magnesium hydroxide, and magnesium sulfates across the following industries and uses, in descending order, environmental, agricultural, chemical, and deicing. The remaining magnesium compounds were consumed for refractories in the form of dead-burned magnesia, fused magnesia, and olivine. Across all industries, the leading magnesium compounds consumed, in descending order, were magnesium oxide (caustic-calcined magnesia, dead burned magnesia, and fused magnesia), magnesium hydroxide, and magnesium chloride.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production	438	405	376	363	390
Shipments (gross weight)	616	610	563	547	590
Imports for consumption	436	551	564	480	560
Exports	103	116	88	66	90
Consumption, apparent[3]	771	840	852	777	860
Employment, plant, number[e]	260	270	270	260	270
Net import reliance[4] as a percentage of apparent consumption	43	52	56	53	55

Recycling: Some magnesia-based refractories are recycled, either for reuse as refractory material or for use as construction aggregate.

Import Sources (2017–20): Caustic-calcined magnesia: China,[5] 71%; Canada, 20%; Israel, 4%; Australia, 3%; and other, 2%. Crude magnesite: China,[5] 86%; Singapore, 11%; Pakistan, 2%; and other, 1%. Dead-burned and fused magnesia: China,[5] 69%; Brazil, 13%; Turkey, 5%; Mexico, 4%; and other, 9%. Magnesium chloride: Israel, 63%; the Netherlands, 23%; China,[5] 5%; India, 3%; and other, 6%. Magnesium hydroxide: Mexico, 54%; the Netherlands, 15%; Israel, 11%; Austria, 9%; and other, 11%. Magnesium sulfates: China,[5] 58%; India, 14%; Germany, 10%; Canada, 5%; and other, 13%. Total imports: China,[5] 56%; Brazil, 10%; Israel, 10%; Canada, 7%; and other, 17%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Crude magnesite	2519.10.0000	Free.
Dead-burned and fused magnesia	2519.90.1000	Free.
Caustic-calcined magnesia	2519.90.2000	Free.
Kieserite	2530.20.1000	Free.
Epsom salts	2530.20.2000	Free.
Magnesium hydroxide and peroxide	2816.10.0000	3.1% ad valorem.
Magnesium chloride	2827.31.0000	1.5% ad valorem.
Magnesium sulfate (synthetic)	2833.21.0000	3.7% ad valorem.

Depletion Allowance: Brucite, 10% (domestic and foreign); dolomite, magnesite, and magnesium carbonate, 14% (domestic and foreign); magnesium chloride (from brine wells), 5% (domestic and foreign); and olivine, 22% (domestic) and 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, consumption of dead-burned and fused magnesia increased in the United States and globally by an estimated 20% and 8%, respectively, compared with that in 2020, as the demand for steel recovers from disruptions caused by the COVID-19 pandemic. Demand, and subsequent consumption, for all magnesium compounds has increased following the general trend of the manufacturing industry.

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MAGNESIUM COMPOUNDS

An Austria-based magnesia and refractories producer sold two of its magnesia product subsidiaries to a private equity firm. The subsidiaries, located in Ireland and Norway, produced magnesia-based products used in the agricultural, environmental, hydrometallurgical, pulp and paper, and refractory industries.

A Turkish steelmaker purchased one of Turkey's largest magnesite producers that was a major regional and international source of magnesite. The magnesite producer holds more than 40% of Turkey's magnesite reserves and operates three plants with an annual capacity of 1.2 million tons. The purchase of the magnesite producer will provide refractory materials vital to its steelmaking process.

China remains the leading producer of magnesia and magnesite and was the principal exporter of magnesia to the United States and much of the world. As demand was beginning to recover, supply and shipping constraints were adversely affecting the availability of imported sources of magnesia. In China, power-intensive activities such as mineral processing were adversely affected by power outages resulting from a resurging demand for power, coal shortages, and newly enforced emission standards. The resulting decreased magnesia supply in China affected prices and availability of all grades of magnesia in the world market.

World Magnesite Mine Production and Reserves:[6] In addition to magnesite, vast reserves exist in well and lake brines and seawater from which magnesium compounds can be recovered. Reserves for Australia and Turkey were revised based on information from Government and industry sources.

	Mine production[e]		Reserves[7]
	2020	2021	
United States	W	W	35,000
Australia	700	770	[8]290,000
Austria	790	870	49,000
Brazil	1,800	2,000	200,000
China	19,000	21,000	1,000,000
Greece	500	550	280,000
Russia	1,000	1,100	2,300,000
Slovakia	480	530	370,000
Spain	650	720	35,000
Turkey	1,470	1,600	110,000
Other countries	920	1000	2,600,000
World total (rounded)	[9]27,000	[9]30,000	7,200,000

World Resources:[7] Resources from which magnesium compounds can be recovered range from large to virtually unlimited and are globally widespread. Identified world magnesite and brucite resources total 13 billion tons and several million tons, respectively. Resources of dolomite, forsterite, magnesium-bearing evaporite minerals, and magnesia-bearing brines are estimated to constitute a resource of billions of tons. Magnesium hydroxide can be recovered from seawater. Serpentine could be used as a source of magnesia but global resources, including in tailings of asbestos mines, have not been quantified but are thought to be very large.

Substitutes: Alumina, chromite, and silica substitute for magnesia in some refractory applications.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]See also Magnesium Metal.
[2]Reported as magnesium content through Mineral Commodity Summaries 2016. Based on input from consumers, producers, and others involved in the industry, reporting magnesium compound data in terms of contained magnesium oxide was determined to be more useful than reporting in terms of magnesium content. Calculations were made using the following magnesium oxide (MgO) contents: magnesite, 47.8%; magnesium chloride, 42.3%; magnesium hydroxide, 69.1%; and magnesium sulfate, 33.5%.
[3]Defined as production + imports – exports.
[4]Defined as imports – exports.
[5]Includes Hong Kong.
[6]Gross weight of magnesite (magnesium carbonate) in thousand tons.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 37 million tons.
[9]Excludes U.S. production.

MAGNESIUM METAL[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, primary magnesium was produced by one company in Utah at an electrolytic process smelter that recovered magnesium from brines from the Great Salt Lake. Secondary magnesium was recovered from scrap at smelters that produced magnesium ingot and castings and from aluminum alloy scrap at secondary aluminum smelters. Primary magnesium production in 2021 was estimated to have decreased significantly from that in 2020. Information regarding U.S. primary magnesium production was withheld to avoid disclosing company proprietary data. The leading use for primary magnesium metal, which accounted for 45% of reported consumption, was in castings, principally used for the automotive industry. Aluminum-base alloys that were used for packaging, transportation, and other applications accounted for 35% of primary magnesium metal consumption; desulfurization of iron and steel, 16%; and all other uses, 4%. About 31% of the secondary magnesium was consumed for structural uses, and about 69% was used in aluminum alloys.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Primary	W	W	W	W	W
Secondary (new and old scrap)	112	109	101	100	98
Imports for consumption	42	47	59	61	48
Exports	14	12	10	15	8
Consumption:					
Reported, primary	65	51	52	50	50
Apparent[2]	W	W	W	W	W
Price, annual average:[3]					
U.S. spot Western, dollars per pound	2.15	2.17	2.45	2.49	3.90
European free market, dollars per metric ton	2,265	2,550	2,425	2,149	5,500
Stocks, producer, yearend	W	W	W	W	W
Employment, number[e]	400	400	400	400	400
Net import reliance[4] as a percentage of apparent consumption	<25	<50	<50	<50	<50

Recycling: In 2021, about 29,000 tons of secondary magnesium was recovered from old scrap and 69,000 tons was recovered from new scrap. Aluminum-base alloys accounted for about 57% of the secondary magnesium recovered, and magnesium-based castings, ingot, and other materials accounted for about 43%.

Import Sources (2017–20): Canada, 20%; Israel, 15%; Mexico, 11%; and other, 54%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Unwrought metal	8104.11.0000	8.0% ad valorem.
Unwrought alloys	8104.19.0000	6.5% ad valorem.
Scrap	8104.20.0000	Free.
Powders and granules	8104.30.0000	4.4% ad valorem.
Wrought metal	8104.90.0000	14.8¢/kg on Mg content + 3.5% ad valorem.

Depletion Allowance: Dolomite, 14% (domestic and foreign); magnesium chloride (from brine wells), 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: On September 29, the producer of primary magnesium in Utah declared force majeure, citing equipment failures. Details on the amount of capacity affected and an expected restart date were not reported by the company. A decrease in spot prices in the United States for magnesium imports in the second quarter was attributed to abundant supplies of secondary magnesium favored by secondary aluminum producers. But the average spot price for imported magnesium in the United States increased from $2.06 per pound at the end of June to $2.18 per pound at the end of August, attributed to contracted deliveries being exhausted with strong demand from aluminum smelters and diecasters. The shutdown of capacity in Utah was cited as the reason for the average price of imports into the United States increasing to $5.13 per pound at the end of September and $7.63 per pound at the end of October.

Environmental regulations and power shortages were cited as the reason for raw material shortages, increased power prices, and decreased magnesium production in China, leading to increased magnesium prices in China and Europe. Decreased coal production and increased prices for raw materials such as ferrosilicon starting in April, and strong

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MAGNESIUM METAL

demand for coal by powerplants in the summer months caused prices to continue to rise. Strong demand for magnesium by aluminum smelters and diecasters was also cited for tight supplies, contributing to price increases in the early part of the second quarter of the year. Constrained shipping, high freight rates, and stockpiling by speculators were also cited as reasons for increasing magnesium prices and supply shortages. In August and September, many smelters in China closed capacity to comply with energy consumption targets, leading to further shortages and increased prices. Spot magnesium prices generally trended upward in China and Europe starting in March. The price range in Europe for the first 3 months was $2,600 to $2,700 per metric ton. At the end of June, the price range in Europe increased to between $3,500 and $3,700 per metric ton and, by the end of August, the price ranged between $4,100 and $4,500 per metric ton. At the end of September, the price range in Europe increased to between $10,000 and $11,500 per metric ton and, by mid-October, the price ranged from $12,000 to $15,000 per metric ton. In late October, the price range started to decrease and was $7,700 to $9,500 per metric ton by mid-November.

On March 1, the Government of China removed a 15% tax on magnesium produced in six jurisdictions in the western part of the country. The tax exemption was part of a policy to encourage development of the magnesium industry in the western part of China and increase consumption.

One company obtained a location in Ohio to build a pilot plant to test magnesium production from dolomite. A company in Australia planned to construct a 3,000-ton-per-year smelter to recover magnesium from coal fly ash. A company in Quebec, Canada, planned to construct a primary magnesium smelter to produce magnesium from serpentine-bearing asbestos tailings. The same company in Canada completed construction of an 18,000-ton-per-year secondary magnesium smelter at the same location and started production during the year.

The use of magnesium in automobile parts continued to increase as automobile manufacturers sought to decrease vehicle weight for increased fuel efficiency. Magnesium castings have substituted for aluminum, iron, and steel in some automobiles. The substitution of aluminum for steel in automobile sheet continued to increase consumption of magnesium in aluminum alloy sheet. A shortage of computer chips was cited for some automobile manufacturers decreasing production despite strong demand, resulting in some diecasters decreasing magnesium consumption.

World Primary Production and Reserves:

	Smelter production		Reserves[5]
	2020	2021[e]	
United States	W	W	Magnesium metal can be derived from seawater, natural brines, dolomite, serpentine, and other minerals. The reserves for this metal are sufficient to supply current and future requirements.
Brazil	18	20	
China	886	800	
Israel	19	22	
Kazakhstan	16	20	
Russia	48	60	
Turkey	12	15	
Ukraine	6	10	
World total (rounded)[6]	1,000	950	

World Resources:[5] Resources from which magnesium may be recovered range from large to virtually unlimited and are globally widespread. Resources of dolomite, serpentine, and magnesium-bearing evaporite minerals are enormous. Magnesium-bearing brines are estimated to constitute a resource in the billions of tons, and magnesium could be recovered from seawater along world coastlines.

Substitutes: Aluminum and zinc may substitute for magnesium in castings and wrought products. The relatively light weight of magnesium is an advantage over aluminum and zinc in castings and wrought products in most applications; however, its high cost is a disadvantage relative to these substitutes. For iron and steel desulfurization, calcium carbide may be used instead of magnesium. Magnesium is preferred to calcium carbide for desulfurization of iron and steel because calcium carbide produces acetylene in the presence of water.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]See also Magnesium Compounds.
[2]Defined as primary production + secondary production from old scrap + imports – exports + adjustments for industry stock changes.
[3]Source: S&P Global Platts Metals Week.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.
[6]Excludes U.S. production.

MANGANESE

(Data in thousand metric tons, gross weight, unless otherwise noted)

Domestic Production and Use: Manganese ore containing 20% or more manganese has not been produced domestically since 1970. Manganese ore was consumed mainly by six companies with plants principally in the East and Midwest. Most ore consumption was related to steel production, either directly in pig iron manufacture or indirectly through upgrading the ore to ferroalloys. Manganese ferroalloys were produced at two plants. Additional quantities of ore were used for nonmetallurgical purposes such as in the production of animal feed, brick colorant, dry cell batteries, and fertilizers.

Salient Statistics—United States:[1]	2017	2018	2019	2020	2021[e]
Production, mine	—	—	—	—	—
Imports for consumption:					
Manganese ores and concentrates	297	440	434	367	460
Ferromanganese	331	427	332	223	320
Silicomanganese	351	412	351	269	270
Exports:					
Manganese ores and concentrates	1	3	1	1	1
Ferromanganese	9	10	5	5	11
Silicomanganese	8	4	2	2	4
Shipments from Government stockpile:[2]					
Manganese ore	—	—	—	—	2
Ferromanganese and manganese metal, electrolytic	12	13	10	54	17
Consumption, reported:					
Manganese ore[3]	378	369	442	378	390
Ferromanganese	345	348	336	325	330
Silicomanganese	[4]141	[4]139	[4]143	229	230
Consumption, apparent, manganese content[5]	715	796	748	620	640
Price, average, manganese content, cost, insurance, and freight, China, dollars per metric ton unit[6]	5.97	7.16	5.63	4.59	5.20
Stocks, producer and consumer, yearend:					
Manganese ore[3]	148	191	175	143	170
Ferromanganese	17	27	44	35	35
Silicomanganese	11	21	39	31	31
Net import reliance[7] as a percentage of apparent consumption, manganese content	100	100	100	100	100

Recycling: Manganese was recycled incidentally as a constituent of ferrous and nonferrous scrap; however, scrap recovery specifically for manganese was negligible. Manganese is recovered along with iron from steel slag.

Import Sources (2017–20): Manganese ore: Gabon, 67%; South Africa, 18%; Mexico, 11%; and other, 4%. Ferromanganese: Australia, 20%; South Africa, 20%; Norway, 16%; Malaysia, 14%; and other, 30%. Silicomanganese: Georgia, 27%; Australia, 21%; South Africa, 21%; and other, 31%. Manganese contained in principal manganese imports:[8] Gabon, 23%; South Africa, 19%; Australia, 13%; Georgia, 9%; and other, 36%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Ores and concentrates:		
Containing less than 47% manganese	2602.00.0040	Free.
Containing 47% or more of manganese	2602.00.0060	Free.
Manganese dioxide	2820.10.0000	4.7% ad valorem.
High-carbon ferromanganese	7202.11.5000	1.5% ad valorem.
Ferrosilicon manganese (silicomanganese)	7202.30.0000	3.9% ad valorem.
Metal, unwrought:		
Flake containing at least 99.5% manganese	8111.00.4700	14% ad valorem.
Other	8111.00.4900	14% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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MANGANESE

Government Stockpile:[9]

Material	Inventory as of 9–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Manganese ore, metallurgical grade	291	—	292	—	292
Ferromanganese, high-carbon	119	—	45	—	45
Manganese metal, electrolytic	—	5	—	5	—

Events, Trends, and Issues: Global production of steel, the leading use of manganese, increased in 2021 compared with production in 2020 owing to increased demand following the negative effects of the global COVID-19 pandemic. Global production of manganese ore was estimated to be about 6% more than that in 2020. The leading countries for manganese ore production were, in descending order on a contained-weight basis, South Africa, Gabon, and Australia. On a contained-weight basis, total U.S. manganese imports were estimated to have increased by approximately 20% in 2021 compared with those in 2020. By October 2021, average spot market prices for manganese ore from China had increased by 13% compared with the annual average spot price in 2020.

World Mine Production (manganese content) and Reserves: Reserves for Australia and South Africa were revised based on Government and industry sources.

	Mine production 2020	Mine production 2021[e]	Reserves[10]
United States	—	—	—
Australia	3,330	3,300	[11]270,000
Brazil	494	400	270,000
Burma	254	250	NA
China	1,340	1,300	54,000
Côte d’Ivoire	525	500	NA
Gabon	3,310	3,600	61,000
Georgia	186	190	NA
Ghana	637	640	13,000
India	632	600	34,000
Kazakhstan, concentrate	158	160	5,000
Malaysia	347	360	NA
Mexico	198	200	5,000
South Africa	6,500	7,400	640,000
Ukraine, concentrate	578	670	140,000
Vietnam	121	120	NA
Other countries	260	260	Small
World total (rounded)	18,900	20,000	1,500,000

World Resources:[10] Land-based manganese resources are large but irregularly distributed; those in the United States are very low grade and have potentially high extraction costs. South Africa accounts for about 30% of the world’s manganese reserves.

Substitutes: Manganese has no satisfactory substitute in its major applications.

[e]Estimated. NA Not available. — Zero.

[1]Manganese content typically ranges from 35% to 54% for manganese ore and from 74% to 95% for ferromanganese.

[2]Defined as stockpile shipments – receipts.

[3]Exclusive of ore consumed directly at iron and steel plants and associated yearend stocks.

[4]Imports more nearly represent amount consumed than does reported consumption.

[5]Defined as imports – exports + adjustments for Government and industry stock changes. Manganese content based on estimates of average content for all significant components—including ore, manganese dioxide, ferromanganese, silicomanganese, and manganese metal—except imports, for which content is reported.

[6]For average metallurgical-grade ore containing 44% manganese. Source: CRU Group.

[7]Defined as imports – exports + adjustments for Government and industry stock changes.

[8]Includes imports of ferromanganese, manganese ore, silicomanganese, synthetic manganese dioxide, and unwrought manganese metal.

[9]See Appendix B for definitions.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 91 million tons, gross weight.

MERCURY

(Data in metric tons of contained mercury unless otherwise noted)

Domestic Production and Use: Mercury has not been produced as a principal mineral commodity in the United States since 1992. In 2021, mercury was recovered as a byproduct from processing gold-silver ore at several mines in Nevada; however, production data were not reported. Secondary, or recycled, mercury was recovered from batteries, compact and traditional fluorescent lamps, dental amalgam, medical devices, and thermostats, as well as mercury-contaminated soils. The U.S. Environmental Protection Agency (EPA) reported a revised domestic production of 45 tons in 2018 (the last year for which data were available), and about 82 tons of mercury was stored by manufacturers or producers. The reported domestic consumption of mercury and mercury in compounds in products was 16 tons. The leading domestic end uses of mercury and mercury compounds were dental amalgam (43%); relays, sensors, switches, and valves (41%); bulbs, lamps, and lighting (8%); formulated products (buffers, catalysts, fixatives, and vaccination uses) (7%); and batteries and other end uses (1%). A large quantity of mercury (about 245 tons) is used in manufacturing processes such as catalysts or as a cathode in the chlorine-caustic soda (chloralkali) process. Almost all the mercury is reused in the process. The leading manufacturing processes that use mercury are mercury-cell chloralkali plants. In 2021, only one mercury-cell chloralkali plant operated in the United States. Until December 31, 2012, domestic- and foreign-sourced mercury was refined and then exported for global use, primarily for small-scale gold mining in many parts of the world. Beginning January 1, 2013, export of elemental mercury from the United States was banned, with some exceptions, under the Mercury Export Ban Act of 2008. Effective January 1, 2020, exports of five mercury compounds were added to that ban.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine (byproduct)	NA	NA	NA	NA	NA
Secondary	NA	NA	NA	NA	NA
Imports for consumption, metal (gross weight)	20	6	9	3	2
Exports, metal (gross weight)	—	—	—	—	—
Price, average value, dollars per flask, 99.99%:[1]					
European Union[2]	1,041	1,100	NA	NA	NA
Global locations[3]	1,273	2,709	2,550	NA	NA
Net import reliance[4] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: In 2021, eight facilities operated by six companies in the United States accounted for most of the secondary mercury produced and were authorized by the U.S. Department of Energy (DOE) to temporarily store mercury until the DOE's long-term facility opens. Mercury-containing automobile convenience switches, barometers, compact and traditional fluorescent bulbs, computers, dental amalgam, medical devices, and thermostats were collected by smaller companies and shipped to the refining companies for retorting to reclaim the mercury. In addition, many collection companies recovered mercury when retorting was not required. With the rapid phasing out of compact and traditional fluorescent lighting for light-emitting-diode (LED) lighting, an increased quantity of mercury was being recycled.

Import Sources (2017–20): Canada, 51%; France, 26%; China, 16%; Switzerland, 5%; and other, 2%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Mercury	2805.40.0000	1.7% ad valorem.
Amalgams	2843.90.0000	3.7% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[5] The Defense Logistics Agency Strategic Materials held and managed an inventory of 4,437 tons of mercury in storage at the Hawthorne Army Depot in Hawthorne, NV. On December 3, 2019, the DOE selected a site near Andrews, TX, to store up to 6,800 tons of mercury. Sales of mercury from the stockpiles remained suspended.

		FY 2021		**FY 2022**	
Material	**Inventory as of 9–30–21**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Mercury	4,437	—	—	—	—

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MERCURY

Events, Trends, and Issues: Owing to mercury toxicity and concerns for the environment and human health, overall mercury use has declined in the United States and worldwide. Mercury continues to be released to the environment from numerous sources, including mercury-containing car switches when automobiles (those produced prior to 2003) are scrapped without recovering the switches for recycling, coal-fired powerplant emissions, incineration of mercury-containing medical devices, and naturally occurring sources. Mercury is no longer used in most batteries and paints manufactured in the United States. Some button-type batteries, cleansers, fireworks, folk medicines, grandfather clocks, pesticides, and skin-lightening creams and soaps may still contain mercury. Mercury compounds were used as catalysts in the coal-based manufacture of vinyl chloride monomer in China. In some parts of the world, mercury was used in the recovery of gold in artisanal and small-scale mining operations. Conversion to nonmercury technology for chloralkali production and the ultimate closure of the world's mercury-cell chloralkali plants may release a large quantity of mercury to the global market for recycling, sale, or, owing to export bans in Europe and the United States, long-term storage.

Byproduct mercury production is expected to continue from large-scale domestic and foreign gold-silver mining and processing, as is secondary production of mercury from an ever-diminishing supply of mercury-containing products. Domestic mercury consumption will continue to decline owing to increased use of LED lighting and consequent reduced use of conventional fluorescent tubes and compact fluorescent bulbs and continued substitution of non-mercury-containing products in control, dental, and measuring applications.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States	NA	NA	Quantitative estimates of reserves are not available. China, Kyrgyzstan, and Peru are thought to have the largest reserves.
China	2,200	2,000	
Kyrgyzstan	15	15	
Mexico (net exports)	40	40	
Norway	20	20	
Peru (exports)	30	30	
Tajikistan	178	170	
Other countries	11	11	
World total (rounded)[7]	2,490	2,300	

World Resources:[6] China, Kyrgyzstan, Mexico, Peru, Russia, Slovenia, Spain, and Ukraine have most of the world's estimated 600,000 tons of mercury resources. Mexico reclaims mercury from Spanish colonial silver-mining waste. In Spain, once a leading producer of mercury, mining at its centuries-old Almaden Mine stopped in 2003. In the United States, mercury occurrences are in Alaska, Arkansas, California, Nevada, and Texas. The declining consumption of mercury, except for small-scale gold mining, indicates that these resources are sufficient for centuries of use.

Substitutes: Ceramic composites substitute for the dark-gray mercury-containing dental amalgam. "Galinstan," an alloy of gallium, indium, and tin, replaces the mercury used in traditional mercury thermometers, and digital thermometers have replaced traditional thermometers. At chloralkali plants around the world, mercury-cell technology is being replaced by newer diaphragm and membrane-cell technology. LEDs that contain indium substitute for mercury-containing fluorescent lamps. Lithium, nickel-cadmium, and zinc-air batteries replace mercury-zinc batteries in the United States; indium compounds substitute for mercury in alkaline batteries; and organic compounds are being used instead of mercury fungicides in latex paint.

[e]Estimated. NA Not available. — Zero.

[1]Some international data and dealer prices are reported in flasks. One metric ton (1,000 kilograms) = 29.0082 flasks, and 1 flask = 76 pounds, or 34.47 kilograms, or 0.03447 metric ton.

[2]Average annual price of minimum 99.99% mercury. Source: Argus Media group—Argus Metals International. Price discontinued on May 1, 2018.

[3]Average midpoint of free market 99.99% mercury in warehouse, global locations. Source: Metal Bulletin. Price discontinued on December 1, 2019.

[4]Defined as imports – exports + adjustments for Government stock changes.

[5]See Appendix B for definitions.

[6]See Appendix C for resource and reserve definitions and information concerning data source.

[7]Excludes U.S. production.

MICA (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Scrap and flake mica production, excluding low-quality sericite, was estimated to be 43,000 tons valued at $4.8 million. Mica was mined in Georgia, North Carolina, and South Dakota. Scrap mica was recovered principally from mica and sericite schist and as a byproduct from the production of feldspar and kaolin and the beneficiation of industrial sand. Eight companies produced an estimated 64,000 tons of ground mica valued at about $20 million from domestic and imported scrap and flake mica. Most of the domestic production was processed into small-particle-size mica by either wet or dry grinding. Primary uses were joint compound, oil-well-drilling additives, paint, roofing, and rubber products.

A minor amount of sheet mica has been produced as incidental production from feldspar mining in North Carolina in the past several years. Data on sheet mica production were not available in 2021. The domestic consuming industry was dependent on imports to meet demand for sheet mica. Most sheet mica was fabricated into parts for electrical and electronic equipment.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Scrap and flake:					
Production:[e, 1]					
Sold and used	40,000	42,000	40,100	34,600	43,000
Ground	69,700	68,400	61,300	59,800	64,000
Imports[2]	29,700	28,100	27,300	19,400	22,000
Exports[3]	6,790	6,030	5,500	4,000	5,000
Consumption, apparent[e, 4]	62,900	64,100	61,900	50,000	60,000
Price, average, dollars per metric ton:[e]					
Scrap and flake	165	125	118	111	110
Ground:					
Dry	292	308	316	300	300
Wet	424	422	394	338	350
Net import reliance[5] as a percentage of apparent consumption	36	34	35	31	28
Sheet:					
Sold and used	W	W	W	W	NA
Imports[6]	1,850	1,890	3,150	2,850	3,800
Exports[7]	704	686	779	527	670
Consumption, apparent[e, 4]	1,150	1,200	2,370	2,320	3,100
Price, average value, muscovite and phlogopite mica, dollars per kilogram:[e]					
Block	W	W	W	W	W
Splittings	1.66	1.65	1.66	1.57	1.60
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2017–20): Scrap and flake: Canada, 43%; China, 34%; India, 8%; and other, 15%. Sheet: China, 63%; Brazil, 14%; Belgium, 5%; India, 4%; and other, 14%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Split block mica	2525.10.0010	Free.
Mica splittings	2525.10.0020	Free.
Unworked, other	2525.10.0050	Free.
Mica powder	2525.20.0000	Free.
Mica waste	2525.30.0000	Free.
Plates, sheets, and strips of agglomerated or reconstituted mica	6814.10.0000	2.7% ad valorem.
Worked mica and articles of mica, other	6814.90.0000	2.6% ad valorem.

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MICA (NATURAL)

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic production of scrap and flake mica was estimated to have increased by 24% in 2021, compared with that in 2020, and apparent consumption of scrap and flake mica increased by 20%. Apparent consumption of sheet mica was estimated to have increased by 34% in 2021. Increased production and consumption of scrap and flake mica reflected the recovery from the effects of the COVID-19 pandemic of some of industries that use mica, primarily for use in oil-well-drilling fluid and joint compound. No environmental concerns are associated with the manufacture and use of mica products. Supplies of sheet mica for United States consumption were expected to continue to be from imports, primarily from Belgium, Brazil, China, and India.

World Mine Production and Reserves: World production of sheet mica has remained steady; however, reliable production data for some countries that were thought to be major contributors to the world total were unavailable.

	Scrap and flake			Sheet		
	Mine production		Reserves[8]	Mine production[e]		Reserves[8]
	2020	2021[e]		2020	2021	
United States	34,600	43,000	Large	W	NA	Very small
Canada	15,000	15,000	Large	NA	NA	NA
China	95,000	95,000	Large	NA	NA	NA
Finland	64,900	65,000	Large	NA	NA	NA
France	19,000	19,000	Large	NA	NA	NA
India	15,000	15,000	Large	1,000	1,000	110,000
Korea, Republic of	21,000	22,000	11,000,000	—	—	NA
Madagascar	33,000	35,000	Large	—	—	NA
Turkey	4,140	4,000	620,000	—	—	NA
Other countries	51,000	50,000	Large	200	200	Moderate
World total (rounded)	353,000	360,000	Large	NA	NA	NA

World Resources:[8] Resources of scrap and flake mica are available in clay deposits, granite, pegmatite, and schist, and are considered more than adequate to meet anticipated world demand in the foreseeable future. World resources of sheet mica have not been formally evaluated because of the sporadic occurrence of this material. Large deposits of mica-bearing rock are known to exist in countries such as Brazil, India, and Madagascar. Limited resources of sheet mica are available in the United States. Domestic resources were subeconomic because of the high cost of the hand labor required to mine and process sheet mica from pegmatites.

Substitutes: Some lightweight aggregates, such as diatomite, perlite, and vermiculite, may be substituted for ground mica when used as filler. Ground synthetic fluorophlogopite, a fluorine-rich mica, may replace natural ground mica for uses that require the thermal and electrical properties of mica. Many materials can be substituted for mica in numerous electrical, electronic, and insulation uses. Substitutes include acrylic, cellulose acetate, fiberglass, fishpaper, nylatron, nylon, phenolics, polycarbonate, polyester, styrene, polyvinyl chloride, and vulcanized fiber. Mica paper made from scrap mica can be substituted for sheet mica in electrical and insulation applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Excludes low-quality sericite used primarily for brick manufacturing.
[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2525.10.0050, <$6.00 per kilogram; 2525.20.0000; and 2525.30.0000.
[3]Includes data for the following Schedule B codes: 2525.10.0000, <$6.00 per kilogram; 2525.20.0000; and 2525.30.0000.
[4]Defined as sold or used by producing companies + imports – exports.
[5]Defined as imports – exports.
[6]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2525.10.0010; 2525.10.0020; 2525.10.0050, >$6.00 per kilogram; 6814.10.0000; and 6814.90.0000.
[7]Includes data for the following Schedule B codes: 2525.10.0000, >$6.00 per kilogram; 6814.10.0000; and 6814.90.0000.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.

MOLYBDENUM

(Data in metric tons of contained molybdenum unless otherwise noted)

Domestic Production and Use: U.S. mine production of molybdenum in 2021 decreased by 6% to an estimated 48,000 tons compared with that in the previous year. Molybdenum ore was produced as a primary product at two mines—both in Colorado—whereas seven copper mines (four in Arizona and one each in Montana, Nevada, and Utah) recovered molybdenite concentrate as a byproduct. Three roasting plants converted molybdenite concentrate to molybdic oxide, from which intermediate products, such as ferromolybdenum, metal powder, and various chemicals, were produced. Metallurgical applications accounted for more than 88% of the total molybdenum consumed.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, mine	40,700	41,400	43,600	51,100	48,000
Imports for consumption	36,000	37,500	34,200	24,700	29,000
Exports	43,200	48,400	67,200	62,400	66,000
Consumption:					
Reported[1]	17,400	16,700	16,400	15,800	16,000
Apparent[2]	34,200	31,400	10,500	13,300	13,000
Price, average value, dollars per kilogram[3]	18.06	27.04	26.50	19.90	36
Stocks, consumer materials	2,010	1,940	1,980	1,980	1,700
Employment, mine and plant, number	940	940	950	950	950
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Molybdenum is recycled as a component of catalysts, ferrous scrap, and superalloy scrap. Ferrous scrap consists of revert, new, and old scrap. Revert scrap refers to remnants manufactured in the steelmaking process. New scrap is generated by steel mill customers and recycled by scrap collectors and processors. Old scrap is largely molybdenum-bearing alloys recycled after serving their useful life. The amount of molybdenum recycled as part of new and old steel and other scrap may be as much as 30% of the apparent supply of molybdenum. There are no processes for the separate recovery and refining of secondary molybdenum from its alloys. Molybdenum is not recovered separately from recycled steel and superalloys, but the molybdenum content of the recycled alloys is significant, and the molybdenum content is reused. Recycling of molybdenum-bearing scrap will continue to be dependent on the markets for the principal alloy metals in which molybdenum is contained, such as iron, nickel, and chromium.

Import Sources (2017–20): Ferromolybdenum: Chile, 58%; the Republic of Korea, 35%; Canada, 3%; and other, 4%. Molybdenum ores and concentrates: Peru, 58%; Chile, 17%; Canada, 12%; Mexico, 12%; and other, 1%. Total: Peru, 42%; Chile, 26%; Canada, 10%; Mexico, 8%; and other, 14%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Molybdenum ore and concentrates, roasted	2613.10.0000	12.8¢/kg + 1.8% ad valorem.
Molybdenum ore and concentrates, other	2613.90.0000	17.8¢/kg.
Molybdenum chemicals:		
Molybdenum oxides and hydroxides	2825.70.0000	3.2% ad valorem.
Molybdates of ammonium	2841.70.1000	4.3% ad valorem.
Molybdates, all others	2841.70.5000	3.7% ad valorem.
Molybdenum pigments, molybdenum orange	3206.20.0020	3.7% ad valorem.
Ferroalloys, ferromolybdenum	7202.70.0000	4.5% ad valorem.
Molybdenum metals:		
Powders	8102.10.0000	9.1¢/kg + 1.2% ad valorem.
Unwrought	8102.94.0000	13.9¢/kg + 1.9% ad valorem.
Wrought bars and rods	8102.95.3000	6.6% ad valorem.
Wrought plates, sheets, strips, etc.	8102.95.6000	6.6% ad valorem.
Wire	8102.96.0000	4.4% ad valorem.
Waste and scrap	8102.97.0000	Free.
Other	8102.99.0000	3.7% ad valorem.

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MOLYBDENUM

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, the estimated average molybdic oxide price increased by 81% compared with that in 2020, and U.S. estimated mine production of molybdenum decreased by 6% from that in 2020. The decrease in production was mainly the result of one byproduct mine in Utah decreasing its production by almost more than 70%. This decrease in production in Utah was offset by production increases at other molybdenum producers.

Estimated U.S. imports for consumption increased by 18% compared with those in 2020. U.S. exports increased by 5% from those in 2020. Apparent consumption in 2021 was essentially unchanged compared with that in 2020.

Global molybdenum production in 2021 increased slightly compared with that in 2020. In descending order of production, China, Chile, the United States, Peru, and Mexico provided 93% of total global production. Chinese molybdenum imports continued to be at historically high levels as China continued to focus on infrastructure growth to support its COVID-19 recovery. A major producer in China increased its molybdenum concentrate production in 2021 after having suspended its production for 6 months in 2020 following a tailings leakage accident. Many Chinese producers also continued to limit their molybdenum exports citing higher freight costs owing to container shortages and shipping delays. These factors all continued to contribute to decade-high molybdenum prices.

World Mine Production and Reserves: The reserves data for Mongolia, Peru, Russia, and Turkey were revised on the basis of new information from company and Government reports.

	Mine production		Reserves[5]
	2020	2021[e]	(thousand metric tons)
United States	51,100	48,000	2,700
Argentina	—	—	100
Armenia	[e]8,700	8,200	150
Canada	2,530	1,700	96
Chile	59,400	51,000	1,400
China	[e]120,000	130,000	8,300
Iran	[e]1,400	1,400	43
Korea, Republic of	411	400	NA
Mexico	16,600	18,000	130
Mongolia	2,890	2,900	NA
Peru	32,200	32,000	2,300
Russia	[e]2,700	2,800	430
Turkey	—	—	360
Uzbekistan	[e]200	200	60
World total (rounded)	298,000	300,000	16,000

World Resources:[5] Identified resources of molybdenum in the United States are about 5.4 million tons, and in the rest of the world, about 20 million tons. Molybdenum occurs as the principal metal sulfide in large low-grade porphyry molybdenum deposits and as an associated metal sulfide in low-grade porphyry copper deposits. Resources of molybdenum are adequate to supply world needs for the foreseeable future.

Substitutes: There is little substitution for molybdenum in its major application in steels and cast irons. In fact, because of the availability and versatility of molybdenum, industry has sought to develop new materials that benefit from its alloying properties. Potential substitutes include boron, chromium, niobium (columbium), and vanadium in alloy steels; tungsten in tool steels; graphite, tantalum, and tungsten for refractory materials in high-temperature electric furnaces; and cadmium-red, chrome-orange, and organic-orange pigments for molybdenum orange.

