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

MINERAL COMMODITY SUMMARIES 2024

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
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: Photograph of microchips, also known as integrated circuits (ICs), on a semiconductor wafer. Microchips have become an integral part of daily life, as they are essentially the brain of modern electronics found in everything from computers, communication devices, medical and healthcare technology, vehicle and transportation systems, satellites, military systems, clean energy technology, wireless networks, the Internet of Things (IoT), and countless other applications. Advances in semiconductor and microchip technology have enabled the development of more compact, faster, more powerful, more reliable, and less expensive electronic devices. Gallium (p. 74) and silicon (p. 160) are two important materials in modern semiconductor technology. Gallium, which is extracted from bauxite (aluminum) and zinc ores, used in the form of gallium arsenide (GaAs) and gallium nitride (GaN) on a silicon substrate, offers superior semiconductor performance compared to silicon, including higher electron mobility, optical features, and higher energy efficiency, making it the preferred material of choice for high-performance and high-frequency specialty applications, such as high-speed telecommunications (for example, 5G networks), high-performance computers, and aerospace systems. High-purity silicon is currently the most widely used material for semiconductor microchips because of its electrical properties, abundance, and cost effectiveness. Photograph courtesy of Taiwan Semiconductor Manufacturing Co., Ltd. (TSMC).

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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
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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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, world production and reserves, 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.

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- 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.

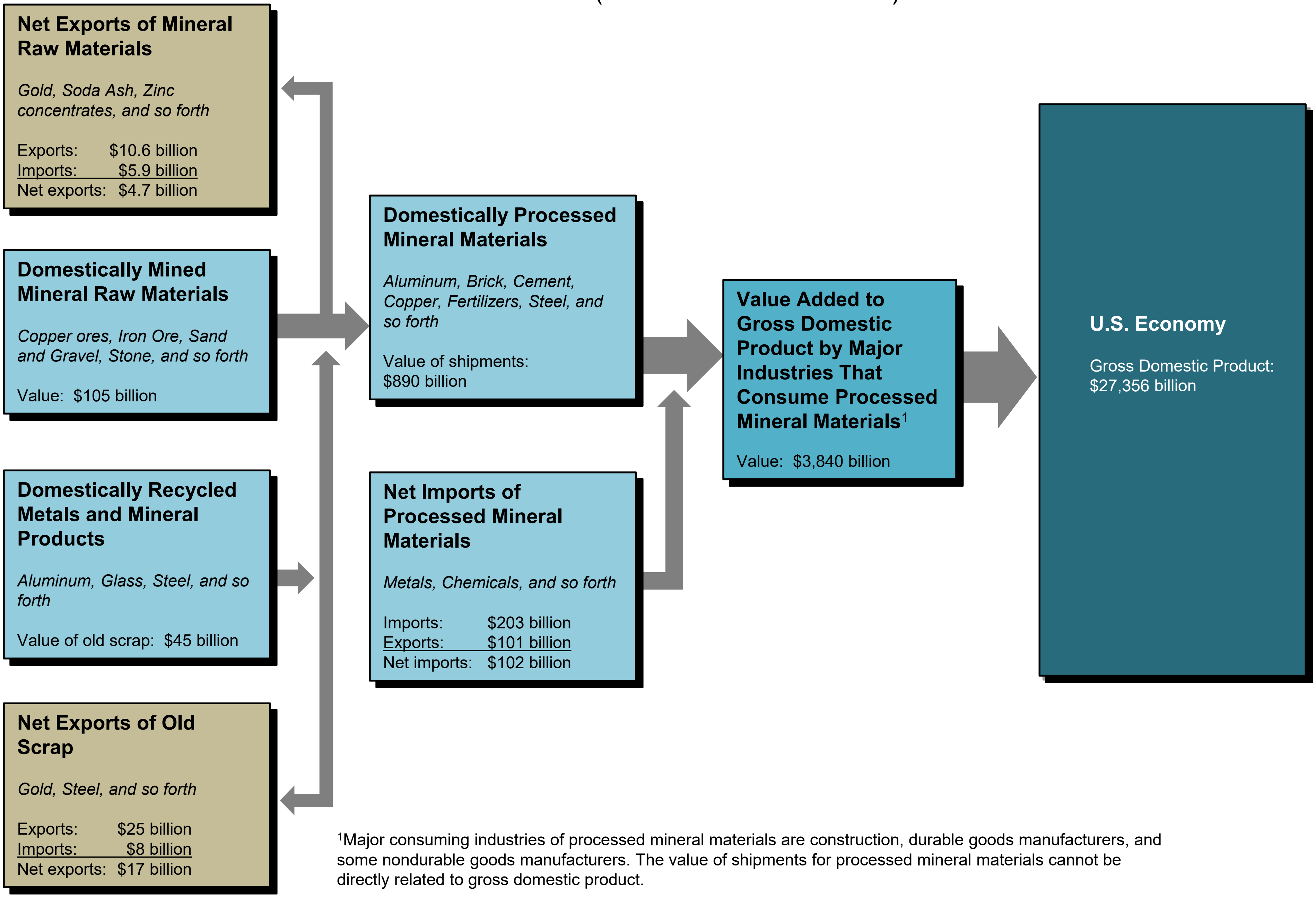
INTRODUCTION

Each mineral commodity chapter of the 2024 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 2023 mineral production data for the world. More than 90 individual minerals and materials are covered by 2-page synopses.

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 2024 are welcomed.

Figure 1.—The Role of Nonfuel Mineral Commodities in the U.S. Economy
(Estimated values in 2023)



[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 2023, the estimated total value of nonfuel mineral production in the United States was $105 billion, an increase of 4% from the revised total of $101 billion in 2022. The estimated value of metal production in 2023 decreased slightly to $34.9 billion from a revised total of $35.4 billion in 2022. The total value of industrial minerals production was $69.9 billion, a 7% increase from a revised total of $65.3 billion in 2022 (table 1). Of the total value of industrials minerals production, $35.2 billion was construction aggregates production (construction sand and gravel and crushed stone). Crushed stone was the leading nonfuel mineral commodity in 2023 with a production value of $24 billion and accounted for 23% of the total value of U.S. nonfuel mineral production.

Increases in production and prices of some industrial minerals contributed to the total value of nonfuel mineral production in the United States increasing in 2023. For the industrial minerals sector, increased demand for aggregates for construction and 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 bromine, helium, iodine, peat, pumice, sand and gravel (industrial), stone (crushed), and vermiculite.

For the metal sector, production decreased for several metal commodities owing to operational issues, reduced ore grades, and weather-related issues. The metal sector also had reduced prices in 2023 attributed to oversupply in the global market. Cobalt, copper, lithium, nickel, palladium, rare earths, and zinc had some of the largest percentage decreases in production value. The reduction in prices caused some domestic mining projects to delay operations or stop processing material.

In 2023, three recycling facilities became operational in the United States that transformed scrap into new metals and chemicals that could be returned to domestic supply chains. One plant in Nevada that recycled copper from, and produced copper for, lithium-ion batteries became operational in January; one facility in Ohio, capable of recovering nickel and cobalt from a range of waste types, became operational in June; and one plant in Michigan that produced secondary aluminum became operational in November. Seven commercial recycling plants were either under construction or undergoing expansion in 2023, including secondary copper plants, facilities that recover multiple metals like cobalt and nickel from lithium-ion battery scrap, and facilities that recover copper and precious metals from electronic scrap.

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 included 50 mineral commodities. In 2023, there were many initiatives and projects in response to legislation passed previously to advance securing American supply chains and supporting domestic production projects. See the “U.S. Critical Minerals Update” section beginning on page 18 for more details.

Foreign Trade

In April 2023, a 200% ad valorem tariff on aluminum articles and derivative aluminum articles from Russia was put in place.

In May 2023, the suspension of the 25% ad valorem tariffs imposed under section 232 of the Trade Expansion Act of 1962 for steel articles and derivative steel articles from Ukraine was extended for another year.

In 2023, the additional tariffs placed on imports from China remained while the Office of the United States Trade Representative (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.

In December 2023, China implemented export bans and export restrictions on certain strategic materials and technologies in the “Catalogue of Technologies Prohibited and Restricted from Export in China.” Export bans prohibited any materials or technology from leaving China. Those items under an export ban included a category called “Nonferrous Metal Smelting and Processing Industry.” Export restrictions required exporters to apply for a license, which, according to some sources, required export contracts, technical product specifications, and the identity of the end user as well as the specific end use. Export restrictions included nonferrous metal mining technology, smelting, and processing. China was the dominant global producer for many of materials and many of the materials were on United States critical minerals list. More details on specific items can be found in the “U.S. Critical Minerals Update” section beginning on page 18.

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 2023 was $105 billion. The value of net exports of mineral raw materials decreased slightly to $4.7 billion from a revised $4.77 billion in 2022. The value of net exports of old scrap increased to $17 billion. The value of domestically recycled products totaled $45 billion. The commodities accounting for the highest percentages of the total value were iron and steel scrap (54%), gold (12%), and aluminum (10%). Domestic raw materials and domestically recycled materials were used to produce mineral materials worth $890 billion. These mineral materials as well as $102 billion of net imports of processed mineral materials were, in turn, consumed by downstream industries creating an estimated value of $3.84 trillion in 2023, a 6% increase from $3.62 trillion in 2022.

Figure 2 illustrates the reliance of the United States on foreign sources for raw and processed mineral materials. In 2023, imports made up more than one-half of the U.S. apparent consumption for 49 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 29 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 beginning on page 18.

Figure 3 shows the countries that were sources of nonfuel mineral commodities for which the United States was greater than 50% net import reliant 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, 24 mineral commodities; Canada, 23 mineral commodities; Germany, 12 mineral commodities; Brazil, 10 mineral commodities; and Belgium, Mexico, Russia, and South Africa, 8 mineral commodities each.

The estimated value of U.S. metal mine production in 2023 was $34.9 billion, slightly lower than the revised value in 2022 (table 1). In 2023, the capacity utilization for the metal mining industry continued a 5-year downward trend and was 59%, less than the 60% capacity utilization in 2022 (table 2). Principal contributors to the total value of metal mine production in 2023 were gold, 29%; copper, 28%; iron ore, 22%; zinc, 7%; and molybdenum, 6%.

The estimated value of U.S. industrial minerals production in 2023, including construction aggregates, was $69.9 billion, about 7% more than the revised value in 2022 (table 1). In 2023, the capacity utilization for the nonmetallic minerals mining industry was 87%, unchanged from the capacity utilization in 2022 (table 2). The value of industrial minerals production in 2022 was dominated by crushed stone, 34%; cement (masonry and portland), 16%; construction sand and gravel, 16%; and industrial sand and gravel, 10%.

In 2023, U.S. production of 14 mineral commodities was valued at more than $1 billion each. These commodities were, in decreasing order of value, crushed stone, construction sand and gravel, cement, gold, copper, iron ore, industrial sand and gravel, salt, lime, zinc, phosphate rock, soda ash, molybdenum, and helium.

In 2023, 10 States had more than $3 billion worth of publishable nonfuel mineral commodities production value and another 13 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, Texas, Arizona, Nevada, Minnesota, California, Florida, Alaska, Michigan, Wyoming, and Missouri (table 3).

The West region was the leading region in the production of metals and metallic minerals; the estimated value was $25 billion in 2023 (fig. 5).

The South region was the leading region in the production of industrial minerals (excluding construction sand and gravel and crushed stone); the estimated value was $15.1 billion in 2023 (fig. 6).

In 2023, seven States produced more than $1 billion worth of crushed stone. These States were, in descending order of production value, Texas, Florida, Georgia, Pennsylvania, North Carolina, Tennessee, and Virginia. 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 and Texas each produced more than $1 billion worth of construction sand and gravel in 2023, and Arizona was the only State that produced more than $500 million but less than $1 billion. Colorado, Washington, Michigan, New York, Utah, Ohio, and Florida, in descending order of production value, were the other top 10 producing States (fig. 8).

The Defense Logistics Agency Strategic Materials (DLA Strategic Materials) is responsible for the operational oversight of the National Defense Stockpile (NDS) of strategic and critical materials. Managing the security, providing environmentally sound stewardship, and ensuring the readiness of all NDS stocks is the mission of the DLA Strategic Materials. The NDS currently contains 50 unique commodities stored at nine locations within the continental United States. In fiscal year 2023, the NDS added four materials along with additional quantities of four other materials, and approximately $41.17 million of excess materials were sold. Revenue from the Stockpile Sales Program funds 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. Most stocks are held in reserve. Additional information regarding Annual Material Plans (AMPs) for acquisitions and disposals 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.—2023 U.S. Net Import Reliance[1]

Commodity	Net import reliance as a percentage of apparent consumption in 2023	Leading import sources (2019–22)[2]
ARSENIC, all forms	100	China,[3] Morocco, Malaysia, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Germany
FLUORSPAR	100	Mexico, Vietnam, China, South Africa
GALLIUM	100	Japan, China, Germany, Canada
GRAPHITE (NATURAL)	100	China,[3] Mexico, Canada, Madagascar
INDIUM	100	Republic of Korea, Canada, Belgium
MANGANESE	100	Gabon, South Africa, Australia, Georgia
MICA (NATURAL), sheet	100	China, Brazil, India, Belgium
NIOBIUM (COLUMBIUM)	100	Brazil, Canada
RUBIDIUM	100	China, Germany, Russia
SCANDIUM	100	Japan, China, Germany, Philippines
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China,[3] Germany, Australia, Indonesia
YTTRIUM	100	China,[3] Germany, France, Republic of Korea
GEMSTONES	99	India, Israel, Belgium, South Africa
ABRASIVES, fused aluminum oxide	>95	China,[3] Canada, Brazil, Austria
NEPHELINE SYENITE	>95	Canada
RARE EARTHS,[4] compounds and metals	>95	China,[3] Malaysia, Japan, Estonia
TITANIUM, sponge metal	>95	Japan, Kazakhstan, Saudi Arabia, Ukraine
BISMUTH	94	China,[3] Republic of Korea, Belgium, Mexico
POTASH	91	Canada, Russia, Belarus
STONE (DIMENSION)	87	Brazil, China,[3] Italy, Turkey
DIAMOND (INDUSTRIAL), stones	84	India, South Africa, Russia, Congo (Kinshasa)
PLATINUM	83	South Africa, Switzerland, Germany, Belgium
ANTIMONY, metal and oxide	82	China,[3] Belgium, India, Bolivia
ZINC, refined	77	Canada, Mexico, Peru, Republic of Korea
BARITE	>75	India, China,[3] Morocco, Mexico
BAUXITE	>75	Jamaica, Turkey, Guyana, Australia
IRON OXIDE PIGMENTS, natural and synthetic	75	China,[3] Germany, Brazil, Canada
TITANIUM MINERAL CONCENTRATES	75	South Africa, Madagascar, Australia, Canada
CHROMIUM, all forms	74	South Africa, Kazakhstan, Russia, Canada
PEAT	74	Canada
TIN, refined	74	Peru, Bolivia, Indonesia, Malaysia
ABRASIVES, silicon carbide	73	China,[3] Brazil, Canada, Netherlands
SILVER	69	Mexico, Canada, Poland, Switzerland
COBALT	67	Norway, Canada, Finland, Japan
GARNET (INDUSTRIAL)	67	South Africa, Australia, China,[3] India
RHENIUM	60	Chile, Canada, Germany, Kazakhstan
ALUMINA	59	Brazil, Australia, Jamaica, Canada
VANADIUM	58	Canada, Brazil, Austria, Russia
NICKEL	57	Canada, Norway, Finland, Russia
DIAMOND (INDUSTRIAL), bort, grit, and dust and powder	56	China,[3] Republic of Korea, Ireland, Russia
MAGNESIUM COMPOUNDS	52	China,[3] Israel, Canada, Brazil
GERMANIUM	>50	Belgium, China, Canada
IODINE	>50	Chile, Japan
MAGNESIUM METAL	>50	Canada, China,[3] Israel, Taiwan
SELENIUM	>50	Philippines, Mexico, Germany, Canada
TUNGSTEN	>50	China,[3] Germany, Bolivia, Vietnam
SILICON, metal and ferrosilicon	<50	Brazil, Russia, Canada, Norway
COPPER, refined	46	Chile, Canada, Mexico
ALUMINUM	44	Canada, United Arab Emirates, Bahrain, Russia
PALLADIUM	37	Russia, South Africa, Italy, Canada
LEAD, refined	35	Canada, Mexico, Republic of Korea, Australia
MICA (NATURAL), scrap and flake	28	China, Canada, India, Finland
PERLITE	26	Greece, China, Mexico
LITHIUM	>25	Argentina, Chile, China, Russia
TELLURIUM	>25	Canada, Germany, Philippines, Japan
SALT	25	Canada, Chile, Mexico, Egypt
BROMINE	<25	Israel, Jordan, China[3]
ZIRCONIUM, ores and concentrates	<25	South Africa, Australia, Senegal, Russia
CEMENT	22	Turkey, Canada, Greece, Mexico
VERMICULITE	20	South Africa, Brazil, Zimbabwe

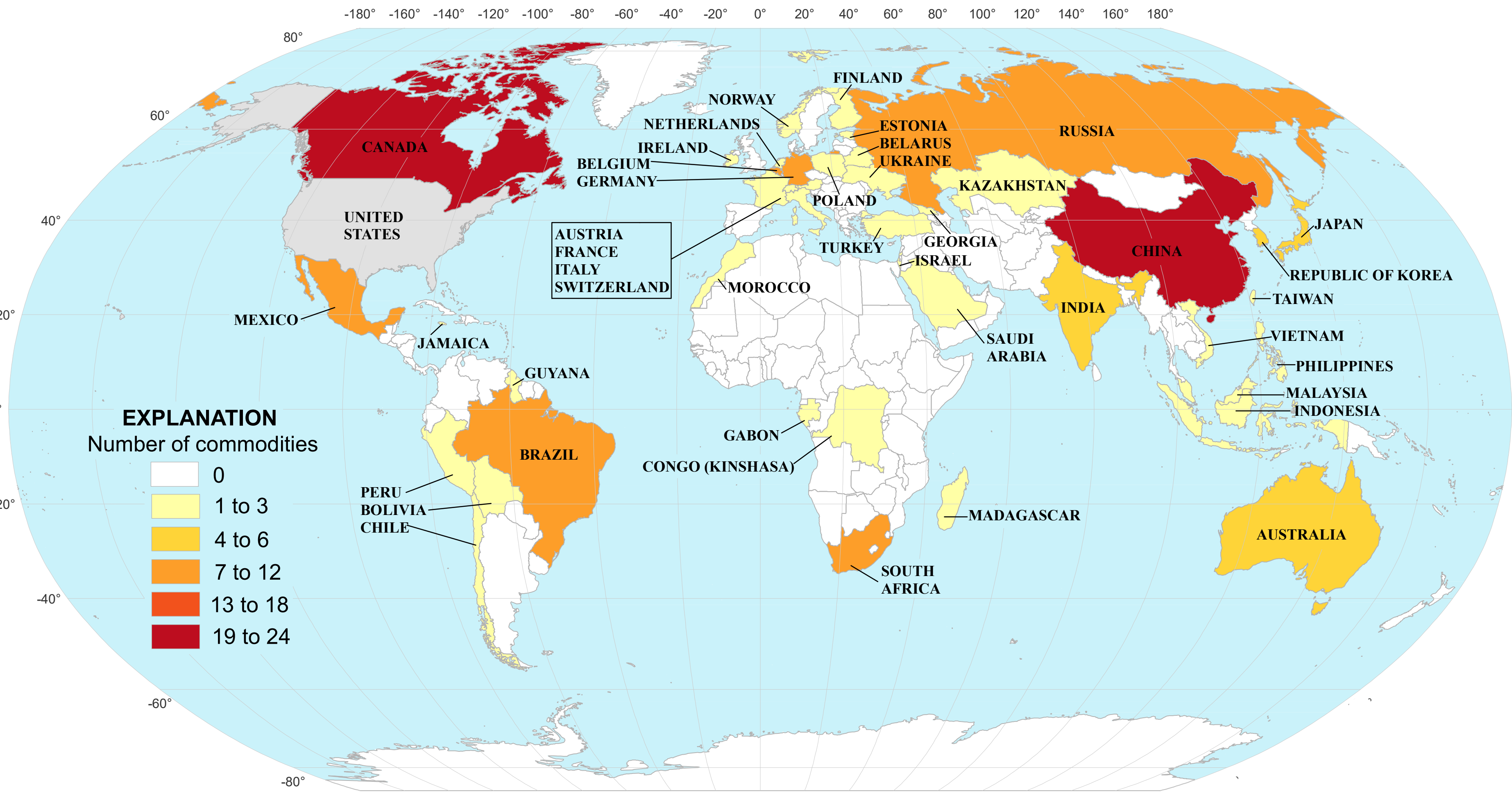
[1]Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (abrasives, metallic; beryllium; boron; cadmium; clays; diatomite; gold; helium; iron and steel scrap; iron ore; kyanite; lime; molybdenum; 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 (feldspar; gypsum; iron and steel; iron and steel slag; nitrogen (fixed)—ammonia; phosphate rock; pumice; sand and gravel, construction; stone, crushed; sulfur; and talc and pyrophyllite). For some mineral commodities (hafnium; mercury; quartz, high-purity and industrial cultured crystal; 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]Includes Hong Kong.

[4]Includes lanthanides cerium, dysprosium, erbium, europium, gadolinium, holmium, lanthanum, lutetium, neodymium, praseodymium, samarium, terbium, thulium, and ytterbium.

Figure 3.—Leading Import Sources (2019–22) of Nonfuel Mineral Commodities for Which the United States Was Greater Than 50% Net Import Reliant



Source: U.S. Geological Survey

Table 1.—U.S. Mineral Industry Trends

	2019	2020	2021	2022	2023[e]
Total mine production (million dollars):					
Metals	26,900	27,600	36,900	35,400	34,900
Industrial minerals	56,500	54,000	58,200	65,300	69,900
Coal	25,500	16,800	21,000	32,300	31,700
Employment (thousands of workers):					
Coal mining, all employees	51	40	38	40	41
Nonfuel mineral mining, all employees	140	136	138	143	150
Chemicals and allied products, production workers	559	537	541	570	570
Stone, clay, and glass products, production workers	312	296	300	315	310
Primary metal industries, production workers	301	272	270	282	290
Average weekly earnings of workers (dollars):					
Coal mining, all employees	1,617	1,517	1,618	1,762	1,800
Chemicals and allied products, production workers	1,066	1,065	1,103	1,119	1,200
Stone, clay, and glass products, production workers	968	981	1,017	1,086	1,100
Primary metal industries, production workers	1,027	1,006	1,073	1,172	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

	2019	2020	2021	2022	2023[e]
Gross domestic product (billion dollars)	21,521	21,323	23,594	25,744	27,356
Industrial production (2017=100):					
Total index:	102	95	99	103	100
Manufacturing:	99	93	98	100	100
Nonmetallic mineral products	101	97	101	109	110
Primary metals:	97	87	96	95	95
Iron and steel	95	87	102	96	97
Aluminum	101	92	97	96	91
Nonferrous metals (except aluminum)	102	92	95	106	110
Chemicals	97	95	100	102	100
Mining:	121	103	106	113	120
Coal	92	69	75	77	78
Oil and gas extraction	130	122	123	130	140
Metals	96	95	92	88	85
Nonmetallic minerals	104	98	102	102	100
Capacity utilization (percent):					
Total industry:	79	73	78	80	79
Mining:	87	72	82	90	93
Metals	68	66	63	60	59
Nonmetallic minerals	88	82	86	87	87
Housing starts (thousands)	1,292	1,397	1,606	1,551	1,400
Light vehicle sales (thousands)	16,961	14,472	14,947	13,754	15,500
Highway construction, value, put in place (billion dollars)	99	103	104	114	130

[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 2023[p, 1, 2]

State	Value (millions)	Rank[3]	Percent of U.S. total[4]	Principal nonfuel mineral commodities[5]
Alabama	$2,010	18	1.92	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Alaska	4,100	7	3.91	Gold, lead, sand and gravel (construction), silver, zinc.
Arizona	9,500	2	9.07	Cement, copper, molybdenum mineral concentrates, sand and gravel (construction), stone (crushed).
Arkansas	1,180	30	1.12	Bromine, cement, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
California[6]	5,080	5	4.85	Boron minerals, cement, rare earths, sand and gravel (construction), stone (crushed).
Colorado	2,220	15	2.12	Cement, gold, molybdenum mineral concentrates, sand and gravel (construction), stone (crushed).
Connecticut	264	43	0.25	Sand and gravel (construction), stone (crushed), stone (dimension).
Delaware[7]	17	50	0.02	Magnesium compounds, sand and gravel (construction), stone (crushed).
Florida[6, 7]	2,900	6	2.77	Cement, clay (attapulgite and kaolin), phosphate rock, sand and gravel (construction), stone (crushed).
Georgia[6]	2,620	12	2.50	Cement, clay (common clay, kaolin, montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Hawaii	154	46	0.15	Sand and gravel (construction), stone (crushed).
Idaho[7]	482	32	0.46	Lead, phosphate rock, sand and gravel (construction), silver, stone (crushed).
Illinois	1,770	20	1.69	Cement (portland), magnesium compounds, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Indiana	1,440	25	1.37	Cement, lime, sand and gravel (construction), stone (crushed), stone (dimension).
Iowa	879	33	0.84	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Kansas[7]	915	26	0.87	Cement, helium, salt, sand and gravel (construction), stone (crushed).
Kentucky[7]	919	27	0.88	Cement, clay (common clay), lime, sand and gravel (construction), stone (crushed).
Louisiana[7]	1,070	31	1.02	Clay (common clay), lime, salt, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Maine[7]	116	47	0.11	Cement, peat, sand and gravel (construction), stone (crushed), stone (dimension).
Maryland[7]	431	35	0.41	Cement, sand and gravel (construction), stone (crushed), stone (dimension).
Massachusetts[7]	329	41	0.31	Clay (common clay), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Michigan	4,060	8	3.87	Cement, iron ore, nickel sulfide concentrates, sand and gravel (construction), stone (crushed).
Minnesota[7]	6,820	4	6.51	Iron ore, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Mississippi	338	42	0.32	Clay (ball clay, bentonite, common clay, montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Missouri	3,160	10	3.01	Cement, lead, lime, sand and gravel (industrial), stone (crushed).
Montana	1,290	28	1.23	Copper, molybdenum mineral concentrates, palladium, platinum, sand and gravel (construction).

