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

MINERAL COMMODITY SUMMARIES 2023

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. Cross section of a superconducting electromagnet used in the Large Hadron Collider (LHC), the world's largest and most powerful particle accelerator, at the European Organization for Nuclear Research (CERN)'s accelerator complex. The superconducting properties of the magnet are achieved using copper-clad niobium-titanium (NbTi) coils, which surround the particle beam pipes. The particle beams travel in an ultrahigh vacuum at close to the speed of light, and huge forces are needed to guide them around the 27-kilometer-long ring of the LHC. NbTi magnets are used to bend, flatten, and focus the particle beams along the way. Photograph by Abraham J. Padilla, U.S. Geological Survey.

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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
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Thallium
Thorium
Tin
Titanium
Tungsten
Vanadium
Vermiculite
Wollastonite
Yttrium
Zeolites
Zinc
Zirconium

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CONTENTS

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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/national-minerals-information-center/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/national-minerals-information-center/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/national-minerals-information-center/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/national-minerals-information-center/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/national-minerals-information-center/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/national-minerals-information-center/historical-statistics-mineral-and-material-commodities.

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/national-minerals-information-center.

INTRODUCTION

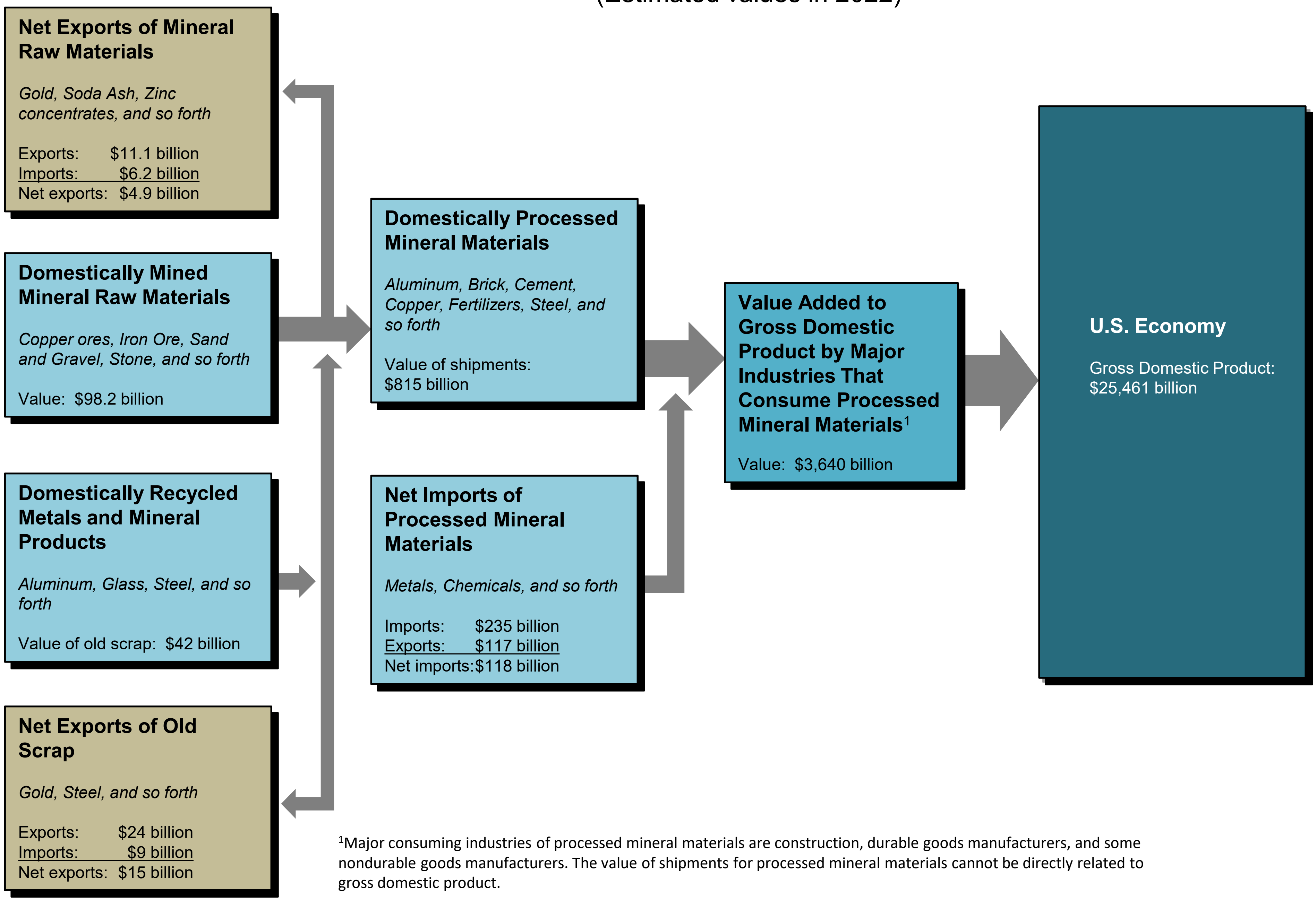
Each mineral commodity chapter of the 2023 edition of the U.S. Geological Survey (USGS) Mineral Commodity Summaries (MCS) includes information on events, trends, and issues for each mineral commodity as well as discussions and tabular presentations on domestic industry structure, Government programs, tariffs, 5-year salient statistics, and world production, reserves, and resources. The MCS is the earliest comprehensive source of 2022 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 2023 are welcomed.

Figure 1.—The Role of Nonfuel Mineral Commodities in the U.S. Economy
(Estimated values in 2022)



[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 2022, the estimated total value of nonfuel mineral production in the United States was $98.2 billion, an increase of 4% from the revised total of $94.6 billion in 2021. The estimated value of metals production decreased by 6% to $34.7 billion from a revised total of $36.9 billion in 2021. The total value of industrial minerals production was $63.5 billion, a 10% increase from that in 2021 (table 1). Of this total, $31.4 billion was construction aggregates production (construction sand and gravel and crushed stone). Crushed stone was the leading nonfuel mineral commodity in 2022 with a production value of $21 billion and accounted for 21% of the total value of U.S. nonfuel mineral production.

Increases in production of nonfuel mineral commodities and increases in prices of some industrial minerals and minerals used to make batteries contributed to the total value of nonfuel mineral production increasing in 2022. For the metals sector, there was reduced production for several metals owing to reduced ore grades and weather-related issues. Gold, iron ore, magnesium metal, palladium, platinum, silver, and titanium had some of the largest percentage decreases in production value. For the industrial minerals sector, increased construction and materials for energy and infrastructure projects as well as other manufacturing sectors led to increased production value. The largest percentage increases in production value were in barite, bromine, feldspar, helium, iodine, lithium, potash, pumice, and sand and gravel (industrial).

The U.S. Geological Survey (USGS) published the "2022 Final List of Critical Minerals" in the Federal Register (87 FR 10381). The 2022 list of critical minerals, which revised the U.S. critical minerals list (CML) published in 2018 (83 FR 23295), included 50 mineral commodities instead of 35 mineral commodities or mineral groups. There were also many initiatives, projects, and legislation passed that focused on securing American supply chains and supporting domestic production projects. Please refer to the "U.S. Critical Minerals Update" section for more details.

Foreign Trade

Presidential Proclamation 10328 of December 27, 2021, established a tariff rate quota for member countries of the European Union (EU) and provided for quarterly limits on imports of certain steel commodities that could be imported without being subject to the 25% ad valorem tariffs imposed in 2018 under section 232 of the Trade Expansion Act of 1962. Additionally, the proclamation authorized the U.S. Department of Commerce to renew all EU exclusions utilized in fiscal year 2021 for a period of 2 years from the date of the proclamation.

In February 2022, it was announced that the United States and Japan had reached an agreement for the quota of steel that could be imported without being subject to the 25% ad valorem tariffs under section 232 of the Trade Expansion Act of 1962 that were put in place in 2018. The additional 10% ad valorem tariff on aluminum remained in place.

In March 2022, it was announced that the United States and the United Kingdom reached an agreement on import quotas of steel and aluminum products that would not be subject to the ad valorem tariffs. However, certain requirements had to be met including a certificate of analysis and the imported items could not contain primary material from Belarus, China, or Russia.

In February 2022, Executive Order 14065 "Blocking Property of Certain Persons and Prohibiting Certain Transactions With Respect to Continued Russian Efforts to Undermine the Sovereignty and Territorial Integrity of Ukraine" was issued outlining certain prohibitions on investments; exportation and importation of goods, services, or technology to or from covered regions; and financing.

In September 2022, the Office of the United States Trade Representative (USTR) published a Federal Register notice (87 FR 55073) that announced that the USTR was keeping the additional tariffs placed on imports from China while the USTR was conducting its 4-year review of the actions imposed under section 301(b) of the Trade Act of 1974, (19 U.S.C. 2411, as amended): China's acts, policies, and practices related to technology transfer, intellectual property, and innovation. The decision incorporated public comments that had been received from a prior notice published in May soliciting input on whether to retain or terminate the additional 25% ad valorem duty for products imported from China (Lists 1, 2, and 3) and an additional tariff for List 4 items that had been put in place in July and August 2018. In October, the USTR issued a Federal Register notice (87 FR 62914) seeking public comment on the effectiveness of the actions taken under section 301 in achieving the objectives and any other actions that could be taken.

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 2022 was $98.2 billion. The value of net exports of mineral raw materials decreased by 4% to $4.9 billion from a revised $5.1 billion in 2021. The value of net exports of old scrap decreased to $15 billion. The value of domestically recycled products totaled $42 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 $810 billion. These mineral materials as well as $118 billion of imports of processed mineral materials were, in turn, consumed by downstream industries creating an estimated value of $3.64 trillion in 2022, a 9% increase from that in 2021.

Figure 2 illustrates the reliance of the United States on foreign sources for raw and processed mineral materials. In 2022, imports made up more than one-half of the U.S. apparent consumption for 51 nonfuel mineral commodities, and the United States was 100% net import reliant for 15 of those. Of the 50 mineral commodities identified in the “2022 Final List of Critical Minerals,” the United States was 100% net import reliant for 12, and an additional 31 critical mineral commodities (including 14 lanthanides, which are listed under rare earths) 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 “U.S. Critical Minerals Update” section.

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 2022 and the number of mineral commodities for which each highlighted country was a leading supplier. China and 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, 26 mineral commodities; Canada, 20 mineral commodities; Germany, 14 mineral commodities; Brazil, 11 mineral commodities; South Africa, 10 mineral commodities; and Mexico, 9 mineral commodities.

The estimated value of U.S. metal mine production in 2022 was $34.7 billion, 6% lower than the revised value in 2021 (table 1). In 2022, the capacity utilization for the metals mining industry was 61%, less than the 63% capacity utilization in 2021 (table 2). Principal contributors to the total value of metal mine production in 2022 were copper, 33%; gold, 28%; iron ore, 15%; zinc, 9%; and molybdenum, 5%.

The estimated value of U.S. industrial minerals production in 2022, including construction aggregates, was $63.5 billion, about 10% more than the revised value of 2021 (table 1). In 2022, the capacity utilization for the nonmetallic minerals mining industry was 88%, slightly more than the 87% capacity utilization in 2021 (table 2). The value of industrial minerals production in 2022 was dominated by crushed stone, 33%; cement (masonry and portland), 18%; construction sand and gravel, 16%; and industrial sand and gravel, 9%.

In 2022, U.S. production of 13 mineral commodities was valued at more than $1 billion each. These commodities were, in decreasing order of value, crushed stone, cement, copper, construction sand and gravel, gold, industrial sand and gravel, iron ore, zinc, salt, lime, phosphate rock, molybdenum, and soda ash.

In 2022, 9 States had more than $3 billion worth of publishable nonfuel mineral commodities production value and another 12 States had more than $1.5 billion (fig. 4).

The top 10 ranked States (based on total value including withheld values) were, in descending order of production value, Arizona, Nevada, Texas, California, Minnesota, Alaska, Florida, Utah, Michigan, and Missouri (table 3).

The West region was the leading region in the production of the metals and metallic minerals with an estimated value of $27 billion in 2022 (fig. 5).

The South region was the leading region in the production of other industrial minerals (excludes construction sand and gravel and crushed stone production) with an estimated value of $13.2 billion in 2022 (fig. 6).

In 2022, there were seven States that produced more than $1 billion worth of crushed stone. These States were, in descending order of production value, Texas, Florida, Pennsylvania, North Carolina, Georgia, Virginia, and Tennessee. There were another nine States with more than $500 million worth of crushed stone production (fig. 7).

Construction sand and gravel was produced in every State. California was the only State that produced more than $1 billion worth of construction sand and gravel in 2022 but three other States, in descending order of production value, Texas, Arizona, and Washington, produced more than $500 million. Florida, Colorado, New York, Ohio, Utah, and Michigan, 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 47 unique commodities stored at nine locations within the continental United States. In fiscal year 2022, the NDS added one material along with additional quantities of eight other materials and approximately $103 million of excess materials were sold. Revenue from the Stockpile Sales Program fund the operation of the NDS and the acquisition of new stocks. 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.—2022 U.S. Net Import Reliance[1]

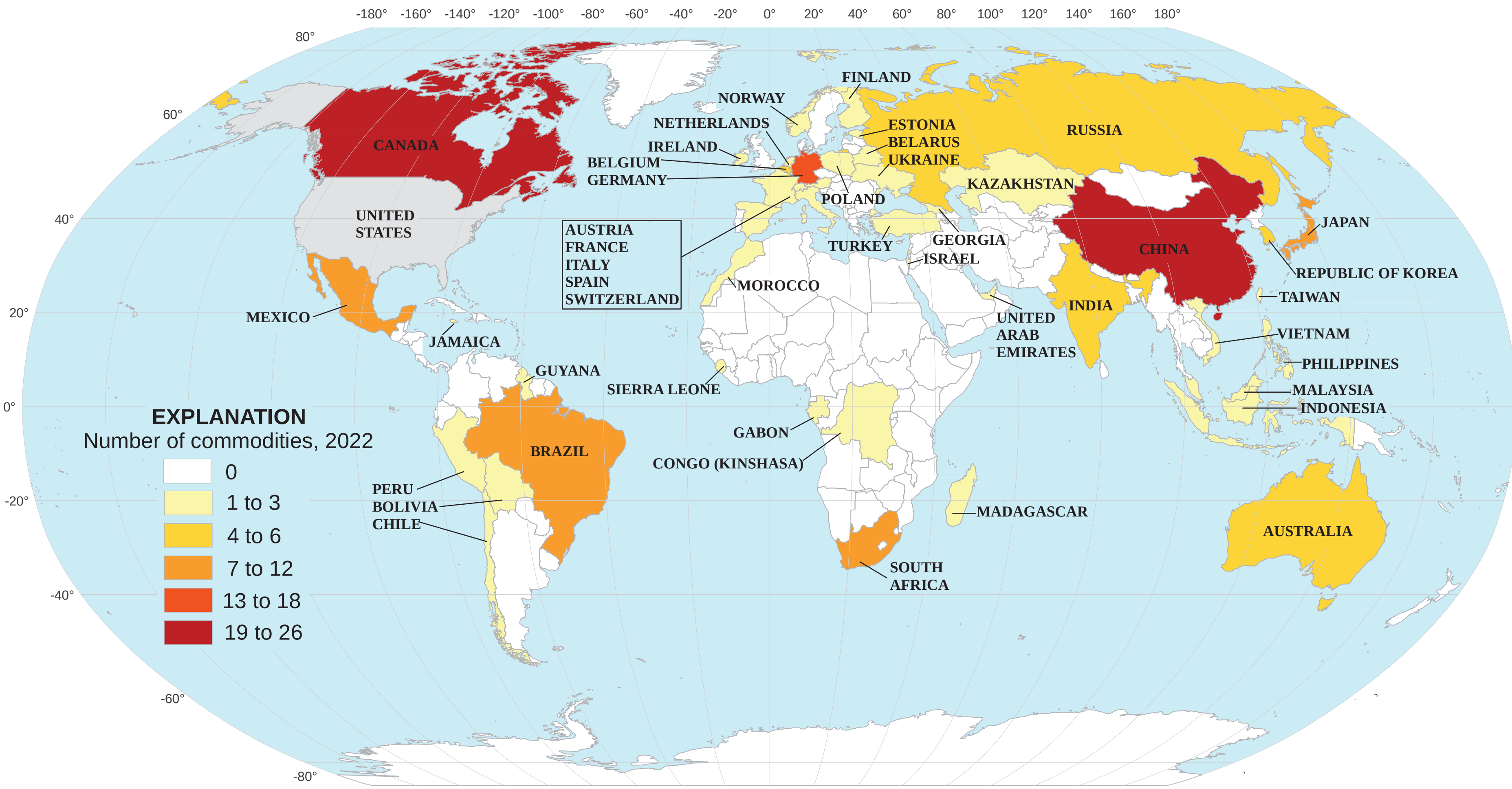
Commodity	Net import reliance as a percentage of apparent consumption	Major import sources (2018–21)[2]
ARSENIC, all forms	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Germany
FLUORSPAR	100	Mexico, Vietnam, South Africa, Canada
GALLIUM	100	China, Germany, Japan, Ukraine
GRAPHITE (NATURAL)	100	China, Mexico, Canada, Madagascar
INDIUM	100	Republic of Korea, Canada, China, France
MANGANESE	100	Gabon, South Africa, Australia, Georgia
MICA (NATURAL), sheet	100	China, Brazil, Belgium, Austria
NIOBIUM (COLUMBIUM)	100	Brazil, Canada
RUBIDIUM	100	Germany
SCANDIUM	100	Europe, China, Japan, Philippines
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Germany, Australia, Indonesia
YTTRIUM	100	China, Germany, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
BISMUTH	96	China, Republic of Korea, Mexico, Belgium
NEPHELINE SYENITE	>95	Canada
RARE EARTHS,[3] compounds and metals	>95	China, Malaysia, Estonia, Japan
TITANIUM, sponge metal	>95	Japan, Kazakhstan, Ukraine
POTASH	94	Canada, Russia, Belarus
DIAMOND (INDUSTRIAL), stones	89	South Africa, Congo (Kinshasa), India, Sierra Leone
IRON OXIDE PIGMENTS, natural and synthetic	87	China, Germany, Brazil, Canada
ANTIMONY, metal and oxide	83	China, Belgium, India
CHROMIUM, all forms	83	South Africa, Kazakhstan, Russia, Germany
STONE (DIMENSION)	82	Brazil, China, Italy, India
PEAT	81	Canada
TITANIUM MINERAL CONCENTRATES	81	South Africa, Australia, Madagascar, Canada
ABRASIVES, silicon carbide	79	China, Brazil, Netherlands, South Africa
TIN, refined	77	Peru, Indonesia, Bolivia, Malaysia
COBALT	76	Norway, Canada, Finland, Japan
ZINC, refined	76	Canada, Mexico, Peru, Spain
ABRASIVES, fused aluminum oxide	>75	China, Canada, Brazil, Austria
BARITE	>75	China, India, Morocco, Mexico
BAUXITE	>75	Jamaica, Brazil, Guyana, Turkey
TELLURIUM	>75	Canada, Germany, China, Philippines
GARNET (INDUSTRIAL)	69	South Africa, China, India, Australia
RHENIUM	69	Chile, Canada, Germany, Kazakhstan
SILVER	69	Mexico, Canada, Poland, Chile
PLATINUM	66	South Africa, Germany, Switzerland, Italy
DIAMOND (INDUSTRIAL), bort, grit, dust, and powder	62	China, Republic of Korea, Ireland, Russia
ALUMINA	59	Brazil, Australia, Jamaica, Canada
NICKEL	56	Canada, Norway, Australia, Finland
ALUMINUM	54	Canada, United Arab Emirates, Russia, China
VANADIUM	54	Canada, China, Brazil, South Africa
MAGNESIUM COMPOUNDS	53	China, Israel, Canada, Brazil
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
MAGNESIUM METAL	>50	Canada, Israel, Mexico, Taiwan
SELENIUM	>50	Philippines, Mexico, Germany, China
TUNGSTEN	>50	China, Germany, Bolivia, Vietnam
ZIRCONIUM, ores and concentrates	<50	South Africa, Senegal, Australia, Russia
SILICON, metal and ferrosilicon	45	Russia, Brazil, Canada, Norway
LEAD, refined	42	Canada, Mexico, Republic of Korea
COPPER, refined	41	Chile, Canada, Mexico
FELDSPAR	39	Turkey, Mexico
SALT	29	Chile, Canada, Mexico, Egypt
PERLITE	28	Greece, China, Mexico
PALLADIUM	26	Russia, South Africa, Italy, Germany
LITHIUM	>25	Argentina, Chile, China, Russia
BROMINE	<25	Israel, Jordan, China
CADMIUM, unwrought	<25	Australia, Germany, China, Peru
MICA (NATURAL), scrap and flake	24	Canada, China, India, Finland
CEMENT	21	Canada, Turkey, Greece, Mexico
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 (abrasives, metallic; 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, ores and concentrates) or less than 20% net import reliant (beryllium; gypsum; iron and steel; iron and steel slag; lime; nitrogen (fixed)—ammonia; phosphate rock; pumice and pumicite; 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 2022



Source: U.S. Geological Survey

Table 1.—U.S. Mineral Industry Trends

	2018	2019	2020	2021	2022[e]
Total mine production (million dollars):					
Metals	28,000	26,900	27,700	36,900	34,700
Industrial minerals	56,000	56,000	53,000	57,700	63,500
Coal	27,200	25,500	16,800	21,000	21,300
Employment (thousands of workers):					
Coal mining, all employees	52	51	40	37	38
Nonfuel mineral mining, all employees	140	140	136	138	140
Chemicals and allied products, production workers	546	558	537	540	570
Stone, clay, and glass products, production workers	311	312	296	298	310
Primary metal industries, production workers	295	301	272	269	280
Average weekly earnings of workers (dollars):					
Coal mining, all employees	1,546	1,617	1,518	1,619	1,800
Chemicals and allied products, production workers	1,071	1,065	1,065	1,104	1,100
Stone, clay, and glass products, production workers	945	968	981	1,017	1,100
Primary metal industries, production workers	1,038	1,026	1,008	1,074	1,200

[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

	2018	2019	2020	2021	2022[e]
Gross domestic product (billion dollars)	20,533	21,381	21,061	23,315	25,461
Industrial production (2017=100):					
Total index:	103	102	95	100	100
Manufacturing:	101	100	93	99	100
Nonmetallic mineral products	100	101	97	98	100
Primary metals:	103	97	86	97	97
Iron and steel	103	95	86	102	96
Aluminum	106	102	90	104	110
Nonferrous metals (except aluminum)	102	102	94	95	110
Chemicals	99	97	95	100	100
Mining:	113	121	103	106	110
Coal	98	92	69	75	78
Oil and gas extraction	116	130	122	122	130
Metals	98	96	92	91	88
Nonmetallic minerals	104	106	100	105	110
Capacity utilization (percent):					
Total industry:	79	78	73	77	80
Mining:	87	87	72	81	87
Metals	70	68	66	63	61
Nonmetallic minerals	89	90	83	87	88
Housing starts (thousands)	1,247	1,291	1,395	1,605	1,570
Light vehicle sales (thousands)	17,225	16,961	14,472	14,947	13,800
Highway construction, value, put in place (billion dollars)	91	99	103	101	110

[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 2022[p, 1, 2]

State	Value (millions)	Rank[3]	Percent of U.S. total[4]	Principal nonfuel mineral commodities[5]
Alabama	$1,920	17	1.96	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Alaska	4,510	6	4.59	Gold, lead, sand and gravel (construction), silver, zinc.
Arizona	10,100	1	10.31	Cement, copper, molybdenum mineral concentrates, sand and gravel (construction), stone (crushed).
Arkansas	1,100	29	1.12	Bromine, cement, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
California[6]	5,610	4	5.71	Boron minerals, cement, rare earths, sand and gravel (construction), stone (crushed).
Colorado	1,870	19	1.91	Cement, gold, molybdenum mineral concentrates, sand and gravel (construction), stone (crushed).
Connecticut	194	43	0.20	Sand and gravel (construction), stone (crushed), stone (dimension).
Delaware[7]	25	50	0.03	Magnesium compounds, sand and gravel (construction), stone (crushed).
Florida[6, 7]	2,810	7	2.86	Cement, clay (attapulgite and kaolin), phosphate rock, sand and gravel (construction), stone (crushed).
Georgia[6]	2,320	12	2.37	Cement, clay (kaolin and montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Hawaii	156	44	0.16	Sand and gravel (construction), stone (crushed).
Idaho	371	33	0.38	Lead, phosphate rock, sand and gravel (construction), silver, zinc.
Illinois[7]	1,250	25	1.27	Cement, magnesium compounds, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Indiana	1,380	26	1.40	Cement, lime, sand and gravel (construction), stone (crushed), stone (dimension).
Iowa	846	34	0.86	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Kansas[7]	1,170	27	1.19	Cement, helium (Grade-A), salt, sand and gravel (construction), stone (crushed).
Kentucky[7]	806	28	0.82	Cement, clay (common clay), lime, sand and gravel (construction), stone (crushed).
Louisiana	1,030	31	1.05	Clay (common clay), salt, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Maine[7]	100	47	0.10	Cement, peat, sand and gravel (construction), stone (crushed), stone (dimension).
Maryland[7]	414	35	0.42	Cement, sand and gravel (construction), stone (crushed), stone (dimension).
Massachusetts[7]	206	41	0.21	Clay (common clay), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Michigan	3,360	9	3.42	Cement, iron ore, magnesium compounds, nickel sulfide concentrates, salt.
Minnesota[7]	4,780	5	4.86	Iron ore, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Mississippi	225	42	0.23	Clay (ball clay, bentonite, common clay, montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Missouri	3,150	10	3.21	Cement, lead, lime, sand and gravel (industrial), stone (crushed).
Montana	1,600	21	1.63	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 2022[p, 1, 2]—Continued

State	Value (millions)	Rank[3]	Percent of U.S. total[4]	Principal nonfuel mineral commodities[5]
Nebraska[7]	$256	39	0.26	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Nevada	8,930	2	9.09	Copper, diatomite, gold, and sand gravel (construction), stone (crushed).
New Hampshire[7]	135	45	0.14	Sand and gravel (construction), stone (crushed), stone (dimension).
New Jersey	425	38	0.43	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
New Mexico	1,470	24	1.49	Cement, copper, potash, sand and gravel (construction), stone (crushed).
New York	1,950	15	1.98	Cement, salt, sand and gravel (construction), stone (crushed), zinc.
North Carolina	1,900	18	1.93	Clay (common clay and fire clay), phosphate rock, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
North Dakota[7]	105	48	0.11	Lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Ohio[7]	1,490	14	1.52	Cement, lime, salt, sand and gravel (construction), stone (crushed).
Oklahoma	1,030	30	1.05	Cement, iodine, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Oregon	693	36	0.70	Cement, diatomite, pumice and pumicite, sand and gravel (construction), stone (crushed).
Pennsylvania[7]	2,060	13	2.09	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Rhode Island[7]	88	49	0.09	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
South Carolina[7]	1,160	23	1.18	Cement, gold, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
South Dakota	475	37	0.48	Cement, gold, lime, sand and gravel (construction), stone (crushed).
Tennessee	1,940	16	1.97	Cement, sand and gravel (construction), sand and gravel (industrial), stone (crushed), zinc.
Texas	8,030	3	8.17	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Utah	3,600	8	3.66	Copper, gold, potash, salt, sand and gravel (construction).
Vermont[7]	136	46	0.14	Sand and gravel (construction), stone (crushed), stone (dimension), talc (crude).
Virginia	1,530	22	1.56	Cement, kyanite, lime, sand and gravel (construction), stone (crushed).
Washington	901	32	0.92	Cement, diatomite, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
West Virginia[7]	204	40	0.21	Cement, lime, salt, sand and gravel (industrial), stone (crushed).
Wisconsin[7]	1,720	20	1.75	Lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Wyoming	2,480	11	2.53	Cement, clay (bentonite and common clay), helium (Grade-A), sand and gravel (construction), soda ash.
Undistributed	4,210	XX	4.29	XX
Total	98,200	XX	100.00	

[p]Preliminary. XX Not applicable.

[1]Includes data available through December 14, 2022.

[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.

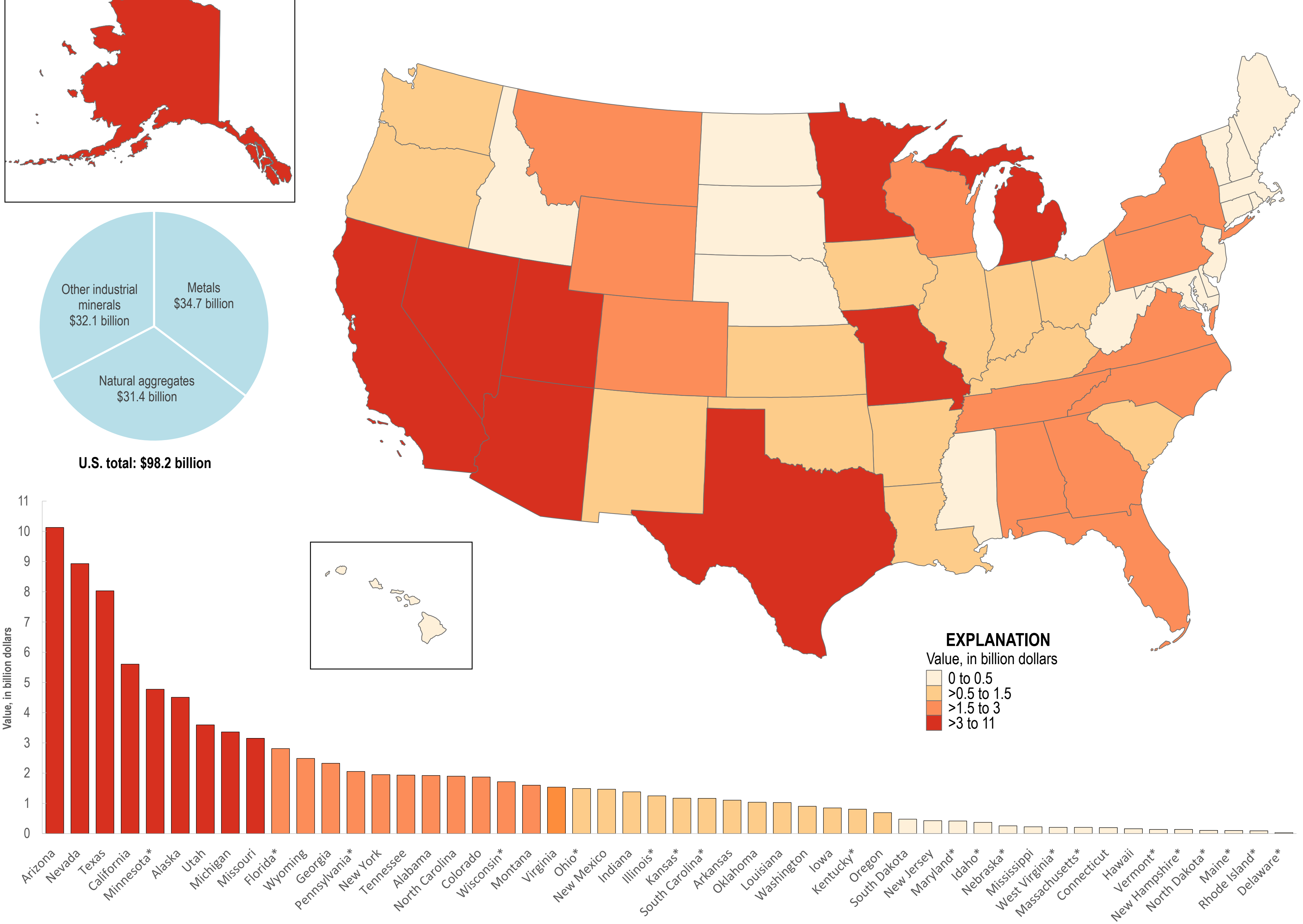
[4]"Percent of U.S. total" calculated to two decimal places.

[5]Listed in alphabetical order.

[6]California also produces significant quantities of titanium mineral concentrates and Florida and Georgia produce significant quantities of rare earths and titanium and zirconium mineral concentrates. Breakdown by State is not included in State total to avoid disclosure of company proprietary data.

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

Figure 4.—Value of Nonfuel Minerals Produced in 2022, 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 2022, by Region

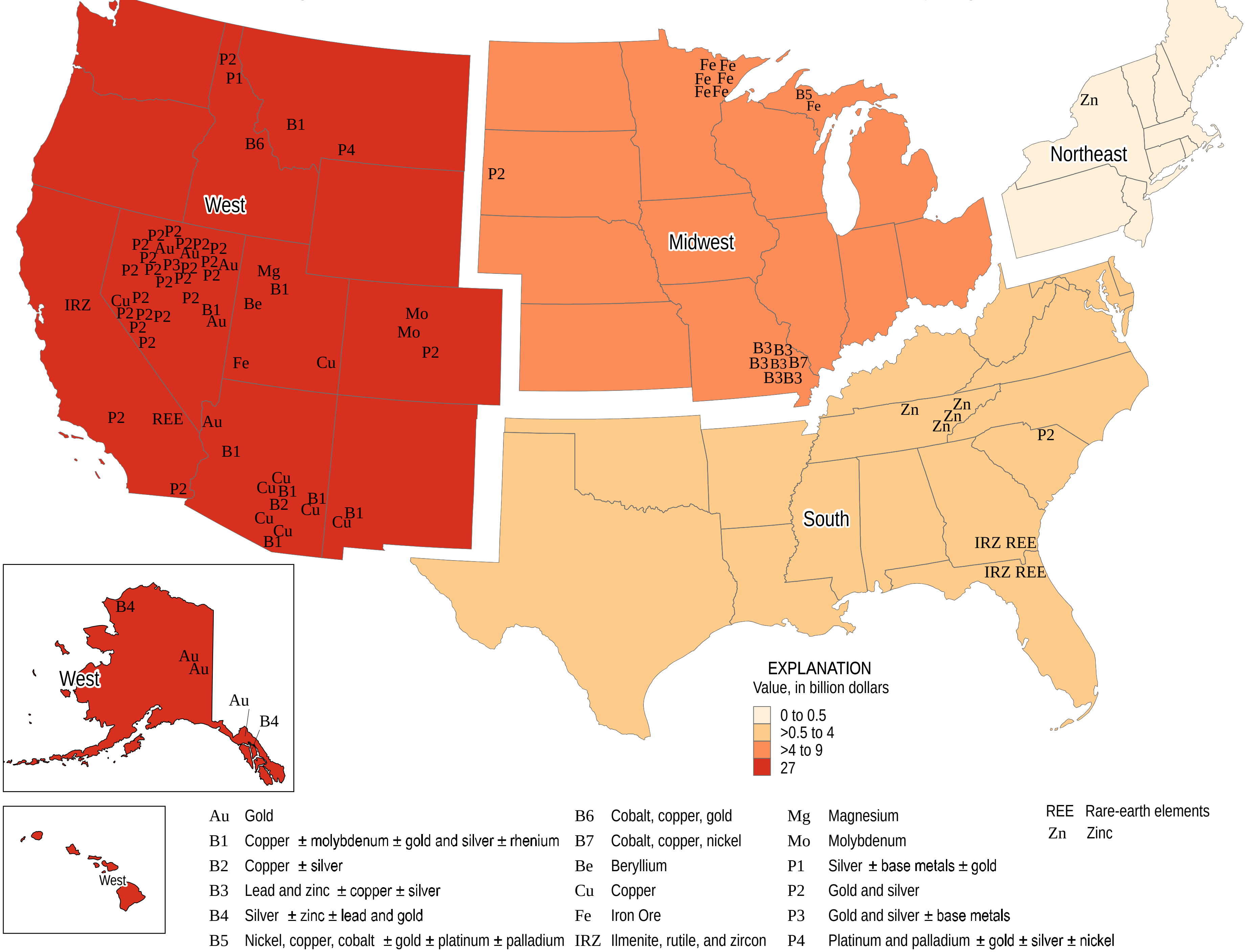


Figure 6.—Value of Other Industrial Minerals Produced in 2022, by Region

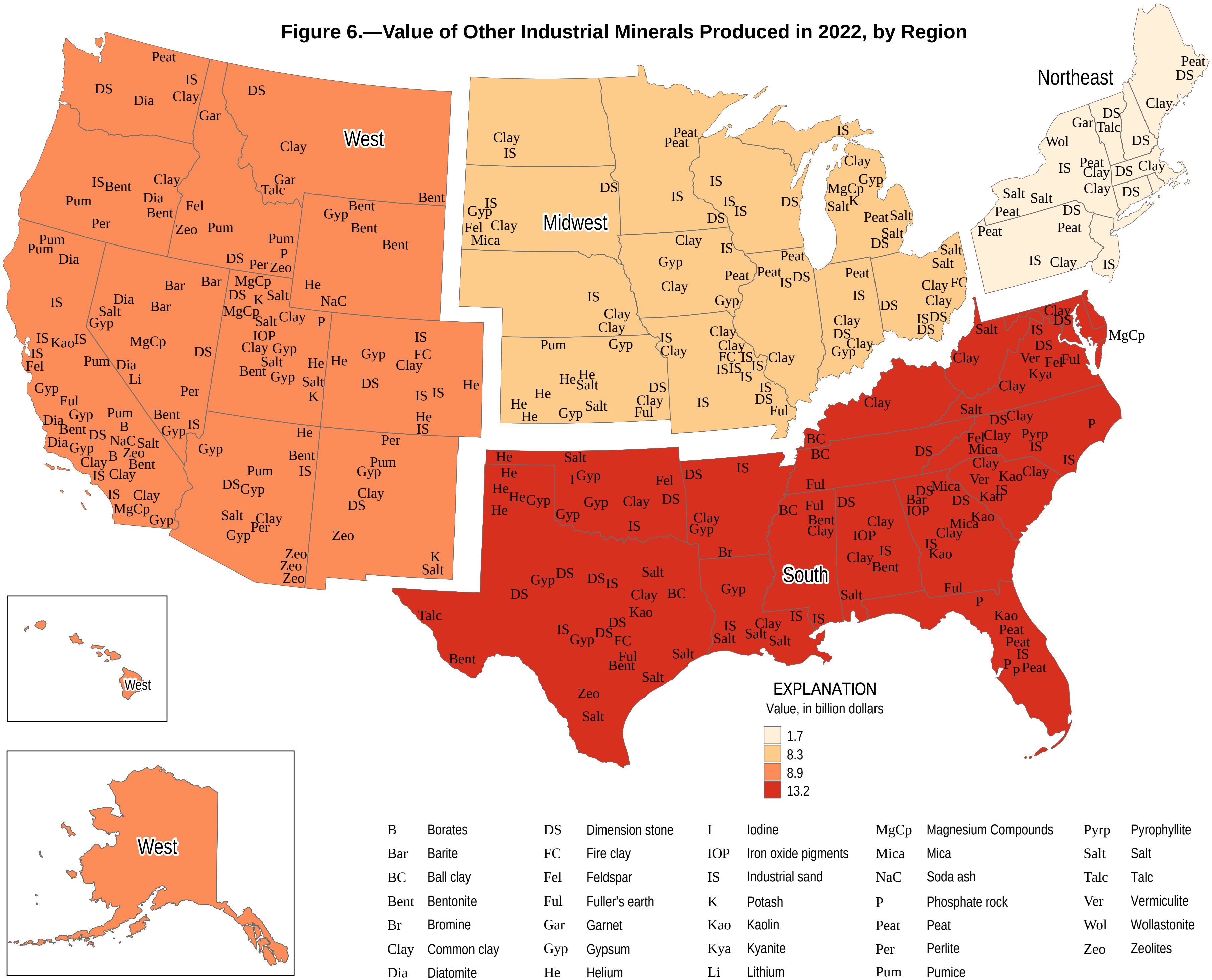


Figure 7.—Value of Crushed Stone Produced in 2022, by State

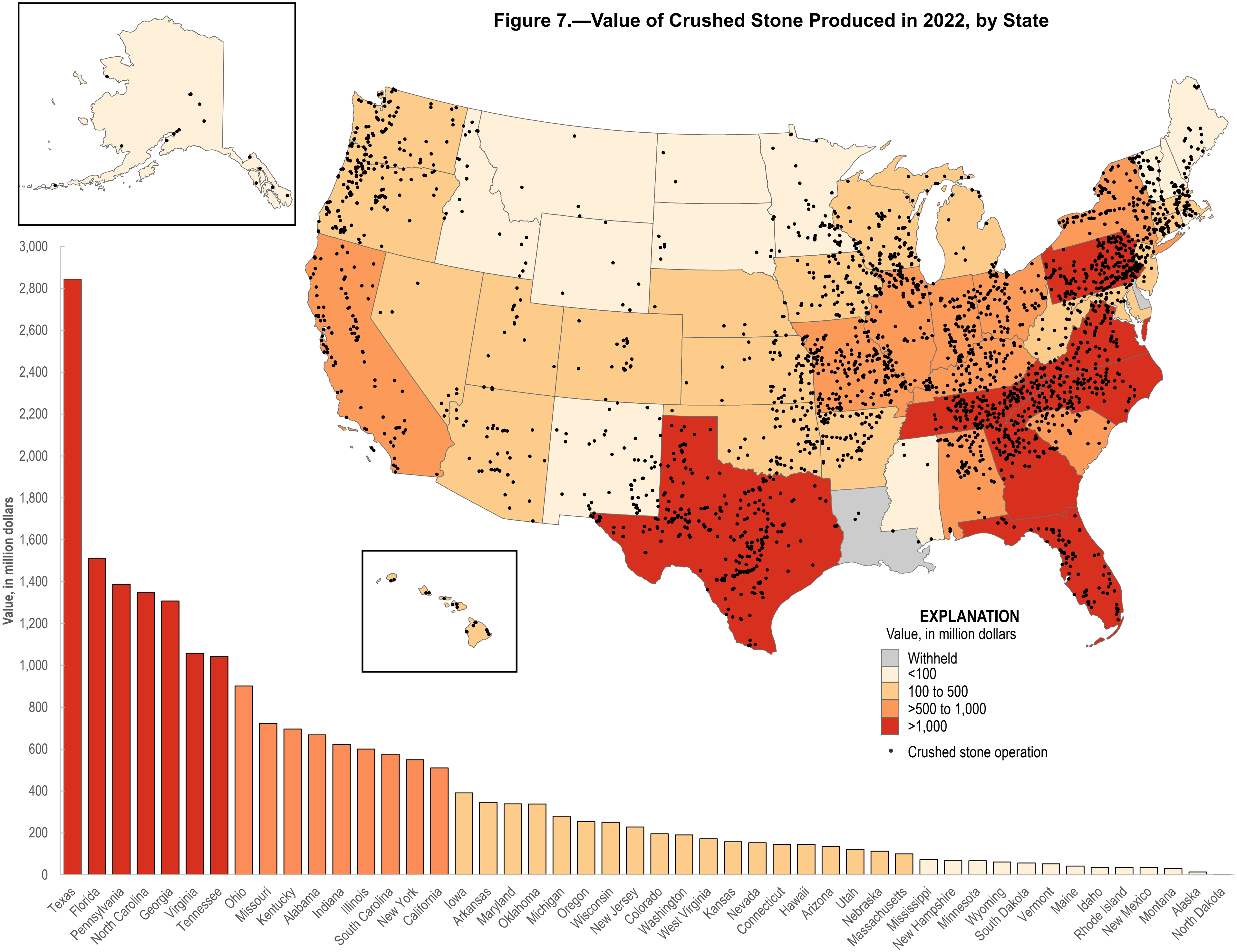


Figure 8.—Value of Construction Sand and Gravel Produced in 2022, by State

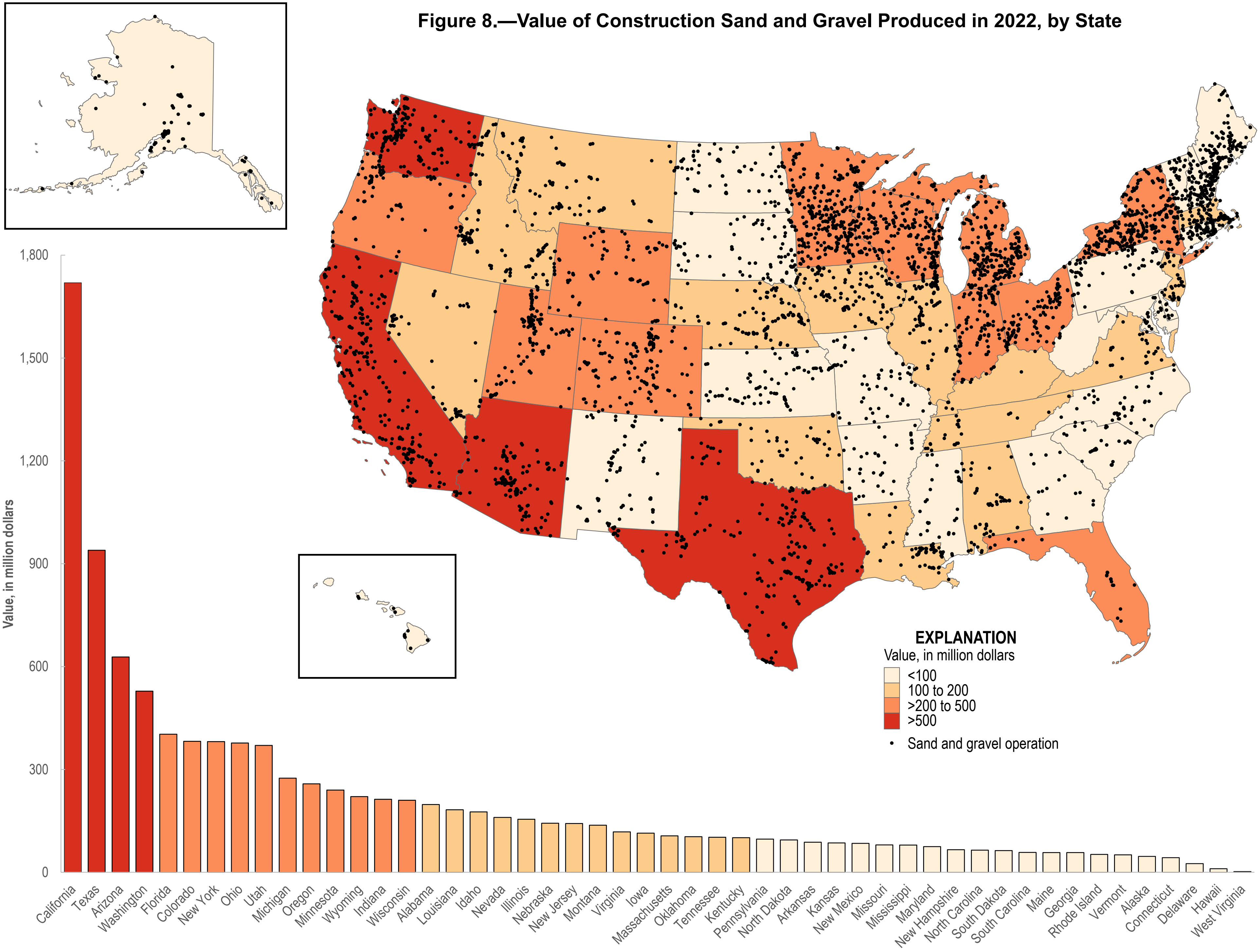


Table 4.—The 2022 U.S. Critical Minerals List[1]

Critical mineral	Applications
Aluminum	Metallurgy and many sectors of the economy.
Antimony	Flame retardants and lead-acid batteries.
Arsenic	Semiconductors.
Barite	Hydrocarbon production.
Beryllium	Aerospace and defense.
Bismuth	Medical, metallurgy, and atomic research.
Cerium[2]	Catalytic converters, ceramics, glass, metallurgy, and polishing compounds.
Cesium	Research and development.
Chromium	Metallurgy.
Cobalt	Batteries and metallurgy.
Dysprosium[2]	Data storage devices, lasers, and permanent magnets.
Erbium[2]	Fiber optics, glass colorant, lasers, and optical amplifiers.
Europium[2]	Nuclear control rods and phosphors.
Fluorspar	Cement, industrial chemical, and metallurgy.
Gadolinium[2]	Medical imaging, metallurgy, and permanent magnets.
Gallium	Integrated circuits and optical devices.
Germanium	Defense and fiber optics.
Graphite	Batteries, fuel cells, and lubricants.
Hafnium	Ceramics, nuclear control rods, and metallurgy.
Holmium[2]	Lasers, nuclear control rods, and permanent magnets.
Indium	Liquid crystal displays.
Iridium[3]	Anode coatings for electrochemical processes and chemical catalyts.
Lanthanum[2]	Batteries, catalysts, ceramics, glass, and metallurgy.
Lithium	Batteries.
Lutetium[2]	Cancer therapies, electronics, and medical imaging.
Magnesium	Metallurgy.
Manganese	Batteries and metallurgy.
Neodymium[2]	Catalysts, lasers, and permanent magnets.
Nickel	Batteries and metallurgy.
Niobium	Metallurgy.
Palladium[3]	Catalytic converters and catalysts.
Platinum[3]	Catalytic converters and catalysts.
Praseodymium[2]	Aerospace alloys, batteries, ceramics, colorants, and permanent magnets.
Rhodium[3]	Catalytic converters, catalysts, and electrical components.
Rubidium	Research and development.
Ruthenium[3]	Catalysts, electronic components, and computer chips.
Samarium[2]	Cancer treatments, nuclear, and permanent magnets.
Scandium	Ceramics, fuel cells, and metallurgy.
Tantalum	Capacitors and metallurgy.
Tellurium	Metallurgy, solar cells, and thermoelectric devices.
Terbium[2]	Fiber optics, lasers, permanent magnets, and solid state devices.
Thulium[2]	Lasers and metallurgy.
Tin	Metallurgy.
Titanium	Metallurgy and pigments.
Tungsten	Metallurgy.
Vanadium	Batteries, catalysts, and metallurgy.
Ytterbium[2]	Catalysts, lasers, metallurgy, and scintillators.
Yttrium	Catalysts, ceramics, lasers, metallurgy, and phosphors.
Zinc	Metallurgy.
Zirconium	Metallurgy and nuclear.

[1]The 2022 Final List of Critical Minerals published February 24, 2022 by U.S. Geological Survey (87 FR 10381).

[2]Included in the Rare Earths chapter.

[3]Included in the Platinum-Group Metals chapter.

U.S. CRITICAL MINERALS UPDATE

The U.S. Critical Minerals List

On February 24, 2022, pursuant to section 7002 of the Energy Act of 2020 (Public Law 116–260) and using the definition of “critical mineral” and the criteria specified therein, the U.S. Geological Survey (USGS) published the “2022 Final List of Critical Minerals” in the Federal Register (87 FR 10381). The 2022 list of critical minerals, which revised the U.S. critical minerals list (CML) published in 2018 (83 FR 23295), included 50 mineral commodities instead of 35 mineral commodities or mineral groups (table 4). The changes in the 2022 CML from the prior 2018 CML were the addition of nickel and zinc, listing out individual platinum-group metals and rare-earth elements, and the removal of helium, potash, rhenium, strontium, and uranium. The CML is to be updated at least every 3 years and revised as necessary consistent with available data.

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 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 CML. Uranium was excluded by its definition as mineral fuels 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). Following adjudication of public comments, the new CML was published in February 2022 (87 FR 10381).

Background

A series of actions by the Government in recent years have addressed domestic supply chain vulnerabilities, beginning with Executive Order 13817, “A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals,” which was issued on December 26, 2017, and initiated a whole-of-government call to action to identify critical minerals and develop a strategy to address U.S. supply-chain vulnerabilities. Subsequently, there have been additional actions including: (1) the 2018 CML was published by the USGS; (2) the 2019 Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals was published by the Department of Commerce with interagency input; (3) several Presidential determinations were issued directing the use of Defense Production Act (DPA) Title III authorities to strengthen the U.S. industrial base for rare-earth magnets; (4) Executive Order 13953, Addressing the Threat to the Domestic Supply Chain Reliance on Critical Minerals from Foreign Adversaries and Supporting the Domestic Mining and Processing Industries was issued; and (5) the Energy Act of 2020 was passed by Congress and signed into law.