[e]Estimated. E Net exporter. NA Not available. — Zero.

[1]Reported consumption of primary molybdenum products.

[2]Defined as production + imports – exports + adjustments for concentrate, consumer, and product producer stock changes.

[3]Time-weighted average price per kilogram of molybdenum contained in technical-grade molybdic oxide, as reported by CRU Group.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

NICKEL

(Data in metric tons of contained nickel unless otherwise noted)

Domestic Production and Use: In 2021, the underground Eagle Mine in Michigan produced approximately 18,000 tons of nickel in concentrate, which was exported to smelters in Canada and overseas. A company in Missouri recovered metals, including nickel, from mine tailings as part of the Superfund Redevelopment Initiative. Nickel in crystalline sulfate was produced as a byproduct of smelting and refining platinum-group-metal ores mined in Montana.

In the United States, the leading uses for primary nickel are alloys and steels, electroplating, and other uses including catalysts and chemicals. Stainless and alloy steel and nickel-containing alloys typically account for more than 85% of domestic consumption.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Mine	22,100	17,600	13,500	16,700	18,000
Refinery, byproduct	W	W	W	W	W
Imports:					
Ores and concentrates	64	3	4	95	24
Primary	150,000	144,000	119,000	105,000	110,000
Secondary	38,100	45,100	37,700	31,800	35,000
Exports:					
Ores and concentrates	20,000	18,000	14,300	13,400	15,000
Primary	11,000	9,780	12,800	11,300	10,000
Secondary	51,500	59,400	47,800	34,100	29,000
Consumption:					
Reported, primary	105,000	107,000	105,000	[e]84,000	82,000
Reported, secondary, purchased scrap	133,000	123,000	111,000	[e]99,000	110,000
Apparent, primary[1]	140,000	136,000	106,000	94,100	100,000
Apparent, total[2]	273,000	259,000	217,000	[e]190,000	210,000
Price, average annual, London Metal Exchange (LME), cash:					
Dollars per metric ton	10,403	13,114	13,903	13,772	18,000
Dollars per pound	4.719	5.948	6.306	6.25	8.3
Stocks, yearend:					
Consumer	14,600	16,300	13,400	13,000	13,000
LME U.S. warehouses	3,780	2,268	1,974	1,734	1,500
Net import reliance[3] as a percentage of total apparent consumption	51	52	49	49	48

Recycling: Nickel in alloyed form was recovered from the processing of nickel-containing waste, including flue dust, grinding swarf, mill scale, and shot blast generated during the manufacturing of stainless steel; filter cakes, plating solutions, spent catalysts, spent pickle liquor, sludges, and all types of spent nickel-containing batteries. Nickel-containing alloys and stainless-steel scrap were also melted and used to produce new alloys and stainless steel. The U.S. Department of Energy's ReCell Center continued to investigate methods to more effectively recover raw materials, including nickel, from recycled batteries. In 2021, recycled nickel in all forms accounted for approximately 52% of apparent consumption.

Import Sources (2017–20): Nickel contained in ferronickel, metal, oxides, and salt: Canada, 43%; Norway, 10%; Finland, 9%; Australia, 8%; and other, 30%. Nickel-containing scrap, including nickel content of stainless-steel scrap: Canada, 37%; Mexico, 26%; United Kingdom, 9%; and other, 28%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Nickel ores and concentrates, nickel content	2604.00.0040	Free.
Ferronickel	7202.60.0000	Free.
Unwrought nickel, not alloyed	7502.10.0000	Free.
Nickel waste and scrap	7503.00.0000	Free.
Nickel powders	7504.00.0010	Free.
Nickel flakes	7504.00.0050	Free.

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NICKEL

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[4] The U.S. Department of Energy is holding nickel ingot contaminated by low-level radioactivity at Paducah, KY, and shredded nickel scrap at Oak Ridge, TN. See Lithium for statistics on lithium-nickel-cobalt-aluminum oxide.

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Nickel alloys, gross weight	790	—	—	—	—

Events, Trends, and Issues: On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

In 2021, the annual average LME cash price was estimated to have increased by 30% compared with that in 2020, which was attributed to expectations of increased use of nickel in electric vehicle batteries and continued strong demand for stainless steel.

Mine production in Indonesia increased by an estimated 30%, which was facilitated by the ongoing commissioning of integrated nickel pig iron and stainless-steel projects. The country's first hydrometallurgical plant began operation in May on Obi Island. It was among several similar projects in the country that were designed to produce intermediate nickel products to be used as feed material at battery-grade nickel sulfate plants.

World Mine Production and Reserves: Reserves for Australia, Canada, Russia, and the United States were revised based on new information from company and (or) Government reports.

	Mine production		Reserves[5]
	2020	2021[e]	
United States	16,700	18,000	[6]340,000
Australia	169,000	160,000	[7]21,000,000
Brazil	77,100	100,000	16,000,000
Canada	167,000	130,000	2,000,000
China	120,000	120,000	2,800,000
Indonesia	771,000	1,000,000	21,000,000
New Caledonia[8]	200,000	190,000	NA
Philippines	334,000	370,000	4,800,000
Russia	283,000	250,000	7,500,000
Other countries	373,000	410,000	20,000,000
World total (rounded)	2,510,000	2,700,000	>95,000,000

World Resources:[5] Identified land-based resources averaging approximately 0.5% nickel or greater contain at least 300 million tons of nickel, with about 60% in laterites and 40% in sulfide deposits. Extensive nickel resources also are found in manganese crusts and nodules on the ocean floor.

Substitutes: Low-nickel, duplex, or ultrahigh-chromium stainless steels have been substituted for austenitic grades in construction. Nickel-free specialty steels are sometimes used in place of stainless steel in the power-generating and petrochemical industries. Titanium alloys can substitute for nickel metal or nickel-base alloys in corrosive chemical environments.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Defined as primary imports – primary exports + adjustments for industry stock changes, excluding secondary consumer stocks.
[2]Defined as apparent primary consumption + reported secondary consumption.
[3]Defined as imports – exports + adjustments for consumer stock changes.
[4]See Appendix B for definitions.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.
[6]Includes reserve data for three projects. An additional three domestic projects have defined resources but have not yet defined reserves.
[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 8.3 million tons.
[8]Overseas Territory of France.

NIOBIUM (COLUMBIUM)

(Data in metric tons of contained niobium unless otherwise noted)

Domestic Production and Use: Significant U.S. niobium mine production has not been reported since 1959. Companies in the United States produced niobium-containing materials from imported niobium concentrates, oxides, and ferroniobium. Niobium was consumed mostly in the form of ferroniobium by the steel industry and as niobium alloys and metal by the aerospace industry. In 2021, there was an increase in apparent consumption of niobium for high-strength low-alloy steel and superalloy applications. Major end-use distribution of domestic niobium consumption was estimated as follows: steels, about 80%, and superalloys, about 20%. The estimated value of niobium consumption was $340 million, as measured by the value of imports.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, mine	—	—	—	—	—
Imports for consumption[1]	9,330	11,200	10,100	7,200	8,000
Exports[1]	1,490	955	668	785	1,000
Shipments from Government stockpile[2]	−66	−76	−84	−88	−1
Consumption:[e]					
Apparent[3]	7,780	10,100	9,370	6,330	7,000
Reported[4]	7,640	6,850	6,680	5,120	5,700
Price, unit value, ferroniobium, dollars per kilogram[5]	20	21	23	21	20
Net import reliance[3] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Niobium was recycled when niobium-bearing steels and superalloys were recycled; scrap recovery, specifically for niobium content, was negligible. The amount of niobium recycled is not available, but it may be as much as 20% of apparent consumption.

Import Sources (2017–20): Niobium and tantalum ores and concentrates: Australia, 36%; Rwanda, 34%; Congo (Kinshasa), 7%; Mozambique, 6%; and other, 17%. Niobium oxide: Brazil, 60%; Thailand, 15%; Russia, 11%; Estonia, 6%; and other, 8%. Ferroniobium and niobium metal: Brazil, 67%; Canada, 31%; Germany, 1%, and other, 1%. Total imports: Brazil, 65%; Canada, 27%; and other, 8%. Of the U.S. niobium material imports (by contained weight), 89% was ferroniobium, 10% was niobium oxide, 1% was niobium ores and concentrates, and <1% was niobium metal.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Niobium ores and concentrates	2615.90.6030	Free.
Niobium oxide	2825.90.1500	3.7% ad valorem.
Ferroniobium:		
Less than 0.02% P or S, or less than 0.4% Si	7202.93.4000	5% ad valorem.
Other	7202.93.8000	5% ad valorem.
Niobium:		
Waste and scrap[6]	8112.92.0600	Free.
Powders and unwrought metal	8112.92.4000	4.9% ad valorem.
Niobium, other[6]	8112.99.9000	4% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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NIOBIUM (COLUMBIUM)

Government Stockpile:[7]

Material	Inventory as of 9–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Ferroniobium (gross weight)	544	—	—	—	—
Niobium metal (gross weight)	10	—	—	—	—

Events, Trends, and Issues: In 2021, U.S. niobium apparent consumption (measured in niobium content) was estimated to be 7,000 tons, an 11% decrease from that in 2020. One domestic company developing its Elk Creek project in Nebraska announced that it acquired a key land parcel in April, affording ownership of 90% of the project's mineral reserves and resources. The project would be the only niobium mine and primary niobium-processing facility in the United States, with construction to begin after financing was obtained.

Brazil continued to be the world's leading niobium producer with approximately 88% of global production, followed by Canada with about 10%. Global niobium production and consumption were thought to have increased in 2021 as steel production in most countries began to recover from the global COVID-19 pandemic. According to international trade statistics under the Harmonized Tariff Code 7202.93 (ferroniobium), Brazil's total exports were 69,400 tons from January through September 2021, 31% greater than through the same period in 2020. Most of Brazil's exports were sent to China, followed by the Netherlands and the Republic of Korea.

A leading niobium producer in Brazil completed its most recent capacity upgrades which increased the original capacity by 50% to 150,000 tons per year of niobium products (approximately 98,000 tons per year of niobium content). Further, two additional producers in Brazil entered the funding stages for new capacity upgrades. The completion of those projects could provide a potential significant increase in production in Brazil over the next decade.

World Mine Production and Reserves:

	Mine production 2020	Mine production 2021[e]	Reserves[8]
United States	—	—	170,000
Brazil	59,800	66,000	16,000,000
Canada	6,500	7,400	1,600,000
Other countries	1,350	1,400	NA
World total (rounded)	67,700	75,000	>17,000,000

World Resources:[8] World resources of niobium are more than adequate to supply projected needs. Most of the world's identified resources of niobium occur as pyrochlore in carbonatite (igneous rocks that contain more than 50%-by-volume carbonate minerals) deposits and are outside the United States.

Substitutes: The following materials can be substituted for niobium, but a performance loss or higher cost may ensue: ceramic matrix composites, molybdenum, tantalum, and tungsten in high-temperature (superalloy) applications; molybdenum, tantalum, and titanium as alloying elements in stainless and high-strength steels; and molybdenum and vanadium as alloying elements in high-strength low-alloy steels.

[e]Estimated. NA Not available. — Zero.
[1]Imports and exports include the estimated niobium content of ferroniobium, niobium and tantalum ores and concentrates, niobium oxide, and niobium powders and unwrought metal.
[2]Change in total inventory from prior yearend inventory. If negative, net increase in inventory.
[3]Defined as imports – exports + adjustments for Government stock changes.
[4]Only includes ferroniobium and nickel niobium.
[5]Unit value is weighted average unit value of gross weight of U.S. ferroniobium trade (imports plus exports.)
[6]This category includes niobium-containing material and other material.
[7]See Appendix B for definitions.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.

NITROGEN (FIXED)—AMMONIA

(Data in thousand metric tons of contained nitrogen unless otherwise noted)

Domestic Production and Use: Ammonia was produced by 16 companies at 35 plants in 16 States in the United States during 2021; 2 additional plants were idle for the entire year. About 60% of total U.S. ammonia production capacity was in Louisiana, Oklahoma, and Texas because of their large reserves of natural gas, the dominant domestic feedstock for ammonia. In 2021, U.S. producers operated at about 84% of rated capacity. The United States was one of the world's leading producers and consumers of ammonia. Urea, ammonium nitrate, nitric acid, ammonium phosphates, and ammonium sulfate were, in descending order of quantity produced, the major derivatives of ammonia produced in the United States.

Approximately 88% of apparent domestic ammonia consumption was for fertilizer use, including anhydrous ammonia for direct application, urea, ammonium nitrates, ammonium phosphates, and other nitrogen compounds. Ammonia also was used to produce explosives, plastics, synthetic fibers and resins, and numerous other chemical compounds.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production[1]	11,600	13,100	13,500	14,000	14,000
Imports for consumption	3,090	2,530	2,020	1,980	2,200
Exports	612	224	338	369	260
Consumption, apparent[2]	14,100	15,300	15,200	15,700	16,000
Stocks, producer, yearend	320	490	420	310	360
Price, average, free on board gulf coast,[3] dollars per short ton	247	281	232	223	510
Employment, plant, number[e]	1,500	1,600	1,600	1,600	1,600
Net import reliance[4] as a percentage of apparent consumption	18	14	11	11	12

Recycling: None.

Import Sources (2017–20): Trinidad and Tobago, 63%; Canada 34%; Venezuela, 2%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Ammonia, anhydrous	2814.10.0000	Free.
Urea	3102.10.0000	Free.
Ammonium sulfate	3102.21.0000	Free.
Ammonium nitrate	3102.30.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: The Henry Hub spot natural gas price ranged between $2.36 and $6.23 per million British thermal units for most of the year, with an average of about $4.12 per million British thermal units. Natural gas prices in 2021 were higher than those in 2020—a result of below average storage levels of natural gas and strong demand for U.S. liquified natural gas. The U.S. Department of Energy, Energy Information Administration, projected that Henry Hub natural gas spot prices would average around $4.00 per million British thermal units in 2022.

The weekly average gulf coast ammonia price was $245 per short ton at the beginning of 2021 and increased to $603 per short ton in late October. The average ammonia price for 2021 was estimated to be $510 per short ton. In 2021, high natural gas prices resulted in higher ammonia prices.

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NITROGEN (FIXED)—AMMONIA

A long period of stable and low natural gas prices in the United States made it economical for companies to upgrade existing ammonia plants and construct new nitrogen facilities. The additional capacity has reduced ammonia imports. Expansion in the ammonia industry took place throughout the past 5 years; however, no additional U.S. ammonia capacity increases have been announced.

Global ammonia capacity is expected to increase by a total of 4% during the next 4 years. Capacity additions are expected in Africa, eastern Europe, and south Asia. As part of the capacity increase several decarbonized ammonia projects are being proposed. Demand for ammonia is expected to increase by 1% per year with the largest increases expected in Latin America and south Asia.

Large corn plantings maintain the continued demand for nitrogen fertilizers. According to the U.S. Department of Agriculture, U.S. corn growers planted 37.4 million hectares of corn in crop-year 2021 (July 1, 2020, through June 30, 2021), which was 3% greater than the area planted in crop-year 2020. Corn acreage in crop-year 2022 is expected to increase because of anticipated higher returns for corn compared with those of other crops.

World Ammonia Production and Reserves:

	Plant production		Reserves[5]
	2020	2021[e]	
United States	14,000	14,000	Available atmospheric nitrogen and sources of natural gas for production of ammonia are considered adequate for all listed countries.
Algeria	2,200	2,200	
Australia	1,600	1,600	
Canada	3,900	3,900	
China	39,000	39,000	
Egypt	4,200	4,200	
Germany	2,330	2,200	
India	12,200	12,000	
Indonesia	5,900	5,900	
Iran	3,600	3,600	
Malaysia	1,300	1,300	
Netherlands	2,100	2,000	
Oman	1,730	1,700	
Pakistan	3,300	3,300	
Poland	2,260	2,200	
Qatar	3,300	3,300	
Russia	16,100	16,000	
Saudi Arabia	4,300	4,300	
Trinidad and Tobago	4,170	4,200	
Ukraine	2,300	2,300	
Uzbekistan	1,100	1,100	
Vietnam	1,150	1,200	
Other countries	15,400	15,000	
World total (rounded)	147,000	150,000	

World Resources:[5] The availability of nitrogen from the atmosphere for fixed nitrogen production is unlimited. Mineralized occurrences of sodium and potassium nitrates, such as those found in the Atacama Desert of Chile, contribute minimally to the global nitrogen supply.

Substitutes: Nitrogen is an essential plant nutrient that has no substitute. No practical substitutes for nitrogen explosives and blasting agents are known.

[e]Estimated.

[1]Source: The Fertilizer Institute; data adjusted by the U.S. Geological Survey.

[2]Defined as production + imports – exports + adjustments for industry stock changes.

[3]Source: Green Markets.

[4]Defined as imports – exports + adjustments for industry stock changes.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

PEAT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The estimated free on board (f.o.b.) mine value of marketable peat sold by producers in the conterminous United States was $14 million in 2021. Peat was harvested and processed by 29 companies in 11 conterminous States. Florida, Illinois, Maine, Michigan, and Minnesota were the leading producing States and accounted for 98% of peat sold. Reed-sedge peat accounted for approximately 87% of the total volume produced, followed by sphagnum moss with 10%. Domestic peat applications included earthworm culture medium, golf course construction, mixed fertilizers, mushroom culture, nurseries, packing for flowers and plants, seed inoculants, and vegetable cultivation. In the industrial sector, peat was used as an oil absorbent and as an efficient filtration medium for the removal of waterborne contaminants in mine waste streams, municipal storm drainage, and septic systems.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production	498	479	456	444	420
Sales by producers	515	545	556	524	540
Imports for consumption	1,150	1,200	1,160	1,390	1,700
Exports	30	37	46	46	38
Consumption, apparent[1]	1,520	1,670	1,480	1,780	2,000
Price, average value, f.o.b. mine, dollars per ton	27.55	25.88	24.59	24.74	25.00
Stocks, producer, yearend	222	196	280	288	290
Employment, mine and plant, number[e]	540	540	540	530	530
Net import reliance[2] as a percentage of apparent consumption	67	71	69	75	80

Recycling: None.

Import Sources (2017–20): Canada, 96%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Peat	2703.00.0000	Free.

Depletion Allowance: 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Peat is an important component of plant-growing media, and the demand for peat generally follows that of horticultural applications. In the United States, the short-term outlook is for production to average about 420,000 tons per year and imported peat from Canada is expected to continue to account for more than 80% of domestic consumption. Imports for 2021 were estimated to have increased to 1.7 million tons from 1.4 million tons in 2020, and exports were estimated to have decreased to about 38,000 tons from 46,000 tons in 2020. In 2021, peat stocks were estimated to have remained about the same as those in the previous year. Based on estimated world production for 2021, the world's leading peat producers were, in descending order of production, Finland, Sweden, Germany, Latvia, Belarus, and Canada.

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PEAT

In many parts of the world, concerns about climate change prompted several countries to plan to decrease or eliminate the use of peat, owing to peatland's ability to act as a carbon sink. Most of Ireland's peat production ended in 2021, as the country transitioned to alternative fuel sources. Ireland continued to produce peat briquettes but was expected to stop by 2024. The country's goal was to have at least 80% of its fossil-fuel sector employment transitioned to the renewable energy sector by 2025. In 2021, Finland continued to work toward its goal of becoming carbon neutral by 2035. To achieve this, peat production was to be phased out in favor of other forms of noncarbon energy. In 2021, about 35% of Finland's energy consumption was supplied by peat and other fossil fuels. Several European countries, including Belarus, Ireland, and Sweden, were planning or implementing peatland restoration projects to help combat greenhouse-gas emissions and restore wildlife habitats. These initiatives were expected to decrease peat production across Europe in the future.

World Mine Production and Reserves: Reserves for countries that reported by volume only and had insufficient data for conversion to tons were combined and included with "Other countries." Reserves for Estonia and Latvia were revised based on information from company reports.

	Mine production		Reserves[3]
	2020	2021[e]	
United States	444	420	150,000
Belarus	2,590	1,900	2,600,000
Canada	1,400	1,300	720,000
Estonia	1,060	1,100	570,000
Finland	12,000	12,000	6,000,000
Germany	2,300	2,300	([4])
Ireland	1,300	—	([4])
Latvia	2,000	2,100	150,000
Lithuania	460	460	210,000
Poland	900	900	([4])
Russia	1,000	1,000	1,000,000
Sweden	2,400	2,400	([4])
Ukraine	680	330	([4])
Other countries[e]	350	350	1,400,000
World total (rounded)	28,900	27,000	13,000,000

World Resources:[3] Peat is a renewable resource, continuing to accumulate on 60% of global peatlands. However, the volume of global peatlands has been decreasing at a rate of 0.05% annually owing to harvesting and land development. Many countries evaluate peat resources based on volume or area because the variations in densities and thickness of peat deposits make it difficult to estimate tonnage. Volume data have been converted using the average bulk density of peat produced in each of those countries. More than 50% of the U.S. peat resources are located in undisturbed areas of Alaska.

Substitutes: Natural organic materials, such as composted yard waste and coir (coconut fiber), compete with peat in horticultural applications. Shredded paper and straw are used to hold moisture for some grass-seeding applications. The superior water-holding capacity and physiochemical properties of peat limit substitution alternatives in most applications.

[e]Estimated. — Zero.

[1]Defined as production + imports – exports + adjustments for industry stock changes.

[2]Defined as imports – exports + adjustments for industry stock changes.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Included with "Other countries."

PERLITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, the quantity of domestic processed crude perlite sold and used was estimated to be 500,000 tons with a value of $31 million. Crude ore production was from eight mines operated by five companies in six Western States. One other mine was idle throughout the year. New Mexico and Oregon continued to be the leading producing States. Domestic apparent consumption of crude perlite was estimated to be 650,000 tons. Processed crude perlite was expanded at 55 plants in 28 States. The applications for expanded perlite were building construction products, 44%; horticultural aggregate, 21%; fillers, 14%; filter aid, 12%; and other, 9%. Other applications included specialty insulation and miscellaneous uses.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Mine production, crude ore	587	504	629	845	860
Sold and used, processed crude perlite	479	444	397	493	500
Imports for consumption[1]	171	204	183	158	180
Exports[1]	18	16	19	25	32
Consumption, apparent[2]	632	632	561	626	650
Price, average value, free on board mine, dollars per ton	71	69	64	61	63
Employment, mine and mill, number	139	130	140	140	145
Net import reliance[3] as a percentage of apparent consumption	24	30	29	21	23

Recycling: Not available.

Import Sources (2017–20): Greece, 90%; China, 7%; Mexico, 2%; and Turkey, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Vermiculite, perlite, and chlorites, unexpanded	2530.10.0000	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Perlite is a siliceous volcanic glass that expands up to 20 times its original volume when rapidly heated. In horticultural uses, expanded perlite is used to provide moisture retention and aeration without compaction when added to soil. Horticultural perlite is useful to both commercial growers and hobby gardeners. Owing primarily to cost, some commercial greenhouse growers in the United States have recently switched to a wood fiber material over perlite. Perlite, however, remained a preferred soil amendment for segments of greenhouse growers because it does not degrade or compact over lengthy growing times and is inert. Construction applications for expanded perlite are numerous because it is fire resistant, an excellent insulator, and lightweight. Novel and small markets for perlite have increased during the past 10 years; cosmetics, environmental remediation, and personal care products have become increasing markets for perlite.

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PERLITE

A California company opened a second expanding plant in southern California and began shipping in April 2021. Project planning progressed at a perlite deposit in Nevada that could be developed as a potential supplier of crude perlite ore for household and industrial applications.

The value of total construction put in place in the United States increased by about 6% during the first 6 months of 2021 compared with that of the same period in 2020, indicating a similar change in consumption of perlite. Construction products remained the largest domestic market for perlite. Increased interest in commercial greenhouse and hobby gardening may also correspond to increased consumption of horticultural-grade perlite.

Based on estimated world production for 2021, the world's leading producers were, in descending order of production, China, Turkey, Greece, and the United States, with about 36%, 29%, 17%, and 12%, respectively, of world production. Although China was the leading producer, most of its perlite production was thought to be consumed internally. Greece and Turkey remained the leading exporters of perlite.

World Mine Production and Reserves:

	Production		Reserves[4]
	2020	2021[e]	
United States	[5]493	[5]500	50,000
Argentina[e]	18	20	NA
Armenia[e]	50	50	NA
China[e]	1,500	1,500	NA
Greece	710	710	120,000
Hungary[e]	80	80	49,000
Iran[e]	72	70	73,000
Mexico[e]	20	20	NA
New Zealand[e]	18	20	NA
Slovakia[e]	32	30	NA
Turkey[e]	1,200	1,200	57,000
Other countries[e]	30	30	NA
World total (rounded)	4,220	4,200	NA

World Resources:[4] Perlite occurrences in Arizona, California, Idaho, Nevada, New Mexico, and Oregon are thought to contain large resources. Significant deposits have been reported in China, Greece, Hungary, and Turkey, and a few other countries. Insufficient information was available to make reliable estimates of resources in many perlite-producing countries.

Substitutes: In construction applications, diatomite, expanded clay and shale, pumice, and slag can be substituted for perlite. For horticultural uses, coco coir, pumice, vermiculite, and wood pulp are alternative soil additives and are sometimes used in conjunction with perlite.

[e]Estimated. NA Not available.
[1]Exports and imports were estimated by the U.S. Geological Survey from U.S. Census Bureau combined data for vermiculite, perlite, and chlorites, unexpanded.
[2]Defined as sold or used processed perlite + imports – exports.
[3]Defined as imports − exports.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]Processed ore sold and used by producers.

PHOSPHATE ROCK

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, phosphate rock ore was mined by five companies at 10 mines in four States and processed into an estimated 22 million tons of marketable product, valued at $1.7 billion, free on board (f.o.b.) mine. Florida and North Carolina accounted for more than 75% of total domestic output; the remainder was produced in Idaho and Utah. Marketable product refers to beneficiated phosphate rock with phosphorus pentoxide (P_2O_5) content suitable for phosphoric acid or elemental phosphorus production. More than 95% of the phosphate rock mined in the United States was used to manufacture wet-process phosphoric acid and superphosphoric acid, which were used as intermediate feedstocks in the manufacture of granular and liquid ammonium phosphate fertilizers and animal feed supplements. About 25% of the wet-process phosphoric acid produced was exported in the form of upgraded granular diammonium phosphate (DAP) and monoammonium phosphate (MAP) fertilizer and merchant-grade phosphoric acid. The balance of the phosphate rock mined was for the manufacture of elemental phosphorus, which was used to produce phosphorus compounds for industrial applications, primarily glyphosate herbicide.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, marketable	27,900	25,800	23,300	23,500	22,000
Sold or used by producers	26,300	23,300	23,400	22,600	23,000
Imports for consumption	2,470	2,770	2,140	2,520	2,400
Consumption, apparent[1]	28,800	26,000	25,500	25,100	25,000
Price, average value, f.o.b. mine,[2] dollars per ton	73.67	70.77	67.98	75.86	75.00
Stocks, producer, yearend	8,440	10,600	9,830	11,000	10,000
Employment, mine and beneficiation plant, number[e]	1,800	1,900	1,900	1,800	1,900
Net import reliance[3] as a percentage of apparent consumption	5	2	11	5	13

Recycling: None.

Import Sources (2017–20): Peru, 87%; Morocco, 13%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Natural calcium phosphates:		
Unground	2510.10.0000	Free.
Ground	2510.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, domestic consumption of phosphate rock was estimated to be about the same as that in 2020. DAP and MAP production decreased as a result, in part, of technical problems at a phosphate plant in Florida and owing to the effects of Hurricane Ida in August, which damaged phosphate facilities in Louisiana. The affected facilities reopened in the fourth quarter.

World production was estimated to be about the same as that in 2020, with China, Morocco, and the United States remaining the leading producers. Production in Jordan, Morocco, and Saudi Arabia increased as expansions to capacity were being ramped up in 2021. Capacity expansion projects were ongoing in Brazil, Kazakhstan, Mexico, Russia, and South Africa; however, none of the projects were expected to be completed until after 2024.

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PHOSPHATE ROCK

One producer in Idaho submitted plans to shift production to a new phosphate rock mine when its existing mine is exhausted in about 5 years. The new mine would be located close to the current mine in Caribou County, and annual production capacity was expected to remain the same.

World consumption of P_2O_5 contained in fertilizer products was estimated to have increased by 7% in crop-year 2021 (July 1, 2020, to June 30, 2021) compared with that in crop-year 2020. The increases in world consumption and trade were driven by high crop prices, increased planted crop area, and increased crop exports. This was a continuation of the trend that began late in 2020, as markets rebounded from poor weather conditions in the growing season. South America and Asia were leading regions of growth in consumption of phosphate fertilizer, in terms of percentage increase over that in 2020.

World Mine Production and Reserves: Reserves for Israel, Jordan, and South Africa were updated with information from the producing companies in the respective countries. Turkey was listed separately from "Other countries."

	Mine production		Reserves[4]
	2020	2021[e]	
United States	23,500	22,000	1,000,000
Algeria	1,200	1,200	2,200,000
Australia	2,000	2,200	[5]1,100,000
Brazil	6,000	5,500	1,600,000
China[6]	88,000	85,000	3,200,000
Egypt	4,800	5,000	2,800,000
Finland	995	1,000	1,000,000
India	1,400	1,400	46,000
Israel	3,090	3,000	53,000
Jordan	8,940	9,200	1,000,000
Kazakhstan	1,300	1,500	260,000
Mexico	577	530	30,000
Morocco	37,400	38,000	50,000,000
Peru	3,300	3,800	210,000
Russia	14,000	14,000	600,000
Saudi Arabia	8,000	8,500	1,400,000
Senegal	1,600	2,200	50,000
South Africa	1,800	2,000	1,600,000
Togo	942	1,200	30,000
Tunisia	3,190	3,200	100,000
Turkey	600	600	50,000
Uzbekistan	900	900	100,000
Vietnam	4,500	4,700	30,000
Other countries	870	1,000	2,600,000
World total (rounded)	219,000	220,000	71,000,000

World Resources:[4] Some world reserves were reported only in terms of ore tonnage and grade. Phosphate rock resources occur principally as sedimentary marine phosphorites. The largest sedimentary deposits are found in northern Africa, the Middle East, China, and the United States. Significant igneous occurrences are found in Brazil, Canada, Finland, Russia, and South Africa. Large phosphate resources have been identified on the continental shelves and on seamounts in the Atlantic Ocean and the Pacific Ocean. World resources of phosphate rock are more than 300 billion tons. There are no imminent shortages of phosphate rock.

Substitutes: There are no substitutes for phosphorus in agriculture.

[e]Estimated.
[1]Defined as phosphate rock sold or used by producers + imports. U.S. producers stopped exporting phosphate rock in 2003.
[2]Marketable phosphate rock, weighted value, all grades.
[3]Defined as imports + adjustments for industry stock changes.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 110 million tons.
[6]Production data for large mines only, as reported by the National Bureau of Statistics of China.

PLATINUM-GROUP METALS

(Palladium, platinum, iridium, osmium, rhodium, and ruthenium)
[Data in kilograms of contained platinum-group metals (PGMs) unless otherwise noted]

Domestic Production and Use: One company in Montana produced approximately 18,000 kilograms of PGMs with an estimated value of about $1.4 billion. Small quantities of primary PGMs also were recovered as byproducts of copper-nickel mining in Michigan; however, this material was sold to foreign companies for refining. The leading domestic use for PGMs was in catalytic converters to decrease harmful emissions from automobiles. PGMs are also used in catalysts for bulk-chemical production and petroleum refining; dental and medical devices; electronic applications, such as in computer hard disks, hybridized integrated circuits, and multilayer ceramic capacitors; glass manufacturing; investment; jewelry; and laboratory equipment.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Mine production:[1]					
Palladium	14,000	14,300	14,300	14,600	14,000
Platinum	4,000	4,160	4,150	4,200	4,200
Imports for consumption:[2]					
Palladium	86,000	92,900	84,300	76,400	76,000
Platinum	53,200	58,500	42,300	64,800	56,000
PGM waste and scrap	354,000	40,700	35,200	188,000	210,000
Iridium	1,420	1,020	875	1,620	2,500
Osmium	856	25	([3])	1	1
Rhodium	11,600	14,500	15,000	20,700	17,000
Ruthenium	14,600	17,900	11,200	13,900	23,000
Exports:[4]					
Palladium	52,300	52,900	55,500	48,600	43,000
Platinum	16,700	18,900	17,400	28,900	30,000
PGM waste and scrap	37,200	31,700	20,800	33,200	42,000
Rhodium	844	2,010	1,210	1,470	1,300
Other PGMs	939	2,500	1,330	1,440	2,800
Consumption, apparent:[5, 6]					
Palladium	89,700	96,300	85,100	80,400	90,000
Platinum	51,600	53,700	37,000	47,200	37,000
Price, dollars per troy ounce:[7]					
Palladium	874.30	1,036.43	1,544.31	2,205.27	2,600.00
Platinum	951.23	882.66	866.94	886.02	1,200.00
Iridium	908.35	1,293.27	1,485.80	1,633.51	5,400.00
Rhodium	1,112.59	2,225.30	3,918.78	11,205.06	24,000.00
Ruthenium	76.86	244.41	262.59	271.83	510.00
Employment, mine, number	1,513	1,628	1,789	1,881	1,700
Net import reliance[6, 8] as a percentage of apparent consumption:					
Palladium	38	42	34	35	37
Platinum	71	74	67	77	70

Recycling: About 115,000 kilograms of palladium and platinum was recovered globally from new and old scrap in 2021, including about 53,000 kilograms recovered from automobile catalytic converters in the United States.

Import Sources (2017–20): Palladium: Russia, 35%; South Africa, 31%; Germany, 9%; and other, 25%. Platinum: South Africa, 38%; Germany, 20%; Switzerland, 12%; Italy, 6%; and other, 24%.

Tariff: All unwrought and semimanufactured forms of PGMs are imported duty free. See footnotes for specific Harmonized Tariff Schedule of the United States codes.

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PLATINUM-GROUP METALS

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[9]

Material	Inventory as of 9–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Iridium	15	—	15	—	15
Platinum	261	—	261	—	261

Events, Trends, and Issues: Progress continued at a domestic mine expansion project, but full production was delayed to 2024 owing to disruptions from the COVID-19 pandemic and operational challenges associated with ventilation and ground conditions. Production of PGMs in South Africa, the world's leading supplier of mined material, increased by 13% compared with that in 2020 owing to increased mining in the UG2 orebody of the Bushveld Complex.

The estimated annual average prices of palladium, platinum, and ruthenium increased by 18%, 35%, and 88%, respectively, compared with those in 2020, and the estimated prices for rhodium doubled and iridium more than tripled. In addition, the prices of iridium, rhodium, and ruthenium all reached record highs in 2021.

Constrained automobile production owing to semiconductor chip shortages and a decline in diesel passenger vehicle production are expected to result in decreased demand for palladium, platinum, and rhodium used in catalytic converters.

World Mine Production and Reserves: Reserves for Russia were revised based on Government reports.

	Mine production				PGM reserves[10]
	Palladium		Platinum		
	2020	2021[e]	2020	2021[e]	
United States	14,600	14,000	4,200	4,200	900,000
Canada	20,000	17,000	7,000	6,000	310,000
Russia	93,000	74,000	23,000	19,000	4,500,000
South Africa	73,500	80,000	112,000	130,000	63,000,000
Zimbabwe	12,900	13,000	15,000	15,000	1,200,000
Other countries	2,670	2,800	4,320	4,300	NA
World total (rounded)	217,000	200,000	166,000	180,000	70,000,000

World Resources:[10] World resources of PGMs are estimated to total more than 100 million kilograms. The largest reserves are in the Bushveld Complex in South Africa.

Substitutes: Palladium has been substituted for platinum in most gasoline-engine catalytic converters because of the historically lower price for palladium relative to that of platinum. About 25% of palladium can routinely be substituted for platinum in diesel catalytic converters; the proportion can be as much as 50% in some applications. For some industrial end uses, one PGM can substitute for another, but with losses in efficiency.

[e]Estimated. NA Not available. — Zero.
[1]Estimated from published sources.
[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 7110.11.0010, 7110.11.0020, 7110.11.0050, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0010, 7110.41.0020, 7110.41.0030, 7110.49.0010, 7112.92.0000, and 7118.90.0020.
[3]Less than ½ unit.
[4]Includes data for the following Schedule B codes: 7110.11.0000, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0000, 7110.49.0000, and 7112.92.0000.
[5]Defined as primary production + secondary production + imports – exports.
[6]Excludes imports and (or) exports of waste and scrap.
[7]Engelhard Corp. unfabricated metal.
[8]Defined as imports – exports.
[9]See Appendix B for definitions.
[10]See Appendix C for resource and reserve definitions and information concerning data sources.