See footnotes at end of table.

Table 3.—Value of Nonfuel Mineral Production in the United States and Principal Nonfuel Mineral Commodities Produced in 2023[p, 1, 2]—Continued

State	Value (millions)	Rank[3]	Percent of U.S. total[4]	Principal nonfuel mineral commodities[5]
Nebraska[7]	$260	40	0.25	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Nevada	8,880	3	8.47	Copper, gold, lime, sand and gravel (construction), stone (crushed).
New Hampshire[7]	203	44	0.19	Sand and gravel (construction), stone (crushed), stone (dimension).
New Jersey	515	38	0.49	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
New Mexico	1,450	24	1.38	Cement, copper, potash, sand and gravel (construction), stone (crushed).
New York[7]	1,750	16	1.67	Cement, salt, sand and gravel (construction), stone (crushed), zinc.
North Carolina	2,500	13	2.39	Phosphate rock, quartz (high-purity), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
North Dakota[7]	78	49	0.07	Lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Ohio[7]	1,580	17	1.51	Cement, lime, salt, sand and gravel (construction), stone (crushed).
Oklahoma	1,210	29	1.15	Cement, iodine, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Oregon[7]	527	36	0.50	Cement (portland), diatomite, perlite, sand and gravel (construction), stone (crushed).
Pennsylvania[7]	2,220	14	2.12	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Rhode Island[7]	109	48	0.10	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
South Carolina	1,680	21	1.60	Cement, gold, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
South Dakota	549	37	0.52	Cement (portland), gold, lime, sand and gravel (construction), stone (crushed).
Tennessee	1,950	19	1.86	Cement, sand and gravel (construction), sand and gravel (industrial), stone (crushed), zinc.
Texas	9,750	1	9.31	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Utah	3,140	11	3.00	Cement (portland), copper, gold, potash, salt.
Vermont[7]	160	45	0.15	Sand and gravel (construction), stone (crushed), stone (dimension), talc (crude).
Virginia	1,590	23	1.52	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Washington	796	34	0.76	Cement, diatomite, lime, sand and gravel (construction), stone (crushed).
West Virginia[7]	231	39	0.22	Cement, lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Wisconsin[7]	1,510	22	1.44	Lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Wyoming	3,170	9	3.02	Clay (bentonite and common clay), helium, sand and gravel (construction), soda ash, stone (crushed).
Undistributed	4,900	XX	4.68	XX
Total	105,000	XX	100.00	

[p]Preliminary. XX Not applicable.

[1]Includes data available through December 21, 2023.

[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.

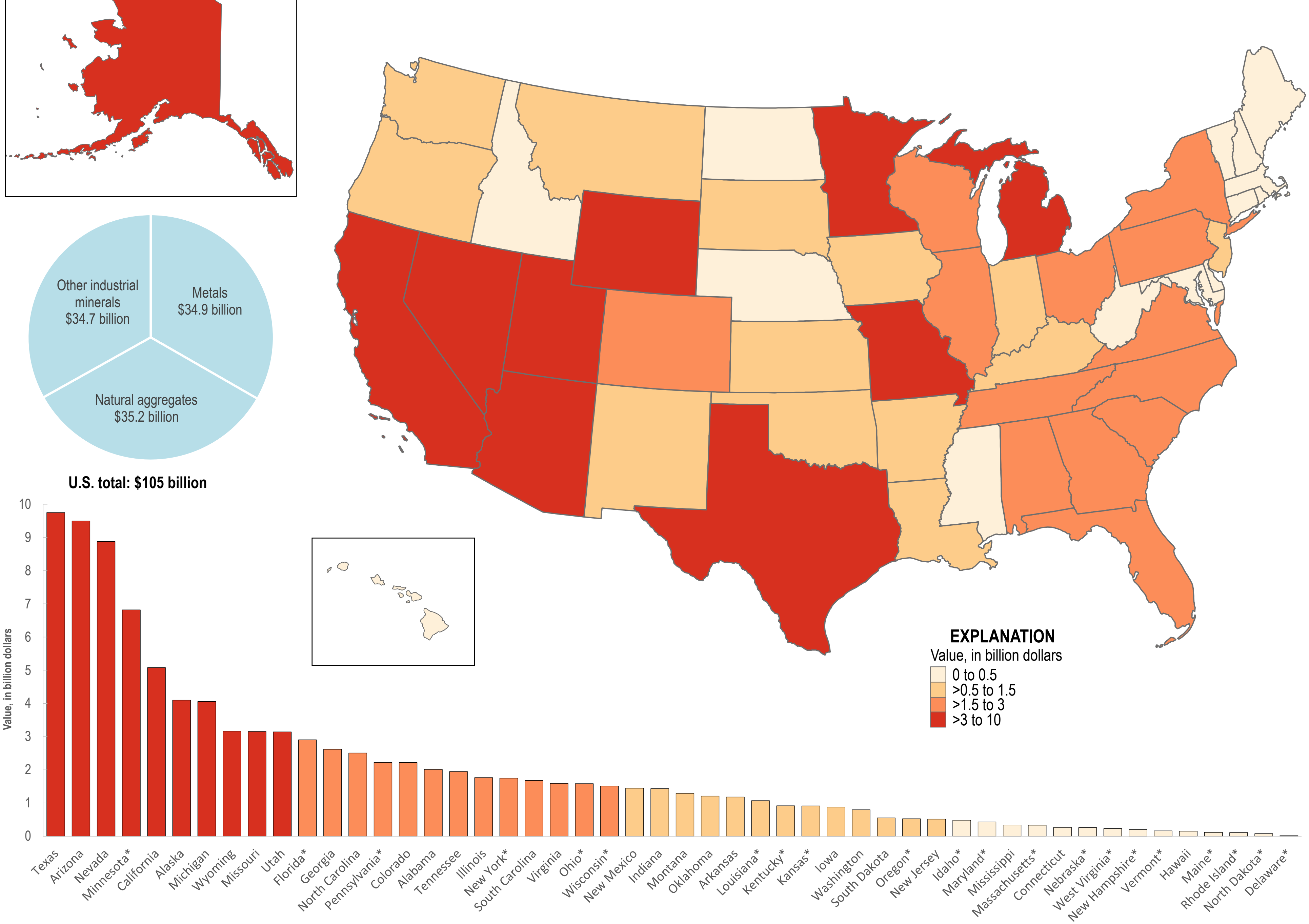
[4]"Percent of U.S. total" calculated to two decimal places.

[5]Listed in alphabetical order.

[6]California, Florida, and Georgia also produce significant quantities of titanium mineral concentrates and zirconium mineral concentrates. Breakdown by State is not available 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 Mineral Commodities Produced in 2023, 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 2023, by Region

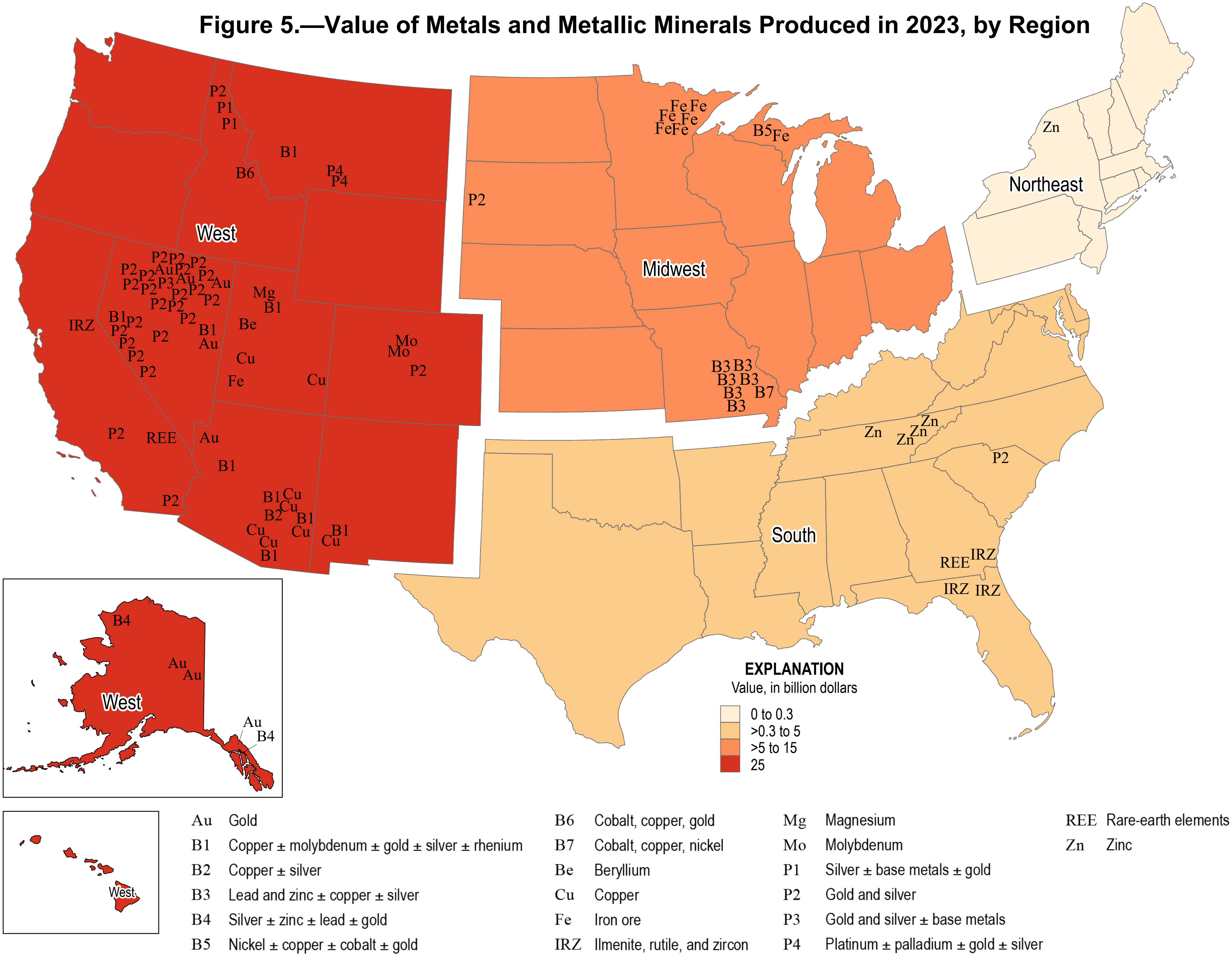
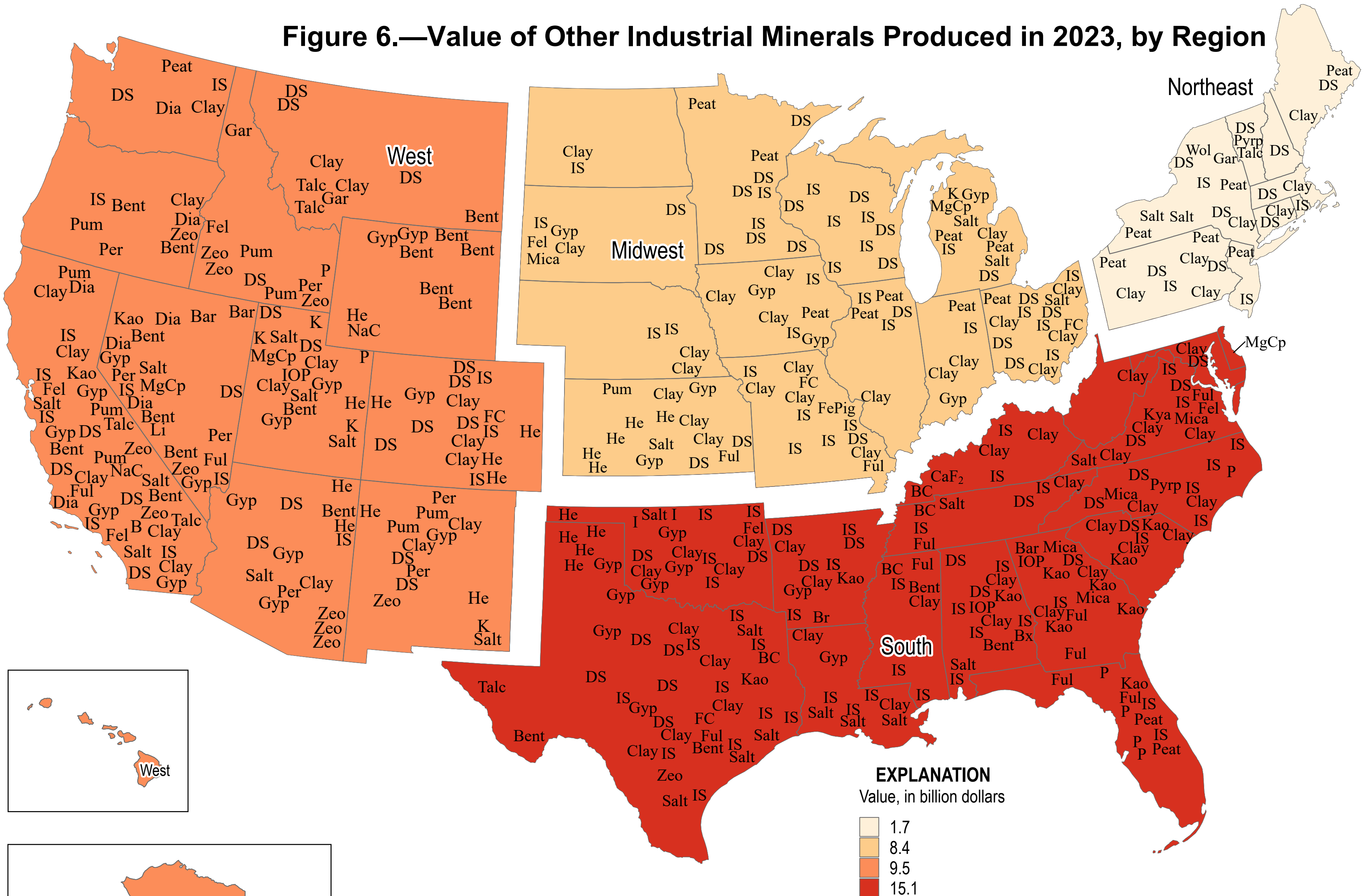
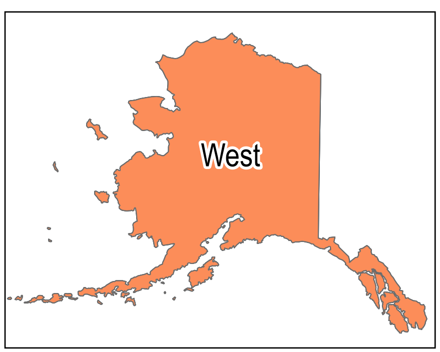


Figure 6.—Value of Other Industrial Minerals Produced in 2023, by Region





B	Borates	Clay	Common clay	Gyp	Gypsum	Kya	Kyanite	Per	Perlite
Bar	Barite	Dia	Diatomite	He	Helium	Li	Lithium	Pum	Pumice
BC	Ball clay	DS	Dimension stone	I	Iodine	MgCp	Magnesium compounds	Pyrp	Pyrophyllite
Bent	Bentonite	FC	Fire clay	IOP	Iron oxide pigments	Mica	Mica	Salt	Salt
Br	Bromine	Fel	Feldspar	IS	Industrial sand	NaC	Soda ash	Talc	Talc
Bx	Bauxite	Ful	Fuller's earth	K	Potash	P	Phosphate rock	Wol	Wollastonite
CaF_2	Fluorspar	Gar	Garnet	Kao	Kaolin	Peat	Peat	Zeo	Zeolites

Figure 7.—Value of Crushed Stone Produced in 2023, by State

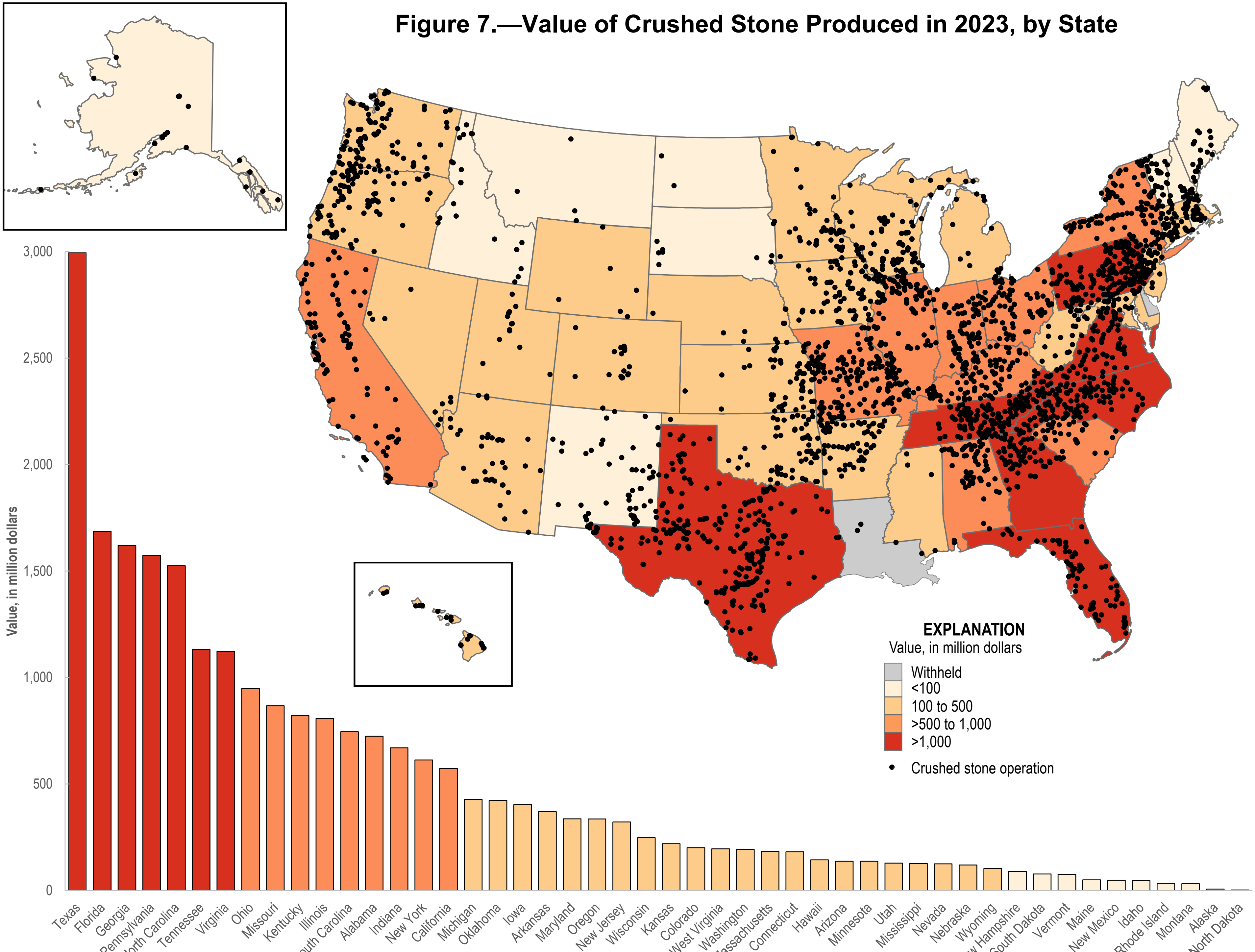


Figure 8.—Value of Construction Sand and Gravel Produced in 2023, by State

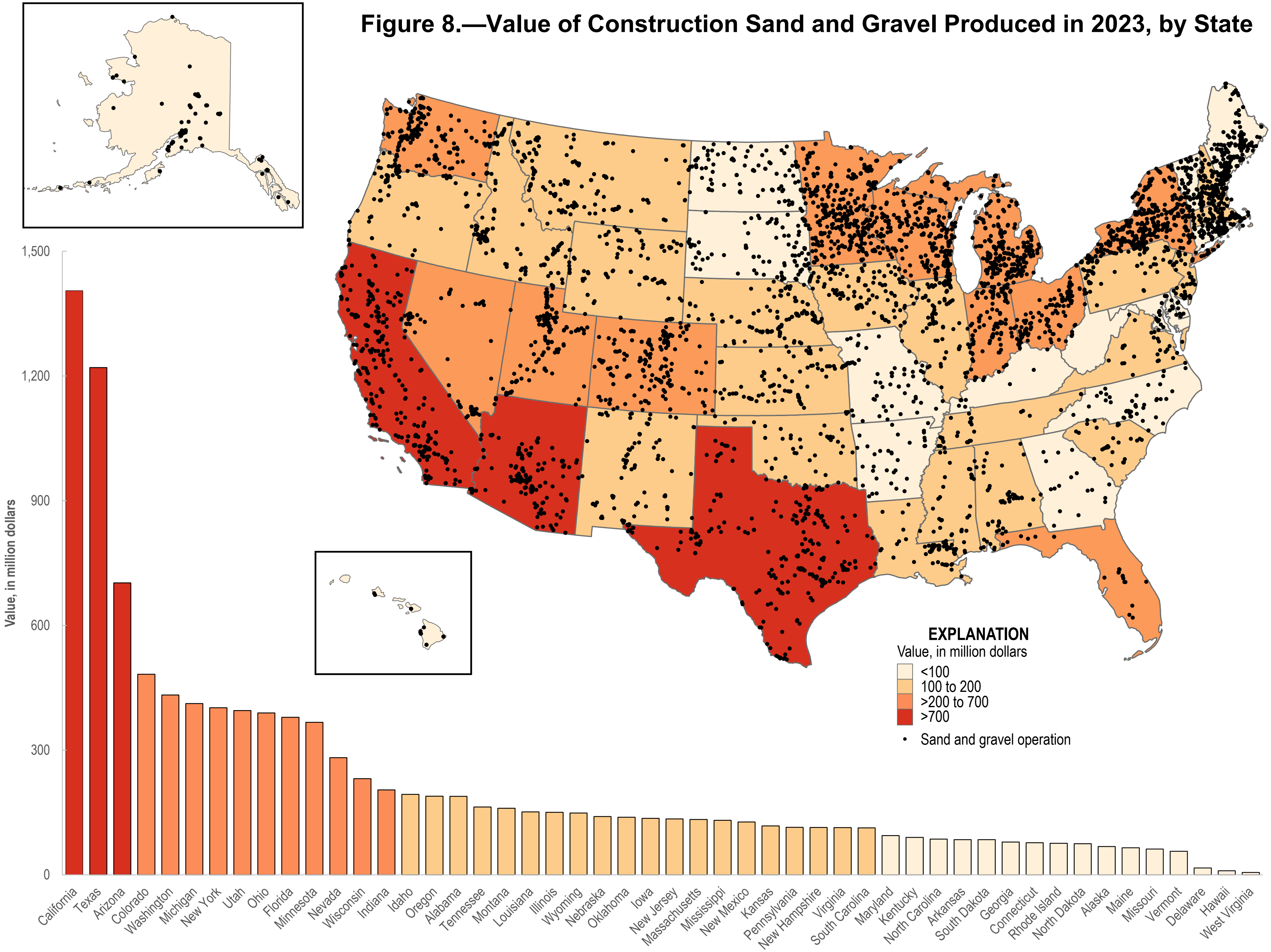


Table 4.—The 2022 U.S. Critical Minerals List[1]

Critical mineral	Applications
Aluminum	Metallurgy and many sectors of the economy.
Antimony	Flame retardants and lead-acid batteries.
Arsenic	Pesticides and 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 chemicals, 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 catalysts.
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 the 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 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.