Most recently, actions were taken to accomplish the objectives outlined in Executive Order 14017, “America’s Supply Chains,” issued in February 2021, that directed the Executive Branch agencies to launch an immediate 100-day review and strategy development process to identify and address vulnerabilities in the supply chains of four key product sectors: semiconductors manufacturing and advanced packaging, high-capacity batteries, including electric-vehicle batteries, critical and strategic minerals and materials, and pharmaceuticals and active pharmaceutical ingredients. The reports outlining strategies for the four sectors were released in June 2021.

In November 2021, Congress passed and the President signed the $1.2 trillion Bipartisan infrastructure Law (Infrastructure Investment and Jobs Act, H.R. 3684, Public Law 117–58) (BIL). The law outlined investments for bridges, roads, telecommunications broadband networks, water, energy systems, and ports and rail improvements for efficient transport of goods and produce across the country. It also provided funding for research and development of clean energy projects, domestic production of batteries, critical mineral recycling, reclamation and domestic critical minerals production and supply-chain projects including $320 million over 5 years for the USGS Earth Mapping Resources Initiative (Earth MRI).

Supply Chain Security and U.S. Government Critical Minerals Initiatives in 2022

In 2022, many Executive Branch and Congressional actions were taken to support and enhance America’s supply chains in the areas of focus identified in Executive Order 14017.

On March 31, 2022, a Presidential determination was signed requiring the use of DPA title III authorities to strengthen the U.S. industrial base for large-capacity batteries and specifically increasing domestic mining and processing of critical materials for the large-capacity battery supply chain such as cobalt, graphite, lithium, and nickel. The determination directed the Secretary of Defense to support (1) feasibility studies for “mature mining, beneficiation, and value-added processing projects” for such critical materials; (2) byproduct and coproduct production at existing mining and other industrial facilities; and (3) improvements to increase productivity, workforce safety, and sustainability in critical minerals mining, beneficiation, and processing.

On May 21, 2022, the Ukraine Supplemental Appropriations Act of 2022 provided $600 million for DPA title III funds for missiles and munitions in support of Ukraine and strategic and critical materials to expand domestic capacity. The areas of interest for funding for critical materials included feasibility studies, byproduct and coproduct extraction, modernization and productivity improvements, recycling and reclamation, and industrial resources.

On August 9, 2022, the CHIPS and Science Act of 2022 (Public Law 117–167) was signed into law; it provided $280 billion in funding over the next 10 years for domestic research, commercialization, and manufacturing of semiconductors as well next generation technology and workforce development. The goals of the law are to enhance domestic capability in several areas: reduce the likelihood that shocks abroad might disrupt the supply of semiconductor chips; create domestic jobs; improve international competitiveness; and ensure a secure supply of semiconductors to limit manufacturing vulnerabilities.

On August 16, 2022, the Inflation Reduction Act of 2022 (Public Law 117–169) was signed into law with the aim to reduce inflation. Specifically related to critical minerals, it authorized $391 billion in funding for climate change and domestic energy production. The legislation included targeted tax incentives aimed at manufacturing U.S.-sourced materials such as batteries, electric vehicles, solar, and wind parts and technologies like carbon capture systems. The legislation also includes key requirements around domestic sourcing—for example, for use of domestic steel in wind projects.

In October 2022, the "American Battery Materials Initiative" was launched, which will be led by a White House steering committee and coordinated by the U.S. Department of Energy (DOE) with support from the U.S. Department of the Interior. The initiative will work through the Partnership for Global Infrastructure and Investment and leverage ongoing work by the U.S. Department of State, to work with partners and allies to strengthen critical mineral supply chains globally, and it will leverage and maximize ongoing efforts throughout the U.S. government to meet resource requirements and bolster energy security.

In December 2022, the $858 billion National Defense Authorization Act was signed into law, which included a provision requiring a Federal strategy be developed to recycle and recover critical minerals from batteries used in the Federal electric vehicle fleet.

Critical Minerals Investments in 2022

On February 22, 2022, the U.S. Department of Defense (DOD) awarded a $35 million contract to a company to design and build a facility to process heavy rare-earth elements (HREEs) in California. The project would establish the first processing and separation facility for HREEs in the United States. Including this project, the DOD had invested over $100 million in enhancing America's rare-earth supply-chain resiliency and expanding domestic rare-earth magnet processing capabilities and capacity.

In July 2022, the USGS Earth MRI, a collaborative project between the USGS and State geological surveys to collect and modernize the Nation's geologic mapping and data resources, released two reports. Open-File Report 2019–1023–D, "Focus Areas for Data Acquisition for Potential Domestic Resources of 13 Critical Minerals in the Conterminous United States and Puerto Rico—Antimony, Barite, Beryllium, Chromium, Fluorspar, Hafnium, Helium, Magnesium, Manganese, Potash, Uranium, Vanadium, and Zirconium," defined focus areas for future data collection for resources for the 13 critical minerals evaluated in the conterminous United States and Puerto Rico during phase 3 of the study. Phases 1 and 2 of the Earth MRI addressed aluminum, cobalt, graphite, lithium, niobium, platinum-group elements (PGEs), rare-earth elements (REEs), tantalum, tin, titanium, and tungsten. The second report, Open-File Report 2019–1023–E, "Alaska Focus Area Definition for Data Acquisition for Potential Domestic Sources of Critical Minerals in Alaska for Antimony, Barite, Beryllium, Chromium, Fluorspar, Hafnium, Magnesium, Manganese, Uranium, Vanadium, and Zirconium," similarly defined focus areas for further investigation into critical mineral resources in Alaska.

In August 2022, the Defense Advanced Research Projects Agency (DARPA) partnered with the USGS to launch the Artificial Intelligence for Critical Mineral Assessment Competition. The goal of the competition was to develop methods to reduce the time required to complete parts of the resource assessment using artificial intelligence and machine learning to automate key processes. The partnership will help the USGS conduct assessments for more than 50 critical mineral resources to aid in economic planning and land-use decision making. The USGS has over a century of accumulated data, contained mostly within 100,000 geologic maps and many reports that provide the fundamental basis for these resource assessments. Only about 5% of the materials were fully digitized vector files which are needed for analysis and the rest were scanned images of paper maps. In December 2022, winners of the competition were announced: a Canadian company received top prize for automated georeferencing and a United States university partnership received top prize for legend-based feature extraction.

On October 19, 2022, the DOE announced the first set of projects funded by the Bipartisan Infrastructure Law to expand domestic manufacturing of batteries for electric vehicles (EVs) and the electrical grid including $2.8 billion for 20 manufacturing and processing companies in 12 States—Alabama, Georgia, Kentucky, Louisiana, Missouri, Nevada, New York, North Carolina, North Dakota, Ohio, Tennessee, and Washington. When matched by recipients, the funding will leverage a total of more than $9 billion to boost American production of EV batteries.

In October 2022, the USGS announced a $3.2 million project to collect geophysical data to improve mapping of critical mineral resources in parts of Iowa, Minnesota, Nebraska, and South Dakota. Substantial funding for the project came from the USGS Earth MRI using supplemental appropriation from the BIL.

In November 2022, the USGS announced a $1.45 million project to conduct geologic mapping, airborne geophysical surveying and geochemical sampling in support of critical mineral resource studies in Nevada and Oregon. Substantial funding for the project came from the USGS Earth MRI using supplemental appropriation from the BIL.

In December 2022, the DOD announced its first critical minerals award using Ukraine Supplemental Appropriations funds to a stibnite-gold project in Idaho for completing environmental and engineering studies.

Other information regarding individual projects and new production facilities can be found within each critical mineral chapter in this publication (p. 28–203).

U.S. Production and Consumption of Critical Minerals in 2022

In 2022, the value of domestic primary mine production of critical minerals was $5.4 billion. A total of 14 individual mineral commodities and the rare-earths group of minerals (without specification of the specific lanthanides) were produced in the United States.

The United States was 100% net import reliant for 12 of the 50 individually listed critical minerals and was more than 50% net import reliant for an additional 31 critical mineral commodities (including 14 lanthanides, which are listed under rare earths (fig. 2, tables 4, 5). The United States had secondary production for 14 critical minerals which resulted in net import reliance being less than 100%. Recycling provided the only source of domestic supply for antimony, bismuth, chromium, germanium, tin, tungsten, and vanadium (table 5).

China was the leading producing nation for 30 of the 50 critical minerals (including 14 lanthanides, which are listed under rare earths). The other leading producers of critical minerals were Australia and South Africa with three critical minerals each and Congo (Kinshasa) with two critical minerals (table 5). For 30 critical minerals, production was highly concentrated (50% or more) in a single country, of which 5 critical minerals had 80% or more of global production dominated by one country, 17 (including 14 lanthanides, which are listed under rare earths) with 70% to less than 80% of global production dominated by one country, 4 with 60% to less than 70% of global production dominated by one country, and 4 with 50% to less than 60% of global production dominated by one country.

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, magnesium, and zirconium.

Figure 10 shows both the 1-year percent change in prices of critical minerals between 2021 and 2022 and the 5-year compound annual growth rate (CAGR) in the prices of critical minerals from 2018 to 2022. In 2022, the 1-year percent change in the prices of lithium, neodymium, and yttrium were all above 100% (double) compared with their respective prices in 2021. The CAGR for most critical minerals has been positive over the past 5 years, reflecting a trend of increasing prices for these commodities.

All supply chains, from mine to final distribution and retail, were affected when the coronavirus disease 2019 (COVID-19) emerged and became a global pandemic. For the United States, the 2020 consumption of most nonfuel mineral commodities decreased relative to that in 2019. Of the critical mineral commodities, 16 experienced decreases in consumption during that time period, whereas 6 experienced increases. The markets for mineral commodities vary such that the trends can differ significantly for the different commodities depending on their unique market situations. For example, gold, platinum, and silver, precious metals perceived as investment metals, experienced large increases in consumption between 2019 and 2020 (fig. 11).

Mineral commodity markets can be quite volatile, but the nonfuel mineral commodity mining and refining sectors did experience significant disruptions, especially in the first half of 2020. However, the second half of 2020 and 2021 were characterized by a rebound in demand and prices, so the overall effect of the disruptions between 2020 and 2021 were dampened (fig. 12). In 2022, consumption for many mineral commodities continued to increase and began to approach or exceed pre-pandemic levels, and consumption of most commodities in 2022 increased from that in 2021 (fig. 13).

Figure 14 shows the relationship between primary metals and byproduct or companion metals. As discussed in Open-File Report 2021–1045, “Methodology and Technical Input for the 2021 Review and Revision of the U.S. Critical Minerals List,” the degree to which a metal is obtained largely or entirely as a byproduct of one or more host metals from geologic ores may complicate the supply of these commodities. Of the 50 critical minerals, only aluminum, nickel, platinum, tin, titanium, and zinc are primary metals.

Table 5.—Estimated Salient Critical Minerals Statistics in 2022[1]

(Metric tons, mine production, unless otherwise specified)

Critical mineral	United States					World			
	Primary production	Secondary production	Apparent consumption	Net import reliance as a percentage of apparent consumption	Primary import source (2018–21)	Leading producing country	Production in leading country	Percentage of world total	World production total
Aluminum (bauxite)	W	—	[2]2,900,000	>75	Jamaica	Australia	100,000,000	26	[3]380,000,000
Antimony	—	4,200	[4]27,000	83	China[5]	China	60,000	55	110,000
Arsenic	—	NA	[6]5,300	100	China[5]	Peru	[7]28,000	46	[7]61,000
Barite	W	—	W	>75	China[5]	India	2,600,000	33	[3]7,900,000
Beryllium	180	NA	180	1	Kazakhstan	United States	180	64	280
Bismuth[8]	—	80	2,000	96	China[5]	China	16,000	80	20,000
Chromium	—	100,000	590,000	83	South Africa	South Africa	18,000,000	44	41,000,000
Cobalt	800	1,900	7,800	76	Norway	Congo (Kinshasa)	130,000	68	190,000
Fluorspar	NA	—	500,000	100	Mexico	China	5,700,000	69	8,300,000
Gallium	NA	NA	[2]18	100	China	China	540	98	550
Germanium[8]	NA	W	[6]30	>50	China	China	NA	NA	NA
Graphite (natural)	—	NA	72,000	100	China[5]	China	850,000	65	1,300,000
Indium[8]	—	NA	[6]160	100	Republic of Korea	China	530	59	900
Lithium	W	NA	[6]3,000	>25	Argentina	Australia	61,000	47	[3]130,000
Magnesium[8]	W	37,000	[2]50,000	>50	Israel	China	900,000	90	[3]1,000,000
Manganese	—	—	890,000	100	Gabon	South Africa	7,200,000	36	20,000,000
Nickel	18,000	W	[9]220,000	56	Canada	Indonesia	1,600,000	48	3,300,000
Niobium	—	NA	7,600	100	Brazil	Brazil	71,000	90	79,000
Palladium	11	40	68	26	Russia	Russia	88	42	210
Platinum	3	11	42	66	South Africa	South Africa	140	74	190
Rare Earths (compounds and metals)[10]	250	NA	9,300	>95	China[5]	China	210,000	70	300,000
Scandium	—	—	NA	100	Europe	China	NA	NA	NA
Tantalum	—	NA	1,200	100	China[5]	Congo (Kinshasa)	860	43	2,000
Tellurium[8]	W	—	W	>75	Canada	China	340	53	[3]640
Tin	—	18,000	43,000	77	Peru	China	95,000	31	310,000
Titanium (metal)[8]	W	W	[3]28,000	>95	Japan	China	150,000	58	[3]260,000
Tungsten	—	W	W	>50	China[5]	China	71,000	85	84,000
Vanadium	—	4,400	9,500	54	Canada	China	70,000	70	100,000
Yttrium	NA	—	1,000	100	China[5]	China	NA	NA	NA
Zinc[8]	[11]220,000	([11])	910,000	76	Canada	NA	NA	NA	NA
Zirconium (ores and concentrates)	<100,000	NA	<100,000	<50	South Africa	Australia	500,000	36	[3]1,400,000

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

[1]Critical minerals as published in the Federal Register on February 24, 2022 (87 FR 10381). Not all critical minerals are listed here. Cesium, hafnium,iridium, rhodium, rubidium, and ruthenium are not shown because available information is insufficient to make estimates of U.S. or world production.

[2]Reported consumption.

[3]Excludes U.S. production.

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

[5]Includes Hong Kong.

[6]Estimated consumption.

[7]Arsenic trioxide.

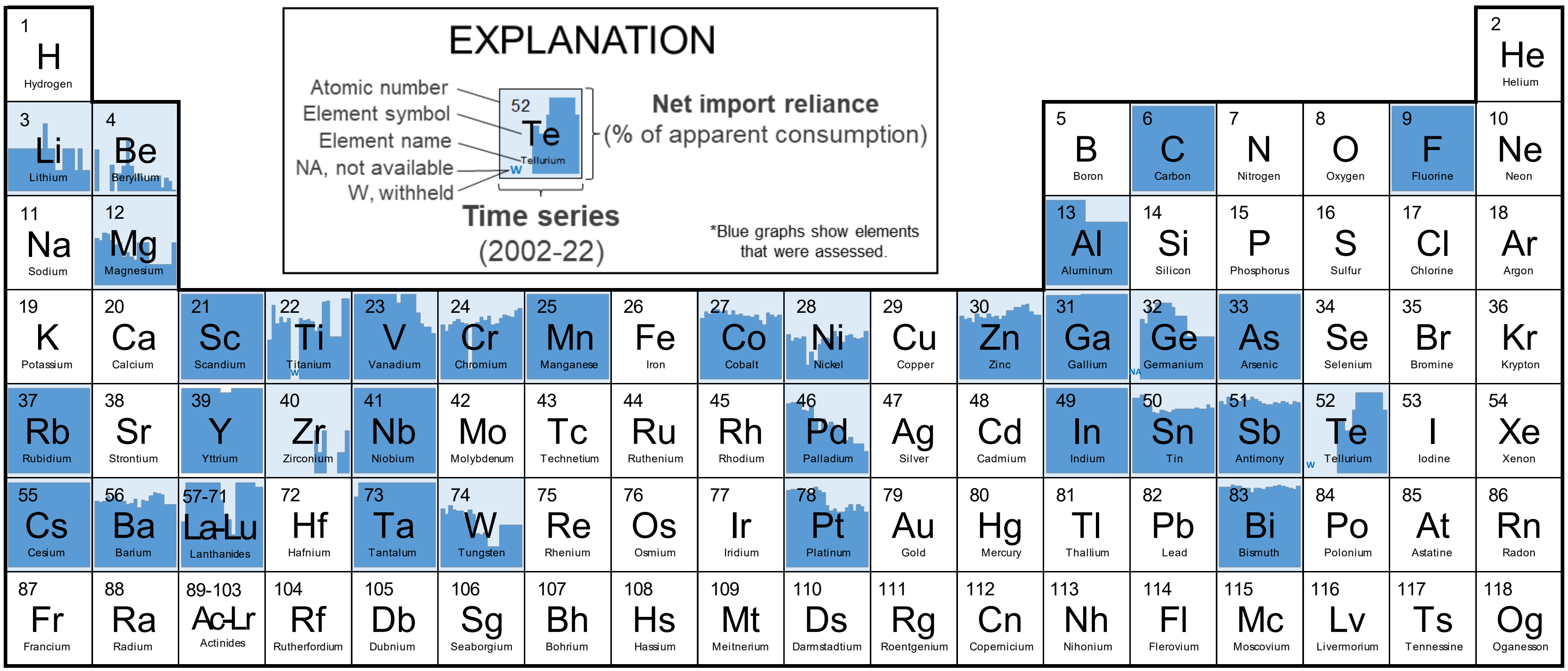
[8]Refinery production.

[9]Nickel in primary metal and secondary scrap.

[10]Data include lanthanides.

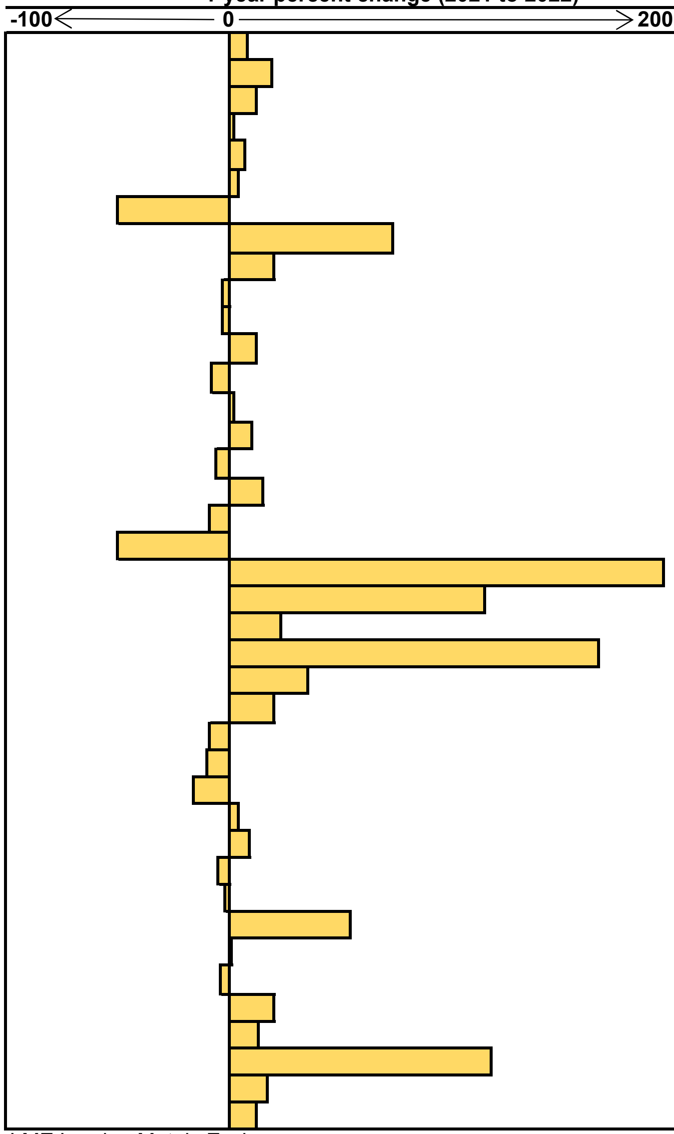
[11]Primary production includes both primary and secondary metal production.

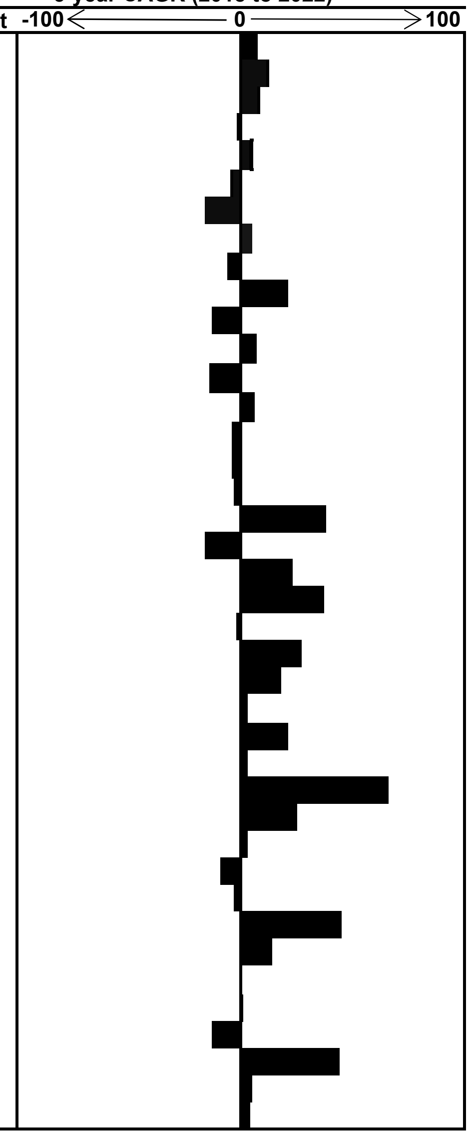
Figure 9.—20-Year Trend of U.S. Net Import Reliance for Critical Minerals



For elements of the periodic table associated with mineral commodities identified as critical in 2022 (87 FR 10381), the figure displays the U.S. net import reliance (NIR) as a percent of apparent consumption from 2002 through 2022. 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). Rare earths are listed under lanthanides (La–Lu). Net import reliance data are not available for hafnium, iridium, and rhodium for 2002 through 2022 and for germanium prior to 2004; data were withheld for tellurium prior to 2010 and titanium for 2008 and 2009. For some years, the NIR for antimony, barite, bauxite, germanium, lithium, magnesium, rare earths, tellurium, titanium, tungsten, yttrium, and zirconium are rounded to avoid disclosing company proprietary data.

Figure 10.—Estimated 1-Year Percent Change and 5-Year Compound Annual Growth Rate (CAGR) in Prices of Critical Minerals[1]





1-year percent change (2021 to 2022), Percent	Critical mineral (price source)[2]	5-year CAGR (2018 to 2022), Percent
8	Aluminum, bauxite	7
19	Antimony, metal	13
12	Arsenic, metal (Rotterdam)	8
2	Barite	-1
7	Beryllium[3]	5
4	Bismuth	-4
-50	Cerium, oxide 99.5% minimum	-16
73	Chromium, chromite ore[3]	5
20	Cobalt (U.S. spot cathode)	-6
-3	Dysprosium, oxide 99.5% minimum	21
-3	Europium, oxide 99.99% minimum	-13
12	Fluorspar, acid grade[3]	7
-7	Fluorspar, metallurgical grade[3]	-14
2	Gallium, high purity refined[3]	6
10	Germanium, metal	-4
-6	Graphite, natural, flake[3]	-4
15	Indium (Rotterdam)	-3
-9	Iridium	38
-50	Lanthanum, oxide 99.5% minimum	-16
194	Lithium, battery grade	23
114	Magnesium, metal (U.S. spot Western)	37
23	Manganese	-2
165	Neodymium, oxide 99.5% minimum	27
35	Nickel (LME)	18
20	Niobium, ferroniobium[3]	3
-9	Palladium	21
-10	Platinum	3
-16	Rhodium	66
4	Ruthenium	25
9	Scandium, ingot	3
-5	Tantalum	-9
-2	Tellurium (Europe)	-3
54	Terbium, oxide 99.99% minimum	45
1	Tin (New York delear)	14
-4	Titanium, sponge[3]	0
20	Tungsten, concentrate (Rotterdam)	1
13	Vanadium, vanadium pentoxide	-13
117	Yttrium, oxide	44
17	Zinc (LME)	5
12	Zirconium, ores and concentrates (China)	4

LME London Metals Exchange.

[1]Critical minerals as published in the Federal Register on February 24, 2022 (87 FR 10381). Not all critical minerals are listed here. Cesium, erbium, gadolinium, hafnium, holmium, lutetium, praseodymium, rubidium, samarium, thulium, and ytterbium are not shown because there was not enough information available regarding prices.

[2]Price source is only included for those commodities that have multiple price sources in their Salient table. For those commodities with a single price source, please refer to that commodity chapter's Salient table.

[3]Average annual unit value of imports.

Figure 11.—Change in U.S. Consumption of Nonfuel Mineral Commodities From 2019 to 2020

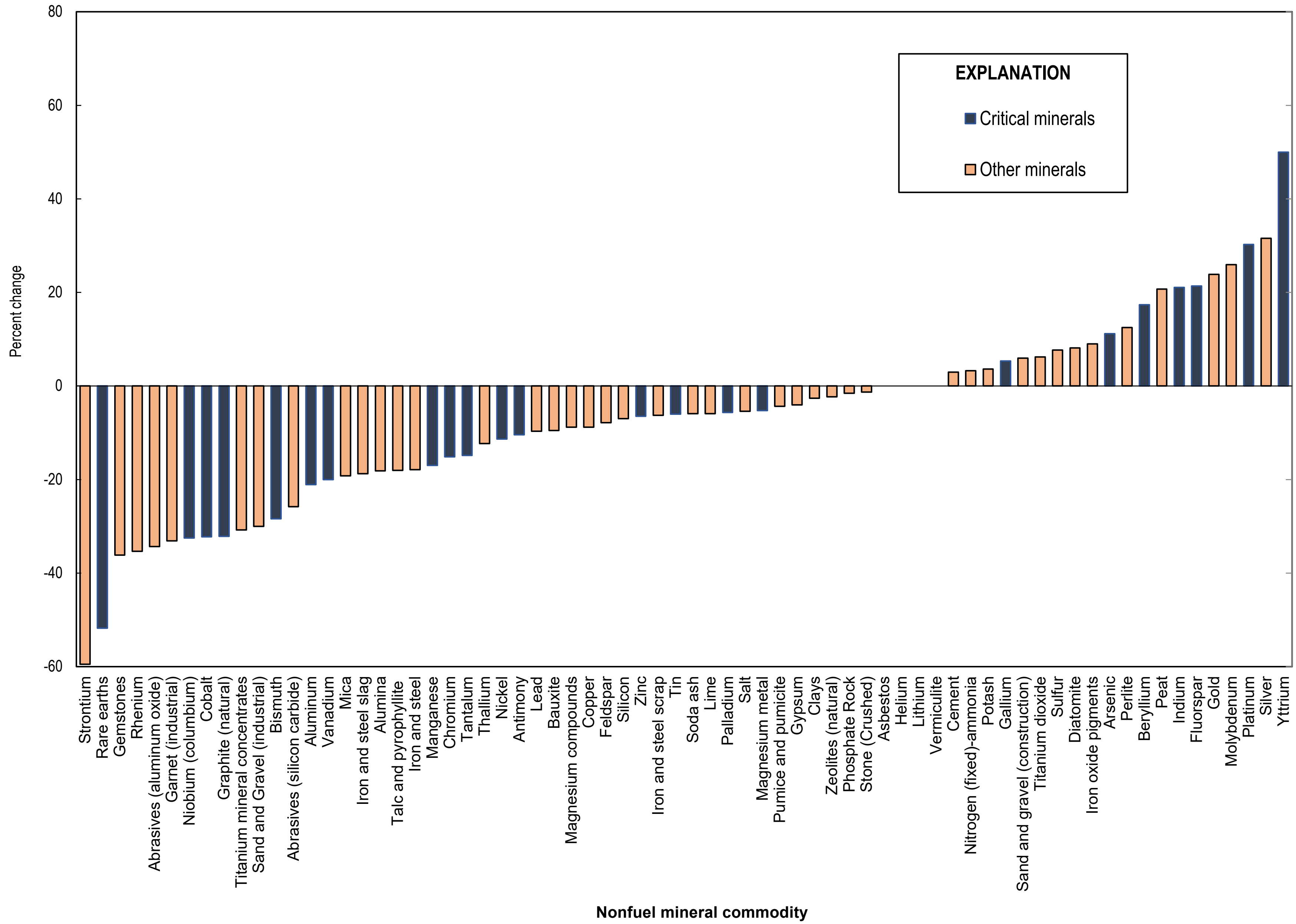


Figure 12.—Change in U.S. Consumption of Nonfuel Mineral Commodities From 2020 to 2021

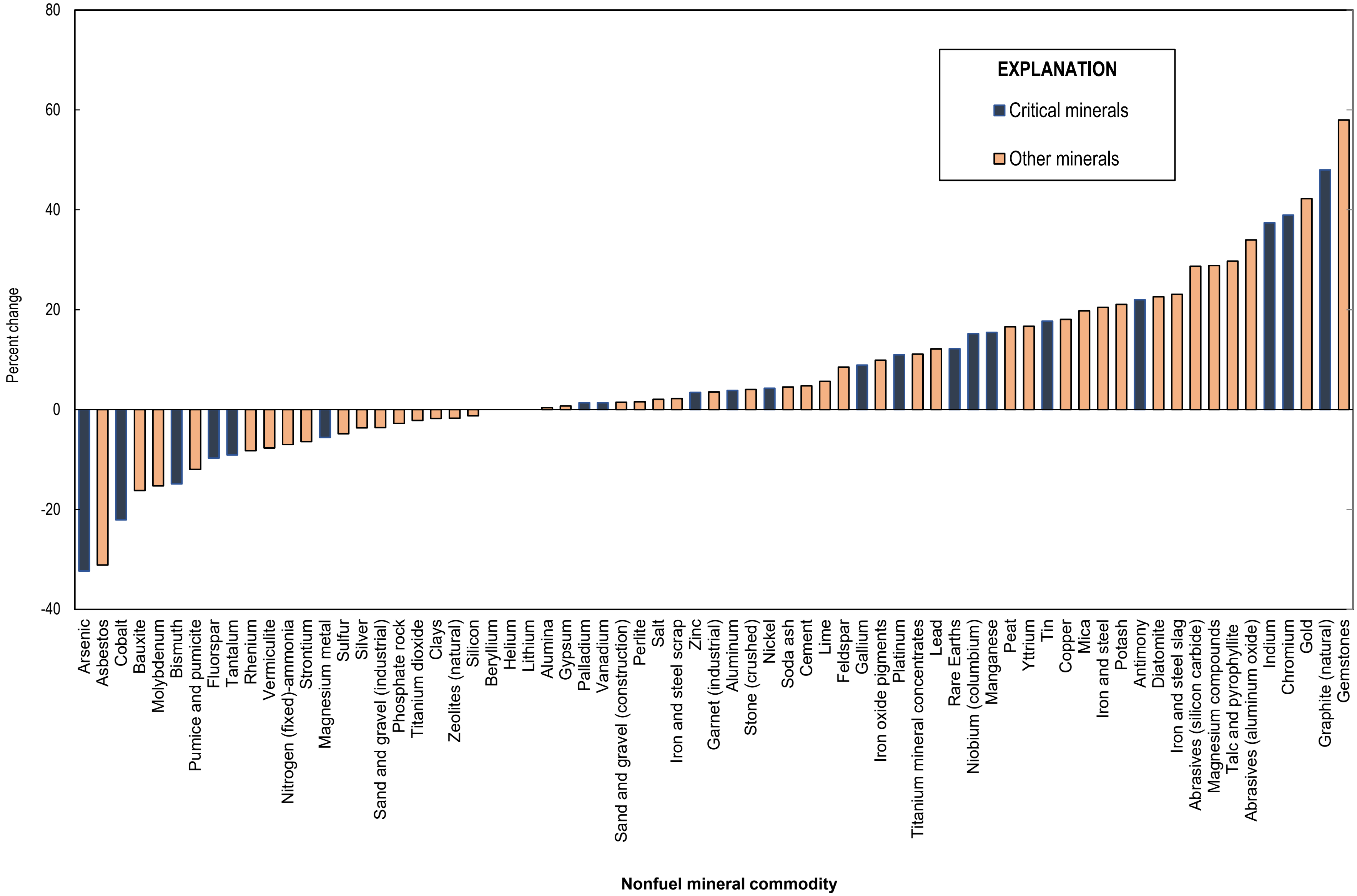


Figure 13.—Change in U.S. Consumption of Nonfuel Mineral Commodities From 2021 to 2022

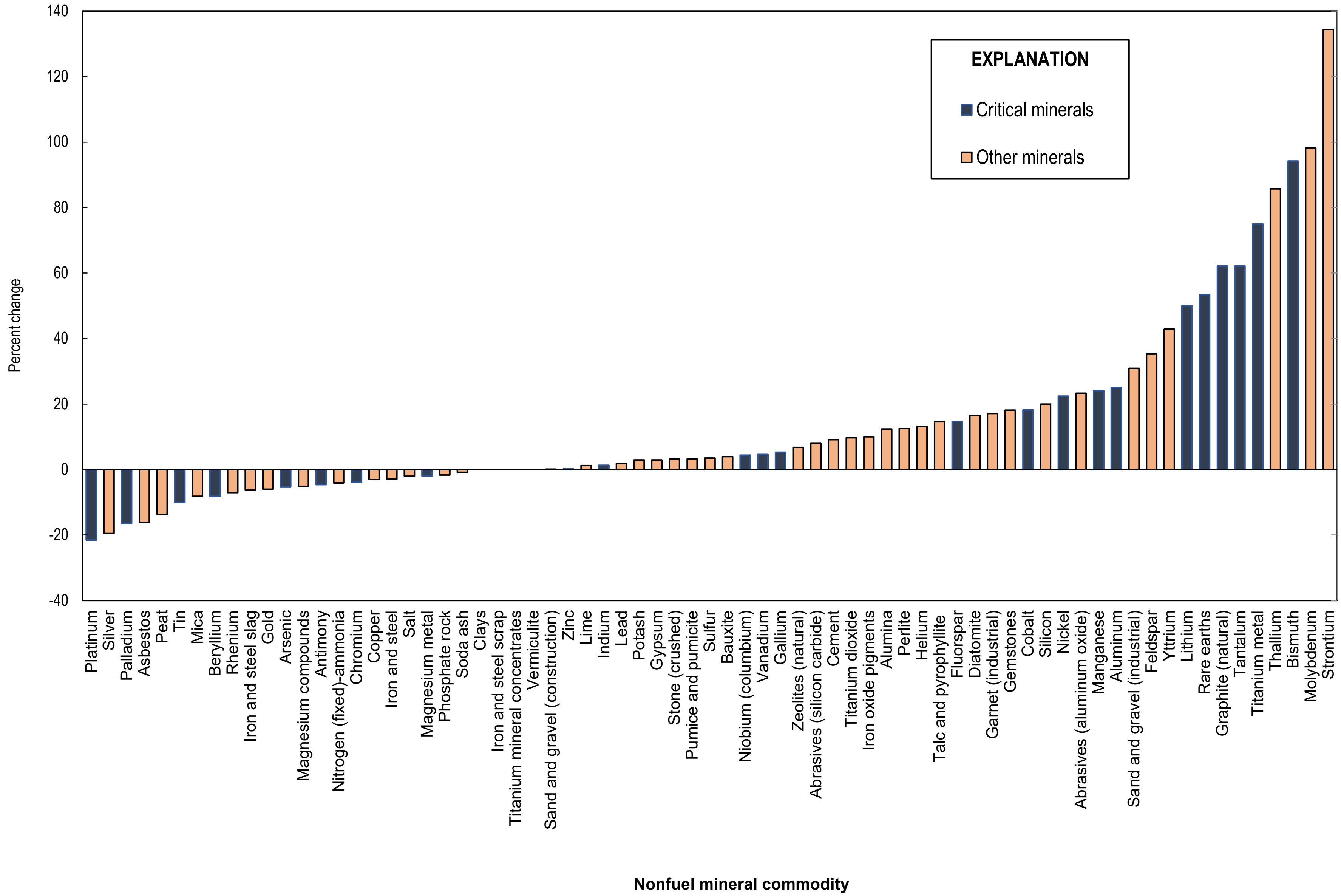
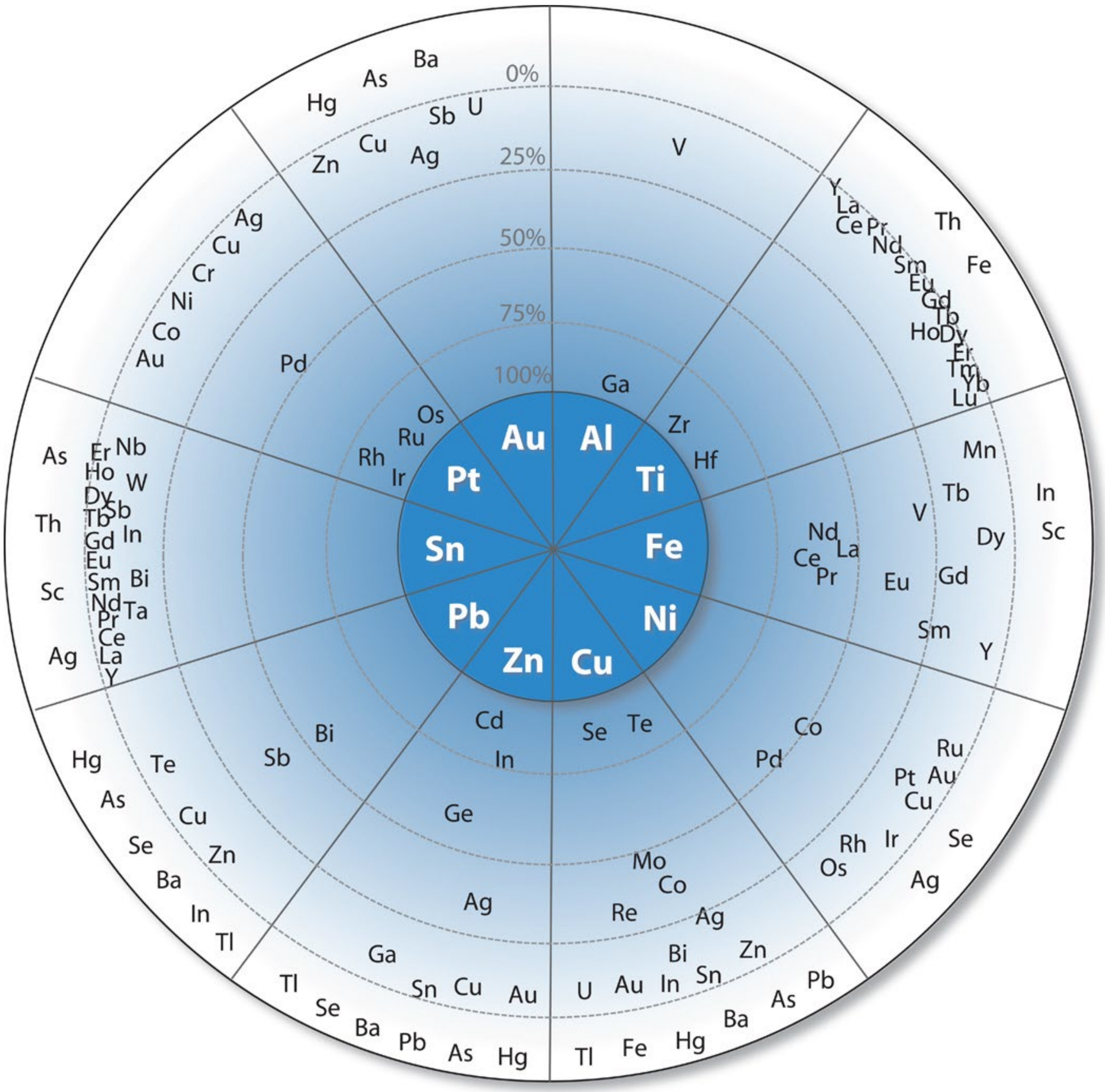


Figure 14.—Relation Between Byproduct Elements and Host Metals



The principal host metals form the inner circle. Byproduct elements are in the outer circle at distances proportional to the percentage of their primary production (from 100% to 0%) that originates with the host metal indicated. Source: Nassar, N.T., Graedel, T.E., and Harper, E.M., 2015, By-product metals are technologically essential but have problematic supply: ScienceAdvances, v. 1, no. 3, article E1400180. (Accessed January 19, 2023, at https://doi.org/10.1126/sciadv.1400180.)

ABRASIVES (MANUFACTURED)

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

Domestic Production and Use: In 2022, 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 $160 million, and metallic abrasive shipments were valued at $190 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:	2018	2019	2020	2021	2022[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	180,000	177,000	176,000	176,000	180,000
Shipments, metallic abrasives	196,000	195,000	194,000	193,000	190,000
Imports for consumption:					
Fused aluminum oxide	192,000	184,000	120,000	159,000	200,000
Silicon carbide	146,000	131,000	88,400	125,000	140,000
Metallic abrasives	29,900	27,900	25,800	26,400	21,000
Exports:					
Fused aluminum oxide	20,100	18,400	11,400	13,500	17,000
Silicon carbide	10,100	11,500	8,310	12,000	12,000
Metallic abrasives	33,600	31,200	18,100	20,200	22,000
Consumption, apparent:					
Fused aluminum oxide[3]	172,000	166,000	109,000	146,000	180,000
Silicon carbide[4]	171,000	155,000	115,000	148,000	160,000
Metallic abrasives[5]	192,000	192,000	202,000	199,000	190,000
Price, average unit value of imports, dollars per ton:					
Fused aluminum oxide, crude	681	716	666	674	800
Fused aluminum oxide, ground and refined	1,290	1,250	1,180	1,290	1,500
Silicon carbide, crude	670	701	628	587	1,000
Metallic abrasives	1,180	1,310	1,130	1,510	2,100
Net import reliance[6] as a percentage of apparent consumption:					
Fused aluminum oxide	>75	>75	>75	>75	>75
Silicon carbide	80	77	70	76	79
Metallic abrasives	E	E	4	3	E

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

Import Sources (2018–21): Fused aluminum oxide, crude: China,[7] 93%; Bahrain, 3%; Russia, 2%; Canada, 1%; and other, 1%. Fused aluminum oxide, ground and refined: Canada, 25%; Brazil, 19%; Austria, 15%; China,[7] 13%; and other, 28%. Total fused aluminum oxide: China,[7] 63%; Canada, 10%; Brazil, 7%; Austria, 5%; and other, 15%. Silicon carbide, crude: China,[7] 90%; Netherlands and South Africa, 3% each; Luxembourg, 1%; and other 3%. Silicon carbide, ground and refined: China,[7] 48%; Brazil, 21%; Canada, 9%; Russia, 7%; and other, 15%. Total silicon carbide: China,[7] 79%; Brazil, 6%; Netherlands and South Africa, 3%, each; and other, 9%. Metallic abrasives: Canada, 33%; Turkey, 16%; China,[7] 12%; Thailand, 9%; and other, 30%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022, China was the world's leading manufacturer of abrasive fused aluminum oxide and abrasive silicon carbide. Imports from China, where production costs were lower, continued to challenge abrasives manufacturers in the United States and Canada. China accounted for 93% of United States imports of crude fused aluminum oxide, 13% of ground and refined fused aluminum oxide imports, 90% of crude silicon carbide imports, and 48% of ground and refined silicon carbide imports. Foreign competition is expected to persist and continue to limit production in North America. The import quantity and value of abrasive fused aluminum oxide (crude and ground and refined) in 2022 were 26% and 44% higher, respectively, than those in 2021. The import quantity and value of abrasive silicon carbide (crude and ground and refined) in 2022 were 9% and 76% higher, respectively, than those in 2021.

The United States returned to being a net exporter of metallic abrasives in 2022 as compared with being a net importer in 2020 and 2021. Canada was the leading supplier of metallic abrasive imports.

The consumption of abrasives in the United States is influenced by activity in the manufacturing sectors that use them, particularly the aerospace, automotive, furniture, housing, and steel industries. The U.S. abrasive markets also are influenced by technological trends. Imports and exports continued to recover from the negative effects from the global coronavirus disease 2019 (COVID-19) pandemic, and they have returned to pre-pandemic levels.

World Production Capacity:

	Fused aluminum oxide[e]		Silicon carbide[e]	
	2021	2022	2021	2022
United States	—	—	40,000	40,000
United States and Canada	60,000	60,000	—	—
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, metallic abrasives, or staurolite, can be substituted for fused aluminum oxide and silicon carbide in various applications.

[e]Estimated. E Net exporter. — Zero.
[1]Production data for fused aluminum oxide are combined 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 2022, three companies operated six primary aluminum smelters in five States. Two of these six smelters operated at full capacity throughout the year. The other four smelters operated at reduced capacity and one of these four smelters began a temporary shutdown in June. A seventh smelter remained on standby throughout the year. Domestic smelters were operating at about 52% of capacity of 1.64 million tons per year at yearend 2022. Estimated primary production decreased by 3% compared with that in 2021 but estimated secondary production from new and old scrap increased by 3% compared with that in 2021. Based on published prices, the value of primary aluminum production was about $2.90 billion, 7% more than the $2.71 billion in 2021. The average annual U.S. market price increased by about 8% from that in 2021. Transportation applications accounted for 35% of domestic consumption; the remainder was used in packaging, 23%; building, 16%; electrical, 10%; machinery, 7%; consumer durables, 6%; and other, 3%.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Primary	891	1,093	1,012	889	860
Secondary (from old scrap)	1,570	1,540	1,420	1,520	1,500
Secondary (from new scrap)	2,140	1,920	1,630	1,780	1,900
Imports for consumption:					
Crude and semimanufactures	5,550	5,280	4,260	4,830	5,900
Scrap	695	596	542	680	640
Exports:					
Crude and semimanufactures	1,310	1,110	906	851	1,000
Scrap	1,760	1,860	1,840	2,100	2,100
Consumption, apparent[2]	4,900	4,980	3,930	4,080	5,100
Supply, apparent[3]	7,040	6,910	5,560	5,860	7,000
Price, ingot, average U.S. market (spot), cents per pound[4]	114.7	99.5	89.7	138.5	150
Stocks, yearend:					
Aluminum industry	1,570	1,600	1,490	1,870	2,000
London Metal Exchange (LME), U.S. warehouses[5]	186	120	235	69	17
Employment, number[6]	31,600	32,900	30,100	28,900	28,000
Net import reliance[7] as a percentage of apparent consumption	50	47	38	41	54

Recycling: In 2022, aluminum recovered from purchased scrap in the United States was about 3.4 million tons, of which about 56% came from new (manufacturing) scrap and 44% from old scrap (discarded aluminum products). Aluminum recovered from old scrap was equivalent to about 29% of apparent consumption.

Import Sources (2018–21): Canada, 50%; United Arab Emirates, 9%; Russia, 5%; China,[8] 4%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 June, a 250,000-ton-per-year primary aluminum smelter in Hawesville, KY, idled its full production for an estimated 9 to 12 months owing to high energy costs. In July, a 161,000-ton-per-year primary aluminum smelter in Newburgh, IN, curtailed one of three operating aluminum smelting lines, citing operational challenges. In July, force majeure was declared at a rolling mill and aluminum packaging products manufacturer in Newburgh, IN, that produced approximately 310,000 tons per year of rolled aluminum. A shortage of magnesium, an essential component of aluminum packaging products, was cited for the declaration. Production at the plant was reduced by up to 50% before the declaration was lifted in September. In August, low local demand led to the permanent closure of aluminum beverage can manufacturing facilities in Phoenix, AZ, and St. Paul, MN.

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ALUMINUM

In October, construction began on a $2.5 billion aluminum recycling and rolling plant in Bay Minette, AL. When completed in 2025, the plant was expected to produce 600,000 tons per year of finished products, including beverage cans. Prices for aluminum increased through March, then generally trended downward throughout 2022 in the United States and in world markets.

In June, a tariff-rate quota system began that exempted certain aluminum imports from the United Kingdom from the 10% tariff imposed since 2018 under the authority of section 232 of the Trade Expansion Act of 1962. The quota system consisted of quantity limits during two periods in 2022 and the requirement that imports of aluminum articles be accompanied by a certificate of analysis for the smelted primary aluminum contained within in the articles. To be eligible for the tariff exemption, imports could not contain primary aluminum from Belarus, China, or Russia.

In April, a 447,000-ton-per-year primary aluminum smelter in Sao Luis, Brazil, restarted operations with full production expected by yearend. Several European aluminum producers announced production curtailments owing to high energy costs. In August, a 175,000-ton-per-year primary aluminum smelter in Slovakia ceased production, and a 94,000-ton-per-year primary aluminum smelter in Norway curtailed operation of a single potline. In September, a 70,000-ton-per-year primary aluminum smelter in Germany reduced production by 50%, and a 290,000-ton-per-year primary aluminum smelter in France reduced production by 22%. By yearend, a Norwegian primary aluminum smelter reduced production across two facilities by 110,000 to 130,000 tons per year. These facilities have annual capacities of 197,000 tons per year and 270,000 tons per year of primary aluminum.

World Smelter Production and Capacity: Capacity data for China were revised based on company and Government reports.

	Smelter production		Yearend capacity	
	2021	2022[e]	2021	2022[e]
United States	889	860	1,640	1,600
Australia	1,570	1,500	1,720	1,700
Bahrain	1,560	1,600	1,550	1,600
Canada	3,140	3,000	3,270	3,300
China	38,900	40,000	42,300	44,000
Iceland	[e]750	750	890	900
India	3,970	4,000	4,060	4,100
Norway	[e]1,400	1,400	1,430	1,400
Russia	3,640	3,700	4,020	4,000
United Arab Emirates	2,540	2,700	2,780	2,800
Other countries	9,140	9,100	12,300	12,000
World total (rounded)	67,500	69,000	76,000	77,000

World Resources:[9] 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 the Bauxite and Alumina chapter.
[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]Source: S&P Global Platts Metals Week.
[5]Includes aluminum alloy. Starting with 2019, also includes off-warrant stocks of primary and alloyed aluminum; estimated for 2019.
[6]Alumina and aluminum production workers (North American Industry Classification System—3313). Source: U.S. Department of Labor, Bureau of Labor Statistics.
[7]Defined as imports – exports ± adjustments for industry stock changes; excludes imported scrap.
[8]Includes Hong Kong.
[9]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 2022, 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 2022. 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 2022 was about $60 million. Recycling supplied about 15% of estimated domestic consumption, and the remainder came mostly from imports. 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:	2018	2019	2020	2021	2022[e]
Production:					
Mine (recoverable antimony)	—	—	—	—	—
Smelter:					
Primary	331	377	254	379	400
Secondary	4,090	4,140	[e]4,250	[e]4,250	4,200
Imports for consumption:					
Ore and concentrates	96	121	105	31	30
Oxide	19,200	17,200	15,000	19,100	19,000
Unwrought, powder	5,760	6,030	5,200	6,970	6,500
Waste and scrap[1]	202	17	6	13	60
Exports:					
Ore and concentrates[1]	38	9	10	9	67
Oxide	1,750	1,570	1,230	1,530	2,100
Unwrought, powder	313	296	296	824	1,300
Waste and scrap[1]	9	14	11	136	35
Consumption, apparent[2]	27,300	25,900	23,200	28,300	27,000
Price, metal, average, dollars per pound[3]	3.81	3.04	2.67	5.31	6.30
Net import reliance[4] as a percentage of apparent consumption	84	83	81	84	83

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 (2018–21): Ore and concentrates: China, 46%; Italy, 34%; India, 12%; Belgium, 5%; and other, 3%. Oxide: China,[5] 74%; Belgium, 10%; Bolivia, 5%; Thailand, 3%; and other, 8%. Unwrought metal and powder: China,[5] 30%; India, 28%; Vietnam, 13%; Burma, 12%; and other, 17%. Total metal and oxide: China,[5] 63%; Belgium, 8%; India, 7%; and other, 22%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Antimony	90.16	1,100	—	1,100	—

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ANTIMONY

Events, Trends, and Issues: China continued to be the leading global antimony producer in 2022 and accounted for 55% of global mine production. The supply of antimony raw materials and downstream production of antimony products was constrained in 2022 as a result of various temporary mine shutdowns to mitigate the spread of the coronavirus disease 2019 (COVID-19). The antimony price reached a high of $7.03 per pound in March 2022 and the estimated average price was $6.30 per pound in 2022 compared with the annual average price of $5.31 per pound in 2021.