POTASH

[Data in thousand metric tons of potassium oxide (K_2O) equivalent unless otherwise noted]

Domestic Production and Use: In 2021, the estimated sales value of marketable potash, free on board (f.o.b.) mine, was $520 million, which was 24% higher than that in 2020. Potash denotes a variety of mined and manufactured salts that contain the element potassium in water-soluble form. In agriculture, the term potash refers to potassic fertilizers, which are potassium chloride (KCl), potassium sulfate or sulfate of potash (SOP), and potassium magnesium sulfate (SOPM) or langbeinite. Muriate of potash (MOP) is an agriculturally acceptable mix of KCl (95% pure or greater) and sodium chloride for fertilizer use. The majority of U.S. production was from southeastern New Mexico, where two companies operated two underground mines and one deep-well solution mine. Sylvinite and langbeinite ores in New Mexico were beneficiated by flotation, dissolution-recrystallization, heavy-media separation, solar evaporation, and (or) combinations of these processes. In Utah, two companies operated three facilities. One company extracted underground sylvinite ore by deep-well solution mining. Solar evaporation crystallized the sylvinite ore from the brine solution, and a flotation process separated the MOP from byproduct sodium chloride. The firm also processed subsurface brines by solar evaporation and flotation to produce MOP at its other facility. Another company processed brine from the Great Salt Lake by solar evaporation to produce SOP and other byproducts.

The fertilizer industry used about 85% of U.S. potash sales, and the remainder was used for chemical and industrial applications. About 60% of the potash produced was SOPM and SOP, which are required to fertilize certain chloride-sensitive crops. The remainder of production was MOP and was used for agricultural and chemical applications.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, marketable[1]	480	520	510	460	480
Sales by producers, marketable[1]	490	520	480	500	530
Imports for consumption	5,860	5,710	5,150	5,370	7,000
Exports	128	105	145	147	100
Consumption, apparent[1, 2]	6,200	6,100	5,500	5,700	7,400
Price, average, all products,[3] f.o.b. mine, dollars per ton of K_2O	770	750	820	850	980
Price, average, muriate, f.o.b. mine, dollars per ton of K_2O	410	440	480	450	550
Employment, mine and mill, number	900	900	900	900	900
Net import reliance[4] as a percentage of apparent consumption	92	92	91	92	93

Recycling: None.

Import Sources (2017–20): Canada, 75%; Russia, 10%; Belarus, 8%; and other, 7%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Potassium nitrate	2834.21.0000	Free.
Potassium chloride	3104.20.0000	Free.
Potassium sulfate	3104.30.0000	Free.
Potassic fertilizers, other	3104.90.0100	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, U.S. potash consumption and trade reached record levels driven by high crop prices, increased planted crop area, and increased crop exports. This was a continuation of the trend that began late in 2020, as markets rebounded from poor weather conditions in the growing season and high potash stocks. The North American price of potash also increased substantially owing to increased consumption and tighter supplies. Industrial potash consumption continued to be lower, primarily for oil- and gas-well-drilling additives. The number of active oil- and gas-well-drilling rigs gradually increased throughout the year but was still well below the level before the COVID-19 pandemic.

On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

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POTASH

World potash consumption in 2021 for fertilizers was estimated to have increased to 45 million tons from 44 million tons in 2020, as demand peaked in the first half of the year in major consuming regions. Asia and South America continued to be the leading consuming regions. North America and South America and southeast Asia had the largest increases in consumption over that of 2020. World potash production increased, owing primarily to increased output in the major exporting countries of Belarus, Canada, and Russia to meet high demand in the first half of the year.

In August 2021, the United States imposed economic sanctions on Belarus for violations of international law, which included the state-run potash producer. The sanctions did not include the state-run exporting company for Belarus, and potash imports from Belarus continued, but at a lower volume because many buyers used other sources owing to uncertainty of future sanctions.

A new potash mine was in the development stage and pending operating permits in Osceola County, MI. The proposed solution mine would have an initial production capacity of 650,000 tons per year of MOP and was planned to increase to 1 million tons per year.

World annual potash capacity was projected to increase to near 69 million tons in 2025 from 62.3 million tons in 2021. Most of the increase would be MOP from new mines and expansion projects in Belarus, Canada, and Russia. New SOP mines were planned in Australia and Eritrea, and a polyhalite mine in the United Kingdom would also contribute to the capacity growth. New MOP mines in Brazil, Canada, Ethiopia, Morocco, Spain, and the United States were planned to begin operation past 2025 but could be delayed because of future unfavorable economic conditions or lack of funding.

World Mine Production and Reserves: Reserves for Russia were updated with the Australasian Joint Ore Reserves Committee (JORC)-compliant reserves reported by the producing companies.

	Mine production		Reserves[5]	
	2020	2021[e]	Recoverable ore	K_2O equivalent
United States[1]	460	480	970,000	220,000
Belarus	7,400	8,000	3,300,000	750,000
Brazil	254	210	10,000	2,300
Canada	13,800	14,000	4,500,000	1,100,000
Chile	900	900	NA	100,000
China	6,000	6,000	NA	350,000
Germany	2,200	2,300	NA	150,000
Israel	2,280	2,300	NA	[6]Large
Jordan	1,590	1,600	NA	[6]Large
Laos	270	300	500,000	75,000
Russia	8,110	9,000	NA	400,000
Spain	420	400	NA	68,000
Other countries	360	370	1,500,000	300,000
World total (rounded)	44,000	46,000	>11,000,000	>3,500,000

World Resources:[5] Estimated domestic potash resources total about 7 billion tons. Most of these lie at depths between 1,800 and 3,100 meters in a 3,110-square-kilometer area of Montana and North Dakota as an extension of the Williston Basin deposits in Manitoba and Saskatchewan, Canada. The Paradox Basin in Utah contains resources of about 2 billion tons, mostly at depths of more than 1,200 meters. The Holbrook Basin of Arizona contains resources of about 0.7 to 2.5 billion tons. A large potash resource lies about 2,100 meters under central Michigan and contains more than 75 million tons. Estimated world resources total about 250 billion tons.

Substitutes: No substitutes exist for potassium as an essential plant nutrient and as an essential nutritional requirement for animals and humans. Manure and glauconite (greensand) are low-potassium-content materials that can be profitably transported only short distances to crop fields. Glauconite is used as a potassium source for organic farming.

[e]Estimated. NA Not available.
[1]Data are rounded to no more than two significant digits to avoid disclosing company proprietary data.
[2]Defined as sales + imports – exports.
[3]Includes MOP, SOP, and SOPM. Does not include other chemical compounds that contain potassium.
[4]Defined as imports – exports.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.
[6]Israel and Jordan recover potash from the Dead Sea, which contains nearly 2 billion tons of potassium chloride.

PUMICE AND PUMICITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, 10 operations in five States produced pumice and pumicite. Estimated production[1] was 580,000 tons with an estimated processed value of about $18.6 million, free on board (f.o.b.) plant. That represented a slight increase in quantity and a 4% increase in value from the 2020 reported production of 578,000 tons valued at $17.9 million. Pumice and pumicite were mined in California, Idaho, Kansas, New Mexico, and Oregon. The porous, lightweight properties of pumice are well suited for its main uses. Mined pumice was used in the production of abrasives, concrete admixtures and aggregates, lightweight building blocks, horticultural purposes, and other uses, including absorbent, filtration, laundry stone washing, and road use.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine[1]	383	496	565	578	580
Imports for consumption	166	159	136	90	140
Exports[e]	12	11	11	8	11
Consumption, apparent[2]	537	644	690	660	710
Price, average value, f.o.b. mine or mill, dollars per ton	39	32	28	31	32
Employment, mine and mill, number	140	140	140	140	140
Net import reliance[3] as a percentage of apparent consumption	29	23	18	12	18

Recycling: Little to no known recycling.

Import Sources (2017–20): Greece, 92%; Iceland, 6%; and Mexico, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Pumice, crude or in irregular pieces, including crushed	2513.10.0010	Free.
Pumice, other	2513.10.0080	Free.

Depletion Allowance: 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The amount of domestically produced pumice and pumicite sold or used in 2021 was estimated to be slightly more than that in 2020. Imports and exports were estimated to have increased compared with those of 2020. Almost all imported pumice originated from Greece in 2021 and primarily supplied markets in the eastern and gulf coast regions of the United States.

Pumice and pumicite are plentiful in the Western United States, but legal challenges and public land designations could limit access to known deposits. Pumice and pumicite production are sensitive to mining and transportation costs. Although unlikely in the short term, an increase in fuel prices would likely lead to increases in production costs, making imports and competing materials attractive substitutes for domestic products.

All known domestic pumice and pumicite mining in 2021 was accomplished through open pit methods, generally in remote areas away from major population centers. Although the generation and disposal of reject fines in mining and milling may result in local dust issues at some operations, such environmental impacts are thought to be restricted to relatively small geographic areas.

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PUMICE AND PUMICITE

World production of pumice and related material was estimated to be 17 million tons in 2021, which was 10% more than that of 2020. Turkey, followed by Uganda, was the leading global producer of pumice and pumicite. Pumice is used more extensively as a building material outside the United States, which explained the large global production of pumice relative to that of the United States. In Europe, basic home construction uses stone and concrete as the preferred building materials. Prefabricated lightweight concrete walls, which may contain pumice as lightweight aggregate, are often produced and shipped to construction locations. Because of their cementitious properties, light weight, and strength, pumice and pumicite perform well in European-style construction.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States[1]	578	580	Large in the United States. Quantitative estimates of reserves for most countries are not available.
Algeria[5]	900	900	
Cameroon[5]	300	110	
Chile[5]	680	700	
Ecuador[5]	800	800	
Ethiopia	510	500	
France[5]	280	300	
Greece[5]	1,020	1,000	
Guadeloupe	200	200	
Guatemala	570	600	
Indonesia	200	200	
Jordan	900	900	
New Zealand	220	220	
Saudi Arabia[5]	560	560	
Spain	290	300	
Syria[5]	200	200	
Tanzania	260	160	
Turkey	5,400	7,000	
Uganda	960	1,100	
Other countries[5]	570	570	
World total (rounded)	15,400	17,000	

World Resources:[4] The identified U.S. resources of pumice and pumicite, estimated to be more than 25 million tons, are concentrated in the Western States. The estimated total resources (identified and undiscovered) in the Western and Great Plains States are at least 250 million tons and may total more than 1 billion tons. Large resources of pumice and pumicite have been identified on all continents.

Substitutes: The costs of transportation determine the maximum economic distance pumice and pumicite can be shipped and still remain competitive with alternative materials. Competitive materials that may be substituted for pumice and pumicite include crushed aggregates, diatomite, expanded shale and clay, and vermiculite.

[e]Estimated.
[1]Quantity sold and used by producers.
[2]Defined as production + imports – exports.
[3]Defined as imports – exports.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]Includes pozzolan and (or) volcanic tuff.

QUARTZ CRYSTAL (INDUSTRIAL)

(Data in kilograms unless otherwise noted)

Domestic Production and Use: Industrial cultured quartz crystal is electronic-grade quartz crystal that is manufactured, not mined. In the past, cultured quartz crystal was primarily produced using lascas[1] as raw quartz feed material. Lascas mining and processing in Arkansas ended in 1997. In 2021, two companies produced cultured quartz crystal in the United States. However, production data were withheld in order to avoid disclosing company proprietary data. In addition to lascas, these companies may use cultured quartz crystal that has been rejected during the manufacturing process, owing to crystallographic imperfections, as feed material. The companies likely use a mix of cultured quartz and imported lascas as feed material. In the past several years, cultured quartz crystal has been increasingly produced overseas, primarily in Asia. Electronic applications accounted for most industrial uses of quartz crystal; other uses included special optical applications.

Virtually all quartz crystal used for electronics was cultured, rather than natural, crystal. Electronic-grade quartz crystal is used to make frequency filters, frequency controls, and timers in electronic circuits employed for a wide range of products, such as communications equipment, computers, and many consumer goods, such as electronic games and television receivers.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine (lascas)	—	—	—	—	—
Cultured quartz crystal	W	W	W	W	W
Imports for consumption:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	6,760	16,100	54,800	114,000	84,000
Exports:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	55,300	43,400	40,900	37,100	37,000
Price, dollars per kilogram:					
As-grown cultured quartz	280	300	200	200	200
Lumbered quartz[2]	300	500	500	400	400
Net import reliance[3] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: An unspecified amount of rejected cultured quartz crystal was used as feed material for the production of cultured quartz crystal.

Import Sources (2017–20): Import statistics specific to lascas are not available because they are combined with other types of quartz. Cultured quartz crystal (piezoelectric quartz, unmounted): China,[4] 88%; Japan, 4%; Russia, 2%; and other, 6%.

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QUARTZ CRYSTAL (INDUSTRIAL)

Tariff: Item	Number	Normal Trade Relations 12–31–21
Quartz (including lascas)	2506.10.0050	Free.
Piezoelectric quartz, unmounted	7104.10.0000	3% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[5] The National Defense Stockpile contains 11 weight classes for natural quartz crystal that range from 0.2 kilogram to more than 10 kilograms. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals, which are very thin crystals cut to exact dimensions, to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal.

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Quartz crystal	7,140	—	7,148	—	7,148

Events, Trends, and Issues: Increased imports of piezoelectric quartz in the past several years are likely the result of increased demand for vibration sensors and frequency-control oscillators for aerospace, automotive, and telecommunication applications. Growth of the consumer electronics market (for example, personal computers, electronic games, and tablet computers) is also likely to remain a factor in sustaining global production of cultured quartz crystal.

World Mine Production and Reserves:[6] This information is unavailable, but the global reserves for lascas are thought to be large.

World Resources:[6] Limited resources of natural quartz crystal suitable for direct electronic or optical use are available throughout the world. World dependence on these resources will continue to decline because of the increased acceptance of cultured quartz crystal as an alternative material. Additionally, techniques using rejected cultured quartz crystal as feed material may result in decreased dependence on lascas for growing cultured quartz.

Substitutes: Silicon is increasingly being used as a substitute for quartz crystal for frequency-control oscillators in electronic circuits. Other materials, such as aluminum orthophosphate (the very rare mineral berlinite), langasite, lithium niobate, and lithium tantalate, which have larger piezoelectric coupling constants, have been studied and used. The cost competitiveness of these materials, as opposed to cultured quartz crystal, is dependent on the type of application that the material is used for and the processing required.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Lascas is a nonelectronic-grade quartz used as a feedstock for growing cultured quartz crystal and for production of fused quartz.
[2]As-grown cultured quartz that has been processed by sawing and grinding.
[3]Defined as imports – exports.
[4]Includes Hong Kong.
[5]See Appendix B for definitions.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.

RARE EARTHS[1]

[Data in metric tons of rare-earth-oxide (REO) equivalent unless otherwise noted]

Domestic Production and Use: Rare earths were mined domestically in 2021. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined as a primary product at a mine in Mountain Pass, CA. Monazite, a phosphate mineral, was produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates in the southeastern United States. The estimated value of rare-earth compounds and metals imported by the United States in 2021 was $160 million, a significant increase from $109 million in 2020. The estimated end-use distribution of rare earths was as follows: catalysts, 74%; ceramics and glass, 10%; metallurgical applications and alloys, 6%; polishing, 4%; and other, 6%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:[e]					
Mineral concentrates	—	14,000	28,000	39,000	43,000
Compounds and metals	—	—	—	—	230
Imports:[e, 2]					
Compounds	11,000	10,800	12,200	6,510	7,700
Metals:					
Ferrocerium, alloys	309	298	330	274	320
Rare-earth metals, scandium, and yttrium	524	526	627	362	540
Exports:[e, 2]					
Ores and compounds	1,740	17,900	28,300	40,000	45,000
Metals:					
Ferrocerium, alloys	982	1,250	1,290	625	740
Rare-earth metals, scandium, and yttrium	55	28	83	25	29
Consumption, apparent, compounds and metals[3]	9,300	9,600	11,200	5,400	6,100
Price, average, dollars per kilogram:[4]					
Cerium oxide, 99.5% minimum	2	2	2	2	2
Dysprosium oxide, 99.5% minimum	187	179	239	261	400
Europium oxide, 99.99% minimum	77	53	35	31	31
Lanthanum oxide, 99.5% minimum	2	2	2	2	2
Mischmetal, 65% cerium, 35% lanthanum	6	6	6	5	6
Neodymium oxide, 99.5% minimum	50	50	45	49	49
Terbium oxide, 99.99% minimum	501	455	507	670	1,300
Employment, mine and mill, annual average, number	24	190	202	185	290
Net import reliance[5] as a percentage of apparent consumption:[6]					
Compounds and metals	100	100	100	100	>90
Mineral concentrates	XX	E	E	E	E

Recycling: Limited quantities of rare earths are recovered from batteries, permanent magnets, and fluorescent lamps.

Import Sources (2017–20): Rare-earth compounds and metals: China, 78%; Estonia, 6%; Malaysia, 5%; Japan, 4%; and other, 7%. Compounds and metals imported from Estonia, Japan, and Malaysia were derived from mineral concentrates and chemical intermediates produced in Australia, China, and elsewhere.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Rare-earth metals	2805.30.0000	5.0% ad valorem.
Cerium compounds	2846.10.0000	5.5% ad valorem.
Other rare-earth compounds:		
Oxides or chlorides	2846.90.2000	Free.
Carbonates	2846.90.8000	3.7% ad valorem.
Ferrocerium and other pyrophoric alloys	3606.90.3000	5.9% ad valorem.

Depletion Allowance: Monazite, 22% on thorium content and 14% on rare-earth content (domestic), 14% (foreign); bastnäsite and xenotime, 14% (domestic and foreign).

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RARE EARTHS

Government Stockpile:[7] In the addition to the materials listed below, the FY 2021 and FY 2022 potential acquisitions include neodymium, 600 tons; praseodymium, 70 tons; and samarium-cobalt alloy, 50 tons.

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Cerium	—	500	—	550	—
Dysprosium	0.2	20	—	20	—
Europium	27.7	—	—	—	—
Ferrodysprosium	0.5	—	—	—	—
Lanthanum	—	1,300	—	1,300	—
Rare-earth-magnet block	—	100	—	100	—
Yttrium	25	600	—	25	—

Events, Trends, and Issues: Global mine production was estimated to have increased to 280,000 tons of REO equivalent. According to China's Ministry of Industry and Information Technology, the mine production quota for 2021 was 168,000 tons with 148,850 tons allocated to light rare earths and 19,150 tons to ion-adsorption clays.

World Mine Production and Reserves: Reserves for Australia, Russia, the United States, and "Other countries" were revised based on information from Government and industry reports.

	Mine production		Reserves[8]
	2020	2021[e]	
United States	39,000	43,000	1,800,000
Australia	21,000	22,000	[9]4,000,000
Brazil	600	500	21,000,000
Burma	31,000	26,000	NA
Burundi	300	100	NA
Canada	—	—	830,000
China	[10]140,000	[10]168,000	44,000,000
Greenland	—	—	1,500,000
India	2,900	2,900	6,900,000
Madagascar	2,800	3,200	NA
Russia	2,700	2,700	21,000,000
South Africa	—	—	790,000
Tanzania	—	—	890,000
Thailand	3,600	8,000	NA
Vietnam	700	400	22,000,000
Other countries	100	300	280,000
World total (rounded)	240,000	280,000	120,000,000

World Resources:[8] Rare earths are relatively abundant in the Earth's crust, but minable concentrations are less common than for most other mineral commodities. In North America, measured and indicated resources of rare earths were estimated to include 2.4 million tons in the United States and more than 15 million tons in Canada.

Substitutes: Substitutes are available for many applications but generally are less effective.

[e]Estimated. E Net exporter. NA Not available. XX Not applicable. — Zero.
[1]Data include lanthanides and yttrium but exclude most scandium. See also Scandium and Yttrium.
[2]REO equivalent or content of various materials were estimated. Source: U.S. Census Bureau.
[3]Defined as production + imports – exports.
[4]Source: Argus Media group—Argus Metals International.
[5]Defined as imports – exports.
[6]In 2018–2020, all domestic production of mineral concentrates was exported or held in inventory, and all compounds and metals consumed were assumed to be imported material.
[7]Gross weight. See Appendix B for definitions.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 3.0 million tons.
[10]Production quota; does not include undocumented production.

RHENIUM

(Data in kilograms of contained rhenium unless otherwise noted)

Domestic Production and Use: During 2021, rhenium-containing products including ammonium perrhenate (APR), metal powder, and perrhenic acid were produced as byproducts from roasting molybdenum concentrates from porphyry copper-molybdenum deposits in Arizona and Montana. U.S. primary production was approximately 9,100 kilograms in 2021, a 4% increase from the previous year. The United States continued to be a leading producer of secondary rhenium, recovering rhenium from nickel-base superalloy scrap, spent oil-refining catalysts, and foundry revert. The major uses of rhenium were in superalloys used in high-temperature turbine engine components and in petroleum-reforming catalysts, representing an estimated 80% and 15%, respectively, of end uses. Bimetallic platinum-rhenium catalysts were used in petroleum reforming for the production of high-octane hydrocarbons, which are used in the production of lead-free gasoline. Rhenium improves the high-temperature (>1,000 degrees Celsius) strength properties of some nickel-base superalloys. Rhenium alloys were used in crucibles, electrical contacts, electromagnets, electron tubes and targets, heating elements, ionization gauges, mass spectrographs, metallic coatings, semiconductors, temperature controls, thermocouples, vacuum tubes, and other applications. The value of rhenium consumed in 2021 was about $35 million as measured by the value of imports of rhenium metal and APR.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production[1]	8,200	8,220	8,360	8,830	9,100
Imports for consumption[2]	34,500	39,400	44,300	25,200	23,000
Exports	NA	NA	NA	NA	NA
Consumption, apparent[3]	42,700	47,600	52,600	34,000	32,000
Price, average value, gross weight, dollars per kilogram:[4]					
Metal pellets, 99.99% pure	1,550	1,470	1,300	1,030	980
Ammonium perrhenate	1,530	1,410	1,280	1,130	1,000
Employment, number	Small	Small	Small	Small	Small
Net import reliance[5] as a percentage of apparent consumption	81	83	84	74	72

Recycling: Nickel-base superalloy scrap and scrapped turbine blades and vanes continued to be recycled hydrometallurgically to produce rhenium metal for use in new superalloy melts. The scrapped parts were also processed to generate engine revert—a high-quality, lower cost superalloy meltstock—by an increasing number of companies, mainly in the United States, Canada, Estonia, France, Germany, Japan, Poland, and Russia. Rhenium-containing catalysts were also recycled.

Import Sources (2017–20): Ammonium perrhenate: Kazakhstan, 21%; Canada, 18%; Germany, 16%; Poland, 16%; and other, 29%. Rhenium metal powder: Chile, 84%; Germany, 7%; Canada, 6%; and other, 3%. Total imports: Chile, 51%; Canada, 13%; Kazakhstan, 11%; Japan, 7%; and other, 18%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Salts of peroxometallic acids, other, ammonium perrhenate	2841.90.2000	3.1% ad valorem.
Rhenium (and other metals), waste and scrap	8112.92.0600	Free.
Rhenium, unwrought and powders	8112.92.5000	3% ad valorem.
Rhenium (and other metals), wrought	8112.99.9000	4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: For the 10th year in a row, rhenium metal and catalytic-grade APR prices decreased. In 2021, the price of catalytic-grade APR averaged $1,000 per kilogram, a 12% decrease from the annual average price in 2020. The rhenium metal pellet price averaged $980 per kilogram in 2021, a 5% decrease from the annual average price in 2020.

In 2021, apparent consumption in the United States decreased by 6% compared with that in 2020. During 2021, the United States continued to rely on imports for much of its supply of rhenium. Canada, Chile, Japan, and Kazakhstan supplied most of the imported rhenium. Imports of APR decreased by 32% in 2021 compared with those in the previous year. Imports of rhenium metal decreased by 6% in 2021 compared with those in the previous year. World rhenium production in 2021 was estimated to be essentially the same as that in 2020.

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RHENIUM

The United States and Germany continued to be the leading secondary rhenium producers. Secondary rhenium production also took place in Canada, Estonia, France, Japan, Poland, and Russia. Available information was insufficient to make U.S. secondary production estimates; however, industry sources estimated annual U.S. capacity between 18 and 20 tons of rhenium. Industry sources estimated approximately 25 tons of secondary rhenium was produced worldwide in 2021.

There were no primary rhenium projects in 2021 that were expected to significantly contribute to rhenium availability in the near future. Continued low prices of rhenium as well as the global COVID-19 pandemic continued to cause many rhenium recyclers as well as primary-rhenium production facilities to stop recycling or producing rhenium to focus on a more profitable market. The major aerospace companies were expected to continue testing superalloys that contain one-half the quantity of rhenium used in engine blades as currently designed, as well as testing rhenium-free alloys for other engine components.

On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

World Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2020	2021[e]	
United States	8,830	9,100	400,000
Armenia	260	260	95,000
Chile[8]	30,000	29,000	1,300,000
China	2,500	2,500	NA
Kazakhstan	500	1,000	190,000
Korea, Republic of	2,800	2,800	NA
Poland	9,510	9,500	NA
Russia	NA	NA	310,000
Uzbekistan	4,900	4,900	NA
World total (rounded)	59,300	59,000	Large

World Resources:[7] Most rhenium occurs with molybdenum in porphyry copper deposits. Identified U.S. resources are estimated to be about 7 million kilograms. Rhenium also is associated with copper minerals in sedimentary deposits in Armenia, Kazakhstan, Poland, Russia, and Uzbekistan, where ore is processed for copper recovery and the rhenium-bearing residues are recovered at copper smelters.

Substitutes: Substitutes for rhenium in platinum-rhenium catalysts are continually being evaluated. Iridium and tin have achieved commercial success in one such application. Other metals being evaluated for catalytic use include gallium, germanium, indium, selenium, silicon, tungsten, and vanadium. The use of these and other metals in bimetallic catalysts might decrease rhenium’s share of the existing catalyst market; however, this would likely be offset by rhenium-bearing catalysts being considered for use in several proposed gas-to-liquid projects. Materials that can substitute for rhenium in various end uses are as follows: cobalt and tungsten for coatings on copper x-ray targets, rhodium and rhodium-iridium for high-temperature thermocouples, tungsten and platinum-ruthenium for coatings on electrical contacts, and tungsten and tantalum for electron emitters.

[e]Estimated. NA Not available.

[1]Based on 80% recovery of estimated rhenium contained in molybdenum disulfide concentrates. Secondary rhenium production is not included.

[2]Does not include wrought forms or waste and scrap. The rhenium content of ammonium perrhenate is 69.42%.

[3]Defined as production + imports – exports.

[4]Average price per kilogram of rhenium in pellets or catalytic-grade ammonium perrhenate. Source: Argus Media group—Argus Metals International.

[5]Defined as imports – exports.

[6]Estimated amount of rhenium recovered in association with copper and molybdenum production. Secondary rhenium production not included.

[7]See Appendix C for resource and reserve definitions and information concerning data sources.

[8]Estimated rhenium recovered from roaster residues from Belgium, Chile, Mexico, and Peru.

RUBIDIUM

(Data in metric tons of rubidium oxide unless otherwise noted)

Domestic Production and Use: In 2021, no rubidium was mined in the United States; however, occurrences of rubidium-bearing minerals are known in Alaska, Arizona, Idaho, Maine, South Dakota, and Utah. Rubidium is also associated with some evaporate mineral occurrences in other States. Rubidium is not a major constituent of any mineral. Rubidium concentrate is produced as a byproduct of pollucite (cesium) and lepidolite (lithium) mining and is imported from other countries for processing in the United States.

Applications for rubidium and its compounds include biomedical research, electronics, specialty glass, and pyrotechnics. Specialty glasses are the leading market for rubidium; rubidium carbonate is used to reduce electrical conductivity, which improves stability and durability in fiber-optic telecommunications networks. Biomedical applications include rubidium salts used in antishock agents and the treatment of epilepsy and thyroid disorder; rubidium-82, a radioactive isotope used as a blood-flow tracer in positron emission tomographic imaging; and rubidium chloride, used as an antidepressant. Rubidium atoms are used in academic research, including the development of quantum-mechanics-based computing devices, a future application with potential for relatively high consumption of rubidium. Quantum computing research uses ultracold rubidium atoms in a variety of applications. Quantum computers, which have the ability to perform more complex computational tasks than traditional computers by calculating in two quantum states simultaneously, were expected to be in prototype phase within 10 years.

Rubidium's photoemissive properties make it useful for electrical-signal generators in motion-sensor devices, night-vision devices, photoelectric cells (solar panels), and photomultiplier tubes. Rubidium is used as an atomic resonance-frequency-reference oscillator for telecommunications network synchronization, playing a vital role in global positioning systems. Rubidium-rich feldspars are used in ceramic applications for spark plugs and electrical insulators because of their high dielectric constant. Rubidium hydroxide is used in fireworks to oxidize mixtures of other elements and produce violet hues. The U.S. military frequency standard, the United States Naval Observatory (USNO) timescale, is based on 48 weighted atomic clocks, including 4 USNO rubidium fountain clocks.

Salient Statistics—United States: Consumption, export, and import data are not available. Some concentrate was imported to the United States for further processing. Industry information during the past decade suggests a domestic consumption rate of approximately 2,000 kilograms per year. The United States was 100% import reliant for rubidium minerals.

In 2021, one company offered 1-gram ampoules of 99.75%-grade rubidium (metal basis) for $93.40, a 5% increase from $89.00 in 2020, and 100-gram ampoules of the same material for $1,673.00, a 4% increase from $1,608.00 in 2020. The price for 10-gram ampoules of 99.8% rubidium formate hydrate (metal basis) was $262.00.

In 2021, the prices for 10 grams of 99.8% (metal basis) rubidium acetate, rubidium bromide, rubidium carbonate, rubidium chloride, and rubidium nitrate were $51.40, $71.20, $54.80, $62.70, and $48.50, respectively. The price for a rubidium-plasma standard solution (10,000 micrograms per milliliter) was $57.70 for 50 milliliters and $93.70 for 100 milliliters, a 17% and 16% increase, respectively, from those of 2020.

Recycling: None.

Import Sources (2017–20): No reliable data have been available to determine the source of rubidium ore imported by the United States since 1988. Prior to 2016, Canada was thought to be the primary supplier of rubidium ore.

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RUBIDIUM

Tariff: Item	Number	Normal Trade Relations 12–31–21
Alkali metals, other	2805.19.9000	5.5% ad valorem.
Chlorides, other	2827.39.9000	3.7% ad valorem.
Bromides, other	2827.59.5100	3.6% ad valorem.
Iodides, other	2827.60.5100	4.2% ad valorem.
Sulfates, other	2833.29.5100	3.7% ad valorem.
Nitrates, other	2834.29.5100	3.5% ad valorem.
Carbonates, other	2836.99.5000	3.7% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic rubidium occurrences will remain uneconomic unless market conditions change, such as the development of new end uses or increased consumption for existing end uses, which in turn could lead to increased prices. No known human health issues are associated with exposure to naturally occurring rubidium, and its use has minimal environmental impact.

During 2021, no rubidium production was reported globally but rubidium was thought to have been produced in China. Production of rubidium from all countries, excluding China, ceased within the past two decades. Production in Namibia ceased in the early 2000s, followed by the Tanco Mine in Canada shutting down and later being sold after a mine collapse in 2015. The Bikita Mine in Zimbabwe was depleted of pollucite ore reserves in 2018, and the Sinclair Mine in Australia completed the mining and shipments of all economically recoverable pollucite ore in 2019. Recent reports indicate that with current processing rates, the world's stockpiles of rubidium ore, excluding those in China, will be depleted by 2022.

The primary processing plant of rubidium compounds globally, located in Germany, has reportedly operated far below capacity for the past few years. A company completed an updated mineral resource estimate for the Karibib project in Namibia, reporting 8.9 million metric tons of measured and indicated resources containing 0.23% rubidium and 303 parts per million cesium. The company also reported 6.72 million metric tons of proven and probable reserves containing 2.26% rubidium and 320 parts per million cesium. Located in the Karibib Pegmatite Belt, lithium would be the primary product, with cesium, potassium, and rubidium as potential byproducts.

World Mine Production and Reserves:[1] There were no official sources for rubidium production data in 2021. Lepidolite and pollucite, the principal rubidium-containing minerals in global rubidium reserves, can contain up to 3.5% and 1.5% rubidium oxide, respectively. Rubidium-bearing mineral resources are found in zoned pegmatites. Mineral resources exist globally, but extraction and concentration are mostly cost prohibitive. No reliable data are available to determine reserves for specific countries; however, Australia, Canada, China, and Namibia were thought to have reserves totaling less than 200,000 tons. Existing stockpiles at multiple former mine sites have continued feeding downstream refineries.

World Resources:[1] Significant rubidium-bearing pegmatite occurrences have been identified in Afghanistan, Australia, Canada, China, Denmark, Germany, Japan, Kazakhstan, Namibia, Peru, Russia, the United Kingdom, the United States, and Zambia. Minor quantities of rubidium are reported in brines in northern Chile and China and in evaporites in the United States (New Mexico and Utah), France, and Germany.

Substitutes: Rubidium and cesium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material for some applications.

[1]See Appendix C for resource and reserve definitions and information concerning data sources.

SALT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Domestic production of salt was estimated to have decreased slightly in 2021 compared with that in 2020 to 40 million tons. The total value of salt sold or used was estimated to be about $2.5 billion. Twenty-six companies operated 63 plants in 16 States. The top producing States were Kansas, Louisiana, Michigan, New York, Ohio, Texas, and Utah. These seven States produced about 95% of the salt in the United States in 2021. The estimated percentage of salt sold or used was, by type, rock salt, 44%; salt in brine, 40%; vacuum pan salt, 10%; and solar salt, 6%.

Highway deicing accounted for about 42% of total salt consumed. The chemical industry accounted for about 39% of total salt sales, with salt in brine accounting for 90% of the salt used for chemical feedstock. Chlorine and caustic soda manufacturers were the main consumers within the chemical industry. The remaining markets for salt were distributors, 9%; food processing, 4%; agricultural, 2%; and general industrial and primary water treatment, 1% each. The remaining 2% was other uses combined with exports.

Salient Statistics—United States:[1]	2017	2018	2019	2020	2021[e]
Production	39,900	43,900	[e]42,000	[e]41,000	40,000
Sold or used by producers	38,700	44,200	[e]41,000	[e]40,000	39,000
Imports for consumption	12,600	17,900	18,600	15,800	16,000
Exports	1,130	986	1,020	1,250	1,000
Consumption:					
Apparent[2]	50,200	61,100	[e]58,000	[e]54,000	54,000
Reported	45,500	53,000	[e]50,000	[e]46,000	47,000
Price, average value of bulk, pellets and packaged salt, free on board (f.o.b.) mine and plant, dollars per ton:					
Vacuum and open pan salt	208.04	214.12	[e]215.00	[e]215.00	220.00
Solar salt	115.88	120.56	[e]125.00	[e]120.00	120.00
Rock salt	60.41	60.78	[e]59.00	[e]57.00	56.00
Salt in brine	9.49	8.30	[e]9.00	[e]9.00	9.00
Employment, mine and plant, number[e]	4,100	4,100	4,100	4,000	4,100
Net import reliance[3] as a percentage of apparent consumption	23	28	30	27	29

Recycling: None.

Import Sources (2017–20): Chile, 30%; Canada, 27%; Mexico, 12%; Egypt, 11%; and other, 20%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Salt (sodium chloride)	2501.00.0000	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The global COVID-19 pandemic affected production and consumption of salt throughout the world in 2020 and 2021. The chloralkali industry was most affected because international trade declined, but the entire salt sector was negatively affected to varying degrees.

For much of the 2020–21 winter, temperatures were near or above average with lower or average precipitation throughout most of the traditional U.S. snowbelt. The number of winter weather events including freezing rain, sleet, and snow is a better predictor of demand for rock salt than total snowfall. Several low snowfall or icing events usually require more salt for highway deicing than a single large snowfall event. Rock salt production and imports in 2021 were expected to be near or slightly less than those in 2020 because demand from many local and State transportation departments decreased. Most local and State governments in regions that experienced a less intense winter season reportedly had remaining stockpiles and therefore less need to replenish supplies of rock salt for the 2021–22 winter.

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SALT

For the 2021–22 winter, the National Oceanic and Atmospheric Administration predicted a La Niña weather pattern for the second consecutive year. A strong La Niña historically favors an average to warmer temperature pattern, but a moderate La Niña favors a colder winter. Based on several factors, the forecasts slightly favor higher precipitation than a normal winter for the Midwest, interior Northeast, and Northwest areas of the United States. All these areas were predicted to be warmer than average except for the Northwest, which is expected to receive more precipitation than average. A warmer and drier pattern than average was predicted for the southern areas of the United States. These forecasts would indicate that demand for rock salt could decrease in the Midwest and northeastern United States.

Demand for salt brine used in the chloralkali industry was expected to increase in 2022 as demand for caustic soda and polyvinyl chloride increases globally, especially in Asia. Salt exports from Australia and especially India have increased in recent years to meet the increasing demand in China, but tensions between China and both countries could affect trade.

World Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States[1]	[e]41,000	40,000	Large. Economic and subeconomic deposits of salt are substantial in principal salt-producing countries. The oceans contain a virtually inexhaustible supply of salt.
Australia	[e]11,000	12,000	
Brazil	[e]7,400	7,400	
Canada	[e]10,000	10,000	
Chile	9,570	10,000	
China	[e]63,000	64,000	
Djibouti	3,100	3,200	
France	[e]5,400	5,400	
Germany	15,300	15,000	
India	[e]29,000	29,000	
Iran	[e]2,600	2,600	
Italy	1,540	2,000	
Mexico	[e]9,000	9,000	
Netherlands	[e]6,000	6,200	
Pakistan	3,750	4,000	
Poland	3,780	4,000	
Russia	[e]8,100	8,000	
Saudi Arabia	2,640	2,700	
Spain	[e]4,200	4,200	
Turkey	[e]6,900	6,900	
Ukraine	[e]2,000	2,000	
United Kingdom	[e]4,700	4,700	
Other countries	[e]30,000	33,000	
World total (rounded)	280,000	290,000	

World Resources:[4] World continental resources of salt are vast, and the salt content in the oceans is nearly unlimited. Domestic resources of rock salt and salt from brine are primarily in Kansas, Louisiana, Michigan, New York, Ohio, and Texas. Saline lakes and solar evaporation salt facilities are in Arizona, California, Nevada, New Mexico, Oklahoma, and Utah. Almost every country in the world has salt deposits or solar evaporation operations of various sizes.