Background

A series of actions by the Government in recent years addressed domestic supply chain vulnerabilities for critical minerals, 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 the following:

1. The USGS published the 2018 CML;
2. The U.S. Department of Commerce with interagency input published the “2019 Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals”;
3. Several Presidential determinations directed the use of Defense Production Act (DPA) title III authorities to strengthen the U.S. industrial base for rare-earth elements;
4. Executive Order 13953 was issued “Addressing the Threat to the Domestic Supply Chain Reliance on Critical Minerals from Foreign Adversaries and Supporting the Domestic Mining and Processing Industries”; and
5. The Energy Act of 2020 was passed by Congress and signed into law.

Several congressional acts and other government actions have focused on investments for clean energy projects; critical mineral mapping, production, recycling, reclamation, and resource assessments; domestic production of batteries; infrastructure projects; research and development; ports and rail improvements; semiconductor supply-chain projects; telecommunications broadband networks; and water systems. These actions have included the following:

1. 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) in November 2021;
2. A Presidential determination on March 31, 2022, authorized 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;
3. 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;
4. The CHIPS and Science Act of 2022 (Public Law 117–167) provided $280 billion in funding over the next 10 years for domestic research, commercialization, and manufacturing of semiconductors;
5. 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 including targeted tax incentives aimed at manufacturing U.S.-sourced materials such as batteries, electric vehicles, solar, and wind parts and technologies;
6. In October 2022, the “American Battery Materials Initiative” was launched to leverage and maximize ongoing efforts throughout the U.S. Government to meet resource requirements and bolster energy security; and
7. In December 2022, the $858 billion National Defense Authorization Act 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 2023

On January 13, 2023, the Loan Program Office (LPO) at the U.S. Department of Energy (DOE) offered a conditional commitment to lend up to $700 million to a company to develop a domestic supply of lithium carbonate for electric vehicle batteries from a mining project in Esmeralda County, NV.

On April 4, 2023, the DOE announced $16 million in funding from the Bipartisan Infrastructure Law to support projects in North Dakota and West Virginia for the development of a first-of-a-kind rare-earth-element and other critical minerals extraction and separation refinery. On September 19, 2023, the U.S. Department of Defense (DOD) awarded $94.1 million to a company to establish a domestic rare-earth permanent magnet manufacturing capability with the goal to begin magnet production by 2025.

On June 15, 2023, the DOD awarded $15 million to a company to support feasibility studies to enhance the definition and characterization of currently known cobalt resources at operations in Idaho as well as to assess requirements of a domestic cobalt refinery.

On July 13, 2023, the DOE announced $32 million in funding for projects to build facilities that produce rare-earth elements and other critical minerals and materials from domestic coal-based resources. Subsequently, on August 21, 2023, the DOE announced up to $30 million in funding to help lower the costs of the onshore production of rare earths and other critical minerals and materials from domestic coal-based resources. The funding is from the Bipartisan Infrastructure Law with the goal to strengthen domestic supply chains, meet the increasing demand for critical minerals, and reduce reliance on foreign sources.

On July 17, 2023, the DOD awarded $37.5 million to a graphite mining project in Alaska. On November 29, 2023, the DOD announced a $3.2 million award to support a graphite project in Alabama. The funds were provided through the Inflation Reduction Act to help secure a domestic supply of graphite to be used in the production of large-capacity batteries.

On September 12, 2023, the DOD awarded $20.6 million to advance nickel exploration and mineral resource definition at a project in Minnesota. Funds were appropriated by the Additional Ukraine Supplemental Appropriations Act.

On September 12, 2023, the DOD awarded $90 million to support the reopening of a lithium mine in North Carolina. The company estimated that the mine would resume operations between 2025 and 2030.

On October 30, 2023, the DOD awarded $12.7 million to a company to increase titanium powder production for defense supply chains. The company would scale up its facility in Virginia to increase the company's powder production to 125 metric tons per year. The goal was to increase production to 10,000 tons per year within 5 years.

In November 2023, production was restarted at a high-purity granular polysilicon facility in Washington which had been idled for 4 years. The material produced was to be shipped to a new fully integrated solar manufacturing facility in Georgia, scheduled to open in phases in 2024, that will produce silicon ingots, wafers, and cells for solar module production. There has been no production of solar-grade wafers in the United States since 2016. Tax incentives for domestically sourced materials for renewable energy, such as solar wafers and cells, in the Inflation Reduction Act of 2022 were cited as drivers for investments in these facilities.

Other information regarding individual projects and new production facilities can be found within each critical mineral chapter in this publication (p. 30–205).

Critical Minerals Recycling Project Investments in 2023

On February 9, 2023, the LPO at the DOE announced a conditional loan commitment of $2 billion to a company for the construction and expansion of a battery materials campus in Nevada that will support the growing electrical vehicle market in America. Once fully operational, the project would be the first domestic facility to support production of anode copper foil and cathode active materials in a fully closed-loop lithium-ion battery manufacturing process by recycling end-of-life battery and production scrap.

On February 27, 2023, the LPO at the DOE announced a conditional loan commitment of $375 million to a company for the construction of a lithium-ion battery resource recovery facility in New York and to help the company expand its operations.

From the fourth quarter of 2022 through 2023, DOE funding through the Bipartisan Infrastructure Law totaled $3 billion for five domestic lithium-ion recycling facilities.

Foreign Trade

In December 2023, China implemented export bans and export restrictions on certain strategic materials and technologies in the "Catalogue of Technologies Prohibited and Restricted from Export in China," which prohibited any of these materials or technologies from leaving China. Those items under an export ban included a category called "Nonferrous Metal Smelting and Processing Industry" had export restrictions that required exporters to apply for a license, which, according to some sources, required export contracts, technical product specifications, and the identity of the end user as well as the specific end use. For critical minerals, export prohibitions were already in place for some rare-earth extraction and separation technology but additional prohibitions on preparation technology for rare-earth magnets and rare-earth compounds were announced. Restrictions included all rare-earth mining, mineral processing, and smelting technologies that were not already on the prohibited list. The export restrictions also applied to several other nonferrous items including preparation technologies for single-crystal materials, lithium tetraborate and lithium triborate crystal technology as well as several other crystal growth processes; beryllium material preparation; flake graphite, spherical graphite (natural and synthetic), expandable graphite, and some synthetic graphite products; and superalloys for aviation. China was the dominant global producer for many critical mineral materials, and many of the materials were on United States critical minerals list.

U.S. Geological Survey Earth Mapping Resources Initiative for Critical Minerals

The USGS Earth Mapping Resources Initiative (Earth MRI) is a collaborative project between the USGS and State geological surveys to collect and modernize the Nation's geologic mapping and data resources. In 2023, the USGS invested millions of dollars to strengthen domestic supply chains for mineral resources critical to every economic sector and every member of society. The flagship effort within these investments is a nationwide mapping effort for critical minerals, which has been expanded and accelerated by funding from the Bipartisan Infrastructure Law. The USGS is improving the understanding of these resources, in the ground and in mine waste, across the Nation through Earth MRI. In fiscal year 2023 alone, the USGS distributed more than $51 million across 35 States and Puerto Rico to fund geoscience data collection and mapping in partnership with State geological surveys, data preservation programs, and scientific interpretation efforts to identify areas of the country with potential for the occurrence of critical minerals. About $40 million of the overall $51 million was part of the broader $510.7 million investment in the USGS from the Bipartisan Infrastructure Law to support scientific innovation.

In February 2023, Earth MRI released the “National Map of Focus Areas for Potential Critical Mineral Resources in the United States” (USGS Fact Sheet 2023–3007). Mapping of focus areas was based on a framework of mineral systems and their associated mineral deposit types that could possibly host critical minerals. These areas will be used to guide future efforts to collect new geologic, geophysical, geochemical, and topographic data that focus on critical minerals through Earth MRI.

In March 2023, nearly $3.4 million was invested to map resources of critical minerals in New Mexico in partnership with the New Mexico Bureau of Geology and Mineral Resources and more than $6.6 million to map resources of critical minerals in Utah in partnership with the Utah Geological Survey. The funding supported airborne magnetic and radiometric surveys covering more than 10,000 square miles in the mineral resource-rich southwestern corner of New Mexico. The airborne-data collection efforts paralleled companion grants to the New Mexico Bureau of Geology and Mineral Resources in support of geochemical mapping and mine-waste studies in southwestern New Mexico. The funding in Utah supported the largest airborne geophysical survey ever flown in the region, stretching from the Indian Peak Range in southwestern Utah to Utah Lake in the center of the State. In addition, light detection and ranging (lidar) surveys of the region’s topography were conducted, and geologic mapping and geochemical analyses were done.

In May 2023, more than $1 million was invested to map resources of critical minerals in Alabama in partnership with the Geological Survey of Alabama, and the USGS will invest more than $5.8 million to map resources of critical minerals in Alaska in partnership with the Alaska Division of Geological & Geophysical Surveys. The funded work in Alabama involved a new airborne electromagnetic survey in the Alabama Graphite Belt in the central and eastern parts of the State. These overflights are expected to improve the understanding of resources of critical minerals within the region, including graphite, the platinum-group elements, the rare-earth elements, and numerous other mineral commodities. The investments in Alaska enabled airborne geophysical surveys of the poorly mapped Kuskokwim River region of western Alaska and continued geologic mapping in the Yukon-Tanana region of east-central Alaska.

In July 2023, more than $1.9 million was invested to map resources of critical minerals in Montana in partnership with the Montana Bureau of Mines and Geology. The investment will enable both traditional geologic mapping and cutting-edge airborne geophysical surveys focusing on the Boulder Batholith and surrounding areas of southwestern Montana.

In September 2023, the USGS invested $500,000 to map geology and resources of critical minerals in New York in partnership with the New York State Geological Survey. The investment involved new airborne magnetic and radiometric surveys. The USGS also invested more than $5 million to map resources of critical minerals and to map resources of minerals important to hurricane resiliency in Alabama and Florida in partnership with the Geological Survey of Alabama and the Florida Geological Survey. This was the first time in more than 40 years that airborne geophysical data were collected over these areas and the first time ever that a high-resolution geophysical survey will be flown in the region.

Also in September, the USGS and the National Aeronautics and Space Administration (NASA) teamed up to map portions of the southwestern United States (including parts of California, Colorado, Nevada, Arizona, New Mexico, and Utah) for critical-mineral resources using airborne hyperspectral imaging. The $16 million, 5-year research project is funded by Earth MRI through investments from the Bipartisan Infrastructure Law.

In October 2023, the USGS invested more than $2 million to map resources of critical minerals in central Minnesota in partnership with several Minnesota State partners. Partners will collaborate on an airborne magnetic and radiometric survey of the Cuyuna Iron Range, a region known for past production of iron ore and for unusually high concentrations of manganese. The USGS also invested more than $3.5 million to map resources of critical minerals in partnership with the geological surveys of Arkansas, Illinois, Indiana, Kentucky, Missouri, and Tennessee. The effort continued a multiyear campaign to collect modern airborne magnetic and radiometric data to map the geology and develop a better understanding of resources of critical minerals in the region.

On October 26, 2023, the USGS announced that $5.8 million was awarded to 32 State geological surveys to enable them to preserve vital geologic and geophysical data and samples as part of the USGS National Geological and Geophysical Data Preservation Program. Of the $5.8 million to be awarded, $4.3 million was from investments made by the Bipartisan Infrastructure Law. Every dollar awarded by the USGS was matched by the State geological surveys, doubling the impact of the Federal investment. These investments expanded the USGS National Geological and Geophysical Data Preservation Program’s capacity to support preservation of physical samples (for example, drill core and geochemical samples) and earth-science assets for future use, to advance new scientific discoveries, and to obtain information needed for hazard mitigation, infrastructure development, critical minerals characterization, and climate resilience.

In November 2023, the USGS invested $3.1 million to map resources of critical minerals in Arizona in partnership with the Arizona Geological Survey. The USGS and the Arizona Geological Survey collaborated on an airborne magnetic and radiometric survey of the Arizona porphyry copper belt in southeastern Arizona near the New Mexico border.

On November 7, 2023, the USGS announced the investment of more than $2 million in cooperative agreements with 14 States to study the potential for critical-mineral resources in mine waste. This funding from the Bipartisan Infrastructure Law will allow the USGS and these States to better map locations of mine waste and assess the probability for the occurrence of undiscovered resources of critical minerals.

U.S. Production and Consumption of Critical Minerals in 2023

In 2023, the value of domestic primary mine production of critical minerals was $4.1 billion, a 24% decrease from $5.4 billion in 2022. Reduced prices for these mineral commodities contributed the most to the reduced value and delayed new production or restarting production of some critical minerals. A total of 13 individual mineral commodities and the rare-earths group of minerals (without specification of the specific lanthanides) had primary production in the United States. Zinc contributed the most to the total value of critical-mineral production (59%) followed by palladium (10%).

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 29 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%. The total value of critical minerals domestically recycled in 2023 was $10 billion, 23% of the total value of domestically recycled old scrap. 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 29 of 43 critical minerals (including 14 lanthanides, which are listed under rare earths) for which information was available to make reliable estimates. The other leading producing nations of critical minerals were Australia and South Africa with three critical minerals each and Congo (Kinshasa) with two critical minerals (table 5). For 29 critical minerals (including 14 lanthanides, which are listed under rare earths), 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, 2 critical minerals with 70% to less than 80% of global production dominated by one country, 20 critical minerals (including 14 lanthanides, which are listed under rare earths) with 60% to less than 70% of global production dominated by one country, and 2 critical minerals with 50% to less than 60% of global production dominated by one country (table 5).

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 2022 and 2023 and the 5-year compound annual growth rate (CAGR) in the prices of critical minerals from 2019 to 2023. In 2023, beryllium and fluorspar were the only critical minerals for which the 1-year percent change in the prices increased by more than 50% compared with their respective prices in 2022, and only 10 other critical minerals had increases in prices. Prices decreased for the other critical minerals; prices decreased by 20% or more for cobalt, gallium, lithium, magnesium, neodymium, palladium, rhodium, terbium, yttrium, and zinc. Despite these decreases from 2022 to 2023, the CAGR for most critical minerals has been positive over the past 5 years, reflecting a trend of increasing prices for these commodities.

In 2023, consumption for many mineral commodities decreased from that in 2022. Consumption in 2022 began to approach or exceed levels before the coronavirus disease 2019 (COVID-19) pandemic, but consumption decreased for most commodities in 2023 (fig. 11). There were reduced imports for many commodities which was reflected in the reduction in consumption in 2023.

For the 5-year period from 2019 to 2023, consumption declined for many mineral commodities indicating substitution of the material or potentially less domestic production of downstream products that required the raw mineral commodities. The largest decreases (greater than 25%) in consumption, in descending order, were for thallium, asbestos, strontium, tantalum, industrial diamond stones, rhenium, bauxite, yttrium, cobalt, pumice and pumicite, alumina, titanium metal, aluminum oxide abrasives, chromium, industrial garnet, rare earths, and iodine. Many nonfuel mineral commodities had smaller variations in consumption. The largest increases (greater than 25%) in consumption, in descending order, were for indium, platinum, natural graphite, gold, titanium mineral concentrates, molybdenum mineral concentrates, dimension stone, feldspar, and gallium (fig. 12).

In 2023, the value of domestically recycled old scrap was $45 billion and the total value of net exports of old scrap was $17 billion (fig. 1). The commodities with the highest value of domestically recycled old scrap as a percentage of the commodity’s total old scrap value (domestically recycled, imported, and exported) were antimony and lead. Antimony and lead were primarily consumed and recycled in lead-acid batteries. The commodities with the highest value of exports in proportion to total old scrap value, in descending order, were copper, silver, and chromium. Domestic copper scrap processing capacity decreased significantly between 1990 and 2002 when many secondary copper smelters and refineries closed. In 2023, domestic secondary processing capacity of copper increased as one new secondary smelter was operational, one recycling plant started up, and at least two secondary plants were under construction. The commodities with the highest value of imports in proportion to total old scrap value, in descending order, were titanium, cobalt, and magnesium metal (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 2023[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 (2019–22)	Leading producing country	Production in leading country	Percentage of world total	World production total
Aluminum (bauxite)	W	—	[2]1,800,000	>75	Jamaica	Australia	98,000,000	25	[3]400,000,000
Antimony	—	4,000	22,000	82	China[4]	China	40,000	48	83,000
Arsenic	—	NA	[5]6,400	100	China[4]	Peru	[6]27,000	45	[6]60,000
Barite	W	—	W	>75	India	India	2,700,000	32	[3]8,500,000
Beryllium	190	NA	150	E	Kazakhstan	United States	190	58	330
Bismuth[7]	—	80	1,400	94	China[4]	China	16,000	80	20,000
Chromium	—	100,000	380,000	74	South Africa	South Africa	18,000,000	44	41,000,000
Cobalt	500	2,100	6,400	67	Norway	Congo (Kinshasa)	170,000	74	230,000
Fluorspar	NA	—	370,000	100	Mexico	China	5,700,000	65	8,800,000
Gallium	—	—	[2]19	100	Japan	China	600	98	610
Germanium[7]	—	NA	NA	>50	Belgium	China	NA	NA	NA
Graphite (natural)	—	—	76,000	100	China[4]	China	1,230,000	77	1,600,000
Indium[7]	—	—	[5]300	100	Republic of Korea	China	650	66	990
Lithium	W	NA	W	>25	Argentina	Australia	86,000	48	[3]180,000
Magnesium[7]	W	100,000	[2]55,000	>50	Canada	China	830,000	88	[3]940,000
Manganese	—	—	690,000	100	Gabon	South Africa	7,200,000	36	20,000,000
Nickel	17,000	W	[8]190,000	57	Canada	Indonesia	1,800,000	50	3,600,000
Niobium	—	NA	8,400	100	Brazil	Brazil	75,000	90	83,000
Palladium	10	42	82	37	Russia	Russia	92	44	210
Platinum	3	9	70	83	South Africa	South Africa	120	67	180
Rare earths (compounds and metals)[9]	250	NA	8,800	>95	China[4]	China	240,000	69	350,000
Scandium	—	—	NA	100	Japan	China	NA	NA	NA
Tantalum	—	NA	370	100	China[4]	Congo (Kinshasa)	980	41	2,400
Tellurium[7]	W	—	W	>25	Canada	China	430	67	[3]640
Tin	—	16,900	39,000	74	Peru	China	68,000	23	290,000
Titanium (metal)[7]	W	W	[3]42,000	>95	Japan	China	220,000	67	[3]330,000
Tungsten	—	W	W	>50	China[4]	China	63,000	81	78,000
Vanadium	—	5,700	14,000	58	Canada	China	68,000	68	100,000
Yttrium	NA	—	200	100	China[4]	China	NA	NA	NA
Zinc[7]	[10]220,000	([10])	970,000	77	Canada	NA	NA	NA	NA
Zirconium (ores and concentrates)	<100,000	NA	<100,000	<25	South Africa	Australia	500,000	31	1,600,000

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

[1]Critical minerals as published in the Federal Register on 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]Includes Hong Kong.

[5]Estimated consumption.

[6]Arsenic trioxide.

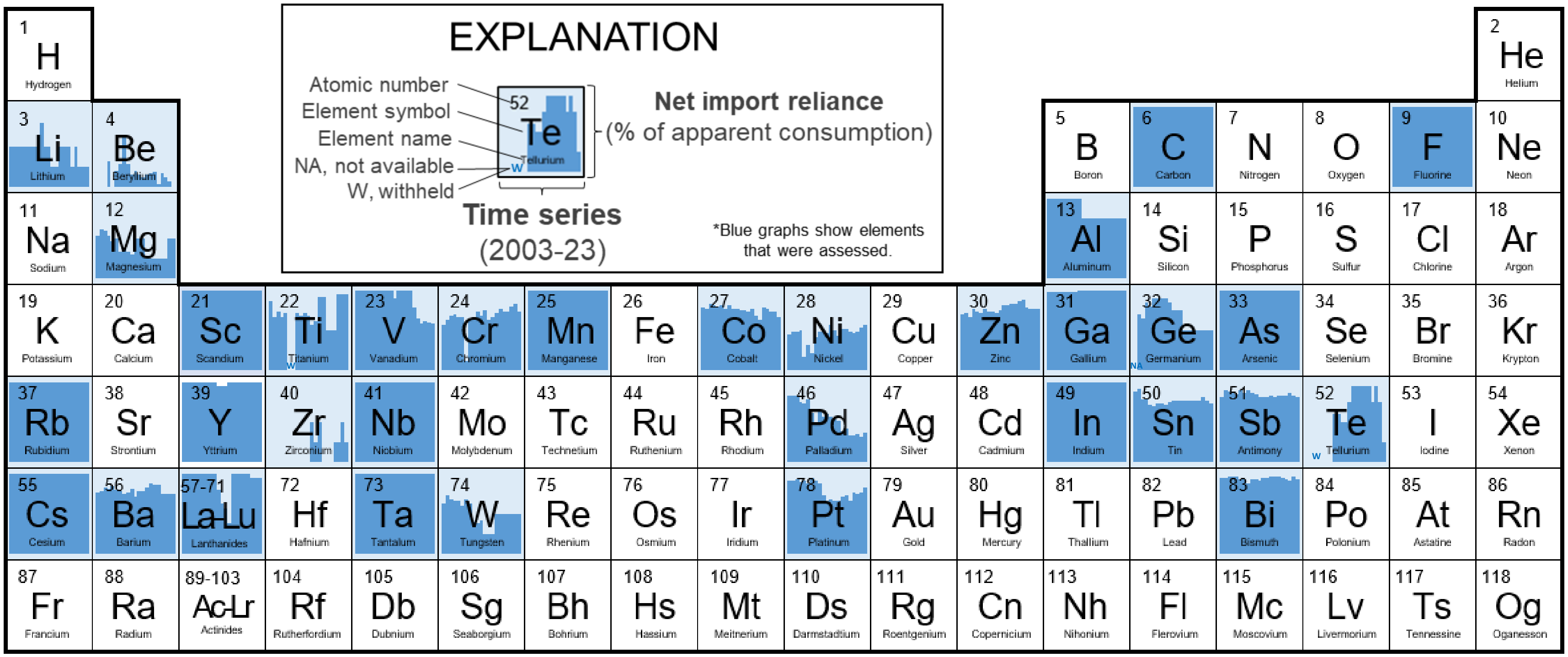
[7]Refinery production.

[8]Nickel in primary metal and secondary scrap.

[9]Data include lanthanides cerium, dysprosium, erbium, europium, gadolinium, holmium, lanthanum, lutetium, neodymium, praseodymium, samarium, terbium, thulium, and ytterbium.