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

	Mine production		Reserves[7]
	2021	2022[e]	
United States	—	—	[8]60,000
Australia	4,000	4,000	[9]120,000
Bolivia	2,600	2,500	310,000
Burma	4,600	4,000	140,000
Canada	2	2	78,000
China	61,000	60,000	350,000
Guatemala	80	80	NA
Iran	400	400	NA
Kazakhstan	100	100	NA
Kyrgyzstan	—	—	260,000
Mexico	750	800	18,000
Pakistan	66	70	26,000
Russia (recoverable)	20,000	20,000	350,000
Tajikistan	16,800	17,000	50,000
Turkey	1,300	1,300	100,000
Vietnam	310	300	NA
World total (rounded)[10]	112,000	110,000	>1,800,000

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 22,000 tons.
[10]In addition to the countries listed, antimony may have been produced in other countries, but available information was inadequate to make reliable estimates of output.

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 compounds was in herbicides and insecticides. Arsenic trioxide was predominantly used for the production of arsenic acid, which is a key ingredient in the production of chromated copper arsenate (CCA) preservatives. CCA preservatives are used for the pressure treating of lumber for primarily nonresidential applications such as light poles, marine applications, and retaining walls. Seven companies produced CCA-treated wood in the United States in 2022. High-purity (99.9999%) arsenic metal was used to produce gallium-arsenide (GaAs) semiconductors for solar cells, space research, and telecommunications. High-purity arsenic also was used for germanium-arsenide-selenide specialty optical materials. Indium-gallium-arsenide (InGaAs) was used for short-wave infrared technology. 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. The value of arsenic compounds and metal imported domestically in 2022 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. Globally, the leading uses of arsenic were as follows: herbicides and insecticides, 45%; wood preservatives, 29%; electronics, 8%; and other, 18%.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Imports for consumption:[2]					
Arsenic metal	929	391	522	835	790
Compounds	5,540	7,050	7,750	4,760	4,600
Total	6,470	7,440	8,270	5,600	5,400
Exports, all forms of arsenic (gross weight)	107	56	29	31	100
Consumption, estimated, all forms of arsenic[3]	6,470	7,440	8,270	5,600	5,300
Price, metal, annual average,[4] dollars per pound:					
Rotterdam	1.10	1.03	0.94	1.34	1.5
U.S. warehouse	0.97	1.01	1.08	1.11	1.8
Net import reliance[5] 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 (2018–21):[2] Arsenic acid: Malaysia, 82%; Hungary, 11%; and China, 7%. Arsenic metal: China,[6] 94%; Japan, 5%; and Germany, 1%. Arsenic trioxide: China, 54%; Morocco, 39%; Belgium, 5%; Germany, 1%; and other, 1%. All forms of arsenic: China,[6] 57%; Morocco, 35%; Belgium, 4%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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, continued to be the leading global producers of arsenic trioxide, accounting for about 93% of estimated world production in 2022. China and Morocco continued to supply about 93% of United States imports of arsenic trioxide in 2022. China was the leading world producer of arsenic metal and supplied about 97% of United States arsenic metal imports in 2022.

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 2022 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.

World Production and Reserves:

	Production[e, 7] (arsenic trioxide, gross weight) 2021	2022	Reserves[8]
United States	—	—	World reserves data are unavailable but are estimated to be more than 20 times world production.
Belgium	1,000	1,000	
Bolivia	120	140	
China	24,000	24,000	
Japan	40	45	
Morocco	[9]6,880	6,900	
Peru	27,000	28,000	
Russia	1,000	1,000	
World total (rounded)	60,000	61,000	

World Resources:[8] 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 is 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]Arsenic content estimated from the reported gross weight of imports.
[3]Estimated to be the same as total imports.
[4]Minimum 99% arsenic. Source Argus Media group, Argus Metals International.
[5]Defined as imports.
[6]Includes Hong Kong.
[7]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.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]Reported.

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 of the unmanufactured asbestos fiber imported into and used within the United States has consisted of chrysotile since no later than 1999. In 2022, U.S. consumption of chrysotile was estimated to be 260 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 domestic asbestos fiber consumption since 2015. In addition to unmanufactured 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 as of 2020 were 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]	2018	2019	2020	2021	2022[e]
Imports for consumption[3]	681	172	305	41	[4]100
Exports[5]	—	—	—	—	—
Consumption, estimated[6]	500	450	450	310	260
Price, average U.S. customs unit value of imports, dollars per ton	1,670	1,570	2,110	1,880	1,900
Net import reliance[7] as a percentage of estimated consumption	100	100	100	100	100

Recycling: None.

Import Sources (2018–21): Brazil, 75%; and Russia, 25%. The U.S. Census Bureau reported imports from China in 2021, but bill of lading information and data reported by the Government of China suggest that shipments from China were misclassified.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 unmanufactured 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 500 tons or less in each year since 2018. 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. As of yearend 2022, asbestos diaphragms were used in nine chloralkali plants in the United States and accounted for about one-third of U.S. chlorine production.

In April 2022, the EPA proposed a rule that would ban the commercial use, distribution in commerce, import, manufacturing, and processing of chrysotile for all chrysotile-containing products that are still used in the United States: aftermarket automotive brakes and linings and other vehicle friction products, diaphragms used in the chloralkali industry, oilfield brake blocks, and sheet and other gaskets. The prohibitions on asbestos diaphragms and sheet gaskets would take effect 2 years after the effective date of the final rule, and the prohibitions on other items would take effect 180 days after finalization. The EPA had not issued the final rule as of the end of September 2022. In 2019, the EPA banned all discontinued uses of asbestos from restarting without the EPA having an opportunity to evaluate each intended use and take any necessary regulatory action. If finalized, the rule proposed in April 2022 would effectively prohibit all uses of asbestos in the United States.

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ASBESTOS

Estimated worldwide consumption of unmanufactured asbestos fiber ranged from 1.1 to 1.3 million tons per year from 2015 through 2021, a significant decrease from approximately 2 million tons in 2000. Global demand for asbestos will likely continue for the foreseeable future, particularly for use in cement pipe, roofing sheets, and other construction materials in Asia.

The Supreme Federal Court of Brazil enacted a national ban on asbestos in November 2017. With the exception of an approximately 2-week pause because of a legal challenge in 2021, the only asbestos producer in the country has operated its mine continuously since November 2020 under the authority of a State law that permits the extraction and processing of asbestos in the State of Goias for export purposes only.

One company in Zimbabwe began producing asbestos in 2019 from tailings of its former mines, with an average monthly output of 500 tons as of August 2019. In 2020, the company was attempting to acquire funds to potentially restart operations at the King Mine (part of the Gaths mining complex) in Mashava and the Shabanie Mine in Zvishavane. Information on the status of asbestos production from tailings was unavailable in 2022, but local media reports suggested that the company lacked the capital required to return the mines to production. In addition to the financial challenges, critical areas of the mines were inaccessible because of flooding and rockfalls.

World Mine Production and Reserves: Reserves for China were revised based on Government reports.

	Mine production		
	2021	**2022[e]**	**Reserves[8]**
United States	—	—	Small
Brazil	[9]154,000	190,000	11,000,000
China	[e]130,000	130,000	15,000,000
Kazakhstan	250,000	230,000	Large
Russia	699,000	700,000	110,000,000
Zimbabwe	[e]10,000	—	Large
World total (rounded)	1,240,000	1,300,000	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, including 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 no. EPA-740-R1-8012, December, 352 p.

[2]Includes unmanufactured asbestos fiber (chrysotile) only; excludes asbestos contained in manufactured products.

[3]Modified from reported U.S. Census Bureau data. Small quantities of additional chrysotile imports from Italy and Japan were reported in 2018, but existing asbestos bans suggest that these shipments were misclassified. Significant additional imports from China were reported in 2021 and 2022, but bill of lading information and data reported by the Government of China suggest that these shipments were also misclassified.

[4]According to the U.S. Census Bureau, chrysotile imports from Brazil totaled 50 tons through July. Final 2022 imports may differ significantly from the provided estimate because chrysotile imports typically do not follow a predictable pattern throughout the year.

[5]Exports of unmanufactured asbestos fiber reported by the U.S. Census Bureau were 235 tons in 2018, 2 tons in 2019, 1 ton in 2020, 461 tons in 2021, and 134 tons through July 2022. These shipments likely consisted of materials misclassified as asbestos, reexports, and (or) waste products because asbestos has not been mined in the United States since 2002.

[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% import reliant since 2002. All domestic consumption of unmanufactured asbestos fiber was from imports and unreported inventories.

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

[9]Asbestos production in Brazil is permitted for export purposes only. The value shown represents reported country exports of asbestos.

BARITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, three companies mined barite in Nevada. Two mines resumed production after having been idle for years, one since 2016 and one since 2020. Mine production increased, but data were withheld to avoid disclosing company proprietary data. The barite assets (two mines and one grinding plant) of a fourth company in Nevada were acquired by a gold-mining company that bought the properties for water and rail access but did not intend to resume barite production. An estimated 2.1 million tons of barite (from domestic production and imports) was sold by crushers and grinders operating in nine States. A company based in Turkey invested $10 million to construct a new grinding plant in Moundsville, WV.

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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Sold or used, mine	366	414	W	W	W
Ground and crushed[1]	2,420	2,350	1,410	1,670	2,100
Imports for consumption[2]	2,460	2,500	1,480	1,660	2,300
Exports[3]	67	38	48	62	89
Consumption, apparent (crude and ground)[4]	2,760	2,880	W	W	W
Price, average unit value, ground, ex-works, dollars per metric ton	176	179	183	167	170
Employment, mine and mill, number[e]	520	480	350	330	360
Net import reliance[5] as a percentage of apparent consumption	87	86	>75	>75	>75

Recycling: None.

Import Sources (2018–21): China,[6] 38%; India, 29%; Morocco, 16%; Mexico, 13%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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.

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BARITE

<u>Events, Trends, and Issues</u>: Historically, rig counts have been a good barometer of barite consumption. In 2022, the monthly average rig count in all regions except for Europe generally increased throughout the year. Through October, the world annual average rig count excluding the United States was 1,050, an increase of 15% compared with that in 2021. In all regions except for Canada, the average annual rig count remained below averages in 2019, before the coronavirus disease 2019 (COVID-19) pandemic. Increases in worldwide rig counts contributed to an estimated 17% increase in world barite production. In the United States, the annual average rig count increased by nearly 50% in 2022. This trend was reflected in domestic sales of ground barite, which were estimated to have increased by 26%. In addition to increased rig counts, barite consumption in the United States was likely supported by a decrease in the number of drilled-but-uncompleted (DUC) wells, which the U.S. Energy Information Administration began tracking in 2014. The number of DUC wells reached its highest level in June 2020, but by September 2022 had reached its lowest level since the inception of the count.

In April, the leading barite mining company in India completed its barite tender that is held every 3 years. Buyers compete for the company's barite production, which is offered in several grades—A-grade with a minimum specific gravity of 4.2, B-grade with a minimum specific gravity of 4.1, and C-, D-, and W-grades, with no guarantee as to specific gravity, but which typically exceeded 3.9. Prices for A- and B-grades increased by about 30% to 45%, or approximately $25 per metric ton. Three U.S. companies reportedly signed agreements to purchase a total of 1.6 million tons of barite.

<u>World Mine Production and Reserves</u>: 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 were included only if developed since the adoption of the 4.1-specific-gravity standard. Reserves for China were revised based on information from Government reports.

	Mine production		Reserves[7]
	2021	2022[e]	
United States	W	W	NA
China	2,100	1,900	37,000
India	1,600	2,600	51,000
Iran	224	220	100,000
Kazakhstan	450	500	85,000
Mexico	321	320	NA
Morocco	1,100	1,300	NA
Russia	150	150	12,000
Turkey	258	300	35,000
Other countries	528	580	70,000
World total (rounded)	[8]6,730	[8]7,900	NA

<u>World Resources</u>:[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.

<u>Substitutes</u>: In the oil- and gas-well-drilling industry, alternatives to barite include celestite, ilmenite, iron ore, and synthetic hematite that is manufactured in Germany. However, substitutes have been used 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 mine production (sold or used) + 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]Excludes U.S. production.

BAUXITE AND ALUMINA[1]

(Data in thousand metric dry tons unless otherwise noted)

Domestic Production and Use: In 2022, a limited amount of bauxite and bauxitic clay was produced for nonmetallurgical use in Alabama, Arkansas, and Georgia. Production statistics for bauxite were withheld to avoid disclosing company proprietary data. In 2022, the reported quantity of bauxite consumed was estimated to be 2.9 million tons, 4% more than that reported in 2021, with an estimated value of about $87 million. About 76% 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 1.2 million tons, slightly more than that in 2021. About 63% 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:	2018	2019	2020	2021	2022[e]
Bauxite:					
Production, mine	W	W	W	W	W
Imports for consumption[2]	3,980	4,620	3,760	3,880	3,600
Exports[2]	16	15	15	12	12
Stocks, industry, yearend[e, 2]	600	300	250	200	200
Consumption:					
Apparent[3]	W	W	W	W	W
Reported	4,460	3,680	3,330	2,790	2,900
Price, average unit value of imports, free alongside ship (f.a.s.), dollars per metric ton	31	32	30	31	30
Net import reliance[4] as a percentage of apparent consumption	>75	>75	>75	>75	>75
Alumina:					
Production, refinery[5]	1,570	1,410	1,340	1,180	1,200
Imports for consumption[5]	1,530	1,930	1,340	1,550	2,000
Exports[5]	288	200	153	180	160
Stocks, industry, yearend[5]	275	275	234	202	300
Consumption, apparent[3]	2,800	3,140	2,570	2,580	2,900
Price, average unit value of imports, f.a.s., dollars per metric ton	592	472	394	462	550
Net import reliance[4] as a percentage of apparent consumption	44	55	48	54	59

Recycling: None.

Import Sources (2018–21): Bauxite:[2] Jamaica, 63%; Brazil, 9%; Guyana and Turkey, 8% each; and other, 12%. Alumina:[5] Brazil, 59%; Australia and Jamaica, 14% each; Canada, 5%; and other, 8%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022, 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. A 500,000-ton-per-year alumina refinery in Burnside, LA, was temporarily shut down in August 2020 and remains idle. No plans were announced regarding its 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 2022 were $30 per ton and $553 per ton, a slight decrease and 25% more than those in the same period of 2021, respectively.

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BAUXITE AND ALUMINA[1]

The conflict between Russia and Ukraine led to the closure of a 1.7-million-ton-per-year alumina refinery in Ukraine. High energy costs in Europe caused a 600,000-ton-per-year alumina refinery in Romania to temporarily shutter and a 1.7-million-ton-per-year alumina refinery in Spain to curtail production by up to 60%. Additionally, several primary aluminum smelters and aluminum product manufacturers throughout Europe announced shutdowns or partial curtailments. In August, a 1.4-million-ton-per-year alumina refinery in Jamaica resumed operations after a fire in 2021 caused a year-long production stoppage. Operations at a 650,000-ton-per-year alumina refinery in Jamaica were suspended by the National Environment and Planning Agency for polluting a nearby river. A United States-based mining company that mines nonmetallurgical bauxite in Guyana acquired a United States proppant manufacturer with two manufacturing facilities located in Georgia.

World Alumina Refinery and Bauxite Mine Production and Bauxite Reserves: Reserves for Australia, China, and Indonesia were revised based company and Government reports.

	Alumina production[5]		Bauxite production		Bauxite reserves[6]
	2021	2022[e]	2021	2022[e]	
United States	1,180	1,200	W	W	20,000
Australia	20,400	20,000	103,000	100,000	[7]5,100,000
Brazil	[e]12,000	11,000	[e]33,000	33,000	2,700,000
Canada	1,360	1,300	—	—	—
China	75,200	76,000	[e]90,000	90,000	710,000
Germany	[e]900	750	—	—	—
Guinea	414	440	[e]86,000	86,000	7,400,000
India	[e]7,000	7,400	[e]17,400	17,000	660,000
Indonesia	[e]1,000	1,100	[e]21,000	21,000	1,000,000
Ireland	1,880	1,800	—	—	—
Jamaica	1,160	480	5,950	3,900	2,000,000
Kazakhstan	[e]1,400	1,400	4,370	4,400	160,000
Russia	3,050	3,100	5,680	5,000	500,000
Saudi Arabia	1,920	2,000	4,780	4,800	180,000
Spain	1,540	1,700	—	—	—
Ukraine	1,770	740	—	—	—
United Arab Emirates	2,300	2,300	—	—	—
Vietnam	1,456	1,500	[e]3,830	3,800	5,800,000
Other countries	2,620	2,200	9,330	8,900	5,100,000
World total (rounded)	139,000	140,000	[8]384,000	[8]380,000	31,000,000

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 the Aluminum chapter. As a general rule, 4 tons of dried bauxite is required to produce 2 tons of alumina, which, in turn, can be used to produce 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 1.7 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. Estimated beryllium apparent consumption in 2022 was 180 tons and was valued at about $130 million based on the most recent beryllium price estimate. Based on sales revenues, approximately 24% of beryllium products were used in industrial components, 21% in automotive electronics, 17% in aerospace and defense applications, 10% in telecommunications infrastructure, 8% in consumer electronics, 5% in energy applications, 2% in semiconductor applications, and 13% 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. To ensure current and future availability of high-quality domestic beryllium to meet critical defense needs, the U.S. Department of Defense, under the Defense Production Act, Title III, invested in a public-private partnership with the leading U.S. beryllium producer to build a primary beryllium facility in Ohio. Construction of the facility was completed in 2011.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine shipments	165	160	165	175	180
Imports for consumption[1]	67	49	48	49	41
Exports[2]	30	37	25	30	47
Shipments from Government stockpile[3]	—	—	3	7	7
Consumption:					
Apparent[4]	202	167	196	196	180
Reported, ore	170	160	170	170	180
Price, annual average unit value, beryllium-copper master alloy,[5] dollars per kilogram of contained beryllium	590	620	620	680	730
Stocks, ore, consumer, yearend	30	35	30	35	35
Net import reliance[6] as a percentage of apparent consumption	18	4	16	11	1

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 (2018–21):[1] Kazakhstan, 43%; Japan, 15%; Latvia, 15%; Brazil, 10%; and other, 17%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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% 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% 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 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Beryl ore (gross weight)	1	—	—	—	—
Metal (all types)	50	—	7	—	7
Structured powder	7	—	—	—	—

Events, Trends, and Issues: Apparent consumption in 2022 decreased by 8% from that in 2021 owing primarily to a 16% decrease in estimated beryllium imports and a 57% increase estimated exports. During the first 6 months of 2022, 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 27% higher than those during the first 6 months of 2021. Net sales of beryllium products increased primarily in the aerospace and defense, energy, and industrial components markets.

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] 2021	Mine production[8, 9] 2022[e]
United States	175	180
Brazil	[e]3	3
China	[e]71	70
Madagascar	[e]1	1
Mozambique	13	13
Nigeria	[e]1	1
Rwanda	[e]1	1
Uganda	[e]7	7
World total (rounded)	272	280

Reserves[10]

The United States has very little beryl that can be economically hand sorted from pegmatite deposits. An epithermal deposit in the Spor Mountain area in Utah is a large bertrandite resource, which is being mined. Proven and probable bertrandite reserves in Utah total about 19,000 tons of contained beryllium. World beryllium reserves are not available.

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 from prior yearend inventory. If negative, increase in 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 64% 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:	**2018**	**2019**	**2020**	**2021**	**2022**[e]
Production:					
Refinery	—	—	—	—	—
Secondary (scrap)[e]	80	80	80	80	80
Imports for consumption, metal, alloys, and scrap[1]	2,470	2,340	1,650	1,980	2,800
Exports, metal, alloys, and scrap[2]	653	636	699	1,010	670
Consumption:					
Apparent[3]	2,040	1,690	1,210	1,030	2,000
Reported	570	548	513	597	600
Price, average,[4] dollars per pound	4.61	3.18	2.72	3.74	3.90
Stocks, yearend, consumer, bismuth metal	346	443	271	297	500
Net import reliance[5] as a percentage of apparent consumption	96	95	93	92	96

Recycling: Recycled bismuth-containing alloy scrap was thought to compose 4% to 8% of U.S. bismuth apparent consumption for the years 2018–22.

Import Sources (2018–21): China,[6] 65%; Republic of Korea, 19%; Mexico, 5%; Belgium, 3%; and other, 8%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Bismuth and articles thereof, including waste and scrap:		
Containing more than 99.99% of bismuth, by weight	8106.10.0000	Free.
Other	8106.90.0000	Free.

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

Government Stockpile: None.

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BISMUTH

Events, Trends, and Issues: The estimated annual average domestic dealer price for bismuth in 2022 was an estimated $3.90 per pound, a 4% increase from that in 2021 and the highest annual average price since 2018. Globally, excess stocks continued to keep prices low compared with those in 2007 through 2014, when the average annual dealer price was above $7.84 per pound. Global primary refined production was estimated to remain unchanged from that in 2021 and increased by 3% from that in 2019, before the coronavirus disease 2019 (COVID-19) pandemic. Exports from China through August 2022 remained flat compared with those during the same period in 2021 but increased by 76% from those in 2019. The increase was attributed to the stockpiling of supplies by foreign buyers avoiding shipping disruptions owing to concerns about COVID-19 pandemic-related production interruptions in China and global shipping issues.

U.S. trade data through July 2022 were mixed when compared with the same period in 2021—whereas bismuth imports for consumption increased, exports decreased. In the long term, bismuth demand from the alloying, chemical, and metallurgical industries was expected to remain stable.

World Refinery Production and Reserves:

	Refinery production[e]		Reserves[7]
	2021	2022	
United States	—	—	Quantitative estimates of reserves were not available.
Bolivia	60	60	
Bulgaria	50	50	
Canada	50	50	
China	16,000	16,000	
Japan	500	480	
Kazakhstan	230	220	
Korea, Republic of	1,000	950	
Laos	[8]2,070	2,000	
Mexico	10	10	
World total (rounded)	20,000	20,000	

World Resources:[7] 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. In Japan and the Republic of Korea, bismuth production is a byproduct or coproduct of zinc 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]Includes data for the following Harmonized Tariff Schedule of the United States codes: 8106.00.0000 (for the years 2018–21), and 8106.10.0000 and 8106.90.0000 (for the year 2022).

[2]Includes data for the following Schedule B numbers: 8106.00.0000 (for the years 2018–21), and 8106.10.0000 and 8106.90.0000 (for the year 2022).

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

[4]Prices are based on 99.99%-purity metal at warehouse (Rotterdam) in minimum lots of 1 ton. Source: Fastmarkets AMM.

[5]Defined as imports – exports ± adjustments for industry stock changes.

[6]Includes Hong Kong.

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

[8]Reported.

BORON

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies in southern California produced borates in 2022, and most of the boron products consumed in the United States were manufactured domestically. Estimated boron production increased in 2022 compared with 2021 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 2022, 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production	W	W	W	W	W
Imports for consumption:					
Refined borax	133	161	174	232	160
Boric acid	51	41	39	54	53
Colemanite (calcium borates)	73	42	18	3	1
Ulexite (sodium borates)	34	38	41	49	36
Exports:					
Boric acid	251	251	257	280	250
Refined borax	610	598	594	607	610
Consumption, apparent[1]	W	W	W	W	W
Price, average unit value of imports, cost, insurance, and freight, dollars per metric ton	404	373	380	394	430
Employment, number	1,350	1,370	1,330	1,330	1,370
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2018–21): All forms: Turkey, 90%; Bolivia, 5%; Chile, 2%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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.

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.

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BORON

China, Malaysia, Canada, Mexico, India, and Indonesia, in decreasing order of tonnage, are the countries that imported the largest quantities of refined borates from the United States in 2022. Domestic shipments of boric acid were sent to China, the Netherlands, the Republic of Korea, Japan, and Malaysia, in decreasing order of tonnage. Because China has low-grade boron reserves and demand for boron is anticipated to rise in that country, imports 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. An Australian-British multinational mining corporation completed and successfully produced battery-grade lithium from waste rock at its Boron Mine's lithium demonstration plant in 2021. The demonstration will be used as the basis for a feasibility assessment. The California mine site could help create an additional revenue stream from almost a century of waste rock once the project is completed. Initial capacity was expected to be 5,000 tons per year. Two Australian-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 and funding necessary to begin and continue construction. The project in California began construction in April and was expected to have a focus on specialty boron products for industries related to global decarbonization and food security once production starts. The Nevada project was expected to begin production by 2025. These companies have the potential to become substantial boron producers when their projects are fully developed.

World Production and Reserves: Reserves for China were revised based on Government reports.

	Production—All forms[e]		Reserves[3]
	2021	2022	
United States	W	W	40,000
Argentina, crude ore	130	130	NA
Bolivia, ulexite	200	200	NA
Chile, ulexite	290	300	35,000
China, boric oxide equivalent	380	300	21,000
Germany, compounds	60	60	NA
Peru, crude borates	[4]246	250	4,000
Russia, datolite ore	80	80	40,000
Turkey, refined borates	1,700	1,700	1,200,000
World total[5]	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]Reported.

[5]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 2022 was estimated to be greater than that in 2021.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production	W	W	W	W	W
Imports for consumption, elemental bromine and compounds[1]	56,200	56,300	30,700	27,200	27,000
Exports, elemental bromine and compounds[2]	21,900	29,300	36,600	27,900	18,000
Consumption, apparent[3]	W	W	W	W	W
Price, average unit value of imports (cost, insurance, and freight), dollars per kilogram	2.21	2.31	2.67	2.85	3.5
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	E	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 of many organic reactions; this byproduct can be recycled with virgin bromine brines and used as a source of bromine production. Bromine contained in plastics, such as BFRs, can be difficult and costly to remove; therefore, bromine-containing polymers will often be recycled with the virgin polymer and used again in new products. Bromine used in zinc-bromine batteries can be removed and completely recovered as bromine at the battery's end of life, purified, and used for new batteries. Available information was insufficient to estimate the quantity of bromine recovered and recycled.

Import Sources (2018–21):[5] Israel, 80%; Jordan, 12%; China,[6] 4%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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.
Methyl bromide[7]	2903.61.0000	Free.
Ethylene dibromide[8]	2903.62.1000	5.4% ad valorem.
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.

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 2022, the leading source of imports of bromine and bromide compounds (gross weight) was Israel. The average import value of bromine and bromine compounds was estimated to have increased by over 20% in 2022 compared with that in 2021. 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%). Estimated total imports of bromine and bromine compounds (bromine content) decreased slightly, whereas estimated total exports decreased by over 30% compared with those in 2021.

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BROMINE

In 2021, the U.S. Environmental Protection Agency issued a final rule to reduce the exposure to decabromodiphenyl ether (decaBDE), a BFR considered to be persistent, bioaccumulative, and toxic. The rule prohibited the manufacture, processing, distribution, or importing of decaBDE or products containing decaBDE. The importing, manufacturing, and processing of decaBDE and products to which decaBDE had been added was prohibited effective March 2021, and distribution prohibitions started in January 2022. Longer compliance dates or exclusions were set for certain uses such as aerospace vehicle parts, hospitality curtains, and wire and cable insulation used in nuclear power facilities. Because of health concerns, some States have established their own policies restricting the use of BFRs.

Globally, bromine selling prices were higher in 2022 compared with those in 2021. Domestic sale volumes of bromine and bromine compounds also increased in 2022 compared with those in 2021 owing primarily to sales of BFRs. BFR sales were driven by strong demand for appliance, automotive, construction, and electronic industries. Sales of clear brine drilling fluids, the second leading use of bromine, also increased compared with those in the previous year.

World Production and Reserves:

	Production[e]		Reserves[9]
	2021	2022	
United States	W	W	11,000,000
Azerbaijan	—	—	300,000
China	70,000	70,000	NA
India	5,000	5,000	NA
Israel	[10]182,000	180,000	Large
Japan	18,000	20,000	NA
Jordan	110,000	110,000	Large
Ukraine	4,500	4,500	NA
World total (rounded)	[11]390,000	[11]390,000	Large

World Resources:[9] 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 (for the years 2018–2021), and 2903.61.0000 and 2903.62.1000 (for the year 2022).
[3]Defined as production (sold or used) + imports – exports.
[4]Defined as imports – exports.
[5]Calculated using the gross weight of imports.
[6]Includes Hong Kong.
[7]Prior to 2022, was listed under Harmonized Tariff Schedule of the United States code 2903.39.1520.
[8]Prior to 2022, was listed under Harmonized Tariff Schedule of the United States code 2903.31.0000.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.
[10]Reported.
[11]Excludes U.S. production.

CADMIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Two companies in the United States produced cadmium metal in 2022. One company, operating in Tennessee, recovered primary refined cadmium as a byproduct of zinc leaching from roasted sulfide concentrates that would otherwise need to be disposed of as waste. 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 in late 2019 restarted zinc production from recycled electric-arc-furnace dust obtained from steel mills. Cadmium metal and compounds are mainly consumed for NiCd batteries, but also for alloys, coatings, and pigments. For the past 5 years, the United States has been a net exporter of wrought cadmium products and of cadmium pigments and preparations based on cadmium.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Primary, refined[1]	73	131	211	241	250
Secondary	W	W	W	W	W
Imports for consumption:					
Unwrought cadmium and powders	273	385	282	155	21
Wrought cadmium and other articles	1	21	3	2	1
Cadmium waste and scrap	20	86	90	85	35
Cadmium oxide	51	33	28	14	21
Cadmium pigments and preparations based on cadmium compounds	310	108	69	101	170
Exports:					
Unwrought cadmium and powders	40	32	4	51	2
Wrought cadmium and other articles	99	84	482	217	90
Cadmium waste and scrap	([2])	6	([2])	—	4
Cadmium pigments and preparations based on cadmium compounds	565	795	2,120	550	510
Consumption of metal, apparent[3]	W	W	W	W	W
Price, metal, annual average,[4] dollars per kilogram	2.89	2.67	2.29	2.56	3.3
Net import reliance[5] as a percentage of apparent consumption	<75	<75	<75	<50	<25

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 (2018–21):[6] Australia, 27%; Germany, 23%; China,[7] 20%; Peru, 12%; and other, 18%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
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.
Cadmium waste and scrap	8112.61.0000	Free.
Unwrought cadmium and powders	8112.69.1000	Free.
Wrought cadmium and other articles	8112.69.9000	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, and semiconductors for solar cells and for radiation-detecting imaging equipment; research into substitutions for cadmium in uses such as coatings continued.

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CADMIUM

The average monthly cadmium price was $2.92 per kilogram in January and increased to $3.58 per kilogram in May and $3.60 per kilogram in September after a decrease earlier in the year. The average prices reflected seasonal buying patterns in India; as a major consumer of cadmium but without significant production, India was an important determinant of cadmium prices in the spot market.

In August 2022, the U.S. Department of Energy announced the formation of a 3-year consortium among academic institutions, industry, and Government in support of the goals of its Cadmium Telluride Photovoltaics (PV) Accelerator program that was initiated in 2021. These goals included enabling solar cell efficiencies above 24% by 2025 and above 26% by 2030, while steadily reducing the per-watt cost of manufacturing by 60% within 10 years.

In response to the Inflation Reduction Act of 2022, which included incentives for transitioning to renewable energy sources, a major United States-based CdTe thin-film solar-cell producer announced plans to build a fourth domestic manufacturing facility by 2025 and expand capacity at its two existing plants and at a third facility which was scheduled to begin production in 2023. According to the consortium, administered by the National Renewable Energy Laboratory, CdTe solar panels supply 40% of the U.S. utility-scale solar market and 5% of the world market.

World Refinery Production and Reserves:

	Refinery production[e]		Reserves[8]
	2021	**2022**	
United States[1]	241	250	Quantitative estimates of reserves were not available. The cadmium content of typical zinc ores averages about 0.03%. See the Zinc chapter for zinc reserves.
Australia	402	400	
Bulgaria	310	310	
Canada	1,800	1,800	
China	10,000	10,000	
Germany	417	420	
Japan	1,900	1,900	
Kazakhstan	1,200	1,200	
Korea, Republic of	4,000	4,000	
Mexico	859	1,200	
Netherlands	854	500	
Norway	350	350	
Peru	600	300	
Poland	500	500	
Russia	1,000	1,000	
Uzbekistan	300	300	
World total (rounded)	24,700	24,000	

World Resources:[8] 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: Batteries with other chemistries, particularly lithium-ion, can replace NiCd batteries in many applications. Except where the surface characteristics of a coating are critical (for example, fasteners for aircraft), coatings of aluminum, zinc, or zinc alloys such as tin-zinc and zinc-nickel 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 polyvinyl chloride (PVC) applications. Amorphous silicon and copper-indium-gallium-selenide photovoltaic cells compete with CdTe in the thin-film solar-cell market. A new thin-film technology based on perovskite material continued to be researched as a potential substitute.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Cadmium metal produced as a byproduct of zinc refining.
[2]Less than ½ unit.
[3]Defined as primary production + secondary production + imports of unwrought cadmium and powders – exports of unwrought cadmium and powders.
[4]Average free market price for 99.95% purity in 10-ton lots; cost, insurance, and freight; global ports. Source: Fastmarkets MB.
[5]Defined as imports of unwrought cadmium and powders – exports of unwrought cadmium and powders.
[6]Unwrought cadmium and powders; Harmonized Tariff Schedule of the United States code 8107.20.0000 prior to 2022 and 8112.69.1000 in 2022.
[7]Includes Hong Kong.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.

CEMENT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, U.S. portland cement production increased slightly to an estimated 92 million tons, and masonry cement production increased to an estimated 2.5 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 approximately 43% 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 2022, shipments of cement were estimated to have increased by about 3% from those in 2021 and were valued at $14.6 billion. In 2022, 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]	2018	2019	2020	2021	2022[e]
Production:					
Portland and masonry cement[2]	86,400	87,600	89,300	[e]93,000	95,000
Clinker	77,112	78,858	78,951	79,000	80,000
Shipments to final customers, includes exports	99,419	102,823	104,645	109,000	110,000
Imports for consumption:					
Hydraulic cement	13,693	14,836	15,531	19,937	24,000
Clinker	967	997	1,204	1,563	1,100
Exports of hydraulic cement and clinker	919	1,024	884	940	900
Consumption, apparent[3]	98,500	102,000	105,000	[e]110,000	120,000
Price, average mill unit value, dollars per metric ton	121	124	125	[e]130	130
Stocks, cement, yearend	8,580	7,990	7,180	[e]7,000	7,500
Employment, mine and mill, number[e]	12,300	12,500	12,200	12,300	13,000
Net import reliance[4] as a percentage of apparent consumption	14	15	15	18	21

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 (2018–21):[5] Canada, 30%; Turkey, 26%; Greece, 11%; Mexico, 8%; and other, 25%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 11% during the first 9 months of 2022 compared with that in the same period in 2021. Residential construction spending increased more than nonresidential construction spending. Despite increased prices owing to increased costs of production, cement shipments increased by about 4% during the first 9 months of 2022 compared with those in the same period in 2021. The leading cement-consuming States continued to be Texas, California, and Florida, in descending order by tonnage.

Increased cement apparent consumption in 2022 resulted from continued economic recovery from the effects of the global coronavirus disease 2019 (COVID-19) pandemic, and the November 2021 passage of the Bipartisan Infrastructure Law. In 2022, regulators implemented new measures designed to aid industry decarbonization efforts, including green procurement strategies and research investments. However, cement industry growth continued to be constrained by increased costs for energy, material, and service inputs; labor and production shortages; and ongoing supply chain disruptions.

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CEMENT

Company merger-and-acquisition activity continued in 2022, including the sale of a United States-based cement company's plant in California to a Japan-based cement company. The Japanese cement company also entered into an agreement to purchase a second cement plant in California from the United States cement company, pending regulatory approval.

Upgrades at a cement plant in Alabama were completed and the facility restarted production in mid-2022. An upgrade of a cement plant in Indiana progressed toward its expected completion date in early 2023. A plant upgrade to increase cement production at a site in Arizona was completed in 2022. Plans to increase capacity at a cement plant in Texas were announced, with completion expected in mid-2025. Upgrades at a terminal in Florida were completed in 2022, and work began to increase capacity at a terminal in Virginia. Plans for new cement terminals in Georgia and Texas were announced. Several minor upgrades were ongoing at some other domestic plants and a few other cement terminals. A Spain-based company reported plans to open a specialty cement facility in Louisiana in 2023.

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. Following widespread acceptance of portland-limestone cement (PLC) blended cement by various authorities, several cement plants announced their transition to PLC (Type IL). Additionally, some plants reported increased alternative fuel substitution, new carbon capture, utilization and storage projects, usage of new technologies, and (or) business diversification efforts. Many plants have installed emissions-reduction equipment to comply with the 2010 National Emissions Standards for Hazardous Air Pollutants (NESHAP). It remained possible that some kilns could be shut, idled, or used at reduced capacity to comply with NESHAP, which would constrain U.S. clinker capacity. In 2022, cement plant closures were announced at cement plants in California and New York.

World Production and Capacity:

	Cement production[e]		Clinker capacity[e]	
	2021	2022	2021	2022
United States (includes Puerto Rico)	93,000	95,000	100,000	100,000
Brazil	66,000	65,000	60,000	60,000
China	2,400,000	2,100,000	2,000,000	2,000,000
Egypt	50,000	51,000	48,000	48,000
India	350,000	370,000	280,000	290,000
Indonesia	65,000	64,000	79,000	79,000
Iran	62,000	62,000	81,000	81,000
Japan	50,000	50,000	54,000	54,000
Korea, Republic of	50,000	50,000	62,000	62,000
Mexico	52,000	50,000	42,000	42,000
Russia	61,000	62,000	80,000	80,000
Saudi Arabia	54,000	54,000	75,000	75,000
Turkey	82,000	85,000	92,000	92,000
Vietnam	110,000	120,000	90,000	100,000
Other countries (rounded)	850,000	850,000	600,000	600,000
World total (rounded)	4,400,000	4,100,000	3,700,000	3,800,000

World Resources: See the Lime and Stone (Crushed) chapters 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.

CESIUM

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

Domestic Production and Use: In 2022, 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 may be used in the production of cesium compounds and photoelectric cells. Cesium bromide may be used in infrared detectors, optics, photoelectric cells, scintillation counters, and spectrophotometers. Cesium carbonate may be 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 may be 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 may be used as an electrolyte in alkaline storage batteries. Cesium iodide may be used in fluoroscopy equipment—Fourier-transform infrared spectrometers—as the input phosphor of X-ray image intensifier tubes, and in scintillators. Cesium nitrate may be used as a colorant and oxidizer in the pyrotechnic industry, in petroleum cracking, in scintillation counters, and in X-ray phosphors. Cesium sulfates are often used as an intermediate form of cesium and may be used 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, may be 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. No more than 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 2022, one company offered 1-gram ampoules of 99.8% (metal basis) cesium for $76.97 and 99.98% (metal basis) cesium for $97.86, 10% increases from $69.90 and $88.90 in 2021, respectively. In 2022, the prices for 50 grams of 99.9% (metal basis) cesium acetate, cesium bromide, cesium carbonate, 99.99% (metal basis) cesium chloride, and cesium iodide were $134.62, $82.43, $118.66, $119.70, and $137.34, respectively, with increases ranging from 3% to 9% from prices in 2021.

The price for a cesium-plasma standard solution (10,000 micrograms per milliliter) in 2022 was $84.53 for 50 milliliters and $129.15 for 100 milliliters, increases of 8% from $78.60 and $120.00 in 2021, respectively. The price for 25 grams of 98% (metal basis) cesium formate was $46.10, an 8% increase from $42.60 in 2021.

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 (2018–21): 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 and refined chemicals. Based on recent import data, it is thought that Germany was a source of refined cesium chemicals.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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	2844.43.0021	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic cesium occurrences will likely remain subeconomic unless market conditions change. No known human health issues are associated with exposure to 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 2022, 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. Mining of cesium in Namibia ceased in the early 2000s. Potential extraction of cesium from pollucite mining at the Tanco Mine in Canada ended in 2015. The Bikita Mine in Zimbabwe was depleted of pollucite ore reserves in 2018. 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 commercial stockpiles of cesium ore, excluding those in China, may be depleted in the near future.

Throughout 2022, multiple projects that would produce cesium through lepidolite, pollucite, spodumene, and zinnwaldite mining, focused primarily on lithium or cesium extraction, were in the feasibility and exploration stage, and one company was working on mine development. Beginning in late 2021 and early 2022, pollucite ore from the Tanco Mine was being shipped to China for lithium recovery.

World Mine Production and Reserves:[1] There were no official sources for cesium production data in 2022. 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 were 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 China, Germany, and India. 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 2022, the United States consumed an estimated 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 $1.5 billion in 2022, as measured by the value of net imports, excluding stainless steel, which was a 75% increase from $874 million in 2021.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine	—	—	—	—	—
Recycling[1]	139	137	119	114	100
Imports for consumption[2]	651	530	457	607	620
Exports[2]	212	149	138	114	140
Shipments from Government stockpile[3]	4	4	5	7	5
Consumption (includes recycling):					
Reported	459	482	386	375	310
Apparent[4]	583	521	442	614	590
Price, average unit value of imports, dollars per metric ton:					
Chromite ore (gross weight)	279	248	179	197	340
Ferrochromium (chromium content)[5]	2,549	2,094	1,878	2,837	6,800
Chromium metal (gross weight)	11,344	10,393	7,931	8,757	21,000
Stocks, consumer, yearend	5	5	6	6	6
Net import reliance[6] as a percentage of apparent consumption	76	74	73	81	83

Recycling: In 2022, recycled chromium (contained in reported stainless-steel scrap receipts) accounted for 17% of apparent consumption.

Import Sources (2018–21): Chromite (ores and concentrates): South Africa, 97%; Canada, 2%; and other, 1%. Chromium-containing scrap:[7] Canada, 48%; Mexico, 42%; Netherlands, 4%; and other, 6%. Chromium (primary metal):[8] South Africa, 30%; Kazakhstan, 13%; Russia, 9%; Germany, 7%; and other, 41%. Chromium-containing chemicals: China,[9] 23%; Germany, 20%; Kazakhstan, 19%; and other, 38%. Total imports: South Africa, 37%; Kazakhstan, 10%; Russia, 7%; Germany, 6%; and other, 40%.

Tariff:[10] Item	Number	Normal Trade Relations 12–31–22
Chromium ores and concentrates:		
Not more than 40% chromic oxide (Cr_2O_3)	2610.00.0020	Free.
More than 40% but less than 46% Cr_2O_3	2610.00.0040	Free.
More than or equal to 46% Cr_2O_3	2610.00.0060	Free.
Ferrochromium:		
More than 4% carbon	7202.41.0000	1.9% ad valorem.
More than 3% but less than 4% carbon	7202.49.1000	1.9% ad valorem.
More than 0.5% but less than 3% carbon	7202.49.5010	3.1% ad valorem.
Not more than 0.5% carbon	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.

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

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CHROMIUM

Government Stockpile:[11, 12]

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Ferrochromium:					
High carbon	17.2	—	[13]21.8	—	[13]21.8
Low carbon	26.6	—	—	—	—
Chromium metal	3.47	—	0.454	—	0.454

Events, Trends, and Issues: South Africa was the leading chromite ore producer. Global chromite ore mine production was estimated to have decreased slightly in 2022, owing to constraints from operational challenges in some countries, slow global economic growth, and increasing labor costs. China was the leading ferrochromium- and stainless-steel-producing country and the leading chromium-consuming country. Coronavirus disease 2019 (COVID-19) pandemic-related lockdowns, tight financial conditions, and a decrease in demand could affect ferrochromium and stainless-steel production in China. The Bipartisan Infrastructure Law provided funding for a critical minerals mapping project, which includes chromium, that the U.S. Geological Survey will undertake as part of its Earth Mapping Resources Initiative.

From September 2021 to September 2022, the monthly average high-carbon ferrochromium price increased by 85%. The price of chromium metal increased by 36% in September 2022 compared with the monthly average price in September 2021.

World Mine Production and Reserves: Reserves for the United States were revised based on industry information. Reserves for Finland were revised based on Government reports.

	Mine production[14] 2021	Mine production[14] 2022[e]	Reserves[15] (shipping grade)[16]
United States	—	—	630
Finland	2,270	2,200	8,300
India	4,250	4,200	100,000
Kazakhstan[e]	6,500	6,500	230,000
South Africa	18,600	18,000	200,000
Turkey	6,960	6,900	26,000
Other countries	3,620	3,500	NA
World total (rounded)	42,200	41,000	560,000

World Resources:[15] 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 chromium chemicals, chromium metal, chromite ores, ferrochromium, and stainless-steel products and scrap.
[3]Defined as change in total inventory from prior yearend inventory. If negative, increase in inventory.
[4]Defined as production (from mines and recycling) + imports – exports ± adjustments for Government and industry stock changes.
[5]Excludes ferrochromium silicon.
[6]Defined as imports – exports ± adjustments for Government and industry stock changes.
[7]Includes chromium metal scrap and stainless-steel scrap.
[8]Includes chromium metal, ferrochromium, and stainless steel.
[9]Includes Hong Kong.
[10]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.
[11]See Appendix B for definitions.
[12]Units are thousand metric tons, gross weight.
[13]High-carbon and low-carbon ferrochromium, combined.
[14]Units are thousand metric tons, gross weight, of marketable chromite ore.
[15]See Appendix C for resource and reserve definitions and information concerning data sources.
[16]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 26 million tons valued at $1.7 billion in 2022, with about 120 companies operating clay and shale mines in 38 States. The leading 20 companies produced approximately 69% of the U.S. tonnage and 83% of the value for all types of clay. Principal domestic uses for specific clays were estimated to be as follows: ball clay—52% floor and wall tile and 19% sanitaryware; bentonite—49% pet waste absorbents and 23% drilling mud; common clay—46% brick, 26% lightweight aggregate, and 23% cement; fuller's earth—83% absorbents (including oil and grease absorbents, pet waste absorbents, and miscellaneous absorbents); and kaolin—52% fillers, extenders, and binders and 25% ceramics. Fire clay uses were withheld to avoid disclosing company proprietary data.

Exports of clay and shale were estimated to have decreased by 4% in 2022 from those in 2021 after increasing by 18% in 2021 from exports in 2020. In 2022, the United States exported an estimated 890,000 tons of bentonite; Canada, Japan, and Mexico, in decreasing order, were the leading destinations. About 2.1 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; Mexico, China, and Japan, in decreasing order, were 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:	2018	2019	2020	2021	2022[e]
Production (sold or used):					
Ball clay	1,110	[e]1,060	1,090	[e]1,200	1,200
Bentonite	4,570	4,520	4,250	4,590	4,500
Common clay	13,300	13,300	13,000	12,800	13,000
Fire clay	567	603	635	675	720
Fuller's earth[e, 1]	1,880	1,990	1,980	2,130	2,100
Kaolin[e]	5,350	5,060	4,570	4,300	4,600
Total[1, 2]	26,800	26,500	25,500	25,700	26,000
Imports for consumption:					
Artificially activated clays and earths	23	31	31	41	59
Kaolin	330	293	224	149	170
Other	68	66	28	47	61
Total[2]	421	389	284	237	290
Exports:					
Artificially activated clays and earths	149	138	127	140	130
Ball clay	90	85	68	139	170
Bentonite	845	906	728	862	890
Clays, not elsewhere classified	244	204	185	186	200
Fire clay[3]	250	194	190	210	180
Fuller's earth	70	73	77	83	84
Kaolin	2,390	2,280	1,990	2,340	2,100
Total[2]	4,030	3,880	3,360	3,960	3,800
Consumption, apparent[4]	23,200	23,000	22,400	22,000	22,000
Price, average unit value, ex-works, dollars per metric ton:					
Ball clay	55	56	58	58	58
Bentonite	98	98	97	100	97
Common clay	17	18	17	17	17
Fire clay	12	14	12	12	12
Fuller's earth[1]	88	88	89	88	92
Kaolin	160	162	160	154	160
Employment (excludes office workers), number:[e]					
Mine (may not include contract workers)	1,110	1,110	1,060	1,060	1,100
Mill	4,310	4,310	4,260	4,240	4,300
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2018–21): All clay types combined: Brazil, 68%; Mexico, 12%; China, 5%; and other, 15%.

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CLAYS

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 March 2022, a Georgia kaolin producer completed the sale of certain North American assets and mining resources that support the paper and packaging markets to another kaolin producer with headquarters in Georgia. Additionally, another kaolin producer with North American headquarters in Georgia completed an acquisition in September 2022, which included four production sites and related mines, reserves, and two processing facilities in central 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	
	2021	2022[e]	2021	2022[e]	2021	2022[e]
United States	4,590	4,500	[1]2,130	[1]2,100	4,300	4,600
Brazil (beneficiated)	220	220	—	—	1,200	1,200
China	2,100	2,100	—	—	8,400	8,400
Czechia	230	230	—	—	[7]3,100	[7]3,100
Denmark	1,000	1,000	—	—	—	—
Greece	[7]1,300	[7]1,300	34	34	—	—
India	3,000	3,000	730	730	[7]8,400	[7]8,400
Iran	700	700	—	—	1,900	1,900
Mexico	79	79	110	110	240	240
Senegal	—	—	117	120	—	—
Spain	210	210	560	560	[7]270	[7]270
Turkey	2,020	2,000	112	110	1,750	1,700
Ukraine	180	180	—	—	2,330	600
Uzbekistan	50	50	—	—	5,000	5,000
Other countries	3,300	3,300	252	250	12,500	13,000
World total (rounded)[2]	19,000	19,000	[1]4,040	[1]4,000	49,300	48,000

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 2022, the nickel-copper Eagle Mine in Michigan produced cobalt-bearing nickel concentrate. In Missouri, a company produced nickel-copper-cobalt concentrate from historic mine tailings and was building a hydrometallurgical processing plant near the mine site. In October, commissioning began at a cobalt-copper-gold mine and mill in Idaho, where cobalt concentrate will be produced. This mine and one in Morocco are the only mines in the world where cobalt is the principal product. Most U.S. cobalt supply consisted of imports and secondary (scrap) materials. About six companies in the United States produced cobalt chemicals. An estimated 40% of the cobalt consumed in the United States was used in superalloys, mainly in aircraft gas turbine engines; 35% in a variety of chemical applications; 15% in various other metallic applications; and 10% in cemented carbides for cutting and wear-resistant applications. The total estimated value of cobalt consumed in 2022 was $530 million.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:[e]					
Mine	480	500	600	650	800
Secondary[1]	2,750	2,750	2,010	1,800	1,900
Imports for consumption	11,900	13,900	9,740	9,800	11,000
Exports	6,980	4,080	3,430	4,930	5,100
Consumption (includes secondary):					
Estimated[2]	9,290	9,050	7,260	7,200	7,800
Apparent[e, 3]	7,680	12,500	8,470	6,600	7,800
Price, average, dollars per pound:					
U.S. spot, cathode[4]	37.43	16.95	15.70	24.21	31
London Metal Exchange (LME), cash	32.94	14.88	14.21	23.17	29
Stocks, yearend:					
Industry[e, 2, 5]	1,060	1,090	952	1,010	1,000
LME, U.S. warehouse	130	102	82	50	30
Net import reliance[6] as a percentage of apparent consumption	64	78	76	73	76

Recycling: In 2022, cobalt contained in purchased scrap represented an estimated 24% of estimated cobalt consumption.