Substitutes: No economic substitutes or alternatives for salt exist in most applications. Calcium chloride and calcium magnesium acetate, hydrochloric acid, and potassium chloride can be substituted for salt in deicing, certain chemical processes, and food flavoring, but at a higher cost.

[e]Estimated.
[1]Excludes production from Puerto Rico.
[2]Defined as sold or used by producers + imports – exports.
[3]Defined as imports – exports.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.

SAND AND GRAVEL (CONSTRUCTION)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2021, 1.0 billion tons of construction sand and gravel valued at $9.9 billion was produced by an estimated 3,870 companies operating 6,800 pits and 340 sales and (or) distribution yards in 50 States. Leading producing States were, in order of decreasing tonnage, California, Texas, Arizona, Minnesota, Utah, Michigan, Washington, Ohio, Colorado, and New York, which together accounted for about 53% of total output. It is estimated that about 46% of construction sand and gravel was used as portland cement concrete aggregates, 21% for road base and coverings and road stabilization, 13% for construction fill, 12% for asphaltic concrete aggregate and for other bituminous mixtures, and 4% for other miscellaneous uses. The remaining 4% was used for concrete products, filtration, golf course maintenance, plaster and gunite sands, railroad ballast, road stabilization, roofing granules, and snow and ice control.

The estimated output of construction sand and gravel in the United States shipped for consumption in the first 9 months of 2021 was 753 million tons, an increase of 7% compared with that in the same period of 2020. Third quarter shipments for consumption increased by 4% compared with those in the same period of 2020. Additional production information, by quarter, for each State, geographic division, and the United States is reported by the U.S. Geological Survey in its quarterly Mineral Industry Surveys for crushed stone and sand and gravel.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production	888	912	935	942	1,000
Imports for consumption	7	6	5	5	4
Exports	([2])	([2])	([2])	([2])	([2])
Consumption, apparent[3]	895	918	940	947	1,000
Price, average value, dollars per metric ton	8.84	9.09	9.31	9.58	9.90
Employment, mine and mill, number[4]	36,500	38,600	39,600	37,900	36,000
Net import reliance[5] as a percentage of apparent consumption	1	1	1	1	([2])

Recycling: Road surfaces made of asphalt concrete and portland cement concrete surface layers, which contain sand and gravel aggregate, were recycled on a limited but increasing basis in most States. In 2021, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2017–20): Canada, 95%; Mexico, 3%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Sand, other	2505.90.0000	Free.
Pebbles and gravel	2517.10.0015	Free.

Depletion Allowance: Common varieties, 5% (domestic and foreign).

Government Stockpile: None.

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SAND AND GRAVEL (CONSTRUCTION)

<u>Events, Trends, and Issues</u>: Construction sand and gravel production was about 1.0 billion tons in 2021, an increase of 6% compared with that in 2020. Apparent consumption also increased by 6% to 1.0 billion tons. Consumption of construction sand and gravel increased in 2021 because of growth in the private and public construction markets. Usually, commercial and heavy-industrial construction activity, infrastructure funding, labor availability, new single-family housing unit starts, and weather affect growth in construction sand and gravel production and consumption. Long-term increases in construction aggregates demand are influenced by activity in the public and private construction sectors, as well as by construction work related to infrastructure improvements around the Nation. The underlying factors that would support a rise in prices of construction sand and gravel are expected to be present in 2022, especially in and near metropolitan areas.

The construction sand and gravel industry continued to be concerned with environmental, health, permitting, safety, and zoning regulations. On November 15, 2021, the Infrastructure Investment and Jobs Act was signed into law. The legislation will reauthorize surface transportation programs for 5 years and invest $110 billion in additional funding to repair roads and bridges and support major, transformational projects. Movement of sand and gravel operations away from densely populated regions was expected to continue where zoning regulations and local sentiment discouraged them. Resultant regional shortages of construction sand and gravel and higher fuel costs could result in higher-than-average price increases in industrialized and urban areas.

<u>World Mine Production and Reserves</u>:

	Mine production		Reserves[6]
	2020	2021[e]	
United States	942	1,000	Reserves are controlled largely by land use and (or) environmental concerns.
Other countries[7]	NA	NA	
World total	NA	NA	

<u>World Resources</u>:[6] Sand and gravel resources are plentiful throughout the world. However, because of environmental regulations, geographic distribution, and quality requirements for some uses, sand and gravel extraction is uneconomical in some cases. The most important commercial sources of sand and gravel have been glacial deposits, river channels, and river flood plains. Use of offshore deposits in the United States is mostly restricted to beach erosion control and replenishment. Other countries routinely mine offshore deposits of aggregates for onshore construction projects.

<u>Substitutes</u>: Crushed stone, the other major construction aggregate, is often substituted for natural sand and gravel, especially in more densely populated areas of the Eastern United States. Crushed stone remains the dominant choice for construction aggregate use. Increasingly, recycled asphalt and portland cement concretes are being substituted for virgin aggregate, although the percentage of total aggregate supplied by recycled materials remained very small in 2021.

[e]Estimated. NA Not available.
[1]See also Sand and Gravel (Industrial) and Stone (Crushed).
[2]Less than ½ unit.
[3]Defined as production + imports – exports.
[4]Including office staff. Source: Mine Safety and Health Administration.
[5]Defined as imports – exports.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]No reliable production information is available for most countries owing to the wide variety of ways in which countries report their sand and gravel production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the U.S. Geological Survey Minerals Yearbook, volume III, Area Reports—International.

SAND AND GRAVEL (INDUSTRIAL)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2021, industrial sand and gravel valued at an estimated $2.3 billion was produced by 167 companies from 248 operations in 33 States. The value of production of industrial sand and gravel in 2021 increased slightly compared with that in the previous year. The leading producing States were, in descending order of production, Texas, Wisconsin, Illinois, Missouri, Oklahoma, Louisiana, North Carolina, Alabama, California, Tennessee, New Jersey, and Minnesota. Combined production from these States accounted for about 86% of total domestic sales and use. Approximately 64% of the U.S. tonnage was used as hydraulic-fracturing sand and well-packing and cementing sand; 11% as other whole-grain silica; and 10% as glassmaking sand. Other uses were, in decreasing quantity of use, foundry sand, whole-grain fillers for building products, recreational sand, other ground silica sand, and silica gravel, which accounted for 12%, combined. Other minor uses were, in decreasing quantity of use, chemicals, abrasives, filtration sand, ceramics, roofing granules, fillers, traction, and metallurgic flux, combined, accounted for the remaining 3% of industrial sand and gravel end uses.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Sold or used	104,000	126,000	108,000	70,000	72,000
Imports for consumption	366	392	389	417	360
Exports	4,600	6,440	5,540	4,030	5,600
Consumption, apparent[2]	99,800	120,000	103,000	66,400	67,000
Price, average value, dollars per ton	52.10	56.10	46.10	30.70	33.00
Employment, quarry and mill, number[e]	4,000	4,000	3,500	2,000	2,500
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Some foundry sand is recycled, and recycled cullet (pieces of glass) represents a significant proportion of reused silica. About 33% of glass containers are recycled.

Import Sources (2017–20): Canada, 85%; Vietnam, 5%; Brazil and Taiwan, 2% each; and other, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Sand containing 95% or more silica and not more than 0.6% iron oxide	2505.10.1000	Free.

Depletion Allowance: Industrial sand or pebbles, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. apparent consumption of industrial sand and gravel was estimated to be 67 million tons in 2021, a slight increase from that of the previous year. The most important driving force in the industrial sand and gravel industry remained the production and sale of hydraulic-fracturing sand (frac sand). For several years, the consumption of frac sand increased as hydrocarbon exploration in the United States transitioned to natural gas and petroleum extracted from shale deposits. However, industrial sand and gravel consumption decreased in recent years, primarily as a result of decreased natural-gas- and petroleum-well drilling in North America and oil well completion activity. These decreases were exacerbated by restrictions imposed as the result of the global COVID-19 pandemic, which resulted in a significant decline in consumption of petroleum products, which in turn prompted a decrease in demand for hydraulic-fracturing sand. Imports of industrial sand and gravel in 2021 were an estimated 360,000 tons, a 14% decrease from those of the previous year. Imports of silica are generally of two types—small shipments of very high-purity silica or a few large shipments of lower grade silica shipped only under special circumstances (for example, very low freight rates). The United States remained a net exporter of industrial sand and gravel; U.S. exports of industrial sand and gravel increased by 39% in 2021 compared with those of the previous year.

The United States was the world's leading producer and consumer of industrial sand and gravel based on estimated world production figures. Collecting definitive data on industrial sand and gravel production in most nations is difficult because of the wide range of terminology and specifications used by different countries. The United States remained a major exporter of industrial sand and gravel, shipping it to almost every region of the world. High global demand for U.S. industrial sand and gravel can be attributed to the high quality and advanced processing techniques used in the United States for many grades of industrial sand and gravel, meeting specifications for virtually any use.

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SAND AND GRAVEL (INDUSTRIAL)

The duration and outcome of the global COVID-19 pandemic remains uncertain; however, measures previously instituted to mitigate the spread of the global COVID-19 pandemic are expected to continue to be eased or lifted in the United States and around the world. The pandemic is likely to have less of a negative effect on the economies of the United States and the world going forward, which could result in increased production and consumption of industrial sand and gravel.

Additionally, the industrial sand and gravel industry continued to be concerned with safety and health regulations and environmental restrictions in 2021, especially those concerning crystalline silica exposure. In 2016, the Occupational Safety and Health Administration (OSHA) finalized regulations to further restrict exposure to crystalline silica at quarry sites and in other industries that use materials containing it. Phased implementation of the new regulations took effect through 2021, affecting various industries that use materials containing silica. Local shortages of industrial sand and gravel were expected to continue to increase owing to land development priorities, local zoning regulations, and logistical issues, including ongoing development and permitting of operations producing hydraulic-fracturing sand. These factors may result in future sand and gravel operations being located farther from high-population centers.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2020	2021[e]	
United States	70,000	72,000	Large. Industrial sand and gravel deposits are widespread.
Argentina	2,500	3,500	
Australia	3,000	3,500	
Austria	1,570	1,600	
Bulgaria	8,350	8,400	
Canada	4,700	5,000	
France	11,000	11,000	
Guatemala	1,900	1,900	
India	11,900	12,000	
Indonesia	2,640	2,600	
Italy	10,000	10,000	
Japan	1,920	1,900	
Malaysia	3,700	4,000	
Mexico	2,700	3,000	
Netherlands	54,000	54,000	
Poland	5,490	5,500	
South Africa	2,300	2,200	
Spain	5,700	5,700	
Turkey	10,300	12,000	
United Kingdom	4,400	4,400	
Other countries	16,900	18,000	
World total (rounded)	235,000	240,000	

World Resources:[4] Sand and gravel resources of the world are large. However, because of their geographic distribution, environmental restrictions, and quality requirements for some uses, extraction of these resources is sometimes uneconomical. Quartz-rich sand and sandstone, the main sources of industrial silica sand, occur throughout the world.

Substitutes: Alternative materials that can be used for glassmaking and for foundry and molding sands are chromite, olivine, staurolite, and zircon sands. Although costlier and mostly used in deeper wells, alternative materials that can be used as proppants are sintered bauxite and kaolin-based ceramic proppants.

[e]Estimated. E Net exporter.
[1]See also Sand and Gravel (Construction).
[2]Defined as production (sold or used) + imports – exports.
[3]Defined as imports – exports.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.

SCANDIUM[1]

(Data in metric tons of scandium oxide equivalent unless otherwise noted)

Domestic Production and Use: Domestically, scandium was neither mined nor recovered from process streams or mine tailings in 2021. Previously, scandium was produced domestically primarily from the scandium-yttrium silicate mineral thortveitite and from byproduct leach solutions from uranium operations. Limited capacity to produce ingot and distilled scandium metal existed at facilities in Ames, IA; Tolleson, AZ; and Urbana, IL. The principal uses for scandium in 2021 were in aluminum-scandium alloys and solid oxide fuel cells (SOFCs). Other uses for scandium included ceramics, electronics, lasers, lighting, and radioactive isotopes.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Price, yearend:					
Compounds, dollars per gram:					
Acetate, 99.9% purity, 5-gram lot size[2]	44	44	45	45	43
Chloride, 99.9% purity, 5-gram lot size[2]	124	125	129	133	137
Fluoride, 99.9% purity, 1- to 5-gram lot size[3]	277	206	209	214	216
Iodide, 99.999% purity, 5-gram lot size[2]	183	165	157	161	161
Oxide, 99.99% purity, 5-kilogram lot size[4]	4.6	4.6	3.9	3.8	2.2
Metal:					
Scandium, distilled dendritic, 2-gram lot size,[2] dollars per gram	226	226	233	233	238
Scandium, ingot, 5-gram lot size,[2] dollars per gram	132	132	134	134	137
Scandium-aluminum alloy, 1-kilogram lot size,[4] dollars per kilogram	350	360	300	340	350
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2017–20): Although no definitive data exist listing import sources, imported material was thought to be mostly from Europe, China, Japan, and Russia.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Rare-earth metals, unspecified	2805.30.0000	5.0% ad valorem.
Compounds of rare-earth metals:		
Mixtures of oxides of yttrium or scandium as the predominant metal	2846.90.2015	Free.
Mixtures of chlorides of yttrium or scandium as the predominant metal	2846.90.2082	Free.
Mixtures of other rare-earth carbonates, including scandium	2846.90.8075	3.7% ad valorem.
Mixtures of other rare-earth compounds, including scandium	2846.90.8090	3.7% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The global supply and consumption of scandium oxide was estimated to be about 15 to 25 tons per year. Scandium was recovered from titanium, zirconium, cobalt, and nickel process streams. China, the Philippines, and Russia were the leading producers. Prices quoted for scandium oxide in the United States in 2021 decreased significantly compared with those in 2020. Owing in part to low capacity utilization, China's ex-works prices for scandium oxide were significantly less than United States quoted prices.

In the United States, a new metallurgical testing program for production of scandium recently achieved success at the bench scale for the Nebraska polymetallic Elk Creek project where additional financing for construction was being sought. Probable reserves were estimated to be 36 million tons containing 65.7 parts per million (2,400 tons) scandium. Plans for the project included downstream production of ferroniobium, titanium dioxide, and scandium oxide. At the La Paz Scandium and Rare Earths project in Arizona, necessary permits and approvals were in place for the core drilling campaign to determine if a primary scandium mine could be established.

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SCANDIUM

The Bokan project in Alaska and the Round Top project in Texas also included scandium recovery in their process plans. In addition, research continued to develop methods for separating scandium from coal and coal byproducts. SOFC sourcing of scandium is expanding beyond China to include Japan and the Philippines.

A global mining and polymetallic metal producer announced the commissioning of a new scandium plant in Sorel-Tracy, Quebec, Canada, with a capacity of 3 tons per year of 99.99% scandium oxide. The company announced completion of the first sale of high-performance aluminum-scandium alloy for metal additive manufacturing. In Australia, several polymetallic projects were under development and seeking permitting, financing, and offtake agreements. Projects and prospects included the Nyngan, Owendale, and Sunrise projects in New South Wales along with others. The SCONI project commissioned the construction phase of its pilot P-CAM production plant in North Queensland.

In the Philippines, a 7.5-ton-per-year scandium oxide equivalent commercial plant designed to recover scandium at the Taganito high-pressure acid-leach nickel operation produced an estimated gross output of about 13 dry tons of scandium oxalate in 2020 with 2021 first quarter production of 3.6 tons. In Russia, feasibility studies for making scandium oxide as a byproduct of alumina refining at a smelter in the Ural Mountains were ongoing. The pilot plant was reported to have produced scandium oxide with purity greater than 99%. Based on pilot-plant test results, plans were in place for a 3-ton-per-year scandium oxide plant. In the Kurgan region of Russia, two mobile sorption plants were put into operation and two additional sorption columns were mounted directly at the plant site with extractive purification technology to obtain scandium oxide with a purity of 99.9%. Another technology made it possible for production aluminum-scandium alloys as byproduct of uranium production. In 2019 (the most recent year for which there were published data), commercial production at the scandium project was 230 kilograms of metal produced and shipped to customers. At Agios Nikolaos, Greece, a pilot plant successfully demonstrated recovery of scandium from bauxite residue in industrial waste at a vertically integrated aluminum and alumina plant through a patented selective ion recovery technology as part of the European Union’s Horizon 2020 research and development program.

The Kiviniemi scandium project in eastern Finland features a resource of 13.4 million tons at a grade of 163 parts per million scandium where scandium is mainly incorporated into the lattice of clinopyroxene and amphibole.

In China, a large state-owned enterprise in Shanghai was producing 50 tons per year of scandium oxide raw material with a long-term expected capacity of 100 tons per year. Another company in Henan Province had a 10-ton-per-year scandium oxide capacity with plans to increase annual output to 20 tons.

World Mine Production and Reserves:[6] No scandium was recovered from mining operations in the United States. As a result of its low concentration, scandium is produced exclusively as a byproduct during processing of various ores or recovered from previously processed tailings or residues. Historically, scandium was produced as byproduct material in China (iron ore, rare earths, titanium, and zirconium), Kazakhstan (uranium), the Philippines (nickel), Russia (apatite and uranium), and Ukraine (uranium). Foreign mine production data for 2020 and 2021 were not available.

World Resources:[6] Resources of scandium are abundant. Scandium’s crustal abundance is greater than that of lead. Scandium lacks affinity for the common ore-forming anions; therefore, it is widely dispersed in the lithosphere and forms solid solutions with low concentrations in more than 100 minerals. Scandium resources have been identified in Australia, Canada, China, Finland, Guinea, Kazakhstan, Madagascar, Norway, South Africa, the Philippines, Russia, Ukraine, and the United States.

Substitutes: Titanium and aluminum high-strength alloys as well as carbon-fiber materials may substitute in high-performance scandium-alloy applications. Under certain conditions, light-emitting diodes may displace mercury-vapor high-intensity lamps that contain scandium iodide. In some applications that rely on scandium’s unique properties, substitution is not possible.

[e]Estimated.
[1]See also Rare Earths. Scandium is one of the 17 rare-earth elements.
[2]Source: Alfa Aesar, a part of Thermo Fisher Scientific Inc.
[3]Source: Sigma-Aldrich, a part of MilliporeSigma.
[4]Source: Stanford Materials Corp.
[5]Defined as imports – exports. Quantitative data are not available.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.

SELENIUM

(Data in metric tons of contained selenium unless otherwise noted)

Domestic Production and Use: In 2021, the only domestic selenium-producing copper refinery halted production of refined selenium but produced selenium-bearing anode slime. The two other electrolytic copper refineries, operating in Arizona and Utah, did not recover selenium domestically, but did produce selenium-bearing anode slimes. U.S. selenium production in prior years and consumption and stock data were withheld to avoid disclosing company proprietary data. Estimates for end uses in global consumption were, in descending order, metallurgy (including manganese production), glass manufacturing, agriculture, chemicals and pigments, electronics, and other uses.

Selenium is used in blasting caps to control delays; in catalysts to enhance selective oxidation; in copper, lead, and steel alloys to improve machinability; in the electrolytic production of manganese to increase yields; in glass manufacturing to decolorize the green tint caused by iron impurities in container glass and other soda-lime silica glass; in gun bluing to improve cosmetic appearance and provide corrosion resistance; in plating solutions to improve appearance and durability; in rubber compounding chemicals to act as a vulcanizing agent; and in thin-film photovoltaic copper-indium-gallium-diselenide (CIGS) solar cells.

Selenium is an essential micronutrient and is used as a human dietary supplement, a dietary supplement for livestock, and as a fertilizer additive to enrich selenium-poor soils. Selenium is also used as an active ingredient in antidandruff shampoos.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, refinery	W	W	W	W	—
Imports for consumption:					
Selenium metal	450	445	496	366	360
Selenium dioxide	19	12	5	18	77
Exports,[1] metal	242	158	361	147	240
Consumption, apparent,[2] metal	W	W	W	W	W
Price, average,[3] dollars per pound	15.55	16.85	9.15	6.61	8.00
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption, metal	E	<25	<25	<50	>75

Recycling: Domestic production of secondary selenium was estimated to be very small because most scrap from older plain paper photocopiers and electronic materials was exported for recovery of the contained selenium.

Import Sources (2017–20): Selenium metal: Philippines, 18%; China,[5] 16%; Mexico, 14%; Germany, 13%; and other, 39%. Selenium dioxide: Republic of Korea, 29%; China, 24%; Germany, 18%; Canada, 14%; and other, 15%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Selenium metal	2804.90.0000	Free.
Selenium dioxide	2811.29.2000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The supply of selenium is directly affected by the supply of the materials from which it is a byproduct—copper and, to a lesser extent, nickel—and it is directly affected by the number of facilities that recover selenium. The estimated annual average price for selenium was $8.00 per pound in 2021, a 21% increase from that in 2020. Average weekly prices have risen steadily from the beginning of 2021. Copper producers in China had opted to stop sales from their inventories, reducing availability of selenium. Selenium prices increased owing to a rise in crude selenium feedstock costs.

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SELENIUM

In China, selenium suppliers and consumers both experienced difficulties acquiring adequate materials. Electrolytic manganese production was the main metallurgical end use for selenium in China, where selenium dioxide was used in the electrolytic process to increase current efficiency and the metal deposition rate. Manganese production decreased in 2021, owing to output reductions by major manganese producers in China. The reductions were put in place to reduce spot availability and raise prices. The manganese industry alliance had a commitment to shut down operations for 30 days every 4 months, with a total of 90 days in 2021.

World Refinery Production and Reserves:

	Refinery production[6]		Reserves[7]
	2020	2021[e]	
United States	W	—	10,000
Belgium	200	200	—
Canada	60	60	6,000
China	1,200	1,100	26,000
Finland	84	100	—
Germany	300	300	—
India	14	10	—
Japan	740	750	—
Peru	35	40	13,000
Poland	74	65	3,000
Russia	340	300	20,000
Sweden	10	20	—
Turkey	50	50	—
Other countries[8]	14	25	22,000
World total (rounded)	[9]3,120	3,000	100,000

World Resources:[7] Reserves for selenium are based on identified copper deposits and average selenium content. Coal generally contains between 0.5 and 12 parts per million selenium, or about 80 to 90 times the average for copper deposits. The recovery of selenium from coal fly ash, although technically feasible, does not appear likely to be economical in the foreseeable future.

Substitutes: Silicon is the major substitute for selenium in low- and medium-voltage rectifiers. Organic pigments have been developed as substitutes for cadmium sulfoselenide pigments. Other substitutes include cerium oxide as either a colorant or decolorant in glass; tellurium in pigments and rubber; bismuth, lead, and tellurium in free-machining alloys; and bismuth and tellurium in lead-free brasses. Sulfur dioxide can be used as a replacement for selenium dioxide in the production of electrolytic manganese metal, but it is not as energy efficient.

The selenium-tellurium photoreceptors used in some plain paper copiers and laser printers have been replaced by organic photoreceptors in newer machines. Amorphous silicon and cadmium telluride are the two principal competitors with CIGS in thin-film photovoltaic solar cells.

[e]Estimated. E Net exporter. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]There was no exclusive Schedule B number for selenium dioxide exports.
[2]Defined as production + imports – exports + adjustments for industry stock changes.
[3]Selenium metal powder, free on board, U.S. warehouse, minimum 99.5% purity. Source: Argus Media group—Argus Metals International.
[4]Defined as imports – exports + adjustments for industry stock changes; export data are incomplete for common forms of selenium, which may be exported under unexpected or misidentified forms, such as copper slimes, copper selenide, or zinc selenide.
[5]Includes Hong Kong.
[6]Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in blister copper, copper concentrates, copper ores, and (or) refinery residues but did not recover refined selenium from these materials indigenously were excluded to avoid double counting.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]Australia, Iran, Kazakhstan, Mexico, the Philippines, and Uzbekistan are known to produce refined selenium, but output was not reported, and information was inadequate to make reliable production estimates.
[9]Excludes U.S. production.

SILICON

(Data in thousand metric tons of contained silicon unless otherwise noted)

Domestic Production and Use: Six companies produced silicon materials in 2021, all east of the Mississippi River. Most ferrosilicon was consumed in the ferrous foundry and steel industries, predominantly in the Eastern United States, and was sourced primarily from domestic quartzite (silica). The main consumers of silicon metal were producers of aluminum alloys and the chemical industry, in particular for the manufacture of silicones. The semiconductor and solar energy industries, which manufacture chips for computers and photovoltaic cells from high-purity silicon, respectively, also consumed silicon metal.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, ferrosilicon[1] and silicon metal[2]	415	430	310	277	310
Imports for consumption:					
Ferrosilicon, all grades	147	140	127	140	120
Silicon metal	136	116	124	97	93
Exports:					
Ferrosilicon, all grades	11	12	8	4	7
Silicon metal	71	45	40	31	57
Consumption, apparent,[3] ferrosilicon[1] and silicon metal[2]	616	637	517	481	459
Price, average, cents per pound of silicon:					
Ferrosilicon, 50% Si[4]	94.47	104.24	102.35	103.38	110.00
Ferrosilicon, 75% Si[5]	86.88	107.58	89.15	87.40	140.00
Silicon metal[2, 5]	116.56	134.15	105.70	96.84	140.00
Stocks, producer, ferrosilicon[1] and silicon metal,[2] yearend	26	19	15	12	11
Net import reliance[6] as a percentage of apparent consumption:					
Ferrosilicon, all grades	<50	<50	<50	>50	<50
Silicon metal[2]	<50	<50	<50	<50	<50
Total	33	32	40	42	32

Recycling: Insignificant.

Import Sources (2017–20): Ferrosilicon: Russia, 40%; Canada, 14%; Brazil, 10%; Iceland, 8%; and other, 28%. Silicon metal: Brazil, 30%; Canada, 21%; Norway, 13%; Australia, 8%; and other, 28%. Total: Russia, 21%; Brazil, 20%; Canada, 17%; Norway, 7%; and other, 35%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Silicon, more than 99.99% Si	2804.61.0000	Free.
Silicon, 99.00%–99.99% Si	2804.69.1000	5.3% ad valorem.
Silicon, other	2804.69.5000	5.5% ad valorem.
Ferrosilicon, 55%–80% Si:		
More than 3% Ca	7202.21.1000	1.1% ad valorem.
Other	7202.21.5000	1.5% ad valorem.
Ferrosilicon, 80%–90% Si	7202.21.7500	1.9% ad valorem.
Ferrosilicon, more than 90% Si	7202.21.9000	5.8% ad valorem.
Ferrosilicon, other:		
More than 2% Mg	7202.29.0010	Free.
Other	7202.29.0050	Free.

Depletion Allowance: Quartzite, 14% (domestic and foreign); gravel, 5% (domestic and foreign).

Government Stockpile: None.

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SILICON

Events, Trends, and Issues: Combined domestic ferrosilicon and silicon metal production in 2021, expressed in terms of contained silicon, increased from that in 2020. One producer reopened its ferrosilicon production facility in March 2021 owing to increased demand for ferrosilicon products and improved domestic pricing. The facility had closed in July 2020 owing to decreased demand and lower prices—in part because of the global COVID-19 pandemic, as well as competition from lower priced imported ferrosilicon. Domestic production during the first 8 months of 2021 was about 5% more, on a silicon-content basis, than that during the same period in 2020. By August 2021, average U.S. spot market prices increased by almost 9% for 50%-grade ferrosilicon and by almost 60% for 75%-grade ferrosilicon compared with the annual averages in 2020; the average silicon metal spot market price increased by almost 50% compared with the annual average spot price in 2020.

Excluding the United States, ferrosilicon accounted for almost 70% of world silicon production on a silicon-content basis in 2021. The leading countries for ferrosilicon production were, in descending order and on a silicon-content basis, China, Russia, and Norway. For silicon metal, the leading producers were China, Brazil, and Norway. China accounted for approximately 70% of total global estimated production of silicon materials in 2021. Global production of silicon materials, on a silicon-content basis, was estimated to be about 5% more than that in 2020. Global production of steel, the leading use of ferrosilicon, increased in 2021 compared with production in 2020 owing to increased demand following the negative effects of the global COVID-19 pandemic.

World Production and Reserves:

	Production[7]		Reserves[8]
	2020	2021[e]	
United States	277	310	The reserves in most major producing countries are ample in relation to demand. Quantitative estimates are not available.
Australia	42	42	
Bhutan[9]	67	70	
Brazil	404	390	
Canada	47	50	
China	5,600	6,000	
France	112	120	
Iceland	103	110	
India[9]	59	60	
Kazakhstan	67	67	
Malaysia[9]	109	80	
Norway	345	350	
Poland	42	42	
Russia	576	580	
Spain	55	58	
Ukraine[9]	40	49	
Other countries	175	160	
World total (rounded)	8,120	8,500	

World Resources:[8] World and domestic resources for making silicon metal and alloys are abundant and, in most producing countries, adequate to supply world requirements for many decades. The source of the silicon is silica in various natural forms, such as quartzite.

Substitutes: Aluminum, silicon carbide, and silicomanganese can be substituted for ferrosilicon in some applications. Gallium arsenide and germanium are the principal substitutes for silicon in semiconductor and infrared applications.

[e]Estimated.
[1]Ferrosilicon grades include the two standard grades of ferrosilicon—50% silicon and 75% silicon—plus miscellaneous silicon alloys.
[2]Metallurgical-grade silicon metal.
[3]Defined as production + imports – exports + adjustments for industry stock changes.
[4]Source: CRU Group, transaction prices based on weekly averages.
[5]Source: S&P Global Platts Metals Week, mean import prices based on monthly averages.
[6]Defined as imports – exports + adjustments for industry stock changes.
[7]Production quantities are the silicon content of combined totals for ferrosilicon and silicon metal, except as noted.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]Silicon content of ferrosilicon only.

SILVER

(Data in metric tons[1] of contained silver unless otherwise noted)

Domestic Production and Use: In 2021, U.S. mines produced approximately 1,000 tons of silver with an estimated value of $830 million. Silver was produced at 4 silver mines and as a byproduct or coproduct from 33 domestic base- and precious-metal operations. Alaska continued as the country's leading silver-producing State, followed by Nevada. There were 24 U.S. refiners that reported production of commercial-grade silver with an estimated total output of 2,000 tons from domestic and foreign ores and concentrates and from new and old scrap. The physical properties of silver include high ductility, electrical conductivity, malleability, and reflectivity. In 2021, the estimated domestic uses for silver were physical investment, 26%; electrical and electronics, 21%; coins and medals, 11%; jewelry and silverware, 4%; and other, 38%. Other applications for silver include use in antimicrobial bandages, clothing, pharmaceuticals, and plastics; batteries; bearings; brazing and soldering; catalytic converters in automobiles; electroplating; inks; mirrors; photography; photovoltaic solar cells; water purification; and wood treatment. Mercury and silver, the main components of dental amalgam, are biocides, and their use in amalgam inhibits recurrent decay.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine	1,030	934	981	1,030	1,000
Refinery:					
Primary	1,420	1,420	1,420	1,420	1,400
Secondary (new and old scrap)	490	632	643	640	650
Imports for consumption[2]	5,040	4,840	4,770	6,740	6,500
Exports[2]	157	603	220	140	160
Consumption, apparent[3]	6,400	5,790	6,290	8,260	8,000
Price, bullion, average, dollars per troy ounce[4]	17.08	15.73	16.24	20.58	25.00
Stocks, yearend:					
Industry	150	170	52	60	60
Treasury[5]	498	498	498	498	498
New York Commodities Exchange—COMEX	7,570	9,150	9,860	12,330	11,000
Employment, mine and mill, number[6]	1,050	982	1,000	1,180	1,500
Net import reliance[7] as a percentage of apparent consumption	76	73	74	80	79

Recycling: In 2021, approximately 650 tons of silver was recovered from new and old scrap, about 8% of apparent consumption.

Import Sources (2017–20):[2] Mexico, 47%; Canada, 23%; Chile, 4%; Poland, 4%; and other, 22%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Silver ores and concentrates	2616.10.0040	0.8 ¢/kg on lead content.
Bullion	7106.91.1010	Free.
Dore	7106.91.1020	Free.

Depletion Allowance: 15% (domestic), 14% (foreign).

Government Stockpile: The U.S. Department of the Treasury maintains stocks of silver (see salient statistics above).

Events, Trends, and Issues: The estimated average silver price in 2021 was $25.00 per troy ounce, 22% higher than the average price in 2020. The price began the year at $27.51 per troy ounce, increased to a high of $29.45 per troy ounce on February 1, then decreased to a low of $21.75 per troy ounce on September 30. The price of silver generally decreased throughout the year. The February 1 daily price was the highest since December 11, 2020. U.S. investment was a major contributing factor to the rise in silver prices. Increased investment was driven by novice buyers from nontraditional sources in late January and early February.

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SILVER

In 2021, global consumption of silver was estimated to have increased slightly from that in 2020. Coin and bar consumption increased in 2021 for the fifth year in a row, led by U.S. investments. In 2021, physical investment in the United States in silver reached an estimated 7,900 tons (250 million troy ounces) compared with 6,240 tons (201 million troy ounces) in 2020. This was partially offset by an 85% decrease in investments in India. Consumption for industrial uses was estimated to have increased in the first 6 months of 2021 owing to the reopening of economies. Consumption of silver in jewelry and silverware was estimated to have increased by 24% and 32%, respectively. Despite decreased investment in India, global physical holdings of silver reached a reported 36,600 tons (1.18 billion troy ounces) compared with 33,200 tons (1.07 billion troy ounces) in 2020.[8]

World silver mine production increased slightly in 2021 to an estimated 24,000 tons, principally as a result of increased production from mines in Argentina, India, Mexico, and Peru following shutdowns in 2020 in response to the global COVID-19 pandemic. Domestic silver mine production was estimated to have decreased by 3% in 2021 to 1,000 tons compared with the 1,030 tons produced in 2020.

World Mine Production and Reserves: Reserves for Australia, Peru, and Poland were revised based on information from Government sources.

	Mine production		Reserves[9]
	2020	2021[e]	
United States	1,030	1,000	26,000
Argentina	710	800	NA
Australia	1,340	1,300	[10]90,000
Bolivia	930	1,000	22,000
Chile	1,580	1,600	26,000
China	3,380	3,400	41,000
Kazakhstan	435	450	NA
Mexico	5,540	5,600	37,000
Peru	2,770	3,000	120,000
Poland	1,250	1,300	67,000
Russia	1,320	1,300	45,000
Other countries	3,230	3,100	57,000
World total (rounded)	23,500	24,000	530,000

World Resources:[9] Although silver was a principal product at several mines, silver was primarily obtained as a byproduct from lead-zinc, copper, and gold mines, in descending order of production. The polymetallic ore deposits from which silver was recovered account for more than two-thirds of U.S. and world resources of silver. Most recent silver discoveries have been associated with gold occurrences; however, copper and lead-zinc occurrences that contain byproduct silver will continue to account for a significant share of reserves and resources in the future.

Substitutes: Digital imaging, film with reduced silver content, silverless black-and-white film, and xerography substitute for traditional photographic applications for silver. Surgical pins and plates may be made with stainless steel, tantalum, and titanium in place of silver. Stainless steel may be substituted for silver flatware. Nonsilver batteries may replace silver batteries in some applications. Aluminum and rhodium may be used to replace silver that was traditionally used in mirrors and other reflecting surfaces. Silver may be used to replace more costly metals in catalytic converters for off-road vehicles.

[e]Estimated. NA Not available.

[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.

[2]Silver content of base metal ores and concentrates, ash and residues, refined bullion, and dore; excludes coinage, and waste and scrap material.

[3]Defined as mine production + secondary production + imports – exports + adjustments for Government and industry stock changes.

[4]Engelhard's industrial bullion quotations. Source: S&P Global Platts Metals Week.

[5]Source: U.S. Mint. Balance in U.S. Mint only; includes deep storage and working stocks.

[6]Source: U.S. Department of Labor, Mine Safety and Health Administration (MSHA). Only includes mines where silver is the primary product. In 2021, MSHA changed the Mine Employment values in their publicly available database.

[7]Defined as imports – exports + adjustments for Government and industry stock changes.

[8]DiRienzo, Michael, and Newman, Philip, 2020, Key components of silver market affected by pandemic in 2020—Global demand and mine supply impacted, while physical silver investment expected to surge to a 5-year high: Silver Institute and Metal Focus, November 19, 2 p.

[9]See Appendix C for resource and reserve definitions and information concerning data sources.

[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 25,000 tons.