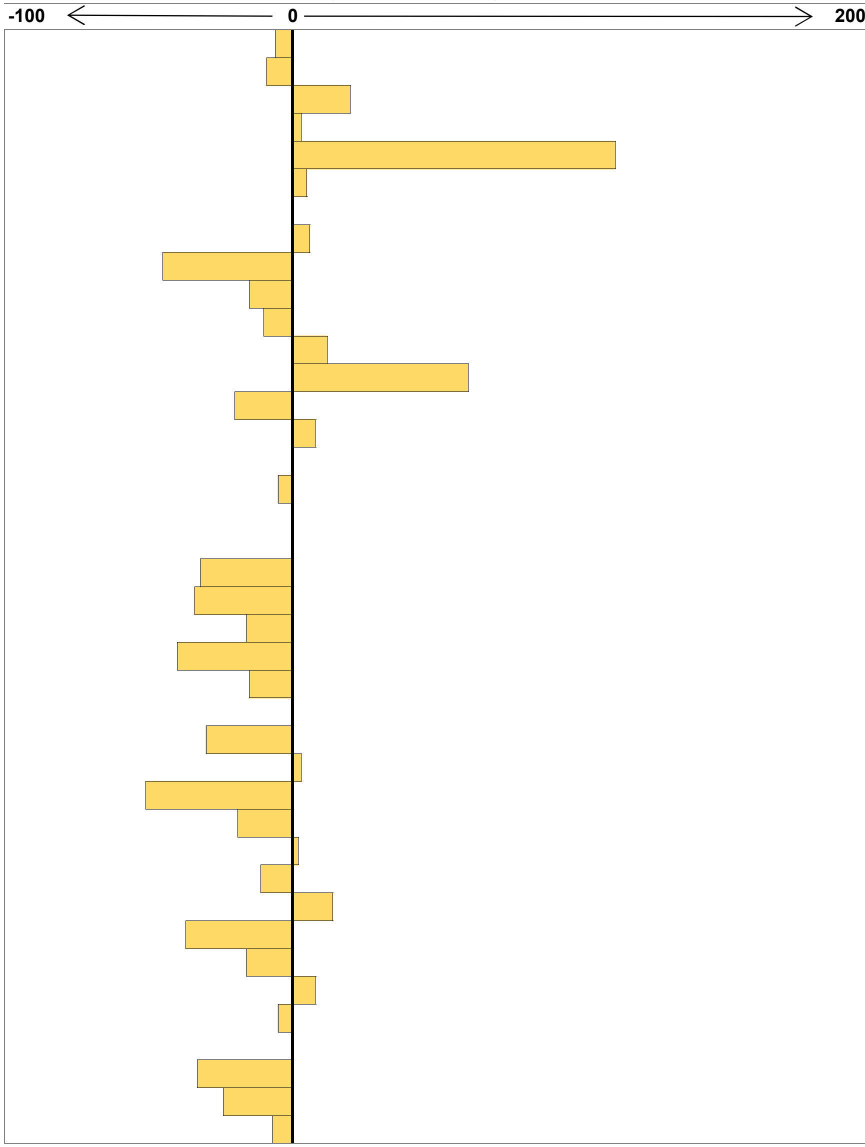
[10]Primary production includes both primary and secondary metal production.

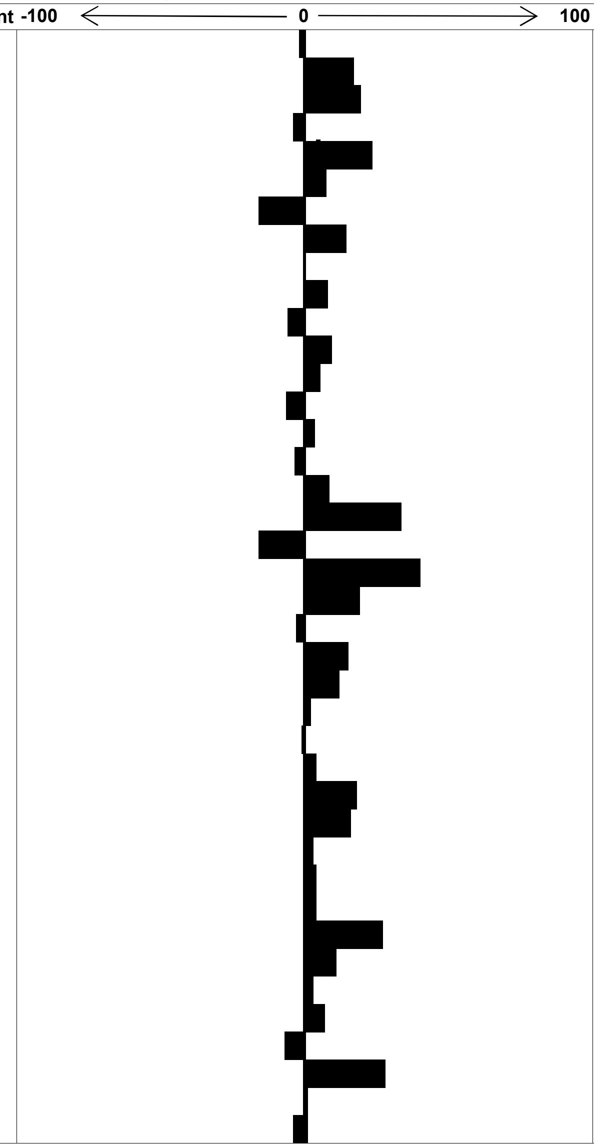
Figure 9.—20-Year Trend of U.S. Net Import Reliance for Critical Minerals



For elements of the periodic table associated with mineral commodities identified as critical in 2023 (87 FR 10381), the figure displays the U.S. net import reliance (NIR) as a percent of apparent consumption from 2003 through 2023. 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 2003 through 2023 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 (2022 to 2023) Percent	Critical mineral (price source)[2]	5-year CAGR (2019 to 2023) Percent
-6	Aluminum, bauxite	-2
-9	Antimony, metal	17
20	Arsenic, metal	19
3	Barite	-4
112	Beryllium[3]	23
5	Bismuth	7
0	Cerium, oxide 99.5% minimum	-16
6	Chromium, chromite ore	14
-45	Cobalt (U.S. spot cathode)	0
-15	Dysprosium, oxide 99.5% minimum	8
-10	Europium, oxide 99.99% minimum	-6
12	Fluorspar, acid grade[3]	9
61	Fluorspar, metallurgical grade[3]	5
-20	Gallium, high purity refined[3]	-6
8	Germanium, metal	3
0	Graphite, natural, flake[3]	-3
-5	Indium (Rotterdam)	8
0	Iridium	33
0	Lanthanum, oxide 99.5% minimum	-16
-32	Lithium, battery grade	40
-34	Magnesium, metal (U.S. spot Western)	19
-16	Manganese	-3
-40	Neodymium, oxide 99.5% minimum	15
-15	Nickel	12
0	Niobium, ferroniobium[3]	2
-30	Palladium	-1
3	Platinum	4
-51	Rhodium	18
-19	Ruthenium	16
2	Scandium, ingot	3
-11	Tantalum	4
14	Tellurium (U.S.)	4
-37	Terbium, oxide 99.99% minimum	27
-16	Tin (New York dealer)	11
8	Titanium, sponge[3]	3
-5	Tungsten, concentrate	7
0	Vanadium, vanadium pentoxide	-7
-33	Yttrium, oxide	28
-24	Zinc (LME)	1
-7	Zirconium, sponge[3]	-5

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 Statistics table. For those commodities with a single price source, please refer to that commodity chapter's Salient Statistics tables.

[3]Average annual unit value of imports.

Figure 11.—Change in U.S. Consumption of Nonfuel Mineral Commodities From 2022 to 2023

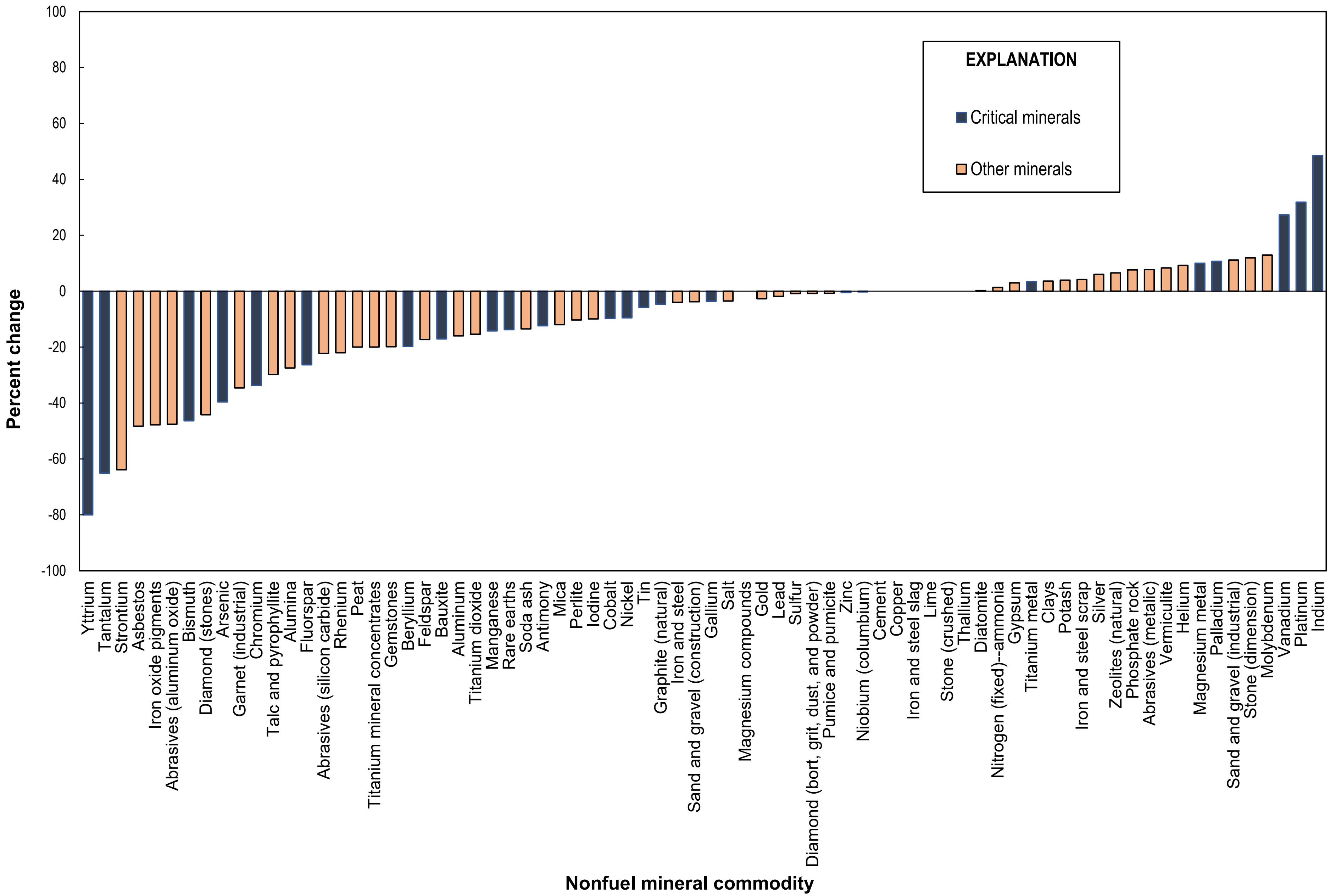


Figure 12.—Change in U.S. Consumption of Nonfuel Mineral Commodities From 2019 to 2023

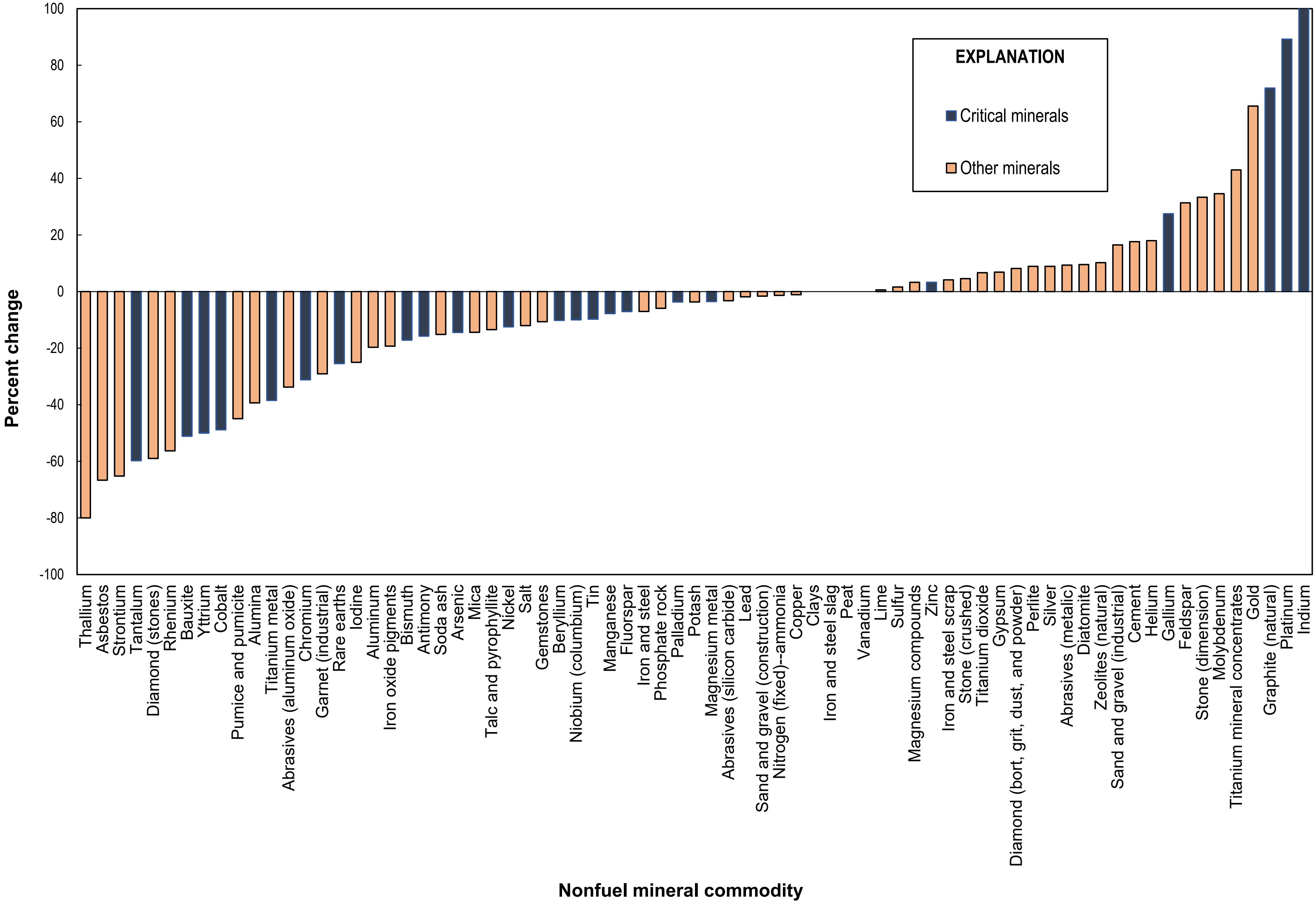


Figure 13.—Value of Old Scrap Domestically Recycled, Imported, and Exported, as a Percentage of Total Old Scrap Value

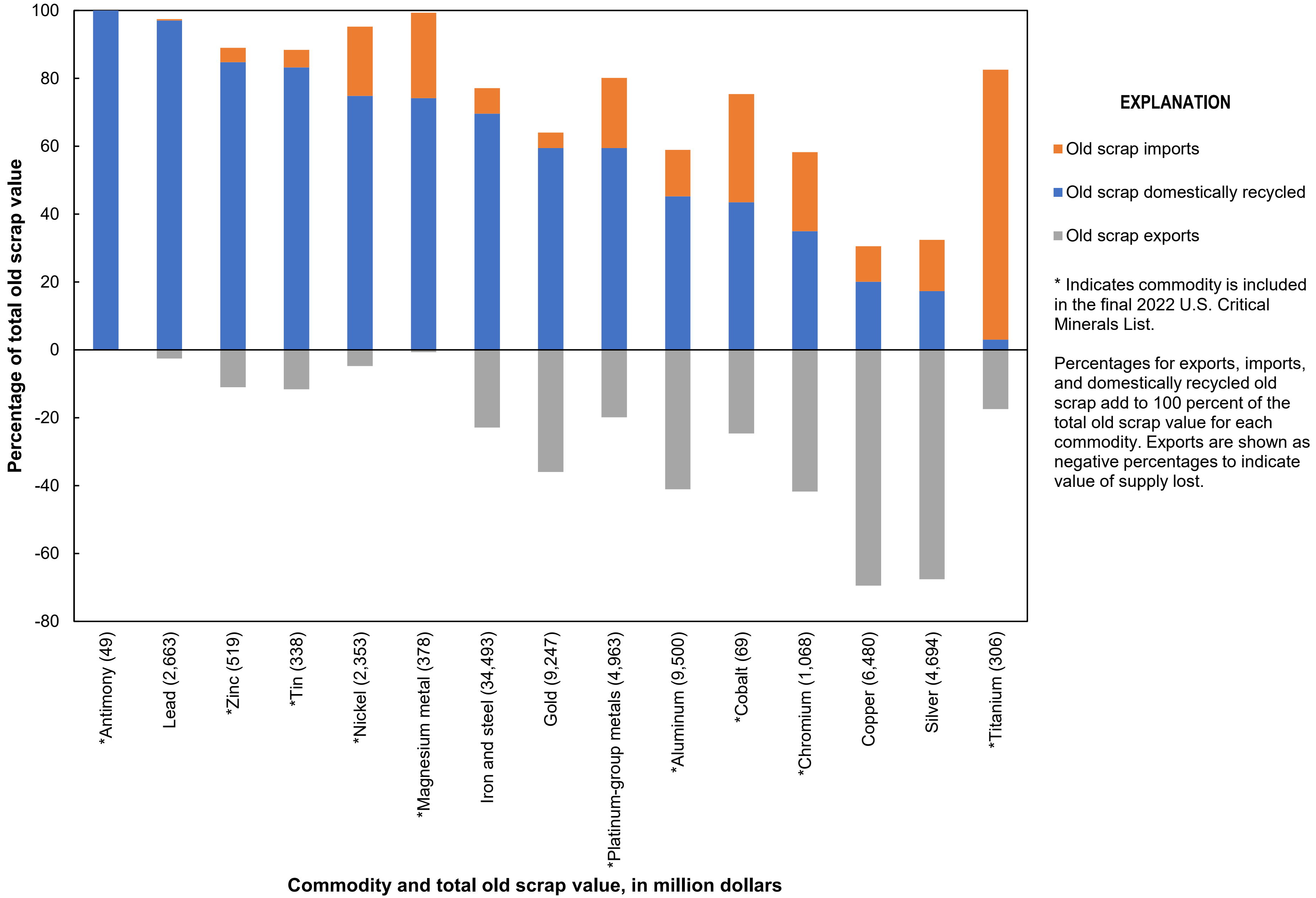
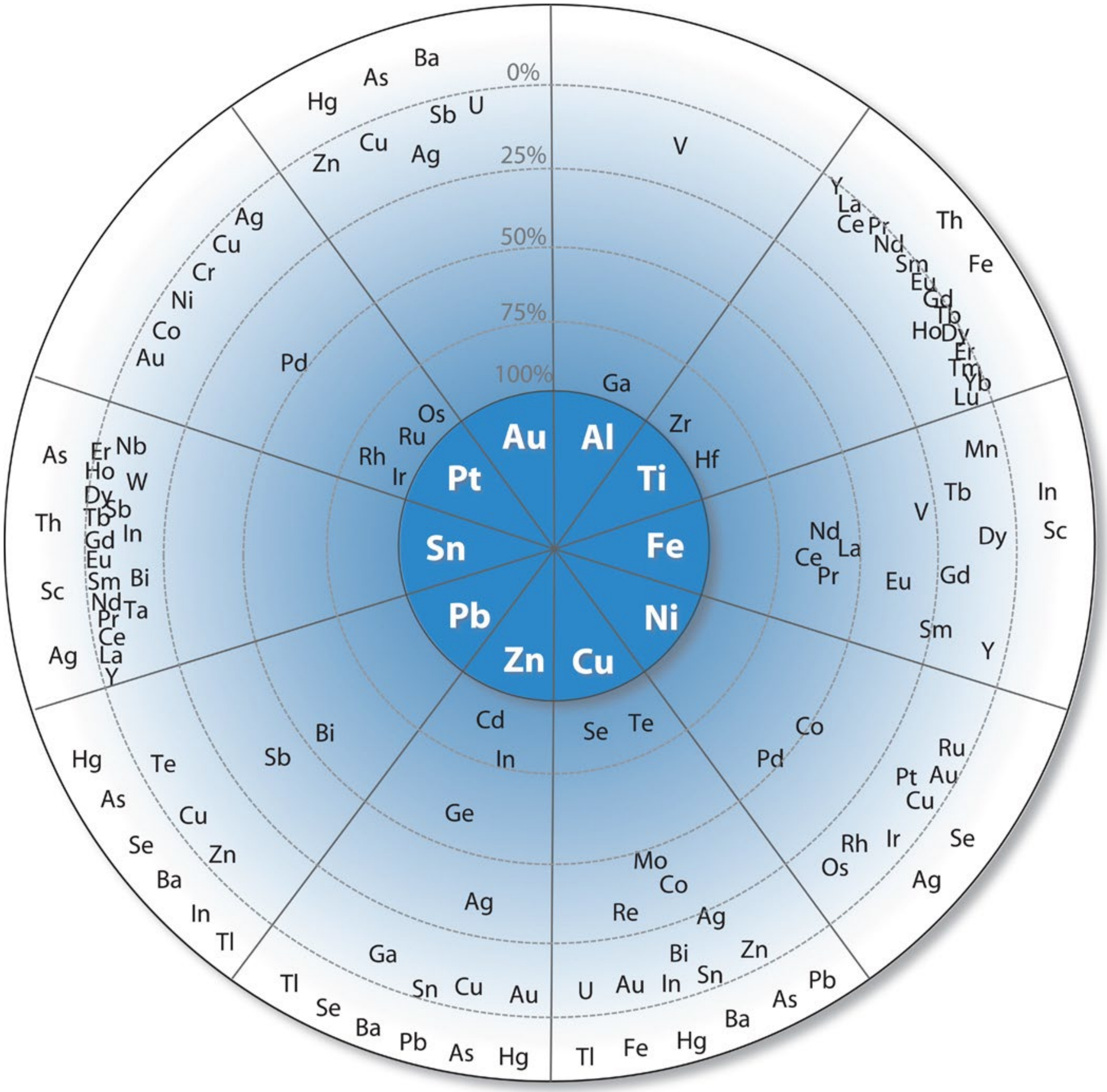


Figure 14.—Relation Between Byproduct Elements and Host Metals



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. The companion elements in the white region of the outer circle are elements for which the percentage of their production that originates with the host metal indicated has not been determined. Al, aluminum; Ag, silver; As, arsenic; Au, gold; Ba, barium; Bi, bismuth; Cd, cadmium; Ce, cerium; Co, cobalt; Cr, chromium; Cu, copper; Dy, dysprosium; Er, erbium; Eu, europium; Fe, iron; Ga, gallium; Gd, gadolinium; Ge, germanium; Hf, hafnium; Hg, mercury; Ho, holmium; In, indium; Ir, iridium; La, lanthanum; Lu, lutetium; Mn, manganese; Mo, molybdenum; Nd, neodymium; Ni, nickel; Os, osmium; Pb, lead; Pd, palladium; Pt, platinum; Pr, praseodymium; Re, rhenium; Rh, rhodium; Ru, ruthenium; Sb, antimony; Sc, scandium; Se, selenium; Sm, samarium; Sn, tin; Ta, tantalum; Tb, terbium; Te, tellurium; Th, thorium; Ti, titanium; Tl, thallium; U, uranium; V, vanadium; W, tungsten; Y, yttrium; Yb, ytterbium; Zn, zinc; Zr, zirconium. 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 specified)

Domestic Production and Use: In 2023, 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 $3.4 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 $28 million. Metallic abrasives were produced by 11 companies in eight States. Production of metallic abrasives had an estimated value of about $130 million, and metallic abrasive shipments were valued at $140 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:	2019	2020	2021	2022	2023[e]
Production:					
Fused aluminum oxide, crude[1, 2]	10,000	10,000	10,000	20,000	20,000
Silicon carbide[2]	35,000	35,000	35,000	40,000	40,000
Metallic abrasives	177,000	176,000	176,000	180,000	180,000
Shipments, metallic abrasives	195,000	194,000	193,000	199,000	210,000
Imports for consumption:					
Fused aluminum oxide	184,000	121,000	159,000	225,000	120,000
Silicon carbide	131,000	88,400	125,000	165,000	120,000
Metallic abrasives	27,900	25,800	26,400	20,100	18,000
Exports:					
Fused aluminum oxide	18,400	11,400	13,500	14,400	10,000
Silicon carbide	11,500	8,310	12,000	12,000	11,000
Metallic abrasives	31,200	18,000	20,100	23,900	22,000
Consumption, apparent:					
Fused aluminum oxide[3]	166,000	109,000	146,000	210,000	110,000
Silicon carbide[4]	155,000	115,000	148,000	193,000	150,000
Metallic abrasives[5]	192,000	202,000	199,000	195,000	210,000
Price, average unit value of imports, dollars per metric ton:					
Fused aluminum oxide, crude	716	666	674	797	670
Fused aluminum oxide, ground and refined	1,250	1,180	1,290	1,030	1,400
Silicon carbide, crude	701	628	587	1,080	910
Metallic abrasives	1,310	1,130	1,510	2,130	1,900
Net import reliance[6] as a percentage of apparent consumption:					
Fused aluminum oxide	>95	>95	>95	>95	>95
Silicon carbide	77	70	76	79	73
Metallic abrasives	E	4	3	E	E

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

Import Sources (2019–22): Fused aluminum oxide, crude: China,[7] 91%; Bahrain, 3%; Russia, 2%; Turkey, 2%; and other, 2%. Fused aluminum oxide, ground and refined: Canada, 26%; Brazil, 19%; Austria, 15%; China,[7] 13%; and other, 27%. Total fused aluminum oxide: China,[7] 65%; Canada, 10%; Brazil, 7%; Austria, 5%; and other, 13%. Silicon carbide, crude: China,[7] 91%; Netherlands, 3%; South Africa, 2%; Vietnam, 2%; and other 2%. Silicon carbide, ground and refined: China,[7] 51%; Brazil, 19%; Canada, 11%; Norway, 8%; and other, 11%. Total silicon carbide: China,[7] 81%; Brazil, 5%; Canada, 3%; Netherlands, 2%; and other, 9%. Metallic abrasives: Canada, 40%; Turkey, 16%; Thailand, 10%; China,[7] 8%; and other, 26%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023, 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 98% of United States imports of crude fused aluminum oxide, 23% of ground and refined fused aluminum oxide imports, 98% of crude silicon carbide imports, and 63% of ground and refined silicon carbide imports. Foreign competition was expected to persist and continue to limit production in North America. The import quantities of abrasive fused aluminum oxide (crude and ground and refined) in 2023 were 59% and 7% lower, respectively, than those in 2022. The import quantities of abrasive silicon carbide (crude and ground and refined) in 2023 were 31% and 23% lower, respectively, than those in 2022.