Import Sources (2018–21): Cobalt contained in metal, oxide, and salts: Norway, 22%; Canada, 16%; Finland, 12%; Japan, 12%; and other, 38%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
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 the Lithium chapter for statistics on lithium-cobalt oxide and lithium-nickel-cobalt-aluminum oxide.

		FY 2022		**FY 2023**	
Material	**Inventory as of 9–30–22**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Cobalt	302	—	—	—	—
Cobalt alloys, gross weight[8]	14	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 2022. The increase in mine production was mainly in Congo (Kinshasa) and in Indonesia, where new mining and processing projects were starting production. Congo (Kinshasa) continued to be the world's leading source of mined cobalt, accounting for about 70% of world cobalt mine production. With the exception of some production in the United States, 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 about 80% of its consumption used by the rechargeable battery industry.

World Mine Production and Reserves: Reserves for Australia, China, and Congo (Kinshasa) were revised based on company and Government reports.

	Mine production		Reserves[9]
	2021	2022[e]	
United States	[e]650	800	69,000
Australia	5,295	5,900	[10]1,500,000
Canada	4,361	3,900	220,000
China	[e]2,200	2,200	140,000
Congo (Kinshasa)	[e]119,000	130,000	4,000,000
Cuba	[e]4,000	3,800	500,000
Indonesia	[e]2,700	10,000	600,000
Madagascar	[e]2,800	3,000	100,000
Morocco	[e]2,300	2,300	13,000
Papua New Guinea	2,953	3,000	47,000
Philippines	[e]3,600	3,800	260,000
Russia	[e]8,000	8,900	250,000
Turkey	[e]2,400	2,700	36,000
Other countries	4,567	5,200	610,000
World total (rounded)	165,000	190,000	8,300,000

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 670,000 tons.

COPPER

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

Domestic Production and Use: In 2022, the recoverable copper content of U.S. mine production was an estimated 1.3 million tons, an increase of 6% from that in 2021, and was valued at an estimated $11 billion, 6% less than $11.7 billion in 2021. Arizona was the leading copper-producing State and accounted for approximately 70% of domestic output; copper was also mined in Michigan, Missouri, Montana, Nevada, New Mexico, and Utah. Copper was recovered or processed at 25 mines (17 of which accounted for more than 99% of mine production), 2 primary smelters, 2 electrolytic refineries, and 14 electrowinning facilities. An additional primary smelter and electrolytic refinery have been closed indefinitely since October 2019, and a new secondary smelter was in the process of starting up as of September. Refined copper and scrap were consumed at about 30 brass mills, 14 rod mills, and 500 foundries and miscellaneous manufacturers. 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Mine, recoverable copper content	1,220	1,260	1,200	1,230	1,300
Refinery:					
Primary (from ore)	1,070	985	874	922	960
Secondary (from scrap)	41	44	43	49	40
Copper recovered from old (post-consumer) scrap[2]	141	166	160	[e]170	160
Imports for consumption:					
Ore and concentrates	32	27	2	11	15
Refined	778	663	676	919	810
Exports:					
Ore and concentrates	253	356	383	347	330
Refined	190	125	41	48	30
Consumption:					
Reported, refined metal	1,820	1,810	1,770	1,770	1,800
Apparent, primary refined and old scrap[3]	1,820	1,820	1,660	1,960	1,900
Price, annual average, cents per pound:					
U.S. producer, cathode (COMEX + premium)	298.7	279.6	286.7	432.3	410
COMEX, high-grade, first position	292.6	272.3	279.9	424.3	400
London Metal Exchange, grade A, cash	296.0	272.4	279.8	422.5	400
Stocks, refined, held by U.S. producers, consumers, and metal exchanges, yearend	244	110	118	117	120
Employment, mine and plant, number	11,700	12,000	11,000	11,400	12,000
Net import reliance[4] as a percentage of apparent consumption	33	37	38	44	41

Recycling: Old (post-consumer) scrap, converted to refined metal, alloys, and other forms, provided an estimated 160,000 tons of copper in 2022, and an estimated 670,000 tons of copper was recovered from new (manufacturing) scrap derived from fabricating operations. Of the total copper recovered from scrap, brass and wire-rod mills accounted for approximately 85%; smelters, refiners, and ingot makers, 10%; and chemical plants, foundries, and miscellaneous manufacturers, 5%. Copper recovered from scrap contributed 32% of the U.S. copper supply.[5]

Import Sources (2018–21): Copper content of blister and anodes: Finland, 90%; and other, 10%. Copper content of matte, ash, and precipitates: Canada, 34%; Belgium, 17%; Japan, 15%; Mexico, 11%; and other, 23%. Copper content of ore and concentrates: Mexico, 82%; Canada, 18%; and other, <1%. Copper content of scrap: Canada, 51%; Mexico, 37%; and other, 12%. Refined copper: Chile, 64%; Canada, 20%; Mexico, 11%; and other, 5%. Refined copper accounted for 86% of all unmanufactured copper imports.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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% ad valorem.
Copper wire rod	7408.11.0000	1% or 3% ad valorem.

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

Government Stockpile: None.

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COPPER

Events, Trends, and Issues: In 2022, the largest increase in mined copper output in the United States was at the Bingham Canyon Mine in Utah, where ore grades and recovery rates were higher than those in 2021 following the transition to mining a new area of the open pit. Copper production also rose significantly at the Morenci and Safford Mines in Arizona, reflecting increased mining, milling, and (or) leaching rates. Owing to labor shortages and lower copper ore grades, the most significant decrease in mined copper output was at the Mission Mine in Arizona. The rampups of the Gunnison Mine in Arizona and the Pumpkin Hollow Mine in Nevada continued to be delayed by technical issues. Refined copper production in the United States increased by an estimated 3% in 2022 compared with that in 2021 because of a greater supply of copper concentrates to the Miami smelter in Arizona, which was partially offset by unplanned stoppages and labor shortages at the Garfield smelter in Utah. A new smelter in North Carolina designed to produce copper anodes from scrap was in the process of ramping up as of September, and at least five other domestic facilities that would recover copper from scrap were expected to begin operating within the next few years. In August, a leading copper wire-rod plant in Amarillo, TX, was indefinitely shut down owing to high production costs, maintenance issues, and labor shortages.

The annual average COMEX copper price was projected to be about $4 per pound in 2022, 6% less than that in 2021. Analysts attributed the decreased price primarily to widespread global expectations for reduced economic growth and lower demand for copper in the near future, coronavirus disease 2019 (COVID-19) mitigation measures in China, and increased strength of the United States dollar relative to other currencies.

World Mine and Refinery Production and Reserves: Reserves for Australia, Canada, Chile, China, Peru, Poland, the United States, and Zambia were revised based on company and Government reports.

	Mine production		Refinery production		Reserves[6]
	2021	2022[e]	2021	2022[e]	
United States	1,230	1,300	971	1,000	44,000
Australia	813	830	385	380	[7]97,000
Canada	550	530	287	310	7,600
Chile	5,620	5,200	2,270	2,100	190,000
China	1,910	1,900	10,500	11,000	27,000
Congo (Kinshasa)	1,740	2,200	1,450	1,700	31,000
Germany	—	—	615	620	—
Indonesia	731	920	290	300	24,000
Japan	—	—	1,510	1,600	—
Kazakhstan	510	580	500	510	20,000
Korea, Republic of	—	—	647	660	—
Mexico	734	740	473	470	53,000
Peru	2,300	2,200	336	290	81,000
Poland	391	390	578	590	30,000
Russia	[e]940	1,000	981	1,100	62,000
Zambia	842	770	354	350	19,000
Other countries	2,850	3,400	3,170	3,000	200,000
World total (rounded)	21,200	22,000	25,300	26,000	890,000

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.
[2]Copper converted to refined metal, alloys, and other forms by brass and wire-rod mills, foundries, refineries, and other manufacturers.
[3]Primary refined production + copper recovered from old scrap + refined imports – refined exports ± refined copper stock change.
[4]Defined as refined imports – refined exports ± refined copper stock change.
[5]Primary refined production + copper recovered from old and new scrap + refined imports – refined exports ± refined copper stock change.
[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]Source: 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 2022, total domestic primary production of manufactured industrial diamond bort, grit, and dust and powder was estimated to be 150 million carats with a value of $48 million, a 14% increase in quantity and value compared with that in 2021. 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 99% 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:	2018	2019	2020	2021	2022[e]
Bort, grit, and dust and powder; natural and synthetic:					
Production:					
Manufactured diamond[e]	184	114	130	132	150
Secondary	32	36	35	1.2	1.2
Imports for consumption	574	310	190	261	340
Exports	139	114	90	99	100
Consumption, apparent[2]	652	347	265	295	390
Price, unit value of imports, dollars per carat	0.12	0.14	0.19	0.18	0.19
Net import reliance[3] as a percentage of apparent consumption	67	57	38	55	62
Stones, natural and synthetic:					
Production:					
Manufactured diamond[e]	—	—	—	—	—
Secondary	0.13	0.10	0.10	0.08	0.08
Imports for consumption	2.52	1.07	0.51	0.33	0.64
Exports	—	—	0.02	—	([4])
Consumption, apparent[2]	2.65	1.17	0.59	0.41	0.71
Price, unit value of imports, dollars per carat	2.96	5.82	8.41	13.0	10
Net import reliance[3] as a percentage of apparent consumption	95	91	83	81	89

Recycling: In 2022, the amount of diamond bort, grit, and dust and powder recycled was estimated to be 1.2 million carats with an estimated value of $400,000. It was estimated that 75,000 carats of diamond stone were recycled with an estimated value of $110,000.

Import Sources (2018–21): Bort, grit, and dust and powder; natural and synthetic: China,[5] 81%; Republic of Korea, 6%; Ireland, 5%; Russia, 4%; and other, 4%. Stones, primarily natural: South Africa, 22%; Congo (Kinshasa), 19%; India, 17%; Sierra Leone, 10%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Industrial Miners' diamonds:		
Carbonados	7102.21.1010	Free.
Other	7102.21.1020	Free.
Industrial diamonds:		
Simply sawn, cleaved, or bruted	7102.21.3000	Free.
Not worked	7102.21.4000	Free.
Grit or dust and powder of natural diamonds:		
80 mesh or finer	7105.10.0011	Free.
Over 80 mesh	7105.10.0015	Free.
Grit or dust and powder of synthetic diamonds:		
Coated with metal	7105.10.0020	Free.
Not coated with metal, 80 mesh or finer	7105.10.0030	Free.
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 was essentially the same in 2022 as in the previous year. Russia, the leading country in the production of natural industrial diamond, produced 17 million carats or 37% of total world production, followed by Congo (Kinshasa), 11 million carats (24%); Botswana, 7 million carats (15%); South Africa, 6 million carats (13%); and Zimbabwe, 4 million carats (9%). These five countries produced 98% of the world's natural industrial diamond. In recent years, mines have closed and output has been lower 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.

In 2022, U.S. synthetic-industrial-diamond producers did not manufacture any diamond stone, and the combined apparent consumption of all types of industrial diamond increased. Domestic and global consumption of synthetic diamond grit and powder is expected to remain greater than that of natural diamond material. Imports of all types of natural and synthetic industrial diamond imports increased by 29%. In 2022, 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 15.4 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 is impregnated in or 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 Russia were revised based on company and Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	—	—	NA
Australia	—	—	[7]11
Botswana	7	7	300
Congo (Kinshasa)	11	11	150
Russia	17	17	600
South Africa	6	6	120
Zimbabwe	4	4	NA
Other countries	1	1	120
World total (rounded)	46	46	1,300

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 the Gemstones chapter 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 2022, production of diatomite, also known as diatomaceous earth, was estimated to be 1.1 million tons with an estimated processed value of $450 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 2022, 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. The price for diatomite used for filtration was approximately $550 per ton.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production[1]	957	768	822	998	1,100
Imports for consumption	9	10	14	14	13
Exports	68	66	66	68	60
Consumption, apparent[2]	898	712	770	944	1,100
Price, average value, f.o.b. plant, dollars per ton	330	340	330	410	430
Employment, mine and plant, number[e]	370	370	370	370	370
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None.

Import Sources (2018–21): Canada, 62%; Mexico, 13%; Germany, 10%; Argentina, 5%; Japan, 5%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022 was 10% higher than that in 2021. Apparent domestic consumption in 2022 was estimated at 1.1 million tons, 17% more than that in 2021. Exports were estimated to have decreased by 12%. 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. Domestically, diatomite used in the production of cement was the second-ranked use. Other applications for diatomite include filtration of human blood plasma, pharmaceutical processing, and use as a nontoxic insecticide.

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DIATOMITE

In 2022, the United States accounted for an estimated 44% of total world production; followed by Denmark with 16%; China with 6%; and Argentina, Mexico, and Turkey, each with 4%. Smaller quantities of diatomite were mined in 21 additional countries. The production of diatomite in 2022 remained about the same as that in 2021.

World Mine Production and Reserves: Reserves for China and the Republic of Korea were revised based on Government reports.

	Mine production[e] 2021	Mine production[e] 2022	Reserves[4]
United States[1]	998	1,100	250,000
Argentina	100	100	NA
China	140	140	150,000
Denmark[5] (processed)	420	400	NA
France	75	80	NA
Germany	50	50	NA
Japan	40	40	NA
Korea, Republic of	65	65	2,300
Mexico	96	100	NA
New Zealand	40	40	NA
Peru	85	85	NA
Russia	51	50	NA
Spain	50	50	NA
Turkey	100	100	44,000
Other countries	140	140	NA
World total (rounded)	2,450	2,500	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 2022 had an estimated value of $45 million. Feldspar was produced by seven companies in California, Idaho, North Carolina, Oklahoma, South Dakota, and Virginia. Feldspar processors reported joint product recovery of mica and silica sand. One company produced nepheline syenite in the United States as a flux, but production data were not available.

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. Glass manufacturing accounted for an estimated 47% of the 2022 end-use distribution of domestic feldspar and nepheline, and ceramic tile, pottery, and other uses, accounted for the remaining 53%.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, feldspar, marketable[1]	550	450	430	340	420
Imports for consumption:					
Feldspar	181	64	43	169	270
Nepheline syenite	1,070	508	503	529	500
Exports, feldspar	4	4	3	4	3
Consumption, apparent:[1, 2]					
Feldspar only	730	510	470	510	690
Feldspar and nepheline syenite	1,800	1,000	970	1,000	1,200
Price, average unit value, dollars per metric ton:					
Feldspar only, marketable production	97	107	108	110	110
Nepheline syenite, imports	76	156	163	164	180
Employment, mine, preparation plant, and office, number[e]	240	240	240	220	220
Net import reliance[3] as a percentage of apparent consumption:					
Feldspar	24	12	8	33	39
Nepheline syenite	>95	>95	>95	>95	>95

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 (2018–21): Feldspar: Turkey, 94%; Mexico, 4%; and other, 2%. Nepheline syenite: Canada, 100%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022, estimated domestic production and sales of feldspar increased by about 24%, and the average unit value of sales was essentially unchanged compared with that in 2021. Estimated imports of feldspar increased by 60% compared with those in 2021, whereas nepheline syenite imports decreased by an estimated 5% in 2022 from those in 2021. Imports of nepheline syenite reported by the U.S. Census Bureau in 2018 were unusually high.

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FELDSPAR AND NEPHELINE SYENITE

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, was unchanged during the first 10 months of 2022 compared with that in the same period in 2021. 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—accounted for nearly one-half of all end uses of feldspar in the United States. Production and sales of feldspar were expected to increase into 2023, owing in part to an increase in demand for automotive glass manufacturing and for solar glass, used in the production of solar panels.

A company based in Canada continued development of a feldspar-quartz-kaolin project in Idaho that contains 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 feldspathic sand product with low-iron and low-trace-element concentrations from old mine tailings, which was sold to ceramic tile producers.

World Mine Production and Reserves:[4] Reserves for China were revised based on Government reports.

	Mine production		Reserves[5]
	2021	2022[e]	
United States[1]	340	420	NA
Brazil (beneficiated, marketable)	491	630	150,000
China	[e]2,500	2,400	130,000
Czechia	[e]450	460	22,000
India	[e]6,600	6,600	320,000
Iran	[e]2,000	2,000	630,000
Italy	2,200	2,200	NA
Korea, Republic of	987	1,000	180,000
Mexico	356	320	NA
Pakistan	[e]440	360	NA
Saudi Arabia	549	820	NA
Spain (includes pegmatites)	[e]800	800	NA
Thailand	[e]1,200	1,300	220,000
Turkey	6,100	6,200	240,000
Other countries	2,610	2,600	NA
World total (rounded)	27,600	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 2022, 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. A second company, which was developing a mine in Utah, received a $5 million loan from the U.S. Department of Agriculture which it expected would be used to fund completion of a metallurgical-grade fluorspar-processing plant, rail spur, and tailings dam. An estimated 40,000 tons of fluorosilicic acid (FSA), equivalent to about 65,000 tons of fluorspar grading 100% CaF_2, was recovered from three phosphoric acid plants processing phosphate rock. A company in Aurora, NC, continued construction on a plant to produce hydrofluoric acid (HF) from FSA. 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; the aqueous HF was sold into the commercial market.

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:	2018	2019	2020	2021	2022[e]
Production:					
Finished, metallurgical grade	NA	NA	NA	NA	NA
Fluorosilicic acid from phosphate rock	33	29	22	40	40
Imports for consumption:					
Acid grade	381	346	427	391	450
Metallurgical grade	78	59	65	59	80
Total fluorspar imports	459	405	492	451	530
Hydrofluoric acid	122	124	103	103	110
Aluminum fluoride	25	38	21	28	22
Cryolite	17	21	26	42	29
Exports, fluorspar, all grades[1]	9	8	9	15	27
Consumption, apparent[2]	450	398	483	436	500
Price, average unit value of imports, cost, insurance, and freight, dollars per metric ton:					
Acid grade	276	304	309	322	360
Metallurgical grade	258	292	149	151	140
Employment, mine, number[e]	18	14	16	17	17
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 (2018–21):[3] Mexico, 66%; Vietnam, 16%; South Africa, 7%; Canada, 7%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Metallurgical grade (97% or less CaF_2)	2529.21.0000	Free.
Acid grade (more than 97% 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.

Events, Trends, and Issues: World production of fluorspar was estimated to have decreased in 2022. Global fluorspar supply, which is highly concentrated, was constrained by the bankruptcy and subsequent idling of a fluorspar mine in Canada and the declaration of force majeure for supply contracts by the world's leading exporting

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FLUORSPAR

mine in Mexico. Although prices from leading exporting countries such as Mexico, South Africa, and Vietnam reportedly increased, overall adverse impacts to supply appear to have been more than offset by decreased consumption in China. Overall, China decreased its fluorspar trade deficit. Chinese exports, including to the United States, increased. Chinese imports also decreased substantially, particularly from Mongolia, which likely contributed to a significant decrease in Mongolia's fluorspar production.

In September, the United States became the 137th country to ratify the Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer. The goal of the amendment is to reduce production and consumption of hydrofluorocarbon (HFC) gases, commonly used as aerosols, refrigerants, and solvents, by 80% over the next 30 years and which is expected to reduce projected global warming by as much as 0.5 degree Celsius by the end of the century. The American Innovation and Manufacturing Act of 2020 essentially established all of the HFC phasedown provisions and enforcement mechanisms needed to comply with the Kigali Amendment.

The U.S. Department of Energy awarded $2.8 billion funding from the Bipartisan Infrastructure Law to stimulate domestic development of raw materials used in the production of electric-vehicle batteries. Nearly $280 million in funding was awarded for the construction of a new facility in Louisiana to produce lithium hexafluorophosphate ($LiPF_6$) and for the expansion of polyvinylidene difluoride (PVDF) production capacity in Georgia. $LiPF_6$ is the main salt used in lithium-ion battery electrolytes; PVDF is used as a binder and separator coating. Additionally, more than $500 million was allocated to facilities that were likely to consume fluorochemicals in the processing of spherical graphite and the production of separator materials.

World Mine Production and Reserves: Reserves for China and Morocco were revised based on company and Government reports.

	Mine production		Reserves[4]
	2021	2022[e]	
United States	NA	NA	4,000
Canada	140	18	NA
China	5,700	5,700	49,000
Germany	65	65	NA
Iran	50	50	3,400
Kazakhstan	67	67	NA
Mexico	1,000	970	68,000
Mongolia	650	350	22,000
Morocco	77	77	NA
Pakistan	65	65	NA
South Africa	403	420	41,000
Spain	155	160	10,000
Vietnam	215	220	5,000
Other countries	93	98	55,000
World total (rounded)	8,680	8,300	260,000

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 has been used as an alternative to fluorspar in the production of 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. In 2022, a company in Australia was finalizing the design of a pilot plant to recover fluorine from aluminum smelter bath and then produce AlF_3 using either bauxite or aluminum smelting dross. 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.

[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 New York 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 $5 million and $220 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 74% of domestic gallium consumption, optoelectronic devices accounted for 25%, and research and development accounted for 1%. About 77% of the gallium consumed in the United States was in GaAs, GaN, and gallium phosphide 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:	2018	2019	2020	2021	2022[e]
Production, primary	—	—	—	—	—
Imports for consumption:					
Metal	32,000	5,740	4,430	8,890	12,000
Gallium arsenide wafers (gross weight)	444,000	272,000	178,000	306,000	550,000
Exports	NA	NA	NA	NA	NA
Consumption, reported	15,000	14,900	15,700	17,100	18,000
Price, average unit value of imports, dollars per kilogram:					
High-purity, refined[1]	508	573	596	625	640
Low-purity, primary[2]	185	153	163	254	420
Stocks, consumer, yearend	2,920	2,850	2,920	2,810	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 New York.

Import Sources (2018–21): Metal: China, 53%; Germany and Japan, 13% each; Ukraine, 5%; and other, 16%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Gallium arsenide wafers, doped	3818.00.0010	Free.
Gallium metal	8112.92.1000	3% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Imports of gallium metal, GaAs wafers, and GaN wafers continued to account for all U.S. consumption of gallium. In 2022, gallium metal imports increased by an estimated 34% from those in 2021 owing to increased imports from Canada, China, Slovakia, and the United Kingdom. Beginning in 2019, U.S. gallium metal imports decreased substantially from those in previous years because higher tariffs were placed on China's gallium exports to the United States.

Primary low-purity (99.99%-pure) gallium prices in China averaged $510 per kilogram in June 2022, an increase of 34% from $380 per kilogram in January. This followed a 36% increase in China's primary low-purity gallium in 2021, to $375 per kilogram in December from $275 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 economic impact of the global coronavirus disease 2019 (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 recovered in the second half of 2020 owing increasingly to gallium consumption in fifth-generation (5G) telecommunications networks and neodymium-iron-boron (NdFeB) magnets in China for electric vehicles. Gallium prices increased significantly in the last quarter of 2020, continuing through June 2022. By October, gallium prices in China decreased by 33% to $340 per kilogram owing to reduced demand for NdFeB magnets and an increase in China's primary low-purity gallium production capacity.

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GALLIUM

China's primary low-purity gallium production capacity increased by 100,000 kilograms per year in 2022 to 750,000 kilograms per year. This latest increase followed a series of expansions from a capacity of 140,000 kilograms per year in 2010. China accounted for approximately 86% of worldwide primary low-purity gallium production capacity of an estimated 870,000 kilograms per year. China accounted for 98% of worldwide primary low-purity gallium production.

The remaining primary low-purity gallium producers outside of China most likely restricted output owing to China's dominant production capacity. These producers included Japan, the Republic of Korea, Russia, and Ukraine. Germany, Hungary, and Kazakhstan ceased primary production in 2016, 2015, and 2013, respectively. However, owing to the increase in gallium prices, Germany announced that it would eventually restart primary gallium production.

High-purity refined gallium production in 2022 was estimated to be about 290,000 kilograms, a 16% increase from the revised estimated figure of 250,000 kilograms in 2021. Canada, 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, Japan, Slovakia, and the United States. World high-purity refined gallium production capacity was an estimated 320,000 kilograms per year, and secondary high-purity gallium production capacity was an estimated 300,000 kilograms per year.

Beginning in 2002, Northrop Grumman has been awarded Defense Advanced Research Project Agency (DARPA) contracts by the U.S. Department of Defense to develop GaN Monolithic Microwave Integrated Circuits for military and commercial uses.

World Production and Reserves: Quantitative estimates of reserves were not available.

	Primary production		Production capacity
	2021	2022[e]	2022
United States	—	—	—
China	[4]423,000	540,000	750,000
Japan	3,000	3,000	[e]10,000
Korea, Republic of	2,000	2,000	[e]16,000
Russia	5,000	5,000	[e]10,000
Ukraine	1,000	1,000	[e]15,000
Other countries[5]	—	—	[e]73,000
World total (rounded)	434,000	550,000	[e]870,000

World Resources:[6] 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]Reported.
[5]Other countries thought to still have primary low-purity gallium production capacity include Germany, Hungary, and Kazakhstan.
[6]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 2022, garnet for industrial use was mined by four companies—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 $17 million, and refined material sold or used had an estimated value of $52 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:	2018	2019	2020	2021	2022[e]
Production:					
Crude	101,000	104,000	101,000	81,700	76,000
Refined, sold or used	166,000	147,000	146,000	127,000	120,000
Imports for consumption[2]	265,000	208,000	115,000	144,000	190,000
Exports	18,900	16,700	18,200	20,300	24,000
Consumption, apparent[3]	347,000	296,000	198,000	205,000	240,000
Price, average import unit value, dollars per ton	215	214	250	280	200
Employment, mine and mill, number[e]	170	160	130	120	110
Net import reliance[4] as a percentage of apparent consumption	71	65	49	60	69

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 (2018–21):[e] South Africa, 48%; China,[5] 18%; India, 18%; Australia, 11%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Emery, natural corundum, natural garnet, and other natural abrasives:		
Crude	2513.20.1000	Free.
Other than crude	2513.20.9000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: During 2022, estimated domestic production of crude garnet concentrates decreased by 7% compared with production in 2021. This decrease was due to the closing of the Emerald Creek Garnet Mine in Idaho in July 2022. U.S. garnet production was estimated to be about 8% of total global garnet production. The 2022 estimated domestic sales or use of refined garnet decreased by about 6% compared with sales in 2021.

Garnet imports in 2022 were estimated to have increased by 32% compared with those in 2021. This increase was attributed to increased imports of garnet from Australia, India, and South Africa. In 2022, the average unit value of garnet imports was $200 per ton, a decrease of 29% compared with the average unit value in 2021. In the United States, most domestically produced crude garnet concentrate was priced at about $220 per ton. U.S. exports in 2022 were estimated to have increased by 18%. During 2022, the United States consumed an estimated 240,000 tons of garnet. This was a 17% increase from that in 2021.

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GARNET (INDUSTRIAL)

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. At the end of September 2022, the number of drill rigs operating in the United States was 765 rigs, an increase of 237 rigs over the end of September 2021, likely indicating that more garnet was consumed in well drilling.[6]

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.

Garnet production in India is still recovering from the effects of the global coronavirus disease 2019 (COVID-19) pandemic and has not yet returned to pre-pandemic levels.

World Mine Production and Reserves: Reserves data for China was revised based on Government reports.

	Mine production		Reserves[7]
	2021	2022[e]	
United States	81,700	76,000	5,000,000
Australia	321,000	370,000	Moderate to large
China	[e]310,000	310,000	2,200,000
India	12,000	15,000	13,000,000
South Africa	[e]140,000	150,000	NA
Other countries	60,000	60,000	6,500,000
World total (rounded)	925,000	980,000	Moderate to large

World Resources:[7] 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]Source: Baker Hughes Co., 2022, Rig count overview & summary count: Baker Hughes Co., accessed October 4, 2022, at https://bakerhughesrigcount.gcs-web.com/.
[7]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 2022 was an estimated $95 million, a 7% increase compared with that in 2021. 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, followed by Oregon and Nevada. These three States accounted for 47% of the natural gemstone production in the United States. Other top producing States, in descending order of production value, were California, Montana, Maine, Colorado, Arkansas, Utah, and Idaho. Synthetic gemstones were manufactured by eight companies in North Carolina, California, Oregon, Maryland, New York, South Carolina, Wisconsin, and Arizona, in descending order of production value. U.S. synthetic gemstone production increased by 7% compared with that in 2021. Major gemstone end uses were carvings, gem and mineral collections, and jewelry.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:[2]					
Natural[3]	9.47	9.22	9.82	9.48	9.5
Laboratory-created (synthetic)	64.9	94.3	55.0	79.3	85
Imports for consumption	27,700	24,400	16,300	24,600	30,000
Exports, excluding reexports	1,850	1,020	1,330	977	1,600
Consumption, apparent[4]	25,900	23,500	15,000	23,700	28,000
Price	Variable, depending on size, type, and quality				
Employment, mine, number[e]	1,120	1,120	1,100	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 (2018–21, by value): Diamond: India, 45%; Israel, 28%; Belgium, 11%; South Africa, 5%; and other, 11%. Diamond imports accounted for an average of 89% of the total value of gem imports during the period 2018 to 2021.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Coral and similar materials, unworked	0508.00.0000	Free.
Imitation gemstones	3926.90.4000	2.8% ad valorem.
Imitation pearls and imitation pearl beads, not strung	7018.10.1000	4% ad valorem.
Imitation gemstones	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, cut, 0.5 carat or less	7102.39.0010	Free.
Diamonds, cut, more than 0.5 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 diamonds, cut but not set	7104.91.1000	Free.
Synthetic gemstones, worked or cut but not set	7104.99.1000	Free.
Synthetic gemstones, other	7104.99.5000	6.4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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GEMSTONES

Events, Trends, and Issues: In 2022, the U.S. gemstone and jewelry industries had recovered for the most part from the effects of the coronavirus disease 2019 (COVID-19) pandemic-related restrictions, lockdowns, and temporary mine and store closings.

Total world diamond production during 2022 was estimated to have increased slightly from 2021 levels. The largest production increases in 2022 were in Angola, Botswana, and Namibia. The largest production decreases in 2022 were in Canada, Congo (Kinshasa), Lesotho, and Russia. Production would need to increase by about 2% per year during the next 5 years to allow the market to fully rebalance after the COVID-19 pandemic.

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; online diamond jewelry sales exceeded 25% of 2022 sales. Global gemstone sales are expected to increase at a steady rate over the next 5 years.

In 2022, U.S. imports for consumption of gemstones were about $30 billion, which was a 22% increase compared with $24.6 billion in 2021. These imports consisted of about $26 billion in gem-quality diamonds, which was an 18% increase compared with $21.8 billion in 2021, and about $4.3 billion in nondiamond gemstones, which was a 49% increase compared with $2.88 billion in 2021. The increase in U.S. gemstone production combined with the increase in U.S. gemstone imports and the increase in gemstone exports produced a 19% increase in apparent consumption to a value of $28 billion. This apparent consumption consisted of $24 billion in gem-quality diamond and $4 billion in nondiamond gemstones. The United States was one of the leading global markets in terms of sales and is expected to continue to dominate global gemstone consumption.

World Gem-Quality Diamond Mine Production and Reserves:

	Mine production[6] 2021	Mine production[6] 2022[e]
United States	—	—
Angola	7,850	10,000
Botswana	16,000	18,000
Brazil	143	150
Canada	17,600	16,000
Central African Republic	73	73
Congo (Kinshasa)	2,820	2,500
Ghana	55	57
Guinea	219	220
Lesotho	339	230
Namibia	1,760	2,300
Russia	21,900	21,000
Sierra Leone	671	680
South Africa	3,890	3,900
Zimbabwe	423	470
Other countries	139	130
World total (rounded)	73,900	76,000

Reserves[7]

World reserves of diamond-bearing deposits are substantial. No reserves data were available for other gemstones.

World Resources:[7] Most diamond ore bodies have a diamond content that ranges from less than 1 carat 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 also the Diamond (Industrial) and Garnet (Industrial) chapters.
[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-quality 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 2022, 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 germanium leach concentrates recovered from processing zinc concentrates from the Middle Tennessee Zinc 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 2022, based on the annual average germanium metal price, was $39 million, 10% more than that in 2021.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, refinery:					
Primary	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:[e, 1]					
Germanium metal	10,000	14,000	14,000	13,000	14,000
Germanium dioxide	12,000	21,000	12,000	17,000	15,000
Exports, germanium metal and dioxide[e, 1]	3,600	4,500	4,800	7,500	5,800
Shipments from Government stockpile[2]	—	—	—	—	—
Consumption, estimated[3]	30,000	30,000	30,000	30,000	30,000
Price, annual average, dollars per kilogram:[4]					
Germanium metal	1,543	1,236	1,046	1,187	1,300
Germanium dioxide	1,084	913	724	770	840
Net import reliance[5] as a percentage of estimated consumption	>50	>50	>50	>50	>50

Recycling: 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 (2018–21):[1, 6] Germanium metal: China, 54%; Belgium, 27%; Germany, 9%; Russia, 8%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Germanium metal	14,000	—	5,000	—	5,000
Germanium scrap (gross weight)	6,910	—	—	—	—
Germanium wafers (each)	68,700	—	—	—	—

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GERMANIUM

<u>Events, Trends, and Issues</u>: The major global end uses for germanium were electronics and solar applications, fiber-optic systems, infrared optics, and polymerization catalysts. Other uses included chemotherapy, metallurgy, and phosphors.

The prices for germanium metal and germanium dioxide (Europe, minimum 99.999% purity) increased from January to May and then decreased through late October. The price for germanium metal increased from $1,380 per kilogram to $1,470 per kilogram and then decreased to $1,100 per kilogram. The price for germanium dioxide increased from $885 per kilogram to $970 per kilogram and then decreased to $705 per kilogram.

The Defense Logistics Agency Strategic Materials initiated a program to recycle germanium scrap recovered from decommissioned military equipment. The recycling program was expected to produce up to 3,000 kilograms per year of high-purity germanium ingot that could be consumed for night-vision and thermal-sensing devices and other military uses.

The owner of a zinc smelter in Clarksville, TN, planned to construct a new $90 million gallium and germanium processing plant at the site, according to local news sources. The plant could potentially recover an estimated 40,000 kilograms per year of germanium.

China was a leading global producer and exporter of germanium in 2022. Exports of unwrought germanium, germanium powders, and germanium waste and scrap (China's export code 8112.99.10) for the year through August were 23,100 kilograms, 7% less than exports in the same period in 2021. More than 90% of exports were sent to Germany, Hong Kong, Japan, Belgium, the United States, and Russia, in descending order of quantity.

<u>World Refinery Production and Reserves</u>:

	Refinery production[e, 8]		Reserves[9]
	2021	2022	
United States	W	W	Data on the recoverable germanium content of zinc ores were not available.
China	NA	NA	
Russia	NA	NA	
Other countries	NA	NA	
World total (rounded)	NA	NA	

<u>World Resources</u>:[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.

<u>Substitutes</u>: 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. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Data have been adjusted to exclude low-value shipments.
[2]Defined as change in total inventory from prior yearend inventory. If negative, increase in inventory.
[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]Available information was inadequate to make reliable estimates of world production of germanium.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.

GOLD

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

Domestic Production and Use: In 2022, domestic gold mine production was estimated to be 170 tons, 9% less than that in 2021, and the value was estimated to be $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 72% 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 28 operations yielded about 98% of the mined gold produced in the United States. Commercial-grade gold was produced at 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.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine	226	201	193	187	170
Refinery:					
Primary	205	205	181	[e]170	160
Secondary (new and old scrap)	117	116	92	92	90
Imports for consumption[2]	213	199	545	192	140
Exports[2]	474	360	297	386	430
Consumption, reported[3]	154	151	187	266	250
Stocks, Treasury, yearend[4]	8,130	8,130	8,130	8,130	8,130
Price, dollars per troy ounce[5]	1,272	1,395	1,774	1,801	1,800
Employment, mine and mill, number[6]	11,400	11,600	12,000	12,200	12,000
Net import reliance[7] as a percentage of apparent consumption[8]	E	E	47	E	E

Recycling: In 2022, 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 in 2021.

Import Sources (2018–21): Ores and concentrates: Canada, 89%; Greece, 9%; and Germany, 2%. Dore: Mexico, 45%; Colombia, 12%; Peru, 8%; Nicaragua, 7%; and other, 28%. Bullion: Switzerland, 38%; Canada, 23%; Australia and South Africa, 7% each; and other, 25%. Total: Switzerland, 24%; Mexico, 20%; Canada, 15%; Colombia, 6%; and other, 35%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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	7112.91.0100	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 2022 was unchanged from the previous record-high annual price in 2021. The Engelhard daily price of gold in 2022 increased in the first quarter, decreased in the second quarter, and fluctuated in the third quarter. Several factors were reported to have caused the increase in the gold price: gold demand for safe-haven buying increased owing to the continued coronavirus disease 2019 (COVID-19) pandemic, and global investor uncertainty.

In 2022, worldwide gold mine production was estimated to be unchanged compared with that in 2021. Production decreases in Papua New Guinea and the United States were more than offset by production increases in Colombia, Indonesia, and Burkina Faso.

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GOLD

Estimated global gold consumption was in jewelry, 47%; physical bars, 17%; central banks and other institutions, 20%; official coins and medals and imitation coins, 9%; electrical and electronics, 6%; and other, 1%. In the first 9 months of 2022, global consumption of gold in physical bars decreased by 3%, jewelry increased by 5%, electronics decreased by 4%, other industrial applications were essentially unchanged, and coins and medals increased by 15% compared with those in the first 9 months of 2021. Global investments in gold-based exchange-traded funds decreased twofold, while gold holdings in central banks increased by 62% during the same period. Total global consumption in the first 9 months of 2022 increased by 18% compared with that in the first 9 months of 2021.[9]

World Mine Production and Reserves: Reserves for Australia, Canada, China, and Peru were revised based on company and Government reports.

	Mine production		Reserves[10]
	2021	2022[e]	
United States	187	170	3,000
Australia	315	320	[11]8,400
Brazil	61	60	2,400
Burkina Faso	67	70	NA
Canada	223	220	2,300
China	329	330	1,900
Colombia	55	60	NA
Ghana	88	90	1,000
Indonesia	[e]66	70	2,600
Kazakhstan	[e]116	120	1,000
Mali	[e]51	50	800
Mexico	[e]120	120	1,400
Papua New Guinea	[e]54	50	1,100
Peru	[e]97	100	2,900
Russia	320	320	6,800
South Africa	[e]107	110	5,000
Sudan	50	50	NA
Tanzania	60	60	NA
Uzbekistan	100	100	1,800
Other countries	626	620	9,200
World total (rounded)	3,090	3,100	52,000

World Resources:[10] An assessment of U.S. gold resources indicated 33,000 tons of gold in identified (15,000 tons) and undiscovered (18,000 tons) resources.[12] 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 bars, coins, and jewelry. Excludes gold as an investment (except consumer purchased bars and coins). Source: World Gold Council.
[4]Includes gold in the 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 2022, 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]Source: World Gold Council.
[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 4,200 tons.
[12]Source: 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 2022, natural graphite was not produced in the United States; however, approximately 95 U.S. companies, primarily in the Great Lakes and Northeast regions, consumed 72,000 tons valued at an estimated $140 million. The major uses of natural graphite were batteries, brake linings, lubricants, powdered metals, refractory applications, and steelmaking. During 2022, U.S. natural graphite imports were an estimated 82,000 tons, consisting of about 77% flake and high-purity, 22% amorphous, and 1% lump and chip graphite.

Graphite consumption is expected to continue to increase, owing largely to growth from the electric-vehicle market. The battery end-use market for graphite has grown by 250% globally since 2018. In the United States, 4 lithium-ion battery manufacturing plants are currently in operation, with an additional 21 in development. At full capacity, these plants are expected to require approximately 1.2 million tons per year of spherical purified graphite, with an estimated 40% to 60% coming from synthetic graphite.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine	—	—	—	—	—
Imports for consumption	70,700	50,100	36,000	53,100	82,000
Exports	9,950	5,890	5,930	8,670	9,600
Consumption, apparent[1]	60,700	44,200	30,000	44,400	72,000
Price, average unit value of imports, dollars per metric ton at foreign ports:					
Flake	1,520	1,340	1,340	1,390	1,300
Lump and chip (Sri Lanka)	1,890	2,380	2,940	2,010	2,500
Amorphous	319	511	567	622	560
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 (2018–21): China,[5] 33%; Mexico, 18%; Canada, 17%; Madagascar, 10%; and other, 22%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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]

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Graphite	—	900	—	—	—

Events, Trends, and Issues: U.S. natural graphite imports decreased by 29% and 28% in 2019 and 2020, respectively, and then increased by 48% in 2021, and by 55% in 2022. U.S. imports for consumption and U.S. apparent consumption increased by 16% and 19%, respectively, for the 5-year period of 2018 to 2022. The increase in consumption is likely due to rising demand from the lithium-ion battery industry.

In 2022, China was the world's leading graphite producer, producing an estimated 65% of total world production. Approximately 24% of graphite produced in China was amorphous 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.

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GRAPHITE (NATURAL)

North America produced only 1.2% of the world's graphite supply with production in Canada and Mexico. Three companies were developing graphite-mining projects in the United States—two in Alabama and one in Alaska. Two spherical graphite plants were in construction during 2022, located in Kellyton, AL, and Vidalia, LA, with production expected to begin during 2023. In 2022, the Vidalia project was awarded a grant of up to $220 million under the Bipartisan Infrastructure Law towards expanding the production capacity to 45,000 tons per year.

Africa has been a recent focus for graphite exploration, with projects under development in Madagascar, Mozambique, Namibia, and Tanzania. Additional projects were in advanced development stages in Australia, Canada, and Sweden. A Canadian company and an Australian company continued to construct mines in Madagascar and Tanzania, respectively, with production expected to begin by 2023. In 2022, an Australian company commissioned a graphite anode plant in Sweden, becoming the first commercial plant operating in Europe.

In February, Ukraine halted graphite production, citing Russian military action. Operations recommenced in August, although future production was uncertain as the conflict continued. Additionally, the United States and many other countries have suspended normal trade relations with Russia, removing supplies of Russian graphite from much of the global market. Leading up to the conflict, Russia and Ukraine were considered among the top 10 producers of graphite.

World Mine Production and Reserves: Reserves for Brazil, China, and Russia were revised based on company and Government reports.

	Mine production		Reserves[3]
	2021	2022[e]	
United States	—	—	([4])
Austria	500	500	([4])
Brazil	82,000	87,000	74,000,000
Canada	12,000	15,000	([4])
China	820,000	850,000	52,000,000
Germany	250	250	([4])
India	7,000	8,300	8,000,000
Korea, North	8,100	8,100	2,000,000
Korea, Republic of	10,500	17,000	1,800,000
Madagascar	70,000	110,000	26,000,000
Mexico	2,100	1,900	3,100,000
Mozambique	72,000	170,000	25,000,000
Norway	6,290	10,000	600,000
Russia	15,000	15,000	14,000,000
Sri Lanka	3,000	3,000	1,500,000
Tanzania	—	8,000	18,000,000
Turkey	2,700	2,900	90,000,000
Ukraine	10,000	3,000	([4])
Uzbekistan	110	—	7,600,000
Vietnam	5,000	5,000	([4])
World total (rounded)	1,130,000	1,300,000	330,000,000

World Resources:[3] Domestic resources of graphite are relatively small, but the rest of the world's 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 in "World total."
[5]Includes Hong Kong.

GYPSUM

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2022, domestic production of crude gypsum was estimated to be 21 million tons with a value of about $250 million. The leading crude-gypsum-producing States were estimated to be California, Iowa, Kansas, Nevada, Oklahoma, and Texas. 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 42 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 2022, the production capacity of 63 operating gypsum panel manufacturing plants in the United States was about 34 billion square feet[1] per year. Total wallboard sales in 2022 were estimated to be 28 billion square feet.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Crude	21,100	21,700	21,500	21,300	21,000
Synthetic[2]	16,600	14,400	13,000	13,000	14,000
Calcined[3]	17,500	17,900	17,900	18,600	20,000
Wallboard products sold, million square feet[1]	23,700	25,900	26,200	27,300	28,000
Imports, crude, including anhydrite	5,210	6,140	6,030	6,520	6,800
Exports, crude, not ground or calcined	36	37	32	42	40
Consumption, apparent[4]	42,900	42,200	40,500	40,800	42,000
Price, average, dollars per metric ton:					
Crude, free on board (f.o.b.) mine	8.3	8.6	8.6	11	12
Calcined, f.o.b. plant	32	34	35	42	44
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	12	15	15	16	16

Recycling: Approximately 700,000 tons per year 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 (2018–21): Mexico, 35%; Spain, 33%; Canada, 28%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Gypsum, anhydrite	2520.10.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. crude gypsum production was estimated to have decreased slightly, whereas apparent consumption increased by 3% compared with that in 2021. U.S. gypsum imports increased by an estimated 4% compared with those in 2021. Exports, although very low compared with imports and often subject to wide fluctuations, decreased by an estimated 5%.

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 coronavirus disease 2019 (COVID-19) pandemic, the production of gypsum was not affected.

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GYPSUM

The United States, the world's leading crude gypsum producer, produced an estimated 21 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: Reserves for China were revised based on Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	21,300	21,000	700,000
Algeria	[e]2,500	2,500	NA
Brazil	[e]2,000	2,000	450,000
Canada	[e]2,400	2,400	450,000
China	12,600	13,000	1,500,000
France	1,950	2,000	350,000
Germany	5,200	5,200	NA
India	[e]4,300	4,300	37,000
Iran	[e]16,000	16,000	NA
Japan	[e]4,300	4,300	NA
Mexico	[e]5,400	5,400	NA
Oman	12,300	12,000	NA
Pakistan	1,820	1,800	6,000
Russia	[e]4,100	4,100	NA
Saudi Arabia	3,990	4,000	NA
Spain	[e]11,000	11,000	NA
Thailand	[e]9,300	9,300	1,700
Turkey	[e]9,300	9,300	200,000
Uzbekistan	2,200	2,200	NA
Other countries	21,000	22,000	NA
World total (rounded)	153,000	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; 81 countries were estimated to produce gypsum in 2022.

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 2022, synthetic gypsum was estimated to account for about 25% 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 0.0929 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 gypsum and synthetic gypsum.

[4]Defined as crude gypsum production + synthetic gypsum 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% helium or greater) sold during 2022 by private industry was about $820 million. Five plants (three in Texas and two in Kansas) extracted helium from natural gas and produced crude helium that ranged from 50% to 80% helium. Five plants (two in Kansas, one each in Arizona, New Mexico, and Oklahoma) produced gaseous helium that ranged from 95% to 99.5% helium. Four plants (two in Colorado and one each in Utah and 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 2022, estimated domestic apparent consumption of Grade-A helium was 43 million cubic meters (1.5 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:	2018	2019	2020	2021	2022[e]
Helium extracted from natural gas[2]	62	72	76	69	60
Withdrawn from storage[3]	28	17	7	7	15
Grade-A helium sales	90	89	83	76	75
Imports for consumption	8	7	7	9	8
Exports	[4]58	58	52	47	40
Consumption, apparent[5]	40	38	38	38	43
Net import reliance[6] as a percentage of apparent consumption	E	E	E	E	E

The estimated price for private industry's Grade-A helium was about $11 per cubic meter ($310 per thousand cubic feet) in 2022, 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 (2018–21): Qatar, 53%; Canada, 20%; Algeria, 15%; Russia, 5%; and other, 7%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 BLM Crude Helium Enrichment Unit, 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. As of the end of fiscal year (FY) 2022, the remaining conservation helium is about 60.7 million cubic meters (2.19 billion cubic feet). The BLM will continue to deliver helium from private storage until all Cliffside Field assets are sold or disposed of. It is expected that all Cliffside Field assets will be disposed of in FY 2023. In FY 2022, privately owned companies purchased about 5.10 million cubic meters (185 million cubic feet) of in-kind crude helium. During FY 2022, the BLM's Amarillo Field Office, Helium Operations, accepted about 9.2 million cubic meters (331 million cubic feet) of private helium for storage and redelivered nearly 17.8 million cubic meters (640 million cubic feet). As of September 30, 2022, about 57.2 million cubic meters (2.06 billion cubic feet) of privately owned helium remained in storage at Cliffside Field.

Material	Inventory as of 9–30–22	Authorized for disposal	Disposal plan FY 2023
Helium	60.7	60.7	60.7

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HELIUM

Events, Trends, and Issues: Helium sales in 2022 decreased slightly in the United States owing to several unplanned shutdowns taking place, including the BLM Crude Helium Enrichment Unit, which was not operational from mid-January 2022 through late June 2022. World helium production, excluding the United States, decreased owing to delays of added production capacity in Russia, helium plant shutdowns in Qatar, reduced separation of helium from natural gas in Algeria, and constraints on transportation for helium products.

World Mine Production and Reserves: Reserves for the United States were revised based on Government reports.

	Mine production		Reserves[9]
	2021	2022[e]	
United States (extracted from natural gas)	69	60	8,500
United States (from Cliffside Field)	7	15	61
Algeria	[e]14	9	[e]1,800
Australia	[e]4	4	NA
Canada	[e]1	2	NA
China	[e]1	1	NA
Poland	[e]1	1	24
Qatar	[e]61	60	[e]Large
Russia	[e]5	5	[e]1,700
South Africa	[e]1	1	NA
World total (rounded)	[e]164	160	NA

World Resources:[9] 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.[10] 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 60.7 million cubic meters (2.19 billion cubic feet) in the Federal helium inventory. The estimated mean for the Midcontinent region was 4,330 million cubic meters (156 billion cubic feet); the Rocky Mountain region, 4,110 million cubic meters (148 billion cubic feet); the North Central region, 52.7 million cubic meters (1.9 billion cubic feet); the Gulf Coast region, 12.5 million cubic meters (0.45 billion cubic feet); and the Alaska region, 1.11 million cubic meters (0.04 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.

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 pounds per square inch [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]Exports were adjusted by the U.S. Geological Survey for 2018 as the data reported by the U.S. Census Bureau were unusually high and may have contained misclassified items.

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

[6]Defined as imports – exports.

[7]See Appendix B for definitions.

[8]General Engineer (contractor), Bureau of Land Management, Amarillo Field Office—Helium Operations, Amarillo, TX.

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

[10]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 2022. 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 160 tons in 2022 and was based on the annual estimated import quantity. There were no readily available recycling or end-use data available for indium. The estimated value of refined indium consumed domestically in 2022, based on the average U.S. warehouse price, was about $40 million.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, refinery	—	—	—	—	—
Imports for consumption	125	95	115	158	160
Exports	NA	NA	NA	NA	NA
Consumption, estimated[1]	125	95	115	158	160
Price, annual average, dollars per kilogram:					
New York dealer[2]	375	390	395	NA	NA
U.S. warehouse, free on board[3]	285	182	161	223	250
Rotterdam, duties unpaid[4]	281	177	158	217	250
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. Indium-containing scrap was recycled domestically; however, data on the quantity of indium recovered from scrap were not available.

Import Sources (2018–21): Republic of Korea, 32%; Canada, 22%; China,[6] 18%; France, 9%; and other, 19%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Unwrought indium, including powders	8112.92.3000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2022, the estimated annual average U.S. warehouse price (free on board) was $250 per kilogram, 12% greater than the reported average price 2021. The U.S. price, as reported by Argus Media group, Argus Metals International, began the year at $275 per kilogram and generally trended downward for most of the year to $240 per kilogram at the end of September.

A leading manufacturer of indium products in the United States invested $10 million to expand operations at its facility in Rome, NY. According to the company, the plant produced solder fabrications that were primarily used in advanced electronics, and the expansion would increase the number of manufacturing processes at the plant to 25.

The Utah Geological Survey received a Federal grant to research the genesis and geology of the zinc-copper-indium West Desert deposit in Juab County, UT. The funding was awarded under the U.S. Geological Survey's Earth Mapping Resource Initiative (Earth MRI) program. The research would focus on the spatial and mineralogical distribution of indium throughout the deposit and exploration indicators to help identify similar deposits.

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INDIUM

An indium-producing zinc smelter in Auby, France, was placed on care-and-maintenance status in January owing to high power prices. The smelter resumed production at a reduced rate in March. Annual indium production at the smelter was last reported in 2018 at 43 tons.