SODA ASH

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The total value of domestic natural soda ash (sodium carbonate) produced in 2021 was estimated to be about $1.8 billion[1], and the quantity produced was 12 million tons, about 20% more than that of the previous year. The U.S. soda ash industry comprised four companies in Wyoming operating five plants and one company in California operating one plant. The five producing companies have a combined annual nameplate capacity of 13.9 million tons (15.3 million short tons). Borax, salt, and sodium sulfate were produced as coproducts of sodium carbonate production in California. Chemical caustic soda, sodium bicarbonate, and sodium sulfite were manufactured as coproducts at several of the Wyoming soda ash plants. Sodium bicarbonate was produced at an operation in Colorado using soda ash feedstock shipped from the company's Wyoming facility.

Based on 2021 quarterly reports, the estimated distribution of soda ash by end use was glass, 49%; chemicals, 28%; miscellaneous uses, 8%; distributors, 5%; soap and detergents, 5%; flue gas desulfurization, 3%; pulp and paper, 1%; and water treatment, 1%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production[2]	12,000	11,900	11,700	9,990	12,000
Imports for consumption	19	51	115	98	80
Exports	6,990	6,960	7,020	5,590	6,500
Consumption:					
Apparent[3]	5,040	4,980	4,830	4,480	5,400
Reported	4,910	4,850	4,720	4,440	5,300
Price, average sales value (natural source), free on board (f.o.b.) mine or plant:					
Dollars per metric ton	146.26	148.69	153.24	145.67	155
Dollars per short ton	132.68	134.89	139.02	132.15	141
Stocks, producer, yearend	293	297	289	305	290
Employment, mine and plant, number[e]	2,600	2,600	2,600	2,400	2,400
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: No soda ash was recycled by producers; however, glass container producers use cullet glass, thereby reducing soda ash consumption.

Import Sources (2017–20): Turkey, 81%; Bulgaria and Mexico, 4% each; and other, 11%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Disodium carbonate	2836.20.0000	1.2% ad valorem.

Depletion Allowance: Natural, 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Production, exports, and consumption in 2021 nearly returned to levels seen before the global COVID-19 pandemic. More than one-half of U.S. production of soda ash was exported, and exports were estimated to have increased by 16% compared with those in 2020. Domestic consumption reported by producers increased by about 19% in 2021 compared with that in 2020, and apparent consumption in 2021 increased by about 21% compared with that in 2020.

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SODA ASH

Relatively low production costs and lower environmental impacts provide natural soda ash producers some advantage over producers of synthetic soda ash. The production of synthetic soda ash normally consumes more energy and releases more carbon dioxide than that of natural soda ash. In recent years, U.S. producers of natural soda ash were able to expand their markets when several synthetic soda ash plants were closed or idled in other parts of the world.

After increasing capacity during the past 4 years, total production capacity in Turkey was estimated to be between 4 million and 5 million tons per year, and soda ash shipments in Turkey, especially for export, were expected to increase during the next few years. Total United States imports, mostly from Turkey, have recently been about 100,000 tons per year, which was more than double the average quantity of annual imports during the past decade.

World Mine Production and Reserves: Reserves for Turkey were revised based on Government and industry reports.

	Mine production		Reserves[5, 6]
	2020	2021[e]	
Natural:			
United States	9,990	12,000	[7]23,000,000
Botswana	250	260	400,000
Ethiopia	18	20	400,000
Kenya	220	250	7,000
Turkey	4,200	4,400	880,000
Other countries	NA	NA	280,000
World total, natural (rounded)	14,700	17,000	25,000,000
World total, synthetic (rounded)	40,400	42,000	XX
World total (rounded)	55,100	59,000	XX

World Resources:[6] Natural soda ash is obtained from trona and sodium carbonate-rich brines. The world's largest deposit of trona is in the Green River Basin of Wyoming. About 47 billion tons of identified soda ash resources could be recovered from the 56 billion tons of bedded trona and the 47 billion tons of interbedded or intermixed trona and halite, which are in beds more than 1.2 meters thick. Underground room-and-pillar mining, using conventional and continuous mining, is the primary method of mining Wyoming trona ore. This method has an average 45% mining recovery, whereas average recovery from solution mining is 30%. Improved solution-mining techniques, such as horizontal drilling to establish communication between well pairs, could increase this extraction rate and enable companies to develop some of the deeper trona beds. Wyoming trona resources are being depleted at the rate of about 15 million tons per year (8.3 million tons of soda ash). Searles Lake and Owens Lake in California contain an estimated 815 million tons of soda ash reserves. At least 95 natural sodium carbonate deposits have been identified in the world, the resources of only some of which have been quantified. Although soda ash can be manufactured from salt and limestone, both of which are practically inexhaustible, synthetic soda ash is costlier to produce and generates environmental wastes.

Substitutes: Caustic soda can be substituted for soda ash in certain uses, particularly in the pulp and paper, water treatment, and certain chemical sectors. Soda ash, soda liquors, or trona can be used as feedstock to manufacture chemical caustic soda, which is an alternative to electrolytic caustic soda.

[e]Estimated. E Net exporter. NA Not available. XX Not applicable.
[1]Does not include values for soda liquors and mine waters.
[2]Natural only.
[3]Defined as production + imports – exports + adjustments for industry stock changes.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]The reported quantities are sodium carbonate only. About 1.8 tons of trona yield 1 ton of sodium carbonate.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]From trona, nahcolite, and dawsonite deposits.

STONE (CRUSHED)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2021, 1.5 billion tons of crushed stone valued at more than $19 billion was produced by an estimated 1,410 companies operating 3,440 quarries and 180 sales and (or) distribution yards in 50 States. Leading States were, in descending order of production, Texas, Missouri, Florida, Pennsylvania, Ohio, Georgia, North Carolina, Virginia, California, and Tennessee, which together accounted for about 54% of total crushed stone output. Of the total domestic crushed stone produced in 2021, about 70% was limestone and dolomite; 15%, granite; 6%, traprock; 5%, miscellaneous stone; 3%, sandstone and quartzite; and the remaining 1% was divided, in descending order of tonnage, among marble, volcanic cinder and scoria, calcareous marl, slate, and shell. It is estimated that about 72% of crushed stone was used as a construction aggregate, mostly for road construction and maintenance; 16% for cement manufacturing; 8% for lime manufacturing; 2% for agricultural uses; and the remaining 2% for other chemical, special, and miscellaneous uses and products.

The estimated output of crushed stone in the United States shipped for consumption in the first 9 months of 2021 was 1.14 billion tons, an increase of 3% compared with that in the same period of 2020. Third quarter shipments for consumption increased by 4% compared with those in the same period of 2020. Additional production information, by quarter, for each State, geographic division, and the United States is reported by the U.S. Geological Survey in its quarterly Mineral Industry Surveys for crushed stone and sand and gravel.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production	1,370	1,390	1,490	1,470	1,500
Recycled material	43	38	38	38	38
Imports for consumption	19	21	24	20	18
Exports	1	([2])	([2])	([2])	([2])
Consumption, apparent[3]	1,430	1,450	1,550	1,530	1,600
Price, average value, dollars per metric ton	11.36	11.64	11.96	12.22	13.00
Employment, quarry and mill, number[4]	68,600	68,500	69,000	67,000	67,000
Net import reliance[5] as a percentage of apparent consumption	1	1	2	1	1

Recycling: Road surfaces made of asphalt concrete and portland cement concrete surface layers, which contain crushed stone aggregate, were recycled on a limited but increasing basis in most States. In 2021, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2017–20): Mexico, 54%; Canada, 28%; The Bahamas, 12%; Honduras, 5%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Chalk:		
Crude	2509.00.1000	Free.
Other	2509.00.2000	Free.
Limestone, except pebbles and gravel	2517.10.0020	Free.
Crushed or broken stone	2517.10.0055	Free.
Marble granules, chippings and powder	2517.41.0000	Free.
Stone granules, chippings and powders	2517.49.0000	Free.
Limestone flux; limestone and other calcareous stone	2521.00.0000	Free.

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STONE (CRUSHED)

Depletion Allowance: For some special uses, 14% (domestic and foreign); if used as ballast, concrete aggregate, riprap, road material, and similar purposes, 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Crushed stone production was about 1.5 billion tons in 2021, an increase of 3% compared with 1.47 billion tons in 2020. Apparent consumption also increased to 1.6 billion tons. Consumption of crushed stone increased in 2021 because of growth in the private and public construction markets. Usually, commercial and heavy-industrial construction activity, infrastructure funding, labor availability, new single-family housing unit starts, and weather affect growth in crushed stone production and consumption. Long-term increases in construction aggregates demand are influenced by activity in the public and private construction sectors, as well as by construction work related to infrastructure improvements around the Nation. The underlying factors that would support a rise in prices of crushed stone are expected to be present in 2022, especially in and near metropolitan areas.

The crushed stone industry continued to be concerned with environmental, health, safety, and zoning regulations. On November 15, 2021, the Infrastructure Investment and Jobs Act was signed into law. The legislation will reauthorize surface transportation programs for 5 years and invest $110 billion in additional funding to repair roads and bridges and support major, transformational projects. Shortages in some urban and industrialized areas are expected to continue to increase owing to local zoning regulations and land-development alternatives. These issues are expected to continue and to cause new crushed stone quarries to be located away from large population centers. Resultant regional shortages of crushed stone and higher fuel costs could result in higher-than-average price increases in industrialized and urban areas.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States	1,470	1,500	Adequate, except where special
Other countries[7]	NA	NA	types are needed or where local
World total	NA	NA	shortages exist.

World Resources:[6] Stone resources are plentiful throughout the world. The supply of high-purity limestone and dolomite suitable for specialty uses is limited in many geographic areas. The largest resources of high-purity limestone and dolomite in the United States are in the central and eastern parts of the country.

Substitutes: Crushed stone substitutes for roadbuilding include sand and gravel, and iron and steel slag. Substitutes for crushed stone used as construction aggregates include construction sand and gravel, iron and steel slag, sintered or expanded clay or shale, perlite, or vermiculite. Increasingly, recycled asphalt and portland cement concretes are being substituted for virgin aggregate, although the percentage of total aggregate supplied by recycled materials remained very small in 2021.

[e]Estimated. NA Not available.
[1]See also Sand and Gravel (Construction) and Stone (Dimension).
[2]Less than ½ unit.
[3]Defined as production + recycled material + imports – exports.
[4]Including office staff. Source: Mine Safety and Health Administration.
[5]Defined as imports – exports.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]No reliable production information is available for most countries owing to the wide variety of ways in which countries report their crushed stone production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the U.S. Geological Survey Minerals Yearbook, volume III, Area Reports—International.

STONE (DIMENSION)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Approximately 2.3 million tons of dimension stone, valued at $430 million, was sold or used by U.S. producers in 2021. Dimension stone was produced by approximately 200 companies operating 236 quarries in 34 States. Leading producing States were, in descending order by tonnage, Texas, Wisconsin, Indiana, Georgia, and Vermont. These five States accounted for about 67% of the production quantity and contributed about 56% of the value of domestic production. Approximately 47%, by tonnage, of dimension stone sold or used was limestone, followed by sandstone (20%), granite (18%), dolomite and slate (4% each), and the remaining 7% was divided, in descending order of tonnage, among quartzite, miscellaneous stone, marble, and traprock. By value, the leading sales or uses were for limestone (43%), followed by granite (28%), sandstone (11%), slate (7%), dolomite (4%), and the remaining 7% was divided, in descending order of total value, among marble, quartzite, traprock and miscellaneous stone. Rough stone represented 59% of the tonnage and 54% of the value of all the dimension stone sold or used by domestic producers, including exports. The leading uses and distribution of rough stone, by tonnage, were in building and construction (52%) and in irregular-shaped stone (34%). The leading uses and distribution of dressed stone, by tonnage, were in ashlars and partially squared pieces (45%), flagging (11%), slabs and blocks for building and construction (10%), and curbing (9%).

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Sold or used by producers:[2]					
Quantity	2,880	2,660	2,520	2,350	2,300
Value, million dollars	453	437	415	424	430
Imports for consumption, value, million dollars	2,120	2,090	1,900	1,750	2,300
Exports, value, million dollars	69	70	59	47	48
Consumption, apparent, value, million dollars[3]	2,510	2,460	2,250	2,130	2,700
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	3,900	3,900	3,900	3,800	3,700
Net import reliance[5] as a percentage of apparent consumption (based on value)	82	82	82	80	84
Granite only, sold or used by producers:					
Quantity	526	484	430	436	420
Value, million dollars	115	108	105	110	120
Imports, value, million dollars	1,020	915	863	794	890
Exports, value, million dollars	22	19	17	13	11
Consumption, apparent, value, million dollars[3]	1,110	1,000	950	892	1,000
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	800	800	800	800	800
Net import reliance[5] as a percentage of apparent consumption (based on value)	90	89	89	88	88

Recycling: Small amounts of dimension stone were recycled, principally by restorers of old stone work.

Import Sources (2017–20, by value): All dimension stone: China,[6] 24%; Brazil, 23%; Italy, 19%; India, 13%; and other, 21%. Granite only: Brazil, 44%; China,[6] 22%; India, 19%; Italy, 6%; and other, 9%.

Tariff: Dimension stone tariffs ranged from free to 6.5% ad valorem, according to type, degree of preparation, shape, and size, for countries with normal trade relations in 2021. Most crude or roughly trimmed stone was imported at 3.7% ad valorem or less.

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STONE (DIMENSION)

Depletion Allowance: All dimension stone, 14% (domestic and foreign); slate used or sold as sintered or burned lightweight aggregate, 7.5% (domestic and foreign); dimension stone used for rubble and other nonbuilding purposes, 5% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The United States remained one of the world's leading markets for dimension stone. In 2021, total imports of dimension stone increased in value by about 33% compared with the value in 2020. In 2021, increased demand for dimension stone for construction and refurbishment used in residential markets helped offset decreased demand in commercial markets. Both markets were affected by the measures instituted to mitigate the spread of the global COVID-19 pandemic. These measures also affected the home remodeling sector, which increased by 7.6% in the third quarter of 2021 compared with that in 2020, according to the Joint Center for Housing Studies of Harvard University. Dimension stone exports increased slightly to about $48 million. Apparent consumption, by value, was estimated to be $2.7 billion in 2021—a 28% increase compared with that in 2020.

In November 2021, a $1.2 trillion infrastructure bill, the Infrastructure Investment and Jobs Act, was signed into law, which included $110 billion for construction and repair of bridges and roads and transportation research and other projects. Additional funding included $17 billion and $25 billion to upgrade and repair ports and airports, respectively. The leading uses of rough blocks of stone are in building and construction. Dressed stone, such as slabs, ashlars, and flagging are often used in airport interiors and exteriors.

The dimension stone industry continued to be concerned with safety and health regulations and environmental restrictions in 2021, especially those concerning crystalline silica exposure. In 2016, the Occupational Safety and Health Administration finalized new regulations to further restrict exposure to crystalline silica at quarry sites and other industrial operations that use materials containing it. Final implementation of the new regulations took effect in 2021, affecting various industries that use materials containing silica. Most provisions of the new regulations became enforceable on June 23, 2018, for general industry and maritime operations.

World Mine Production and Reserves:

	Mine production		Reserves[7]
	2020	2021[e]	
United States	2,350	2,300	Adequate, except for certain special types and local shortages.
Other countries	NA	NA	
World total	NA	NA	

World Resources:[7] Dimension stone resources of the world are sufficient. Resources can be limited on a local level or occasionally on a regional level by the lack of a particular kind of stone that is suitable for dimension purposes.

Substitutes: Substitutes for dimension stone include aluminum, brick, ceramic tile, concrete, glass, plastics, resin-agglomerated stone, and steel.

[e]Estimated. NA Not available.
[1]See also Stone (Crushed).
[2]Includes granite, limestone, and other types of dimension stone.
[3]Defined as sold or used + imports – exports.
[4]Excludes office staff.
[5]Defined as imports – exports.
[6]Includes Hong Kong.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.

STRONTIUM

(Data in metric tons of contained strontium unless otherwise noted)

Domestic Production and Use: Although deposits of strontium minerals occur widely throughout the United States, none have been mined in the United States since 1959. Domestic production of strontium carbonate, the principal strontium compound, ceased in 2006. Virtually all the strontium mineral celestite consumed in the United States since 2006 is thought to have been used as an additive in drilling fluids for oil and natural gas wells. A few domestic companies produced small quantities of downstream strontium chemicals from imported strontium carbonate.

Based on import data, the estimated end-use distribution in the United States for strontium, including celestite and strontium compounds, was ceramic ferrite magnets and pyrotechnics and signals, 40% each; and other uses, including drilling fluids, electrolytic production of zinc, master alloys, pigments and fillers, and other applications, including glass accounted for the remaining 20%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production	—	—	—	—	—
Imports for consumption:					
Celestite[1]	11,300	16,900	7,960	1,060	—
Strontium compounds[2]	6,660	6,350	5,560	4,440	4,800
Exports, strontium compounds	36	32	20	32	12
Consumption, apparent:[3]					
Celestite	11,300	16,900	7,960	1,060	—
Strontium compounds	6,620	6,320	5,540	4,410	4,800
Total	17,900	23,200	13,500	5,470	4,800
Price, average value of celestite imports at port of exportation, dollars per ton	74	78	82	90	XX
Net import reliance[3] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2017–20): Celestite: Mexico, 100%. Strontium compounds: Mexico, 47%; Germany, 43%; China, 5%; and other, 5%. Total imports: Mexico, 80%; Germany, 16%; China, 2%; and other, 2%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Celestite	2530.90.8010	Free.
Strontium compounds:		
Strontium metal	2805.19.1000	3.7% ad valorem.
Strontium oxide, hydroxide, peroxide	2816.40.1000	4.2% ad valorem.
Strontium nitrate	2834.29.2000	4.2% ad valorem.
Strontium carbonate	2836.92.0000	4.2% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Apparent consumption of total strontium declined by 12% in 2021. Apparent consumption of strontium compounds increased by 9%, but apparent consumption of celestite decreased by 100% to zero. Following a 59% decrease of apparent consumption of all forms of strontium in 2020 because of the economic downturn caused by restrictions imposed worldwide as the result of the global COVID-19 pandemic, consumption of strontium compounds increased as the economy began to recover in 2021. World celestite production was estimated to have increased slightly from that of 2020.

On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

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STRONTIUM

No imports of celestite, the most commonly used strontium mineral, were reported in 2021, likely the result of decreased use of celestite in natural-gas- and oil-well-drilling fluids. Although drilling activity increased in 2021, it remained very low compared with that seen in the few years before the pandemic. In recent years, nearly all celestite imports were from Mexico and were thought to be used as additives in drilling fluids for oil and natural gas exploration and production. For these applications, celestite is ground but undergoes no chemical processing. A small quantity of high-value celestite imports were reported; these were most likely mineral specimens. Although no strontium carbonate was produced in the United States, celestite is the raw material from which strontium carbonate and other strontium compounds are produced.

Strontium carbonate is the most commonly traded strontium compound and is used as the raw material from which other strontium compounds are derived. Strontium carbonate is sintered with iron oxide to produce permanent ceramic ferrite magnets, and strontium nitrate contributes a brilliant red color to fireworks and signal flares. Smaller quantities of these and other strontium compounds were consumed in several other applications, including electrolytic production of zinc, glass production, master alloys, and pigments and fillers. Imports of strontium compounds were estimated to have increased by 8% in 2021.

World Mine Production and Reserves:[4]

	Mine production		Reserves[5]
	2020	2021[e]	
United States	—	—	Quantitative estimates of reserves for most countries were not available.
Argentina	[e]700	700	
China	[e]80,000	80,000	
Iran	[e]90,000	90,000	
Mexico	33,500	35,000	
Spain	[e]150,000	150,000	
World total (rounded)	[e]350,000	360,000	

World Resources:[5] World resources of strontium are thought to exceed 1 billion tons.

Substitutes: Barium can be substituted for strontium in ferrite ceramic magnets; however, the resulting barium composite will have a reduced maximum operating temperature when compared with that of strontium composites. Substituting for strontium in pyrotechnics is hindered by difficulty in obtaining the desired brilliance and visibility imparted by strontium and its compounds. In drilling mud, barite is the preferred material, but celestite may substitute for some barite, especially when barite prices are high.

[e]Estimated. XX Not applicable. — Zero.
[1]The strontium content of celestite is 43.88%, assuming an ore grade of 92%, which was used to convert units of celestite to strontium content.
[2]Strontium compounds, with their respective strontium contents, in descending order, include metal (100.00%); oxide, hydroxide, and peroxide (70.00%); carbonate (59.35%); and nitrate (41.40%). These factors were used to convert gross weight of strontium compounds to strontium content.
[3]Defined as imports − exports.
[4]Gross weight of celestite in tons.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.

SULFUR

(Data in thousand metric tons of contained sulfur unless otherwise noted)

Domestic Production and Use: In 2021, recovered elemental sulfur and byproduct sulfuric acid were produced at 95 operations in 27 States. Total shipments were valued at about $740 million. Elemental sulfur production was estimated to be 7.5 million tons; Louisiana and Texas accounted for about 55% of domestic production. Elemental sulfur was recovered, in descending order of tonnage, at petroleum refineries, natural-gas-processing plants, and coking plants by 35 companies at 90 plants in 26 States. Byproduct sulfuric acid, representing about 7% of production of sulfur in all forms, was recovered at five nonferrous-metal smelters in four States by four companies. Domestic elemental sulfur provided 59% of domestic consumption, and byproduct sulfuric acid accounted for about 5%. The remaining 36% of sulfur consumed was provided by imported sulfur and sulfuric acid. About 90% of sulfur consumed was in the form of sulfuric acid.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Recovered elemental	9,070	9,000	8,110	7,310	7,500
Other forms	560	672	596	581	600
Total (rounded)	9,630	9,670	8,710	7,890	8,100
Shipments, all forms	9,680	9,690	8,700	7,900	8,200
Imports for consumption:					
Recovered elemental[e]	1,850	2,230	1,850	2,230	2,500
Sulfuric acid	954	997	971	1,200	1,100
Exports:					
Recovered elemental	2,340	2,390	2,200	1,310	1,700
Sulfuric acid	80	112	72	64	140
Consumption, apparent, all forms[1]	10,100	10,400	9,250	9,960	10,000
Price, reported average value, free on board, mine and (or) plant, dollars per ton of elemental sulfur	46.40	81.20	51.10	24.40	90
Stocks, producer, yearend	124	118	124	109	120
Employment, mine and (or) plant, number	2,400	2,400	2,400	2,400	2,400
Net import reliance[2] as a percentage of apparent consumption	4	7	6	21	18

Recycling: Typically, between 2.5 million and 5 million tons of spent sulfuric acid is reclaimed from petroleum refining and chemical processes during any given year.

Import Sources (2017–20): Elemental: Canada, 73%; Russia, 17%; Kazakhstan, 5%; and other, 5%. Sulfuric acid: Canada, 61%; Mexico, 18%; Spain, 7%; Germany, 5%; and other, 9%. Total sulfur imports: Canada, 69%; Russia, 11%; Mexico, 6%; Kazakhstan, 4%; and other, 10%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Sulfur, crude or unrefined	2503.00.0010	Free.
Sulfur, all kinds, other	2503.00.0090	Free.
Sulfur, sublimed or precipitated	2802.00.0000	Free.
Sulfuric acid	2807.00.0000	Free.

Depletion Allowance: 22% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Total U.S. sulfur production in 2021 was estimated to have increased by 3% from that of 2020, and shipments also increased by 4% from those of 2020. Domestic production of elemental sulfur from petroleum refineries and recovery from natural gas operations increased by 3%. However, in the first 6 months of 2021, U.S. sulfur production was lower than 2020 because of the cold weather that affected the central United States in mid-February, leading to the largest reduction in Gulf Coast refining operations over the past several years. In addition, Hurricanes Ida and Nicholas brought Gulf Coast refining to a standstill. Domestically, refinery sulfur production is expected to increase as refining utilization increases. Domestic byproduct sulfuric acid is expected to remain relatively constant, unless one or more of the remaining nonferrous-metal smelters close.

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SULFUR

Domestic phosphate rock consumption in 2021 was estimated to have remained the same as that in 2020, which resulted in the same consumption of sulfur to process the phosphate rock into phosphate fertilizers.

World sulfur production was slightly more than it was in 2020 as a result of increased demand and is likely to steadily increase for the foreseeable future. New sulfur demand associated with phosphate fertilizer projects is expected mostly in Africa, and sulfur demand likely will also increase in Asia and Eastern Europe.

Contract sulfur prices in Tampa, FL, began 2021 at around $69 per long ton. The sulfur price decreased to $195 per long ton in mid-July, and then decreased to $183 per long ton by the end of September. Fourth-quarter 2021 prices remained at $183 per long ton. In the past few years, sulfur prices have been variable, a result of the volatility in the demand for sulfur. High sulfur prices in 2021 were a result of supply issues.

World Production and Reserves:

	Production, all forms	
	2020	2021[e]
United States	7,890	8,100
Australia	900	900
Brazil	500	500
Canada	4,900	4,900
Chile	1,300	1,300
China[4]	17,300	17,000
Finland	717	720
Germany	633	630
Greece	500	500
India	3,460	3,500
Iran	2,200	2,200
Japan	3,040	3,000
Kazakhstan	4,480	4,500
Korea, Republic of	3,080	3,100
Kuwait	620	600
Poland	992	1,000
Qatar	2,000	2,000
Russia	7,530	7,500
Saudi Arabia	6,500	6,500
South Africa	900	900
Turkmenistan	700	700
United Arab Emirates	6,000	6,000
Other countries	3,600	3,600
World total (rounded)	79,800	80,000

Reserves[3]

Reserves of sulfur in crude oil, natural gas, and sulfide ores are large. Because most sulfur production is a result of the processing of fossil fuels, supplies are expected to be adequate for the foreseeable future. Because petroleum and sulfide ores can be processed long distances from where they are produced, sulfur production may not be in the country to which the reserves were attributed. For instance, sulfur from Saudi Arabian oil may be recovered at refineries in the United States.

World Resources:[3] Resources of elemental sulfur in evaporite and volcanic deposits, and sulfur associated with natural gas, petroleum, tar sands, and metal sulfides, total about 5 billion tons. The sulfur in gypsum and anhydrite is almost limitless, and 600 billion tons of sulfur is contained in coal, oil shale, and shale that is rich in organic matter. Production from these sources would require development of low-cost methods of extraction. The domestic sulfur resource is about one-fifth of the world total.

Substitutes: Substitutes for sulfur at present or anticipated price levels are not satisfactory; some acids, in certain applications, may be substituted for sulfuric acid, but usually at a higher cost.

[e]Estimated.

[1]Defined as shipments + imports – exports.

[2]Defined as imports – exports + adjustments for industry stock changes.

[3]See Appendix C for resource and reserve definitions and information concerning data sources.

[4]Sulfur production in China includes byproduct elemental sulfur recovered from natural gas and petroleum, the estimated sulfur content of byproduct sulfuric acid from metallurgy, and the sulfur content of sulfuric acid from pyrite.

TALC AND PYROPHYLLITE[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Three companies operated five talc producing mines in three States during 2021, and domestic production of crude talc was estimated to be nearly unchanged at 490,000 tons valued at $22 million. Talc was mined in Montana, Texas, and Vermont. Total sales (domestic and export) of talc by U.S. producers were estimated to be 490,000 tons valued at about $130 million, a 9% increase from the value in 2020. Talc produced and sold in the United States was used in ceramics (including automotive catalytic converters) (23%), paper (18%), paint (17%), plastics (11%), rubber (6%), roofing (4%), and cosmetics (1%). The remaining 20% was for agriculture, export, insecticides, and other miscellaneous uses.

One company in North Carolina mined and processed pyrophyllite in 2020. Domestic production was withheld to avoid disclosing company proprietary data and was estimated to have increased from that in 2020. Pyrophyllite was sold for refractory, paint, and ceramic products.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine	610	648	578	[e]490	490
Sold by producers	528	537	515	[e]460	490
Imports for consumption	336	313	281	189	280
Exports	220	273	234	188	240
Consumption, apparent[2]	644	577	562	[e]460	530
Price, average, milled, dollars per metric ton[3]	214	227	240	265	270
Employment, mine and mill, number:[4]					
Talc	206	208	202	187	190
Pyrophyllite	31	30	31	31	30
Net import reliance[5] as a percentage of apparent consumption	18	7	8	<1	8

Recycling: Insignificant.

Import Sources (2017–20): Pakistan, 46%; Canada, 28%; China,[6] 11%; and other, 15%. Large quantities of crude talc were thought to have been mined in Afghanistan before being milled in and exported from Pakistan.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Natural steatite and talc:		
Not crushed, not powdered	2526.10.0000	Free.
Crushed or powdered	2520.26.0000	Free.
Talc, steatite, and soapstone; cut or sawed	6815.99.2000	Free.

Depletion Allowance: Block steatite talc: 22% (domestic), 14% (foreign). other talc and pyrophyllite: 14% (domestic and foreign).

Government Stockpile: None.

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TALC AND PYROPHYLLITE

Events, Trends, and Issues: Canada, China, and Pakistan were the principal sources for United States talc imports in recent years. Imports from Pakistan have increased in recent years and accounted for nearly one-half of total imports. Imports from Canada have supplied nearly one-third of the total, whereas imports from China have decreased recently to about 10% of total imports. Canada and Mexico continued to be the primary destinations for United States talc exports, collectively receiving about one-half of exports. Imports and exports of talc and related materials were estimated to have increased by at least 35% in 2021 compared with those of 2020. Primarily owing to the global COVID-19 pandemic, U.S. talc consumption, exports, imports, production, and sales were unusually low in 2020. Production and sales of domestically sourced talc remained at near 2020 levels in 2021, but apparent consumption increased as trade rebounded in 2021, returning to near 2019 levels.

The amount of talc used in rubber production increased in 2020 and 2021 in response to greater demand for rubber stoppers as the medical industry shipped large quantities of COVID-19 vaccines. Ceramic tile and sanitaryware formulations and the technology for firing ceramic tile changed over recent decades, reducing the amount of talc required for the manufacture of some ceramic products. For paint, the industry shifted its focus to production of water-based paint (a product for which talc is not well suited because it is hydrophobic) from oil-based paint in order to reduce volatile emissions. The amount of talc used for paper manufacturing began to decrease beginning in the 1990s, and some talc used for pitch control was replaced by chemical agents. For cosmetics, manufacturers of body dusting powders shifted some of their production from talc-based to corn-starch-based products.

World Mine Production and Reserves:

	Mine production		Reserves[7]
	2020	2021[e]	
United States (crude)	[e, 8]490	[8]490	140,000
Brazil (crude and beneficiated)[9]	650	650	45,000
Canada (unspecified minerals)	230	240	NA
China (unspecified minerals)	1,300	1,400	82,000
Finland	278	300	Large
France (crude)	450	450	Large
India[9]	1,670	1,700	110,000
Italy (includes steatite)	165	170	NA
Japan[9]	160	160	100,000
Korea, Republic of[9]	476	450	81,000
Pakistan	126	120	NA
South Africa[9]	126	130	NA
Other countries (includes crude)[9]	600	700	Large
World total (rounded)	[8]6,720	[8]7,000	Large

World Resources:[7] The United States is self-sufficient in most grades of talc and related minerals, but lower priced imports have replaced domestic minerals for some uses. Talc occurs in the United States from New England to Alabama in the Appalachian Mountains and the Piedmont region, as well as in California, Montana, Nevada, Texas, and Washington. Domestic and world identified resources are estimated to be approximately five times the quantity of reserves.

Substitutes: Substitutes for talc include bentonite, chlorite, feldspar, kaolin, and pyrophyllite in ceramics; chlorite, kaolin, and mica in paint; calcium carbonate and kaolin in paper; bentonite, kaolin, mica, and wollastonite in plastics; and kaolin and mica in rubber.

[e]Estimated. NA Not available.
[1]All statistics exclude pyrophyllite unless otherwise noted.
[2]Defined as sold by producers + imports – exports.
[3]Average ex-works unit value of milled talc sold by U.S. producers, based on data reported by companies.
[4]Includes only companies that mine talc or pyrophyllite. Excludes office workers and mills that process imported or domestically purchased material.
[5]Defined as imports – exports.
[6]Includes Hong Kong.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]Excludes U.S. production of pyrophyllite.
[9]Includes pyrophyllite.

TANTALUM

(Data in metric tons of contained tantalum unless otherwise noted)

Domestic Production and Use: Significant U.S. tantalum mine production has not been reported since 1959. Domestic tantalum resources are of low grade, some are mineralogically complex, and most are not commercially recoverable. Companies in the United States produced tantalum alloys, capacitors, carbides, compounds, and tantalum metal from imported tantalum ores and concentrates and tantalum-containing materials. Tantalum metal and alloys were recovered from foreign and domestic scrap. Domestic tantalum consumption was not reported by consumers. Major end uses for tantalum included alloys for gas turbines used in the aerospace and oil and gas industries; tantalum capacitors for automotive electronics, mobile phones, and personal computers; tantalum carbides for cutting and boring tools; and tantalum oxide (Ta_2O_5) was used in glass lenses to make lighter weight camera lenses that produce a brighter image. The value of tantalum consumed in 2021 was estimated to exceed $220 million as measured by the value of imports.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production:					
Mine	—	—	—	—	—
Secondary	NA	NA	NA	NA	NA
Imports for consumption[1]	1,460	1,660	1,380	1,230	1,300
Exports[1]	549	681	423	417	580
Shipments from Government stockpile[2]	—	—	—	−16	−10
Consumption, apparent[3]	907	975	956	797	710
Price, tantalite, dollars per kilogram of Ta_2O_5 content[4]	193	214	161	158	158
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Tantalum was recycled mostly from new scrap that was generated during the manufacture of tantalum-containing electronic components and from tantalum-containing cemented carbide and superalloy scrap. The amount of tantalum recycled was not available, but it may be as much as 30% of apparent consumption.

Import Sources (2017–20): Tantalum ores and concentrates: Australia, 36%; Rwanda, 34%; Congo (Kinshasa), 7%; Mozambique, 6%; and other, 17%. Tantalum metal and powder: China,[6] 39%; Germany, 22%; Kazakhstan, 12%; Thailand, 12%; and other, 15%. Tantalum waste and scrap: Indonesia, 20%; China,[6] 17%; Japan, 16%; and other, 47%. Total: China,[6] 23%; Germany, 11%; Australia, 8%; Indonesia, 8%; and other, 50%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Niobium ores and concentrates	2615.90.6030	Free.
Tantalum ores and concentrates	2615.90.6060	Free.
Tantalum oxide[7]	2825.90.9000	3.7% ad valorem.
Potassium fluorotantalate[7]	2826.90.9000	3.1% ad valorem.
Tantalum, unwrought:		
Powders	8103.20.0030	2.5% ad valorem.
Alloys and metal	8103.20.0090	2.5% ad valorem.
Tantalum, waste and scrap	8103.30.0000	Free.
Tantalum, other	8103.90.0000	4.4% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[8]

		FY 2021		FY 2022	
Material	**Inventory as of 9–30–21**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Tantalum carbide powder	—	—	1.71	—	1.71
Tantalum niobium concentrate (gross weight)	92	—	—	—	—
Tantalum metal[9] (gross weight)	0.085	15.4	0.09	—	0.09
Tantalum alloy (gross weight)	0.0015	—	—	—	—

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TANTALUM

Events, Trends, and Issues: U.S. tantalum apparent consumption (measured in contained tantalum) was estimated to have decreased by 11% from that in 2020. In 2021, estimated U.S. imports for consumption increased by 6%. Most of the tantalum imported was in the form of metal and powder (45%), followed by ores and concentrates (30%), and waste and scrap (24%). Waste and scrap imports saw the most significant variation by declining 37% from that in 2020. Estimated U.S. exports increased by 39% in 2021. In 2021, the average monthly price of tantalum ore remained constant at about $158 per kilogram of Ta_2O_5 content between both years.

Global tantalum production and consumption were thought to have increased in 2021 as steel production in most countries began to recover from the global COVID-19 pandemic. Production in Rwanda was estimated to have increased based on reported ore production through August 2021. China remained the leading export destination through the same period, accounting for approximately 30% of tantalum ores and concentrates, waste and scrap, and metals consumption. Brazil, Congo (Kinshasa), Nigeria, and Rwanda accounted for about 80% of estimated global tantalum production in 2021.

World Mine Production and Reserves: Reserves for Australia were revised based on Government information.

	Mine production		Reserves[10]
	2020	2021[e]	
United States	—	—	—
Australia	34	62	[11]94,000
Bolivia	7	7	NA
Brazil	470	470	40,000
Burundi	24	32	NA
China	74	76	NA
Congo (Kinshasa)	780	700	NA
Ethiopia	69	52	NA
Mozambique	43	43	NA
Nigeria	260	260	NA
Russia	49	39	NA
Rwanda	254	270	NA
Uganda	38	40	NA
World total (rounded)	2,100	2,100	NA

World Resources:[10] Identified world resources of tantalum, most of which are in Australia, Brazil, and Canada, are considered adequate to supply projected needs. The United States has about 55,000 tons of tantalum resources in identified deposits, most of which were considered uneconomical at 2021 prices for tantalum.

Substitutes: The following materials can be substituted for tantalum, but a performance loss or higher costs may ensue: niobium and tungsten in carbides; aluminum, ceramics, and niobium in electronic capacitors; glass, molybdenum, nickel, niobium, platinum, stainless steel, titanium, and zirconium in corrosion-resistant applications; and hafnium, iridium, molybdenum, niobium, rhenium, and tungsten in high-temperature applications.