The United States returned to being a net exporter of metallic abrasives in 2022 and 2023 as compared with being a net importer in 2020 and 2021. The import quantity of metallic abrasives in 2023 was 9% lower than that in 2022. 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.

World Production Capacity: Fused aluminum oxide capacity data for Austria were revised based on company reports.

	Fused aluminum oxide[e]		Silicon carbide[e]	
	2022	2023	2022	2023
United States	—	—	40,000	40,000
United States and Canada	60,000	60,000	—	—
Australia	50,000	50,000	—	—
Austria	90,000	90,000	—	—
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)	1,310,000	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 specified)

Domestic Production and Use: In 2023, three companies operated five primary aluminum smelters across five States. Two of these smelters operated at full capacity throughout the year, whereas three smelters operated at reduced capacity. A sixth smelter, located in Hawesville, KY, has been temporarily shut down since 2022. In March, permanent closure was announced for a seventh smelter located in Ferndale, WA, that had ceased operations in 2020. Domestic smelter capacity decreased to 1.36 million tons per year from 1.64 million tons per year in 2022. Estimated primary production decreased by 13% from that in 2022, whereas estimated secondary production from new and old scrap was essentially unchanged from that in 2022. Based on published prices, the value of primary aluminum production was about $2.15 billion, 26% less than that in 2022. The estimated average annual U.S. market price decreased by 15% from that in 2022. Transportation applications accounted for 35% of domestic consumption; the remainder was used in packaging, 22%; building, 14%; electrical, 9%; consumer durables and machinery, 8% each; and other, 4%.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:					
Primary	1,090	1,010	889	861	750
Secondary (from old scrap)	1,540	1,420	1,520	1,450	1,500
Secondary (from new scrap)	1,920	1,630	1,780	1,890	1,800
Imports for consumption:					
Crude and semimanufactures	5,280	4,260	4,820	5,610	4,800
Scrap	596	542	680	690	740
Exports:					
Crude and semimanufactures	1,110	906	900	1,040	1,200
Scrap	1,860	1,840	2,100	2,000	2,100
Consumption, apparent[2]	4,980	3,930	4,020	4,760	4,000
Supply, apparent[3]	6,910	5,560	5,800	6,650	5,800
Price, ingot, average U.S. market (spot), cents per pound[4]	99.5	89.7	138.5	152.6	130
Stocks, yearend:					
Aluminum industry	1,600	1,490	1,870	2,050	1,800
London Metal Exchange (LME), U.S. warehouses[5]	120	235	69	9	4
Employment, number[6]	32,900	30,100	28,900	30,200	30,000
Net import reliance[7] as a percentage of apparent consumption	47	38	40	52	44

Recycling: In 2023, aluminum recovered from purchased scrap in the United States was about 3.3 million tons, of which about 55% came from new (manufacturing) scrap and 45% from old scrap (discarded aluminum products). Aluminum recovered from old scrap was equivalent to about 38% of apparent consumption.

Import Sources (2019–22): Canada, 52%; United Arab Emirates, 8%; Bahrain, 4%; Russia, 4%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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.
Other	7602.00.0096	Free.

Depletion Allowance: Not applicable.[1]

Government Stockpile:[8]

	FY 2023		FY 2024	
Material	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Aluminum, high-purity and alloys	—	—	18.5	—

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ALUMINUM

Events, Trends, and Issues: In April, a U.S. primary aluminum producer acquired a majority stake in a company operating a bauxite mine and a 1.4-million-ton-per-year alumina refinery located in Jamaica. The Government of Jamaica did not object to the transaction and stated that the company would be responsible for investments to repair damage caused by a fire that shut down production in 2021. In May, a 4-year collective bargaining agreement was ratified at an aluminum rolling mill in Evansville, IN, while a 3-year agreement was ratified at primary aluminum smelters in Warrick, IN, and Massena, NY. In October, a 3-year power deal was signed between the owner of a 229,000-ton-per-year primary aluminum smelter in Mt. Holly, SC, and its power provider. The contract is scheduled to remain in effect through 2026.

The United States announced a 200% tariff on imported aluminum products and aluminum derivatives from Russia, effective March 10, and April 10, respectively. These ad valorem tariffs are authorized under section 232 of the Trade Expansion Act of 1962, which authorizes the President to impose trade restrictions when products are imported in a manner that threatens to impair national security.

In February, workers at a 228,000-ton-per-year primary aluminum smelter located in San Ciprian, Spain, approved a plan to restart the smelter in January 2024. Originally curtailed in 2021, the smelter is expected to return to 75% capacity by 2026. In March, a 230,000-ton-per-year primary aluminum smelter located in Neuss, Germany, began fully ramping down operations and a 358,000-ton-per-year primary aluminum smelter located in Victoria, Australia, reduced production by 75%. In May, the operator of a 120,000-ton-per-year primary aluminum smelter in Podgorica, Montenegro, ceased operations and began permanent closure. In October, a 432,000-ton-per-year primary aluminum smelter located in British Columbia, Canada, returned to full production. The smelter has been operating at reduced production levels since 2018.

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

	Smelter production		Yearend capacity	
	2022	2023[e]	2022	2023[e]
United States	861	750	1,640	1,360
Australia	1,510	1,500	1,730	1,730
Bahrain	1,600	1,600	1,600	1,600
Brazil	811	1,100	1,280	1,280
Canada	2,770	3,000	3,270	3,270
China	40,200	41,000	44,300	45,000
Iceland	[e]720	730	880	880
India	[e]4,100	4,100	4,060	4,060
Malaysia	[e]900	980	1,080	1,080
Norway	[e]1,400	1,300	1,460	1,460
Russia	3,720	3,800	4,080	4,080
United Arab Emirates	2,650	2,700	2,790	2,790
Other countries	7,110	7,000	10,300	10,000
World total (rounded)	68,400	70,000	78,500	79,000

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

ANTIMONY

(Data in metric tons, antimony content, unless otherwise specified)

Domestic Production and Use: In 2023, no marketable antimony was mined in the United States. Primary antimony metal and oxide were produced by one company in Montana using imported feedstock; data were not available. Secondary antimony production was derived mostly from antimonial lead recovered from spent lead-acid batteries. The estimated value of secondary antimony produced in 2023 was about $49 million. Recycling supplied about 18% of estimated domestic apparent consumption, and the remainder came mostly from imports. In the United States, the leading uses of antimony were metal products, including antimonial lead and ammunition, 43%; flame retardants, 35%; and nonmetal products, including ceramics and glass and rubber products, 22%.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:					
Mine (recoverable antimony)	—	—	—	—	—
Smelter:					
Primary	377	254	NA	NA	NA
Secondary	4,140	3,520	4,050	4,100	4,000
Imports for consumption:					
Ore and concentrates	121	105	31	29	8
Oxide	17,200	15,000	19,100	16,900	14,000
Unwrought, powder	6,670	5,520	7,480	8,300	8,300
Waste and scrap[1]	17	6	13	71	5
Exports:					
Ore and concentrates[1]	9	10	9	53	30
Oxide	1,570	1,230	1,530	2,420	1,800
Unwrought, powder	370	393	921	1,820	2,100
Waste and scrap[1]	14	11	136	26	3
Consumption, apparent[2]	26,100	22,400	28,200	25,100	22,000
Price, metal, average, dollars per pound[3]	3.90	2.67	5.31	6.18	5.60
Net import reliance[4] as a percentage of apparent consumption	84	84	86	84	82

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 (2019–2022): Ore and concentrates: Italy, 36%; China, 35%; India, 15%; Belgium, 9%; and other, 5%. Oxide: China,[5] 76%; Belgium, 11%; Bolivia, 5%; France, 3%; and other, 5%. Unwrought metal and powder: China,[5] 26%; India, 23%; Vietnam, 12%; Burma, 10%; and other, 29%. Total metal and oxide: China,[5] 63%; Belgium, 8%; India, 6%; Bolivia, 4%, and other, 19%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023		FY 2024	
Material	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Antimony	1,100	—	1,100	—

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ANTIMONY

Events, Trends, and Issues: China's antimony mine production has fallen significantly over the past several years. However, China continued to be the leading global antimony producer in 2023 and accounted for 48% of global antimony mine production. The world's leading antimony-producing mine was a gold-antimony mine with 23,000-ton-per-year capacity in Russia. The mine had significantly reduced antimony production in 2021 through 2023 because gold production was maximized. The antimony price in 2023 decreased, and the estimated average price was $5.60 per pound in the first 11 months of 2023 compared with the annual average price of $6.18 per pound in 2022.

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

	Mine production		Reserves[7]
	2022	2023[e]	
United States	—	—	[8]60,000
Australia	2,290	2,300	[9]140,000
Bolivia	3,000	3,000	310,000
Burma	[e]4,600	4,600	140,000
Canada	[e]2	2	78,000
China	[e]40,000	40,000	640,000
Guatemala	24	24	NA
Iran	[e]500	500	NA
Kazakhstan	[e]300	300	NA
Kyrgyzstan	40	40	260,000
Laos	[e]220	220	NA
Mexico	[e]700	700	18,000
Pakistan	[e]79	80	26,000
Russia	4,300	4,300	350,000
Tajikistan	21,000	21,000	50,000
Turkey	[e]5,800	6,000	99,000
Vietnam	250	250	NA
World total (rounded)[10]	83,100	83,000	>2,000,000

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

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

[e]Estimated. NA Not available. — Zero.
[1]Gross weight.
[2]Defined as secondary production from old scrap + imports of antimony in oxide and unwrought metal, powder – exports of antimony in oxide and unwrought metal, powder.
[3]Antimony minimum 99.65%, cost, insurance, and freight. Source: Argus Media group, Argus Non-Ferrous Markets.
[4]Defined as imports of antimony in oxide and unwrought metal, powder – exports of antimony in oxide and unwrought metal, powder.
[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 20,000 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, arsenic content,[1] unless otherwise specified)

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 2023. 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 shortwave 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 2023 was estimated to be $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 products containing arsenic. Therefore, the estimated consumption reported under U.S. salient statistics reflects only imports of arsenic products. Domestically, the leading uses of arsenic were as follows: herbicides and insecticides and wood preservatives, 80%; semiconductor, 6%; metallurgical, 3%; batteries, 1%; and other, 10%.

Salient Statistics—United States:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Imports for consumption:[2]					
Arsenic metal	391	522	835	858	710
Compounds	7,090	7,750	4,760	9,750	5,700
Total	7,480	8,270	5,600	10,600	6,400
Exports, all forms of arsenic (gross weight)	56	29	31	82	15
Consumption, estimated, all forms of arsenic[3]	7,480	8,270	5,600	10,600	6,400
Price, metal, annual average, U.S. warehouse,[4] dollars per pound	1.01	1.08	1.11	1.67	2
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 (2019–22):[2] Arsenic acid: Malaysia, 95%; Hungary, 4%; and China, 1%. Arsenic metal: China,[6] 93%; Japan, 5%; Germany, 1%; and other, 1%. Arsenic trioxide: China, 59%; Morocco, 35%; Belgium, 4%; Germany, 1%; and other, 1%. All forms of arsenic: China,[6] 58%; Morocco, 30%; Malaysia, 7%; Belgium, 4%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
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.

Events, Trends, and Issues: Peru, China, and Morocco, in descending order of production, continued to be the leading global producers of arsenic trioxide, accounting for about 97% of estimated world production in 2023. China and Morocco continued to supply about 91% of United States imports of arsenic trioxide in 2023. China was the leading world producer of arsenic metal and supplied 98% of United States arsenic metal imports as of September 2023. Malaysia supplied all of the arsenic acid that was imported as of September 2023.

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ARSENIC

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 decreased in 2023 because of inflation, high interest rates, and fears of a recession have caused a lower deployment of fifth-generation 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 global market.

World Production and Reserves:

	Production[e, 7] (arsenic trioxide, gross weight)		Reserves[8]
	2022	2023	
United States	—	—	World reserves data were unavailable but were estimated to be more than 20 times world production.
Belgium	1,000	1,000	
Bolivia	40	—	
China	24,000	24,000	
Japan	40	40	
Morocco	7,500	8,000	
Peru	27,000	27,000	
Russia	500	200	
World total (rounded)	60,100	60,000	

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. Many semiconductor manufacturers were moving away from GaAs- and silicon-based lateral diffused metal-oxide-semiconductor field-effect transistors to those using gallium nitride. 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 Non-Ferrous Markets.

[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.

ASBESTOS

(Data in metric tons unless otherwise specified)

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 use associated with health and liability issues. Since then, the United States has 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. Domestic consumption of chrysotile was estimated to be 150 tons in 2023; all consumption was from stockpiles, as no chrysotile was imported based on data available through September. The chloralkali industry, which uses chrysotile in 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 U.S. asbestos fiber consumption since no later than 2015. In addition to unmanufactured asbestos fiber, an 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]	**2019**	**2020**	**2021**	**2022**	**2023**[e]
Imports for consumption[3]	172	305	41	224	([4])
Exports[5]	—	—	—	—	—
Consumption, estimated[6]	450	450	310	290	150
Price, average U.S. customs unit value of imports, dollars per ton	1,570	2,110	1,880	2,630	—
Net import reliance[7] as a percentage of estimated consumption	100	100	100	100	100

Recycling: None.

Import Sources (2019–22): Brazil, 70%; and Russia, 30%. The U.S. Census Bureau reported imports from China and Poland during this time period, but bill of lading information, data reported by the Government of China, and an asbestos ban in Poland suggest that these shipments were misclassified.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
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 significantly during the past several decades, 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. In 2023, asbestos diaphragms were used in eight chloralkali plants in the United States, three of which were in the process of transitioning to alternative materials.

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 announced in July 2023 that it planned to issue the final rule by yearend. 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. Once finalized, the rule proposed in April 2022 would effectively prohibit all uses of asbestos in the United States.

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ASBESTOS

In July 2023, the EPA finalized reporting requirements for asbestos under the Toxic Substances Control Act of 1976. Companies that imported, manufactured, or processed asbestos from 2019 through 2022 and sold more than $500,000 worth of products in any of those years would be required to disclose to the EPA the quantity of asbestos manufactured or processed and the types of products in which the asbestos was used by no later than May 2024. The rule applied to all types of unmanufactured asbestos fiber and asbestos-containing manufactured products, including articles that contained asbestos as an impurity.

Estimated worldwide consumption of unmanufactured asbestos fiber ranged from 1.1 million to 1.3 million tons per year from 2015 through 2023, 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.

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

	Mine production[e]		Reserves[8]
	2022	2023	
United States	—	—	Small
Brazil	[9, 10]197,100	190,000	11,000,000
China	130,000	200,000	18,000,000
Kazakhstan	[9]250,100	260,000	Large
Russia	750,000	630,000	110,000,000
World total (rounded)	1,330,000	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. Additional chrysotile imports from China were reported in 2021 (59 tons) and 2022 (99 tons), but bill of lading information and data reported by the Government of China suggest that these shipments were misclassified. In 2023, imports of 2 tons from Poland were reported as of the end of September, but an asbestos ban in Poland suggests that these shipments were also misclassified.

[4]No chrysotile was imported into the United States during the first 9 months of 2023. Final 2023 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 were reported by the U.S. Census Bureau but not listed in the Salient Statistics because those 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 was 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]Reported.

[10]Asbestos production in Brazil was permitted for export purposes only. The value shown is reported country exports of asbestos because production data were unavailable.

BARITE

(Data in thousand metric tons unless otherwise specified)

Domestic Production and Use: In 2023, three companies mined barite in Nevada. Mine production increased, but data were withheld to avoid disclosing company proprietary data. An estimated 2.5 million tons of barite (from domestic production and imports) was sold by crushers and grinders operating in nine States.

Typically, more than 90% of the barite sold in the United States is used as a weighting agent in fluids used in the drilling of oil and natural gas wells. The majority of Nevada crude barite was ground in Nevada and then sold to companies drilling in the Central and Western United States. Because of the higher cost of rail and truck transportation compared to ocean freight, offshore drilling operations in the Gulf of Mexico and onshore drilling operations in other regions primarily used imported barite.

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

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:					
Sold or used, mine	414	W	W	W	W
Ground and crushed[1]	2,350	1,410	1,670	2,200	2,500
Imports:[2]					
For consumption	2,500	1,480	1,660	2,330	2,500
General	2,330	869	1,440	1,890	2,400
Exports[3]	38	48	62	86	84
Consumption, apparent (crude and ground)[4]	2,880	W	W	W	W
Price, average unit value, ground, ex-works, dollars per metric ton	179	183	167	145	150
Employment, mine and mill, number[e]	480	360	330	380	390
Net import reliance[5] as a percentage of apparent consumption	86	>75	>75	>75	>75

Recycling: None.

Import Sources (2019–22): India, 36%; China,[6] 30%; Morocco, 17%; Mexico, 13%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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

Events, Trends, and Issues: Historically, rig counts have been a good indicator of barite consumption. Through October 2023, the world annual average rig count excluding the United States was 1,120, an increase of 9% compared with that in 2022. In all countries or localities except for Canada, however, the average annual rig count remained below average counts in 2019, before the coronavirus disease 2019 (COVID-19) pandemic. Increases in worldwide rig counts contributed to an estimated 3% increase in world barite production. In the United States, the annual average rig count decreased slightly in 2023, and the monthly average rig count decreased throughout the year. Despite the slowing pace of domestic drilling activity, barite sales were estimated to have increased by more than 10%.

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

	Mine production[e]		Reserves[7]
	2022	2023	
United States	W	W	NA
China	1,900	1,900	92,000
India	2,700	2,700	51,000
Iran	300	300	38,000
Kazakhstan	650	600	85,000
Laos	[8]303	600	NA
Mexico	[8]316	260	NA
Morocco	1,200	1,200	NA
Russia	250	250	12,000
Turkey	250	250	NA
Other countries	394	430	NA
World total (rounded)	[9]8,260	[9]8,500	NA

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

Substitutes: Owing to technical and economic factors, there are no large-scale alternatives to barite in oil- and gas-drilling fluids. Calcium carbonate, hematite, ilmenite, and manganese tetroxide are the most common alternatives used in specific circumstances. Some technical literature and patents also mention use of celestite, iron carbonate, and strontium carbonate, but these are not estimated to be widely used.

[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. General imports and imports for consumption data differ because of barite processed in free trade zones. General import data reports the form of imported barite at the time it entered the United States, whereas imports for consumption data reports crude barite processed in free trade zones as ground. Imports for consumption may not be immediately reported depending on processing time.
[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 for consumption – exports.
[5]Defined as imports for consumption – exports.
[6]Includes Hong Kong.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]Reported.
[9]Excludes U.S. production.

BAUXITE AND ALUMINA[1]

(Data in thousand metric dry tons unless otherwise specified)

Domestic Production and Use: In 2023, a limited amount of bauxite and bauxitic clay was produced for nonmetallurgical use in Alabama, Arkansas, and Georgia. Production statistics were withheld for bauxite and estimated for alumina to avoid disclosing company proprietary data. In 2023, the reported quantity of bauxite consumed was estimated to be 1.8 million tons, 17% less than that reported in 2022, with an estimated value of about $58 million. About 78% 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 780,000 tons, 15% less than that in 2022. About 68% 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:	2019	2020	2021	2022	2023[e]
Bauxite:					
Production, mine	W	W	W	W	W
Imports for consumption[2]	4,620	3,760	3,880	3,630	3,100
Exports[2]	16	16	13	10	12
Stocks, industry, yearend[e, 2]	300	250	200	200	240
Consumption:					
Apparent[3]	W	W	W	W	W
Reported	3,680	3,330	2,790	2,170	1,800
Price, average unit value of imports, free alongside ship (f.a.s.), dollars per metric ton	32	30	31	32	30
Net import reliance[4] as a percentage of apparent consumption	>75	>75	>75	>75	>75
Alumina:					
Production, refinery[e, 5]	1,400	1,300	1,000	920	780
Imports for consumption[5]	1,930	1,340	1,550	1,880	1,300
Exports[5]	200	153	180	174	140
Stocks, industry, yearend[5]	275	234	202	213	230
Consumption, apparent[3]	3,130	2,530	2,410	2,620	1,900
Price, average unit value of imports, f.a.s., dollars per metric ton	472	394	462	518	500
Net import reliance[4] as a percentage of apparent consumption	55	49	58	65	59

Recycling: None.

Import Sources (2019–22): Bauxite:[2] Jamaica, 64%; Turkey, 9%; Guyana, 8%; Australia, 6%; and other, 13%. Alumina:[5] Brazil, 61%; Australia, 13%; Jamaica, 12%; Canada, 4%; and other, 10%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023, 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 remained idle in 2023. 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 8 months of 2023 were $32 per ton and $501 per ton, 3% more and 8% less than those in the same period in 2022, respectively.

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BAUXITE AND ALUMINA

A U.S. primary aluminum producer acquired a majority stake in a company operating a bauxite mine and a 1.4-million-ton-per-year alumina refinery located in Jamaica. In Europe, high energy costs in 2022 led to the closure and curtailment of alumina refineries, aluminum smelters, and aluminum product manufacturers, which continued into 2023. Ukraine's 1.7-million-ton-per-year alumina refinery remained closed owing to the conflict between Russia and Ukraine. A China-based aluminum producer acquired an Indonesia-based miner with mining rights to three bauxite mines in the Kalimantan Province of Indonesia; one mine has estimated bauxite reserves of 68 million tons of bauxite. China's Shanghai Futures Exchange began selling alumina future contracts after receiving approval from China's securities regulatory commission.

World Alumina Refinery and Bauxite Mine Production and Bauxite Reserves: Reserves for Australia, India, and Russia were revised based on company and Government reports.

	Alumina production[5]		Bauxite production		Bauxite reserves[6]
	2022	2023[e]	2022	2023[e]	
United States	[e]920	780	W	W	20,000
Australia	19,500	19,000	102,000	98,000	[7]3,500,000
Brazil	[e]10,000	10,000	[e]30,000	31,000	2,700,000
Canada	1,360	1,600	—	—	—
China	81,900	82,000	[e]90,000	93,000	710,000
Germany	[e]1,000	720	—	—	—
Greece	861	860	[e]1,200	1,200	—
Guinea	340	330	[e]100,000	97,000	7,400,000
India	[e]7,500	7,300	[e]24,000	23,000	650,000
Indonesia	[e]1,200	1,200	[e]21,000	20,000	1,000,000
Ireland	1,630	1,200	—	—	—
Jamaica	634	1,500	4,370	6,000	2,000,000
Kazakhstan	1,340	1,300	4,400	4,300	160,000
Russia	3,080	2,400	5,780	5,800	480,000
Saudi Arabia	[e]1,900	1,800	[e]4,800	4,600	180,000
Spain	1,340	640	—	—	—
Turkey	300	290	2,800	2,000	63,000
Ukraine	300	—	—	—	—
United Arab Emirates	2,430	2,300	—	—	—
Vietnam	1,430	1,400	[e]3,900	3,700	5,800,000
Other countries	1,200	880	5,900	5,600	5,100,000
World total (rounded)	140,000	140,000	[8]400,000	[8]400,000	30,000,000

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 1.6 billion tons.
[8]Excludes U.S. production.