China, the leading producer and exporter of indium globally, exported 421 tons of indium in the first 8 months of 2022, a 13% increase compared with exports in the same period in 2021. Exports were primarily sent to the Republic of Korea, 55%; Singapore, 14%; and Hong Kong, 12%. Some zinc smelters in Sichuan and Yunnan Provinces temporarily cut production during the year in response to power supply issues, according to news sources; however, the extent of the cuts and their effect on related byproduct metal production, including indium, could not be quantified.

World Refinery Production and Reserves:

	Refinery production[e, 7]		Reserves[8]
	2021	2022	
United States	—	—	Quantitative estimates of reserves were not available.
Belgium	20	20	
Canada	60	55	
China	540	530	
France	38	20	
Japan	66	66	
Korea, Republic of	190	200	
Peru	12	—	
Russia	5	5	
Uzbekistan	1	1	
World total (rounded)	932	900	

World Resources:[8] 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—indium recovery from most deposits of these minerals was not economic.

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 by 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]Refinery production data for indium were limited or unavailable for most countries. Estimates were derived from trade data, production capacity, and (or) changes in related lead and zinc smelter production.
[8]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 2022 by three companies operating in Oklahoma. U.S. iodine production in 2022 was withheld to avoid disclosing company proprietary data but was estimated to have increased from that in 2021. The annual average cost, insurance, and freight unit value of iodine imports in 2022 was estimated to be $41 per kilogram, about 26% more than that in 2021.

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 2022. 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:	2018	2019	2020	2021	2022[e]
Production	W	W	W	W	W
Imports for consumption	4,930	4,300	4,570	4,120	4,600
Exports	1,190	1,230	1,130	1,280	1,000
Consumption:					
Apparent[1]	W	W	W	W	W
Reported	4,620	4,000	3,750	3,720	4,000
Price, crude iodine, average unit value of imports (cost, insurance, and freight), dollars per kilogram	22.46	26.38	31.57	32.72	41
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 (2018–21): Chile, 89%; Japan, 10%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Iodine, crude	2801.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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IODINE

<u>Events, Trends, and Issues</u>: According to trade publications, spot prices for iodine crystal averaged about $67 per kilogram during the first 9 months of 2022. This was about 77% more than the 2021 annual average of $37.83 per kilogram. Iodine price increases were attributed to strong global demand, particularly in Asia.

In the latter part of 2022, some countries in Europe began distributing and stockpiling potassium iodide tablets amid concerns over the possible use of nuclear weapons by Russia in Ukraine as well as concerns regarding the security of the Zaporizhzhia nuclear powerplant in Ukraine. Potassium iodide tablets can be taken to prevent radioactive iodine from accumulating in the thyroid gland following exposure to nuclear radiation.

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 2022. 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.

<u>World Mine Production and Reserves</u>: China also produces crude iodine, but output is not officially reported, and available information was inadequate to make reliable estimates of output. Available information was inadequate to make an estimate of iodine reserves in Indonesia for 2022.

	Mine production[e]		Reserves[3]
	2021	2022	
United States	W	W	250,000
Azerbaijan	190	200	170,000
Chile	22,000	22,000	610,000
Indonesia	[4]36	40	NA
Iran	700	700	NA
Japan	8,900	9,000	4,900,000
Russia	3	3	120,000
Turkmenistan	700	700	70,000
World total (rounded)	[5]32,500	[5]33,000	6,100,000

<u>World Resources</u>:[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.

<u>Substitutes</u>: 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. NA Not available.

[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]Reported.

[5]Excludes U.S. 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 2022 with an estimated value of about $132 billion, a 13% increase from $118 billion in 2021. Pig iron and raw steel were 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 per year. Indiana accounted for an estimated 26% of total raw steel production, followed by Ohio, 12%; Pennsylvania and Illinois, 5% each; Texas, 4%; and Michigan, 3%; with no other State having more than 3% of total domestic raw steel production. Construction accounted for an estimated 46% of total domestic shipments by market classification, followed by transportation (predominantly automotive), 26%; machinery and equipment, 8%; energy, 6%; appliances, 5%; and other applications, 9%.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Pig iron production[2]	24.1	22.3	18.3	22.2	21
Raw steel production	86.6	87.8	72.7	85.8	82
Distribution of raw steel production, percent:					
Basic oxygen furnaces	32	30	29	29	29
Electric arc furnaces	68	70	71	71	72
Continuously cast steel, percent	98.2	99.8	99.8	99.8	99.8
Shipments, steel mill products	86.4	87.3	73.5	85.9	82
Imports, steel mill products:					
Finished	23.3	19.1	14.6	20.6	22
Semifinished	7.3	6.2	5.3	7.9	8
Total	30.6	25.3	20.0	28.5	30
Exports, steel mill products:					
Finished	7.9	6.6	6.7	7.4	8
Semifinished	0.1	0.1	0.1	0.1	0.1
Total	8.0	6.7	6.8	7.5	8
Stocks, service centers, yearend[3]	7.3	7.4	5.8	5.8	5.8
Consumption, apparent (steel mill products)[4]	102	100	82.1	98.9	96
Producer price index for steel mill products (1982=100)[5]	211	204	184	351	400
Employment, average, number:					
Iron and steel mills[5]	82,100	85,700	83,200	78,300	75,000
Steel product manufacturing[6]	56,700	57,800	54,900	52,700	50,000
Net import reliance[7] as a percentage of apparent consumption	15	12	12	13	14

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

Import Sources (2018–21): Canada, 21%; Brazil, 15%; Mexico, 14%; Republic of Korea, 9%; and other, 41%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
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 decrease by 2.3% in 2022 and increase by 1.0% in 2023. End-use consumption of steel products was expected to decline in 2022 following concurrent events affecting consumer demand, including the conflict in Ukraine, continuing coronavirus disease 2019 (COVID-19) mitigation measures in China, rising energy costs and interest rates, and global inflation. In the United States, the apparent consumption of finished steel products was estimated to have increased by 2% in 2022 owing to strong economic recovery from COVID-19 supply disruptions. The Infrastructure Investment and Jobs Act was expected to spur growth in the energy and construction sectors.

The economic conditions in China significantly affected steel production, with finished steel production decreasing by 4% in 2022 and expected to remain unchanged in 2023 owing to extended COVID-19 mitigation strategies that led to decreased demand for real estate and construction investments. In Japan and the Republic of Korea, steel demand was estimated to be lower in 2022 owing to decreases in the construction sector. Production of finished steel products in India was expected to increase by 6% in 2022 owing to infrastructure spending, strong demand for consumer goods, and increased demand in the automotive sector.

World Production:

	Pig iron		Raw steel	
	2021	2022[e]	2021	2022[e]
United States	22	21	86	82
Brazil	28	26	36	33
China	869	830	1,030	990
Germany	26	24	40	38
India	78	83	118	130
Iran	3	3	28	29
Italy	4	4	24	24
Japan	70	71	96	97
Korea, Republic of	46	45	71	69
Mexico	3	3	18	17
Russia	54	50	76	71
Taiwan	15	15	23	23
Turkey	10	10	40	39
Ukraine	21	19	21	19
Vietnam	15	15	23	23
Other countries	81	88	216	230
World total (rounded)	1,350	1,300	1,950	1,900

World Resources: Not applicable. See the Iron Ore chapter 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]U.S. production and shipments data source is the American Iron and Steel Institute; see also the Iron and Steel Scrap and Iron Ore chapters.
[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, September 2021.
[4]Defined as steel mill product 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 331100.
[6]Source: U.S. Department of Labor, Bureau of Labor Statistics, North American Industry Classification System Code 332100.
[7]Defined as imports of finished steel mill products – total exports ± adjustments for industry stock changes.
[8]Source: World Steel Association, 2022, Short range outlook October 2022: Brussels, Belgium, World Steel Association press release, October 19, 6 p.

IRON AND STEEL SCRAP[1]

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

Domestic Production and Use: In 2022, 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 $23 billion, a 5% decrease from the $24.3 billion in 2021 and 74% more than the $13.2 billion in 2020. U.S. apparent consumption of steel, the leading end use for iron and steel scrap, was estimated to have decreased by 3% to 96 million tons in 2022 from 98.9 million tons in 2021. 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.

In 2022, estimated raw steel production decreased by 4% to 82 million tons from 85.8 million tons in 2021, and net shipments of steel mill products were an estimated 82 million tons, down by 5% from 85.9 million tons in 2021.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Home scrap	5.8	5.3	5.1	4.7	4.7
Purchased scrap[2]	59	55	50	52	49
Imports for consumption[3]	5.0	4.3	4.5	5.3	4.8
Exports[3]	17	18	15	16	13
Consumption:					
Reported	52	47	45	46	44
Apparent[4]	52	48	45	46	46
Price, average, delivered, No. 1 heavy melting composite price, dollars per metric ton[5]	326	249	228	418	415
Stocks, consumer, yearend	5.1	3.9	3.9	4.4	4.6
Employment, dealers, brokers, processors, number[e]	27,000	26,000	24,500	25,300	24,000
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 (2018–21): Canada, 73%; Mexico, 12%; Netherlands, 5%; United Kingdom, 5%; and other, 5%.

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IRON AND STEEL SCRAP

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022, steel mills maintained normal operating rates of 76% to 82% of production capacity utilization, as compared with the low monthly rate of 54.6% in May 2020. Rates fluctuated slightly from 79.8% in January to 81.9% in April before slowly declining to 76.4% in September. Average composite prices published for No. 1 heavy melting steel scrap increased from the previous high rate in 2021 of $457.66 per ton in November and December to the high for 2022 of $523.27 per ton in March, after which prices declined. The annual average price delivered in the first 9 months of 2022 decreased to $405.35 per ton compared with the full-year annual average of $408.34 per ton in 2021 and contributed to the 5% decrease in the total estimated value of domestic purchases and exports of iron and steel scrap in 2022.

In the first 9 months of 2022, Turkey was the primary destination for exports of ferrous scrap, by tonnage, accounting for 22% of total exports, followed by Mexico, 19%; Bangladesh, 12%; and India and Taiwan, 7% each. The value of exported scrap decreased to an estimated $5.8 billion in 2022 from $6.7 billion in 2021. In the first 9 months of 2022, Canada was the leading source of imports of ferrous scrap, by tonnage, accounting for 73% of total imports, followed by Mexico, 13%; the Netherlands and Sweden, 4% each; and the United Kingdom, 3%.

The World Steel Association[7] forecast global finished steel consumption to decrease by 2.3% in 2022 and increase by 1.0% in 2023. End-use consumption of steel products was expected to decline in 2022 following concurrent events affecting consumer demand, including the conflict in Ukraine, continuing coronavirus disease 2019 (COVID-19) mitigation measures in China, rising energy costs and interest rates, and global inflation.

World Production and Reserves: Because scrap is not mined, the concept of reserves does not apply. World production data for scrap were not available. See the Iron and Steel and Iron Ore chapters.

World Resources: Not applicable. See the Iron Ore chapter.

Substitutes: An estimated 4.9 million tons of direct-reduced iron was consumed in the United States in 2022 as a substitute for iron and steel scrap, down from 5.0 million tons in 2021.

[e]Estimated. E Net exporter.
[1]See also the Iron and Steel, Iron and Steel Slag, and Iron Ore chapters.
[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]Source: World Steel Association, 2022, Short range outlook October 2022: Brussels, Belgium, World Steel Association press release, October 19, 6 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 were unavailable on actual U.S. ferrous slag production, but domestic slag sales[1] in 2022 were estimated to be 15 million tons valued at about $795 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 25 companies servicing active iron and steel facilities or reprocessing old slag piles at about 123 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 2022. 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production (sales)[e, 1, 2]	16.8	16.3	13.4	15.7	15
Imports for consumption[e, 3]	2.6	2.1	2.3	2.4	2.0
Exports	([4])	([4])	([4])	([4])	([4])
Consumption, apparent[e, 5]	17	16	13	16	15
Price, average unit value, free on board plant, dollars per metric ton[6]	26.50	28.50	31.00	40.50	53
Employment, number[e]	1,500	1,500	1,500	1,500	1,500
Net import reliance[7] as a percentage of apparent consumption	13	10	14	15	13

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 (2018–21): Japan, 46%; Brazil, 17%; China, 15%; and other, 22%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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 an estimated 72% of U.S. steel production in 2022 owing to the overall cost advantages of environmental factors, such as less 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 allows for processing of slag for years after closures. The World Steel Association[8] forecast global finished steel consumption to decrease by 2.3% in 2022 and increase by 1.0% in 2023. The U.S. iron and steel industry produced raw steel in 2022 with an estimated value of about $132 billion, a 13% increase from $118 billion in 2021. Pig iron production in the United States was estimated to have decreased by 5% to 21 million tons in 2022 from 22.2 million tons in 2021.

During 2022, 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.

The domestic supply of fly ash, which is used as an additive in concrete production, rebounded from low production levels in 2020; however, supply remained constrained and was expected to decrease in upcoming years owing to restrictions of mercury and carbon dioxide (CO_2) emissions at coal-fired powerplants, powerplant closures, and conversion of powerplants to natural gas. 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 not available, 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 2022, world iron slag production was estimated to be between 330 million and 390 million tons, and steel slag production was estimated to be between 190 million and 290 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]Source: World Steel Association, 2022, Short range outlook October 2022: Brussels, Belgium, World Steel Association press release, October 19, 6 p.

IRON ORE[1]

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

Domestic Production and Use: In 2022, seven open pit iron ore mines (each with associated concentration and pelletizing plants) in Michigan and Minnesota shipped 98% of domestic usable iron ore products, which were consumed in the steel industry in the United States. The remaining 2% of domestic iron ore products were consumed in nonsteel end uses. In 2022, the United States produced iron ore with an estimated value of $5.2 billion, a 22% decrease from $6.7 billion in 2021. 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 with an estimated value of $1.3 billion. The United States was estimated to have produced 1.8% and consumed 1.5% of the world's iron ore output.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Iron ore	49,500	46,900	38,100	47,500	46,000
Iron metallics	3,560	3,660	3,500	5,010	4,900
Shipments	50,400	47,000	38,000	43,400	46,000
Imports for consumption	3,790	3,980	3,240	3,740	3,200
Exports	12,700	11,400	10,400	14,300	9,400
Consumption:					
Reported	36,600	34,800	NA	NA	NA
Apparent[2]	41,400	39,100	31,100	36,800	40,000
Price, average unit value reported by mines, dollars per metric ton	93.00	92.94	91.27	141.75	114
Stocks, mine, dock, and consuming plant, yearend	3,100	3,470	3,290	3,170	2,800
Employment, mine, concentrating and pelletizing plant, number	4,860	4,960	4,300	4,980	4,900
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None. See the Iron and Steel Scrap chapter.

Import Sources (2018–21): Brazil, 57%; Canada, 22%; Sweden, 8%; and other, 13%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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: Slight decreases in production and trade in 2022 were due to rising global inflation, which resulted in decreased steel demand and consumption. Domestic iron ore production was estimated to be 46 million tons in 2022, a 3% decrease from 47.5 million tons in 2021. Total raw steel production was estimated to have decreased to 82 million tons in 2022 from 85.5 million tons in 2021. The World Steel Association[4] forecast global finished steel consumption to decrease by 2.3% in 2022 and increase by 1.0% in 2023. End-use consumption of steel products was expected to decline in 2022 following concurrent events affecting consumer demand, including the conflict in Ukraine, continuing coronavirus disease 2019 (COVID-19) mitigation measures in China, and rising energy costs and interest rates.

Overall, global prices trended downward to an average year-to-date unit value of $128.65 per ton in the first 9 months of 2022, a 28% decrease from the 2021 average year-to-date unit value of $178.27 per ton, but the 2022 average year-to-date unit value was a 28% increase from the 2020 average year-to-date unit value of $100.83 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 2022 was $152.07 per ton in March compared with the high of $214.43 per ton in June 2021. The lowest monthly average price during the same period in 2022 was $99.80 per ton in September compared with the low of $96.24 per ton in November 2021.

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IRON ORE

In November, one company petitioned the Minnesota Supreme Court for a review of State mineral leases that were terminated by the Minnesota Department of Natural Resources. In October, another company began construction on a $150 million project to build a direct-reduced grade pellet plant that could be sold or feed a potential future DRI or HBI plant. An iron ore mine in northern Minnesota was expected to deplete its reserves of iron ore around 2025, and the company's leadership was seeking the land and mineral rights to a nearby deposit where construction of a new mine and facility was stalled and the mineral leases were expected to be reassigned in the near future.

World Mine Production and Reserves: Reserves for Australia, Peru, and Russia were revised based on company and Government reports.

	Mine production				Reserves[5] (million metric tons)	
	Usable ore		Iron content			
	2021	2022[e]	2021	2022[e]	Crude ore	Iron content
United States	47,500	46,000	30,100	29,000	3,000	1,000
Australia	912,000	880,000	565,000	540,000	[6]51,000	[6]27,000
Brazil	431,000	410,000	273,000	260,000	34,000	15,000
Canada	57,500	58,000	34,500	35,000	6,000	2,300
Chile	17,700	16,000	11,200	10,000	NA	NA
China	394,000	380,000	246,000	240,000	20,000	6,900
India	273,000	290,000	169,000	180,000	5,500	3,400
Iran	72,900	75,000	47,900	49,000	2,700	1,500
Kazakhstan	64,100	66,000	13,100	14,000	2,500	900
Mauritania	12,800	13,000	8,000	8,100	NA	NA
Mexico	10,800	11,000	6,810	6,900	NA	NA
Peru	18,100	17,000	12,100	11,000	2,600	1,200
Russia	96,000	90,000	66,700	63,000	29,000	14,000
South Africa	73,100	76,000	46,500	48,000	1,000	670
Sweden	40,200	39,000	28,600	28,000	1,300	600
Turkey	16,100	17,000	9,710	10,000	130	38
Ukraine	83,800	76,000	52,400	47,000	[7]6,500	[7]2,300
Other countries	56,700	59,000	4,900	5,000	18,000	9,500
World total (rounded)	2,680,000	2,600,000	1,630,000	1,600,000	180,000	85,000

World Resources:[5] 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—excluding iron metallics such as DRI, HBI, and iron nuggets—unless otherwise noted. See also the Iron and Steel and Iron and Steel Scrap chapters.

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

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

[4]Source: World Steel Association, 2022, Short range outlook October 2022: Brussels, Belgium, World Steel Association press release, October 19, 6 p.

[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 23 billion tons of crude ore and 10 billion tons of iron content.

[7]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, was slightly higher in 2022 compared with that in 2021. Five companies, including the two producers of natural IOPs, processed and sold about 29,000 tons of finished natural and synthetic IOPs with an estimated value of $29 million. About 50% of natural and synthetic finished IOPs were used in concrete and other construction materials; 15% each in industrial chemicals and in foundry sands and other foundry uses; 5% each in animal feed and in paint and coatings; 3% each in plastics and in glass and ceramics; and the remaining 4% in other uses.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Mine production, crude	W	W	W	W	W
Sold or used, finished natural and synthetic IOPs	48,200	19,200	18,300	26,900	29,000
Imports for consumption	179,000	159,000	173,000	192,000	200,000
Exports, pigment grade	11,100	11,000	9,120	9,910	12,000
Consumption, apparent[1]	216,000	167,000	182,000	200,000	220,000
Price, average unit value, dollars per kilogram[2]	1.58	0.69	0.72	0.70	0.75
Employment, mine and mill, number	60	55	47	55	55
Net import reliance[3] as a percentage of apparent consumption	78	89	90	87	87

Recycling: None.

Import Sources (2018–21): Natural: Cyprus, 40%; Spain, 30%; France, 14%; Austria, 13%; and other, 3%. Synthetic: China,[4] 43%; Germany, 34%; Brazil, 8%; and other, 15%. Total: China,[4] 42%; Germany, 33%; Brazil, 7%; Canada, 5%; and other, 13%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 the United States, residential construction, in which IOPs are commonly used to color concrete block and brick, ready-mixed concrete, and roofing tiles, increased slightly during the first 9 months of 2022 compared with that in the same period in 2021. IOPs are also used in paints and coatings for the aerospace, automotive, and marine industries. Vehicle production in the United States through August 2022 was 4.9% higher than that in 2021. IOPs' characteristics of chemical and thermal stability, color strength, low cost, and weather resistance make IOPs a primary choice for colorant for coatings and construction materials.

Imports of natural and synthetic pigments were estimated to have increased by 4% in 2022. Exports of pigment-grade IOPs were estimated to have increased by 21% in 2022 compared with those in 2021, mostly owing to an increase in exports to Chile, China, France, and the United Kingdom. Approximately 49% of pigment-grade IOPs exports went to Mexico; the other leading countries for exports were China (21%), Belgium (10%), and Chile (5%).

IOPs are produced by several companies, but the three largest producers with facilities in multiple countries account for approximately 50% of the global IOP production capacity, with other companies in China accounting for a majority of the rest of the capacity. Some expansions of IOP production capacity in China were announced in early 2022.

World Mine Production and Reserves: Reserves for Pakistan were revised based on company reports.

	Mine production[e]		Reserves[5]
	2021	2022	
United States	W	W	Moderate
Cyprus (umber)	3,100	3,500	Moderate
France	5,000	5,000	NA
Germany[6]	400,000	400,000	Moderate
India (ocher)	3,000,000	2,700,000	37,000,000
Italy	33,000	30,000	NA
Pakistan (ocher)	100,000	100,000	Large
Spain (ocher and red iron oxide)	9,000	9,000	Large
World total (rounded)	[7]NA	[7]NA	Large

World Resources:[5] 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]Includes Hong Kong.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.
[6]Includes natural and synthetic iron oxide pigments.
[7]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, may produce iron oxide pigments, but available information was inadequate to make reliable estimates of output.

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 100,000 tons of kyanite worth $40 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 were 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Kyanite, mine	[1]89,200	[1]91,300	[1]67,100	[1]105,000	100,000
Synthetic mullite	W	W	W	W	W
Imports for consumption (andalusite)	8,590	6,960	714	1,390	6,200
Exports (kyanite)	43,000	40,100	37,400	48,000	46,000
Consumption, apparent[2]	W	W	W	W	W
Price, average unit value of exports (free alongside ship),[3, 4] dollars per metric ton	347	358	369	369	400
Employment, number:[e, 5]					
Kyanite, mine, office, and plant	150	150	140	140	140
Synthetic mullite, office and plant	200	200	200	200	200
Net import reliance[6] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2018–21):[4] South Africa, 72%; Peru, 14%; France, 9%; United Kingdom, 5%; and other, <1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Andalusite, kyanite, and sillimanite	2508.50.0000	Free.
Mullite	2508.60.0000	Free.

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

Government Stockpile: None.

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KYANITE AND RELATED MINERALS

Events, Trends, and Issues: Crude steel production in the United States, which ranked fourth in the world, decreased by about 4% in the first 8 months of 2022 compared with that in the same period in 2021, indicating a similar change in consumption of kyanite-mullite refractories. Total world steel production decreased by about 5% during the first 8 months of 2022 compared with that in the same period in 2021. The decrease in world steel production during the first 8 months of 2022 was the result of ongoing logistical issues and high input costs. The steel industry continued to be the largest consumer of refractories.

A company in South Africa that accounted for nearly one-third of global andalusite output remained in business rescue status. 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 a new owner. In January 2021, the company announced that a new investor and owner had been approved.

Andalusite production in 2022 remained constrained by challenges that disrupted market conditions. Andalusite mines in South Africa were adversely affected by electricity supply issues, flooding, and shipping problems. Andalusite output from Peru was expected to remain significantly higher than that in 2020 but was not expected to meet overall market demand. Andalusite exports from France were higher than those from Peru, but reported production statistics remained unavailable. In India, mining of new groups of minerals, including andalusite, was approved, but some sillimanite mines had previously been reclassified as beach sand minerals mines and, as a result, those mines were no longer considered sillimanite-producing mines. Additional factors that contributed to market uncertainty included the conflict in Ukraine, increased costs for raw materials, increased rates for freight, and higher sales prices. If andalusite producers are unable to meet demand, market participants may consider alternatives such as bauxite and mullite. Development of and production from new bauxite sources in Brazil and Guyana continued to progress in 2022.

World Mine Production and Reserves:

	Mine production		Reserves[7]
	2021	2022[e]	
United States (kyanite)	[1]105,000	100,000	Large
France (andalusite)	[e]65,000	65,000	NA
India (kyanite and sillimanite)	[e]15,000	15,000	7,200,000
Peru (andalusite)	[e]42,000	42,000	NA
South Africa (andalusite)	[e]170,000	160,000	NA
World total (rounded)	[8]NA	[8]NA	NA

World Resources:[7] 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 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]Estimated based on data from the U.S. Department of Labor, Mine Safety and Health Administration.
[6]Defined as imports – exports.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]In addition to the countries and (or) localities listed, Brazil and China may have produced kyanite and related minerals, but information was not available to make reliable estimates of output.

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 2022 was an estimated $710 million, 3% less than that in 2021. 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 2022 was $2.4 billion, essentially unchanged from that in 2021. The lead-acid battery industry accounted for an estimated 92% of reported U.S. lead consumption during 2022. 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.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Mine, lead in concentrates	280	274	306	294	280
Primary refinery	—	—	—	—	—
Secondary refinery, old scrap	1,140	1,070	1,030	975	950
Imports for consumption:					
Lead in concentrates	—	([1])	([1])	1	([1])
Refined metal, unwrought	563	501	382	613	700
Exports:					
Lead in concentrates	251	259	265	262	270
Refined metal, unwrought (gross weight)	67	25	17	22	25
Consumption, apparent[2]	1,640	1,550	1,400	1,570	1,600
Price, average, cents per pound:[3]					
North American market	110.9	99.9	91.2	113.0	115
London Metal Exchange (LME), cash	101.8	90.6	82.7	100.0	97
Employment, mine and mill (average), number[4]	1,800	1,770	1,750	1,860	1,900
Net import reliance[5] as a percentage of apparent consumption, refined metal	30	31	26	38	42

Recycling: In 2022, an estimated 950,000 tons of secondary lead was produced, an amount equivalent to 59% of apparent domestic consumption. Nearly all secondary lead was recovered from old scrap, mostly lead-acid batteries.

Import Sources (2018–21): Refined metal: Canada, 42%; Mexico, 18%; Republic of Korea, 14%; and other, 26%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022, the average LME cash price for lead was 97 cents per pound, essentially unchanged from the annual average price in 2021. Global stocks of lead in LME-approved warehouses were 27,625 tons at the end of October, which was 49% less than those at yearend 2021.

In 2022, domestic mine production and production of secondary lead decreased by an estimated 5% and 3%, respectively, from that in 2021. U.S. apparent consumption of refined lead increased slightly from that in 2021, and the net import reliance increased to 42% from 38%. In the first 9 months of 2022, 24.6 million spent SLI lead-acid batteries were exported, 4% less than exports in the same period in 2021.

According to the International Lead and Zinc Study Group,[6] global refined lead production in 2022 was forecast to decrease by 0.3% to 12.34 million tons and refined lead consumption to increase by 0.8% to 12.42 million tons.

World Mine Production and Reserves: Reserves estimates for China, Peru, Russia, Sweden, and the United States were revised based on new information from company or Government reports.

	Mine production		Reserves[7]
	2021	2022[e]	
United States	294	280	4,600
Australia	485	440	[8]37,000
Bolivia	93	90	1,600
China	1,960	2,000	12,000
India	215	240	2,500
Iran	[e]50	50	2,000
Mexico	272	270	5,600
Peru	264	250	5,300
Russia	[e]200	200	6,000
Sweden	65	65	1,700
Tajikistan	[e]56	55	NA
Turkey	[e]75	75	860
Other countries	510	510	5,900
World total (rounded)	4,550	4,500	85,000

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. Lithium-ion, nickel-cadmium, and nickel-metal hydride batteries are common alternatives to lead-acid batteries in certain applications. Currently, most all-electric vehicles and plug-in hybrid electric vehicles use lithium-ion batteries.

[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 refined imports – refined exports.
[6]Source: International Lead and Zinc Study Group, 2022, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 24, [4] 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 2022, an estimated 17 million tons of quicklime and hydrated lime was produced (excluding independent commercial hydrators[2]), valued at about $2.3 billion. Lime was produced by 28 companies—18 with commercial sales and 10 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 2022. Of the 28 companies, 5 operated only hydrating plants in nine States. In 2022, the five leading U.S. lime companies produced quicklime or hydrated in 22 States and accounted for about 79% of U.S. lime production. Principal producing States were 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production[2, 3]	18,000	16,900	15,800	16,800	17,000
Imports for consumption	370	342	308	323	350
Exports	424	347	266	335	300
Consumption, apparent[4]	18,000	16,900	15,900	16,800	17,000
Price, average value, dollars per ton at plant:					
Quicklime	125.2	128.3	131.4	133.4	140
Hydrated	151.6	154.6	156.0	159.6	160
Net import reliance[5] as a percentage of apparent consumption	E	E	<1	E	<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 double counting.

Import Sources (2018–21): Canada, 90%; Mexico, 7%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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 2022, domestic lime production was estimated to be essentially unchanged from that in 2021. In 2020, a decline in lime production was a result of plants temporarily closing owing to the global coronavirus disease 2019 (COVID-19) pandemic. As the economy continues to rebound from the effects of the pandemic, so does the lime industry. However, some of the lime producers have increased product pricing owing to increased costs of production. In 2022, 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]		Reserves[7]
	2021	2022[e]	
United States	16,800	17,000	Adequate for all countries listed.
Australia	2,000	2,000	
Belgium[8]	1,500	1,500	
Brazil	8,400	8,400	
Bulgaria	1,520	1,500	
Canada (shipments)	1,590	1,600	
China	310,000	310,000	
France	2,600	2,600	
Germany	5,600	5,600	
India	16,000	16,000	
Iran	3,900	3,900	
Italy[8]	3,600	3,600	
Japan (quicklime only)	6,650	7,000	
Korea, Republic of	5,200	5,200	
Malaysia	1,500	1,500	
Poland (hydrated and quicklime)	1,700	1,700	
Romania	1,430	1,400	
Russia (industrial and construction)	11,400	11,000	
Slovenia	1,120	1,200	
South Africa	1,000	1,000	
Spain	1,800	1,800	
Turkey	4,800	4,800	
Ukraine	2,350	2,000	
United Kingdom	1,500	1,500	
Other countries	15,600	16,000	
World total (rounded)	430,000	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: Commercial-scale lithium production in the United States was from one continental brine operation in Nevada. Lithium was also commercially produced from the brine-sourced waste tailings of a Utah-based magnesium producer. 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 were estimated as follows: batteries, 80%; ceramics and glass, 7%; lubricating greases, 4%; continuous casting mold flux powders, 2%; air treatment, 1%; medical, 1%; and other uses, 5%. Lithium consumption for batteries increased significantly in recent years because rechargeable lithium batteries have been used extensively in the growing market for electric vehicles and portable electronic devices, and increasingly have been 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:	2018	2019	2020	2021	2022[e]
Production	W	W	W	W	W
Imports for consumption	3,420	2,620	2,460	2,640	3,400
Exports	1,660	1,660	1,200	1,870	2,700
Consumption, estimated[1]	3,000	2,000	2,000	2,000	3,000
Price, annual average-nominal, battery-grade lithium carbonate, dollars per metric ton[2]	16,000	11,700	8,400	12,600	37,000
Employment, mine and mill, number	70	70	70	70	70
Net import reliance[3] as a percentage of estimated consumption	>50	>25	>50	>25	>25

Recycling: Construction of lithium battery recycling plants increased at a rapid pace. As of November 2022, about 44 companies in Canada and the United States and 47 companies in Europe recycled lithium batteries or planned to do so. Automobile companies and battery recyclers partnered to supply the automobile industry with a source of battery materials.

Import Sources (2018–21): Argentina, 51%; Chile, 40%; China, 4%; Russia, 3%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022		FY 2023	
Material	Inventory as of 9–30–22	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 2022 increased by 21% to approximately 130,000 tons from 107,000 tons in 2021 in response to strong demand from the lithium-ion battery market and increased prices of lithium. Global consumption of lithium in 2022 was estimated to be 134,000 tons, a 41% increase from 95,000 tons in 2021.

Spot lithium carbonate prices in China (cost, insurance, and freight [c.i.f.]) increased from approximately $35,000 per ton in January to about $67,000 per ton in November. For fixed contracts, the annual average U.S. lithium carbonate price was $37,000 per ton in 2022, almost three times higher than that in 2021. Spot lithium hydroxide prices in China (free on board) increased from approximately $35,300 per ton in January to about $78,000 per ton in November. Spot spodumene (6% lithium oxide) prices in China (c.i.f.) increased from approximately $4,900 per ton in January to about $5,800 per ton in November.

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LITHIUM

Six mineral operations in Australia, one mineral tailings operation in Brazil, two brine operations each in Argentina and Chile, and three mineral and two brine operations in China accounted for the majority of world lithium production. Additionally, smaller operations in Brazil, Canada, China, Portugal, the United States, and Zimbabwe also contributed to world lithium production. Owing to the rapid increase in demand and prices of lithium in 2022, established lithium operations worldwide increased or were in the process of increasing production capacity.

The U.S. Department of Energy selected 12 lithium-based projects funded with $1.6 billion from the 2022 U.S. Bipartisan Infrastructure Law to support new commercial-scale domestic facilities to extract and process lithium, manufacture battery components, recycle batteries, and develop new technologies to increase U.S. lithium reserves.

Lithium supply security has become a top priority for technology companies in Asia, Europe, and North America. 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 or exploration in Argentina, Bolivia, Chile, China, and the United States; mineral-based lithium sources were in various stages of development or exploration in Australia, Austria, Brazil, Canada, China, Congo (Kinshasa), Czechia, Ethiopia, Finland, Germany, Ghana, Kazakhstan, Mali, Namibia, Nigeria, Peru, Portugal, Russia, Serbia, Spain, Thailand, the United States, and Zimbabwe; lithium-clay sources were in various stages of development or exploration in Mexico and the United States.

World Mine Production and Reserves: Reserves for Argentina, Australia, Brazil, Canada, Chile, China, the United States, Zimbabwe, and "Other countries" were revised based on information from company and Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	W	W	1,000,000
Argentina	5,970	6,200	2,700,000
Australia	55,300	61,000	[7]6,200,000
Brazil	[e]1,700	2,200	250,000
Canada	—	500	930,000
Chile	28,300	39,000	9,300,000
China	[e]14,000	19,000	2,000,000
Portugal	[e]900	600	60,000
Zimbabwe	[e]710	800	310,000
Other countries[8]	—	—	3,300,000
World total (rounded)	[9]107,000	[9]130,000	26,000,000

World Resources:[6] Owing to continuing exploration, identified lithium resources have increased substantially worldwide and total about 98 million tons. Identified lithium resources in the United States—from continental brines, claystone, geothermal brines, hectorite, oilfield brines, and pegmatites—are 12 million tons. Identified lithium resources in other countries have been revised to 86 million tons. Identified lithium resources are distributed as follows: Bolivia, 21 million tons; Argentina, 20 million tons; Chile, 11 million tons; Australia, 7.9 million tons; China, 6.8 million tons; Germany, 3.2 million tons; Congo (Kinshasa), 3 million tons; Canada, 2.9 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, 840,000 tons; Brazil, 730,000 tons; Zimbabwe, 690,000 tons; Spain, 320,000 tons; Portugal, 270,000 tons; Namibia; 230,000 tons; Ghana, 180,000 tons; Finland, 68,000 tons; Austria, 60,000 tons; and Kazakhstan, 50,000 tons.

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 price assessments for spot and long-term contracts. Source: Benchmark Mineral Intelligence Ltd.
[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-compliant or equivalent reserves were 3.8 million tons.
[8]Other countries with reported reserves: Austria, Congo (Kinshasa), Czechia, Finland, Germany, Ghana, Mali, Mexico, Namibia, Serbia, and Spain.
[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 67% of U.S. magnesium compound production in 2022. The value of shipments of all types of magnesium compounds was estimated to be $460 million, a 5% increase from the revised value in 2021. Magnesium 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 75% 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 of quantity, environmental, chemical, agricultural, 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 of quantity, were magnesium oxide (caustic-calcined magnesia, dead burned magnesia, and fused magnesia), magnesium hydroxide, magnesium chloride, and magnesium sulfate.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production	405	376	363	432	450
Shipments (gross weight)	610	563	547	634	660
Imports for consumption	551	564	480	655	640
Exports	116	88	66	86	140
Consumption, apparent[3]	840	852	777	1,001	950
Employment, plant, number[e]	270	270	260	270	280
Net import reliance[4] as a percentage of apparent consumption	52	56	53	57	53

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

Import Sources (2018–21): Caustic-calcined magnesia: China,[5] 74%; Canada, 20%; Israel, 3%; and other, 3%. Crude magnesite: China,[5] 87%; Singapore, 10%; and other, 3%. Dead-burned and fused magnesia: China,[5] 68%; Brazil, 16%; Turkey, 5%; Mexico, 3%; and other, 8%. Magnesium chloride: Israel, 60%; Netherlands, 26%; China,[5] 5%; and other, 9%. Magnesium hydroxide: Mexico, 57%; Netherlands, 15%; Israel, 11%; Austria, 7%; and other, 10%. Magnesium sulfates: China,[5] 58%; India, 15%; Germany, 10%; Vietnam, 4%; and other, 13%. Total imports: China,[5] 61%; Israel, 10%; Canada, 7%; Brazil, 6%; and other, 16%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022, consumption of dead-burned and fused magnesia is expected to decrease in the United States and globally by an estimated 4% and 5%, respectively, compared with that in 2021 based on steel production data through August. Coronavirus disease 2019 (COVID-19) pandemic-related shutdowns in China, especially in manufacturing dominated Provinces and port cities, contributed to the decrease in consumption of magnesium compounds. Domestic consumption for all magnesium compounds has somewhat followed the general trend of the performance of the U.S. manufacturing industry. Globally, China is the leading producer of magnesia and magnesite and remains the principal exporter of magnesia to the United States and much of the world.

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MAGNESIUM COMPOUNDS

In August 2022, a China-based magnesia and refractories producer commenced operations in Mayfield, KY. The new plant was designed to produce between 50,000 and 60,000 tons per year of refractory products. Feed material for the plant was sourced from company-owned mines located overseas. Products produced by the plant included resin bonded magnesia-carbon and magnesia-alumina-carbon refractory bricks for use in furnaces servicing the steel industry.

In the third quarter of 2022, North America's largest producer of epsom salts opened a bulk production facility in Hazelwood, NC. In spring 2023, an Austria-based magnesia and refractories producer plans to open its North American corporate headquarters in Tampa, FL.

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

	Mine production[e]		Reserves[7]
	2021	2022	
United States	W	W	35,000
Australia	2,700	2,600	[8]290,000
Austria	800	800	49,000
Brazil	1,600	1,500	200,000
Canada	190	180	NA
China	18,000	17,000	580,000
Greece	540	510	280,000
India	99	100	82,000
Iran	200	190	12,000
Russia	1,000	950	2,300,000
Slovakia	500	480	370,000
Spain	650	620	35,000
Turkey	1,900	1,800	110,000
Other countries	400	400	2,500,000
World total (rounded)	[9]29,000	[9]27,000	6,800,000

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 the Magnesium Metal chapter.
[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 2022, 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 2022 was estimated to have decreased significantly from that in 2021. 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 58% 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 20% of primary magnesium metal consumption; desulfurization of iron and steel, 14%; and all other uses, 8%. About 35% of the secondary magnesium was consumed for structural uses, and about 65% was used in aluminum alloys.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Primary	W	W	W	W	W
Secondary (new and old scrap)	109	103	95	103	120
Imports for consumption	47	59	61	50	97
Exports	12	10	15	8	5
Consumption:					
Reported, primary	56	57	54	51	50
Apparent[2]	W	W	W	W	W
Price, annual average:[3]					
U.S. spot Western, dollars per pound	2.17	2.45	2.49	3.55	7.60
European free market, dollars per metric ton	2,550	2,425	2,149	5,008	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	>25	>25	>25	>50

Recycling: In 2022, about 37,000 tons of secondary magnesium was recovered from old scrap and 83,000 tons was recovered from new scrap. Aluminum-base alloys accounted for about 58% of the secondary magnesium recovered, and magnesium-based castings, ingot, and other materials accounted for about 42%.

Import Sources (2018–21): Magnesium metal (99.8% purity): Israel, 31%; Russia, 29%; Turkey, 27%; Canada, 6%; and other, 7%. Magnesium alloys (magnesium content): Taiwan, 28%; Czechia, 16%; Germany and Israel, 14% each; and other, 28%. Sheet, powder, and other (magnesium content): Austria, China,[5] and Mexico, 20% each; Canada, 17%; and other, 23%. Scrap: Canada, 38%; Mexico, 19%; China,[5] 14%; Taiwan, 6%; and other, 23%. Combined total (includes magnesium content of alloys, metal, powder, and other): Canada, 21%; Israel, 11%; Mexico, 10%; Taiwan, 9%; and other, 49%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Unwrought metal	8104.11.0000	8% ad valorem.
Unwrought alloys	8104.19.0000	6.5% ad valorem.
Waste and scrap	8104.20.0000	Free.
Powders and granules	8104.30.0000	4.4% ad valorem.
Wrought metal	8104.90.0000	14.8¢/kg on magnesium 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: Production issues continued throughout the year at the only U.S. primary magnesium smelter. On September 29, 2021, the producer of primary magnesium in Utah declared force majeure on supply contracts, citing equipment failures. Details on the amount of capacity affected and the expected restart date were not reported by the company. In 2022, some customers reported temporarily shutting down some facilities citing magnesium shortages including a facility in Indiana that produces aluminum can sheet which shut down some capacity in July until September when an alternative source of magnesium was obtained. The shutdown of capacity in Utah was cited as the reason why the average annual U.S. spot Western price nearly doubled from the annual average price in 2021. In August, the producer applied for a permit to extend the brine intake canals on the Great Salt

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MAGNESIUM METAL

Lake into deeper water, but in December the permit was denied by State regulators. The producer stated that the declining water level after several years of drought threatened to disrupt production.

Magnesium prices in Europe decreased significantly during the first half of the year compared with those of the last quarter of 2021 when they reached record highs. By the end of January 2022, the price range in Europe was $8,400 to $8,700 per metric ton and it continued to decline, reaching a range of $3,700 to $3,900 per metric ton at the end of July. For the remainder of the year, the price range in Europe declined, reaching a range of $3,400 to $3,550 per metric ton at the end of November, a price range not observed since May 2021. The 2022 annual average price range for magnesium in Europe was 10% higher than that for 2021.

One company planned to build a pilot plant in Ohio to test magnesium production from dolomite. A company in Quebec, Canada, planned to construct a primary magnesium smelter to produce magnesium from serpentine-bearing asbestos tailings. In Australia, a company started construction of a 1,000-ton-per-year demonstration plant to recover magnesium from coal fly ash, with production scheduled to start by the end of June 2023.

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	
	2021	2022[e]
United States	W	W
Brazil	20	20
China	[e]930	900
Israel	18	20
Kazakhstan	16	15
Russia	[e]58	50
Turkey	13	13
Ukraine	10	2
World total (rounded)[7]	1,070	1,000

Reserves[6]

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.

World Resources:[6] 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 the Magnesium Compounds chapter.
[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]Includes Hong Kong.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]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 five companies at six facilities with plants principally in the Eastern and Midwestern States. Most ore consumption was related to steel production, either directly in pig iron manufacture or indirectly through upgrading the ore to ferroalloys. Additional quantities of ore were used for nonmetallurgical purposes, such as in the production of animal feed, brick colorant, dry cell batteries, and fertilizers. Manganese ferroalloys were produced at two plants.

Salient Statistics—United States:[1]	2018	2019	2020	2021	2022[e]
Production, mine	—	—	—	—	—
Imports for consumption:					
Manganese ores and concentrates	440	434	367	497	650
Ferromanganese	427	332	223	329	330
Silicomanganese	412	351	269	313	420
Exports:					
Manganese ores and concentrates	3	1	1	1	1
Ferromanganese	10	5	5	9	2
Silicomanganese	4	2	2	5	4
Shipments from Government stockpile:[2]					
Manganese ore	—	—	—	2	—
Ferromanganese and manganese metal, electrolytic	13	10	54	21	11
Consumption, reported:					
Manganese ore[3]	369	442	378	399	370
Ferromanganese	348	336	325	335	340
Silicomanganese	[4]139	[4]143	229	237	240
Consumption, apparent, manganese content[5]	796	748	621	717	890
Price, average, manganese content, cost, insurance, and freight, China, dollars per metric ton unit[6]	7.16	5.63	4.59	5.27	6.50
Stocks, producer and consumer, yearend:					
Manganese ore[3]	191	175	143	220	230
Ferromanganese	27	44	35	40	40
Silicomanganese	21	39	31	34	34
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 (2018–21): Manganese ore: Gabon, 67%; South Africa, 19%; Mexico, 12%; and other, 2%. Ferromanganese: Australia, 19%; Malaysia, 18%; South Africa, 17%; Norway, 15%; and other, 31%. Silicomanganese: Georgia, 28%; South Africa, 22%; Australia, 21%; and other, 29%. Manganese contained in principal manganese imports:[8] Gabon, 25%; South Africa, 19%; Australia, 12%; Georgia, 8%; and other, 36%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Manganese ore, metallurgical grade	291	—	292	—	151
Ferromanganese, high carbon	104	—	45	—	45
Manganese metal, electrolytic	—	5	—	5	—

Events, Trends, and Issues: Global production of steel, the leading use of manganese, decreased in 2022 compared with production in 2021 owing to supply chain disruptions resulting from the conflict between Russia and Ukraine and intermittent coronavirus disease 2019 (COVID-19) pandemic-related lockdowns in China. Global production of manganese ore was estimated to be unchanged from that in 2021. 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 almost 20% in 2022 compared with those in 2021. By September 2022, average spot market prices for manganese ore, 44% grade, from China had increased by 23% compared with the annual average spot price in 2021.

World Mine Production (manganese content) and Reserves: Reserves for China were revised based on Government reports.

	Mine production 2021	Mine production 2022[e]	Reserves[10]
United States	—	—	—
Australia	3,260	3,300	[11]270,000
Brazil	542	400	270,000
Burma	206	200	NA
China	991	990	280,000
Côte d'Ivoire	362	360	NA
Gabon	4,340	4,600	61,000
Georgia	224	220	NA
Ghana	940	940	13,000
India	453	480	34,000
Kazakhstan, concentrate	90	110	5,000
Malaysia	356	360	NA
Mexico	226	230	5,000
South Africa	7,200	7,200	640,000
Ukraine, concentrate	600	400	140,000
Vietnam	146	150	NA
Other countries	150	150	Small
World total (rounded)	20,100	20,000	1,700,000

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 an estimated 70% of the world's manganese resources.

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 change in total inventory from prior yearend inventory. If negative, increase in inventory.

[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 ferromanganese, manganese dioxide, manganese ore, manganese waste and scrap, silicomanganese, unwrought manganese metal, and wrought manganese metal.

[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 dioxide, manganese ore, silicomanganese, 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 135 million tons.

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 2022, 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 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 domestically 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 2022, 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Mine (byproduct)	NA	NA	NA	NA	NA
Secondary	NA	NA	NA	NA	NA
Imports for consumption, metal (gross weight)	6	9	3	1	2
Exports, metal (gross weight)	—	—	—	—	—
Price, average unit value of imports, dollars per kilogram	7	23	26	29	33
Net import reliance[1] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: In 2022, 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 replacement of compact and traditional fluorescent lighting by light-emitting-diode (LED) lighting, more mercury was being recycled.

Import Sources (2018–21): Canada, 69%; China, 31%; and other, <1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Mercury	2805.40.0000	1.7% ad valorem.
Amalgams	2843.90.0000	3.7% ad valorem.

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

Government Stockpile:[2] 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 2022		**FY 2023**	
Material	**Inventory as of 9–30–22**	**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. According to the United Nations Environment Programme (UNEP) Global Mercury Partnership 2018 report, the top five leading sources of anthropogenic mercury emissions were artisanal and small-scale gold mining (37.7%), stationary combustion of coal (21.3%), nonferrous-metal production (14.7%), cement production (10.5%), and waste from products (6.6%). 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[e]		Reserves[3]
	2021	2022	
United States	NA	NA	Quantitative estimates of reserves were not available. China, Kyrgyzstan, and Peru have the largest reserves.
China	2,000	2,000	
Kyrgyzstan	20	6	
Mexico (net exports)	39	40	
Morocco	2	2	
Norway	20	20	
Peru (exports)	30	30	
Tajikistan	120	120	
World total (rounded)[4]	2,200	2,200	

World Resources:[3] 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]Defined as imports – exports ± adjustments for Government stock changes.
[2]See Appendix B for definitions.
[3]See Appendix C for resource and reserve definitions and information concerning data sources.

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 42,000 tons valued at $4.2 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 67,000 tons of ground mica valued at about $21 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 2022. 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Scrap and flake:					
Production:[e, 1]					
Sold and used	42,000	40,100	34,600	40,600	42,000
Ground	68,400	61,300	59,900	66,800	67,000
Imports[2]	28,100	27,300	20,400	24,100	21,000
Exports[3]	6,030	5,500	3,980	4,850	7,600
Consumption, apparent[e, 4]	64,100	61,900	50,000	59,900	55,000
Price, average, dollars per metric ton:[e]					
Scrap and flake	116	105	120	100	100
Ground:					
Dry	308	316	303	299	300
Wet	422	394	337	336	340
Net import reliance[5] as a percentage of apparent consumption	34	35	31	32	24
Sheet:					
Sold and used	W	W	W	NA	NA
Imports[6]	1,890	3,150	2,840	3,980	4,200
Exports[7]	686	779	528	633	950
Consumption, apparent[e, 4]	1,200	2,370	2,310	3,350	3,300
Price, average value, muscovite and phlogopite mica, dollars per kilogram:[e]					
Block	W	W	W	W	W
Splittings	1.65	1.66	1.57	1.88	1.80
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2018–21): Scrap and flake: Canada, 39%; China, 38%; India, 8%; Finland, 4%; and other, 11%. Sheet: China, 72%; Brazil, 9%; Belgium, 4%, Austria, 3%, and other, 12%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
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 3% in 2022 compared with that in 2021. Apparent consumption of scrap and flake mica decreased by 8% owing to higher exports of mica powder in 2022. Apparent consumption of sheet mica was estimated to have been essentially unchanged from that in 2021. 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 China with some imports from Brazil.

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[e]		Reserves[8]	Mine production[e]		Reserves[8]
	2021	2022		2021	2022	
United States	40,600	42,000	Large	W	NA	Very small
Canada	15,000	16,000	Large	NA	NA	NA
China	100,000	100,000	Large	NA	NA	NA
Finland	[9]55,900	60,000	Large	NA	NA	NA
France	19,000	19,000	Large	NA	NA	NA
India	16,000	16,000	Large	1,000	1,000	110,000
Korea, Republic of	[9]11,000	13,000	11,000,000	—	—	NA
Madagascar	70,000	65,000	Large	—	—	NA
Turkey	[9]1,670	1,700	620,000	—	—	NA
Other countries	55,000	54,000	Large	200	200	Moderate
World total (rounded)	384,000	390,000	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.
[9]Reported.