[e]Estimated. NA Not available. — Zero.

[1]Imports and exports include the estimated tantalum content of synthetic tantalum-niobium concentrates, niobium and tantalum ores and concentrates, tantalum waste and scrap, unwrought tantalum alloys and powder, and other tantalum articles. Synthetic concentrates and niobium ores and concentrates were assumed to contain 32% Ta_2O_5. Tantalum ores and concentrates were assumed to contain 37% Ta_2O_5. Ta_2O_5 is 81.897% tantalum.

[2]Change in total inventory from prior yearend inventory. If negative, increase in inventory.

[3]Defined as production + imports – exports + adjustments for Government stock changes.

[4]Price is annual average price reported by CRU Group. The estimate for 2021 includes data available through October 2021.

[5]Defined as imports – exports + adjustments for Government stock changes.

[6]Includes Hong Kong.

[7]This category includes tantalum-containing material and other material.

[8]See Appendix B for definitions.

[9]Potential acquisitions are for unspecified tantalum materials; potential disposals are for tantalum scrap in the Government stockpile.

[10]See Appendix C for resource and reserve definitions and information concerning data sources.

[11]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 39,000 tons.

TELLURIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2021, tellurium was recovered in copper slimes in the United States. One company in Texas was thought to export copper anode slimes to Mexico for recovery of commercial-grade tellurium. One company in Utah announced the development of a tellurium plant with a capacity of 20 tons per year which was expected to begin production in the fourth quarter of 2021. Downstream companies further refined imported commercial-grade metal to produce tellurium dioxide, high-purity tellurium, and tellurium compounds for specialty applications.

Tellurium was predominantly used in the production of cadmium telluride (CdTe) for thin-film solar cells. Another important end use was for the production of bismuth telluride (BiTe), which is used in thermoelectric devices for both cooling and energy generation. Other uses were as an alloying additive in steel to improve machining characteristics, as a minor additive in copper alloys to improve machinability without reducing conductivity, in lead alloys to improve resistance to vibration and fatigue, in cast iron to help control the depth of chill, and in malleable iron as a carbide stabilizer. It was used in the chemical industry as a vulcanizing agent and accelerator in the processing of rubber and as a component of catalysts for synthetic fiber production. Other uses included those in photoreceptor and thermoelectric devices, blasting caps, and as a pigment to produce various colors in glass and ceramics.

Global consumption estimates of tellurium by end use are solar, 40%; thermoelectric production, 30%; metallurgy, 15%; rubber applications, 5%; and other, 10%.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021**[e]
Production, refinery	W	W	W	W	W
Imports for consumption	163	192	59	12	22
Exports	2	4	1	([1])	2
Consumption, apparent[2]	W	W	W	W	W
Price,[3] dollars per kilogram	38	74	60	56	68
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption	>95	>95	>95	>95	>95

Recycling: For traditional metallurgical and chemical uses, there was little or no old scrap from which to extract secondary tellurium because these uses of tellurium are highly dispersive or dissipative. A very small amount of tellurium was recovered from scrapped selenium-tellurium photoreceptors employed in older plain-paper copiers in Europe. A plant in the United States recycled tellurium from CdTe solar cells; however, the amount recycled was limited because most CdTe solar cells were relatively new and had not reached the end of their useful life.

Import Sources (2017–20): Canada, 57%; Germany, 19%; China,[5] 17%; the Philippines, 4%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Tellurium	2804.50.0020	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2021, domestic tellurium content in anode slimes was estimated to have remained essentially unchanged from that in 2020. One domestic producer of anode slimes shipped at least a portion of its anode slimes to Mexico for treatment and refining. In 2021, the domestic average monthly price of tellurium generally increased throughout the year, continuing a trend from December 2020. The price increased from around $60 per kilogram in January to $71 per kilogram in October.

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TELLURIUM

Domestic imports of tellurium were estimated to have increased by about 83% in 2021 from those of 2020, mostly as a result of a significant increase in imports from the Philippines. During the first 8 months of 2021, the United States imported 9.5 tons of tellurium from the Philippines, an increase of 82% with respect to the total imports from the Philippines in 2020, and an increase of 325% with respect to the same time period in 2020. Imports from Japan also increased in the first 8 months of 2021, by 161% compared with the same time period in 2020.

World production of tellurium was estimated to be about 580 tons in 2021. China was the leading producer of refined tellurium, recovering tellurium from copper anode slimes and from residues generated during the lead, nickel, precious metals, and zinc smelting processes. In early 2021, a Chinese producer of tellurium metal announced an increase of tellurium production following the Lunar New Year holiday, rising from 3 to 4 tons per month to 6 tons per month, or 72 tons per year. In Canada, one producer announced further investment in their new ultrahigh-purity tellurium line. The line is expected to produce up to 7N purity (99.99999%) tellurium for digital and solid-state radiation detectors, as well as other applications. Solid-state radiation detectors produce highly accurate images, and are used in healthcare, security, and military systems.

World Refinery Production and Reserves: The values shown for reserves include only tellurium contained in copper reserves. These estimates assume that more than one-half of the tellurium contained in unrefined copper anodes is recoverable.

	Refinery production		Reserves[6]
	2020	2021[e]	
United States	W	W	3,500
Bulgaria	[e]3	5	NA
Canada	[e]44	45	800
China	[e]330	340	6,600
Japan	[e]70	75	—
Russia	71	70	NA
South Africa	[e]2	3	—
Sweden	42	40	670
Other countries[7]	NA	NA	19,000
World total (rounded)	[8]562	[8]580	31,000

World Resources:[6] Data on tellurium resources were not available. More than 90% of tellurium has been produced from anode slimes collected from electrolytic copper refining, and the remainder was derived from skimmings at lead refineries and from flue dusts and gases generated during the smelting of bismuth, copper, and lead-zinc ores. Potential sources of tellurium include bismuth telluride and gold telluride ores.

Substitutes: Several materials can replace tellurium in most of its uses, but usually with losses in efficiency or product characteristics. Bismuth, calcium, lead, phosphorus, selenium, and sulfur can be used in place of tellurium in many free-machining steels. Several of the chemical process reactions catalyzed by tellurium can be carried out with other catalysts or by means of noncatalyzed processes. In rubber compounding, sulfur and (or) selenium can act as vulcanization agents in place of tellurium. The selenides and sulfides of niobium and tantalum can serve as electrical-conducting solid lubricants in place of tellurides of those metals.

The selenium-tellurium photoreceptors used in some plain paper photocopiers and laser printers have been replaced by organic photoreceptors in newer devices. Amorphous silicon and copper-indium-gallium selenide were the two principal competitors of CdTe in thin-film photovoltaic solar cells. Bismuth selenide and organic polymers can be used to substitute for some BiTe thermal devices.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Less than ½ unit. U.S. Census Bureau export data were adjusted by U.S. Geological Survey.
[2]Defined as production + imports – exports + adjustments for industry stock changes.
[3]Average annual price for 99.95% tellurium, in warehouse, Rotterdam. Source: Argus Media group—Argus Metals International.
[4]Defined as imports – exports + adjustments for industry stock changes. For 2020, exports were not included in the calculation.
[5]Includes Hong Kong.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]In addition to the countries listed, Australia, Belgium, Chile, Colombia, Germany, Kazakhstan, Mexico, the Philippines, and Poland produced refined tellurium, but output was not reported and available information was inadequate to make reliable production estimates.
[8]Excludes U.S. production.

THALLIUM

(Data in kilograms unless otherwise noted)

Domestic Production and Use: Small quantities of thallium are consumed annually, but variations in pricing and value data make it difficult to estimate the value of consumption. The primary end uses included the following: radioisotope thallium-201 used for medical purposes in cardiovascular imaging; thallium used as an activator (sodium iodide crystal doped with thallium) in gamma radiation detection equipment; thallium-barium-calcium-copper-oxide high-temperature superconductors used in filters for wireless communications; thallium used in lenses, prisms, and windows for infrared detection and transmission equipment; thallium-arsenic-selenium crystal filters used for light diffraction in acousto-optical measuring devices; and thallium used in mercury alloys for low-temperature measurements. Other uses include as an additive in glass to increase its refractive index and density, a catalyst for organic compound synthesis, and a component in high-density liquids for gravity separation of minerals.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, refinery	—	—	—	—	—
Imports for consumption:					
Unwrought metal and metal powders	—	—	—	57	—
Waste and scrap	—	23	27	—	—
Other articles	—	41	38	—	10
Exports:					
Unwrought metal and powders	34	100	290	300	300
Waste and scrap	364	853	133	359	100
Other articles	1,560	[1]31,400	[1]79,100	580	600
Consumption, estimated[2]	—	64	65	57	10
Price, metal,[e, 3] dollars per kilogram	NA	NA	7,600	8,200	8,400
Net import reliance[4] as a percentage of estimated consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2017–2020): China, 41%; Russia 31%, Norway, 15%; and the United Kingdom, 13%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Unwrought and powders	8112.51.0000	4.0% ad valorem.
Waste and scrap	8112.52.0000	Free.
Other	8112.59.0000	4.0% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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THALLIUM

<u>Events, Trends, and Issues</u>: As of August 2021, no imports of unwrought thallium metal and powder or thallium waste and scrap were reported. All exports of unwrought thallium and powders left the New Orleans, LA, customs district and went to Taiwan. No exports of thallium waste and scrap were reported through August 2021, but 100 kilograms was estimated for the year based on prior year data. Most exports of other thallium articles (Schedule B number 8112.59.0000) were exported from Washington, DC, to Hungary, and a small quantity was sent to Hungary from Buffalo, NY. In 2018 and 2019, reported exports of thallium articles were unusually high in quantity; these exports likely were misclassified material.

Demand for thallium for use in cardiovascular-imaging applications has declined owing to superior performance and availability of alternatives, such as the medical isotope technetium-99. A global shortage of technetium-99 from 2009 to 2011 had contributed to an increase in thallium consumption during that period. Since 2011, consumption of thallium has declined significantly. Small quantities of thallium are used for research.

The leading global uses for thallium were gamma radiation detection equipment, high-temperature superconductors, infrared optical materials, low-melting glasses, photoelectric cells, and radioisotopes. Producers of these products were in China, Japan, the Republic of Korea, and the United States.

Thallium metal and its compounds are highly toxic materials and are strictly controlled to prevent harm to humans and the environment. Thallium and its compounds can be absorbed into the human body by skin contact, ingestion, or inhalation of dust or fumes. Under its national primary drinking water regulations for public water supplies, the U.S. Environmental Protection Agency has set an enforceable Maximum Contaminant Level of 2 parts per billion thallium in drinking water.

<u>World Refinery Production and Reserves</u>:[5] Thallium is produced commercially in only a few countries as a byproduct in the roasting of copper, lead, and zinc ores and is recovered from flue dust. Because most producers withhold thallium production data, global production data are limited. In 2021, global production of thallium was estimated to be about 10,000 kilograms. China, Kazakhstan, and Russia were thought to be leading producers of primary thallium. Since 2005, substantial thallium-rich deposits have been identified in Brazil, China, North Macedonia, and Russia. Quantitative estimates of reserves are not available, owing to the difficulty in identifying deposits where thallium can be extracted economically. Previous estimates of reserves were based on the thallium content of zinc ores.

<u>World Resources</u>:[5] Although thallium is reasonably abundant in the Earth's crust, estimated at about 0.7 part per million, it exists mostly in association with potassium minerals in clays, granites, and soils, and it is not generally considered to be commercially recoverable from those materials. The major source of recoverable thallium is trace amounts found in sulfide ores of copper, lead, zinc, and other metallic elements. World resources of thallium contained in identified zinc resources could be as much as 17,000,000 kilograms; most are in Canada, Europe, and the United States. World identified resources of coal contain an estimated 630,000,000 kilograms of thallium.

<u>Substitutes</u>: Although other materials and formulations can substitute for thallium in gamma radiation detection equipment and optics used for infrared detection and transmission, thallium materials are presently superior and more cost effective for these very specialized uses. The medical isotope technetium-99 can be used in cardiovascular-imaging applications instead of thallium. Nonpoisonous substitutes, such as tungsten compounds, are being marketed as substitutes for thallium in high-density liquids for gravity separation of minerals.

[e]Estimated. NA Not available. — Zero.
[1]Includes material that may have been misclassified.
[2]Estimated to be equal to imports.
[3]Estimated price of 99.99%-pure granules in 100-gram lots.
[4]Defined as imports – exports. Consumption and exports of unwrought thallium were from imported material or from a drawdown in unreported inventories.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.

THORIUM

(Data in kilograms, gross weight, unless otherwise noted)

Domestic Production and Use: The world's primary source of thorium is the rare-earth and thorium phosphate mineral monazite. In 2021, monazite may have been produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. Essentially, all thorium compounds and alloys consumed by the domestic industry were derived from imports. The number of companies that processed or fabricated various forms of thorium for commercial use was not available. Thorium's use in most products was generally limited because of concerns over its naturally occurring radioactivity. Imports of thorium compounds are sporadic owing to changes in consumption and fluctuations in consumer inventory levels. The estimated value of thorium compounds imported for consumption by the domestic industry in 2021 was $427,000 (through August 2021), compared with $55,400 in 2020.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine[1]	—	[2]500,000	[2]1,700,000	[2]960,000	W
Imports for consumption:					
Ore and concentrates (monazite)	—	1,000	—	3,000	—
Compounds (oxide, nitrate, and so forth)	8,510	9,000	3,970	1,920	8,000
Exports:					
Ore and concentrates (monazite)	—	520,000	1,700,000	960,000	—
Compounds (oxide, nitrate, and so forth)[3]	2,060	3,260	1,660	213	2,500
Consumption, apparent:[4]					
Ore and concentrates (monazite)	—	1,000	—	3,000	—
Compounds (oxide, nitrate, and so forth)	6,450	5,740	2,310	1,710	5,500
Price, average value, compounds, India,[5] dollars per kilogram	73	72	72	NA	NA
Net import reliance[6] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2017–20): Monazite: United Kingdom, 75%; and Canada, 25%. Thorium compounds: India, 74%; and France, 26%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Thorium ore and concentrates (monazite)	2612.20.0000	Free.
Thorium compounds	2844.30.1000	5.5% ad valorem.

Depletion Allowance: Monazite, 22% on thorium content, and 14% on rare-earth and yttrium content (domestic); 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic demand for thorium alloys, compounds, and metals was limited. In addition to research purposes, various commercial uses of thorium included catalysts, high-temperature ceramics, magnetrons in microwave ovens, metal-halide lamps, nuclear medicine, optical coatings, tungsten filaments, and welding electrodes.

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THORIUM

Exports of unspecified thorium compounds were estimated to be 2,500 kilograms in 2021. More than 90% of the exports have a unit value of less than $50 per kilogram, so it is likely that they were misclassified. Only the quantity of compounds with unit values more than $50 per kilogram were included in the total export estimate. Owing to potentially misclassified material and variations in the type and purity of thorium compounds, the unit value of exports varied widely by month and by exporting customs district.

Globally, monazite was produced primarily for its rare-earth-element content, and only a small fraction of the byproduct thorium produced was consumed. Madagascar was the leading producer of monazite. Thorium consumption worldwide is relatively small compared with that of most other mineral commodities. In international trade, China was the leading importer of monazite; Brazil, Madagascar, Thailand, and Vietnam were China's leading import sources. The United States exported monazite to China, including Hong Kong. China's exports became more regulated and were optimized to add value.

The Eneabba mineral sands project (Australia) was exporting monazite but had upgraded its processing facilities and was studying the feasibility of an integrated rare-earths refinery. Monazite from the Moma Mine (Mozambique) was being exported. The status of the Kvanefjeld project (Greenland) was in flux because of environmental concerns. The Steenkrampskraal Mine (South Africa) made several improvements to its plant and was working with an energy company in Norway to develop fuel pellets for use in nuclear powerplants.

Several companies and countries were active in the pursuit of commercializing thorium as a fuel material for a new generation of nuclear reactors. Thorium-based nuclear research and development programs have been or were underway in Australia, Belgium, Brazil, Canada, China, Czechia, Denmark, Finland, France, Germany, India, Israel, Italy, Japan, the Republic of Korea, the Netherlands, Norway, Russia, the United Kingdom, and the United States.

World Mine Production and Reserves:[7] Production and reserves are associated with the recovery of monazite in heavy-mineral-sand deposits. Without demand for the rare earths, monazite likely would not be recovered for its thorium content under current market conditions.

World Resources:[7] The world's leading thorium resources are found in placer, carbonatite, and vein-type deposits. Thorium is found in several minerals, including monazite, thorite, and thorianite. According to the World Nuclear Association,[8] worldwide identified thorium resources were estimated to total 6.4 million tons of thorium. Thorium resources are found throughout the world, most notably in Australia, Brazil, India, and the United States. India has the largest resources (850,000 tons), followed by Brazil (630,000 tons) and Australia and the United States (600,000 tons each).

Substitutes: Nonradioactive substitutes have been developed for many applications of thorium. Yttrium compounds have replaced thorium compounds in incandescent lamp mantles. A magnesium alloy containing lanthanides, yttrium, and zirconium can substitute for magnesium-thorium alloys in aerospace applications. Cerium, lanthanum, yttrium, and zirconium oxides can substitute for thorium in welding electrodes. Several replacement materials (such as yttrium fluoride and proprietary materials) are in use as optical coatings instead of thorium fluoride.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Monazite may have been produced as a separate concentrate or included as an accessory mineral in heavy-mineral concentrates.
[2]Estimates based on exports.
[3]Excludes estimates of material that may have been misclassified.
[4]Defined as production + imports – exports. Shown separately for ore and concentrates and for compounds. Production is only for ore and concentrates.
[5]Calculated from U.S. Census Bureau import data.
[6]Defined as imports – exports; however, a meaningful net import reliance could not be calculated owing to uncertainties in the classification of material being imported and exported.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]World Nuclear Association, 2017, Thorium: London, United Kingdom, World Nuclear Association, February.

TIN

(Data in metric tons of contained tin unless otherwise noted)

Domestic Production and Use: Tin has not been mined or smelted in the United States since 1993 and 1989, respectively. Twenty-five firms accounted for over 90% of the primary tin consumed domestically in 2021. The major uses for tin in the United States were chemicals, 25%; tinplate, 22%; alloys, 12%; solder, 9%; babbitt, brass and bronze, and tinning, 8%; bar tin, 2%; and other, 22%. Based on the average S&P Global Platts Metals Week New York dealer price for tin, the estimated value of imported refined tin in 2021 was $1.2 billion, and the estimated value of tin recovered from old scrap domestically in 2021 was $342 million.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, secondary:[e]					
Old scrap	10,000	9,890	10,500	9,550	10,000
New scrap	8,100	8,100	8,100	8,000	8,100
Imports for consumption:					
Refined	34,300	36,800	34,100	31,600	35,000
Tin alloys, gross weight	1,550	1,430	1,020	843	1,300
Tin waste and scrap, gross weight	52,100	47,700	30,400	20,700	17,000
Exports:					
Refined	1,560	941	1,300	519	1,600
Tin alloys, gross weight	966	885	1,200	1,130	680
Tin waste and scrap, gross weight	3,460	5,980	2,470	1,200	2,500
Shipments from Government stockpile, gross weight	2	13	1	—	410
Consumption, apparent, refined[1]	42,500	42,300	43,100	41,300	45,000
Price, average, cents per pound:[2]					
New York dealer	937	936	868	799	1,600
London Metal Exchange (LME), cash	911	914	846	777	1,500
Stocks, consumer and dealer, yearend	6,660	10,100	10,300	9,590	8,400
Net import reliance[3] as a percentage of apparent consumption, refined	76	77	76	77	78

Recycling: About 18,000 tons of tin from old and new scrap was estimated to have been recycled in 2021. Of this, about 10,000 tons was recovered from old scrap at 1 detinning plant and about 75 secondary nonferrous metal-processing plants, accounting for 23% of apparent consumption.

Import Sources (2017–20): Refined tin: Indonesia, 25%; Peru, 22%; Malaysia, 19%; Bolivia, 17%; and other, 17%. Waste and scrap: Canada, 99%; and other, 1%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Unwrought tin:		
Tin, not alloyed	8001.10.0000	Free.
Tin alloys, containing, by weight:		
5% or less lead	8001.20.0010	Free.
More than 5% but not more than 25% lead	8001.20.0050	Free.
More than 25% lead	8001.20.0090	Free.
Tin waste and scrap	8002.00.0000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[4]

		FY 2021		FY 2022	
Material	**Inventory as of 9–30–21**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Tin (gross weight)	3,617	—	4,034	—	4,000

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TIN

<u>Events, Trends, and Issues</u>: The estimated amount of tin recycled domestically in 2021 increased by 3% compared with that in 2020. The estimated annual average New York dealer price for refined tin in 2021 was 1,600 cents per pound, double that in 2020. The estimated annual average LME cash price for refined tin in 2021 was 1,500 cents per pound, a 93% increase from that in 2020. In 2021, the monthly average New York dealer tin price increased for 8 consecutive months from January through August. Supply constraints owing to shipping bottlenecks, reimposed COVID-19 pandemic shutdowns, and an increased demand for electronic and consumer goods, were largely responsible for the almost doubling of refined tin prices during 2021. In March, the United States Defense Logistics Agency began offering stockpiled tin for sale.

Throughout the year, global production struggled to maintain an adequate supply of refined tin to meet rebounding consumer demand. Pandemic-related measures, including shutdowns and border restrictions, affected refined tin production in Burma, Indonesia, Malaysia, and Rwanda. Smelters were temporarily closed for repair and annual maintenance in China and Malaysia. Shipping container shortages and bottlenecks at shipping terminals exacerbated supply constraints. Globally, consumption increased in 2021 for alloys, chemicals, solder, and tinplate while demand for lead-acid batteries remained steady.

<u>World Mine Production and Reserves</u>: Reserves for Australia, Burma, Congo (Kinshasa), Malaysia, Peru, Russia, and "Other countries" were revised based on information from company and Government reports.

	Mine production		Reserves[5]
	2020	2021[e]	
United States	—	—	—
Australia	8,120	8,300	[6]560,000
Bolivia	14,700	18,000	400,000
Brazil	16,900	22,000	420,000
Burma[e]	29,000	28,000	700,000
China[e]	84,000	91,000	1,100,000
Congo (Kinshasa)[e]	17,300	16,000	130,000
Indonesia[e]	53,000	71,000	800,000
Laos[e]	1,400	1,600	NA
Malaysia	2,960	3,100	81,000
Nigeria[e]	5,000	1,200	NA
Peru	20,600	30,000	150,000
Russia	2,500	3,500	200,000
Rwanda[e]	1,800	2,200	NA
Vietnam[e]	5,400	6,100	11,000
Other countries	782	930	310,000
World total (rounded)	264,000	300,000	4,900,000

<u>World Resources</u>:[5] Identified resources of tin in the United States, primarily in Alaska, were insignificant compared with those of the rest of the world. World resources, principally in western Africa, southeastern Asia, Australia, Bolivia, Brazil, Indonesia, and Russia, are extensive and, if developed, could sustain recent annual production rates well into the future.

<u>Substitutes</u>: Aluminum, glass, paper, plastic, or tin-free steel substitute for tin in cans and containers. Other materials that substitute for tin are epoxy resins for solder; aluminum alloys, alternative copper-base alloys, and plastics for bronze; plastics for bearing metals that contain tin; and compounds of lead and sodium for some tin chemicals.

[e]Estimated. NA Not available. — Zero.

[1]Defined as production from old scrap + refined tin imports – refined tin exports + adjustments for Government and industry stock changes.

[2]Source: S&P Global Platts Metals Week.

[3]Defined as refined imports – refined exports + adjustments for Government and industry stock changes.

[4]See Appendix B for definitions.

[5]See Appendix C for resource and reserve definitions and information concerning data sources.

[6]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 261,000 tons.

TITANIUM AND TITANIUM DIOXIDE[1]

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Titanium sponge metal was produced by one operation in Utah. Production data were withheld to avoid disclosing company proprietary data. The facility in Salt Lake City, UT, with an estimated capacity of 500 tons per year, produced titanium that was further refined for use in electronics. A second sponge facility in Henderson, NV, with an estimated capacity of 12,600 tons per year, was idled since 2020 owing to market conditions. A third facility, in Rowley, UT, with an estimated capacity of 10,900 tons per year, has remained on care-and-maintenance status since 2016.

Although detailed 2021 consumption data were withheld to avoid disclosing proprietary data, the majority of titanium metal was used in aerospace applications, and the remainder was used in armor, chemical processing, marine hardware, medical implants, power generation, consumer, and other applications. The value of imported sponge was about $140 million, a significant decrease compared with $173 million in 2020.

In 2021, titanium dioxide (TiO_2) pigment production, by four companies operating five facilities in four States, was valued at about $3.2 billion. The estimated end-use distribution of TiO_2 pigment consumption was paints (including lacquers and varnishes), 60%; plastics, 20%; paper, 5%; and other, 15%. Other uses of TiO_2 included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Titanium sponge metal:					
Production	W	W	W	W	W
Imports for consumption[e]	23,300	23,700	30,000	19,200	14,000
Exports	3,090	533	869	711	120
Consumption, reported	37,400	35,200	W	W	W
Price, dollars per kilogram[2]	10.40	10.70	11.80	11.70	11.70
Stocks, industry, yearend[e]	13,200	10,700	W	W	W
Employment, number[e]	150	150	150	150	20
Net import reliance[3] as a percentage of reported consumption	88	73	>50	>50	>90
Titanium dioxide pigment:					
Production	1,260,000	1,150,000	1,100,000	[e]890,000	1,100,000
Imports for consumption	240,000	268,000	226,000	263,000	260,000
Exports	634,000	528,000	401,000	386,000	520,000
Consumption, apparent[4]	870,000	893,000	930,000	770,000	840,000
Price, dollars per metric ton[2]	2,570	2,730	2,750	2,710	2,900
Producer price index (1982=100), yearend[5]	205	205	NA	NA	NA
Employment, number[e]	3,110	3,050	3,050	3,100	3,100
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Owing to limited responses from voluntary surveys, consumption of titanium scrap metal was withheld for the titanium metal industry. Consumption data for the steel, superalloy, other industries were not available.

Import Sources (2017–20): Sponge metal: Japan, 88%; Kazakhstan, 8%; Ukraine, 3%; and other, 1%. Titanium dioxide pigment: Canada, 40%; China, 19%; Germany, 9%; Belgium, 5%; and other, 27%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Titanium oxides (unfinished TiO_2 pigments)	2823.00.0000	5.5% ad valorem.
TiO_2 pigments, 80% or more TiO_2	3206.11.0000	6.0% ad valorem.
TiO_2 pigments, other	3206.19.0000	6.0% ad valorem.
Ferrotitanium and ferrosilicon titanium	7202.91.0000	3.7% ad valorem.
Unwrought titanium metal	8108.20.0010	15.0% ad valorem.
Titanium waste and scrap metal	8108.30.0000	Free.
Other titanium metal articles	8108.90.3000	5.5% ad valorem.
Wrought titanium metal	8108.90.6000	15.0% ad valorem.

Depletion Allowance: Not applicable.

Government Stockpile: None.

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TITANIUM AND TITANIUM DIOXIDE

Events, Trends, and Issues: The 500-ton-per-year Salt Lake City, UT, plant was the only active domestic producer of titanium sponge, and the Salt Lake City operations primarily supported the production of electronic-grade materials. Consequently, U.S. producers of titanium ingot and downstream products were reliant on imports of titanium sponge and scrap. Reduced demand from the aerospace and other industries resulted in a 27% decrease in imports of titanium sponge compared with those in 2020. Japan (92%) and Kazakhstan (6%) were the leading import sources for titanium sponge in 2021. U.S. imports of titanium waste and scrap were about 11,000 tons. Germany (20%), the United Kingdom (15%), Canada (13%), France (10%), and Japan (8%) were the leading import sources for titanium waste and scrap in 2021. The duty-paid unit value of scrap imports was about $4.70 per kilogram. The U.S. Department of Commerce (DOC) led investigations under section 232 of the Trade Expansion Act of 1962 that determined titanium sponge imports into the United States threatened to impair national security. The investigation concluded that the United States was at risk of losing the remaining industrial capacity and technical knowledge related to titanium sponge production that is essential to meet national defense and critical infrastructure requirements. In October, the DOC published its findings and recommendations from the investigation in the Federal Register (86 FR 59115). Changes to existing tariff rates for titanium sponge were not recommended.

Domestic production of TiO_2 pigment in 2021 was estimated to be about 1.1 million tons. Although heavily reliant on imports of titanium mineral concentrates, the United States was a net exporter of TiO_2 pigments. After a multiyear low in 2020, exports of titanium pigments increased significantly in 2021. China's TiO_2 pigment production was estimated to be 3.7 million tons.

World Sponge Metal Production and Sponge and Pigment Capacity:

	Sponge production[e]		Capacity, 2021[6]	
	2020	2021	Sponge	Pigment
United States	W	W	500	1,370,000
Australia	—	—	—	260,000
Canada	—	—	—	104,000
China	123,000	120,000	177,000	4,000,000
Germany	—	—	—	472,000
India	250	250	500	108,000
Japan	49,200	35,000	68,800	314,000
Kazakhstan	15,000	16,000	26,000	1,000
Mexico	—	—	—	300,000
Russia	31,000	27,000	46,500	55,000
Saudi Arabia	2,800	3,700	15,600	210,000
Ukraine	5,000	5,400	12,000	120,000
United Kingdom	—	—	—	315,000
Other countries	—	—	—	784,000
World total (rounded)	[7]230,000	[7]210,000	350,000	8,400,000

World Resources:[8] Reserves and resources of titanium minerals are discussed in the Titanium Mineral Concentrates chapter.

Substitutes: Few materials possess titanium metal's strength-to-weight ratio and corrosion resistance. In high-strength applications, titanium competes with aluminum, composites, intermetallics, steel, and superalloys. Aluminum, nickel, specialty steels, and zirconium alloys may be substituted for titanium for applications that require corrosion resistance. Ground calcium carbonate, precipitated calcium carbonate, kaolin, and talc compete with titanium dioxide as a white pigment.

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]See also Titanium Mineral Concentrates.
[2]Landed duty-paid value based on U.S. imports for consumption.
[3]Defined as imports – exports.
[4]Defined as production + imports – exports.
[5]U.S. Department of Labor, Bureau of Labor Statistics.
[6]Yearend operating capacity.
[7]Excludes U.S. production.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.

TITANIUM MINERAL CONCENTRATES[1]

[Data in thousand metric tons of contained titanium dioxide (TiO_2) unless otherwise noted]

Domestic Production and Use: In 2021, one company recovered ilmenite and rutile concentrates from its surface-mining operations near Nahunta, GA, and Starke, FL. A second company processed existing mine tailings to recover a mixed heavy-mineral concentrate in South Carolina. Based on reported data through September, the estimated value of titanium mineral and synthetic concentrates imported into the United States in 2021 was $690 million. Abrasive sands, monazite, and zircon were coproducts of domestic titanium minerals mining operations. An estimated 95% of titanium mineral concentrates were consumed by domestic TiO_2 pigment producers. The remaining 5% was used in welding-rod coatings and for manufacturing carbides, chemicals, and titanium metal.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production[2]	100	100	100	[e]100	100
Imports for consumption	1,170	1,100	1,160	807	1,000
Exports, all forms[e]	6	32	8	18	6
Consumption, apparent[3]	1,300	1,200	1,300	[e]900	1,100
Price, dollars per metric ton:					
Rutile, bulk, minimum 95% TiO_2, free on board (f.o.b.) Australia[4]	740	1,025	1,125	1,175	1,500
Ilmenite and leucoxene, bulk, f.o.b. Australia[5]	393	420	504	460	640
Ilmenite, average value of imports[6]	173	219	186	215	240
Slag, 80%–95% TiO_2, average value of imports[6]	664	738	792	757	750
Employment, mine and mill, number	286	299	310	216	250
Net import reliance[7] as a percentage of apparent consumption	92	91	92	88	90

Recycling: None.

Import Sources (2017–20): South Africa, 41%; Australia, 17%; Madagascar, 12%; Mozambique, 8%; and other, 22%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Synthetic rutile	2614.00.3000	Free.
Ilmenite and ilmenite sand	2614.00.6020	Free.
Rutile concentrate	2614.00.6040	Free.
Titanium slag	2620.99.5000	Free.

Depletion Allowance: Ilmenite and rutile, 22% (domestic), 14% (foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of titanium mineral concentrates is tied to production of TiO_2 pigments that are primarily used in paint, paper, and plastics. Demand for these primary uses is related to changes in the gross domestic product. Domestic apparent consumption of titanium mineral concentrates in 2021 was estimated to have increased significantly from that in 2020 when apparent consumption was affected by a downturn in economic activity owing to the global COVID-19 pandemic. Inventory changes were not included in the apparent consumption calculation. Exports of titanium mineral concentrates were small compared with apparent consumption. As of September, South Africa (27%), Madagascar (18%), Australia (15%), and Mozambique (15%) were the leading sources of titanium mineral concentrates imports to the United States. Mining and heavy-mineral-processing operations were expanded near Starke, FL, and prefeasibility studies were underway at the Titan heavy-mineral-sands project near Camden, TN.

In 2021, China continued to be the leading producer and consumer of titanium mineral concentrates, accounting for 37% of global production of ilmenite. Mozambique and South Africa also were leading producers of titanium mineral concentrates. China's imports of titanium mineral concentrates were about 3.6 million tons in gross weight, an increase of 21% compared with those in 2020. As of October, Mozambique (32%), Australia (14%), Vietnam (13%), and Kenya (9%) were the leading sources of titanium mineral concentrates to China. In Saudi Arabia, commissioning of a project to produce up to 500,000 tons per year of titanium slag was delayed by technical problems and supply constraints resulting from COVID-19 restrictions. Other projects were being developed in Australia, China, Malawi, Mozambique, Norway, Senegal, and Tanzania.

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TITANIUM MINERAL CONCENTRATES

World Mine Production and Reserves: Reserves for Australia, Kenya, Madagascar, and South Africa were revised based on Government or industry reports.

	Mine production 2020	Mine production 2021[e]	Reserves[8]
Ilmenite:			
United States[2, 9]	100	100	2,000
Australia	480	480	[10]160,000
Brazil	34	66	43,000
Canada[11]	595	600	31,000
China	2,800	3,000	230,000
India	174	180	85,000
Kenya	201	190	390
Madagascar[11]	254	310	22,000
Mozambique	965	970	26,000
Norway	444	440	37,000
Senegal	300	360	NA
South Africa[11]	1,020	1,000	30,000
Ukraine	464	430	5,900
Vietnam	138	220	1,600
Other countries	67	67	26,000
World total (ilmenite, rounded)[9]	8,000	8,400	700,000
Rutile:			
United States	([9])	([9])	([9])
Australia	190	200	[10]31,000
India	11	11	7,400
Kenya	73	71	170
Madagascar	8	10	400
Mozambique	6	9	890
Senegal	9	10	NA
Sierra Leone	114	120	490
South Africa	86	90	6,500
Ukraine	95	95	2,500
Other countries	13	13	NA
World total (rutile, rounded)[9]	605	630	49,000
World total (ilmenite and rutile, rounded)	8,600	9,000	750,000

World Resources:[8] Ilmenite accounts for about 90% of the world's consumption of titanium minerals. World resources of anatase, ilmenite, and rutile total more than 2 billion tons.

Substitutes: Ilmenite, leucoxene, rutile, slag, and synthetic rutile compete as feedstock sources for producing TiO_2 pigment, titanium metal, and welding-rod coatings.

[e]Estimated. NA Not available.
[1]See also Titanium and Titanium Dioxide.
[2]Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data.
[3]Defined as production + imports – exports. Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data.
[4]Source: Fast Markets IM; average of yearend price.
[5]Zen Innovations AG, Global Trade Tracker.
[6]Landed duty-paid unit value based on U.S. imports for consumption. Source: U.S. Census Bureau.
[7]Defined as imports – exports.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]U.S. rutile production and reserves data are included with ilmenite.
[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves for ilmenite and rutile were estimated to be 38 million and 9.4 million tons, respectively.
[11]Mine production is primarily used to produce titaniferous slag.

TUNGSTEN

(Data in metric tons of contained tungsten unless otherwise noted)

Domestic Production and Use: No domestic production of commercial tungsten concentrates has been reported since 2015. Approximately six U.S. companies had the capability to convert tungsten concentrates, ammonium paratungstate (APT), tungsten oxide, and (or) scrap to tungsten metal powder, tungsten carbide powder, and (or) tungsten chemicals. Nearly 60% of the tungsten consumed in the United States was used in cemented carbide parts for cutting and wear-resistant applications, primarily in the construction, metalworking, mining, and oil and gas drilling industries. The remainder was used to make various alloys and specialty steels; electrodes, filaments, wires, and other components for electrical, electronic, heating, lighting, and welding applications; and chemicals for various applications. The estimated value of apparent consumption in 2021 was approximately $600 million.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Mine	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Concentrate	3,920	4,050	2,760	2,020	1,400
Other forms[1]	9,780	10,400	11,100	8,650	10,000
Exports:					
Concentrate	531	284	583	480	390
Other forms[2]	3,010	3,210	2,780	2,460	2,500
Shipments from Government stockpile:					
Concentrate	1,460	1,180	663	728	800
Other forms	—	—	—	34	93
Consumption:					
Reported, concentrate	W	W	W	W	W
Apparent,[3] all forms	W	W	W	W	W
Price,[4] concentrate, average U.S. spot market, dollars per metric ton unit of tungsten trioxide[5]	245	326	270	270	270
Stocks, industry, concentrate and other forms, yearend	W	W	W	W	W
Net import reliance[6] as a percentage of apparent consumption	>50	>50	>50	>50	>50

Recycling: The estimated quantity of secondary tungsten produced and the amount consumed from secondary sources by processors and end users in 2021 were withheld to avoid disclosing company proprietary data.