BERYLLIUM

(Data in metric tons, beryllium content, unless otherwise specified)

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 2023 was 150 tons and was valued at about $205 million based on the most recent beryllium price estimate. Based on sales revenues, approximately 25% of beryllium products were used in industrial components, 17% in aerospace and defense applications, 14% in automotive electronics, 10% in telecommunications infrastructure, 7% each in consumer electronics and energy applications, 1% in semiconductor applications, and 19% 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:	2019	2020	2021	2022	2023[e]
Production, mine shipments	160	165	175	175	190
Imports for consumption[1]	49	48	49	39	25
Exports[2]	37	25	30	61	75
Shipments from Government stockpile[3]	—	3	7	9	NA
Consumption:					
Apparent[4]	167	196	196	187	150
Reported, ore	160	170	170	170	170
Price, annual average unit value, beryllium-copper master alloy,[5] dollars per kilogram of contained beryllium	620	620	680	660	1,400
Stocks, ore, consumer, yearend	35	30	35	10	—
Net import reliance[6] as a percentage of apparent consumption	4	16	11	6	E

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 its beryllium products, recovering approximately 40% of the beryllium content of the new and old beryllium alloy scrap.

Import Sources (2019–22):[1] Kazakhstan, 44%; Latvia, 22%; Japan, 16%; Canada, 7%; and other, 11%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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]

Material	FY 2023 Potential acquisitions	FY 2023 Potential disposals	FY 2024 Potential acquisitions	FY 2024 Potential disposals
Metal (all types)	—	7	—	7

Events, Trends, and Issues: Apparent consumption in 2023 decreased by 20% from that in 2022 owing primarily to a 36% decrease in estimated beryllium imports and a 23% increase in estimated exports. The decrease in imports reflected a large reduction in beryllium-copper master alloy imports from Kazakhstan. During the first 6 months of 2023, 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 21% higher than those during the first 6 months of 2022. Net sales of beryllium products increased primarily in the aerospace and defense market. 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] 2022	Mine production[8, 9] 2023[e]
United States	175	190
Brazil	[e]40	40
China	[e]70	74
Madagascar	[e]1	1
Mozambique	25	24
Rwanda	[e]1	1
Uganda	[e]1	1
World total (rounded)	313	330

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 beryllium content. 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. E Net exporter. NA Not available. — 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. Beginning in 2023, Government stock changes no longer available.
[4]Defined for 2019–22 as production + imports − exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.
[5]Calculated from gross weight and customs value of imports; beryllium content estimated to be 4%. Rounded to two significant figures.
[6]Defined for 2019–22 as imports − exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.
[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 4% beryllium content of bertrandite and beryl sources.
[10]See Appendix C for resource and reserve definitions and information concerning data sources.

BISMUTH

(Data in metric tons unless otherwise specified)

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.

Most 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 compounds such as bismuth nitrate, bismuth oxychloride, and bismuth vanadate are also used in industrial applications for the manufacture of ceramic glazes, crystalware, high-performance pigments, 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 aluminum alloys and 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. 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:	2019	2020	2021	2022	2023[e]
Production:					
Refinery	—	—	—	—	—
Secondary (scrap)[e]	80	80	80	80	80
Imports for consumption, metal, alloys, and scrap:					
Containing more than 99.99% bismuth, by weight	NA	NA	NA	754	540
Other	NA	NA	NA	2,340	1,300
Total[1]	2,340	1,650	1,980	3,090	1,800
Exports, metal, alloys, and scrap:					
Containing more than 99.99% bismuth, by weight	NA	NA	NA	144	180
Other	NA	NA	NA	359	340
Total[2]	636	699	1,010	502	520
Consumption:					
Apparent[3]	1,690	1,210	1,030	2,610	1,400
Reported	548	513	597	724	NA
Price, average,[4] dollars per pound	3.18	2.72	3.74	3.90	4.10
Stocks, yearend, consumer, bismuth metal	443	271	297	356	340
Net import reliance[5] as a percentage of apparent consumption	95	93	92	97	94

Recycling: Recycled bismuth-containing alloy scrap was thought to compose 3% to 8% of U.S. bismuth apparent consumption for the years 2019–23.

Import Sources (2019–22): China,[6] 68%; Republic of Korea, 20%; Belgium, 2%; Mexico, 2%; and other, 8%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 price for bismuth (in-warehouse, Rotterdam) in 2023 was $4.10 per pound, a 5% increase from that in 2022 and the highest annual average price since 2018. Bismuth metal prices in China, the leading producer and exporter of bismuth, reached a 5-year high in September reportedly owing to high feedstock prices as competition for bismuth ore increased among domestic smelters, despite lower exports. Bismuth metal exports from China (Harmonized System code 8106) through August 2023 were 2,510 tons, about 40% less than exports during the same periods in 2021 and 2022. In March 2023, the Liyang Zhonglianjin E-commerce commodity exchange platform began trading 99.99% bismuth.

Estimated world production of bismuth was essentially the same in 2023 as in 2022; reported bismuth production data were unavailable for most countries.

World Refinery Production and Reserves:

	Refinery production[e]		Reserves[7]
	2022	2023	
United States	—	—	Quantitative estimates of reserves were not available.
Bolivia	—	40	
Bulgaria	50	50	
China	15,500	16,000	
Japan	490	500	
Kazakhstan	190	160	
Korea, Republic of	810	850	
Laos	[8]1,940	2,000	
World total (rounded)	19,000	20,000	

World Resources:[7] Bismuth reserves data were generally not reported at a mine or country level and thus difficult to quantify. Bismuth minerals rarely occur in sufficient quantities to be mined as principal products; bismuth is produced most often as a byproduct during the processing of lead ores. In China and Vietnam, bismuth is also produced as a byproduct or coproduct of tungsten and other metal ore processing. In Japan and the Republic of Korea, bismuth is produced as a byproduct or coproduct of zinc ore processing. The Tasna Mine in Bolivia, which has been inactive since 1996, and a mine in China are the only mines where bismuth has been the primary product.

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 certain 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 glycerin-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. NA Not available. — Zero.

[1]Includes data for the following Harmonized Tariff Schedule of the United States codes: 8106.00.0000 (2019–21), and 8106.10.0000 and 8106.90.0000 (2022–23).

[2]Includes data for the following Schedule B numbers: 8106.00.0000 (2019–21), and 8106.10.0000 and 8106.90.0000 (2022–23).

[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.

[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 specified)

Domestic Production and Use: Two companies in southern California produced borates in 2023, and most of the boron products consumed in the United States were manufactured domestically. Estimated boron production increased in 2023 compared with 2022 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 2023, 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, insulation, and in the production of semiconductors.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production	W	W	W	W	W
Imports for consumption:					
Refined borax	161	174	232	168	170
Boric acid	41	39	54	48	42
Colemanite (calcium borates)	42	18	3	1	1
Ulexite (sodium borates)	38	41	49	38	17
Exports:					
Boric acid	251	257	280	240	250
Refined borax	598	594	607	651	640
Consumption, apparent[1]	W	W	W	W	W
Price, average unit value of imports, cost, insurance, and freight, dollars per metric ton	373	380	394	485	620
Employment, number	1,370	1,330	1,330	1,400	1,400
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2019–22): All forms: Turkey, 90%; Bolivia, 5%; Chile, 1%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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, India, Mexico, Malaysia, and Japan, in decreasing order of tonnage, are the countries that imported the largest quantities of refined borates from the United States in 2023. Domestic shipments of boric acid were sent to China, the Netherlands, the Republic of Korea, Japan, and Taiwan, 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 the United States were expected to remain steady during the next several years.

Interests and investments in boron derivatives increased domestically and abroad. The National Defense Authorization Act for fiscal year 2024 included an amendment to study boron supply chains, particularly in regard to ferroboron and boron carbide production. The Under Secretary of Defense for Acquisition and Sustainment was expected to complete the report by the first quarter of 2024.

Turkey opened its first boron carbide facility in March and began construction of a ferroboron facility in September 2022. Boron carbide is produced in only five countries in the world. Turkey's new boron carbide facility has a capacity of 1,000 tons per year. Boron carbide is used in the manufacturing of body armor and ferroboron is used in the production of permanent magnets.

Continued investment in new borate refineries and the continued rise in demand were expected to fuel growth in world production for the next few years. Two 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 continued construction as it neared the completion of its first phase. This project was expected to have a focus on specialty boron products for industries related to global decarbonization and food security once production starts. These companies have the potential to become substantial boron producers when their projects are fully developed. The project in Nevada was offered a conditional commitment loan of up to $700 million with a 10-year term from the U.S. Department of Energy to fund the project. If work begins at the Nevada project, it was anticipated to create 600 construction jobs and up to 300 operation positions.

World Production and Reserves: Reserves data for China, Turkey, and the United States were revised based on Government and company reports.

	Production—All forms[e]		Reserves[3]
	2022	2023	
United States	W	W	48,000
Argentina, crude ore	130	130	NA
Bolivia, ulexite	170	170	NA
Chile, ulexite	360	360	35,000
China, boric oxide equivalent	200	200	20,000
Germany, compounds	60	60	NA
Peru, crude borates	200	200	4,000
Russia, datolite ore	80	80	40,000
Turkey, refined borates	2,200	2,200	950,000
World total[4]	XX	XX	XX

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

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

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable.
[1]Defined as production + imports – exports.
[2]Defined as imports – exports.
[3]See Appendix C for resource and reserve definitions and information concerning data sources.
[4]World totals cannot be calculated because production and reserves are not reported in a consistent manner by all countries.

BROMINE

(Data in metric tons, bromine content, unless otherwise specified)

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 2023 was estimated to be less than that in 2022.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production	W	W	W	W	W
Imports for consumption, elemental bromine and compounds[1]	56,300	30,700	27,200	36,500	51,000
Exports, elemental bromine and compounds[2]	29,300	36,600	27,900	19,400	34,000
Consumption, apparent[3]	W	W	W	W	W
Price, average unit value of imports (cost, insurance, and freight), dollars per kilogram, bromine content	2.31	2.67	2.85	3.29	3.10
Employment, number[e]	1,050	1,050	1,050	1,050	1,050
Net import reliance[4] as a percentage of apparent consumption	<25	E	E	<25	<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 because the BFR is often bound to the polymer or resin matrix; therefore, bromine will often be recycled via the parent polymer with the polymer 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 (2019–22):[5] Israel, 82%; Jordan, 10%; China,[6] 4%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023, estimated total imports of bromine and bromine compounds (bromine content) increased by more than 30% from those in 2022, and the leading source of imports of bromine and bromide compounds (gross weight) was Israel (83%), followed by Jordan (14%). The average annual import unit value of bromine and bromine compounds (contained weight) was approximately $3.10 per kilogram, which was about 5% less than that in 2022. 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, accounting for over 90% of total imported bromine. These compounds are used in a variety of applications, with clear brine drilling fluids likely being the leading consuming end-use application.

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BROMINE

In 2023, estimated total exports (bromine content) increased by more than 70% compared with those in 2022, and the leading destinations for exports (gross weight) were Guyana (28%), Saudi Arabia (19%), and Brazil (18%). The average annual export unit value of bromine and bromine compounds (contained weight) was approximately $3.60 per kilogram, which was slightly more than the $3.54 per kilogram in 2022.

Globally, bromine selling prices were lower in 2023 compared with those in 2022. Bromine consumption was expected to be less in 2023 compared with that in 2022 owing to weak demand for BFRs from the construction and electronics industries. Sales of clear brine drilling fluids, the second leading use of bromine, were expected to remain strong in 2023. In the first half of 2023, the average number of worldwide active drilling rigs increased compared with the annual average count in 2022.

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

	Production[e]		Reserves[9]
	2022	2023	
United States	W	W	11,000,000
Azerbaijan	—	—	300,000
China	73,000	76,000	130,000
India	3,500	3,500	NA
Israel	[10]178,000	170,000	Large
Japan	20,000	20,000	NA
Jordan	115,000	120,000	Large
Ukraine	10,800	11,000	NA
World total (rounded)	[11]400,000	[11]400,000	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, and 2827.59.0000 (2019–23); 2903.31.0000 and 2903.39.1520 (2019–21); and 2903.61.0000 and 2903.62.1000 (2022–23).

[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 specified)

Domestic Production and Use: One company operating in Tennessee recovered primary cadmium metal as a byproduct of zinc leaching from roasted sulfide concentrates that would otherwise need to be disposed of as waste. One company operating in Ohio recovered secondary cadmium metal through the recycling of spent nickel-cadmium (NiCd) batteries. Cadmium metal and compounds are mainly consumed for NiCd batteries, but also for alloys, coatings, and pigments. An increasing use for cadmium was in cadmium-telluride (CdTe) thin-film solar panels, and in cadmium-zinc-telluride (CdZnTe) substrates for radiation detectors and imaging applications.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:					
Primary, refined[1]	131	211	241	212	220
Secondary	W	W	W	W	W
Imports for consumption:					
Unwrought cadmium and powders	385	282	155	99	80
Wrought cadmium and other articles	21	3	2	1	1
Cadmium waste and scrap	86	90	85	40	1
Cadmium oxide	33	28	14	33	30
Cadmium pigments and preparations based on cadmium compounds	108	69	101	146	130
Exports:					
Unwrought cadmium and powders	32	4	51	68	150
Wrought cadmium and other articles	84	482	217	60	14
Cadmium waste and scrap	6	([2])	—	2	15
Cadmium pigments and preparations based on cadmium compounds	795	2,120	550	747	1,100
Consumption of metal, apparent[3]	W	W	W	W	W
Price, metal, annual average,[4] dollars per kilogram	2.67	2.29	2.56	3.42	4.10
Net import reliance[5] as a percentage of apparent consumption	<75	<75	<50	<25	E

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 CdTe solar panels.

Import Sources (2019–22):[6] Germany, 30%; Australia, 25%; China,[7] 18%; Peru, 11%; and other, 16%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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:[8] The fiscal year (FY) 2024 potential acquisitions include 1,000 square centimeters of CdZnTe substrates.

Events, Trends, and Issues: Imports of unwrought cadmium have generally been greater than exports, but in recent years imports have decreased while exports have increased. Based on estimated data, the United States become a net exporter in 2023. The average cadmium price began the year at $3.97 per kilogram in January, increased to $5.35 per kilogram in April, decreased midyear, and rose to $4.35 per kilogram by October. These prices reflected seasonal buying patterns in India, which, as a major importer, was an important determinant of cadmium prices in the spot market. In 2023, cadmium was added to India's list of 30 critical minerals. Cadmium was not included on the most recent U.S. critical minerals list because of low supply risk. In 2023, a company in Ohio was developing a facility capable of recovering cadmium and other metals through the recycling of NiCd batteries.

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CADMIUM

Cadmium use in semiconductors was increasing, especially CdTe in thin-film solar panels. The leading domestic CdTe solar panel manufacturer, also the world leader, began commercial production in early 2023 at a third facility in Ohio, bringing its domestic capacity to 5.9 gigawatts per year. A fourth facility, initiated in 2022, was under construction in Alabama and would add 3.5 gigawatts per year of capacity after planned completion in 2025. In June, plans for a fifth facility were announced and, in September, construction began in Louisiana that would add 3.5 gigawatts per year of capacity by 2026. The capacity increases were in part owing to the Inflation Reduction Act of 2022, which included incentives for transitioning to renewable energy sources. According to the U.S. Department of Energy's National Renewable Energy Laboratory (NREL), 34% of utility-scale photovoltaics and 21% of all photovoltaic systems were CdTe-based at yearend 2022. NREL was the administrator of the Cadmium Telluride Photovoltaics Accelerator Program, in its second year, which continued to provide research grants with the goals of achieving cell efficiencies of 24% by 2025 and 26% by 2030 while decreasing costs, and to maintain or increase domestic CdTe photovoltaic material and module production. The company supplying CdTe feedstock, with facilities in Canada and the United States, secured a domestic source of tellurium in late 2022 and produced cadmium-zinc-telluride substrates for security and medical imaging applications at a facility in Utah.

World Refinery Production and Reserves:

	Refinery production[e] 2022	Refinery production[e] 2023	Reserves[9]
United States[1]	[10]212	220	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	[10]328	380	
Bulgaria	340	340	
Canada	1,800	1,800	
China	8,700	9,000	
Germany	320	—	
Japan	1,800	1,800	
Kazakhstan	1,000	1,000	
Korea, Republic of	4,000	4,000	
Mexico	[10]1,170	1,100	
Netherlands	574	750	
Norway	420	380	
Peru	[10]460	790	
Poland	250	230	
Russia	1,000	1,000	
Uzbekistan	220	220	
World total (rounded)	22,600	23,000	

World Resources:[9] 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 such as 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 stabilizers can replace barium-cadmium stabilizers in flexible polyvinyl chloride (PVC) applications. Thin-film technologies based on copper-indium-gallium-selenide and perovskite materials continued to be investigated but were not yet commercially feasible.

[e]Estimated. E Net exporter. 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 for 2019–21 and 8112.69.1000 beginning in 2022.
[7]Includes Hong Kong.
[8]See Appendix B for definitions.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.
[10]Reported.

CEMENT

(Data in thousand metric tons unless otherwise specified)

Domestic Production and Use: In 2023, U.S. portland (including blended) cement production decreased slightly to an estimated 88 million tons, and masonry cement production decreased to an estimated 2.4 million tons. Cement was produced at 99 plants in 34 States and 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 2023, shipments of cement were an estimated 110 million tons with an estimated value of $16 billion. In 2023, 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]	**2019**	**2020**	**2021**	**2022**	**2023**[e]
Production:					
Portland and masonry cement[2]	87,600	89,300	91,000	[e]93,000	91,000
Clinker	78,858	78,951	79,616	[e]80,000	77,000
Shipments to final customers, includes exports	102,823	104,580	108,969	[e]110,000	110,000
Imports for consumption:					
Hydraulic cement	14,836	15,531	19,937	24,984	26,000
Clinker	997	1,204	1,563	1,021	1,000
Exports, hydraulic cement and clinker	1,024	884	940	902	900
Consumption, apparent[3]	102,000	105,000	111,000	[e]120,000	120,000
Price, average mill unit value, dollars per metric ton	124	125	127	[e]140	150
Stocks, cement, yearend	7,990	7,180	6,280	[e]8,000	7,500
Employment, mine and mill, number[e]	12,500	12,200	12,300	12,800	13,000
Net import reliance[4] as a percentage of apparent consumption	15	15	19	22	22

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 (2019–22):[5] Turkey, 31%; Canada, 25%; Greece, 10%; Mexico, 9%; and other, 25%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
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 5% during the first 9 months of 2023 compared with that in the same period in 2022. Nonresidential construction spending increased, but residential construction spending decreased. Construction starts of new housing units through September 2023 decreased by 12% compared with those during the same period in 2022. Reported cement shipments decreased slightly during the first 9 months of 2023 compared with those in the same period in 2022. The leading cement-consuming States continued to be Texas, Florida, and California, in descending order by tonnage.

According to the Bureau of Economic Analysis, real gross domestic product (GDP) increased by 7% during the first 9 months of 2023 compared with GDP for full year 2022, and monetary policy actions focused on reducing inflation continued. Regulators continued to implement measures designed to aid industry decarbonization efforts, such as green procurement strategies and research investments. Additionally, funding from the November 2021 passage of the Bipartisan Infrastructure Law continued to be allocated. However, cement industry growth was constrained by increased costs for energy, material, and service inputs; labor and production shortages; and supply chain disruptions. Apparent consumption of cement in 2023 was estimated to be unchanged from that in 2022.

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CEMENT

Company merger-and-acquisition activity continued in 2023, including the sale of a United States-based cement company's plant in California to a Peru-based cement company. In 2022, a Japanese cement company had entered into an agreement to purchase the same cement plant in California from the United States cement company, but this transaction did not meet regulatory approval and was abandoned in May 2023. In September, a Colombia-based cement company and a United States-based cement company announced plans to combine their United States operations in order to expand their geographic footprint, and in November, an agreement to sell a United States-based company's plant in Texas to an Ireland-based company was announced—each pending regulatory approval.

The upgrade and capacity expansion of a cement plant in Indiana was completed in June 2023. Work progressed on plans to increase capacity at a cement plant in Texas and plans to expand capacity at a cement plant in Missouri were announced. Several minor upgrades to increase storage capacity and (or) transition to low-carbon cement were ongoing at some other domestic plants and terminals. A Turkey-based company announced plans to build a grey cement grinding plant in the United States by 2025.

Numerous companies continued to make announcements aligned with the industry's commitment to sustainability and decarbonization, including increased use of alternative fuels and alternative materials, carbon capture, utilization and storage projects, increased energy efficiency and digitalization, shifting to renewable energy sources, and other innovations. Several cement plants transitioned to portland-limestone blended cement (PLC) following its widespread acceptance by various authorities in 2022. In 2023, total blended shipments increased significantly and 97% of the blended shipments were estimated to be PLC (Type IL). In addition, development of other innovative low-carbon and (or) new blended cement product lines progressed. 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 and 2023, cement plant closures were announced in California, Maine, and New York.

World Production and Capacity:

	Cement production[e]		Clinker capacity[e]	
	2022	2023	2022	2023
United States (includes Puerto Rico)	93,000	91,000	100,000	100,000
Brazil	64,000	63,000	60,000	60,000
China	2,100,000	2,100,000	2,000,000	2,000,000
Egypt	46,000	50,000	60,000	60,000
India	380,000	410,000	290,000	300,000
Indonesia	64,000	62,000	79,000	79,000
Iran	59,000	65,000	81,000	81,000
Japan	53,000	50,000	54,000	54,000
Korea, Republic of	51,000	50,000	62,000	62,000
Mexico	50,000	50,000	42,000	42,000
Russia	61,000	57,000	80,000	80,000
Saudi Arabia	52,000	53,000	75,000	75,000
Turkey	74,000	79,000	92,000	92,000
Vietnam	120,000	110,000	100,000	110,000
Other countries (rounded)	850,000	850,000	600,000	600,000
World total (rounded)	4,100,000	4,100,000	3,800,000	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 specified; excludes Puerto Rico unless otherwise specified.

[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, cesium oxide, unless otherwise specified)

Domestic Production and Use: In 2023, 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, Congress set a goal for the National Nuclear Security Administration to eliminate cesium-137 blood irradiators by 2027 in the United States. Alternatives, including X-ray irradiators, have been developed with similar capabilities and have been partially implemented with subsidization.

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, and the primary global producers were estimated to include Canada, China, Germany, and Russia.

In 2023, one company offered 1-gram ampoules of 99.8% (metal basis) cesium for $91.60, a 19% increase from $76.97 in 2022, and 99.98% (metal basis) cesium for $117, a 20% increase from $97.86 in 2022. At the end of September 2023, the prices for 50 grams of 99.9% (metal basis) cesium acetate, cesium bromide, cesium carbonate, cesium chloride, and cesium iodide were $142.00, $98.10, $127.80, $143.40, and $163.80, respectively, with increases ranging from 5% to 20% compared with prices in 2022.

The price for a cesium-plasma standard solution (10,000 micrograms per milliliter) in 2023 was $89.80 for 50 milliliters and $137.00 for 100 milliliters, increases of 6% from $84.53 and $129.15 in 2022, respectively. The price for 25 grams of 98% (metal basis) cesium formate was $49.40, a 7% increase from $46.10 in 2022.

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 (2019–22): 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 was estimated that Germany was a source of refined cesium chemicals.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 impacts. 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 2023, no primary cesium mine production was reported globally but cesium was thought to have been mined in Canada and China. Primary 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. 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.

Throughout 2023, 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. Consistent extraction of cesium from pollucite mining at the Tanco Mine in Canada ended in 2015; however, mining resumed intermittently in recent years with most of the ore and preexisting stockpiles processed on site.

World Mine Production and Reserves:[1] There were no official sources for cesium production data in 2023. Cesium reserves are, therefore, estimated based on the occurrence of pollucite, a primary cesium 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 estimated 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 that stockpiles may 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 estimated 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, chromium content, unless otherwise specified)

Domestic Production and Use: In 2023, the United States consumed an estimated 4% of world chromite ore production in various forms of imported materials, such as chromite ore, chromium chemicals, ferrochromium, 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 estimated to be about $830 million in 2023 (as measured by the value of net imports, excluding stainless steel), which was a 44% decrease from $1.5 billion in 2022.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:					
Mine	—	—	—	—	—
Secondary[1]	137	119	114	91	100
Imports for consumption[2]	530	448	571	609	440
Exports[2]	149	138	114	133	150
Shipments from Government stockpile[3]	4	5	7	5	NA
Consumption (includes recycling):					
Reported	482	386	364	275	260
Apparent[4]	522	433	579	573	380
Price:[5]					
Chromite ore (gross weight), dollars per metric ton	174	154	201	274	290
Ferrochromium (chromium content), dollars per pound[6]	1.00	0.90	1.56	3.21	3.50
Chromium metal (gross weight), dollars per pound	4.13	3.22	4.35	7.12	5.50
Stocks, consumer, yearend	5	6	6	5	5
Net import reliance[7] as a percentage of apparent consumption	74	73	80	84	74

Recycling: In 2023, recycled chromium (contained in reported stainless-steel scrap receipts) accounted for 26% of apparent consumption.