MOLYBDENUM

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

Domestic Production and Use: Total U.S. mine production of molybdenum concentrate increased slightly to 42,000 tons of contained molybdenum in 2022 compared with 41,100 tons in 2021. Molybdenum concentrate production at primary molybdenum mines continued at two U.S. operations in Colorado, accounting for 33% of total U.S. molybdenum concentrate production. Molybdenum concentrate production from mines where molybdenum was a byproduct continued at seven U.S. operations (four in Arizona and one each in Montana, Nevada, and Utah), accounting for 67% of total U.S. molybdenum concentrate production. Three roasting plants converted molybdenite concentrate to molybdic oxide, from which intermediate products, such as ferromolybdenum, metal powder, and various chemicals, were produced.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine	41,400	43,600	51,100	41,100	42,000
Imports for consumption	37,300	34,200	24,700	30,200	33,000
Exports	48,200	67,200	62,500	60,000	53,000
Consumption:					
Reported[1]	16,700	16,400	15,800	15,900	16,000
Apparent[2]	31,300	10,400	13,100	11,100	22,000
Price, average value, dollars per kilogram[3]	27.04	26.50	19.90	35.30	39.25
Stocks, consumer materials	1,940	1,980	1,980	2,020	2,100
Employment, mine and plant, number	940	950	950	940	940
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 (2018–21): Ferromolybdenum: Chile, 69%; Republic of Korea, 26%; and other, 5%. Molybdenum ores and concentrates: Peru, 60%; Mexico, 15%; Chile, 14%; and other, 11%. Total: Peru, 40%; Chile, 28%; Mexico, 10%; Canada, 9%; and other, 13%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Molybdenum ore and concentrates, roasted	2613.10.0000	12.8¢/kg on molybdenum content + 1.8% ad valorem.
Molybdenum ore and concentrates, other	2613.90.0000	17.8¢/kg on molybdenum content.
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 on molybdenum content + 1.2% ad valorem.
Unwrought	8102.94.0000	13.9¢/kg on molybdenum content + 1.9% ad valorem.
Wrought bars and rods	8102.95.3000	6.6% ad valorem.
Wrought plates, sheets, strips, and so forth	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 2022, the estimated average molybdic oxide price increased by 11% compared with that in 2021. Molybdenum prices have not reached this high of a level since 2008. Estimated U.S. imports for consumption increased by 8% compared with those in 2021. U.S. exports decreased by 12% from those in 2021. Estimated apparent consumption in 2022 increased by 96% compared with that in 2021.

Global molybdenum production in 2022 was essentially unchanged compared with that in 2021. In descending order of production, China, Chile, the United States, Peru, and Mexico provided 93% of total global production. Molybdenum producers in China continued to face difficulties owing to tightening of environmental regulations making it more difficult to obtain mining permits. Molybdenum prices in China reached decade-high levels as molybdenum-bearing steel consumption remained high. In Chile, molybdenum producers continued to struggle with persistently lower ore grades. However, molybdenum was expected to continue to make strong contributions in global power generation and infrastructure projects as countries begin to prioritize climate change.

World Mine Production and Reserves: Reserves for Canada, China, the Republic of Korea, Peru, and Uzbekistan were revised based on company and Government reports.

	Mine production		Reserves[5]
	2021	2022[e]	(thousand metric tons)
United States	41,100	42,000	2,700
Argentina	—	—	100
Armenia	7,760	7,800	150
Canada	1,390	970	72
Chile	49,400	44,000	1,400
China	95,300	100,000	3,700
Iran	3,100	3,500	43
Korea, Republic of	408	400	8
Mexico	16,300	16,000	130
Mongolia	2,970	2,300	NA
Peru	34,100	32,000	2,400
Russia	[e]1,700	1,700	430
Turkey	—	—	360
Uzbekistan	[e]1,600	1,600	21
World total (rounded)	255,000	250,000	12,000

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 industry stock changes.
[3]Time-weighted average price per kilogram of molybdenum contained in technical-grade molybdic oxide. Source: 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 2022, the underground Eagle Mine in Michigan produced approximately 18,000 tons of nickel in concentrate, which was exported to smelters in Canada and overseas. Nickel in crystalline sulfate was produced as a byproduct of smelting and refining platinum-group-metal ores mined in Montana. In Missouri, a company produced nickel-copper-cobalt concentrate from historic mine tailings and was building a hydrometallurgical processing plant near the mine site. A nickel beneficiation project was to be built in North Dakota using $115 million awarded from the Bipartisan Infrastructure Law. 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:	2018	2019	2020	2021	2022[e]
Production:					
Mine	17,600	13,500	16,700	18,400	18,000
Refinery, byproduct	W	W	W	W	W
Imports:					
Ores and concentrates	3	4	95	18	—
Primary	144,000	119,000	105,000	108,000	130,000
Secondary	45,100	37,700	31,800	34,400	34,000
Exports:					
Ores and concentrates	18,000	14,300	13,400	14,900	18,000
Primary	9,780	12,800	11,300	11,600	11,000
Secondary	59,400	47,800	46,300	29,100	43,000
Consumption:					
Reported, primary	107,000	105,000	[e]85,000	[e]77,000	80,000
Reported, secondary, purchased scrap	123,000	111,000	[e]100,000	[e]100,000	96,000
Apparent, primary[1]	136,000	106,000	[e]94,000	[e]98,000	120,000
Apparent, total[2]	259,000	217,000	[e]200,000	[e]200,000	220,000
Price, average annual, London Metal Exchange (LME), cash:					
Dollars per metric ton	13,114	13,903	13,772	18,476	25,000
Dollars per pound	5.948	6.306	6.25	8.38	11
Stocks, yearend:					
Consumer	16,300	13,400	[e]14,000	[e]14,000	14,000
LME U.S. warehouses	2,268	1,974	1,734	1,296	6
Net import reliance[3,4] as a percentage of total apparent consumption	52	49	48	49	56

Recycling: Most secondary nickel was in the form of nickel content of stainless-steel scrap. Nickel in alloyed form was recovered from the processing of nickel-containing waste. Most recycled nickel was used to produce new alloys and stainless steel. In 2022, as part of the Bipartisan Infrastructure Law, more than $600 million was allocated to projects to recover nickel from spent lithium-ion batteries and for the synthesis of nickel-containing precursor and cathode active materials. In 2022, recycled nickel in all forms accounted for approximately 56% of apparent consumption.

Import Sources (2018–21): Primary nickel: Canada, 45%; Norway, 9%; Australia, 8%; Finland, 7%; and other, 31%. Nickel-containing scrap, including nickel content of stainless-steel scrap: Canada, 38%; Mexico, 26%; United Kingdom, 9%; and other, 27%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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.

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

Government Stockpile:[5] 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 the Lithium chapter for statistics on lithium-nickel-cobalt-aluminum oxide.

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NICKEL

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Nickel alloys, gross weight	759	—	—	—	—

Events, Trends, and Issues: In 2022, the annual average LME nickel cash price was estimated to have increased by 35% compared with that in 2021 which was attributed to increasing use of nickel in electric vehicle batteries and continued strong demand for stainless steel. Nickel prices were particularly volatile early in the year. In March, after the onset of the conflict between Russia and Ukraine, prices surged, which disrupted nickel trading on the LME for approximately two weeks. Monthly average prices peaked in March, but began to decline through July, and stabilized for the remainder of the year.

Estimated global nickel mine production increased by about 20%, with almost all of the increased production attributed to Indonesia. The largest share of the increase was facilitated by the ongoing commissioning of integrated nickel pig iron and stainless-steel projects. In addition, several companies continued to develop projects to produce intermediate matte or mixed nickel-cobalt hydroxide that were intended to be used as feedstock to produce battery-grade nickel sulfate.

On February 24, 2022, a U.S. critical minerals list was published in the Federal Register (87 FR 10381). The changes in the 2022 list from the prior list published in 2018 (83 FR 23295) were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium. The list is to be updated every 3 years and revised as necessary consistent with available data.

World Mine Production and Reserves: Reserves for Canada, China, New Caledonia, and the United States were revised based on company and Government reports.

	Mine production 2021	Mine production 2022[e]	Reserves[6]
United States	18,400	18,000	[7]370,000
Australia	151,000	160,000	[8]21,000,000
Brazil	76,000	83,000	16,000,000
Canada	134,000	130,000	2,200,000
China	109,000	110,000	2,100,000
Indonesia	1,040,000	1,600,000	21,000,000
New Caledonia[9]	186,000	190,000	7,100,000
Philippines	387,000	330,000	4,800,000
Russia	205,000	220,000	7,500,000
Other countries	429,000	440,000	20,000,000
World total (rounded)	2,730,000	3,300,000	>100,000,000

World Resources:[6] 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]The calculation of net import reliance includes the nickel content of stainless steel and alloy scrap. Excluding scrap, net import reliance would be nearly 100%.
[5]See Appendix B for definitions.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]Includes reserve data for three projects. An additional three domestic projects have defined resources but have not yet defined reserves.
[8]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 9.5 million tons.
[9]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. Major end-use distribution of domestic niobium consumption was estimated as follows: steels, about 75%, and superalloys, about 25%. The estimated value of niobium consumption was $440 million, as measured by the value of imports.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production, mine	—	—	—	—	—
Imports for consumption[1]	11,200	10,100	7,200	8,290	8,800
Exports[1]	955	668	793	1,010	1,200
Shipments from Government stockpile[2]	−76	−84	−88	−1	0
Consumption:[e]					
Apparent[3]	10,100	9,360	6,320	7,280	7,600
Reported[4]	6,850	6,680	6,040	6,140	5,600
Price, average unit value, ferroniobium, dollars per kilogram[5]	21	22	20	20	24
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 (2018–21): Niobium and tantalum ores and concentrates: Australia, 42%; Rwanda, 21%; Congo (Kinshasa), 12%; Mozambique, 7%; and other, 18%. Niobium oxide: Brazil, 72%; Estonia, 5%; China, 2%; Germany, 1%; and other, 20%. Ferroniobium and niobium metal: Brazil, 67%; Canada, 28%; Russia, 3%, Germany, 1%, and other, 1%. Total imports: Brazil, 66%; Canada, 25%; and other, 9%. Of U.S. niobium material imports (by contained weight), 74% was ferroniobium, 16% was niobium metal, 9% was niobium oxide, and 1% was niobium ores and concentrates.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
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% phosphorus or sulfur, or less than 0.4% silicon	7202.93.4000	5% ad valorem.
Other	7202.93.8000	5% ad valorem.
Niobium:		
Waste and scrap[6]	8112.92.0700	Free.
Powders and unwrought metal	8112.92.4000	4.9% ad valorem.
Other[6]	8112.99.9100	4% ad valorem.

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

Government Stockpile:[7]

		FY 2022		FY 2023	
Material	**Inventory as of 9–30–22**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Ferroniobium (gross weight)	544	—	—	—	—
Niobium metal (gross weight)	10	—	—	—	—

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NIOBIUM (COLUMBIUM)

Events, Trends, and Issues: In 2022, U.S. niobium apparent consumption (measured in niobium content) was estimated to be 7,600 tons, a 4% increase from that in 2021. One domestic company developing its Elk Creek project in Nebraska announced the results of its 2022 feasibility study. According to the study, the mining and processing operation is expected to produce 7,350 tons per year of ferroniobium, 102 tons per year of scandium trioxide, and 12,060 tons per year of titanium dioxide over a 38-year mine life. The project would be the only niobium mine and primary niobium-processing facility in the United States, with construction to begin after financing is received as required permits have been obtained.

Brazil continued to be the world's leading niobium producer, accounting for approximately 89% of global production, followed by Canada with about 8%. According to international trade statistics under the Harmonized Tariff Schedule of the United States code 7202.93 (ferroniobium), Brazil's total exports were 56,700 tons from January through August 2022, 6% less than during the same period in 2021. Most of Brazil's exports were sent to China, followed by the Netherlands and Singapore.

In 2022, a leading niobium producer in Brazil announced plans to invest $1.7 billion in its production assets to double its sales volume by 2030. The company completed its most recent facility upgrades in late 2021, increasing its total production capacity of ferroniobium to 150,000 metric tons per year (approximately 98,000 tons per year of niobium content). The completion of those projects would provide a significant increase in production in Brazil over the next decade.

World Mine Production and Reserves: Reserves for the United States were revised based on company reports.

	Mine production		Reserves[8]
	2021	2022[e]	
United States	—	—	210,000
Brazil	78,700	71,000	16,000,000
Canada	7,500	6,500	1,600,000
Congo (Kinshasa)	580	600	NA
Russia	450	450	NA
Rwanda	158	210	NA
Other countries	170	190	NA
World total (rounded)	87,600	79,000	>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]Defined as change in total inventory from prior yearend inventory. If negative, 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 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 2022; 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 2022, U.S. producers operated at about 86% 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production[1]	13,100	13,500	14,000	12,700	13,000
Imports for consumption	2,530	2,020	1,990	2,080	2,100
Exports	224	338	369	231	700
Consumption, apparent[2]	15,300	15,200	15,700	14,600	14,000
Stocks, producer, yearend	490	420	310	270	390
Price, average, free on board gulf coast,[3] dollars per short ton	281	232	213	578	1,100
Employment, plant, number[e]	1,600	1,600	1,600	1,600	1,600
Net import reliance[4] as a percentage of apparent consumption	14	11	11	13	9

Recycling: None.

Import Sources (2018–21): Trinidad and Tobago, 58%; Canada 40%; Venezuela, 1%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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 $3.58 and $9.85 per million British thermal units for most of the year, with an average of about $6.63 per million British thermal units. Natural gas prices in 2022 were higher than those in 2021—a result of below-average storage levels of natural gas and strong demand for U.S. liquified natural gas. The Energy Information Administration, U.S. Department of Energy, projected that Henry Hub natural gas spot prices would average around $6.00 per million British thermal units in 2023.

The weekly average gulf coast ammonia price was $1,030 per short ton at the beginning of 2022 and increased to $1,150 per short ton in late October. The average ammonia price for 2022 was estimated to be $1,100 per short ton. In 2022, 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. About one-third of the capacity additions were expected to take place in Belarus and Russia. As part of the capacity increase, several countries have proposed decarbonized ammonia plants. Consumption of ammonia for fertilizer is expected to increase by 1% per year depending on availability and cost with the largest increases expected in Latin America.

Large corn plantings maintain the continued demand for nitrogen fertilizers in the United States. According to the U.S. Department of Agriculture, U.S. corn growers planted 36.2 million hectares of corn in crop-year 2022 (July 1, 2021, through June 30, 2022), which was 4% less than the area planted in crop-year 2021. Corn acreage in crop-year 2023 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]
	2021	2022[e]	
United States	12,700	13,000	Available atmospheric nitrogen and sources of natural gas for production of ammonia were considered adequate for all listed countries.
Algeria	2,600	2,600	
Australia	1,700	1,700	
Canada	3,760	3,800	
China	42,000	42,000	
Egypt	4,000	4,000	
Germany	2,290	2,000	
India	12,100	12,000	
Indonesia	6,000	6,000	
Iran	4,000	4,000	
Malaysia	1,400	1,400	
Netherlands	2,000	2,000	
Nigeria	1,100	1,100	
Oman	1,730	1,700	
Pakistan	3,400	3,400	
Poland	2,100	2,100	
Qatar	3,270	3,300	
Russia	16,300	16,000	
Saudi Arabia	4,300	4,300	
Trinidad and Tobago	4,050	4,200	
Ukraine	2,170	2,000	
Uzbekistan	1,200	1,100	
Vietnam	1,050	1,200	
Other countries	14,500	13,000	
World total (rounded)	150,000	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 approximately $10 million in 2022. Peat was harvested and processed by 28 companies in 11 of the conterminous United States. Florida was the leading producing State. The other leading producing States were Illinois, Maine, Michigan, and Minnesota, and these top five States 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:	2018	2019	2020	2021	2022[e]
Production	389	366	354	324	340
Sales by producers	409	420	386	386	350
Imports for consumption	1,200	1,160	1,390	1,630	1,500
Exports	37	46	46	37	37
Consumption, apparent[1]	1,580	1,400	1,690	1,970	1,700
Price, average unit value, f.o.b. mine, dollars per metric ton	27.53	25.77	26.25	38.52	28
Stocks, producer, yearend	196	280	288	235	290
Employment, mine and plant, number[e]	520	520	510	510	510
Net import reliance[2] as a percentage of apparent consumption	75	74	79	84	81

Recycling: None.

Import Sources (2018–21): Canada, 96%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 was for production to average about 350,000 tons per year, and imported peat from Canada was expected to continue to account for more than 80% of domestic consumption. Imports for 2022 were estimated to have decreased to 1.5 million tons from 1.6 million tons in 2021, and exports were estimated to have remained about the same as those in 2021 at 37,000 tons. In 2022, peat stocks were estimated to have increased to approximately 290,000 tons from 235,000 tons in 2021. Based on estimated world production for 2022, the world's leading peat producers were, in descending order of production, Finland, Germany, Sweden, Latvia, Belarus, and Canada.

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. 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. Irish horticultural growers are importing peat to compensate for the lack of a domestic supply. Peat alternatives are currently not able to provide comparable crop yields in terms of growing quality and quantity.

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 2022, only about 14% of Finland's energy consumption was supplied by peat and other fossil fuels. About 53% of Finland's energy supply was generated using renewable energy sources, whereas 33% was produced by nuclear energy. Several European countries, including Belarus, Ireland, Scotland, and Sweden, were planning or implementing peatland restoration projects to help combat greenhouse-gas emissions and restore wildlife habitats. In August 2022, the United Kingdom announced a ban on peat sales to amateur gardeners by 2024 in an effort to protect peatlands. These initiatives were expected to decrease peat production across Europe in the future.

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PEAT

World Mine Production and Reserves: Reserves for countries that reported by volume only and had insufficient data for conversion to tonnage were combined and included with "Other countries."

	Mine production		Reserves[3]
	2021	2022[e]	
United States	324	340	150,000
Belarus	1,720	1,700	2,600,000
Canada	1,650	1,700	720,000
Estonia	347	350	570,000
Finland	5,430	5,400	6,000,000
Germany	2,600	2,600	([4])
Ireland	—	—	([4])
Latvia	2,000	2,000	150,000
Lithuania	479	480	210,000
Poland	1,100	1,000	([4])
Russia	1,250	1,200	1,000,000
Sweden	2,320	2,300	([4])
Ukraine	441	440	([4])
Other countries[e]	340	440	1,400,000
World total (rounded)	20,000	20,000	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% per year 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 2022, the quantity of domestic processed crude perlite sold and used was estimated to be 520,000 tons with a value of $34 million. Crude ore production was from nine mines operated by six companies in six Western States. New Mexico continued to be the leading producing State. Domestic apparent consumption of crude perlite was estimated to be 720,000 tons. Processed crude perlite was expanded at 51 plants in 27 States. The applications for expanded perlite were building construction products, 44%; horticultural aggregate, 19%; fillers, 15%; filter aids, 14%; and other, 8%. Other applications included specialty insulation and miscellaneous uses.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Mine production, crude ore	504	629	845	884	880
Sold and used, processed crude perlite	444	397	493	496	520
Imports for consumption[1]	200	180	160	170	230
Exports[1]	16	19	25	27	29
Consumption, apparent[2]	630	560	630	640	720
Price, average value, free on board mine, dollars per ton	69	64	61	64	66
Employment, mine and mill, number	130	140	140	150	150
Net import reliance[3] as a percentage of apparent consumption	30	29	21	23	28

Recycling: Not available.

Import Sources (2018–21): Greece, 92%; China, 5%; Mexico, 2%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 instead of 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

The value of total construction put in place in the United States increased by about 11% during the first 6 months of 2022 compared with that of the same period in 2021, 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 2022, the world's leading producers were, in descending order of production, China, Turkey, Greece, and the United States, accounting for about 35%, 26%, 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: Reserves data for China were revised based on Government reports.

	Production		Reserves[4]
	2021	2022[e]	
United States	[5]496	[5]520	50,000
Argentina[e]	18	20	NA
Armenia[e]	80	180	NA
China[e]	1,500	1,500	78,000
Greece[e]	700	710	120,000
Hungary[e]	77	80	49,000
Iran[e]	32	30	73,000
Mexico[e]	24	20	NA
New Zealand[e]	18	20	NA
Slovakia[e]	37	40	NA
Turkey[e]	1,100	1,100	57,000
Other countries[e]	70	40	NA
World total (rounded)	4,150	4,300	NA

World Resources:[4] Perlite occurrences in Arizona, California, Idaho, Nevada, New Mexico, and Oregon may contain large resources. Significant deposits have been reported in China, Greece, Turkey, and a few other countries. Available information was insufficient 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. Data are rounded to two significant digits.
[2]Defined as processed crude perlite sold and used + imports – exports. Data are rounded to two significant digits.
[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 2022, phosphate rock ore was mined by five companies at nine mines in four States and processed into an estimated 21 million tons of marketable product, valued at $1.9 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production, marketable	25,800	23,300	23,500	21,600	21,000
Sold or used by producers	23,300	23,400	22,600	21,900	21,000
Imports for consumption	2,770	2,140	2,520	2,460	2,400
Consumption, apparent[1]	26,000	25,500	25,100	24,400	24,000
Price, average value, f.o.b. mine,[2] dollars per metric ton	70.80	68.00	75.90	83.10	90
Stocks, producer, yearend	10,600	9,830	11,000	10,700	10,000
Employment, mine and beneficiation plant, number[e]	1,900	1,900	1,800	2,000	2,000
Net import reliance[3] as a percentage of apparent consumption	2	11	5	11	12

Recycling: None.

Import Sources (2018–21): Peru, 95%; and Morocco, 5%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
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: Domestic production and consumption of phosphate rock were lower in 2022, owing to slightly lower production of elemental phosphorus and phosphoric acid. Domestic fertilizer production and consumption also were lower because of adverse weather conditions in some areas of the United States during the spring planting season, rail delays, high fertilizer costs, and hurricane damage to some production facilities. In Idaho, all three producers continued to develop new mines that will replace existing mines within the next decade.

World production of phosphate rock was estimated to have been slightly lower in 2022. The conflict between Russia and Ukraine caused some reduction of exports of phosphate rock and fertilizers from Russia. Although fertilizer materials were exempt from sanctions, some countries did not allow Russian ships in their ports.

In 2022, the global phosphate fertilizer market experienced supply disruptions, high fertilizer prices in the first half of the year, and lower consumption in some regions. The most significant supply disruption was from China placing restrictions on exports of DAP and MAP. This reduced Chinese exports by about 5 million tons. Other countries increased exports but were unable to compensate for the loss to the world market. Global consumption of P_2O_5 contained in fertilizers was estimated to have decreased slightly to about 48 million tons in 2022.

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PHOSPHATE ROCK

World Mine Production and Reserves: Reserves for China and Tunisia were revised based on Government reports. Reserves for Israel were revised based on company reports.

	Mine production 2021	Mine production 2022[e]	Reserves[4]
United States	21,600	21,000	1,000,000
Algeria	[e]1,400	1,800	2,200,000
Australia	[e]2,500	2,500	[5]1,100,000
Brazil	[e]6,000	5,500	1,600,000
China[6]	[e]90,000	85,000	1,900,000
Egypt	[e]5,000	5,000	2,800,000
Finland	990	1,000	1,000,000
India	[e]1,400	1,400	46,000
Israel	2,430	3,000	60,000
Jordan	10,000	10,000	1,000,000
Kazakhstan	[e]1,500	1,500	260,000
Mexico	488	450	30,000
Morocco	38,100	40,000	50,000,000
Peru	4,200	4,200	210,000
Russia	[e]14,000	13,000	600,000
Saudi Arabia	[e]9,200	9,000	1,400,000
Senegal	[e]2,100	2,600	50,000
South Africa	2,130	1,600	1,600,000
Togo	[e]1,000	1,500	30,000
Tunisia	3,730	4,000	2,500,000
Turkey	[e]600	800	50,000
Uzbekistan	[e]900	900	100,000
Vietnam	[e]4,500	4,500	30,000
Other countries	1,950	1,600	2,600,000
World total (rounded)	226,000	220,000	72,000,000

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 124 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 PGMs with an estimated value of about $880 million. 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:	2018	2019	2020	2021	2022[e]
Mine production:[1]					
Palladium	14,300	14,300	14,600	13,700	11,000
Platinum	4,160	4,150	4,200	4,020	3,300
Imports for consumption:[2]					
Palladium	92,900	84,300	76,400	72,600	63,000
Platinum	58,500	42,300	64,800	67,900	56,000
PGM waste and scrap	40,700	35,200	185,000	185,000	49,000
Iridium	1,020	875	1,620	2,310	1,700
Osmium	25	([3])	1	1	—
Rhodium	14,500	15,000	20,700	16,500	13,000
Ruthenium	17,900	11,200	13,900	18,000	15,000
Exports:[4]					
Palladium	52,900	55,500	48,600	43,900	45,000
Platinum	18,900	17,400	28,900	29,400	28,000
PGM waste and scrap	31,700	20,800	33,200	37,800	38,000
Rhodium	2,010	1,210	1,480	1,350	720
Other PGMs	2,500	1,330	1,440	2,180	1,200
Consumption, apparent:[5, 6]					
Palladium	96,300	85,100	80,300	81,400	68,000
Platinum	53,700	37,000	48,200	53,500	42,000
Price, dollars per troy ounce:[7]					
Palladium	1,036.43	1,544.31	2,205.27	2,419.18	2,200
Platinum	882.66	866.94	886.02	1,094.31	980
Iridium	1,293.27	1,485.80	1,633.51	5,158.40	4,700
Rhodium	2,225.30	3,918.78	11,205.06	20,254.10	17,000
Ruthenium	244.41	262.59	271.83	576.12	600
Employment, mine, number	1,242	1,379	1,475	1,598	1,600
Net import reliance[6, 8] as a percentage of apparent consumption:					
Palladium	42	34	35	35	26
Platinum	74	67	75	72	66

Recycling: About 110,000 kilograms of palladium and platinum was recovered globally from new and old scrap in 2022, including about 40,000 kilograms of palladium and 11,000 kilograms of platinum recovered from automobile catalytic converters in the United States.

Import Sources (2018–21): Palladium: Russia, 34%; South Africa, 30%; Italy, 8%, Germany, 8%; and other, 20%. Platinum: South Africa, 34%; Germany, 18%; Switzerland, 14%; Italy, 7%; and other, 27%.

Tariff: All unwrought and semimanufactured forms of PGMs are imported duty free. See footnotes for specific Harmonized Tariff Schedule of the United States codes.

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

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PLATINUM-GROUP METALS

Government Stockpile:[9]

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Iridium	15	—	15	—	15
Platinum	261	—	261	—	261

Events, Trends, and Issues: Production at a domestic mine continued but was constrained owing to operational challenges and flooding that took place in June 2022. Production of PGMs in South Africa, the world's leading producer of PGM-containing mined material, decreased compared with that in 2021 owing to operational challenges at some mines, including disruptions to the supply of electricity, temporary closures of processing facilities, and scheduled maintenance of smelters. A slow economic recovery from coronavirus disease 2019 (COVID-19) pandemic shutdowns and declining capital investments also negatively affected production. Constrained automobile production owing to semiconductor chip shortages, declining diesel passenger vehicle production, inflation, and slow economic growth are expected to result in decreased demand for palladium, platinum, and rhodium used in catalytic converters. Demand could be offset, however, by the development of PGM-based proton-exchange membrane fuel cells (also known as polymer electrolyte membrane fuel cells) used in hydrogen storage and transportation technologies.

The estimated annual average price of ruthenium in 2022 increased by 4% compared with that in 2021, whereas the estimated prices for rhodium, platinum, palladium, and iridium decreased by 16%, 10%, 9%, and 9%, respectively.

World Mine Production and Reserves:

	Mine production				PGM reserves[10]
	Palladium		Platinum		
	2021	2022[e]	2021	2022[e]	
United States	13,700	11,000	4,020	3,300	900,000
Canada	15,000	15,000	6,000	6,000	310,000
Russia	[e]86,000	88,000	[e]21,000	20,000	5,500,000
South Africa	84,300	80,000	142,000	140,000	63,000,000
Zimbabwe	12,400	12,000	14,700	15,000	1,200,000
Other countries	2,540	2,500	4,270	4,200	NA
World total (rounded)	214,000	210,000	192,000	190,000	70,000,000

World Resources:[10] World resources of PGMs are estimated to total more than 100 million kilograms. The largest resources and 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, 7112.92.0100, 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, 7112.92.0000, and 7112.92.0100.

[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 2022, the estimated sales value of marketable potash, free on board (f.o.b.) mine, was $760 million, which was 38% higher than that in 2021. 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 muriate of potash (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 potassium sulfate or sulfate of potash (SOP) and other byproducts.

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), SOP, and potassium magnesium sulfate (SOPM) or langbeinite. MOP is an agriculturally acceptable mix of KCl (95% pure or greater) and sodium chloride for fertilizer use. The fertilizer industry used about 85% of U.S. potash sales, and the remainder was used for chemical and industrial applications. About 70% 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production, marketable[1]	520	510	460	480	440
Sales by producers, marketable[1]	520	480	500	490	440
Imports for consumption	5,710	5,150	5,370	6,480	7,000
Exports	105	145	147	112	300
Consumption, apparent[1, 2]	6,100	5,500	5,700	6,900	7,100
Price, average, f.o.b. mine, dollars per ton of K_2O equivalent:					
All products[3]	750	820	850	1,120	1,700
MOP	440	480	450	650	1,000
Employment, mine and mill, number	900	900	900	900	900
Net import reliance[4] as a percentage of apparent consumption	92	91	92	93	94

Recycling: None.

Import Sources (2018–21): Canada, 79%; Russia, 9%; Belarus, 7%; and other, 5%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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 2022, U.S. consumption was estimated to have increased by about 3% compared with that in 2021. World potash supply was affected by economic sanctions on Belarus and Russia and resulted in higher prices and lower consumption. World potash consumption in 2022 for fertilizers was estimated to have decreased to between 35 to 39 million tons from 40.6 million tons in 2021. In January 2022, the Government of Lithuania, citing national security concerns, cancelled the rail transport contract that allowed the state-run producer in Belarus to ship potash from the port of Klaipeda on the Baltic Sea, its only marine export facility. This followed the enactment of economic sanctions on Belarus in 2021 by the European Union (EU) and the United States, which banned the import of potash. Belarus was the third-leading potash supplier prior to 2022, shipping more than 6 million tons per year of K_2O equivalent. Some Belarus potash was shipped by rail through Russia to other countries in the region and from a Russian port later in the year, but exports and production of potash were significantly lower in 2022.

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POTASH

Following Russian troops taking control of parts of eastern Ukraine in February, the EU, the United States, and other countries placed economic sanctions on Russia. Fertilizer products, including potash, were exempt; however, the EU placed import quotas on potash from Russia. United States sanctions on certain Russian companies, financial institutions, and individuals limited the amount of potash that could be imported. Russia responded by suspending fertilizer exports to countries that it deemed unfriendly. Russia continued exports to China, India, and some countries in Africa and South America, but its exports were about 30% lower in 2022 compared with those in 2021. As a result of the reduction in world supplies of potash, producers in Canada announced production increases over the next year by more than 600,000 tons of K_2O equivalent. Canadian production capacity was planned to increase by more than 3 million tons per year of K_2O equivalent by 2025. Production in other exporting countries was expected to increase as well.

A new potash mine was in the development stage 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 up to 1 million tons per year of MOP. The company planned to start production in 2025.

World annual potash production capacity was projected to increase to about 66 million tons in 2025 from 64 million tons in 2022. 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.

World Mine Production and Reserves: Reserves for China were revised based on Government reports.

	Mine production		Reserves[5]	
	2021	2022[e]	Recoverable ore	K_2O equivalent
United States[1]	480	440	970,000	220,000
Belarus	[e]7,630	3,000	3,300,000	750,000
Brazil	270	270	10,000	2,300
Canada	14,200	16,000	4,500,000	1,100,000
Chile	858	850	NA	100,000
China	[e]6,000	6,000	NA	170,000
Germany	[e]2,800	2,800	NA	150,000
Israel	2,380	2,500	NA	[6]Large
Jordan	1,560	1,700	NA	[6]Large
Laos	[e]260	600	500,000	75,000
Russia	9,100	5,000	NA	400,000
Spain	365	450	NA	68,000
Other countries	350	350	1,500,000	300,000
World total (rounded)	46,300	40,000	>11,000,000	>3,300,000

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 2022, 10 operations in five States produced pumice and pumicite. Estimated production[1] was 510,000 tons with an estimated processed value of about $30 million, free on board (f.o.b.) plant. That represented an increase in both quantity and value from the 2021 reported production of 504,000 tons valued at $23.2 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production, mine[1]	496	565	578	504	510
Imports for consumption	159	136	90	87	100
Exports	11	11	8	11	15
Consumption, apparent[2]	644	690	660	581	600
Price, average unit value, f.o.b. mine or mill, dollars per metric ton	32	28	31	46	50
Employment, mine and mill, number	140	140	140	140	140
Net import reliance[3] as a percentage of apparent consumption	23	18	12	13	14

Recycling: Little to no known recycling.

Import Sources (2018–21): Greece, 92%; Iceland, 5%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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 2022 was estimated to be slightly more than that in 2021. Imports and exports were estimated to have increased compared with those in 2021. Almost all imported pumice originated from Greece in 2022 and primarily supplied markets in the eastern and gulf coast regions of the United States.

Pumice and pumicite are plentiful in the Western States, but legal challenges and public land designations could limit access to known deposits. Production of pumice and pumicite is sensitive to mining and transportation costs.

All known domestic pumice and pumicite mining in 2022 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 were 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 15 million tons in 2022, which was essentially unchanged from that in 2021. 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[7]
	2021	**2022[e]**	
United States[1]	[5]504	510	Large in the United States. Quantitative estimates of reserves for most countries were not available.
Algeria[6]	900	900	
Cameroon[6]	110	110	
Chile[6]	670	670	
Ecuador[6]	800	800	
Ethiopia	510	510	
France[6]	280	300	
Greece[6]	960	960	
Guadeloupe	200	200	
Guatemala	570	570	
Iceland	100	100	
Jordan	900	900	
Saudi Arabia[6]	550	550	
Spain	240	240	
Syria[6]	200	200	
Tanzania	160	160	
Turkey	5,400	5,400	
Uganda	1,130	1,100	
Other countries[6]	710	820	
World total (rounded)	14,900	15,000	

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]Reported.
[6]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 2022, 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 controls, frequency filters, 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:	**2018**	**2019**	**2020**	**2021**	**2022[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	16,100	54,800	114,000	69,300	83,000
Exports:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	43,400	40,900	37,100	39,300	[2]60,000
Price, dollars per kilogram:[e, 3]					
As-grown cultured quartz	300	200	200	200	200
Lumbered quartz[4]	500	500	400	300	300
Net import reliance[5] 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 (2018–21): Import statistics specific to lascas are not available because they are combined with other types of quartz. Cultured quartz crystal (piezoelectric quartz, unmounted): China,[6] 90%; Japan, 3%; Russia, 2%; and other, 5%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Quartz (including lascas)	2506.10.0050	Free.
Piezoelectric quartz, unmounted	7104.10.0000	3% ad valorem.

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QUARTZ CRYSTAL (INDUSTRIAL)

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

Government Stockpile:[7] 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 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Quartz crystal	7,127	—	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 frequency-control oscillators and vibration sensors for aerospace, automotive, and telecommunication applications. Growth of the consumer electronics market (for example, communications equipment, electronic games, personal computers, and tablet computers) is also likely to remain a factor in sustaining global production of cultured quartz crystal.

World Mine Production and Reserves:[8] This information is unavailable, but the global reserves for lascas are thought to be large.

World Resources:[8] 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. Centrosymmetric materials that have induced piezoelectricity have also been studied. 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]Export data were adjusted by the U.S. Geological Survey. The U.S. Census Bureau reported 193,000 kilograms of exports through August 2022. The data were being reviewed by the U.S. Census Bureau for errors.
[3]Price is estimated from a combination of reported prices, trade data prices, and industry trends.
[4]As-grown cultured quartz that has been processed by sawing and grinding.
[5]Defined as imports – exports.
[6]Includes Hong Kong.
[7]See Appendix B for definitions.
[8]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 2022. 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-sand concentrates in the southeastern United States. Mixed rare-earth compounds were also produced in the western United States. The estimated value of rare-earth compounds and metals imported by the United States in 2022 was $200 million, a 25% increase from $160 million in 2021. The estimated leading domestic end use of rare earths was catalysts. A significant amount of rare earths are imported as permanent magnets embedded in finished goods. Other end uses were ceramics and glass, metallurgical applications and alloys, and polishing.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:[e]					
Mineral concentrates	14,000	28,000	39,000	42,000	43,000
Compounds and metals	—	—	—	120	250
Imports:[e, 2]					
Compounds	10,800	12,200	6,510	7,690	11,000
Metals:					
Ferrocerium, alloys	297	330	271	330	420
Rare-earth metals, scandium, and yttrium	526	627	363	580	520
Exports:[e, 2]					
Ores and compounds	17,900	28,300	40,000	44,000	44,000
Metals:					
Ferrocerium, alloys	1,250	1,290	625	825	1,700
Rare-earth metals, scandium, and yttrium	28	83	25	20	21
Consumption, apparent, compounds and metals[3]	9,600	11,200	5,400	6,060	9,300
Price, average, dollars per kilogram:[4]					
Cerium oxide, 99.5% minimum	2	2	2	2	1
Dysprosium oxide, 99.5% minimum	179	239	261	400	390
Europium oxide, 99.99% minimum	53	35	31	31	30
Lanthanum oxide, 99.5% minimum	2	2	2	2	1
Mischmetal, 65% cerium, 35% lanthanum	6	6	5	6	7
Neodymium oxide, 99.5% minimum	50	45	49	49	130
Terbium oxide, 99.99% minimum	455	507	670	1,300	2,000
Employment, mine and mill, annual average, number	190	202	185	293	370
Net import reliance[5] as a percentage of apparent consumption:[6]					
Compounds and metals	100	100	100	>95	>95
Mineral concentrates	E	E	E	E	E

Recycling: Limited quantities of rare earths are recovered from batteries, permanent magnets, and fluorescent lamps.

Import Sources (2018–21): Rare-earth compounds and metals: China,[7] 74%; Malaysia, 8%; Estonia and Japan, 5% each; and other, 8%. 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 12–31–22
Rare-earth metals	2805.30.0000	5% 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:[8] In the addition to the materials listed below, the FY 2022 and FY 2023 potential acquisitions include cerium, 550 tons; lanthanum, 1,300 tons; neodymium, 600 tons; praseodymium, 70 tons; rare-earth magnet block, 100 tons; and samarium cobalt alloy, 50 tons.

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Dysprosium	0.2	20	—	—	—
Europium (gross weight)	35.8	—	—	—	—
Ferrodysprosium	0.5	—	—	—	—
Yttrium	25	25	—	—	—

Events, Trends, and Issues: Global mine production was estimated to have increased to 300,000 tons of REO equivalent. China's Ministry of Industry and Information Technology raised 2022 quotas for rare-earth mining and separation to 210,000 tons and 202,000 tons of REO equivalent, respectively. The mine production quota was allocated to 190,850 tons of light rare earths and 19,150 tons of ion-adsorption clays.

World Mine Production and Reserves: Reserves for Australia and the United States were revised based on company and Government reports.

	Mine production		Reserves[9]
	2021	2022[e]	
United States	42,000	43,000	2,300,000
Australia	[e]24,000	18,000	[10]4,200,000
Brazil	[e]500	80	21,000,000
Burma	[e]35,000	12,000	NA
Burundi	[e]200	—	NA
Canada	—	—	830,000
China	[11]168,000	[11]210,000	44,000,000
Greenland	—	—	1,500,000
India	[e]2,900	2,900	6,900,000
Madagascar	[e]6,800	960	NA
Russia	[e]2,600	2,600	21,000,000
South Africa	—	—	790,000
Tanzania	—	—	890,000
Thailand	[e]8,200	7,100	NA
Vietnam	400	4,300	22,000,000
Other countries	60	80	280,000
World total (rounded)	290,000	300,000	130,000,000

World Resources:[9] 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 3.6 million tons in the United States and more than 14 million tons in Canada.

Substitutes: Substitutes are available for many applications but generally are less effective.

[e]Estimated. E Net exporter. NA Not available. — Zero.
[1]Data include lanthanides and yttrium but exclude most scandium. See also the Scandium and Yttrium chapters.
[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]Includes Hong Kong.
[8]Gross weight. See Appendix B for definitions.
[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 2.98 million tons.
[11]Production quota; does not include undocumented production.

RHENIUM

(Data in kilograms of contained rhenium unless otherwise noted)

Domestic Production and Use: During 2022, 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 9,000 kilograms in 2022, a 3% decrease from that in 2021. 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.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production[1]	8,220	8,360	8,830	9,290	9,000
Imports for consumption					
Rhenium, unwrought and powders[2]	32,000	31,500	15,900	15,900	10,000
Ammonium perrhenate[3]	7,400	12,800	9,320	6,000	10,000
Exports	NA	NA	NA	NA	360
Consumption, apparent[4]	47,600	52,600	34,000	31,200	29,000
Price, average value, gross weight, dollars per kilogram:[5]					
Metal pellets, 99.99% pure	1,470	1,300	1,030	977	1,100
Ammonium perrhenate	1,410	1,280	1,090	866	910
Employment, number	Small	Small	Small	Small	Small
Net import reliance[6] as a percentage of apparent consumption	83	84	74	70	69

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 Canada, Estonia, France, Germany, Japan, Poland, Russia, and the United States. Rhenium-containing catalysts were also recycled. The rhenium recycled from spent catalysts was either returned to the oil companies or to the catalyst producer for production of new catalysts in what is considered a closed-loop system.

Import Sources (2018–21): Ammonium perrhenate: Kazakhstan, 27%; Poland, 16%; Canada, 15%; Germany, 15%; and other, 27%. Rhenium metal powder: Chile, 84%; Canada, 8%; Germany, 6%; and other, 2%. Total imports: Chile, 63%; Canada, 10%; Germany, 8%; Kazakhstan, 7%; and other, 12%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Salts of peroxometallic acids, other, ammonium perrhenate	2841.90.2000	3.1% ad valorem.
Rhenium, unwrought, waste and scrap; powders	8112.41.0000	Free.
Rhenium, unwrought, waste and scrap	8112.41.1000	Free.
Rhenium, unwrought and powders	8112.41.5000	3% ad valorem.
Rhenium, unwrought and powders	8112.92.5000	3% ad valorem.
Rhenium (and other metals), wrought	8112.99.9100	4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2022, the price of catalytic-grade APR averaged $910 per kilogram, a 6% increase from the annual average price in 2021. The rhenium metal pellet price averaged $1,100 per kilogram in 2022, a 15% increase from the annual average price in 2021.

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RHENIUM

In 2022, apparent consumption in the United States was 8% less than that in 2021. During 2022, the United States continued to rely on imports for much of its supply of rhenium. Canada, Chile, Germany, Kazakhstan, and Poland supplied most of the imported rhenium. Imports of APR increased by 66% in 2022 compared with those in the previous year. Imports of rhenium metal decreased by 37% in 2022 compared with those in the previous year. World rhenium production in 2022 decreased slightly compared with that in 2021.

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 that U.S. capacity was between 18,000 and 20,000 kilograms per year of rhenium. Industry sources estimated that approximately 25,000 kilograms of secondary rhenium was produced worldwide in 2022. There were no primary rhenium projects in 2022 that were expected to significantly contribute to rhenium availability in the near future.

On February 24, 2022, a final U.S. critical minerals list was published in the Federal Register (87 FR 10381). The 2022 critical minerals list was an update of the list of critical minerals published in 2018 in the Federal Register (83 FR 23295). The 2022 critical minerals list contained 50 individual mineral commodities instead of 35 minerals and mineral groups. The changes in the 2022 list from the prior list were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium. The list is to be updated every 3 years and revised as necessary consistent with available data.

World Mine Production and Reserves:

	Mine production[e,7]		Reserves[8]
	2021	2022	
United States	9,290	9,000	400,000
Armenia	260	260	95,000
Chile[9]	30,000	29,000	1,300,000
China	2,500	2,500	NA
Kazakhstan	500	500	190,000
Korea, Republic of	2,800	2,800	NA
Poland	9,290	9,500	NA
Russia	NA	NA	310,000
Uzbekistan	4,900	4,900	NA
World total (rounded)	59,500	58,000	Large

World Resources:[8] 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 not included.
[2]Includes Harmonized Tariff Schedule of the United States (HTS) code 8112.92.5000 (2018–2021) and HTS code 8112.41.5000 (2022). Does not include wrought forms or waste and scrap.
[3]The rhenium content of ammonium perrhenate is 69.42%.
[4]Defined as production + imports – exports.
[5]Average price per kilogram of rhenium in pellets or catalytic-grade ammonium perrhenate. Source: Argus Media group, Argus Metals International.
[6]Defined as imports – exports.
[7]Estimated amount of rhenium recovered in association with copper and molybdenum production. Secondary rhenium production not included.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]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 2022, 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, pyrotechnics, and specialty glass. Specialty glasses are the leading market for rubidium; rubidium carbonate may be used to reduce electrical conductivity, which improves stability and durability in fiber-optic telecommunications networks. Biomedical applications may include rubidium salts used in antishock agents and the treatment of epilepsy and thyroid disorder; rubidium-82, a radioactive isotope may be used as a blood-flow tracer in positron emission tomographic imaging; and rubidium chloride may be 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 under development with potential for entering the experimental phase by 2025.

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 may be used as an atomic resonance-frequency-reference oscillator for telecommunications network synchronization, playing a vital role in global positioning systems. Rubidium-rich feldspars may be used in ceramic applications for spark plugs and electrical insulators because of their high dielectric constant. Rubidium hydroxide may be 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 were not available. Some concentrate was imported to the United States in prior years for further processing. Industry information during the past decade suggests a domestic consumption rate of less than 2,000 kilograms per year. The United States was 100% import reliant for rubidium minerals.

In 2022, one company offered 1-gram ampoules of 99.75% (metal basis) rubidium for $100.80, an 8% increase from $93.40 in 2021, and 100-gram ampoules of the same material for $1,818.60, a 9% increase from $1,673.00 in 2021. The price for 10-gram ampoules of 99.8% (metal basis) rubidium formate hydrate was $278.25.

In 2022, the prices for 10 grams of 99.8% (metal basis) rubidium acetate, rubidium bromide, rubidium carbonate, rubidium chloride, and rubidium nitrate were $54.81, $77.70, $52.71, $67.10, and $52.50, respectively. The price for a rubidium-plasma standard solution (10,000 micrograms per milliliter) was $61.53 for 50 milliliters and $109.20 for 100 milliliters, a 7% and 17% increase, respectively, from those in 2021.

Recycling: None.

Import Sources (2018–21): No reliable data have been available to determine the source of rubidium ore or compounds 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 12–31–22**
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 subeconomic 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 2022, 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. Mining of rubidium in Namibia ceased in the early 2000s. Pollucite mining at the Tanco Mine in Canada (with the potential extraction of byproduct rubidium) ended in 2015. The Bikita Mine in Zimbabwe was depleted of pollucite ore reserves in 2018. 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 commercial stockpiles of rubidium ore, excluding those in China, may be depleted in the near future.

Throughout 2022, multiple projects that could produce rubidium as a byproduct of lepidolite, pollucite, spodumene, or zinnwaldite mining, focused primarily on lithium or cesium extraction, were in the exploration and feasibility stages, and one company was working on mine development. Beginning in late 2021 and early 2022, pollucite ore from the Tanco Mine was being shipped to China for lithium recovery.

World Mine Production and Reserves:[1] There were no official sources for rubidium production data in 2022. 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 were 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 at 42 million tons in 2022, essentially unchanged compared with that in 2021. The total value of salt sold or used was estimated to be $2.5 billion, a slight increase from $2.4 billion in 2021. Salt was produced by 26 companies that operated 64 plants in 16 States. The top producing States were Kansas, Louisiana, Michigan, New York, Ohio, Texas, and Utah. These seven States produced about 94% of the salt in the United States in 2022. The estimated percentage of salt sold or used was, by type, rock salt, 43%; salt in brine, 40%; vacuum pan salt, 9%; and solar salt, 8%.

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 91% 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, 3%; general industrial, 2%; and primary water treatment, 1%.

Salient Statistics—United States:[1]	2018	2019	2020	2021	2022[e]
Production	43,900	[e]45,000	[e]43,000	[e]42,000	42,000
Sold or used by producers	44,200	[e]45,000	[e]43,000	[e]42,000	42,000
Imports for consumption	17,900	18,700	15,800	18,100	18,000
Exports	986	1,020	1,250	1,060	700
Consumption:					
Apparent[2]	61,100	62,500	[e]58,000	[e]59,000	59,000
Reported	53,000	51,800	[e]49,000	[e]50,000	49,000
Price, average unit value of bulk, pellets and packaged salt, free on board (f.o.b.) mine and plant, dollars per metric ton:					
Vacuum and open pan salt	214.12	211.57	[e]215	[e]220	230
Solar salt	114.32	126.18	[e]120	[e]125	130
Rock salt	60.78	59.90	[e]58	[e]57	60
Salt in brine	8.30	7.56	[e]8.00	[e]8.00	8.50
Employment, mine and plant, number[e]	4,100	4,100	4,000	4,100	4,000
Net import reliance[3] as a percentage of apparent consumption	28	28	25	29	29

Recycling: None.

Import Sources (2018–21): Chile, 29%; Canada, 28%; Mexico, 13%; Egypt, 11%; and other, 19%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Salt (sodium chloride)	2501.00.0000	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Demand for salt in 2022 remained lower than 2019 levels after the coronavirus disease 2019 (COVID-19) pandemic affected production and consumption of salt throughout the world in 2020 and 2021. Increased energy costs also negatively affected salt markets as increased processing and especially transportation costs negatively affected the ability to import and export salt at competitive prices for some international transactions.

For much of the 2021–22 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 2022 were estimated to be near or slightly less than those in 2021 because demand from many local and State transportation departments were essentially unchanged from the previous year.

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SALT

For the 2022–23 winter, the National Oceanic and Atmospheric Administration predicted a La Niña weather pattern for the third 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 winter than a normal winter for the Midwest, interior Northeast along the Canadian border, and northwestern area of the United States. Within this area, only the upper Midwest and the northwestern area of the United States were predicted to experience below-average temperatures. A warmer and drier pattern than average was predicted for the southern area of the United States. These forecasts would indicate that demand for rock salt could increase slightly in the upper the Midwest and northwestern areas of the United States but decrease in the northeastern United States.

Demand for salt brine used in the chloralkali industry was expected to increase in 2023 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 2021	Mine production 2022[e]	Reserves[4]
United States[1]	[e]42,000	42,000	Large. Economic and subeconomic deposits of salt are substantial in principal salt-producing countries. The oceans contain a virtually inexhaustible supply of salt.
Australia	12,200	13,000	
Brazil	[e]7,400	7,400	
Canada	11,800	11,000	
Chile	8,570	9,000	
China	[e]64,000	64,000	
France	5,400	5,500	
Germany	[e]15,000	15,000	
India	[e]45,000	45,000	
Iran	[e]2,700	2,700	
Italy	1,900	2,000	
Mexico	[e]9,000	9,000	
Netherlands	6,120	6,200	
Pakistan	[e]3,000	3,300	
Poland	[e]4,000	4,000	
Russia	[e]6,500	6,000	
Saudi Arabia	2,330	2,400	
Spain	[e]4,200	4,200	
Turkey	[e]6,900	6,900	
Ukraine	[e]1,800	1,000	
United Kingdom	[e]2,400	2,800	
Other countries	[e]31,000	32,000	
World total (rounded)	294,000	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 2022, 960 million tons of construction sand and gravel valued at $10 billion was produced by an estimated 3,300 companies operating 6,200 pits and 200 sales and (or) distribution yards in 50 States. Leading producing States were, in order of decreasing tonnage, California, Texas, Arizona, Minnesota, Washington, Utah, Michigan, Colorado, Ohio, and New York, which together accounted for about 53% of total output. An estimated 42% of construction sand and gravel was used as portland cement concrete aggregates, 26% for road base and coverings, 13% for construction fill, 10% for asphaltic concrete aggregate and for other bituminous mixtures, and 6% for other miscellaneous uses. The remaining 3% 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 2022 was 724 million tons, a slight increase compared with that in the same period in 2021. Third-quarter shipments for consumption increased slightly compared with those in the same period in 2021. 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 construction sand and gravel and crushed stone.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production	912	914	888	942	960
Imports for consumption	6	5	5	5	4
Exports	([2])	([2])	([2])	([2])	([2])
Consumption, apparent[3]	918	919	893	946	960
Price, average unit value, dollars per metric ton	9.18	9.65	9.93	10.36	11
Employment, mine and mill, number[4]	38,600	39,600	37,900	37,800	37,000
Net import reliance[5] as a percentage of apparent consumption	1	1	1	([2])	([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 2022, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2018–21): Canada, 95%; Mexico, 2%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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)

Events, Trends, and Issues: U.S. construction sand and gravel production was about 960 million tons in 2022, a slight increase compared with that in 2021. Apparent consumption also increased to 960 million tons. Consumption of construction sand and gravel increased in 2022 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 2023, 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 reauthorizes surface transportation programs for 5 years and invests $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.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2021	2022[e]	
United States	942	960	Reserves are controlled largely by land use and (or) environmental concerns.
Other countries[7]	NA	NA	
World total	NA	NA	

World Resources:[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.