Import Sources (2017–20): Tungsten contained in ores and concentrates, intermediate and primary products, wrought and unwrought tungsten, and waste and scrap: China, 32%; Bolivia, 9%; Germany, 9%; Canada, 5%; and other, 45%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Ores	2611.00.3000	Free.
Concentrates	2611.00.6000	37.5¢/kg tungsten content.
Tungsten oxides	2825.90.3000	5.5% ad valorem.
Ammonium tungstates	2841.80.0010	5.5% ad valorem.
Tungsten carbides	2849.90.3000	5.5% ad valorem.
Ferrotungsten	7202.80.0000	5.6% ad valorem.
Tungsten powders	8101.10.0000	7.0% ad valorem.
Tungsten waste and scrap	8101.97.0000	2.8% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7]

		FY 2021		**FY 2022**	
Material	**Inventory as of 9–30–21**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Metal powder	—	—	125	—	125
Ores and concentrates	6,850	—	1,360	—	1,360
Tungsten alloys, gross weight[8]	5	5	—	—	—

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TUNGSTEN

Events, Trends, and Issues: World tungsten supply was dominated by production in China and exports from China. China's Government regulated its tungsten industry by limiting the number of mining and export licenses, imposing quotas on concentrate production, and placing constraints on mining and processing. In 2021, reduced production during or after environmental and safety inspections at Chinese mining operations contributed to periods when supplies of tungsten concentrates were constrained in China. Production of tungsten concentrate outside China was expected to increase in 2021 but to remain at less than 20% of world production. Scrap continued to be an important source of raw material for the tungsten industry worldwide. Beginning in 2020 and into 2021, the tungsten scrap supply was constrained because less scrap is generated during periods of low industrial activity.

China was the world's leading tungsten consumer. Analysts forecast global tungsten consumption in 2021 will be higher than that in 2020 as the global economy and industrial production continued to improve following declines in 2020 resulting from the global COVID-19 pandemic. In 2021, most prices of tungsten concentrates, scrap, and downstream tungsten materials trended upward in response to strong demand, constrained spot supplies of ammonium paratungstate and concentrates, reduced scrap availability, and low inventory levels. Transportation delays and increased freight costs contributed to supply constraints and price increases.

World Mine Production and Reserves: Reserves for Portugal, Spain, Vietnam, and "Other countries" were revised based on updated company data and (or) information from the Governments of those countries.

	Mine production		Reserves[9]
	2020	2021[e]	
United States	—	—	NA
Austria	890	900	10,000
Bolivia	1,350	1,400	NA
China	66,000	66,000	1,900,000
Korea, North	410	400	29,000
Portugal	550	620	5,100
Russia	2,400	2,400	400,000
Rwanda	860	950	NA
Spain	500	900	52,000
Vietnam	4,500	4,500	100,000
Other countries	960	1,200	1,200,000
World total (rounded)	78,400	79,000	3,700,000

World Resources:[9] World tungsten resources are geographically widespread. China ranks first in the world in terms of tungsten resources and reserves and has some of the largest deposits. Canada, Kazakhstan, Russia, and the United States also have significant tungsten resources.

Substitutes: Potential substitutes for cemented tungsten carbides include cemented carbides based on molybdenum carbide, niobium carbide, or titanium carbide; ceramics; ceramic-metallic composites (cermets); and tool steels. Most of these options reduce, rather than replace, the amount of tungsten used. Potential substitutes for other applications are as follows: molybdenum for certain tungsten mill products; molybdenum steels for tungsten steels, although most molybdenum steels still contain tungsten; lighting based on carbon nanotube filaments, induction technology, and light-emitting diodes for lighting based on tungsten electrodes or filaments; depleted uranium or lead for tungsten or tungsten alloys in applications requiring high density or the ability to shield radiation; and depleted uranium alloys or hardened steel for cemented tungsten carbides or tungsten alloys in armor-piercing projectiles. In some applications, substitution would result in increased cost or a loss in product performance.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Includes ammonium and other tungstates; ferrotungsten; tungsten carbides; tungsten metal powders; tungsten oxides, chlorides, and other tungsten compounds; unwrought tungsten; wrought tungsten forms; and tungsten waste and scrap.
[2]Includes ammonium and other tungstates, ferrotungsten, tungsten carbides, tungsten metal powders, unwrought tungsten, wrought tungsten forms, and tungsten waste and scrap.
[3]Defined as mine production + secondary production + imports – exports + adjustments for Government and industry stock changes.
[4]Source: Platts Metals Week.
[5]A metric ton unit of tungsten trioxide contains 7.93 kilograms of tungsten.
[6]Defined as imports – exports + adjustments for Government and industry stock changes.
[7]See Appendix B for definitions.
[8]Tungsten-rhenium metal.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.

VANADIUM

(Data in metric tons of contained vanadium unless otherwise noted)

Domestic Production and Use: Byproduct vanadium production in Utah from the mining of uraniferous sandstones on the Colorado Plateau ceased in early 2020 and was not restarted in 2021. Secondary vanadium production continued in Arkansas and Ohio where processed waste materials (petroleum residues, spent catalysts, and utility ash) were used to produce ferrovanadium, vanadium-bearing chemicals or specialty alloys, and vanadium pentoxide. Two additional secondary producers in Pennsylvania and Texas remained idle. Metallurgical use, primarily as an alloying agent for iron and steel, accounted for about 94% of domestic reported vanadium consumption in 2021. Of the other uses for vanadium, the major nonmetallurgical use was in catalysts to produce maleic anhydride and sulfuric acid.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine, mill	—	—	460	17	—
Imports for consumption:					
Aluminum-vanadium master alloy	288	281	222	101	40
Ash and residues	4,530	5,020	3,780	60	100
Ferrovanadium	2,810	2,970	2,280	1,350	2,000
Oxides and hydroxides, other	148	98	105	67	25
Vanadium chemicals[1]	607	515	201	211	360
Vanadium metal[2]	54	28	45	([3])	1
Vanadium ores and concentrates	2	590	192	4	4
Vanadium pentoxide	3,400	4,600	3,620	1,670	2,000
Exports:					
Aluminum-vanadium master alloy	132	90	29	13	100
Ash and residues	322	287	354	159	260
Ferrovanadium	229	575	295	165	120
Oxides and hydroxides, other	148	53	750	51	270
Vanadium metal[2]	59	39	27	1	2
Vanadium ores and concentrates	37	29	170	164	200
Vanadium pentoxide	126	563	423	50	14
Consumption:					
Apparent[4]	10,800	12,400	8,850	2,860	3,600
Reported	4,670	5,640	4,840	5,010	4,500
Price, average, vanadium pentoxide,[5] dollars per pound	7.61	16.4	12.2	6.7	8.2
Stocks, yearend[6]	227	250	257	269	260
Net import reliance[7] as a percentage of apparent consumption	100	100	95	99	100

Recycling: The quantity of vanadium recycled from spent chemical process catalysts was significant and may compose as much as 40% of total vanadium catalysts.

Import Sources (2017–20): Ferrovanadium: Austria, 44%; Canada, 33%; Russia, 12%; Japan, 4%; and other, 7%. Vanadium pentoxide: Brazil, 47%; South Africa, 35%; China, 8%; Taiwan, 5%; and other, 5%. Total: Canada, 26%; China, 14%; Brazil, 10%; South Africa, 9%; and other, 41%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Vanadium ores and concentrates	2615.90.6090	Free.
Vanadium bearing ash and residues	2620.40.0030	Free.
Vanadium bearing ash and residues, other	2620.99.1000	Free.
Chemical compounds:		
Vanadium pentoxide, anhydride	2825.30.0010	5.5% ad valorem.
Vanadium oxides and hydroxides, other	2825.30.0050	5.5% ad valorem.
Vanadium sulfates	2833.29.3000	5.5% ad valorem.
Vanadates	2841.90.1000	5.5% ad valorem.
Hydrides and nitrides of vanadium	2850.00.2000	5.5% ad valorem.
Ferrovanadium	7202.92.0000	4.2% ad valorem.
Vanadium metal	8112.92.7000	2.0% ad valorem.
Vanadium and articles thereof[8]	8112.99.2000	2.0% ad valorem.

Depletion Allowance: 22% (domestic), 14% (foreign).

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VANADIUM

Government Stockpile: None.

Events, Trends, and Issues: U.S. apparent consumption of vanadium in 2021 increased by 25% from that in 2020. The estimated average Chinese vanadium pentoxide price in 2021 increased by 22% compared with the 2020 price, and the estimated United States ferrovanadium price increased by 51% to $16.30 per pound in 2021 compared with that in 2020. Governments globally announced different measures to revive their economies after they were negatively affected by the global COVID-19 pandemic.

China continued to be the world's top vanadium producer, producing the majority of its vanadium from vanadiferous iron ore processed for steel production. In response to the global pandemic, China's Government implemented stimulus measures which led to record steel production in China. As a result, Chinese steel mills used more domestic titaniferous magnetite ore and resulted in Chinese producers operating at near capacity. Despite the significant increase in vanadium slag production in China, several environmental restrictions by China's Government to cut pollution may impose further constraints on vanadium slag production at steel plants. The limited capacity of vanadium-producing steel plants was expected to continue to cause vanadium prices to fluctuate.

In the third quarter of 2021, a producer in Brazil announced the commissioning of a vanadium trioxide processing plant at its Maracas Menchen Mine. The company emphasized that its decision to include production of high purity vanadium would be key to supporting its vanadium redox flow battery technology business. A vanadium producer in South Africa announced that it was completing an expanded prefeasibility study of its facility to determine the most-capital-efficient manner to increase vanadium production. It aimed to increase its facility's capacity by approximately 50% by yearend 2022 and more than double capacity in the long term if market conditions continued to improve.

World Mine Production and Reserves:

	Mine production		Reserves[9]
	2020	2021[e]	(thousand metric tons)
United States	17	—	45
Australia	—	—	[10]6,000
Brazil	6,620	6,700	120
China	70,000	73,000	9,500
Russia	19,500	19,000	5,000
South Africa	8,580	9,100	3,500
World total (rounded)	105,000	110,000	24,000

World Resources:[9] World resources of vanadium exceed 63 million tons. Vanadium occurs in deposits of phosphate rock, titaniferous magnetite, and uraniferous sandstone and siltstone, in which it constitutes less than 2% of the host rock. Significant quantities are also present in bauxite and carboniferous materials, such as coal, crude oil, oil shale, and tar sands. Because vanadium is typically recovered as a byproduct or coproduct, demonstrated world resources of the element are not fully indicative of available supplies. Although domestic resources and secondary recovery are adequate to supply a large portion of domestic needs, almost all of U.S. demand is currently met by foreign sources.

Substitutes: Steels containing various combinations of other alloying elements can be substituted for steels containing vanadium. Certain metals, such as manganese, molybdenum, niobium (columbium), titanium, and tungsten, are to some degree interchangeable with vanadium as alloying elements in steel. Platinum and nickel can replace vanadium compounds as catalysts in some chemical processes. Currently, no acceptable substitute for vanadium is available for use in aerospace titanium alloys.

[e]Estimated. — Zero.
[1]Includes vanadium chlorides, hydrides, nitrides, and sulfates, as well as vanadates of vanadium.
[2]Includes waste and scrap.
[3]Less than ½ unit.
[4]Defined as production + imports – exports + adjustments for industry stock changes.
[5]The 2017 annual average vanadium pentoxide price includes U.S. monthly averages for January to June 2017 and China monthly average prices for July to December 2017. The prices for 2018–2021 are the China annual average vanadium pentoxide prices. Source: CRU Group.
[6]Includes chlorides, ferrovanadium, vanadates, vanadium-aluminum alloy, other vanadium alloys, vanadium metal, vanadium pentoxide, and other specialty chemicals.
[7]Defined as imports – exports + adjustments for industry stock changes.
[8]Aluminum-vanadium master alloy consisting of 35% aluminum and 64.5% vanadium.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.
[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 1.1 million tons.

VERMICULITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies with mining and processing facilities in South Carolina and Virginia produced approximately 100,000 tons of vermiculite concentrate; data have been rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data. Flakes of raw vermiculite concentrate are micaceous in appearance and contain interlayer water in their structure. When the flakes are heated rapidly to a temperature above 870 degrees Celsius, the water flashes into steam, and the flakes expand into accordionlike particles. This process is called exfoliation or expansion, and the resulting ultralightweight material is chemically inert, fire resistant, and odorless. Most vermiculite concentrate produced in the United States was shipped to 15 exfoliating plants in nine States. The end uses for exfoliated vermiculite were estimated to be agriculture and horticulture, 32%; lightweight concrete aggregates (including cement premixes, concrete, and plaster), 24%; insulation, 9%; and other, 35%.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production[1, 2]	100	100	100	100	100
Imports for consumption[e]	28	37	39	40	38
Exports[e]	15	13	8	8	12
Consumption:					
Apparent, concentrate[e, 3]	110	120	130	130	130
Reported, exfoliated	77	79	79	81	78
Price, range of value, concentrate, ex-plant, dollars per ton	140–575	140–575	NA	NA	NA
Employment, number[e]	63	66	73	73	68
Net import reliance[4] as a percentage of apparent consumption[e, 5]	10	20	20	20	20

Recycling: Insignificant.

Import Sources (2017–20): South Africa, 70%; Brazil, 28%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Vermiculite, perlite, and chlorites, unexpanded	2530.10.0000	Free.
Exfoliated vermiculite, expanded clays, foamed slag, and similar expanded materials	6806.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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VERMICULITE

Events, Trends, and Issues: U.S. exports and imports of vermiculite are not collected as a separate category by the U.S. Census Bureau. U.S. imports were estimated to be about 38,000 tons in 2021, a decrease which could be related to disruptions in the global supply chain. Most imports came from South Africa and Brazil in 2021. One U.S. company announced a packaging surcharge in 2021 owing to the rising costs it was incurring from its suppliers. In 2020, a U.S. exfoliating plant in Florida closed, while another in New Mexico ceased producing exfoliated vermiculite.

Exploration and development of vermiculite deposits containing medium, large, and premium (coarser) grades (greater than 5-millimeter particle size) are likely to continue (mostly in China and South Africa) because of the higher demand for those grades. Finer grade production has exceeded consumption for several years, with Brazil and the United States continuing to be the leading producers. Producers will continue to investigate ways to increase the use of the finer grades in existing products and as a substitute for coarser vermiculite while continuing to develop new and innovative applications.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2020	2021[e]	
United States	[1, 2]100	[1, 2]100	25,000
Brazil	50	60	6,600
Bulgaria	10	10	NA
China	NA	NA	NA
India	2	2	1,600
Mexico	([7])	([7])	NA
Russia	29	30	NA
South Africa	150	140	14,000
Turkey	1	1	NA
Uganda	9	10	NA
Uzbekistan	2	2	NA
Zimbabwe	29	30	NA
World total (rounded)[8]	380	390	NA

World Resources:[6] In addition to the producing mines in South Carolina and Virginia, there are vermiculite occurrences in Colorado, Nevada, North Carolina, Texas, and Wyoming that contain estimated resources of 2 million to 3 million tons. Significant deposits have been reported in Australia, China, Russia, Uganda, and some other countries, but reserve and resource information comes from many sources and, in most cases, it is not clear whether the numbers refer to vermiculite alone or vermiculite plus other minerals and host rock and overburden.

Substitutes: Expanded perlite is a substitute for exfoliated vermiculite in lightweight concrete and plaster. Other denser but less costly alternatives in these applications include expanded clay, shale, slag, and slate. Alternate materials for loose-fill fireproofing insulation include fiberglass, perlite, and slag wool. In agriculture, substitutes include bark and other plant materials, peat, perlite, sawdust, and synthetic soil conditioners.

[e]Estimated. NA Not available.
[1]Concentrate sold or used by producers.
[2]Data are rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data.
[3]Defined as concentrate sold or used by producers + imports – exports.
[4]Defined as imports – exports.
[5]Data are rounded to one significant digit to avoid disclosing company proprietary data.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]Less than ½ unit.
[8]Does not include China's production.

WOLLASTONITE

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Wollastonite was mined by two companies in New York during 2021. U.S. production of wollastonite (sold or used by producers) was withheld to avoid disclosing company proprietary data but was estimated to have increased from that of 2020. Economic resources of wollastonite typically form as a result of thermal metamorphism of siliceous limestone during regional deformation or chemical alteration of limestone by siliceous hydrothermal fluids along faults or contacts with magmatic intrusions. Deposits of wollastonite have been identified in Arizona, California, Idaho, Nevada, New Mexico, New York, and Utah; however, New York is the only State where long-term continuous mining has taken place.

The U.S. Geological Survey does not collect consumption statistics for wollastonite, but consumption was estimated to have increased in 2021 compared with that of 2020. Ceramics (frits, sanitaryware, and tile), friction products (primarily brake linings), metallurgical applications (flux and conditioner), paint (architectural and industrial paints), plastics and rubber markets (thermoplastic and thermoset resins and elastomer compounds), and miscellaneous uses (including adhesives, concrete, glass, and sealants) accounted for wollastonite sales in the United States.

In ceramics, wollastonite decreases shrinkage and gas evolution during firing; increases green and fired strength; maintains brightness during firing; permits fast firing; and reduces crazing, cracking, and glaze defects. In metallurgical applications, wollastonite serves as a flux for welding, a source for calcium oxide, a slag conditioner, and protects the surface of molten metal during the continuous casting of steel. As an additive in paint, it improves the durability of the paint film, acts as a pH buffer, improves resistance to weathering, reduces gloss and pigment consumption, and acts as a flatting and suspending agent. In plastics, wollastonite improves tensile and flexural strength, reduces resin consumption, and improves thermal and dimensional stability at elevated temperatures. Surface treatments are used to improve the adhesion between wollastonite and the polymers to which it is added. As a substitute for asbestos in floor tiles, friction products, insulating board and panels, paint, plastics, and roofing products, wollastonite is resistant to chemical attack, stable at high temperatures, and improves flexural and tensile strength.

Salient Statistics—United States: The United States was thought to be a net exporter of wollastonite in 2021. Comprehensive trade data were not available for wollastonite because it is imported and exported under generic Harmonized Tariff Schedule of the United States and Schedule B codes, respectively, that include multiple mineral commodities. Prices for domestically produced wollastonite were estimated to be between $330 to $360 per metric ton. Price data for globally produced wollastonite were unavailable. Products with finer grain sizes and acicular (highly elongated) particles sold for higher prices. Surface treatment, when necessary, also increased the selling price. Approximately 55 people were employed at wollastonite mines and mills in 2021 (excluding office workers) in the United States.

Recycling: None.

Import Sources (2017–20): Comprehensive trade data were not available, but wollastonite was primarily imported from Canada and Mexico.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

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WOLLASTONITE

Events, Trends, and Issues: Construction starts of new housing units through July 2021 increased by 21.8% compared with those during the same period in 2020 with the largest increase in starts being in single unit, privately owned houses. Sales of wollastonite to domestic construction-related markets, such as adhesives, caulks, cement board, ceramic tile, paints, stucco, and wallboard, were thought to have increased as well as sales of wollastonite for primary iron and steel production, which increased by 18% compared with those during the same period of 2020. Supply-chain issues as well as the continuing impact of the global COVID-19 pandemic limited consumption in two major markets. The production of motor vehicles and parts, which contain wollastonite in friction products and plastic and rubber components, decreased slightly in the first 7 months of 2021 and was 35% lower than production in 2019. Plastics production was expected to be 3% lower in 2021 than that in 2020.

Globally, ceramics, paint, and polymers (such as plastics and rubber) accounted for most wollastonite sales. Lesser global uses for wollastonite included miscellaneous construction products, friction materials, metallurgical applications, and paper. Several research projects continued in Canada, India, and the United States to evaluate the efficacy of wollastonite in carbon dioxide sequestration. Studies were being conducted to evaluate wollastonite's ability to capture atmospheric carbon dioxide when added to crop fields and its ability to enhance crop productivity. Wollastonite's ability to reduce carbon dioxide emissions in cement production by lowering kiln temperatures needed to produce cement and absorbing carbon dioxide in the process was being evaluated. Global sales of wollastonite were estimated to be in the range of 850,000 to 950,000 tons, higher than those in 2020.

World Mine Production and Reserves: More countries than those listed may produce wollastonite; however, many countries do not publish wollastonite production data.

	Mine production[e]		Reserves[1]
	2020	2021	
United States	W	W	World resources of wollastonite are thought to exceed 100 million tons. Many deposits have been identified but have not been surveyed sufficiently to quantify their reserves.
Canada	20,000	20,000	
China	890,000	900,000	
India	170,000	180,000	
Mexico	77,700	100,000	
Other countries	17,000	20,000	
World total (rounded)[2]	1,200,000	1,200,000	

World Resources:[1] Reliable estimates of wollastonite resources do not exist for most countries. Large deposits of wollastonite have been identified in China, Finland, India, Mexico, and the United States. Smaller, but significant, deposits have been identified in Canada, Chile, Kenya, Namibia, South Africa, Spain, Sudan, Tajikistan, Turkey, and Uzbekistan.

Substitutes: The acicular nature of many wollastonite products allows wollastonite to compete with other acicular materials, such as ceramic fiber, glass fiber, steel fiber, and several organic fibers, such as aramid, polyethylene, polypropylene, and polytetrafluoroethylene, in products where improvements in dimensional stability, flexural modulus, and heat deflection are sought. Wollastonite also competes with several nonfibrous minerals or rocks, such as kaolin, mica, and talc, which are added to plastics to increase flexural strength, and such minerals as barite, calcium carbonate, gypsum, and talc, which impart dimensional stability to plastics. In ceramics, wollastonite competes with carbonates, feldspar, lime, and silica as a source of calcium and silica. Its use in ceramics depends on the formulation of the ceramic body and the firing method.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]See Appendix C for resource and reserve definitions and information concerning data sources.
[2]Excludes U.S. production.

YTTRIUM[1]

[Data in metric tons of yttrium oxide (Y_2O_3) equivalent unless otherwise noted]

Domestic Production and Use: Yttrium is one of the rare-earth elements. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined in 2020 as a primary product at the Mountain Pass Mine in California, which was restarted in the first quarter of 2018 after being put on care-and-maintenance status in the fourth quarter of 2015. Yttrium was estimated to represent about 0.12% of the rare-earth elements in the Mountain Pass bastnaesite ore. Insufficient information was available to determine the yttrium content of mine production. Monazite, a rare-earth phosphate mineral, was produced as a separated concentrate that includes yttrium-rich xenotime. Both are accessory minerals in heavy-mineral-sand concentrates.

The leading end uses of yttrium were in catalysts, ceramics, electronics, lasers, metallurgy, and phosphors. In ceramic applications, yttrium compounds were used in abrasives, bearings and seals, high-temperature refractories for continuous-casting nozzles, jet-engine coatings, oxygen sensors in automobile engines, and wear-resistant and corrosion-resistant cutting tools. In electronics, yttrium-iron garnets were components in microwave radar to control high-frequency signals. Yttrium was an important component in yttrium-aluminum-garnet laser crystals used in dental and medical surgical procedures, digital communications, distance and temperature sensing, industrial cutting and welding, nonlinear optics, photochemistry, and photoluminescence. In metallurgical applications, yttrium was used as a grain-refining additive and as a deoxidizer. Yttrium was used in heating-element alloys, high-temperature superconductors, and superalloys. Yttrium was used in phosphor compounds for flat-panel displays and various lighting applications.

Salient Statistics—United States:	2017	2018	2019	2020	2021[e]
Production, mine	—	NA	NA	NA	NA
Imports for consumption, yttrium, alloys, compounds, and metal[e, 2]	380	450	360	650	670
Exports, compounds[e, 3]	2	14	6	1	9
Consumption, apparent[e, 4]	400	400	400	600	700
Price, average, dollars per kilogram:[5]					
Y_2O_3, minimum 99.999% purity	3	3	3	3	5
Yttrium metal, minimum 99.9% purity	35	36	34	34	38
Net import reliance[6, 7] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Insignificant.

Import Sources (2017–20):[8] Yttrium compounds: China,[9] 97%; the Republic of Korea, 1%; Japan, 1%; and other, 1%. Nearly all imports of yttrium metal and compounds are derived from mineral concentrates processed in China. Import sources do not include yttrium contained in value-added intermediates and finished products.

Tariff: Item	Number	Normal Trade Relations 12–31–21
Rare-earth metals, unspecified, whether or not intermixed or interalloyed	2805.30.0090	5.0% ad valorem.
Mixtures of rare-earth oxides containing yttrium or scandium as the predominant metal	2846.90.2015	Free.
Mixtures of rare-earth chlorides containing yttrium or scandium as the predominant metal	2846.90.2082	Free.
Yttrium-bearing materials and compounds containing by weight >19% to <85% Y_2O_3	2846.90.4000	Free.
Other rare-earth compounds, including yttrium and other compounds	2846.90.8000	3.7% ad valorem.

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YTTRIUM

Depletion Allowance: Monazite, thorium content, 22% (domestic), 14% (foreign); yttrium, rare-earth content, 14% (domestic and foreign); and xenotime, 14% (domestic and foreign).

Government Stockpile:[10]

		FY 2021		FY 2022	
Material	Inventory as of 9–30–21	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Yttrium	25	600	—	25	—

Events, Trends, and Issues: China produced most of the world's supply of yttrium from its weathered clay ion-adsorption ore deposits in the southern Provinces—primarily Fujian, Guangdong, and Jiangxi—and from a lesser number of deposits in Guangxi and Hunan. Yttrium also was produced from similar clay deposits in Burma.

Globally, yttrium was mainly consumed in the form of oxide compounds for ceramics and phosphors. Lesser amounts were consumed in electronic devices, lasers, optical glass, and metallurgical applications. The average prices for yttrium metal and Y_2O_3 both increased compared with those in 2020. China's Ministry of Industry and Information Technology raised quotas for rare-earth mining and separation to 168,000 tons and 162,000 tons of rare-earth-oxide equivalent, respectively. The yttrium content of the production quota was not specified. Mine production was allocated to 148,850 tons of light rare earths and 19,150 tons of ion-adsorption clays.

In 2020, China's exports of yttrium compounds and metal were estimated to be 3,300 tons of Y_2O_3 equivalent, and the leading export destinations were, in descending order, Japan, the United States, the Republic of Korea, Germany, and France.

World Mine Production and Reserves:[11] World mine production of yttrium contained in rare-earth mineral concentrates was estimated to be 8,000 to 12,000 tons. Most of this production took place in China and Burma. Global reserves of Y_2O_3 equivalent were estimated to be more than 500,000 tons. The leading countries for these reserves included Australia, Brazil, Canada, China, and India. Although mine production in Burma was significant, information on reserves in Burma was not available. Global reserves may be adequate to satisfy near-term demand at current rates of production; however, recent high demand of ion-adsorption clay rare earths in Burma and China as well as changes in economic conditions, environmental issues, or permitting and trade restrictions could affect the availability and pricing of many of the rare-earth elements, including yttrium.

World Resources:[11] Large resources of yttrium in monazite and xenotime are available worldwide in placer deposits, carbonatites, uranium ores, and weathered clay deposits (ion-adsorption ore). Additional resources of yttrium occur in apatite-magnetite-bearing rocks, deposits of niobium-tantalum minerals, non-placer monazite-bearing deposits, sedimentary phosphate deposits, and uranium ores.

Substitutes: Substitutes for yttrium are available for some applications but generally are much less effective. In most uses, especially in electronics, lasers, and phosphors, yttrium is generally not subject to direct substitution by other elements. As a stabilizer in zirconia ceramics, Y_2O_3 may be substituted with calcium oxide or magnesium oxide, but the substitutes generally impart lower toughness.

[e]Estimated. NA Not available. — Zero.
[1]See also Rare Earths; trade data for yttrium are included in the data shown for rare earths.
[2]Estimated from Trade Mining LLC and IHS Markit Ltd. shipping records.
[3]Includes data for the following Schedule B code: 2846.90.2015.
[4]Defined as imports – exports. Rounded to one significant digit. Yttrium consumed domestically was imported or refined from imported materials.
[5]Free on board China. Source: Argus Media group—Argus Metals International.
[6]Defined as imports – exports.
[7]In 2018, 2019, 2020, and 2021, domestic production of mineral concentrates was stockpiled or exported. Consumers of compounds and metals were reliant on imports and stockpiled inventory of compounds and metals.
[8]Includes estimated Y_2O_3 equivalent from the following Harmonized Tariff Schedule of the United States codes: 2846.90.2015, 2846.90.2082, 2846.90.4000, 2846.90.8050, and 2846.90.8060.
[9]Includes Hong Kong.
[10]See Appendix B for definitions.
[11]See Appendix C for resource and reserve definitions and information concerning data sources.

ZEOLITES (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2021, six companies in the United States operated nine zeolite mines and produced an estimated 87,000 tons of natural zeolites, slightly more than that of 2020. Chabazite was mined in Arizona, and clinoptilolite was mined in California, Idaho, New Mexico, Oregon, and Texas. Minor quantities of erionite, ferrierite, mordenite, and (or) phillipsite also likely were produced. New Mexico was estimated to be the leading natural zeolite-producing State in 2021. The top three companies accounted for approximately 75% of total domestic production.

An estimated 76,000 tons of natural zeolites was sold in the United States during 2021, slightly more compared with that of 2020. Domestic uses were, in descending order of estimated quantity, animal feed, odor control, unspecified end uses (such as ice melt, soil amendment, and synthetic turf), water purification, pet litter, wastewater treatment, fungicide or pesticide carrier, oil and grease absorbent, air filtration and gas absorbent, fertilizer carrier, desiccant, and aquaculture. Animal feed, odor control, and water purification applications likely accounted for about 60% of the domestic sales tonnage.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, mine	82,400	86,100	87,800	86,700	87,000
Sales, mill	81,300	80,500	77,100	75,300	76,000
Imports for consumption[e]	<1,000	<1,000	<1,000	<1,000	<1,000
Exports[e]	<1,000	<1,000	<1,000	<1,000	<1,000
Consumption, apparent[1]	81,300	80,500	77,100	75,300	76,000
Price, range of value, dollars per ton[2]	100–300	[e]50–300	[e]50–300	[e]50–300	50–300
Employment, mine and mill, number[e, 3]	110	110	120	120	120
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Zeolites used for desiccation, gas absorbance, wastewater cleanup, and water purification may be reused after reprocessing of the spent zeolites. Information about the quantity of recycled natural zeolites was unavailable.

Import Sources (2017–20): Comprehensive trade data were not available for natural zeolite minerals because they were imported and exported under generic Harmonized Tariff Schedule of the United States and Schedule B codes, respectively, that include multiple mineral commodities or under codes for finished products. Nearly all imports and exports were thought to be synthetic zeolites.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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ZEOLITES (NATURAL)

Events, Trends, and Issues: Prior to the 1990s, annual output of natural zeolites in the United States was less than 15,000 tons. Production rose more than sixfold from 1990 through 2021 owing predominantly to increases in sales for animal feed applications, although sales for odor control and water purification also increased significantly. In contrast, sales for pet litter declined substantially during this period as a result of competition from other products.

World Mine Production and Reserves: Many countries either do not report production of natural zeolites or production is reported with a 2- to 3-year lag time. End uses for natural zeolites in countries that mine large tonnages of zeolite minerals typically include low-value, high-volume construction applications, such as dimension stone, lightweight aggregate, and pozzolanic cement. As a result, production data for some countries may not accurately indicate the quantities of natural zeolites used in the high-value applications that are reflected in the U.S. data.

World reserves of natural zeolites have not been estimated. Deposits occur in many countries, but companies rarely publish reserves data. Further complicating estimates of reserves is the fact that much of the reported world production includes altered volcanic tuffs with low to moderate concentrations of zeolites that are typically used in high-volume construction applications. Some deposits should, therefore, be excluded from reserves estimates because it is the rock itself and not its zeolite content that makes the deposit valuable.

	Mine production		Reserves[5]
	2020	2021[e]	
United States	86,700	87,000	Two of the leading companies in the United States reported combined reserves of 80 million tons in 2021; total U.S. reserves likely are substantially larger. World data are unavailable, but reserves are estimated to be large.
China	[e]52,000	52,000	
Cuba	[e]53,000	53,000	
Georgia	135,000	140,000	
Hungary	[e]29,000	29,000	
Indonesia	[e]130,000	130,000	
Jordan	12,000	12,000	
Korea, Republic of	131,000	130,000	
New Zealand	[e]100,000	100,000	
Russia	[e]35,000	35,000	
Slovakia	[e]117,000	120,000	
Turkey	[e]73,000	50,000	
Other countries	5,450	5,500	
World total (rounded)	959,000	944,000	

World Resources:[5] Recent estimates for domestic and global resources of natural zeolites are not available. Resources of chabazite and clinoptilolite in the United States are sufficient to satisfy foreseeable domestic demand.

Substitutes: For pet litter, zeolites compete with other mineral-based litters, such as those manufactured using bentonite, diatomite, fuller's earth, and sepiolite; organic litters made from shredded corn stalks and paper, straw, and wood shavings; and litters made using silica gel. Diatomite, perlite, pumice, vermiculite, and volcanic tuff compete with natural zeolites as lightweight aggregate. Zeolite desiccants compete against such products as magnesium perchlorate and silica gel. Zeolites compete with bentonite, gypsum, montmorillonite, peat, perlite, silica sand, and vermiculite in various soil amendment applications. Activated carbon, diatomite, or silica sand may substitute for zeolites in water-purification applications. As an oil absorbent, zeolites compete mainly with bentonite, diatomite, fuller's earth, sepiolite, and a variety of polymer and natural organic products. In animal feed, zeolites compete with bentonite, diatomite, fuller's earth, kaolin, silica, and talc as anticaking and flow-control agents.

[e]Estimated. E Net exporter.
[1]Defined as mill sales + imports – exports. Information about industry stocks was unavailable.
[2]Range of ex-works mine and mill unit values for individual natural zeolite operations, based on data reported by U.S. producers and U.S. Geological Survey estimates. Average unit values per ton for the past 5 years were $140 in 2017, and an estimated $125 in 2018, 2019, 2020, and 2021. Prices vary with the percentage of zeolite present in the product, the chemical and physical properties of the zeolite mineral(s), particle size, surface modification and (or) activation, and end use.
[3]Excludes administration and office staff. Estimates based on data from the Mine Safety and Health Administration.
[4]Defined as imports – exports.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.

ZINC

(Data in thousand metric tons of contained zinc unless otherwise noted)

Domestic Production and Use: The value of zinc mined in 2021, based on zinc contained in concentrate, was about $2.4 billion. Zinc was mined in five States at seven mining operations by five companies. Three smelter facilities, one primary and two secondary, operated by three companies, produced commercial-grade zinc metal. Of the total reported zinc consumed, most was used in galvanizing, followed by brass and bronze, zinc-based alloys, and other uses.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production:					
Zinc in ores and concentrates	774	824	753	718	740
Refined zinc[1]	132	116	115	180	220
Imports for consumption:					
Zinc in ores and concentrates	7	([2])	([2])	3	8
Refined zinc	729	775	830	700	700
Exports:					
Zinc in ores and concentrates	682	806	792	546	580
Refined zinc	33	23	5	2	5
Shipments from Government stockpile	—	—	—	—	—
Consumption, apparent, refined zinc[3]	829	868	939	878	920
Price, average, cents per pound:					
North American[4]	139.3	141.0	124.1	110.8	145
London Metal Exchange (LME), cash	131.2	132.7	115.6	102.7	136
Stocks, reported producer and consumer, refined zinc, yearend	114	119	116	120	110
Employment, number:					
Mine and mill[5]	2,420	2,630	2,470	2,360	2,400
Smelter, primary	240	250	250	220	220
Net import reliance[6] as a percentage of apparent consumption					
Ores and concentrates	E	E	E	E	E
Refined zinc	84	87	88	79	76

Recycling: In 2021, an estimated 60% of the refined zinc produced in the United States was recovered from secondary materials at both primary and secondary smelters. Secondary materials included galvanizing residues and crude zinc oxide recovered from electric arc furnace dust.

Import Sources (2017–20): Ores and concentrates: Peru, 89%; China, 11%; other, <1%. Refined metal: Canada, 63%; Mexico, 15%; Peru, 7%; Spain, 7%; and other, 8%. Waste and scrap (gross weight): Canada, 64%; Mexico, 34%; and other, 2%. Combined total (includes gross weight of waste and scrap): Canada, 63%; Mexico, 15%; Peru, 7%; Spain, 7%; and other, 8%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–21**
Zinc ores and concentrates, zinc content	2608.00.0030	Free.
Zinc oxide; zinc peroxide	2817.00.0000	Free.
Unwrought zinc, not alloyed:		
Containing 99.99% or more zinc	7901.11.0000	1.5% ad valorem.
Containing less than 99.99% zinc:		
Casting-grade	7901.12.1000	3% ad valorem.
Other	7901.12.5000	1.5% ad valorem.
Zinc alloys	7901.20.0000	3% ad valorem.
Zinc waste and scrap	7902.00.0000	Free.