Import Sources (2019–22): Chromite (ores and concentrates): South Africa, 97%; Turkey, 2%; and other, 1%.
Chromium-containing scrap:[8] Canada, 52%; Mexico, 43%; United Kingdom, 1%; and other, 4%.
Chromium (primary metal):[9] South Africa, 28%; Kazakhstan, 15%; Russia, 8%; Finland, 5%; and other, 44%.
Chromium-containing chemicals: Kazakhstan, 22%; Germany, 20%; China,[10] 19%; Italy, 14%; and other, 25%.
Total imports: South Africa, 34%; Kazakhstan, 12%; Russia, 6%; Canada, 5%; and other, 43%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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]

	FY 2023		FY 2024	
Material	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Ferrochromium:				
High carbon	—	[13]21.8	—	[13]21.8
Low carbon	—	—	—	—
Chromium metal	—	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 2023 compared with production in 2022. Production in South Africa, the world's leading producer of chromite, decreased by an estimated 6% compared with production in 2022 owing to disruptions to the supply of electricity and problems with transportation of ore via rail. China was the leading ferrochromium- and stainless-steel-producing country and the leading chromium-consuming country.

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

	Mine production[14]		Reserves[15]
	2022	**2023[e]**	**(shipping grade)[16]**
United States	—	—	630
Finland	2,000	2,000	8,300
India[e]	4,000	4,200	79,000
Kazakhstan[e]	6,000	6,000	230,000
South Africa	19,100	18,000	200,000
Turkey	5,410	6,000	27,000
Other countries	5,380	5,200	NA
World total (rounded)	41,900	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]Secondary production is based on reported receipts of all types of stainless-steel scrap.
[2]Includes chromium chemicals, chromium metal, chromite ores, ferrochromium, ferrosilicon chromium, and stainless-steel products and scrap.
[3]Defined as change in total inventory from prior yearend inventory. Beginning in 2023, Government stock changes no longer available.
[4]Defined for 2019–22 as production (from mines and secondary) + imports – exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.
[5]Source: CRU Group.
[6]Excludes ferrosilicon chromium.
[7]Defined for 2019–22 as imports – exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.
[8]Includes chromium metal scrap and stainless-steel scrap.
[9]Includes chromium metal, ferrochromium, and stainless steel.
[10]Includes Hong Kong.
[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 specified)

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 2023, with about 120 companies operating clay and shale mines in 38 States. The leading 20 companies produced approximately 68% of the U.S. tonnage and 84% of the value for all types of clay. Principal domestic uses for specific clays were estimated to be as follows: ball clay (49% floor and wall tile), bentonite (48% pet waste absorbents and 23% drilling mud), common clay (48% brick, 26% lightweight aggregate, and 22% cement), fuller's earth (81% 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 10% in 2023 from those in 2022. In 2023, the United States exported an estimated 800,000 tons of bentonite; Canada, Japan, and Mexico, in decreasing order, were the leading destinations. About 1.8 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.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production (sold or used):					
Ball clay	[e]967	985	[e]1,080	[e]1,030	1,000
Bentonite	4,520	4,250	4,580	4,580	4,700
Common clay	13,400	12,900	12,700	12,700	13,000
Fire clay	603	635	675	[e]622	660
Fuller's earth[e, 1]	1,990	1,980	2,130	2,160	2,300
Kaolin[e]	5,120	4,640	4,360	4,340	4,400
Total[1, 2]	26,500	25,400	25,600	25,500	26,000
Imports for consumption:					
Artificially activated clays and earths	31	31	41	58	94
Kaolin	293	224	149	200	150
Other	66	28	47	49	38
Total[2]	389	284	237	306	280
Exports:					
Artificially activated clays and earths	138	127	139	135	110
Ball clay	85	68	139	165	130
Bentonite	906	728	861	830	800
Clays, not elsewhere classified	204	185	186	208	210
Fire clay[3]	194	190	210	158	140
Fuller's earth	73	77	83	87	73
Kaolin	2,280	1,990	2,330	2,030	1,800
Total[2]	3,880	3,360	3,950	3,620	3,300
Consumption, apparent[4]	23,000	22,300	21,900	22,200	23,000
Price, average unit value, ex-works, dollars per metric ton:					
Ball clay	45	46	46	47	47
Bentonite	98	97	100	101	99
Common clay	18	17	17	18	17
Fire clay	14	12	12	12	12
Fuller's earth[1]	88	89	88	97	95
Kaolin	161	159	152	157	160
Employment (excludes office workers), number:[e]					
Mine (may not include contract workers)	1,110	1,060	1,060	1,060	1,100
Mill	4,310	4,260	4,240	4,240	4,300
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2019–22): All clay types combined: Brazil, 66%; Mexico, 16%; China, 4%; and other, 14%.

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CLAYS

Tariff: Item	Number	Normal Trade Relations 12–31–23
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: The total tonnage of clays sold or used by domestic producers increased from that in 2022; bentonite, common clay, fire clay, fuller’s earth, and kaolin increased whereas ball clay decreased in 2023. Imports for all types of clay decreased by 8% to 280,000 tons; Brazil, Mexico, and China were the major sources for imported clays. U.S. apparent consumption in 2023 was estimated to be 23 million tons, a 4% increase from that in 2022.

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

	Mine production					
	Bentonite		Fuller’s earth		Kaolin	
	2022	2023[e]	2022	2023[e]	2022	2023[e]
United States	4,580	4,700	[1]2,160	[1]2,300	4,340	4,400
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	908	900	—	—	—	—
Greece	[7]1,420	[7]1,400	33	30	—	—
India	3,700	3,700	730	730	[7]8,370	[7]8,400
Iran	850	850	—	—	2,100	2,100
Mexico	79	80	120	120	240	240
Russia	36	40	—	—	2,500	2,500
Senegal	—	—	117	120	—	—
Spain	170	170	570	570	[7]300	[7]300
Turkey	2,380	2,400	55	60	2,270	2,300
Uzbekistan	50	50	—	—	8,500	8,500
Other countries	3,630	3,600	317	320	10,600	10,000
World total (rounded)[2]	20,400	20,000	[1]4,100	[1]4,300	51,900	51,000

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, cobalt content, unless otherwise specified)

Domestic Production and Use: In 2023, the Eagle Mine, a nickel-copper 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. Ore extraction commenced at a cobalt-copper-gold mine in Idaho, but commissioning was suspended in March owing to low cobalt prices. This mine and one in Morocco were the only mines in the world where cobalt was 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 50% of cobalt consumed in the United States was used in superalloys, mainly aircraft gas turbine engines; 25% 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 2023 was $270 million.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:[e]					
Mine	500	600	650	500	500
Secondary[1]	2,750	2,010	1,800	1,900	2,100
Imports for consumption	13,900	9,740	9,790	10,500	9,600
Exports	4,080	3,430	4,930	5,360	5,300
Consumption (includes secondary):					
Estimated[2]	9,050	7,260	7,270	7,700	8,300
Apparent[e, 3]	12,500	8,480	6,650	7,090	6,400
Price, average, dollars per pound:					
U.S. spot, cathode[4]	16.95	15.70	24.21	30.78	17
London Metal Exchange (LME), cash	14.88	14.21	23.17	28.83	16
Stocks, yearend:					
Industry[e, 2, 5]	1,090	952	1,010	1,000	1,000
LME, U.S. warehouse	102	82	50	34	34
Net import reliance[6] as a percentage of apparent consumption	78	76	73	73	67

Recycling: In 2023, cobalt content of purchased scrap represented an estimated 25% of estimated cobalt consumption.

Import Sources (2019–22): Metal, oxide, and salts: Norway, 25%; Canada, 15%; Finland, 13%; Japan, 12%; and other, 35%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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]

	FY 2023		FY 2024	
Material	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Cobalt	—	—	—	—
Cobalt alloys, gross weight[8]	—	—	200	—

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COBALT

Events, Trends, and Issues: Global cobalt mine and refinery production were estimated to have increased to record highs in 2023. The increase in mine production was mainly in Congo (Kinshasa), the world's leading source of mined cobalt accounting for 74% of world cobalt mine production, and in Indonesia, accounting for 7%. 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 nearly 87% of its consumption used by the lithium-ion battery industry. In 2023, numerous projects were underway globally to recover cobalt from lithium-ion battery scrap. A number of projects progressed in the United States for cobalt processing, refining, or recycling, spurred by incentives from the Bipartisan Infrastructure Law of 2021 and the Inflation Reduction Act of 2022.

World Mine Production and Reserves: Reserves for Australia, Canada, Congo (Kinshasa), Indonesia, Papua New Guinea, Turkey, and "Other countries" were revised based on company and Government reports.

	Mine production[e]		Reserves[9]
	2022	2023	
United States	500	500	69,000
Australia	5,790	4,600	[10]1,700,000
Canada	3,060	2,100	230,000
Congo (Kinshasa)	144,000	170,000	6,000,000
Cuba	3,700	3,200	500,000
Indonesia	9,600	17,000	500,000
Madagascar	3,500	4,000	100,000
New Caledonia[11]	2,000	3,000	NA
Papua New Guinea	2,990	2,900	49,000
Philippines	3,900	3,800	260,000
Russia	9,200	8,800	250,000
Turkey	2,100	2,800	91,000
Other countries	6,600	6,600	780,000
World total (rounded)	197,000	230,000	11,000,000

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. Other important occurrences are in Alaska, California, Idaho, Michigan, Missouri, Montana, Oregon, and Pennsylvania. Identified world terrestrial cobalt resources are about 25 million tons. The vast majority 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 of 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 increase cost. The cobalt contents of lithium-ion batteries, the leading global use for cobalt, are being reduced; cobalt-free substitutes that use iron and phosphorus held significant market share in China. 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. NA Not available. — Zero.
[1]Estimated from consumption of purchased scrap.
[2]Includes reported data and U.S. Geological Survey estimates.
[3]Defined for 2019–22 as secondary production + imports – exports ± adjustments for Government and industry stock changes for refined cobalt. Beginning in 2023, Government stock changes no longer included.
[4]Source: S&P Global 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 for 2019–22 as imports – exports ± adjustments for Government and industry stock changes for refined cobalt. Beginning in 2023, Government stock changes no longer included.
[7]See Appendix B for definitions.
[8]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 610,000 tons.
[11]Overseas territory of France.

COPPER

(Data in thousand metric tons, copper content, unless otherwise specified)

Domestic Production and Use: In 2023, the recoverable copper content of U.S. mine production was an estimated 1.1 million tons, a decrease of 11% from that in 2022, and was valued at an estimated $9.9 billion, 11% less than $11.2 billion in 2022. 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, 1 secondary smelter, 2 primary electrolytic refineries, 14 electrowon refineries, and 3 secondary fire refineries. A new secondary copper refinery was expected to startup by yearend. Refined copper and scrap were consumed at about 30 brass mills, 14 rod mills, and 500 foundries and miscellaneous manufacturers. According to the Copper Development Association, copper and copper alloy products were used in building construction, 45%; electrical and electronic products, 22%; transportation equipment, 16%; consumer and general products, 10%; and industrial machinery and equipment, 7%.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:					
Mine, recoverable	1,260	1,200	1,230	1,230	1,100
Refinery:					
Primary (from ore)	985	872	922	912	850
Secondary (from scrap)	44	43	49	40	40
Copper recovered from old (post-consumer) scrap[1]	166	161	157	[e]150	150
Imports for consumption:					
Ore and concentrates	27	2	11	12	4
Refined	663	676	919	732	890
Exports:					
Ore and concentrates	356	383	344	353	350
Refined	125	41	48	28	30
Consumption:					
Reported, refined copper	1,810	1,680	1,750	1,720	1,700
Apparent, primary refined copper and copper from old scrap[2]	1,820	1,660	1,950	1,800	1,800
Price, annual average, cents per pound:					
U.S. producer, cathode (COMEX + premium)	279.6	286.7	432.3	410.8	400
COMEX, high-grade, first position	272.3	279.9	424.3	400.7	390
London Metal Exchange, grade A, cash	272.4	279.8	422.5	399.8	390
Stocks, refined, held by U.S. producers, consumers, and metal exchanges, yearend	110	118	117	83	100
Employment, mine and plant, number	12,000	11,000	11,400	12,000	12,000
Net import reliance[3] as a percentage of apparent consumption	37	38	45	41	46

Recycling: Old (post-consumer) scrap, converted to refined metal, alloys, and other forms, provided an estimated 150,000 tons of copper in 2023, and an estimated 700,000 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 80%. Copper recovered from scrap contributed 33% of the U.S. copper supply.[4]

Import Sources (2019–22): Copper content of blister and anodes: Finland, 93%; and other, 7%. Copper content of matte, ash, and precipitates: Canada, 37%; Belgium, 21%; Japan, 16%; Spain, 11%; and other, 15%. Copper content of ore and concentrates: Mexico, 52%; Canada, 48%; and other, <1%. Copper content of scrap: Canada, 48%; Mexico, 40%; and other, 12%. Refined copper: Chile, 64%; Canada, 18%; Mexico, 11%; and other, 7%. Refined copper accounted for 86% of all unmanufactured copper imports.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 scrap	7404.00.0000	Free.
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 2023, production decreased at a majority of copper mines in the United States, and domestic mined copper output declined by an estimated 11% from that in 2022. At the Bingham Canyon Mine in Utah, copper production was affected by record-high snowfall in the first quarter and a conveyor belt motor failure that resulted in the concentrator operating at a reduced capacity for several months. At the Robinson Mine in Nevada, low-grade copper ores were processed owing to planned mine sequencing. Production also decreased at multiple mines in Arizona and New Mexico because of unplanned maintenance and lower ore grades and mining rates. The rampups of the Gunnison Mine in Arizona and the Pumpkin Hollow Mine in Nevada continued to be delayed, but ore processing restarted at Pumpkin Hollow in October following a suspension of over a year to address geotechnical challenges. Copper production at U.S. refineries decreased by an estimated 7% in 2023 compared with that in 2022 because of a major rebuild of the smelter and electrolytic refinery near Salt Lake City, UT, from May to September. A new refinery in Kentucky designed to produce copper cathodes from scrap was anticipated to begin operating by yearend 2023, and at least three other domestic facilities that would recover copper from scrap in the form of anodes or cathodes were expected to start within the next several years.

The annual average COMEX copper price was projected to be about $3.90 per pound in 2023, 3% less than that in 2022. Analysts attributed the decreased price primarily to strengthening of the U.S. dollar relative to other global currencies and concerns regarding economic growth in China and inflation.

World Mine and Refinery Production and Reserves: Reserves for Australia, China, Congo (Kinshasa), Peru, Poland, Russia, the United States, Zambia, and “Other countries” were revised based on company and Government reports.

	Mine production		Refinery production		Reserves[5]
	2022	2023[e]	2022	2023[e]	
United States	1,230	1,100	952	890	50,000
Australia	819	810	401	450	[6]100,000
Canada	520	480	278	310	7,600
Chile	5,330	5,000	2,150	2,000	190,000
China	1,940	1,700	11,100	12,000	41,000
Congo (Kinshasa)	2,350	2,500	1,770	1,900	80,000
Germany	—	—	609	610	—
Indonesia	941	840	310	200	24,000
Japan	—	—	1,550	1,500	—
Kazakhstan	593	600	494	440	20,000
Korea, Republic of	—	—	638	620	—
Mexico	754	750	486	480	53,000
Peru	2,450	2,600	391	400	120,000
Poland	393	400	586	590	34,000
Russia	[e]936	910	[e]1,010	1,000	80,000
Zambia	797	760	349	380	21,000
Other countries	2,850	3,100	2,830	2,900	180,000
World total (rounded)	21,900	22,000	25,900	27,000	1,000,000

World Resources:[5] The most recent U.S. Geological Survey assessment of global copper resources indicated that, as of 2015, identified resources contained 2.1 billion tons of copper and undiscovered resources contained an estimated 3.5 billion tons.[7]

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

[e]Estimated. — Zero.

[1]Copper converted to refined metal, alloys, and other forms by brass and wire-rod mills, foundries, refineries, and other manufacturers.

[2]Primary refined production + copper recovered from old scrap + refined imports – refined exports ± adjustments for refined copper stock changes.

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

[4]Primary refined production + copper recovered from old and new scrap + refined imports – refined exports ± adjustments for refined copper stock changes.

[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 27 million tons.

[7]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 specified)

Domestic Production and Use: In 2023, 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, which was essentially unchanged from the quantity and value in 2022. 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 97% 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:	2019	2020	2021	2022	2023[e]
Bort, grit, and dust and powder; natural and synthetic:					
Production:					
Manufactured diamond[e]	114	130	132	150	150
Secondary	35.6	35.0	1.20	14.4	14
Imports for consumption	306	190	261	303	280
Exports	114	90.7	99.1	94.0	72.0
Consumption, apparent[2]	342	264	295	373	370
Price, unit value of imports, dollars per carat	0.14	0.19	0.18	0.19	0.16
Net import reliance[3] as a percentage of apparent consumption	56	38	55	56	56
Stones, natural and synthetic:					
Production:					
Manufactured diamond[e]	—	—	—	—	—
Secondary	0.10	0.10	0.08	0.08	0.08
Imports for consumption	1.07	0.51	0.33	0.79	0.40
Exports	([4])	0.02	—	([4])	([4])
Consumption, apparent[2]	1.17	0.61	0.41	0.86	0.48
Price, unit value of imports, dollars per carat	5.82	8.41	13.0	8.40	14
Net import reliance[3] as a percentage of apparent consumption	91	84	81	91	84

Recycling: In 2023, the amount of diamond bort, grit, and dust and powder recycled was estimated to be 14 million carats with an estimated value of $530,000. An estimated 75,000 carats of diamond stone was recycled with an estimated value of $110,000.

Import Sources (2019–22): Bort, grit, and dust and powder; natural and synthetic: China,[5] 77%; Republic of Korea, 7%; Ireland, 6%; Russia, 4%; and other, 6%. Stones, primarily natural: India, 31%; South Africa, 27%; Russia, 11%; Congo (Kinshasa), 10%; and other, 21%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023 as in the previous year. Russia, the leading country in the production of natural industrial diamond, produced 18 million carats or 41% of total world production, followed by Congo (Kinshasa), 8 million carats (18%); Botswana, 7 million carats (17%); South Africa, 6 million carats (13%); and Zimbabwe, 4 million carats (9%). These five countries produced 97% 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 2023, U.S. synthetic-industrial-diamond producers did not manufacture any diamond stone. The combined apparent consumption of all types of industrial diamond was essentially unchanged from that of the previous year. Domestic and global consumption of synthetic diamond grit and powder is expected to remain greater than that of natural diamond material. During 2023, imports of all types of natural and synthetic industrial diamond imports decreased by 7% from that in 2022. In 2023, China was the leading producing country of synthetic industrial diamond, followed by the United States, and Russia, in descending order of quantity. These three 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 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 Botswana, Russia, and South Africa were revised based on company and Government reports.

	Mine production		Reserves[6]
	2022	2023[e]	
United States	—	—	NA
Angola	1	1	150
Botswana	7	7	280
Congo (Kinshasa)	8	8	150
Russia	18	18	860
South Africa	6	6	95
Zimbabwe	4	4	NA
Other countries	1	1	120
World total (rounded)	45	45	1,700

World Resources:[6] Natural diamond deposits have been discovered in more than 35 countries. Natural diamond accounts for less than 1% 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 more than 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.

DIATOMITE

(Data in thousand metric tons unless otherwise specified)

Domestic Production and Use: In 2023, production of diatomite, also known as diatomaceous earth, was estimated to be 830,000 tons with an estimated processed value of $340 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 50% of diatomite was used in filtration products. The remaining 50% was used in absorbents, lightweight aggregates, fillers, and other applications. A small amount, less than 1%, was used for specialized pharmaceutical and biomedical purposes. The unit value of diatomite varied widely in 2023, from approximately $10 per metric ton when used as a lightweight aggregate in portland cement concrete to more than $1,000 per metric ton for limited specialty markets, including art supplies, cosmetics, and deoxyribonucleic acid (DNA) extraction. The price for diatomite used for filtration was approximately $720 per metric ton.

Salient Statistics—United States:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production[1]	768	822	998	827	830
Imports for consumption	10	14	14	14	13
Exports	66	67	68	63	60
Consumption, apparent[2]	712	769	944	778	780
Price, average value, f.o.b. plant, dollars per metric ton	338	326	410	416	410
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 (2019–22): Canada, 58%; Mexico, 13%; Germany, 12%; Argentina, 7%; and other, 10%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
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 2023 was slightly higher than that in 2022. Apparent consumption in 2023 was an estimated 780,000 tons, essentially unchanged compared with that in 2022. Exports were estimated to have decreased by 5% compared with those in 2022. The United States remained the leading global producer and consumer of diatomite. Filtration (including the cleansing of greases and oils and the purification of beer, liquors, water, and wine) 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. Caution in the processing and use of diatomite was suggested because many forms contain crystalline silica, which is known to cause cancer, birth defects, or other reproductive harm to humans when exposed to levels above permissible levels.

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DIATOMITE

In 2023, the United States accounted for an estimated 32% of total world production, followed by Denmark with 17%; China with 10%; Turkey with 8%; and Argentina, Mexico, and Peru, each with 4%. Smaller quantities of diatomite were mined in 19 additional countries. The production of diatomite in 2023 was essentially unchanged from that in 2022.

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

	Mine production[e]		Reserves[4]
	2022	2023	
United States[1]	827	830	250,000
Argentina	100	100	NA
China	270	270	170,000
Czechia	46	50	NA
Denmark (processed)[5]	440	440	NA
France	75	80	NA
Germany	50	50	NA
Korea, Republic of	50	50	NA
Mexico	96	100	NA
Mozambique	73	75	NA
Peru	95	100	NA
Russia	51	50	NA
Spain	50	55	57,000
Turkey	210	210	44,000
Other countries	171	170	NA
World total (rounded)	2,600	2,600	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), moler (an impure Danish form), and tripolite (after an occurrence near Tripoli, Libya). 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 specified)

Domestic Production and Use: U.S. feldspar production in 2023 had an estimated value of $60 million. Feldspar was produced by six companies in California, Idaho, North Carolina, 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 60% of the 2023 end-use distribution of domestic feldspar and nepheline, and ceramic tile, pottery, and other uses accounted for the remaining 40%.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production, feldspar, marketable[1]	[e]450	420	[e]380	[e]540	590
Imports for consumption:					
Feldspar	64	43	169	276	85
Nepheline syenite	508	503	529	484	380
Exports, feldspar	4	3	4	3	6
Consumption, apparent:[1, 2]					
Feldspar only	[e]510	460	[e]550	[e]810	670
Feldspar and nepheline syenite	1,000	960	1,100	1,300	1,200
Price, average unit value, dollars per metric ton:					
Feldspar only, marketable production[e]	107	108	110	104	102
Nepheline syenite, imports	156	163	164	183	200
Employment, mine, preparation plant, and office, number[e]	240	240	220	220	240
Net import reliance[3] as a percentage of apparent consumption:					
Feldspar	12	9	30	34	12
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 (2019–22): Feldspar: Turkey, 93%; Mexico, 5%; Spain, 1%; and other, 1%. Nepheline syenite: Canada, 99%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023, estimated domestic production and sales of feldspar increased by 9%, and the average unit value decreased by 3% compared with that in 2022. Estimated imports of feldspar and nepheline syenite decreased by 39% compared with those in 2022.

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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, decreased by 12% compared with that in 2022 based on data through September. 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 60% of end uses of feldspar in the United States.

In March 2023, a Canada-based company completed sales of all issued and outstanding shares of its United States subsidiary based in Idaho. The subsidiary previously produced a feldspathic sand product with low-iron and low-trace-element concentrations from old mine tailings, which was sold to ceramic tile producers.

In November 2023, a Saudi Arabia-based mining company, a Turkey-based industrial raw materials company, and a United Arab Emirates-based mining company signed a letter of intent to establish a closed joint-stock company with the objective to invest in industrial minerals, including feldspar, quartz, silica sands, and various clay minerals, in Saudi Arabia.

World Mine Production and Reserves:[4] Reserves for China, Czechia, Iran, Thailand, and Turkey were revised based on Government reports.