Substitutes: 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 2022.

[e]Estimated. NA Not available.
[1]See also the Sand and Gravel (Industrial) and Stone (Crushed) chapters.
[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 2022, industrial sand and gravel production was an estimated 97 million tons valued at an estimated $5.7 billion. The quantity of industrial sand and gravel sold or used increased by 30% and the value increased by 78% compared with that in 2021. Industrial sand and gravel was produced by 122 companies from 201 operations in 32 States. The leading producing States were, in descending order of production, Texas, Wisconsin, Illinois, Louisiana, Missouri, Oklahoma, Arkansas, Alabama, California, and Tennessee. Combined production from these States accounted for about 87% of total domestic sales and use. Approximately 75% of the U.S. tonnage was used as hydraulic-fracturing sand (frac sand) and well-packing and cementing sand; and 10% as glassmaking sand. Other common uses were, in decreasing quantity of use, foundry sand, whole grain fillers for building products, filtration sand, and recreational sand, which accounted for 9%, combined. Other minor uses were, in decreasing quantity of use, chemicals, abrasives, roofing granules, silicon and ferrosilicon, ceramics, fillers, filtration gravel, traction, and metallurgic flux, which accounted for 3%, combined. Other unspecified uses accounted for 3%, combined.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Sold or used	126,000	108,000	75,800	74,600	97,000
Imports for consumption	392	389	417	350	350
Exports	6,550	5,620	4,070	5,430	6,400
Consumption, apparent[2]	120,000	103,000	72,100	69,500	91,000
Price, average value, dollars per metric ton	56.10	46.10	29.50	42.40	58
Employment, quarry and mill, number[e]	8,000	7,500	4,500	5,300	6,000
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Recycled cullet (pieces of glass) represents a significant proportion of reused silica. About 33% of glass containers are recycled. Some abrasive, foundry, frac sands are recycled or reclaimed.

Import Sources (2018–21): Canada, 87%; Vietnam, 3%; Brazil, Taiwan, and Turkey, 2% each; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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 91 million tons in 2022, a 31% increase from that in 2021. The most important driving force in the industrial sand and gravel industry remained the production and sale of hydraulic-fracturing 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 coronavirus disease 2019 (COVID-19) pandemic. These restrictions resulted in a significant decline in consumption of petroleum products, which in turn prompted a decrease in demand for frac sand. In 2022, industrial sand and gravel consumption increased as demand for frac sand increased. The increased demand for frac sand also led to higher prices for frac sand. Imports of industrial sand and gravel in 2022 were an estimated 350,000 tons, unchanged from those in 2021. 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 were an estimated 6,400,000 tons, an 18% increase from those in 2021.

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 for 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 is attributed to its high quality and to the 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 industrial sand and gravel industry continued to be concerned with safety and health regulations and environmental restrictions in 2022, 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.

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. Increased efforts to reduce cost, emissions, and the risk of exposure to crystalline silica have led to an increase of undried "wet sand" being sold or used as frac sand instead of conventional "dry sand." Industrial sand was used for commercial thermal energy storage for the first time in 2022.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2021	2022[e]	
United States	74,600	97,000	Large. Industrial sand and gravel deposits are widespread.
Argentina	[e]3,600	3,900	
Australia	[e]4,000	4,000	
Bulgaria	[e]8,150	8,600	
Canada	4,650	5,000	
China	[e]87,700	88,000	
France	[e]11,000	12,000	
Germany	[e]9,870	11,000	
India	[e]11,900	12,000	
Indonesia	[e]3,540	3,500	
Italy	[e]13,000	14,000	
Malaysia	[e]3,900	4,500	
Mexico	[e]2,500	2,700	
Netherlands	[e]54,000	54,000	
Poland	[e]5,180	5,500	
Russia	[e]7,300	7,300	
South Africa	[e]2,080	2,300	
Spain	[e]5,990	6,000	
Turkey	11,200	11,000	
United Kingdom	[e]5,300	5,300	
Other countries	[e]23,200	25,000	
World total (rounded)	353,000	380,000	

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 the Sand and Gravel (Construction) chapter.
[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 2022. Scandium was last produced domestically in 1969 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 2022 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:	2018	2019	2020	2021	2022[e]
Price, yearend:					
Compounds, dollars per gram:					
Acetate, 99.9% purity, 5-gram lot size[2]	44	45	45	43	46
Chloride, 99.9% purity, 5-gram lot size[2]	125	129	133	137	140
Fluoride, 99.9% purity (99.99% purity in 2022), 1- to 5-gram lot size[3]	206	209	214	216	250
Iodide, 99.999% purity, 5-gram lot size[2]	165	157	161	161	170
Oxide, 99.99% purity, 5-kilogram lot size[4]	4.6	3.9	3.8	2.2	2.1
Metal:					
Scandium, dollars per gram:[2]					
Distilled dendritic, 2-gram lot size	226	233	233	238	260
Ingot, 5-gram lot size	132	134	134	137	150
Scandium-aluminum alloy, dollars per kilogram:[4]					
1-kilogram lot size	360	300	340	350	350
1,000-kilogram lot size	NA	NA	NA	NA	98
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2018–21): Although no definitive data exist listing import sources, imported material was mostly from Europe, China, Japan, and the Philippines.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Rare-earth metals:		
Unspecified, not alloys	2805.30.0050	5% ad valorem.
Unspecified, alloyed	2805.30.0090	5% 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 20 to 30 tons per year with a global capacity estimate of 80 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 2022 continued to decrease over a 5-year period.

In the United States, a metallurgical testing program with the goal of production of scandium from the polymetallic Elk Creek project in Nebraska continued, and additional financing for the project was announced. Probable reserves were estimated to be 36 million tons containing 70.2 parts per million (2,600 tons) of 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, efforts were ongoing—metallurgical test work was completed, and drilling continued in 2022.

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SCANDIUM

The Defense Logistics Agency-sponsored Small Business Innovative Research program is supporting business development to produce high-purity scandium from titanium dioxide acid waste and support commercial-scale efforts. In September, the Department of Defense through the Defense Manufacturing Community Support Program awarded over $4 million to the Supply Chain of Recovered Elements Consortium (SCORE) to utilize mine and industrial waste to extract scandium which would then go into the domestic aluminum alloys supply chain. Research continued to develop methods for separating scandium from coal and coal byproducts. SOFC sourcing of scandium was expanding beyond China to include Japan and the Philippines.

A global mining and polymetallic metal producer completed commissioning of a 3-ton-per-year nameplate capacity scandium commercial-scale plant at its metallurgical complex in Sorel-Tracy, Quebec, Canada, making it the first North American producer of high-purity scandium oxide that will be used to make an aluminum alloy. High-grade scandium resources in Crater Lake, Quebec, exceed 20 million tons according to a Preliminary Economic Assessment.

In Australia, several polymetallic projects were under development and seeking permitting, financing, and offtake agreements including the Sunrise, Nyngan, and Owendale projects. Sunrise Energy Metals in New South Wales has been granted Major Project Status. Additional exploration began at the Sconi project in Queensland.

In the Philippines, the Taganito high-pressure acid-leach nickel commercial plant is recovering 7 to 8 tons per year of scandium oxide. Scandium oxalate production in 2021 was 16 tons, and production in 2022 through June was 9.7 tons.

In Russia, high-purity scandium oxide was recovered from red mud at an industrial site at the Ural Aluminum Smelter by using new process technology. In Greece, a pilot-scale plant demonstrated scandium extraction from bauxite residue using sulfuric acid leaching and selective-ion recovery producing a concentrate containing 22% scandium by weight.

In China, a large state-owned enterprise in Shanghai had 50 tons per year of scandium oxide production capacity with a long-term plan to increase to 100 tons per year. Another company in Henan Province had a 10-ton-per-year scandium oxide capacity with plans to increase output to 20 tons per year.

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 2021 and 2022 were not available.

World Resources:[6] Resources of scandium were 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, the Philippines, Russia, South Africa, 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 the Rare Earths chapter. 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 were 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: Selenium is primarily recovered as a byproduct of the electrolytic refining of copper, where it accumulates in the residues of copper anodes. In 2022, two electrolytic copper refineries operated in the United States, one in Texas and one in Utah, and produced selenium-bearing anode slimes. Domestic selenium production, consumption, and stocks were withheld to avoid disclosing company proprietary data.

Selenium is used as an active ingredient in antidandruff shampoos; in agriculture as a fertilizer additive to increase plant tolerance to environmental stressors; 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 metal 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 photocells and solar cells used in electronics for its photovoltaic and photoconductive properties; in pigments to produce a red color; 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 also an essential micronutrient and is used as a dietary supplement for humans and livestock.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production, refinery[1]	W	W	W	W	W
Imports for consumption:					
Selenium	445	465	366	346	360
Selenium dioxide	12	5	18	71	10
Exports[2]	158	361	147	227	270
Consumption, apparent[3]	W	W	W	W	W
Price, average, dollars per pound:					
United States[4]	16.85	9.15	6.61	8.25	10.00
Europe[5]	17.68	9.27	6.67	8.38	9.00
Stocks, producer, yearend	W	W	W	W	W
Net import reliance[6] as a percentage of apparent consumption	>75	>50	>75	>50	>50

Recycling: Domestic production of secondary selenium was estimated to be very small because most scrap from older photocopiers and electronic materials was exported for recovery of the contained selenium.

Import Sources (2018–21): Selenium: Philippines, 21%; Mexico, 15%; Germany, 13%; China,[7] 9%; and other, 42%. Selenium dioxide: Republic of Korea, 79%; China, 8%; Germany, 6%; Philippines, 5%; and other, 2%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
Selenium	2804.90.0000	Free.
Selenium dioxide	2811.29.2000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The selenium content of domestic copper anode slimes was estimated to have increased in 2022. The annual average price for selenium in the United States was an estimated $10 per pound, an increase of 21% from that in 2021. Producers in China, which accounted for about 40% of estimated global output of refined selenium in 2022, raised their price offers for selenium to counteract increasing production costs. The supply of selenium is directly affected by the supply of the materials from which it is a byproduct, primarily copper.

In China, coronavirus disease 2019 (COVID-19) pandemic lockdowns throughout the country affected the demand for selenium from the ceramics, glass, and manganese industries, and multiple leading manganese producers in the country reportedly reduced output. The leading global end use for selenium in 2022 was estimated to be for the production of electrolytic manganese in China. In June 2022, the Government of China released a development plan for renewable energy and set goals of generating 25% of energy consumption and installing 1.2 million megawatts of capacity for wind and solar power by 2030. If realized, the proposals would likely increase the demand for selenium from the solar industry for thin-film CIGS solar panels. End uses for selenium in global consumption were, in descending order by estimated quantity, metallurgy (including electrolytic manganese metal production), glass manufacturing, agriculture, chemicals and pigments, electronics, and other applications.

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SELENIUM

World Refinery Production and Reserves: The values shown for reserves are the estimated selenium content of copper reserves, with the exception of China. Reserves for China were revised based on Government reports, and reserves for India and Sweden were revised based on company reports.

	Refinery production[e, 8]		Reserves[9]
	2021	2022	
United States	W	W	10,000
Belgium	200	200	—
Canada	57	65	6,000
China	1,260	1,300	6,100
Finland	80	65	NA
Germany	300	300	—
India	14	15	500
Japan	720	730	—
Peru	36	40	13,000
Poland	74	75	3,000
Russia	300	350	20,000
Sweden	5	5	500
Turkey	50	50	NA
Other countries[10]	21	25	22,000
World total (rounded)[11]	3,100	3,200	81,000

World Resources:[9] Reserves for selenium are based on identified copper deposits and average selenium content. Other potential sources of selenium include lead, nickel, and zinc ores. 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: Amorphous silicon and cadmium telluride are the two principal competitors with CIGS in thin-film photovoltaic solar cells. Organic pigments have been developed as substitutes for cadmium sulfoselenide pigments. Silicon is the major substitute for selenium in low- and medium-voltage rectifiers. Sulfur dioxide can be used as a replacement for selenium dioxide in the production of electrolytic manganese metal but is not as energy efficient. Other substitutes include bismuth, lead, and tellurium in free-machining alloys; bismuth and tellurium in lead-free brasses; cerium oxide as either a colorant or decolorant in glass; and tellurium in pigments and rubber.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Selenium content of copper anode slimes.

[2]Includes Schedule B code 2804.90.0000 (selenium) only because there is no exclusive Schedule B code for selenium dioxide.

[3]Production + imports (excluding selenium dioxide) – exports ± adjustments for industry stock changes.

[4]Average annual price for selenium powder, free on board, U.S. warehouse, 99.5% minimum purity. Source: Argus Media group, Argus Metals International.

[5]Average annual price for selenium powder, in warehouse, Rotterdam, 99.5% minimum purity. Source: Argus Media group, Argus Metals International.

[6]Defined as imports (excluding selenium dioxide) – exports ± adjustments for industry stock changes.

[7]Includes Hong Kong.

[8]Insofar as possible, data include refinery output only; 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 were excluded to avoid double counting.

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

[10]Refinery production data include Serbia, South Africa, and Uzbekistan. Australia, Iran, Kazakhstan, Mexico, and the Philippines may also have produced refined selenium, but output was not reported, and available information was inadequate to make reliable production estimates.

[11]Excludes U.S. production.

SILICON

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

Domestic Production and Use: Silicon materials were produced at six facilities in 2022, 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:	2018	2019	2020	2021	2022[e]
Production, ferrosilicon[1] and silicon metal[2]	430	310	277	313	310
Imports for consumption:					
Ferrosilicon, all grades	140	127	140	125	200
Silicon metal	116	124	97	96	120
Exports:					
Ferrosilicon, all grades	12	8	4	7	8
Silicon metal	45	40	31	53	49
Consumption, apparent,[3] ferrosilicon[1] and silicon metal[2]	637	517	481	475	570
Price, average, cents per pound of silicon:					
Ferrosilicon, 50% silicon[4]	104.24	102.35	103.38	137.94	NA
Ferrosilicon, 75% silicon[5]	107.58	89.15	87.40	192.28	350
Silicon metal[2, 5]	134.15	105.70	96.84	220.31	400
Stocks, producer, ferrosilicon[1] and silicon metal,[2] yearend	19	15	12	11	17
Net import reliance[6] as a percentage of apparent consumption:					
Ferrosilicon, all grades	<50	<50	>50	<50	>50
Silicon metal[2]	<25	<50	<50	<25	<50
Total	32	40	42	34	45

Recycling: Insignificant.

Import Sources (2018–21): Ferrosilicon: Russia, 40%; Canada, 14%; Brazil, 12%; Malaysia, 9%; and other, 25%. Silicon metal: Brazil, 31%; Canada, 24%; Norway, 14%; Thailand, 7%; and other, 24%. Total: Russia, 22%; Brazil, 20%; Canada, 18%; Norway, 8%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Silicon:		
More than or equal to 99.99% silicon	2804.61.0000	Free.
More than or equal to 99.00% but less than 99.99% silicon	2804.69.1000	5.3% ad valorem.
Other	2804.69.5000	5.5% ad valorem.
Ferrosilicon:		
More than 55% but less than or equal to 80% silicon:		
More than 3% calcium	7202.21.1000	1.1% ad valorem.
Other	7202.21.5000	1.5% ad valorem.
More than 80% but less than or equal to 90% silicon	7202.21.7500	1.9% ad valorem.
More than 90% silicon	7202.21.9000	5.8% ad valorem.
Other:		
More than 2% magnesium	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 2022, expressed in terms of contained silicon, was unchanged from that in 2021. One producer restarted a silicon metal production facility in early 2022 owing to increased demand for silicon metal in North America. By August 2022, average U.S. spot market prices increased by over 80% for both 75%-grade ferrosilicon and silicon metal compared with the annual averages in 2021.

Excluding the United States, ferrosilicon accounted for over 60% of world silicon production on a silicon-content basis in 2022. The leading countries for ferrosilicon production were, in descending order on a silicon-content basis, China, Russia, and Norway. For silicon metal, the leading producers were, in descending order on a silicon-content basis, China, Brazil, and Norway. China accounted for almost 70% of total global estimated production of silicon materials in 2022. Global production of silicon materials, on a silicon-content basis, was estimated to be about 4% less than that in 2021. Global production of steel, the leading use of ferrosilicon, decreased in 2022 compared with production in 2021 owing to supply chain disruptions resulting from the conflict between Russia and Ukraine and intermittent coronavirus disease 2019 (COVID-19) pandemic-related lockdowns in China.

In August, the President signed the Creating Helpful Incentives to Produce Semiconductors and Science (CHIPS) Act of 2022; the Act supports an increase in U.S. semiconductor manufacturing by providing grants for semiconductor manufacturing, grants for research investments, and tax incentives for chip manufacturing.

World Production and Reserves:

	Production[e, 7] 2021	Production[e, 7] 2022	Reserves[8]
United States	313	310	The reserves in most major producing countries are ample in relation to demand. Quantitative estimates were not available.
Australia	50	50	
Bhutan[9]	85	85	
Brazil	389	400	
Canada	49	49	
China	6,400	6,000	
France	127	120	
Germany	63	63	
Iceland	111	110	
India[9]	59	59	
Kazakhstan	122	120	
Malaysia[9]	85	92	
Norway	362	360	
Poland[9]	49	49	
Russia	644	640	
Spain	60	57	
Ukraine[9]	49	19	
Other countries	128	210	
World total (rounded)	9,150	8,800	

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. NA Not available.
[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. Average spot prices for ferrosilicon, 50% grade, were discontinued in April 2022.
[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 2022, U.S. mines produced approximately 1,100 tons of silver with an estimated value of $720 million. Silver was produced at 4 silver mines and as a byproduct or coproduct from 31 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 2,700 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 2022, the estimated domestic uses for silver were physical investment (bars), 34%; electrical and electronics, 27%; coins and medals, 13%; photovoltaics (PV), 10%; jewelry and silverware, 6%; brazing and solder, 3%; and other industrial uses and photography, 7%. 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Mine	934	981	1,080	1,020	1,100
Refinery:					
Primary	1,420	1,360	1,400	1,920	1,800
Secondary (new and old scrap)	632	627	582	908	900
Imports for consumption[2]	4,840	4,760	6,730	6,160	4,600
Exports[2]	604	220	140	137	230
Consumption, apparent[3]	5,780	6,270	8,250	7,950	6,400
Price, bullion, average, dollars per troy ounce[4]	15.73	16.24	20.58	25.23	21
Stocks, yearend:					
Industry	170	52	55	56	50
Treasury[5]	498	498	498	498	498
New York Commodities Exchange—COMEX	9,150	9,860	12,334	11,064	9,200
Employment, mine and mill, number[6]	971	995	1,180	1,440	1,300
Net import reliance[7] as a percentage of apparent consumption	73	74	80	76	69

Recycling: In 2022, approximately 900 tons of silver was recovered from new and old scrap, accounting for about 14% of apparent consumption.

Import Sources (2018–21):[2] Mexico, 47%; Canada, 21%; Poland, 5%; Chile, 4%; and other, 23%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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 2022 was $21 per troy ounce, 17% lower than the average price in 2021. The price began the year at $22.80 per troy ounce, increased to a high of $26.45 per troy ounce on March 8, then decreased to a low of $17.85 per troy ounce on September 1. The price of silver began to increase in September into December.

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SILVER

In 2022, global consumption of silver was estimated to have reached 38,000 tons, a new record and a 16% increase from that in 2021. Coin and bar consumption increased by 18% in 2022, increasing for the sixth year in a row. Physical investment in India nearly doubled compared with that in 2021. In 2022, consumption of silver for industrial uses was estimated to have increased by 5% compared with that in 2021 owing to the installation of fifth-generation (5G) telecommunications infrastructure, increased production of PV, increased production of light duty vehicles (LDVs), and more silver used in newer LDVs. Consumption of silver in jewelry and silverware was estimated to have increased by 29% and 72%, respectively.[8]

World silver mine production increased by 4% in 2022 to an estimated 26,000 tons, principally as a result of increased production from mines in Chile and other countries as silver mines were still recovering from shutdowns in 2020 in response to the coronavirus disease 2019 (COVID-19) pandemic. Domestic silver mine production was estimated to have increased by 8% in 2022 to 1,100 tons compared with 1,020 tons produced in 2021.

World Mine Production and Reserves: Reserves for Australia, China, Peru, and Poland were revised based on Government reports. Reserves for Argentina and the United States were revised based on company reports.

	Mine production		Reserves[9]
	2021	2022[e]	
United States	1,020	1,100	23,000
Argentina	[e]720	840	6,500
Australia	1,360	1,400	[10]92,000
Bolivia	1,290	1,300	22,000
Chile	1,280	1,600	26,000
China	3,500	3,600	71,000
India	[e]610	630	7,200
Mexico	6,110	6,300	37,000
Peru	3,310	3,100	98,000
Poland	1,300	1,300	65,000
Russia	1,320	1,200	45,000
Other countries	3,200	3,500	57,000
World total (rounded)	25,000	26,000	550,000

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 silver 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.

[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.

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

[8]Source: DiRienzo, Michael, and Newman, Philip, 2022, Global silver demand rising to a new high in 2022: Silver Institute press release, November 17.

[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 27,000 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 2022 was an estimated $1.4 billion[1] and the quantity produced was an estimated 11 million tons, slightly less than that in 2021. 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 nameplate capacity of 13.9 million tons per year (15.3 million short tons per year). 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 2022 quarterly reports, the estimated distribution of soda ash by end use was glass, 48%; chemicals, 28%; miscellaneous uses, 8%; distributors, 5%; soap and detergents, 5%; flue gas desulfurization, 4%; pulp and paper, 1%; and water treatment, 1%.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production[2]	11,900	11,700	9,990	11,300	11,000
Imports for consumption	51	115	[e]98	[e]130	100
Exports	6,960	7,020	5,590	6,900	6,400
Consumption:					
Apparent[3]	4,980	4,810	[e]4,480	[e]4,450	4,600
Reported	4,850	4,720	4,440	4,640	4,600
Price, average unit value of sales (natural source), free on board (f.o.b.) mine or plant:					
Dollars per metric ton	148.69	153.24	140.70	133.37	140
Dollars per short ton	134.89	139.02	127.64	120.99	130
Stocks, producer, yearend	297	289	305	278	260
Employment, mine and plant, number[e]	2,600	2,600	2,400	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 (2018–21): Turkey, 89%; Bulgaria, 3%; Mexico, 2%; and other, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022 continued at similar levels as seen before the global coronavirus disease 2019 (COVID-19) pandemic. More than one-half of U.S. production of soda ash was exported, but exports for 2022 were estimated to have decreased by 7% compared with those in 2021. Domestic consumption reported by producers and apparent consumption in 2022 were close to the amounts consumed in 2021.

China produced an estimated 27 million tons of mostly synthetic soda ash in 2022 and was the leading producing country followed by, in descending order, the United States and Turkey. Other countries annually producing 1 million tons or more were France, Germany, Italy, Poland, and Russia.

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SODA ASH

Relatively low production costs and lower environmental impacts provide U.S. 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.

After increasing capacity of natural soda ash during recent 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, have increased during the past 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:

	Mine production		
	2021	2022[e]	Reserves[5, 6]
Natural:			
United States	11,300	11,000	[7]23,000,000
Botswana	262	260	400,000
Ethiopia	[e]18	20	400,000
Kenya	[e]250	250	7,000
Turkey	[e]4,200	4,400	880,000
Other countries[8]	NA	NA	280,000
World total, natural	16,000	16,000	25,000,000
World total, synthetic	40,100	42,000	XX
World total, natural and synthetic	56,100	58,000	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 810 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.
[8]China is thought to produce natural trona but because the majority of soda ash production is synthetic, China's production is included in "World total, synthetic".

STONE (CRUSHED)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2022, 1.5 billion tons of crushed stone valued at more than $21 billion was produced by an estimated 1,340 companies operating 3,290 quarries and 170 sales and (or) distribution yards in 50 States. Leading States were, in descending order of production, Texas, Florida, Missouri, Pennsylvania, Ohio, Georgia, North Carolina, Tennessee, Kentucky, and Indiana, which together accounted for about 55% of total crushed stone output. Of the total domestic crushed stone produced in 2022, 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. An estimated 74% of crushed stone was used as a construction aggregate, mostly for road construction and maintenance; 17% for cement manufacturing; 5% for lime manufacturing; 1% for agricultural uses; and the remaining 3% for other chemical, special, and miscellaneous uses and products.

The output of crushed stone in the United States shipped for consumption in the first 9 months of 2022 was 1.14 billion tons, an increase of 3% compared with that in the same period in 2021. Third-quarter shipments for consumption increased by 3% compared with those in the same period in 2021. 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 construction sand and gravel and crushed stone.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production	1,390	1,460	1,440	1,500	1,500
Recycled material	30	31	32	33	33
Imports for consumption	21	24	20	19	18
Exports	([2])	([2])	([2])	([2])	([2])
Consumption, apparent[3]	1,440	1,510	1,490	1,550	1,600
Price, average unit value, dollars per metric ton	11.61	12.33	12.69	13.21	14.00
Employment, quarry and mill, number[4]	68,500	69,000	68,000	68,900	69,000
Net import reliance[5] as a percentage of apparent consumption	1	2	1	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 2022, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2018–21): Mexico, 53%; Canada, 28%; The Bahamas, 13%; Honduras, 5%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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.

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.

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STONE (CRUSHED)

Events, Trends, and Issues: U.S. crushed stone production was about 1.50 billion tons in 2022, essentially unchanged compared with 1.50 billion tons in 2021. Apparent consumption increased to 1.6 billion tons. Consumption of crushed stone increased in 2022 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 rates of 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 2023, 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 reauthorizes surface transportation programs for 5 years and invests $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]
	2021	2022[e]	
United States	1,500	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 2022.

[e]Estimated. NA Not available.
[1]See also the Sand and Gravel (Construction) and Stone (Dimension) chapters.
[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 2.5 million tons of dimension stone, valued at $520 million, was sold or used by U.S. producers in 2022. Dimension stone was produced by approximately 200 companies operating 231 quarries in 34 States. Leading producing States were, in descending order by tonnage, Texas, Wisconsin, Indiana, and Vermont. These four States accounted for about 68% of the production quantity and contributed about 58% of the value of domestic production. Approximately 49%, by tonnage, of dimension stone sold or used was limestone, followed by granite (19%), sandstone (18%), dolomite and slate (4% each), and the remaining 6% was divided, in descending order of tonnage, among marble, traprock, miscellaneous stone, and quartzite. By value, the leading sales or uses were for limestone (47%), followed by granite (26%), sandstone (10%), and marble and slate (5% each); the remaining 7% was divided, in descending order of total value, among dolomite, traprock, quartzite, and miscellaneous stone. Rough stone represented 59% of the tonnage and 56% 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 (66%) and in irregular-shaped stone (26%). The leading uses and distribution of dressed stone, by tonnage, were in ashlars and partially squared pieces (43%), curbing (13%), slabs and blocks for building and construction (10%), and flagging (9%).

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Sold or used by producers:[2]					
Quantity	2,660	2,520	2,130	2,330	2,500
Value, million dollars	437	415	414	466	520
Imports for consumption, value, million dollars	2,090	1,890	1,750	2,200	2,400
Exports, value, million dollars	70	59	47	47	49
Consumption, apparent, value, million dollars[3]	2,460	2,250	2,120	2,620	2,900
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	3,900	3,900	3,800	3,700	3,800
Net import reliance[5] as a percentage of apparent consumption (based on value)	82	82	80	82	82
Granite only, sold or used by producers:					
Quantity	484	430	436	464	470
Value, million dollars	108	105	110	128	130
Imports, value, million dollars	915	862	794	903	910
Exports, value, million dollars	19	17	13	11	13
Consumption, apparent, value, million dollars[3]	1,000	950	892	1,020	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)	89	89	88	87	87

Recycling: Small amounts of dimension stone were recycled, principally by restorers of old stone work.

Import Sources (2018–21, by value): All dimension stone: Brazil, 23%; China,[6] 22%; Italy, 18%; India, 14%; and other, 23%. Granite only: Brazil, 44%; India, 21%; China,[6] 19%; Italy, 6%; and other, 10%.

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 2022. 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 2022, total imports of dimension stone increased in value by about 9% compared with those in 2021. The dimension stone market continued to recover to pre-coronavirus disease 2019 (COVID-19) pandemic levels, with production having steadily increased since 2020. In 2022, dimension stone exports increased by 4% to about $49 million. Apparent consumption, by value, was estimated to be $2.9 billion in 2022—an 11% increase compared with that in 2021.

The dimension stone industry continued to be concerned with safety and health regulations and environmental restrictions in 2022, 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]
	2021	2022[e]	
United States	2,330	2,500	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 the Stone (Crushed) chapter.
[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 drilling fluids, 65%; ceramic ferrite magnets and pyrotechnics and signals, 13% each; and other uses, including electrolytic production of zinc, master alloys, pigments and fillers, and other applications, including glass, accounted for the remaining 9%.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production	—	—	—	—	—
Imports for consumption:					
Celestite[1]	16,900	7,960	1,060	106	7,200
Strontium compounds[2]	6,350	5,560	4,440	5,020	5,100
Exports, strontium compounds[3]	32	20	32	6	13
Consumption, apparent:[4]					
Celestite	16,900	7,960	1,060	106	7,200
Strontium compounds	6,320	5,540	4,410	5,010	5,100
Total	23,200	13,500	5,470	5,120	12,000
Price, average unit value of celestite imports at port of exportation, dollars per ton	78	82	89	209	140
Net import reliance[4] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2018–21): Celestite: Mexico, 100%. Strontium compounds: Germany, 47%; Mexico, 45%; China, 4%; and other, 4%. Total imports: Mexico, 75%; Germany, 21%; China, 2%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 increased significantly in 2022. Apparent consumption of strontium compounds increased slightly, but apparent consumption of celestite increased to within 10% of that in 2019. The increase in 2022 was likely the result of improved economic conditions following the economic downturn attributed to the global coronavirus disease 2019 (COVID-19) pandemic in 2020, and the prolonged economic recovery period in 2021. World celestite production in 2022 was estimated to have remained essentially unchanged from that in 2021.

On February 24, 2022, a final U.S. critical minerals list was published in the Federal Register (87 FR 10381). The 2022 critical minerals list was an update of the list of critical minerals published in 2018 in the Federal Register (83 FR 23295). The 2022 critical minerals list contained 50 individual mineral commodities instead of 35 minerals and mineral groups. The changes in the 2022 list from the prior list were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium. The list is to be updated every 3 years and revised as necessary consistent with available data.

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STRONTIUM

Imports of celestite increased significantly 2022, likely the result of increased use of celestite in natural-gas- and oil-well-drilling fluids. Drilling activity increased by nearly 60% in the first 8 months of 2022 compared with that in the same period in 2021, but still remained about 30% below that seen in the same period in 2019 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. Strontium nitrate, the second most commonly traded strontium compound, contributes a brilliant red color to fireworks and signal flares. Smaller quantities of these and other strontium compounds and strontium metal 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 slightly in 2022.

World Mine Production and Reserves:[5] Reserves for China were revised based on Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	—	—	NA
Argentina	[e]700	700	NA
China	[e]80,000	80,000	16,000,000
Iran	[e]110,000	110,000	NA
Mexico	21,400	22,000	NA
Spain	[e]130,000	130,000	NA
World total (rounded)	[e]340,000	340,000	Large

World Resources:[6] World resources of strontium may 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. NA Not available. — 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) 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]Calculated from Schedule B of the United States code 2836.92.0000 for strontium carbonate. Other strontium compounds exports are not included because these shipments likely consisted of materials misclassified as strontium compounds.

[4]Defined as imports − exports.

[5]Gross weight of celestite in metric tons.

[6]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 2022, recovered elemental sulfur and byproduct sulfuric acid were produced at 93 operations in 27 States. Total shipments were valued at about $1.3 billion. Elemental sulfur production was estimated to be 8.0 million tons; Louisiana and Texas accounted for about 46% of domestic production. Elemental sulfur was recovered, in descending order of tonnage, at petroleum refineries, natural-gas-processing plants, and coking plants by 34 companies at 88 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 accounted for 65% of domestic consumption, and byproduct sulfuric acid accounted for about 5%. The remaining 30% 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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Recovered elemental	9,000	8,110	7,310	7,470	8,000
Other forms	672	596	581	600	600
Total (rounded)	9,670	8,710	7,890	8,070	8,600
Shipments, all forms	9,690	8,700	7,900	8,060	8,500
Imports for consumption:					
Recovered elemental[e]	2,230	1,840	2,230	2,370	1,900
Sulfuric acid	996	971	1,190	1,070	1,100
Exports:					
Recovered elemental	2,390	2,200	1,310	1,900	1,600
Sulfuric acid	112	72	64	129	100
Consumption, apparent, all forms[1]	10,400	9,240	9,950	9,470	9,800
Price, average unit value, free on board, mine and (or) plant, dollars per metric ton of elemental sulfur	81.20	51.10	24.60	92.30	150
Stocks, producer, yearend	118	124	109	113	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	7	6	21	15	13

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 (2018–21): Elemental: Canada, 72%; Russia, 15%; Kazakhstan, 10%; and other, 3%. Sulfuric acid: Canada, 59%; Mexico, 19%; Spain, 7%; Germany, 4%; and other, 11%. Total sulfur imports: Canada, 68%; Russia, 10%; Kazakhstan, 7%; Mexico, 6%; and other, 9%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022 was estimated to have increased by 7% from that in 2021, and shipments increased by 5% from those in 2021. Domestic production of elemental sulfur from petroleum refineries and recovery from natural gas operations increased by 7%. Domestically, refinery sulfur production is expected to remain about the same as refining utilization remains high. 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 2022 was estimated to have decreased from that in 2021, which resulted in the lower consumption of sulfur to process the phosphate rock into phosphate fertilizers. New sulfur demand associated with phosphate fertilizer projects is expected mostly in Africa and east Asia.

World sulfur production was unchanged compared with that in 2021. In 2022, world sulfur supplies were hampered by a decrease in the sulfur trade in part related to sanctions on Russia. However, sulfur production from the Middle East will increase sulfur availability. Also, an increase in nickel production to produce battery materials will increase sulfur demand.

Contract sulfur prices in Tampa, FL, began 2022 at around $282 per long ton. The sulfur price increased to $481 per long ton in early April, and then decreased to $352 per long ton in mid-July. Fourth-quarter 2022 prices were $90 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 2022 were a result of supply issues.

World Production and Reserves:

	Production, all forms	
	2021	2022[e]
United States	8,070	8,600
Australia	900	900
Canada	4,880	4,900
Chile	1,500	1,500
China[4]	18,800	18,000
Finland	712	710
Germany	592	600
India	3,540	3,500
Iran	2,200	2,200
Japan	3,150	3,200
Kazakhstan	4,600	4,600
Korea, Republic of	3,080	3,100
Kuwait	620	600
Poland	995	1,000
Qatar	1,700	2,000
Russia	7,530	7,300
Saudi Arabia	7,000	7,000
Turkmenistan	700	700
United Arab Emirates	5,200	6,000
Other countries	5,600	5,600
World total (rounded)	81,400	82,000

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 ± 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]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 2022, and domestic production of crude talc was estimated to be nearly unchanged at 580,000 tons valued at $26 million. Talc was mined in Montana, Texas, and Vermont. Total sales (domestic and export) of talc by U.S. producers were estimated to be 560,000 tons valued at about $180 million. Talc produced and sold in the United States was used in paper, 23%; ceramics (including automotive catalytic converters), 18%; plastics, 18%; paint, 16%; rubber, 4%; and roofing, 2%. The remaining 19% was for agriculture, cosmetics, export, insecticides, and other miscellaneous uses.

One company in North Carolina mined and processed pyrophyllite in 2021. Domestic production data were withheld to avoid disclosing company proprietary data and were estimated to have increased from those in 2021. Pyrophyllite was sold for refractory, paint, and ceramic products.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production, mine	648	578	491	577	580
Sold by producers	537	515	461	556	560
Imports for consumption	313	280	189	278	330
Exports	260	229	186	232	200
Consumption, apparent[2]	590	566	464	602	690
Price, average, milled, dollars per metric ton[3]	227	240	265	321	320
Employment, mine and mill, number:[4]					
Talc	208	202	187	154	150
Pyrophyllite	30	31	31	32	30
Net import reliance[5] as a percentage of apparent consumption	9	9	1	8	19

Recycling: Insignificant.

Import Sources (2018–21): Pakistan, 44%; Canada, 28%; China,[6] 15%; and other, 13%. 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 12–31–22**
Natural steatite and talc:		
Not crushed, not powdered	2526.10.0000	Free.
Crushed or powdered	2526.20.0000	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.

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 increased recently to about 15% of total imports. Belgium and Malaysia were the primary destinations for United States talc exports, collectively receiving about one-half of exports. Imports of talc and related materials were estimated to have increased by about 19% in 2022 compared with those in 2021, whereas exports were estimated to have decreased by at least 10%. U.S. talc consumption, imports, production, and sales increased in 2022, with estimated mine production returning to 2019 levels. Apparent consumption of talc increased as trade continued to rebound in 2022 following a decrease caused by the global coronavirus disease 2019 (COVID-19) pandemic.

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TALC AND PYROPHYLLITE

The amount of talc used in paper and plastic production increased in 2021 and 2022. 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 much of their production from talc-based to corn-starch-based products.

World Mine Production and Reserves: Reserves for China were revised based on Government reports.

	Mine production[e]		Reserves[7]
	2021	2022	
United States (crude)	[8]577	[8]580	140,000
Afghanistan	628	600	Large
Brazil (crude and beneficiated)[9]	660	660	45,000
Canada (unspecified minerals)	150	150	NA
China (unspecified minerals)	1,100	1,100	56,000
Finland	[10]297	300	Large
France (crude)	350	350	Large
India[9]	1,750	1,750	110,000
Italy (includes steatite)	165	165	NA
Japan[9]	160	160	100,000
Korea, Republic of[9]	[10]355	300	81,000
Pakistan	140	230	NA
Turkey[9]	[10]220	220	NA
Other countries (includes crude)[9]	690	690	Large
World total (rounded)	[8]7,240	[8]7,300	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.
[10]Reported.

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 accessories, 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 2022 was estimated to exceed $320 million as measured by the value of imports.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Mine	—	—	—	—	—
Secondary	NA	NA	NA	NA	NA
Imports for consumption[1]	1,660	1,380	1,230	1,380	1,700
Exports[1]	681	423	417	628	480
Shipments from Government stockpile[2]	—	—	−16	−10	—
Consumption, apparent[3]	975	956	814	740	1,200
Price, tantalite, annual average, dollars per kilogram of Ta_2O_5 content[4]	214	161	158	158	150
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 account for as much as 30% of consumption by domestic primary processors.

Import Sources (2018–21): Tantalum ores and concentrates: Australia, 43%; Rwanda, 21%; Congo (Kinshasa), 12%; Mozambique, 7%; and other, 17%. Tantalum metal and powder: China,[6] 42%; Germany, 23%; Kazakhstan, 12%; Thailand, 9%; and other, 14%. Tantalum waste and scrap: Indonesia, 23%; China,[6] 17%; Japan, 15%; and other, 45%. Total: China,[6] 24%; Germany, 12%; Australia, 10%; Indonesia, 8%; and other, 46%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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	8103.99.0000	4.4% ad valorem.

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

Government Stockpile:[8]

		FY 2022		**FY 2023**	
Material	**Inventory as of 9–30–22**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Tantalum carbide powder	—	—	1.71	—	—
Tantalum niobium concentrate (gross weight)	92	—	—	—	—
Tantalum metal[9] (gross weight)	0.085	—	0.09	—	0.09
Tantalum alloy (gross weight)	0.0015	—	—	—	—

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TANTALUM

Events, Trends, and Issues: U.S. tantalum apparent consumption was estimated to have increased by 66% from that in 2021. In 2022, estimated U.S. imports for consumption increased by 25%. The tantalum imported was in the form of waste and scrap (42%), metal and powder (37%), and ores and concentrates (21%). Waste and scrap imports had the most significant increase, more than doubling from those in 2021. Estimated U.S. exports decreased by 24% in 2022. In 2022, the average monthly price of tantalum ore was valued at $150 per kilogram of Ta_2O_5 content, a decrease of 5% compared with that in 2021.

Global tantalum production and consumption were estimated to have increased in 2022 as steel production in most countries continued to rebound from decreases owing to the global coronavirus disease 2019 (COVID-19) pandemic. Buyers sought more raw material supplies after maintaining low stocks in 2021 and there was increased demand from the electronics industry. In 2022, China remained the leading export destination and accounted for approximately 20% of tantalum ores and concentrates, waste and scrap, and metal consumption. Brazil, Congo (Kinshasa), Nigeria, and Rwanda accounted for about 85% of estimated global tantalum production in 2022.

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

	Mine production		Reserves[10]
	2021	2022[e]	
United States	—	—	—
Australia	44	57	[11]99,000
Bolivia	1	1	NA
Brazil	[e]360	370	40,000
Burundi	39	39	NA
China	[e]76	78	180,000
Congo (Kinshasa)	790	860	NA
Ethiopia	32	24	NA
Mozambique	37	34	NA
Nigeria	110	110	NA
Russia	[e]39	39	NA
Rwanda	269	350	NA
Uganda	38	38	NA
World total (rounded)	1,840	2,000	NA

World Resources:[10] Identified world resources of tantalum, most of which are in Australia, Brazil, Canada, and China 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 subeconomic at 2022 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]Defined as 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]Source: CRU Group. The estimate for 2022 includes data available through April 2022.
[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 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 of contained tellurium unless otherwise noted)

Domestic Production and Use: Tellurium is primarily recovered as a byproduct of the electrolytic refining of copper, where it accumulates in the residues of copper anodes. In 2022, two electrolytic copper refineries operated in the United States, one in Texas and one in Utah, and produced copper telluride from tellurium-bearing anode slimes. Copper telluride from the Utah facility was processed by another company in Utah, and copper telluride from the Texas facility was thought to have been exported. Downstream companies refined imported commercial-grade tellurium to produce high-purity tellurium, tellurium compounds for specialty applications, and tellurium dioxide. Domestic tellurium production, consumption, and stocks were withheld to avoid disclosing company proprietary data.

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. Metallurgical 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.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production, refinery[1]	W	W	W	W	W
Imports for consumption	192	59	12	42	50
Exports	4	1	([2])	2	([2])
Consumption, apparent[3]	W	W	W	W	W
Price, average, dollars per kilogram:					
United States[4]	79.55	68.11	59.37	69.72	70
Europe[5]	73.67	60.45	56.05	67.26	66
Stocks, producer, yearend	W	W	W	W	W
Net import reliance[6] as a percentage of apparent consumption	>95	>95	>95	>95	>75

Recycling: For traditional metallurgical and chemical uses, there was little or no 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 photocopiers in Europe. A plant in the United States recycled tellurium from CdTe solar cells, but 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 (2018–21): Canada, 52%; Germany, 24%; China,[7] 12%; Philippines, 8%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
Tellurium	2804.50.0020	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The estimated tellurium content of copper telluride recovered from domestic copper anode slimes increased in 2022. In May, a company in the United States began operating a new tellurium circuit with an annual production capacity of 20 tons at its electrolytic copper refinery in Utah. The company produced copper telluride that was processed by another company in Utah and primarily supplied to the U.S. solar industry. The leading U.S. manufacturer of solar modules announced plans to expand the capacity of its existing production facilities and to build a fourth facility, contingent upon permitting and regulatory approvals. The company expected to increase its total annual capacity in the United States to approximately 10 gigawatts of solar modules by 2025.

In 2022, the annual average price for tellurium in the United States was an estimated $70 per kilogram, essentially unchanged from $69.72 per kilogram in 2021. Production costs for tellurium increased from those in 2021, but the higher costs were likely partially offset by increased supply in the United States. The supply of tellurium is directly affected by the supply of the materials from which it is a byproduct, primarily copper.

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TELLURIUM

In June 2022, the Government of China released a development plan for renewable energy and set goals of generating 25% of energy consumption and installing 1.2 billion kilowatts of capacity for wind and solar power by 2030. If realized, the proposals would likely increase the demand for tellurium from the solar industry for thin-film CdTe solar panels. China was the leading producer of refined tellurium in 2022 and accounted for 53% of estimated global output. Estimated end uses for tellurium in global consumption were solar power cells, 40%; thermoelectric production, 30%; metallurgy, 15%; rubber applications, 5%; and other, 10%.

World Refinery Production and Reserves: The values shown for reserves reflect the estimated tellurium content of copper reserves, with the exception of China and Sweden. Reserves for Sweden were reported by the only tellurium producer in the country. Reserves for China were revised based on Government reports, and reserves for Russia and South Africa were revised based on company reports. These estimates assume that more than one-half of the tellurium contained in unrefined copper anodes is recoverable.

	Refinery production[e, 8]		Reserves[9]
	2021	2022	
United States	W	W	3,500
Bulgaria	4	4	NA
Canada	44	50	800
China	330	340	3,000
Japan	68	70	—
Russia	70	80	4,500
South Africa	4	4	800
Sweden	[10]41	40	670
Uzbekistan	48	50	NA
Other countries[11]	NA	NA	19,000
World total (rounded)[12]	610	640	32,000

World Resources:[9] Reserves for tellurium are based on identified copper deposits and average tellurium content. More than 90% of tellurium has been produced from anode slimes as a byproduct of 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. Other 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. Amorphous silicon and copper-indium-gallium selenide are 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. 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.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.

[1]Refined tellurium production and estimated tellurium content of copper telluride recovered from copper anode slimes.

[2]Less than ½ unit. Export data reported by the U.S. Census Bureau in 2020 were adjusted by the U.S. Geological Survey.

[3]Production + imports – exports ± adjustments for industry stock changes.

[4]Average annual price for 99.95%-minimum-purity tellurium, free on board, U.S. warehouse. Source: Argus Media group, Argus Metals International.

[5]Average annual price for 99.99%-maximum-purity tellurium, in warehouse, Rotterdam. Source: Argus Media group, Argus Metals International.

[6]Defined as imports – exports ± adjustments for industry stock changes.

[7]Includes Hong Kong.

[8]Insofar as possible, data relate to refinery output only; countries that produced tellurium contained in blister copper, copper concentrates, copper ores, and (or) refinery residues but did not recover refined tellurium from these materials were excluded to avoid double counting.

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

[10]Reported.

[11]In addition to the countries listed, Australia, Belgium, Chile, Colombia, Germany, Kazakhstan, Mexico, the Philippines, and Poland may have produced refined tellurium, but output was not reported, and available information was inadequate to make reliable production estimates.

[12]Excludes U.S. production.

THALLIUM

(Data in kilograms unless otherwise noted)

Domestic Production and Use: There has been no domestic production of thallium since 1981. 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; 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:	2018	2019	2020	2021	2022[e]
Production, refinery	—	—	—	—	—
Imports for consumption:					
Unwrought metal and metal powders	—	—	57	—	—
Waste and scrap	23	27	—	—	13
Other articles	41	38	—	7	—
Exports:					
Unwrought metal and powders	100	290	300	190	—
Waste and scrap	853	133	359	—	—
Other articles	[1]31,400	[1]79,100	580	378	400
Consumption, estimated[2]	64	65	57	7	13
Price, metal, dollars per kilogram[e, 3]	NA	7,600	8,200	8,400	9,400
Net import reliance[4] as a percentage of estimated consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2018–2021): China, 40%; Russia, 30%; Norway, 14%; United Kingdom, 12%; and Israel, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Unwrought and powders	8112.51.0000	4% ad valorem.
Waste and scrap	8112.52.0000	Free.
Other	8112.59.0000	4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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THALLIUM

<u>Events, Trends, and Issues</u>: Despite there having been no domestic production of thallium since 1981, exports of thallium have outweighed imports in recent years, which dwindled to near zero in most recent years particularly for unwrought metal and powders. As of September 2022, however, there were no exports of unwrought metal and powders, either a result of inventory depletion or because of reduced worldwide demand. This inventory was thought to be the result of unusually high import quantities from 2008 to 2011, in part because of a global shortage of technetium-99m, which is used as a replacement for thallium in most medical imaging. Data on inventory drawdown of thallium for domestic use were not available. In 2022, estimated exports of thallium articles remained comparable to those in 2021. In 2018 and 2019, reported exports of thallium articles had been unusually high in quantity; these exports had likely been misclassified material. The minor quantities of imports suggests that inventories of thallium remain adequate for domestic needs and for production of articles for export.

The leading global uses for thallium were gamma radiation detection equipment, high-temperature superconductors, infrared optical materials, low-melting glasses, photoelectric cells, and radioisotopes. Demand for thallium for use in medical nuclear-imaging applications declined owing to superior performance and availability of alternatives, such as the medical isotope technetium-99m, although thallium continued to be used in cardiovascular stress testing. Because of thallium's unique properties, new uses for thallium continued to be investigated. In 2022, ongoing research included improvements in scintillators (for radiation detection) that contain thallium as a key component for increased efficiency, and new thallium compounds for use in optoelectronics.

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 recovered from flue dust in the roasting of copper, lead, and zinc ores. Because most producers withhold thallium production data, global production data were limited. In 2022, 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 were 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. As such, world resources of thallium are adequate to supply world requirements.

<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-99m can be used in cardiovascular-imaging applications instead of thallium. Nontoxic 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 2022, monazite may have been produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates, but thorium was not separated or recovered by any domestic facility. 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 2022 was $85,000 (based on data through August 2022), compared with $175,200 in 2021.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine (monazite)[1]	[2]520,000	[2]1,700,000	[2]960,000	W	W
Imports for consumption:					
Ore and concentrates (monazite)	1,000	—	3,000	16,000	—
Compounds (oxide, nitrate, and so forth)	9,000	3,970	1,920	5,790	2,900
Exports:					
Ore and concentrates (monazite)	520,000	1,700,000	960,000	W	W
Compounds (oxide, nitrate, and so forth)[3]	21,000	154,000	60,000	46,000	31,000
Consumption, apparent:[4]					
Ore and concentrates (monazite)	1,000	—	3,000	W	W
Compounds (oxide, nitrate, and so forth)	NA	NA	NA	NA	NA
Price, average unit value of imports, compounds, dollars per kilogram:[5]					
India	72	72	NA	NA	NA
France	29	29	29	29	26
Net import reliance[6] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2018–21): Ores and concentrates (monazite): China, 80%; United Kingdom, 15%; and Canada, 5%. Thorium compounds: France, 56%; India, 43%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 20,300 kilograms through August 2022. About one-half of the exports had a unit value of less than $50 per kilogram, so it is possible that they were misclassified. Owing to potentially misclassified material and variations in the type and purity of thorium compounds, the unit value of exports can vary 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 was recovered and consumed. Thailand 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; Thailand, Madagascar, Vietnam and Nigeria were China's leading import sources, in descending order of quantity.

The Eneabba mineral sands project (Australia) was producing monazite concentrates for export and, in April 2022, it completed a feasibility study for construction of a fully integrated rare-earths refinery. Monazite is a featured product at the Moma Mine (Mozambique); monazite resources were greater than 100 times the current mining rate (the mine increased production in the third quarter of 2022). The license application of the Kvanefjeld project (Greenland) is in arbitration. The Steenkampskraal Mine (South Africa) obtained a favorable ruling regarding its current mining rights and obtained substantial investment to progress mining activities.