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ZINC

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile:[7]

Material	Inventory as of 9–30–21	FY 2021 Potential acquisitions	FY 2021 Potential disposals	FY 2022 Potential acquisitions	FY 2022 Potential disposals
Zinc	7.25	—	7.25	—	7.25

Events, Trends, and Issues: Estimated global zinc mine production in 2021 increased from that in 2020, when mine production was constrained in some countries because of Government-mandated lockdowns and a decrease in zinc prices following the onset of the global COVID-19 pandemic. According to the International Lead and Zinc Study Group,[8] estimated global refined zinc production in 2021 was forecast to increase slightly to 14.13 million tons and estimated metal consumption to increase by 6% to 14.09 million tons, resulting in a production-to-consumption surplus.

On November 9, 2021, a proposed revised U.S. critical minerals list was published in the Federal Register (86 FR 62199). The new list contained 50 individual mineral commodities; proposed changes were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium, which were included in the 2018 critical minerals list.

World Mine Production and Reserves: Reserves for Australia, Canada, India, Mexico, Peru, Sweden, and the United States were revised based on Government or company reports.

	Mine production[9] 2020	Mine production[9] 2021[e]	Reserves[10]
United States	718	740	9,000
Australia	1,310	1,300	[11]69,000
Bolivia	360	490	4,800
Canada	211	260	5,400
China	4,060	4,200	44,000
India	720	810	9,100
Kazakhstan	222	220	12,000
Mexico	638	720	19,000
Peru	1,330	1,600	19,000
Russia	280	280	22,000
Sweden	232	230	3,700
Other countries	1,950	2,000	34,000
World total (rounded)	12,000	13,000	250,000

World Resources:[10] Identified zinc resources of the world are about 1.9 billion tons.

Substitutes: Aluminum and plastics substitute for galvanized sheet in automobiles; aluminum alloys, cadmium, paint, and plastic coatings replace zinc coatings in other applications. Aluminum- and magnesium-base alloys are major competitors for zinc-base diecasting alloys. Many elements are substitutes for zinc in chemical, electronic, and pigment uses.

[e]Estimated. E Net exporter. — Zero.
[1]Includes primary and secondary zinc metal production.
[2]Less than ½ unit.
[3]Defined as refined production + refined imports – refined exports + adjustments for Government stock changes.
[4]Source: S&P Global Platts Metals Week, North American Special High Grade (SHG) zinc; based on the LME cash price plus premium.
[5]Includes mine and mill employment at all zinc-producing mines. Excludes office workers. Source: Mine Safety and Health Administration.
[6]Defined as imports – exports + adjustments for Government stock changes.
[7]See Appendix B for definitions.
[8]International Lead and Zinc Study Group, 2021, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 12, [5] p.
[9]Zinc content of concentrates and direct shipping ores.
[10]See Appendix C for resource and reserve definitions and information concerning data sources.
[11]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 24 million tons.

ZIRCONIUM AND HAFNIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2021, one company recovered zircon (zirconium silicate) from surface-mining operations in Florida and Georgia as a coproduct from the mining of heavy-mineral sands and the processing of titanium and zirconium mineral concentrates, and a second company processed existing mineral sands tailings in Florida. Zirconium metal and hafnium metal were produced from zirconium chemical intermediates by one producer in Oregon and one in Utah. Zirconium and hafnium are typically contained in zircon at a ratio of about 36 to 1. Zirconium chemicals were produced by the metal producer in Oregon and by at least 10 other companies. Ceramics, foundry sand, opacifiers, and refractories are the leading end uses for zircon. Other end uses of zircon include abrasives, chemicals (predominantly, zirconium basic sulfate and zirconium oxychloride octohydrate as intermediate chemicals), metal alloys, and welding rod coatings. The leading consumers of zirconium metal are the chemical process and nuclear energy industries. The leading use of hafnium metal is in superalloys.

Salient Statistics—United States:	**2017**	**2018**	**2019**	**2020**	**2021[e]**
Production, zirconium ores and concentrates (ZrO_2 content)[1]	[2]50,000	[3]100,000	[2]20,000	[2]20,000	[2]20,000
Imports:					
Zirconium ores and concentrates (ZrO_2 content)[1]	24,300	26,400	22,600	15,600	18,000
Zirconium, unwrought, powder, and waste and scrap	899	1,880	1,820	2,030	560
Zirconium, wrought	282	282	289	302	250
Hafnium, unwrought, powder, and waste and scrap	113	42	32	16	16
Exports:					
Zirconium ores and concentrates (ZrO_2 content)[1]	31,500	77,500	40,500	12,200	12,000
Zirconium, unwrought, powder, and waste and scrap	627	556	897	664	550
Zirconium, wrought	972	1,150	816	830	770
Consumption, apparent,[4] zirconium ores and concentrates (ZrO_2 content)[1]	[2]50,000	[3]100,000	[2]10,000	[2]30,000	[2]30,000
Price:					
Zircon, dollars per metric ton (gross weight):					
Australia, free on board[5]	975	NA	NA	NA	NA
China, cost, insurance, and freight[6]	1,295	1,625	1,585	1,415	1,780
Imported[7]	916	1,290	1,490	1,380	1,340
Zirconium, unwrought, imports, China,[8] dollars per kilogram	12	13	14	6	8
Hafnium, unwrought,[6] dollars per kilogram	900	840	780	750	830
Net import reliance[9] as a percentage of apparent consumption:					
Zirconium ores and concentrates	E	E	E	<25	<25
Hafnium	NA	NA	NA	NA	NA

Recycling: Companies in Oregon and Utah recycled zirconium from new scrap generated during metal production and fabrication and (or) from post-commercial old scrap. Zircon foundry mold cores and spent or rejected zirconia refractories are often recycled. Hafnium metal recycling was insignificant.

Import Sources (2017–20): Zirconium ores and concentrates: South Africa, 54%; Senegal, 25%; Australia, 19%; Russia, 2%; and other, <1%. Zirconium, unwrought, including powder: China, 89%; Germany, 8%; and other, 3%. Zirconium, wrought: France, 64%; Germany, 18%; Belgium, 5%; and other, 13%. Hafnium, unwrought: Germany, 42%; France, 29%; China, 24%; the United Kingdom, 2%; and other, 3%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–21**
Zirconium ores and concentrates	2615.10.0000	Free.
Ferrozirconium	7202.99.1000	4.2% ad valorem.
Zirconium, unwrought and powder	8109.20.0000	4.2% ad valorem.
Zirconium waste and scrap	8109.30.0000	Free.
Other zirconium articles	8109.90.0000	3.7% ad valorem.
Hafnium, unwrought, powder, and waste and scrap	8112.92.2000	Free.

Depletion Allowance: 22% (domestic), 14% (foreign).

Government Stockpile: None.

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ZIRCONIUM AND HAFNIUM

Events, Trends, and Issues: Global production of zirconium mineral concentrates was essentially unchanged in 2021 compared with that in 2020. Advanced exploration and development projects with planned production of zircon concentrates were ongoing in Australia, Madagascar, Mozambique, Senegal, Tanzania, and elsewhere. In the United States, mining and heavy-mineral-processing operations were expanded near Starke, FL, and prefeasibility studies were underway at the Titan heavy-mineral-sands project near Camden, TN. U.S. exports of zirconium ores and concentrates were essentially unchanged, whereas imports increased by 15% from those in 2020 but remained lower than those in previous years. Australia, Senegal, and South Africa continued to be the leading import sources of zirconium ores and concentrates. The leading global exporters of zirconium mineral concentrates were Australia, Senegal, and South Africa. The leading global importers were China, India, and Spain.

Global producers of zirconium sponge included China, France, India, Russia, and the United States. The leading global exporters of unwrought zirconium metal under Harmonized System Code 8109.20 were China, Germany, and the United States. France and Russia led the global importers of unwrought zirconium.

World Mine Production and Reserves: World primary hafnium production data were not available, and quantitative estimates of hafnium reserves are not available. Zirconium reserves for Australia were revised on the basis of Government reports. Zirconium reserves for Kenya and South Africa were revised on the basis of company reports.

	Zirconium ores and zircon concentrates, mine production (thousand metric tons, gross weight)		Zirconium reserves[10] (thousand metric tons, ZrO_2 content)[1]
	2020	2021[e]	
United States	[2]30	[2]30	500
Australia	400	400	[11]50,000
China	140	140	500
Indonesia	64	55	NA
Kenya	29	30	50
Mozambique	110	110	1,800
Senegal	60	70	NA
South Africa	280	270	5,900
Other countries	117	110	11,000
World total (rounded)	1,200	1,200	70,000

World Resources:[10] Resources of zircon in the United States included about 14 million tons associated with titanium resources in heavy-mineral-sand deposits. Phosphate rock and sand and gravel deposits could potentially yield substantial amounts of zircon as a byproduct. World resources of hafnium are associated with those of zircon and baddeleyite. Quantitative estimates of hafnium resources were not available.

Substitutes: Chromite and olivine can be used instead of zircon for some foundry applications. Dolomite and spinel refractories can also substitute for zircon in certain high-temperature applications. Niobium (columbium), stainless steel, and tantalum provide limited substitution in nuclear applications, and titanium and synthetic materials may substitute in some chemical processing plant applications. Silver-cadmium-indium control rods are used in lieu of hafnium at numerous nuclear powerplants. Zirconium can be used interchangeably with hafnium in certain superalloys.

[e]Estimated. E Net exporter. NA Not available.
[1]Calculated ZrO_2 content as 65% of gross production.
[2]Data are rounded to one significant digit to avoid disclosing company proprietary data.
[3]Data are rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data.
[4]Defined as production + imports – exports.
[5]Source: Industrial Minerals, average of yearend price. Prices of zircon from Australia were discontinued at yearend 2017.
[6]Source: Argus Media group—Argus Metals International, average of yearend price.
[7]Unit value based on annual United States imports for consumption from Australia, Senegal, and South Africa.
[8]Unit value based on annual United States imports for consumption from China.
[9]Defined as imports – exports.
[10]See Appendix C for resource and reserve definitions and information concerning data sources.
[11]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 22.1 million tons, gross weight.

APPENDIX A

Abbreviations and Units of Measure

1 carat (metric) (diamond)	= 200 milligrams
1 flask (fl)	= 76 pounds, avoirdupois, or 33.47 kilograms
1 karat (gold)	= one twenty-fourth part
1 kilogram (kg)	= 2.2046 pounds, avoirdupois
1 long ton (lt)	= 2,240 pounds, avoirdupois
1 long ton unit (ltu)	= 1% of 1 long ton, or 22.4 pounds, avoirdupois
long calcined ton (lct)	= excludes water of hydration
long dry ton (ldt)	= excludes excess free moisture
Mcf	= 1,000 cubic feet
1 metric ton (t)	= 2,204.6 pounds, avoirdupois, or 1,000 kilograms
1 metric ton (t)	= 1.1023 short ton
1 metric ton unit (mtu)	= 1% of 1 metric ton, or 10 kilograms
metric dry ton (mdt)	= excludes excess free moisture
1 pound (lb)	= 453.6 grams
psia	= pounds per square inch absolute
1 short ton (st)	= 2,000 pounds, avoirdupois
1 short ton unit (stu)	= 1% of 1 short ton, or 20 pounds, avoirdupois
short dry ton (sdt)	= excludes excess free moisture
1 troy ounce (tr oz)	= 1.09714 avoirdupois ounces, or 31.103 grams
1 troy pound	= 12 troy ounces

APPENDIX B

Definitions of Selected Terms Used in This Report

Terms Used for Materials in the National Defense Stockpile and Federal Helium Reserve

Fiscal year for the U.S. Government is the period from October 1 through September 30. Fiscal year (FY) 2021 is from October 1, 2020, through September 30, 2021. FY 2022 is from October 1, 2021, through September 30, 2022.

Inventory refers to the quantity of mineral materials held in the National Defense Stockpile or in the Federal Helium Reserve. Nonstockpile-grade materials may be included in the table; where significant, the quantities of these stockpiled materials are specified in the text accompanying the table.

Potential disposals indicate the total amount of a material in the National Defense Stockpile that the U.S. Department of Defense is permitted to dispose of under the Annual Materials Plan approved by Congress for the fiscal year. Congress has authorized disposal over the long term at rates designed to maximize revenue but avoid undue disruption to the usual markets and financial loss to the United States. Disposals are defined as any disposal or sale of National Defense Stockpile stock. For mineral commodities that have a disposal plan greater than the inventory, the actual quantity will be limited to the remaining disposal authority or inventory. Note that, unlike the National Defense Stockpile, helium stockpile sales by the Bureau of Land Management under the Helium Privatization Act of 1996 are permitted to exceed disposal plans.

Potential acquisitions indicate the maximum amount of a material that may be acquired by the U.S. Department of Defense for the National Defense Stockpile under the Annual Materials Plan approved by Congress for the fiscal year.

Depletion Allowance

The depletion allowance is a business tax deduction analogous to depreciation, but which applies to an ore reserve rather than equipment or production facilities. Federal tax law allows this deduction from taxable corporate income, recognizing that an ore deposit is a depletable asset that must eventually be replaced.

APPENDIX C

Reserves and Resources

Reserves data are dynamic. They may be reduced as ore is mined and (or) the feasibility of extraction diminishes, or more commonly, they may continue to increase as additional deposits (known or recently discovered) are developed, or currently exploited deposits are more thoroughly explored and (or) new technology or economic variables improve their economic feasibility. Reserves may be considered a working inventory of mining companies' supplies of an economically extractable mineral commodity. As such, the magnitude of that inventory is necessarily limited by many considerations, including cost of drilling, taxes, price of the mineral commodity being mined, and the demand for it. Reserves will be developed to the point of business needs and geologic limitations of economic ore grade and tonnage. For example, in 1970, identified and undiscovered world copper resources were estimated to contain 1.6 billion metric tons of copper, with reserves of about 280 million tons of copper. Since then, about 600 million tons of copper have been produced worldwide, but world copper reserves in 2021 were estimated to be 880 million tons of copper, more than triple those in 1970, despite the depletion by mining of much more than the 1970 estimated reserves.

Future supplies of minerals will come from reserves and other identified resources, currently undiscovered resources in deposits that will be discovered in the future, and material that will be recycled from current in-use stocks of minerals or from minerals in waste disposal sites. Undiscovered deposits of minerals constitute an important consideration in assessing future supplies. Mineral-resource assessments have been carried out for small parcels of land being evaluated for land reclassification, for the Nation, and for the world.

Part A—Resource and Reserve Classification for Minerals[1]

Introduction

Through the years, geologists, mining engineers, and others operating in the minerals field have used various terms to describe and classify mineral resources, which as defined herein include energy materials. Some of these terms have gained wide use and acceptance, although they are not always used with precisely the same meaning.

The U.S. Geological Survey (USGS) collects information about the quantity and quality of all mineral resources. In 1976, the USGS and the U.S. Bureau of Mines developed a common classification and nomenclature, which was published as USGS Bulletin 1450–A—"Principles of the Mineral Resource Classification System of the U.S. Bureau of Mines and U.S. Geological Survey." Experience with this resource classification system showed that some changes were necessary in order to make it more workable in practice and more useful in long-term planning. Therefore, representatives of the USGS and the U.S. Bureau of Mines collaborated to revise Bulletin 1450–A. Their work was published in 1980 as USGS Circular 831—"Principles of a Resource/Reserve Classification for Minerals."

Long-term public and commercial planning must be based on the probability of discovering new deposits, on developing economic extraction processes for currently unworkable deposits, and on knowing which resources are immediately available. Thus, resources must be continuously reassessed in the light of new geologic knowledge, of progress in science and technology, and of shifts in economic and political conditions. To best serve these planning needs, known resources should be classified from two standpoints: (1) purely geologic or physical and chemical characteristics—such as grade, quality, tonnage, thickness, and depth—of the material in place; and (2) profitability analyses based on costs of extracting and marketing the material in a given economy at a given time. The former constitutes important objective scientific information of the resource and a relatively unchanging foundation upon which the latter more valuable economic delineation can be based.

The revised classification system, designed generally for all mineral materials, is shown graphically in figures C1and C2; its components and their usage are described in the text. The classification of mineral and energy resources is necessarily arbitrary because definitional criteria do not always coincide with natural boundaries. The system can be used to report the status of mineral and energy-fuel resources for the Nation or for specific areas.[1]

Resource and Reserve Definitions

A dictionary definition of resource, "something in reserve or ready if needed," has been adapted for mineral and energy resources to comprise all materials, including those only surmised to exist, that have present or anticipated future value.

Resource.—A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.

Original Resource.—The amount of a resource before production.

Identified Resources.—Resources for which location, grade, quality, and quantity are known or estimated from specific geologic evidence. Identified resources include economic, marginally economic, and subeconomic components. To reflect varying degrees of geologic certainty, these economic divisions can be subdivided into measured, indicated, and inferred.

[1]Based on U.S. Geological Survey Circular 831, 1980.

Demonstrated.—A term for the sum of measured plus indicated resources.

Measured.—Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and (or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurements are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated.—Quantity and grade and (or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurements are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

Inferred.—Estimates are based on an assumed continuity beyond measured and (or) indicated resources, for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements.

Reserve Base.—That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources). The term "geologic reserve" has been applied by others generally to the reserve-base category, but it also may include the inferred-reserve-base category; it is not a part of this classification system.

Inferred Reserve Base.—The in-place part of an identified resource from which inferred reserves are estimated. Quantitative estimates are based largely on knowledge of the geologic character of a deposit and for which there may be no samples or measurements. The estimates are based on an assumed continuity beyond the reserve base, for which there is geologic evidence.

Reserves.—That part of the reserve base that could be economically extracted or produced at the time of determination. The term "reserves" need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials; thus, terms such as "extractable reserves" and "recoverable reserves" are redundant and are not a part of this classification system.

Marginal Reserves.—That part of the reserve base which, at the time of determination, borders on being economically producible. Its essential characteristic is economic uncertainty. Included are resources that would be producible, given postulated changes in economic or technological factors.

Economic.—This term implies that profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty.

Subeconomic Resources.—The part of identified resources that does not meet the economic criteria of reserves and marginal reserves.

Undiscovered Resources.—Resources, the existence of which are only postulated, comprising deposits that are separate from identified resources. Undiscovered resources may be postulated in deposits of such grade and physical location as to render them economic, marginally economic, or subeconomic. To reflect varying degrees of geologic certainty, undiscovered resources may be divided into two parts, as follows:

Hypothetical Resources.—Undiscovered resources that are similar to known mineral bodies and that may be reasonably expected to exist in the same producing district or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources.

Speculative Resources.—Undiscovered resources that may occur either in known types of deposits in favorable geologic settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity, grade, and quality, they will be reclassified as identified resources.

Restricted Resources or Reserves.—That part of any resource or reserve category that is restricted from extraction by laws or regulations. For example, restricted reserves meet all the requirements of reserves except that they are restricted from extraction by laws or regulations.

Other Occurrences.—Materials that are too low grade or for other reasons are not considered potentially economic, in the same sense as the defined resource, may be recognized and their magnitude estimated, but they are not classified as resources. A separate category, labeled "other occurrences," is included in figures C1 and C2. In figure C1, the boundary between subeconomic and other occurrences is limited by the concept of current or potential feasibility of economic production, which is required by the definition of a resource. The boundary is obviously uncertain, but limits may be specified in terms of grade, quality, thickness, depth, extractable percentage, or other economic-feasibility variables.

Cumulative Production.—The amount of past cumulative production is not, by definition, a part of the resource. Nevertheless, a knowledge of what has been produced is important in order to understand current resources, in terms of both the amount of past production and the amount of residual or remaining in-place resource. A separate space for cumulative production is shown in figures C1 and C2. Residual material left in the ground during current or future extraction should be recorded in the resource category appropriate to its economic-recovery potential.

Figure C1.—Major Elements of Mineral-Resource Classification, Excluding *Reserve Base* and *Inferred Reserve Base*

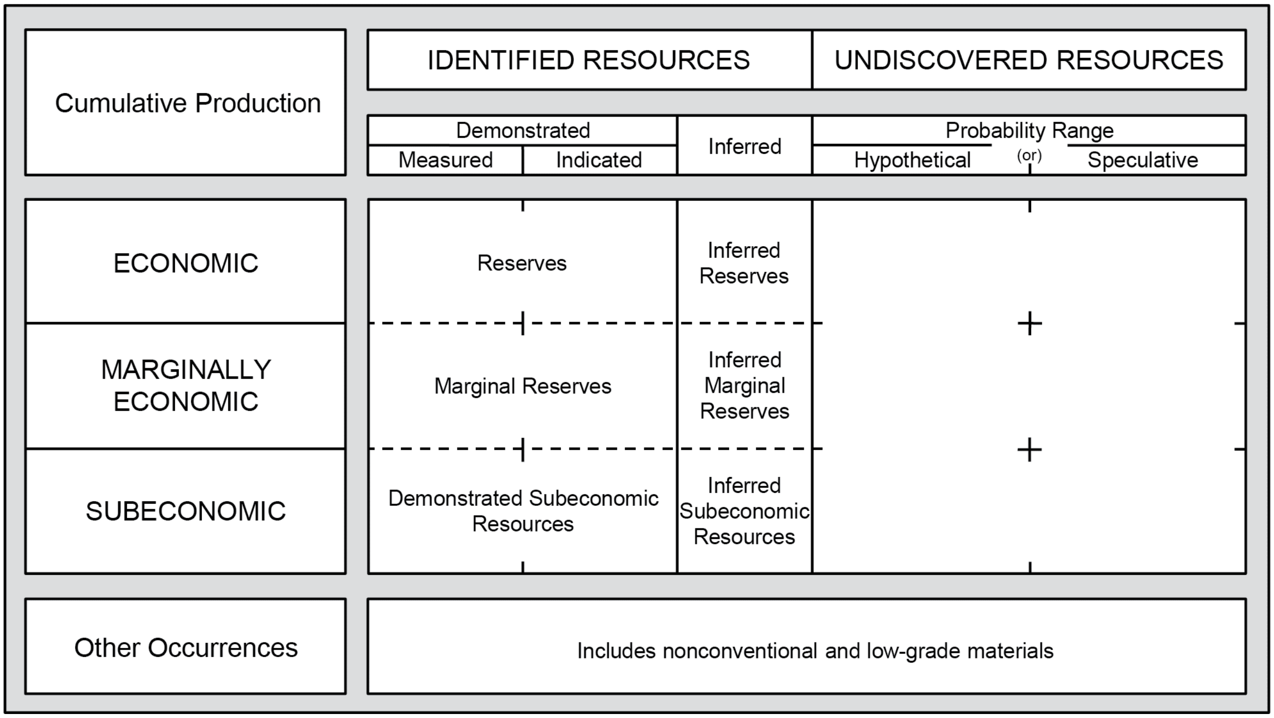
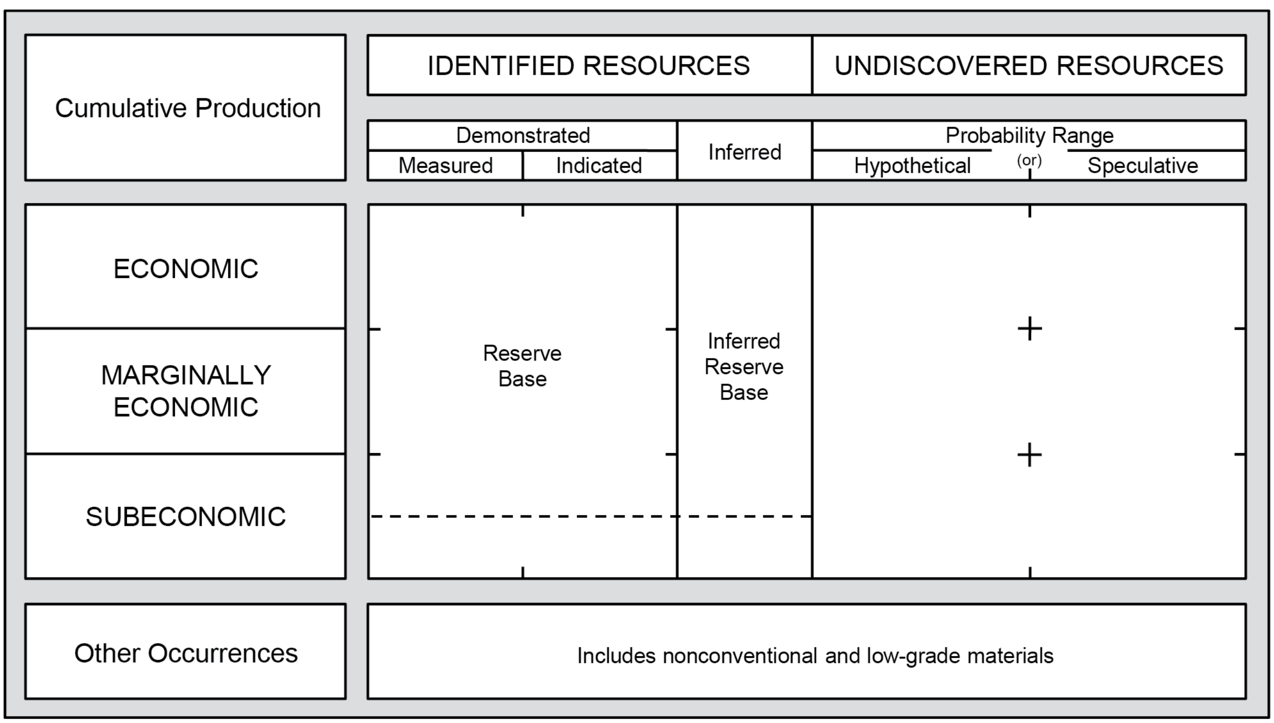


Figure C2.—*Reserve Base* and *Inferred Reserve Base* Classification Categories



Part B—Sources of Reserves Data

National information on reserves for most mineral commodities found in this report, including those for the United States, is derived from a variety of sources. The ideal source of such information would be comprehensive evaluations that apply the same criteria to deposits in different geographic areas and report the results by country. In the absence of such evaluations, national reserves estimates compiled by countries for selected mineral commodities are a primary source of national reserves information. Lacking national assessment information by governments, sources such as academic articles, company reports, presentations by company representatives, and trade journal articles, or a combination of these, serve as the basis for national information on reserves reported in the mineral commodity sections of this publication.

A national estimate may be assembled from the following: historically reported reserves information carried for years without alteration because no new information is available, historically reported reserves reduced by the amount of historical production, and company-reported reserves. International minerals availability studies conducted by the U.S. Bureau of Mines before 1996 and estimates of identified resources by an international collaborative effort (the International Strategic Minerals Inventory) are the bases for some reserves estimates. The USGS collects some qualitative information about the quantity and quality of mineral resources but does not directly measure reserves or resources, and companies or governments do not directly report information about reserves or resources to the USGS. Reassessment of reserves is a continuing process, and the intensity of this process differs by mineral commodity, country, and time period.

Some countries have specific definitions for reserves data, and reserves for each country are assessed separately, based on reported data and definitions. An attempt is made to make reserves consistent among countries for a mineral commodity and its byproducts. For example, the Australasian Joint Ore Reserves Committee (JORC) established the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code) that sets out minimum standards, recommendations, and guidelines for public reporting in Australasia of exploration results, mineral resources, and ore reserves. Companies listed on the Australian Securities Exchange and the New Zealand Stock Exchange are required to report publicly on ore reserves and mineral resources under their control, using the JORC Code.

Data reported for individual deposits by mining companies are compiled in Geoscience Australia's national mineral resources database and used in the preparation of the annual national assessments of Australia's mineral resources. Because of its specific use in the JORC Code, the term "reserves" is not used in the national inventory, where the highest category is "Economic Demonstrated Resources" (EDR). In essence, EDR combines the JORC Code categories "proved reserves" and "probable reserves," plus measured resources and indicated resources. This is considered to provide a reasonable and objective estimate of what is likely to be available for mining in the long term. Accessible Economic Demonstrated Resources represent the resources within the EDR category that are accessible for mining. Reserves for Australia in the Mineral Commodity Summaries 2022 are Accessible EDR. For more information, see table 3 in "Australia's Identified Mineral Resources 2020" (https://doi.org/10.11636/1327-1466.2020).

In Canada, the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) provides definition standards for the classification of mineral resources and mineral reserves estimates into various categories. The category to which a resource or reserves estimate is assigned depends on the level of confidence in the geologic information available on the mineral deposit, the quality and quantity of data available on the deposit, the level of detail of the technical and economic information that has been generated about the deposit, and the interpretation of the data and information. For more information on the CIM definition standards, see https://mrmr.cim.org/en/standards/canadian-mineral-resource-and-mineral-reserve-definitions/.

In Russia, reserves for most minerals can appear in a number of sources, although no comprehensive list of reserves is published. Reserves data for a limited set of mineral commodities are available in the annual report "Gosudarstvennyi Doklad o Sostoyanii i Ispol'zovanii Mineral'no-Syryevyh Resursov Rossiyskoy Federatsii" (State Report on the State and Use of Mineral and Raw Materials Resources of the Russian Federation), which is published by Russia's Ministry of Natural Resources and Environment. Reserves data for various minerals appear at times in journal articles, such as those in the journal "Mineral'nyye Resursy Rossii. Ekonomika i Upravleniye" (Mineral Resources of Russia. Economics and Management), which is published by the "OOO RG-Inform," a subsidiary of Rosgeologiya Holding. It is sometimes not clear if the reserves are being reported in ore or mineral content. It is also in many cases not clear which definition of reserves is being used, because the system inherited from the former Soviet Union has a number of ways in which the term "reserves" is defined, and these definitions qualify the percentage of resources that are included in a specific category. For example, the Soviet reserves classification system, besides the categories A, B, C1, and C2, which represent progressively detailed knowledge of a mineral deposit based on exploration data, has other subcategories cross imposed upon the system. Under the broad category reserves (zapasy), there are subcategories that include balance reserves (balansovyye zapasy, or economic reserves) and outside-the-balance reserves (zabalansovye zapasy, or subeconomic reserves), as well as categories that include explored, industrial, and proven reserves, and the reserves totals can vary significantly, depending on the specific definition of reserves being reported.

APPENDIX D

Country Specialists Directory

Minerals information country specialists at the U.S. Geological Survey collect and analyze information on the mineral industries of more than 170 nations throughout the world. The specialists are available to answer minerals-related questions concerning individual countries.

Africa and the Middle East

Algeria	Mowafa Taib
Angola	Meralis Plaza-Toledo
Bahrain	Philip A. Szczesniak
Benin	Meralis Plaza-Toledo
Botswana	Thomas R. Yager
Burkina Faso	Alberto A. Perez
Burundi	Thomas R. Yager
Cabo Verde	Meralis Plaza-Toledo
Cameroon	Philip A. Szczesniak
Central African Republic	Philip A. Szczesniak
Chad	Philip A. Szczesniak
Comoros	Philip A. Szczesniak
Congo (Brazzaville)	Philip A. Szczesniak
Congo (Kinshasa)	Thomas R. Yager
Côte d'Ivoire	Alberto A. Perez
Djibouti	Thomas R. Yager
Egypt	Mowafa Taib
Equatorial Guinea	Meralis Plaza-Toledo
Eritrea	Thomas R. Yager
Eswatini	Philip A. Szczesniak
Ethiopia	Meralis Plaza-Toledo
Gabon	Alberto A. Perez
The Gambia	Meralis Plaza-Toledo
Ghana	Meralis Plaza-Toledo
Guinea	Alberto A. Perez
Guinea-Bissau	Meralis Plaza-Toledo
Iran	Philip A. Szczesniak
Iraq	Philip A. Szczesniak
Israel	Philip A. Szczesniak
Jordan	Mowafa Taib
Kenya	Thomas R. Yager
Kuwait	Philip A. Szczesniak
Lebanon	Mowafa Taib
Lesotho	Philip A. Szczesniak
Liberia	Meralis Plaza-Toledo
Libya	Mowafa Taib
Madagascar	Thomas R. Yager
Malawi	Thomas R. Yager
Mali	Alberto A. Perez
Mauritania	Mowafa Taib
Mauritius	Philip A. Szczesniak
Morocco and Western Sahara	Mowafa Taib
Mozambique	Meralis Plaza-Toledo
Namibia	Philip A. Szczesniak
Niger	Alberto A. Perez
Nigeria	Thomas R. Yager
Oman	Philip A. Szczesniak
Qatar	Philip A. Szczesniak
Reunion	Philip A. Szczesniak
Rwanda	Thomas R. Yager
São Tomé & Principe	Meralis Plaza-Toledo

Africa and the Middle East—Continued

Saudi Arabia	Mowafa Taib
Senegal	Alberto A. Perez
Seychelles	Philip A. Szczesniak
Sierra Leone	Alberto A. Perez
Somalia	Philip A. Szczesniak
South Africa	Thomas R. Yager
South Sudan	Alberto A. Perez
Sudan	Mowafa Taib
Syria	Mowafa Taib
Tanzania	Thomas R. Yager
Togo	Alberto A. Perez
Tunisia	Mowafa Taib
Uganda	Thomas R. Yager
United Arab Emirates	Philip A. Szczesniak
Yemen	Mowafa Taib
Zambia	Philip A. Szczesniak
Zimbabwe	Philip A. Szczesniak

Asia and the Pacific

Afghanistan	Karine M. Renaud
Australia	Spencer D. Buteyn
Bangladesh	Keita F. DeCarlo
Bhutan	Keita F. DeCarlo
Brunei	Spencer D. Buteyn
Burma (Myanmar)	Ji Won Moon
Cambodia	Ji Won Moon
China	Ji Won Moon
Fiji	Spencer D. Buteyn
India	Karine M. Renaud
Indonesia	Jaewon Chung
Japan	Keita F. DeCarlo
Korea, North	Jaewon Chung
Korea, Republic of	Jaewon Chung
Laos	Ji Won Moon
Malaysia	Spencer D. Buteyn
Mongolia	Jaewon Chung
Nauru	Spencer D. Buteyn
Nepal	Keita F. DeCarlo
New Caledonia	Spencer D. Buteyn
New Zealand	Spencer D. Buteyn
Pakistan	Keita F. DeCarlo
Papua New Guinea	Spencer D. Buteyn
Philippines	Ji Won Moon
Singapore	Spencer D. Buteyn
Solomon Islands	Jaewon Chung
Sri Lanka	Keita F. DeCarlo
Taiwan	Jaewon Chung
Thailand	Ji Won Moon
Timor-Leste	Jaewon Chung
Vietnam	Ji Won Moon

Europe and Central Eurasia

Albania	Jaewon Chung
Armenia	Elena Safirova
Austria	Sinan Hastorun
Azerbaijan	Elena Safirova
Belarus	Elena Safirova
Belgium	Loyd M. Trimmer III
Bosnia and Herzegovina	Karine M. Renaud
Bulgaria	Karine M. Renaud
Croatia	Karine M. Renaud
Cyprus	Sinan Hastorun
Czechia	Loyd M. Trimmer III
Denmark, Faroe Islands, and Greenland	Joanna Goclawska
Estonia	Sinan Hastorun
Finland	Joanna Goclawska
France	Keita F. DeCarlo
Georgia	Elena Safirova
Germany	Elena Safirova
Greece	Sinan Hastorun
Hungary	Loyd M. Trimmer III
Iceland	Joanna Goclawska
Ireland	Joanna Goclawska
Italy	Loyd M. Trimmer III
Kazakhstan	Elena Safirova
Kosovo	Sinan Hastorun
Kyrgyzstan	Karine M. Renaud
Latvia	Sinan Hastorun
Lithuania	Sinan Hastorun
Luxembourg	Keita F. DeCarlo
Malta	Jaewon Chung
Moldova	Elena Safirova
Montenegro	Jaewon Chung
Netherlands	Loyd M. Trimmer III
North Macedonia	Karine M. Renaud
Norway	Joanna Goclawska
Poland	Joanna Goclawska
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Romania	Keita F. DeCarlo
Russia	Elena Safirova
Serbia	Karine M. Renaud
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Tajikistan	Karine M. Renaud
Turkey	Sinan Hastorun
Turkmenistan	Karine M. Renaud
Ukraine	Elena Safirova
United Kingdom	Jaewon Chung
Uzbekistan	Elena Safirova

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The Bahamas	Yadira Soto-Viruet
Belize	Jesse J. Inestroza
Canada	Jesse J. Inestroza
Costa Rica	Jesse J. Inestroza
Cuba	Yadira Soto-Viruet
Dominican Republic	Yadira Soto-Viruet
El Salvador	Jesse J. Inestroza
Guatemala	Jesse J. Inestroza
Haiti	Yadira Soto-Viruet
Honduras	Jesse J. Inestroza
Jamaica	Yadira Soto-Viruet
Mexico	Alberto A. Perez
Nicaragua	Jesse J. Inestroza
Panama	Jesse J. Inestroza
Trinidad and Tobago	Yadira Soto-Viruet

South America

Argentina	Jesse J. Inestroza
Bolivia	Yolanda Fong-Sam
Brazil	Yolanda Fong-Sam
Chile	Yadira Soto-Viruet
Colombia	Jesse J. Inestroza
Ecuador	Jesse J. Inestroza
French Guiana	Yolanda Fong-Sam
Guyana	Yolanda Fong-Sam
Paraguay	Yadira Soto-Viruet
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