Several companies and countries were active in the pursuit of commercializing a new generation of nuclear reactors that would use thorium as a fuel material. 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 an estimated 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]Estimated to be equal to exports.
[3]Includes material that may have been misclassified.
[4]Defined as production + imports – exports. Production is only for ore and concentrates. Monazite is produced for the production of rare-earth compounds and not for thorium recovery. The apparent consumption calculation for thorium compounds results in a negative value for thorium compounds.
[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]Source: 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 or 1989, respectively. Twenty-five firms accounted for over 95% of the primary tin consumed domestically in 2022. The major uses for tin in the United States were chemicals, 23%; tinplate, 22%; alloys, 11%; solder, 10%; babbitt, brass and bronze, and tinning, 7%; bar tin, 2%; and other, 25%. Based on the average S&P Global Platts Metals Week New York dealer price for tin, the estimated value of imported refined tin in 2022 was $1.3 billion, and the estimated value of tin recovered from old scrap domestically in 2022 was $330 million.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, secondary:[e]					
Old scrap	9,890	10,500	9,550	9,030	10,000
New scrap	8,100	8,100	8,000	7,600	8,000
Imports for consumption:					
Refined	36,800	34,100	31,600	38,100	34,000
Tin alloys, gross weight	1,430	1,020	843	1,100	720
Tin waste and scrap, gross weight	47,700	30,400	20,700	18,600	11,000
Exports:					
Refined	941	1,300	519	1,290	1,400
Tin alloys, gross weight	885	1,200	1,130	630	470
Tin waste and scrap, gross weight	5,980	2,470	1,200	2,800	2,900
Shipments from Government stockpile, gross weight[1]	13	18	-7	437	—
Consumption, apparent, refined[2]	42,300	43,200	40,600	47,800	43,000
Price, average, cents per pound:[3]					
New York dealer	936	868	799	1,580	1,600
London Metal Exchange (LME), cash	914	846	777	1,478	1,500
Stocks, consumer and dealer, yearend	10,100	10,300	10,400	8,900	8,600
Net import reliance[4] as a percentage of apparent consumption, refined	77	76	76	81	77

Recycling: About 18,000 tons of tin from old and new scrap was estimated to have been recycled in 2022. Of this, about 10,000 tons was recovered from old scrap at 1 detinning plant and about 22 secondary nonferrous-metal-processing plants, accounting for 22% of apparent consumption.

Import Sources (2018–21): Refined tin: Peru, 25%; Indonesia, 24%; Bolivia, 17%; Malaysia, 16%; and other, 18%. Waste and scrap: Canada, 98%; Mexico, 1%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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:[5]

Material	Inventory as of 9–30–22	FY 2022 Potential acquisitions	FY 2022 Potential disposals	FY 2023 Potential acquisitions	FY 2023 Potential disposals
Tin (gross weight)	3,578	—	4,000	—	688

Events, Trends, and Issues: The estimated amount of tin recycled domestically in 2022 increased by 8% compared with that in 2021. The estimated annual average New York dealer price for refined tin in 2022 was 1,600 cents per pound, a slight increase compared with that in 2021. The estimated annual average LME cash price for refined tin in 2022 was 1,500 cents per pound, unchanged from that in 2021. In 2022, the monthly average New York dealer tin price decreased from March to October.

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TIN

In May, a copper products manufacturer based in Germany purchased a United States metals recycling company capable of processing scrap, including tin, at the rate of 100,000 tons per year. Also in May, a company announced plans to build a $340 million electronic-waste and nonferrous-metals recycling plant in Fort Wayne, IN. The facility will have the capacity to recycle up to 45,000 tons per year of feedstock; construction was expected to begin in 2023 and conclude by 2025. In June, construction began on a secondary smelter for complex recyclable materials in Richmond County, GA. The facility will have the capacity to process up to 90,000 tons per year of recyclables and will recover multiple metals, including tin. The facility, which would cost approximately $320 million to construct, was expected to begin operations in the first half of 2024.

Throughout the year, smelters were temporarily closed in China owing to coronavirus disease 2019 (COVID-19) pandemic-related mitigation measures and annual maintenance. Intermittent truck driver strikes in Spain caused disruptions and halted shipments of tin and tungsten concentrates. In 2022, mining began from a new pit at the Penouta Mine in northwestern Spain, a deposit containing a measured and indicated resource of 76.3 million tons at 443 parts per million tin. In March, the indicated and inferred resources at the Mpama South deposit in Congo (Kinshasa) were updated to 105,000 tons of contained tin. Additionally, the company mining the deposit announced an expansion to begin in late 2023 that would increase its tin production to approximately 20,000 tons per year.

World Mine Production and Reserves: Reserves for Australia, China, Malaysia, Peru, and Russia were revised based on company and Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	—	—	—
Australia	8,772	9,700	[7]570,000
Bolivia	19,628	18,000	400,000
Brazil	15,517	18,000	420,000
Burma	[e]36,900	31,000	700,000
China	[e]90,000	95,000	720,000
Congo (Kinshasa)	[e]16,700	20,000	130,000
Indonesia	[e]70,000	74,000	800,000
Laos	[e]1,980	1,900	NA
Malaysia	5,000	5,000	NA
Nigeria	[e]1,600	1,700	NA
Peru	26,995	29,000	130,000
Russia	3,000	2,700	430,000
Rwanda	[e]2,000	2,200	NA
Vietnam	[e]5,400	5,200	11,000
Other countries	1,180	1,100	310,000
World total (rounded)	305,000	310,000	4,600,000

World Resources:[6] 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.

Substitutes: 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 change in total inventory from prior yearend inventory. If negative, increase in inventory.
[2]Defined as production from old scrap + refined tin imports – refined tin exports ± adjustments for Government and industry stock changes.
[3]Source: S&P Global Platts Metals Week.
[4]Defined as refined imports – refined exports ± adjustments for Government and industry stock changes.
[5]See Appendix B for definitions.
[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 300,000 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 2022 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, and consumer other applications. The value of imported sponge was about $250 million, a significant increase compared with $148 million in 2021.

In 2022, titanium dioxide (TiO_2) pigment production, by four companies operating five facilities in four States, was valued at about $3.4 billion. The leading uses of TiO_2 pigment were, in descending order, paints (including lacquers and varnishes), plastics, and paper. Other uses of TiO_2 pigment included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Titanium sponge metal:					
Production	W	W	W	W	W
Imports for consumption[e]	23,700	30,000	19,200	16,000	28,000
Exports	533	869	711	117	120
Consumption, apparent[2]	W	W	W	[3]16,000	[3]28,000
Consumption, reported	35,200	W	W	W	W
Price, dollars per kilogram[4]	10.70	10.70	10.60	11.20	11
Stocks, industry, yearend[e]	10,700	W	W	W	W
Employment, number[e]	150	150	150	20	20
Net import reliance[5] as a percentage of apparent consumption	>50	>50	>50	>95	>95
TiO_2 pigment:					
Production	1,150,000	1,000,000	1,000,000	1,100,000	1,100,000
Imports for consumption	268,000	226,000	262,000	251,000	260,000
Exports	528,000	401,000	386,000	494,000	420,000
Consumption, apparent[2]	890,000	825,000	876,000	857,000	940,000
Price, dollars per metric ton[4]	2,730	2,750	2,710	2,920	3,400
Producer price index (1982=100), yearend[6]	205	NA	NA	NA	NA
Employment, number[e]	3,050	3,050	3,100	3,200	3,200
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Owing to limited responses from voluntary surveys, consumption data of titanium scrap metal for the titanium metal industry were withheld. Consumption data of titanium scrap for the steel, superalloy, and other industries were not available.

Import Sources (2018–21): Sponge metal: Japan, 89%; Kazakhstan, 9%; Ukraine, 1%, and other, 1%. TiO_2 pigment: Canada, 42%; China, 16%; Germany, 10%; Belgium, 5%; and other, 27%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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% ad valorem.
TiO_2 pigments, other	3206.19.0000	6% ad valorem.
Ferrotitanium and ferrosilicon titanium	7202.91.0000	3.7% ad valorem.
Unwrought titanium metal	8108.20.0000	15% 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% ad valorem.

Depletion Allowance: Not applicable.

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TITANIUM AND TITANIUM DIOXIDE

Government Stockpile: None.

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. Rebounding demand from the aerospace and other industries resulted in a 75% increase in imports of titanium sponge compared with those in 2021. Japan (82%), Kazakhstan (9%), and Saudi Arabia (7%) were the leading import sources for titanium sponge in 2022. U.S. imports of titanium scrap were about 17,000 tons. The United Kingdom and Germany (14% each), France (11%), Canada (10%), and Japan (9%) were the leading import sources for titanium waste and scrap in 2022. In 2022, the annual average duty-paid unit value of scrap imports was about $7.50 per kilogram compared with $4.80 per kilogram in 2021. In 2022, several companies were planning to expand domestic downstream production capacity. In Pennsylvania, one company was adding 7,300 metric tons per year of ingot melting capacity as well as additional forging capabilities. Another company planned to construct a new melt facility in West Virginia, although the annual capacity was not yet available. A third company expected to complete an initial 125 tons per year of titanium powder capacity using new technology and recycled metal feedstock. Following the onset of the conflict between Russia and Ukraine, major European and domestic aerospace consumers of titanium were seeking alternative sources of supply. Prior to the conflict, Ukraine was the leading source of titanium mineral concentrates suppling Russia's titanium metal industry.

Domestic production of TiO_2 pigment in 2022 was an estimated 1.1 million tons. Although heavily reliant on imports of titanium mineral concentrates, the United States was a net exporter of TiO_2 pigments. Exports of TiO_2 pigments decreased in 2022 while imports increased.

World Sponge Metal Production and Sponge and Pigment Capacity:

	Sponge production[e]		Capacity, 2022[7]	
	2021	2022	Sponge	Pigment
United States	W	W	500	1,370,000
Australia	—	—	—	260,000
Canada	—	—	—	104,000
China	140,000	150,000	181,000	5,000,000
Germany	—	—	—	472,000
India	250	250	500	108,000
Japan	49,200	50,000	68,800	322,000
Kazakhstan	15,000	16,000	26,000	1,000
Mexico	—	—	—	300,000
Russia	27,000	25,000	46,500	55,000
Saudi Arabia	5,700	11,000	15,600	210,000
Ukraine	6,100	1,000	12,000	120,000
United Kingdom	—	—	—	315,000
Other countries	—	—	—	784,000
World total (rounded)	[8]240,000	[8]260,000	350,000	9,400,000

World Resources:[9] 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 the Titanium Mineral Concentrates chapter.
[2]Defined as production + imports – exports.
[3]Excludes domestic production of sponge in Utah.
[4]Landed duty-paid value based on U.S. imports for consumption.
[5]Defined as imports – exports.
[6]Source: U.S. Department of Labor, Bureau of Labor Statistics.
[7]Yearend operating capacity.
[8]Excludes U.S. production.
[9]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 2022, 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 California. Based on reported data through September, the estimated value of titanium mineral and synthetic concentrates imported into the United States in 2022 was $780 million. Abrasive sands, monazite, and zircon were coproducts of domestic titanium minerals mining operations. More than 95% of titanium mineral concentrates were consumed by domestic TiO_2 pigment producers. The remainder was used in welding-rod coatings and for manufacturing carbides, chemicals, and titanium metal.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production[2]	100	100	100	100	200
Imports for consumption	1,090	1,160	807	969	950
Exports, all forms[e]	32	8	18	30	120
Consumption, apparent[2, 3]	1,200	1,300	900	1,000	1,000
Price, dollars per metric ton:					
Rutile, bulk, minimum 95% TiO_2, free on board (f.o.b.) Australia[4]	1,025	1,150	1,175	1,450	1,500
Ilmenite and leucoxene, bulk, f.o.b. Australia[5]	407	478	459	595	580
Ilmenite, average unit value of imports[6]	219	186	215	240	290
Slag, 80%–95% TiO_2, average unit value of imports[6]	738	792	757	774	830
Employment, mine and mill, number	296	310	315	290	330
Net import reliance[7] as a percentage of apparent consumption	91	92	89	90	81

Recycling: None.

Import Sources (2018–21): South Africa, 39%; Australia, 15%; Madagascar, 14%; Canada, 10%; and other, 22%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 2022 was estimated to have been unchanged from that in 2021. Inventory changes were not included in the apparent consumption calculation. Exports of titanium mineral concentrates increased significantly owing to increased recovery from mine tailings.

In 2022, as of September, South Africa (37%), Madagascar (16%), Mozambique (15%), and Australia (9%) were the leading sources of titanium mineral concentrates imports to the United States. Mining and heavy-mineral-sand-processing operations were expanded near Starke, FL, and preliminary technical and economic study studies were completed at a heavy-mineral-sands project near Camden, TN. The project plans also included production of synthetic rutile from ilmenite using a proprietary process.

In 2022, China continued to be the leading producer and consumer of titanium mineral concentrates, accounting for more than one-third 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 3.4 million tons in gross weight, a decrease of 10% compared with those in 2021. As of October, Mozambique (47%), Kenya (9%), and Vietnam (8%) 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 resumed in 2022 after being delayed in 2021. Exploration projects for heavy-mineral sands were being developed in Australia, Brazil, Canada, China, Finland, Greenland, Kenya, Malawi, Mozambique, Norway, Papua New Guinea, Russia, Senegal, and Tanzania.

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TITANIUM MINERAL CONCENTRATES

World Mine Production and Reserves: Reserves for China, Madagascar, and "Other countries" were revised based on company and Government reports.

	Mine production 2021	Mine production 2022[e]	Reserves[8]
Ilmenite:			
United States[2, 9]	100	200	2,000
Australia	600	660	[10]160,000
Brazil	33	32	43,000
Canada[11]	430	470	31,000
China	3,400	3,400	190,000
India	204	200	85,000
Kenya	181	180	390
Madagascar[11]	414	300	22,000
Mozambique	1,100	1,200	26,000
Norway	468	430	37,000
Senegal	482	520	NA
South Africa[11]	900	900	30,000
Ukraine	316	200	5,900
Vietnam	122	160	1,600
Other countries	137	77	14,000
World total (ilmenite, rounded)[9]	8,900	8,900	650,000
Rutile:			
United States	([9])	([9])	([9])
Australia	190	190	[10]31,000
India	12	11	7,400
Kenya	72	73	170
Madagascar	—	—	520
Mozambique	8	8	890
Senegal	9	9	NA
Sierra Leone	123	130	490
South Africa	95	95	6,500
Tanzania	—	—	20
Ukraine	95	57	2,500
Other countries	14	14	NA
World total (rutile, rounded)[9]	618	590	49,000
World total (ilmenite and rutile, rounded)	9,500	9,500	700,000

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. — Zero.

[1]See also the Titanium and Titanium Dioxide chapter.

[2]Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data.

[3]Defined as production + imports – exports.

[4]Source: Fast Markets IM; average of yearend price.

[5]Source: 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 37 million and 9.2 million tons, respectively.

[11]Mine production of titaniferous magnetite 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. An estimated 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 2022 was approximately $800 million.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production:					
Mine	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Ores and concentrates	4,050	2,760	2,020	1,590	2,000
Other forms[1]	10,400	11,100	8,660	10,400	12,000
Exports:					
Ores and concentrates	284	583	480	441	600
Other forms[2]	3,210	2,780	2,470	2,970	4,200
Shipments from Government stockpile:[3]					
Concentrate	1,180	663	728	1,030	700
Other forms	—	—	34	93	—
Consumption:					
Reported, concentrate	W	W	W	W	W
Apparent,[4] all forms	W	W	W	W	W
Price,[5] concentrate, average in-warehouse Rotterdam, dollars per dry metric ton unit of tungsten trioxide[6]	261	198	172	225	270
Stocks, industry, concentrate and other forms, yearend	W	W	W	W	W
Net import reliance[7] 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 2022 were withheld to avoid disclosing company proprietary data.

Import Sources (2018–21): Tungsten contained in ores, concentrates, and other forms:[1] China,[8] 29%; Germany, 11%; Bolivia, 9%; Vietnam, 6%; and other, 45%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–22**
Ores	2611.00.3000	Free.
Concentrates	2611.00.6000	37.5¢/kg on 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% ad valorem.
Tungsten waste and scrap	8101.97.0000	2.8% ad valorem.

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

Government Stockpile:[9]

		FY 2022		**FY 2023**	
Material	**Inventory as of 9–30–22**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Metal powder	—	—	125	—	—
Ores and concentrates	6,000	—	1,360	—	1,130
Tungsten alloys, gross weight[10]	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 prohibiting foreign investment in exploration and mining, limiting the number of mining and export licenses and imposing quotas on concentrate production and processing. Production of tungsten concentrate outside China was estimated to have increased in 2022 but remained less than 20% of world production. The increase was from existing operations. Additional production, primarily from reopened mines in Australia, the Republic of Korea, and the United Kingdom, was forecast to begin in 2023. Scrap continued to be an important source of raw material for the world tungsten industry.

Tungsten consumption is strongly influenced by economic conditions and industrial activity. China continued to be the world's leading tungsten consumer. In 2022, China's tungsten consumption by vehicle and other manufacturing industries was negatively affected by lockdowns to control coronavirus disease 2019 (COVID-19) pandemic outbreaks. In the United States, increased oil and gas drilling and a recovery of the aerospace industry resulted in an estimated increase in tungsten consumption. Potential areas of future growth in tungsten consumption include new applications such as powders for additive manufacturing and the use of tungsten in lithium-ion batteries.

World Mine Production and Reserves: Reserves for China, Portugal, Spain, and "Other countries" were revised based on company and Government reports.

	Mine production 2021	Mine production 2022[e]	Reserves[11]
United States	—	—	NA
Austria	[e]900	900	10,000
Bolivia	1,563	1,400	NA
China	[e]71,000	71,000	1,800,000
Portugal	502	500	3,100
Russia	[e]2,300	2,300	400,000
Rwanda	[e]1,340	1,100	NA
Spain	[e]400	700	56,000
Vietnam	4,800	4,800	100,000
Other countries	973	1,400	1,400,000
World total (rounded)	83,800	84,000	3,800,000

World Resources:[11] 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. Significant tungsten resources have been identified on every continent except Antarctica.

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 change in total inventory from prior yearend inventory. If negative, increase in inventory.
[4]Defined as mine production + secondary production + imports – exports ± adjustments for Government and industry stock changes.
[5]Source: Argus Media Group, Argus Metals International.
[6]A metric ton unit of tungsten trioxide contains 7.93 kilograms of tungsten.
[7]Defined as imports – exports ± adjustments for Government and industry stock changes.
[8]Includes Hong Kong.
[9]See Appendix B for definitions.
[10]Tungsten-rhenium ingot.
[11]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: Vanadium production in Utah from the mining of uraniferous sandstones on the Colorado Plateau ceased in early 2020 and was not restarted in 2022. Secondary vanadium production continued in Arkansas, Ohio, and Pennsylvania where processed waste materials (petroleum residues, spent catalysts, utility ash) were used to produce ferrovanadium, vanadium-bearing chemicals or specialty alloys, and vanadium pentoxide. Metallurgical use, primarily as an alloying agent for iron and steel, accounted for about 94% of domestic reported vanadium consumption in 2022. Of the other uses for vanadium, the major nonmetallurgical use was in catalysts to produce maleic anhydride and sulfuric acid.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production from primary ore and concentrate	—	460	17	—	—
Production from ash, residues, and spent catalysts[e]	2,600	3,000	2,900	3,200	4,400
Imports for consumption:					
Aluminum-vanadium master alloy	281	222	101	35	30
Ash and residues[1, 2]	2,810	2,120	1,550	1,680	1,800
Ferrovanadium	2,970	2,280	1,360	2,170	2,700
Oxides and hydroxides, other	98	105	67	69	100
Vanadium chemicals[3]	992	733	942	957	790
Vanadium metal[4]	28	45	([5])	1	2
Vanadium ores and concentrates[1]	330	108	2	4	67
Vanadium pentoxide	4,600	3,620	1,670	1,740	1,500
Exports:					
Aluminum-vanadium master alloy	90	29	13	72	40
Ash and residues[1]	1,430	1,280	503	930	910
Ferrovanadium	575	295	210	173	220
Oxides and hydroxides, other	53	750	51	235	400
Vanadium metal[4]	39	27	1	4	10
Vanadium ores and concentrates[1]	48	95	92	81	140
Vanadium pentoxide	563	423	50	17	170
Consumption:					
Apparent[6]	11,900	9,790	7,670	8,340	9,500
Reported	9,280	9,900	7,920	8,030	8,400
Price, average, vanadium pentoxide,[7] dollars per pound	16.40	12.17	6.68	8.17	9.20
Stocks, yearend[8]	250	257	269	271	270
Net import reliance[9] as a percentage of apparent consumption	78	65	62	62	54

Recycling: Recycling of vanadium is mainly associated with reprocessing vanadium catalysts into new catalysts. The range in vanadium content in spent catalysts varies depending on the crude oil feedstock and the uncertainty associated with the quantity of vanadium recycled from spent chemical process catalysts was significant.

Import Sources (2018–21): Ferrovanadium: Austria, 38%; Canada, 38%; Russia, 10%; Japan, 4%; and other, 10%. Vanadium pentoxide: Brazil, 50%; South Africa, 32%; China, 6%; Russia, 4%; and other, 8%. Total: Canada, 31%; China, 13%; Brazil, 8%; South Africa, 7%; and other, 41%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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.
Vanadium pentoxide, anhydride	2825.30.0010	5.5% ad valorem.
Vanadium oxides and hydroxides, other	2825.30.0050	5.5% ad valorem.
Ferrovanadium	7202.92.0000	4.2% ad valorem.
Vanadium metal	8112.92.7000	2% ad valorem.
Vanadium and articles thereof[10]	8112.99.2000	2% ad valorem.
Vanadium chemicals	([3])	5.5% ad valorem.

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

Government Stockpile: None.

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VANADIUM

Events, Trends, and Issues: Estimated U.S. apparent consumption of vanadium in 2022 increased by 11% from that in 2021. The estimated average Chinese vanadium pentoxide price in 2022 increased by 12% compared with the 2021 price, and the estimated United States ferrovanadium price increased by 55% to $24.00 per pound in 2022 compared with that in 2021.

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 the first half of 2022, a rise in coronavirus disease 2019 (COVID-19) cases led the Chinese Government to impose COVID-19 restrictions, causing a decrease in China's steel production. The vanadium market had anticipated vanadium disruptions owing to the ongoing conflict between Russia and Ukraine. However, according to analysts, vanadium pentoxide trade flows between Russia and Czechia have been relatively unaffected by the conflict and Czechian ferrovanadium exports to customers in China, India, Japan, the Netherlands, Turkey, Ukraine, and the United States have also had limited disruptions. Uncertainty surrounding the supply of Russian material was expected to continue.

Vanadium redox flow battery (VRFB) technology continued to be an increasingly important part of large-scale energy storage as it allows for high-safety, large-scale, environmentally friendly, medium- and long-term energy storage. Installations of VRFB projects increased worldwide as energy companies looked to support renewable energy projects as many countries attempt to lower their carbon emissions.

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

	Mine production		Reserves[11]
	2021	2022[e]	(thousand metric tons)
United States	—	—	45
Australia	—	—	[12]7,400
Brazil	5,780	6,200	120
China	70,300	70,000	9,500
Russia	20,100	17,000	5,000
South Africa	8,800	9,100	3,500
World total (rounded)	105,000	100,000	26,000

World Resources:[11] 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.

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]Reported by the U.S. Census Bureau as metric tons of vanadium pentoxide. To convert vanadium pentoxide content to vanadium content multiply by 0.56.
[2]Includes estimates for data suppressed by U.S. Census Bureau in the years 2020 through 2022.
[3]Includes Harmonized Tariff Schedule of the United States codes for chloride oxides and hydroxides of vanadium (2827.49.1000), hydrides and nitrides of vanadium (2850.00.2000), vanadium sulfates (2833.29.3000), vanadium chlorides (2827.39.1000) and vanadates (2841.90.1000).
[4]Includes waste and scrap.
[5]Less than ½ unit.
[6]Defined as primary production + secondary production + imports – exports ± adjustments for industry stock changes.
[7]Chinese annual average vanadium pentoxide prices. Source: CRU Group.
[8]Includes ferrovanadium, vanadium-aluminum alloy, other vanadium alloys, vanadium metal, vanadium pentoxide, and other specialty chemicals.
[9]Defined as imports – exports ± adjustments for industry stock changes.
[10]Aluminum-vanadium master alloy consisting of 35% aluminum and 64.5% vanadium and is the main master alloy for the vanadium industry. Unwrought aluminum-vanadium master alloy (Harmonized Tariff Schedule of the United States code 7601.20.9030) was not included.
[11]See Appendix C for resource and reserve definitions and information concerning data sources.
[12]For Australia, Joint Ore Reserves Committee or equivalent reserves were 1.7 million tons.

VERMICULITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: One company located in 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, whether produced in the United States or imported, 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), 25%; insulation, 13%; and other, 30%.

Salient Statistics—United States:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production[1, 2]	100	100	100	100	100
Imports for consumption[e]	37	39	40	33	30
Exports[e]	13	8	8	10	7
Consumption:					
Apparent, concentrate[e, 3]	120	130	130	120	120
Reported, exfoliated	79	79	81	78	80
Price, range of value, concentrate, ex-plant, dollars per metric ton	140–575	NA	NA	NA	NA
Employment, number[e]	70	70	70	70	50
Net import reliance[4] as a percentage of apparent consumption[e, 5]	20	20	20	20	20

Recycling: Insignificant.

Import Sources (2018–21): South Africa, 64%; Brazil, 35%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–22**
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: In recent years, two companies mined crude vermiculite domestically; however, a company with operations in South Carolina did not expect to produce vermiculite in 2022. Data for U.S. exports and imports of vermiculite were combined with data for other mineral products by the U.S. Census Bureau. U.S. imports were estimated to be about 30,000 tons in 2022, a decrease which could be related to disruptions in the global supply chain. Most imports came from Brazil and South Africa in 2022. Historically, South Africa was the leading principal source of imports; however, in 2022, Brazil supplied more imports than South Africa.

Exploration and development of vermiculite deposits containing medium, large, and premium (coarser) grades (greater than 5-millimeter particle size) are likely to continue because of the higher demand for those grades. Demand for vermiculite remains strong. With less domestic production, as well as global supply issues, vermiculite exfoliation operations are experiencing difficulties obtaining crude vermiculite (especially medium and coarse grade), which is increasing lead times and could result in consumers using substitute materials. 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: Reserves data for China were revised based on Government reports.

	Mine production		Reserves[6]
	2021	2022[e]	
United States	[1, 2]100	[1, 2]100	25,000
Brazil	60	60	6,600
Bulgaria	10	10	NA
China	39	39	340
India	1	3	1,600
Mexico	([7])	([7])	NA
Russia	29	29	NA
South Africa	160	160	14,000
Turkey	19	19	NA
Uganda	14	14	NA
Uzbekistan	2	2	NA
Zimbabwe	30	30	NA
World total (rounded)	464	470	NA

World Resources:[6] In addition to the producing mine in Virginia, there are vermiculite occurrences in Colorado, Nevada, North Carolina, South Carolina, Texas, and Wyoming that contain estimated resources of 2 million to 3 million tons. Significant deposits have been reported in Australia, 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.

WOLLASTONITE

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Wollastonite was mined by two companies in New York during 2022. 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 in 2021. 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 slightly in 2022 compared with that in 2021. 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 2022. 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 $340 to $370 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 60 people were employed at wollastonite mines and mills in 2022 (excluding office workers) in the United States.

Recycling: None.

Import Sources (2018–21): Comprehensive trade data were not available, but wollastonite was primarily imported from Canada and Mexico.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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 August 2022 increased by 2.7% compared with those during the same period in 2021 with the largest increase in starts being in two- to four-unit dwellings. 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. However, sales of wollastonite were thought to be slightly lower for primary iron and steel production, which decreased by 3% in the first 7 months of 2022 compared with production during the same period of 2021. The production of motor vehicles and parts, which contain wollastonite in friction products and plastic and rubber components, increased by 3% in the first 7 months of 2022. Plastics production was expected to be slightly higher in 2022 than that in 2021.

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 900,000 to 1,000,000 tons, higher than those in 2021.

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]
	2021	2022	
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	110,000	120,000	
Mexico	103,000	100,000	
Other countries	15,000	20,000	
World total (rounded)[2]	1,140,000	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. There is no commercial separation facility in the United States, and rare-earth concentrates were exported for processing.

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:	**2018**	**2019**	**2020**	**2021**	**2022[e]**
Production, mine	NA	NA	NA	NA	NA
Imports for consumption, yttrium, alloys, compounds, and metal[e, 2]	450	360	650	670	1,000
Exports, compounds[e, 3]	14	6	1	9	4
Consumption, apparent[e, 4]	400	400	600	700	1,000
Price, average, dollars per kilogram:[5]					
Y_2O_3, minimum 99.999% purity	3	3	3	6	13
Yttrium metal, minimum 99.9% purity	36	34	34	39	43
Net import reliance[6, 7] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Insignificant.

Import Sources (2018–21):[8] Yttrium compounds: China,[9] 94%; Germany, 3%; Republic of Korea and Japan, 1% each; 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 12–31–22**
Rare-earth metals, unspecified:		
Not alloyed	2805.30.0050	5% ad valorem.
Alloyed	2805.30.0090	5% 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	2846.90.8090	3.7% ad valorem.

Depletion Allowance: Monazite, thorium content, 22% (domestic), 14% (foreign); yttrium, rare-earth content, 14% (domestic and foreign); and xenotime, 14% (domestic and foreign).

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YTTRIUM

Government Stockpile:[10]

		FY 2022		FY 2023	
Material	**Inventory as of 9–30–22**	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Yttrium	25	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 each increased compared with those in 2021. China's Ministry of Industry and Information Technology raised quotas for rare-earth mining and separation to 210,000 tons and 202,000 tons of rare-earth-oxide equivalent, respectively. The yttrium content of the production quota was not specified. Mine production was allocated to 190,850 tons of light rare earths and 19,150 tons of ion-adsorption clays.

In 2022, China's exports of yttrium compounds and metal were estimated to be 2,400 tons of Y_2O_3 equivalent, and the leading export destinations were, in descending order, Japan, the United States, the Republic of Korea, and Germany. In 2021, China's exports of yttrium compounds were 2,100 tons of Y_2O_3 equivalent.

World Mine Production and Reserves:[11] World mine production of yttrium contained in rare-earth mineral concentrates was estimated to be 10,000 to 15,000 tons. Most of this production took place in China and Burma. Global reserves of Y_2O_3 were not quantified; however, the leading countries for total rare-earth-oxide reserves included Australia, Brazil, China, Russia, and Vietnam. 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 the Rare Earths chapter; 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, 2021, and 2022, domestic production of mineral concentrates was stockpiled or exported. For 2018 to 2022, 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 (2018–2021), 2846.90.8060 (2018–2021), 2846.90.8075 (2022), and 2846.90.8090 (2022).
[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 2022, seven companies operated 10 zeolite mines in six States and produced an estimated 86,000 tons of natural zeolites. Total production increased slightly compared with production in 2021. Chabazite was mined in Arizona, and clinoptilolite was mined in California, Idaho, New Mexico, Oregon, and Texas. Small quantities of erionite, ferrierite, mordenite, and phillipsite were likely also produced. The three leading companies accounted for approximately 80% of total domestic production.

An estimated 79,000 tons of natural zeolites were sold in the United States during 2022, 6% more than the sales in 2021. Domestic uses were, in descending order of estimated quantity, animal feed, odor control, water purification, unspecified end uses (such as ice melt, soil amendment, and synthetic turf), pet litter, fertilizer carrier, wastewater treatment, air filtration and gas absorbent, oil and grease absorbent, fungicide or pesticide carrier, aquaculture, and desiccant. Animal feed, odor control, and water purification applications accounted for about 70% of the domestic sales tonnage.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production, mine	86,100	87,800	86,700	85,300	86,000
Sales, mill	80,500	77,100	75,300	73,900	79,000
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]	80,500	77,100	75,300	74,000	79,000
Price, range of value, dollars per metric ton[e, 2]	50–300	50–300	50–300	50–300	50–300
Employment, mine and mill, number[e, 3]	110	120	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 (2018–21): Comprehensive trade data were not available for natural zeolite minerals because they were imported and exported under a generic Harmonized Tariff Schedule of the United States code and Schedule B number, 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 12–31–22
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Production almost tripled from 1992 through 2022 owing to increased sales for animal feed, odor control, and water purification applications. Domestic natural zeolite production has remained steady in recent years. However, sales for natural zeolites have waned over the last few years in pet litter and wastewater cleanup applications as a result of competition from other products such as clays and synthetic zeolites. Reported sales of natural zeolites products for the use of synthetic turf, pool filter media, and traction control have become more common within the past 5 years. The increase in sales in 2022 was the result of the expansion of natural zeolites into other applications.

World Mine Production and Reserves: Many countries either do not report production of natural zeolites, report zeolites as part of a pooled group of mineral commodities often listed as “other,” or report production 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 be comparable to U.S. production data, which are the quantities of natural zeolites used in high-value applications.

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ZEOLITES (NATURAL)

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 these deposits valuable.

	Mine production[e]		Reserves[5]
	2021	2022	
United States	[6]85,300	86,000	Two of the leading companies in the United States reported combined reserves of 80 million tons in 2022; total U.S. reserves likely were substantially larger. World data were unavailable, but reserves were estimated to be large.
China	52,000	52,000	
Cuba	100,000	100,000	
Georgia	130,000	130,000	
Hungary	27,000	27,000	
Indonesia	130,000	130,000	
Jordan	12,000	12,000	
Korea, Republic of	130,000	130,000	
New Zealand	100,000	100,000	
Russia	35,000	35,000	
Slovakia	150,000	150,000	
Turkey	46,000	50,000	
Other countries	5,500	6,000	
World total (rounded)	1,000,000	1,000,000	

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 metric ton for the past 5 years were an estimated $125 in 2018, 2019, 2020, and 2021 and $130 in 2022. 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.

[6]Reported.

ZINC

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

Domestic Production and Use: The estimated value of zinc mined in 2022 was about $3.2 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 to produce galvanized steel, followed by brass and bronze, zinc-base alloys, and other uses.

Salient Statistics—United States:	2018	2019	2020	2021	2022[e]
Production:					
Zinc in ores and concentrates	824	753	723	704	770
Refined zinc[e, 1]	116	115	180	220	220
Imports for consumption:					
Zinc in ores and concentrates	([2])	([2])	3	13	6
Refined zinc	775	830	700	702	700
Exports:					
Zinc in ores and concentrates	806	792	546	644	660
Refined zinc	23	5	2	13	10
Shipments from Government stockpile[3]	—	—	—	—	1
Consumption, apparent, refined zinc[4]	868	939	878	908	910
Price, average, cents per pound:					
North American[5]	141.0	124.1	110.8	145.8	190
London Metal Exchange (LME), cash	132.7	115.6	102.7	136.3	160
Stocks, reported producer and consumer, refined zinc, yearend	119	116	120	110	100
Employment, number:					
Mine and mill[6]	2,630	2,470	2,360	2,470	2,600
Smelter, primary	250	250	220	220	220
Net import reliance[7] as a percentage of apparent consumption:					
Ores and concentrates	E	E	E	E	E
Refined zinc	87	88	79	76	76

Recycling: In 2022, 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 (2018–21): Ores and concentrates: Peru, 71%; Canada, 15%; China, 7%, Taiwan, 4%; and other, 3%. Refined metal: Canada, 66%; Mexico, 16%; Peru, 6%; Spain, 6%; and other, 6%. Waste and scrap (gross weight): Canada, 62%; Mexico, 36%; and other, 2%. Combined total (includes gross weight of waste and scrap): Canada, 66%; Mexico, 16%; Peru, 6%; Spain, 6%; and other, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
Zinc ores and concentrates, zinc content	2608.00.0030	Free.
Zinc oxide; zinc peroxide	2817.00.0000	Free.
Zinc sulfate	2833.29.4500	1.6% ad valorem.
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.

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

Government Stockpile:[8]

		FY 2022		FY 2023	
Material	Inventory as of 9–30–22	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Zinc	6.46	—	7.25	—	2.27

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ZINC

<u>Events, Trends, and Issues</u>: On February 24, 2022, a final U.S. critical minerals list was published in the Federal Register (87 FR 10381). The 2022 critical minerals list was an update of the list of critical minerals published in 2018 in the Federal Register (83 FR 23295). The 2022 critical minerals list contained 50 individual mineral commodities instead of 35 minerals and mineral groups. The changes in the 2022 list from the prior list were the addition of nickel and zinc and the removal of helium, potash, rhenium, strontium, and uranium. The list is to be updated every 3 years and revised as necessary consistent with available data.

U.S. zinc mine production increased by 9% in 2022 compared with that in 2021. Zinc production at the Red Dog zinc-lead mine in Alaska, the largest zinc mine in the United States, increased notably compared with that in 2021 owing to higher mill throughput and zinc ore grades. The owner of the Empire State zinc mine in New York received permitting to begin open pit mining activities. An open pit mine would operate alongside the active underground mine and was expected to contribute to an increase in mill throughput in the first half of 2023. Several other zinc exploration and mine expansion projects were in active development in the United States during 2022. The North American price for Special High Grade (SHG) zinc was estimated to have increased by 30% in 2022 from that in 2021. The North American premium to the LME cash price reached historical highs in 2022 amid decreasing stocks on the London Metal Exchange, reduced production by zinc smelters in Europe because of high energy costs, and the permanent closure of a zinc smelter in Canada. Other zinc smelters in Canada and Mexico reported equipment and operational issues that negatively affected production during the year.

According to the International Lead and Zinc Study Group,[9] estimated global refined zinc production in 2022 was forecast to decrease by 2.7% to 13.49 million tons and estimated metal consumption to decrease by 1.9% to 13.79 million tons, resulting in a production-to-consumption deficit of 297,000 tons.

<u>World Mine Production and Reserves</u>: Reserves for Australia, Bolivia, Canada, China, India, Kazakhstan, Mexico, Peru, Sweden, the United States, and “Other countries” were revised based on company and Government reports.

	Mine production[10]		Reserves[11]
	2021	2022[e]	
United States	704	770	7,300
Australia	1,320	1,300	[12]66,000
Bolivia	500	520	NA
Canada	310	250	1,800
China	4,140	4,200	31,000
India	777	830	9,600
Kazakhstan	194	200	7,400
Mexico	724	740	12,000
Peru	1,530	1,400	17,000
Russia	280	280	22,000
Sweden	234	240	4,000
Other countries	1,960	2,000	30,000
World total (rounded)	12,700	13,000	210,000

<u>World Resources</u>:[10] Identified zinc resources of the world are about 1.9 billion tons.

<u>Substitutes</u>: 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 substitutes for zinc-base diecasting alloys. Many elements are substitutes for zinc in chemical, electronic, and pigment uses.

[e]Estimated. E Net exporter. NA Not available. — Zero.
[1]Includes primary and secondary zinc metal production.
[2]Less than ½ unit.
[3]Defined as changes in total inventory from prior yearend inventory. If negative, increase in inventory.
[4]Defined as refined production + refined imports – refined exports ± adjustments for Government stock changes.
[5]Source: S&P Global Platts Metals Week, North American SHG zinc; based on the LME cash price plus premium.
[6]Includes mine and mill employment at zinc-containing deposits. Excludes office workers. Source: Mine Safety and Health Administration.
[7]Defined as imports – exports ± adjustments for Government stock changes.
[8]See Appendix B for definitions.
[9]Source: International Lead and Zinc Study Group, 2022, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 12, [4] p.
[10]Zinc content of concentrates and direct shipping ores.
[11]See Appendix C for resource and reserve definitions and information concerning data sources.
[12]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 23 million tons.

ZIRCONIUM AND HAFNIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2022, 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 were 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:	2018	2019	2020	2021	2022[e]
Production, zirconium ores and concentrates (ZrO_2 content)[1]	[2]100,000	<100,000	<100,000	<100,000	<100,000
Imports:					
Zirconium ores and concentrates (ZrO_2 content)[1]	26,400	22,600	15,600	18,500	35,000
Zirconium, unwrought, powder, and waste and scrap	1,880	1,820	2,030	746	290
Zirconium, wrought	282	289	302	265	300
Hafnium, unwrought, powder, and waste and scrap	42	32	16	23	33
Hafnium, wrought	NA	NA	NA	NA	2
Exports:					
Zirconium ores and concentrates (ZrO_2 content)[1]	77,500	40,500	12,200	10,000	14,000
Zirconium, unwrought, powder, and waste and scrap	556	897	664	589	1,200
Zirconium, wrought	1,150	816	838	966	820
Consumption, apparent,[3] zirconium ores and concentrates (ZrO_2 content)[1]	[2]100,000	<100,000	<100,000	<100,000	<100,000
Price:					
Zircon, dollars per metric ton (gross weight):					
Premium grade, cost, insurance, and freight, China[4]	1,948	1,933	1,843	2,025	2,270
Imported[5]	1,290	1,490	1,380	1,380	1,950
Zirconium, sponge, ex-works China,[4] dollars per kilogram	35	33	21	31	29
Hafnium, unwrought,[4] dollars per kilogram	838	775	750	950	1,900
Net import reliance[6] as a percentage of apparent consumption:					
Zirconium ores and concentrates	E	E	<25	<25	<50
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 limited but could not be quantified.

Import Sources (2018–21): Zirconium ores and concentrates: South Africa, 51%; Senegal, 25%; Australia, 21%; Russia, 2%; and other, 1%. Zirconium, unwrought, including powder: China, 89%; Germany, 8%; France, 1%; Japan, 1%, and other, 1%. Zirconium, wrought: France, 62%; Germany, 19%; Belgium, 6%; Canada, 4%; and other, 9%. Hafnium, unwrought: Germany, 36%; France, 30%; China, 26%; Russia, 3%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–22
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	8112.31.0000	Free.
Hafnium, other	8112.39.0000	4% ad valorem.

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

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ZIRCONIUM AND HAFNIUM

Government Stockpile: None.

Events, Trends, and Issues: Global mine production of zirconium mineral concentrates increased slightly in 2022 compared with that in 2021. 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 at incorporated mobile mining units. Near Camden, TN, a pilot facility was commissioned at the Titan heavy-mineral-sands project to demonstrate mineral separations. U.S. imports and exports of zirconium ores and concentrates increased significantly in 2022. Australia, Senegal, and South Africa continued to be the leading import sources of zirconium ores and mineral 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 zirconium metal including waste and scrap under the Harmonized System code 8109 were China, France, Germany, South Africa, and the United States. Vietnam and the United States led the global importers of zirconium metal.

World Mine Production and Reserves: World primary hafnium production data were not available, and quantitative estimates of hafnium reserves were not available. Zirconium reserves for Australia, Senegal and "Other countries" were revised based on company and Government reports.

	Zirconium ores and zircon concentrates, mine production[e] (thousand metric tons, gross weight)		Zirconium reserves[7] (thousand metric tons, ZrO_2 content)[1]
	2021	2022	
United States	<100	<100	500
Australia	500	500	[8]48,000
China	140	140	500
Indonesia	55	60	NA
Mozambique	100	100	1,800
Senegal	64	70	2,600
South Africa	320	320	5,900
Other countries	150	160	8,500
World total (rounded)	[9]1,300	[9]1,400	68,000

World Resources:[7] 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 the nearest hundred thousand tons to avoid disclosing company proprietary data.
[3]Defined as production + imports – exports.
[4]Source: Argus Media group, Argus Metals International, average of yearend price.
[5]Unit value based on annual United States imports for consumption from Australia, Senegal, and South Africa.
[6]Defined as imports – exports.
[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 24 million tons, gross weight.
[9]Excludes U.S. production.

APPENDIX A

Abbreviations and Units of Measure

1 carat (metric) (diamond)	= 200 milligrams
1 flask (fl)	= 76 pounds, avoirdupois, or 34.47 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) 2022 is from October 1, 2021, through September 30, 2022. FY 2023 is from October 1, 2022, through September 30, 2023.

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. The Bureau of Land Management will continue to deliver helium from private storage until all Cliffside Field assets are sold or disposed of. It is expected that all Cliffside Field assets will be disposed of in FY 2023.

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 650 million tons of copper have been produced worldwide, but world copper reserves in 2022 were estimated to be 890 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.

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*

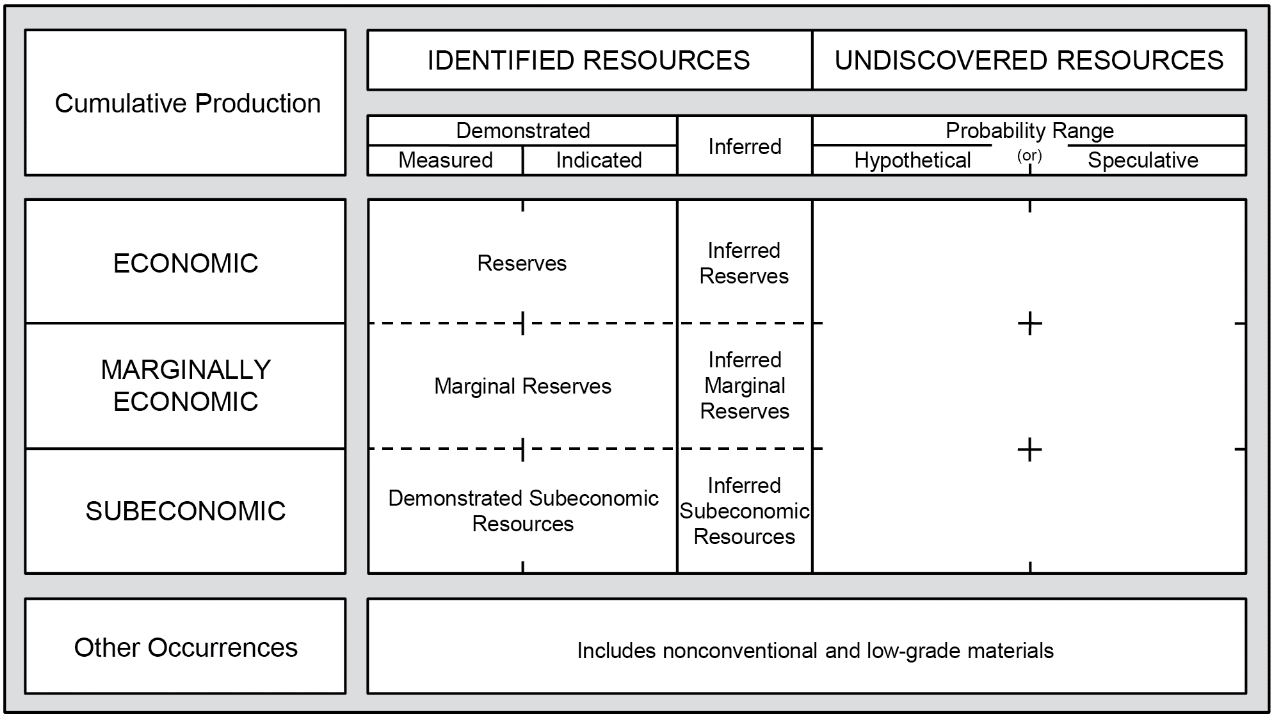
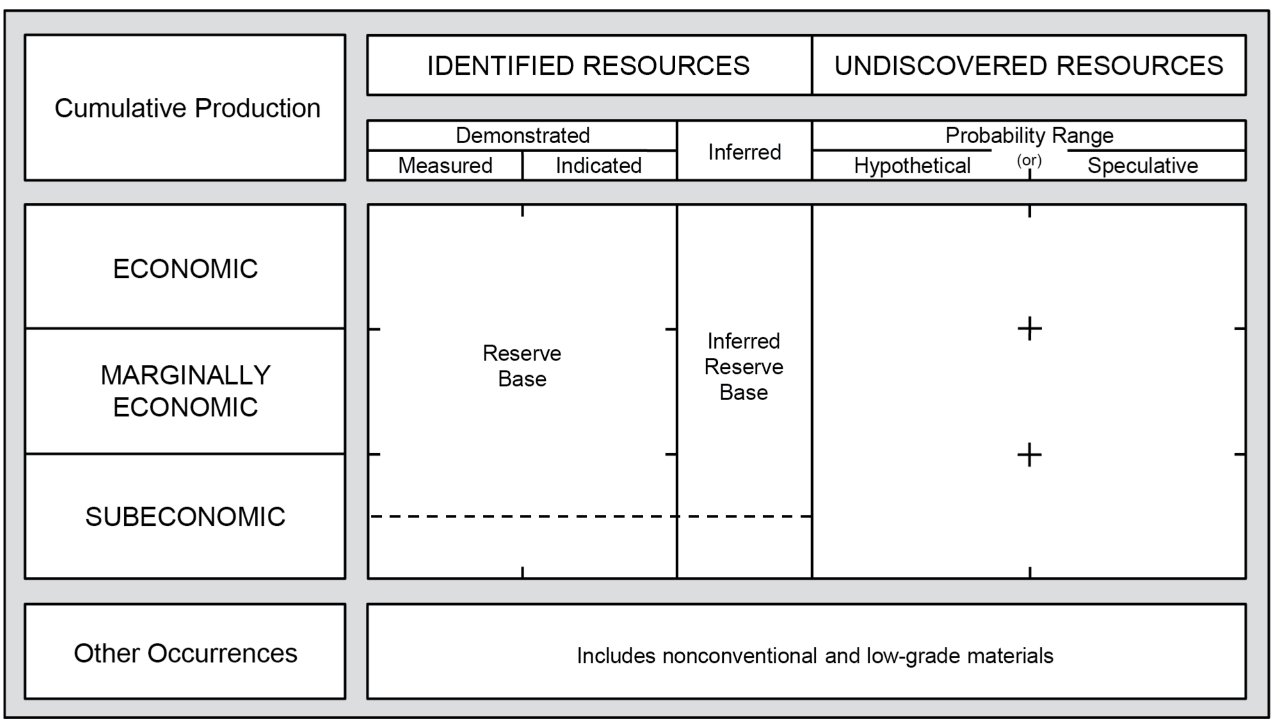


Figure C2.—*Reserve Base* and *Inferred Reserve Base* Classification Categories



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 2023 are Accessible EDR. For more information, see table 3 in "Australia's Identified Mineral Resources 2021" (https://doi.org/10.11636/1327-1466.2021).

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. Also, reserves data for individual jurisdictions are available on the website of the Federal'noye Agenstvo po Nedropol'zovaniyu (Federal Agency for Subsoil Use). 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	Meralis Plaza-Toledo
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	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	Ji Won Moon
Bangladesh	Keita F. DeCarlo
Bhutan	Keita F. DeCarlo
Brunei	Ji Won Moon
Burma (Myanmar)	Ji Won Moon
Cambodia	Ji Won Moon
China	Ji Won Moon
Fiji	Jaewon Chung
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	Jaewon Chung
Mongolia	Jaewon Chung
Nauru	Ji Won Moon
Nepal	Keita F. DeCarlo
New Caledonia	Keita F. DeCarlo
New Zealand	Ji Won Moon
Pakistan	Keita F. DeCarlo
Papua New Guinea	Ji Won Moon
Philippines	Ji Won Moon
Singapore	Ji Won Moon
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	Elena Safirova
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	Loyd M. Trimmer III
Czechia	Loyd M. Trimmer III
Denmark, Faroe Islands, and Greenland	Joanna Goclawska
Estonia	Joanna Goclawska
Finland	Joanna Goclawska
France	Keita F. DeCarlo
Georgia	Elena Safirova
Germany	Elena Safirova
Greece	Jaewon Chung
Hungary	Loyd M. Trimmer III
Iceland	Joanna Goclawska
Ireland	Joanna Goclawska
Italy	Loyd M. Trimmer III
Kazakhstan	Elena Safirova
Kosovo	Karine M. Renaud
Kyrgyzstan	Karine M. Renaud
Latvia	Joanna Goclawska
Lithuania	Joanna Goclawska
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
Portugal	Joanna Goclawska
Romania	Keita F. DeCarlo
Russia	Elena Safirova
Serbia	Karine M. Renaud
Slovakia	Keita F. DeCarlo
Slovenia	Loyd M. Trimmer III
Spain	Loyd M. Trimmer III

Europe and Central Eurasia—Continued

Sweden	Joanna Goclawska
Switzerland	Keita F. DeCarlo
Tajikistan	Karine M. Renaud
Turkey	Karine M. Renaud
Turkmenistan	Karine M. Renaud
Ukraine	Elena Safirova
United Kingdom	Jaewon Chung
Uzbekistan	Elena Safirova

North America, Central America, and the Caribbean

Aruba	Yadira Soto-Viruet
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
Peru	Yadira Soto-Viruet
Suriname	Yolanda Fong-Sam
Uruguay	Yadira Soto-Viruet
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