	Mine production[e]		Reserves[5]
	2022	2023	
United States[1]	540	590	NA
Brazil (beneficiated, marketable)	760	760	150,000
China	2,500	2,500	730,000
Czechia	450	450	54,000
India	5,000	5,000	320,000
Iran	2,000	2,000	95,000
Italy	2,200	2,200	NA
Korea, Republic of	851	900	180,000
Mexico	495	460	NA
Pakistan	448	400	NA
Saudi Arabia	550	550	NA
Spain (includes pegmatites)	800	800	NA
Thailand	1,300	1,300	45,000
Turkey	6,100	6,200	720,000
Other countries	2,600	2,600	NA
World total (rounded)	26,600	27,000	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 specified)

Domestic Production and Use: In 2023, 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. 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. The U.S. Department of Energy continued to produce aqueous hydrofluoric acid (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 anhydrous 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:	2019	2020	2021	2022	2023[e]
Production:					
Finished, metallurgical grade	NA	NA	NA	NA	NA
Fluorosilicic acid from phosphate rock	29	22	40	[e]40	40
Imports for consumption:					
Acid grade	346	427	391	438	350
Metallurgical grade	59	65	59	88	40
Total fluorspar imports	405	492	451	526	390
Hydrofluoric acid	124	103	103	99	100
Aluminum fluoride	38	21	28	21	25
Cryolite	21	26	42	28	34
Exports, fluorspar, all grades[1]	8	9	15	24	22
Consumption, apparent[2]	398	483	436	502	370
Price, average unit value of imports, cost, insurance, and freight, dollars per metric ton:					
Acid grade	304	309	322	383	430
Metallurgical grade	292	149	151	223	360
Employment, mine, number[e]	14	16	17	15	15
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 (2019–22):[3] Mexico, 64%; Vietnam, 15%; China, 6%; South Africa, 6%; and other, 9%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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.

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FLUORSPAR

Events, Trends, and Issues: World production of fluorspar was estimated to have increased by 6% in 2023, primarily from increased production in Mongolia. Mines in Canada, Germany, Italy, Spain, and the United States, some of which had been idle for decades, were preparing to restart operations.

Innovations in fluorine chemistry continued. A company in the United Kingdom developed technology that bypassed use of HF as an intermediate in fluorochemical production, enabling synthesis directly from fluorspar or fluorinated waste streams. Other companies continued to advance projects to develop alternatives to fluorspar in the production of aluminum fluoride (AlF_3) and HF. A company in Australia was finalizing the design of a pilot plant to recover fluorine from aluminum smelting bath which would be used to produce AlF_3, and a company in Aurora, NC, finalized construction and began commissioning a plant to produce HF from FSA.

In July, the U.S. Department of Energy released an updated assessment of critical materials, including fluorine, deemed important for advancements in clean energy technology. Fluorine's future demand trajectory was based solely on its use in lithium-ion batteries, specifically on its use in electrolyte salts, binders, and separator coatings. In a related development, scientists from Argonne National Laboratory and Lawrence Berkeley National Laboratory demonstrated that fluorine-containing electrolyte solvents improved performance of lithium-ion batteries in sub-zero temperatures.

Globally, the regulatory framework governing the production and use of per- and polyfluoroalkyl substances (PFAS) continued to evolve, although countries and localities differed significantly in their approach. For example, in March, the U.S. Environmental Protection Agency announced proposed drinking water standards that would set limits on six PFAS. The European Union, however, proposed new rules that would establish new restrictions on as many as 10,000 PFAS.

World Mine Production and Reserves: Reserves for China, Iran, Mongolia, Spain, the United States, and Vietnam were revised based on company and Government reports.

	Mine production		Reserves[4]
	2022	2023[e]	
United States	NA	NA	NA
China	5,700	5,700	67,000
Germany	60	60	NA
Iran	116	120	4,500
Mexico	1,000	1000	68,000
Mongolia	425	930	34,000
Pakistan	52	52	NA
South Africa	406	410	41,000
Spain	153	150	15,000
Vietnam	218	170	3,400
Other countries	190	170	50,000
World total (rounded)	8,320	8,800	280,000

World Resources:[4, 5] 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 74 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 AlF_3 and HF. Because of differing physical properties, AlF_3 produced from FSA is not readily substituted for AlF_3 produced from fluorspar. Aluminum smelting dross, borax, calcium chloride, iron oxides, manganese ore, silica sand, and titanium dioxide have been used as substitutes for fluorspar fluxes.

[e]Estimated. NA Not available.

[1]Includes data for the following Schedule B codes: 2529.21.0000 and 2529.22.0000.

[2]Defined as total fluorspar imports – exports.

[3]Includes data for the following Harmonized Tariff Schedule of the United States codes: 2529.21.0000 and 2529.22.0000.

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

[5]Measured as 100% CaF_2.

GALLIUM

(Data in kilograms, gallium content, unless otherwise specified)

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. In 2023, imports of gallium metal were valued at about $3 million and gallium arsenide (GaAs) wafer imports were valued at about $110 million, decreases in value of 40% and 50%, respectively, from those in 2022. 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) was used to manufacture ICs and optoelectronic devices; ICs accounted for 74% of domestic gallium consumption, optoelectronic devices accounted for 25%, and research and development accounted for 1%. About 79% 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:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production, primary	—	—	—	—	—
Imports for consumption:					
Metal	5,740	4,430	8,890	11,400	9,400
Gallium arsenide wafers (gross weight)	289,000	208,000	306,000	424,000	150,000
Exports	NA	NA	NA	NA	NA
Consumption, reported	14,900	15,700	17,100	19,700	19,000
Price, average unit value of imports, dollars per kilogram:					
High-purity, refined[1]	573	596	625	560	450
Low-purity, primary[2]	153	163	254	394	290
Stocks, consumer, yearend	2,850	2,920	2,810	2,780	2,700
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 (2019–22): Metal: Japan, 26%; China, 21%; Germany, 19%; Canada, 9%; and other, 25%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
Gallium arsenide wafers, undoped	2853.90.9010	2.8% ad valorem.
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 and domestic production of GaAs and GaN wafers continued to account for all U.S. consumption of gallium. In 2023, gallium metal imports decreased owing to decreased imports from China, Japan, and Slovakia. 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. In August 2023, China's Government implemented gallium export controls, requiring licensing procedures to be carried out by China's gallium exporters.

Primary low-purity (99.99%-pure) gallium prices in China averaged $240 per kilogram in June 2023, a decrease of 23% from $310 per kilogram in January 2023, and a decrease of 53% from $510 per kilogram in June 2022. China's gallium prices decreased in the first half of 2023 owing to reduced gallium demand from the LED and neodymium (NdFeB) magnet markets and an increase in China's primary low-purity gallium production capacity. By October, gallium prices in China increased by 56% to $375 per kilogram owing to renewed gallium demand from the NdFeB magnet market and global concern about reduced gallium availability following China's implementation of gallium export controls.

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GALLIUM

China reported that its primary low-purity gallium production capacity increased by 250,000 kilograms per year in 2022 to 1,000,000 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 89% of worldwide primary low-purity gallium production capacity of an estimated 1,100,000 kilograms per year. China accounted for 98% of worldwide primary low-purity gallium production.

The remaining primary low-purity gallium producers outside of China included Japan, the Republic of Korea, and Russia. Germany, Hungary, and Kazakhstan ceased primary production in 2016, 2015, and 2013, respectively. Ukraine most likely ceased primary production in 2022. Owing to China's 2023 gallium export controls, the United States and other countries began considering the start or restart of domestic primary gallium production.

World high-purity refined gallium production in 2023 was estimated to be about 320,000 kilograms, a 3% increase from the revised 2022 figure of 310,000 kilograms. 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 340,000 kilograms per year, and secondary high-purity gallium production capacity was an estimated 280,000 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
	2022	2023[e]	2023
United States	—	—	—
China	600,000	600,000	1,000,000
Japan[e]	3,000	3,000	10,000
Korea, Republic of[e]	2,000	2,000	16,000
Russia[e]	5,000	5,000	10,000
Other countries[4]	—	—	[e]88,000
World total (rounded)	610,000	610,000	[e]1,100,000

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

Substitutes: Liquid crystals made from organic compounds are used in visual displays as substitutes for LEDs. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier third-generation (3G) cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. In many defense-related applications, GaAs- and GaN-based ICs are used because of their unique properties, and no effective substitutes exist for GaAs and GaN 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]Other countries estimated to still have primary low-purity gallium production capacity include Germany, Hungary, Kazakhstan, and Ukraine.

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

GARNET (INDUSTRIAL)[1]

(Data in metric tons unless otherwise specified)

Domestic Production and Use: In 2023, garnet for industrial use was mined by three companies—one in Montana and two in New York. One processing facility operated in Oregon and another operated in Pennsylvania. The estimated value of crude garnet production was about $15 million, and refined material sold or used had an estimated value of $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:	2019	2020	2021	2022	2023[e]
Production:					
Crude	104,000	101,000	81,700	76,400	68,000
Refined, sold or used	147,000	146,000	127,000	121,000	120,000
Imports for consumption[2]	208,000	115,000	144,000	268,000	160,000
Exports	16,700	18,200	20,400	23,300	19,000
Consumption, apparent[3]	296,000	198,000	205,000	321,000	210,000
Price, average import unit value, dollars per metric ton	214	250	280	194	190
Employment, mine and mill, number[e]	160	130	120	90	78
Net import reliance[4] as a percentage of apparent consumption	65	49	60	76	67

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 (2019–22):[e] South Africa, 51%; Australia, 16%; China,[5] 16%; India, 14%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023, estimated domestic production of crude garnet concentrates decreased by 11% compared with production in 2022. This decrease was due to the Emerald Creek Garnet Mine in Idaho closing in July 2022. U.S. garnet production was estimated to be about 7% of total global garnet production. The 2023 estimated domestic amount of refined garnet sold or used was essentially the same as that in 2022.

Garnet imports in 2023 were estimated to have decreased by 40% compared with those in 2022. This decrease was attributed to decreased garnet imports from Canada, China, and India. In 2023, the average unit value of garnet imports was $190 per ton, a slight decrease compared with the average unit value in 2022. In the United States, most domestically produced crude garnet concentrate was priced at about $220 per ton. U.S. exports in 2023 were estimated to have decreased by 18%. During 2023, the United States consumed an estimated 210,000 tons of garnet, a 35% decrease from that in 2022.

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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 beginning of 2023, the number of drill rigs operating in the United States was 772; by the end of the second week of October 2023, the number of rigs operating had declined to 622, likely indicating that less garnet was consumed in well drilling. The year-to-date average was 705 rigs operating each week in the United States.[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.

World Mine Production and Reserves: Reserves for China, India, and South Africa were revised based on company and Government reports.

	Mine production		Reserves[7]
	2022	2023[e]	
United States	76,400	68,000	5,000,000
Australia	388,000	390,000	Moderate to large
China	310,000	310,000	37,000,000
Czechia	[e]500	500	NA
India	15,000	15,000	8,600,000
Pakistan	1,870	1,900	NA
South Africa	179,000	180,000	320,000
World total (rounded)	971,000	970,000	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, China, Czechia, India, Pakistan, 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 but production data were not reported. Additional garnet resources are in Canada, Chile, Spain, Thailand, and Ukraine; small mining operations have been reported in most of these countries, but available information was inadequate to make reliable estimates of their individual output.

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 increased cost or decreased quality. 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., 2023, North America rotary rig count Jan 2000 - current: Baker Hughes Co., accessed October 16, 2023, at https://rigcount.bakerhughes.com/na-rig-count.

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

GEMSTONES[1]

(Data in million dollars unless otherwise specified)

Domestic Production and Use: The combined value of U.S. natural and synthetic gemstone output in 2023 was an estimated $99 million, a slight increase compared with that in 2022. 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, Nevada, California, and Montana. These five States accounted for 64% of the natural gemstone production in the United States. 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 slightly compared with that in 2022. Major gemstone end uses were carvings, gem and mineral collections, and jewelry.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:[2]					
Natural[3]	9.22	9.82	9.48	9.95	9.9
Laboratory-created (synthetic)	94.3	55.0	79.3	87.1	89
Imports for consumption	24,400	16,300	24,600	28,000	25,000
Exports, excluding reexports	1,020	1,330	992	1,890	3,800
Consumption, apparent[4]	23,500	15,000	23,700	26,200	21,000
Price	Variable, depending on size, type, and quality				
Employment, mine, number[e]	1,120	1,100	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 (2019–22, by value): Diamond: India, 47%; Israel, 27%; Belgium, 11%; South Africa, 4%; and other, 11%. Diamond imports accounted for an average of 89% of the total value of gem imports in 2019–22.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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, unworked or roughly shaped	7104.21.0000	3% ad valorem.
Synthetic gemstones, unworked or roughly shaped	7104.29.0000	3% ad valorem.
Synthetic diamonds, cut but not set	7104.91.1000	Free.
Synthetic diamonds, other	7104.91.5000	6.4% ad valorem.
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: Total world diamond production in 2023 was estimated to have decreased slightly from that in 2022. In 2023, Russia was the world's leading diamond producer and exporter by volume. Russia's state-owned diamond mining company produced nearly one-third of all natural diamonds. The United States was one of the world's leading markets for polished diamonds. In April 2022, the U.S. Government banned the import of rough and finished diamonds from Russia, and the U.S. Treasury Department placed sanctions on the Russian state-owned diamond-mining company to prevent diamond revenues from funding the conflict with Ukraine. During the last part of 2023, the Group of Seven (G7; representatives of the seven leading industrial nations) and the European Union were considering regulatory actions to ban the import of Russian rough and polished diamonds, to take effect at the beginning of 2024.

In 2023, the global natural diamond market experienced a slowdown, which affected the entire diamond pipeline. Fewer jewelry sales led to a decline in polished trading and a buildup of midstream inventory, which in turn led to a decline in diamond rough sales and lower prices, affecting the ability of mining companies to maintain operations. This slowdown was a result of decreased demand for luxury goods and an increasing popularity of synthetic gemstones.

In 2023, U.S. imports for consumption of gemstones were valued at about $25 billion, which was a 10% decrease compared with $28.0 billion in 2022. The decrease in U.S. total gemstone imports combined with the increase in total gemstone exports contributed to a 19% decrease in apparent consumption to a value of $21 billion in 2023 compared with $26.2 billion in 2022. The U.S. apparent consumption value was 92% gem-quality diamond and 8% nondiamond gemstones. The United States was one of the leading global markets in terms of sales and is expected to continue as a dominant global gemstone consumer.

World Gem-Quality Natural Diamond Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2022	2023[e]	
United States	—	—	World reserves of diamond-bearing deposits are substantial. No reserves data were available for other gemstones.
Angola	7,890	7,900	
Botswana	17,100	17,000	
Brazil	158	160	
Canada	16,200	15,000	
Congo (Kinshasa)	1,980	2,000	
Guinea	103	100	
Lesotho	728	730	
Namibia	2,050	2,000	
Russia	23,500	24,000	
Sierra Leone	551	550	
South Africa	3,860	3,800	
Tanzania	319	320	
Zimbabwe	446	440	
Other countries	302	300	
World total (rounded)	75,200	74,000	

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. — Zero.
[1]Excludes industrial diamond and industrial garnet. See 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 (natural and synthetic) – exports (natural and synthetic, excluding reexports).
[5]Defined as imports (natural and synthetic) – exports (natural and synthetic, excluding reexports).
[6]Data in thousands of carats of gem-quality natural diamond.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.

GERMANIUM

(Data in kilograms, germanium content, unless otherwise specified)

Domestic Production and Use: In 2023, zinc concentrates containing germanium were produced at mines in Alaska and Tennessee. Some of the germanium-containing concentrates produced in Alaska were exported to a refinery in Canada for processing and germanium recovery in the form of dioxide and tetrachloride. 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. The value of germanium metal and germanium dioxide (gross weight) imported domestically in 2023 was estimated to be $45 million. A company in Utah produced germanium wafers for the semiconductor industry and for solar cells used in satellites from imported and recycled germanium. A refinery in Oklahoma recovered germanium from scrap and produced germanium tetrachloride for the production of fiber optics.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production, refinery:					
Primary	—	—	—	—	—
Secondary	NA	NA	NA	NA	NA
Imports for consumption:[e, 1]					
Germanium metal	14,000	14,000	13,000	16,000	24,000
Germanium dioxide	21,000	11,000	17,000	15,000	14,000
Germanium tetrachloride	NA	NA	NA	NA	NA
Exports:[e, 1]					
Germanium metal	3,900	4,000	5,500	6,600	6,300
Germanium dioxide	600	800	400	100	100
Germanium tetrachloride	NA	NA	NA	NA	NA
Shipments from Government stockpile[2]	—	—	—	—	NA
Consumption, estimated[3]	30,000	30,000	30,000	NA	NA
Price, annual average, dollars per kilogram:[4]					
Germanium metal	1,236	1,046	1,187	1,294	1,400
Germanium dioxide	913	724	770	828	880
Net import reliance[5] as a percentage of estimated consumption	>50	>50	>50	>50	>50

Recycling: The United States has the capability to recycle new and old germanium scrap. During the manufacture of infrared germanium optics, much of the germanium removed during the machining process is routinely recycled as new scrap. Infrared lenses and windows in decommissioned military equipment are also recycled to recover germanium. Germanium is recycled from certain wastes generated during the manufacture of optical fibers. Germanium wafers used as substrates to produce solar cells are also recycled. Available information was inadequate to make reliable estimates of the amount of secondary germanium produced.

Import Sources (2019–22):[1, 6] Germanium metal: China, 54%; Belgium, 30%; Germany, 8%; Russia, 6%; and other, 2%. Germanium dioxide: Belgium, 47%; Canada, 46%; and other, 7%. Combined total: Belgium, 39%; China, 26%; Canada, 25%; and other, 10%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
Germanium oxides and zirconium dioxide	2825.60.0000	3.7% ad valorem.
Unspecified chlorides, including germanium tetrachloride	2827.39.9000	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 2023		FY 2024	
Material	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Germanium (gross weight)	—	5,000	—	5,000

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GERMANIUM

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

U.S. imports of germanium metal and dioxide (germanium content) in 2023 were estimated to have increased by about 20% in 2023 from those in 2022 to 38,000 kilograms. Imports of germanium tetrachloride could not be quantified from available trade data. More than 99% of total imports of metal and dioxide (germanium content) for the year through August were from China, Belgium, Germany, and Canada, in descending order by quantity.

Global germanium refinery production and recycling data were limited, and available estimates were difficult to verify. China continued to be the leading global producer and exporter of germanium in 2023. In August, the Government of China implemented an export licensing program for germanium. Exporters were required to apply for an export license for each shipment of germanium, providing the Government with details on the overseas buyer and end use. Exports of germanium metal (China's export codes 8112.92.10 and 8112.99.10) for the year through September increased by 34% to 34,600 kilograms compared with those in the same period in 2022, despite virtually no exports reported in August and September 2023 after China's export control measures began. These exports were mostly sent to Russia (21%), Germany (19%), Hong Kong (18%), the United States (17%), Belgium (9%), and Japan (8%). Major germanium producers in China included Yunnan Chihong Germanium and Zinc Co. Ltd. and Yunnan Lincang Xinyuan Germanium Industry Co. Ltd.

Germanium metal and germanium dioxide prices (Europe, minimum 99.999% purity) generally rose between January and October with the price for germanium metal increasing from $1,150 per kilogram to $1,550 per kilogram and the price for germanium dioxide increasing from $725 per kilogram to $940 per kilogram.

World Refinery Production and Reserves:[8] Germanium was known to have been produced or recycled commercially in only a few countries, including the United States, Belgium, Canada, China, Germany, and Russia, with China being the leading producer of germanium. Because most producers do not publicly report germanium production, global production data were limited. Substantial germanium-rich deposits, including tailings sites, that were in operation or in active development were in the United States, China, Congo (Kinshasa), and Russia. However, data were generally not available on the reserves of these deposits.

World Resources:[8] Germanium reserves data were not widely reported at a mine or country level and thus difficult to quantify. The available resources of germanium are associated with certain zinc and lead-zinc-copper sulfide ores and lignite coal deposits.

Substitutes: Silicon or gallium arsenide 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. Chalcogenide glass has been used as a substitute for germanium metal in infrared applications. Antimony and titanium are substitutes for use as polymerization catalysts.

[e]Estimated. NA Not available. — Zero.
[1]Data have been adjusted to exclude low-value shipments. Germanium dioxide data were multiplied by 69% to calculate the germanium content.
[2]Defined as change in total inventory from prior yearend inventory. If negative, increase in inventory. Beginning in 2023, Government stock changes no longer available.
[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 Non-Ferrous Markets.
[5]Defined for 2019–22 as imports – exports ± adjustments for Government stock changes. Beginning in 2023, Government stock changes no longer included.
[6]Germanium metal import sources were based on adjusted data for Harmonized Tariff Schedule of the United States (HTS) codes 8112.92.6000, 8112.92.6500, and 8112.99.1000. Germanium dioxide import sources were based on adjusted data for HTS code 2825.60.0000.
[7]See Appendix B for definitions.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.

GOLD

(Data in metric tons,[1] gold content, unless otherwise specified)

Domestic Production and Use: In 2023, domestic gold mine production was estimated to be 170 tons; the value was estimated to be about $10 billion, a slight decrease from that in 2022. 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 73% of total domestic production, followed by Alaska, which produced about 13% of domestic gold. About 6% of domestic gold was recovered as a byproduct of processing domestic base-metal ores, chiefly copper ores. The top 27 operations yielded about 97% of the mined gold produced in the United States. Commercial-grade gold was produced at approximately 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:	2019	2020	2021	2022	2023[e]
Production:					
Mine	201	193	187	173	170
Refinery:					
Primary	205	181	181	181	160
Secondary (new and old scrap)	116	92	92	93	90
Imports for consumption[2]	199	545	192	138	200
Exports[2]	360	297	386	420	250
Consumption, reported[3]	151	187	265	257	250
Stocks, Treasury, yearend[4]	8,130	8,130	8,130	8,130	8,130
Price, dollars per troy ounce[5]	1,395	1,774	1,801	1,802	1,900
Employment, mine and mill, number[6]	11,800	12,200	12,500	12,300	12,000
Net import reliance[7] as a percentage of reported consumption	E	([8])	E	E	E

Recycling: In 2023, 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 by 3% compared with that in 2022.

Import Sources (2019–22): Ores and concentrates: Canada, 99%; and other, 1%. Dore: Mexico, 42%; Colombia, 15%; Argentina, 9%; Nicaragua, 9%; and other, 25%. Bullion: Switzerland, 40%; Canada, 23%; Singapore, 7%; South Africa, 7%; and other, 23%. Total: Switzerland, 26%; Mexico, 18%; Canada, 16%; Colombia, 8%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023 increased by 5% and reached a new record-high annual price compared with the previous record-high annual price in 2022. The Engelhard daily price for gold in 2023 fluctuated with an increasing trend into the second quarter, then fluctuated with a decreasing trend into the third quarter.

In 2023, worldwide gold mine production was estimated to be essentially unchanged compared with that in 2022. Production decreases in Australia, Canada, Peru, and the United States were offset by production increases Indonesia, Kazakhstan, and South Africa.

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GOLD

Estimated global gold consumption, excluding exchange-traded funds and other similar investments, was in jewelry, 46%; central banks and other institutions, 23%; physical bars, 16%; official coins and medals and imitation coins, 9%; electrical and electronics, 5%; and other, 1%. In the first 9 months of 2023, global consumption of gold in physical bars decreased by 5%, jewelry was essentially unchanged, electronics decreased by 11%, other industrial applications were essentially unchanged, and coins and medals increased by 6% compared with those in the first 9 months of 2022. During the first 9 months of 2023, gold holdings in central banks increased by 14%, but global investments in gold-based exchange-traded funds and similar investments were 189 tons lower in the first 9 months of 2023 compared with the 20-ton decrease during the first 9 months of 2022. Total global consumption in the first 9 months of 2023 decreased by 3% compared with that in the first 9 months of 2022.[9]

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

	Mine production		Reserves[10]
	2022	2023[e]	
United States	173	170	3,000
Australia	314	310	[11]12,000
Brazil	[e]61	60	2,400
Burkina Faso	58	60	NA
Canada	206	200	2,300
China	372	370	3,000
Ghana	[e]88	90	1,000
Indonesia	105	110	2,600
Kazakhstan	[e]115	130	1,000
Mali	[e]64	60	800
Mexico	[e]120	120	1,400
Peru	97	90	2,300
Russia	[e]310	310	11,100
South Africa	89	100	5,000
Tanzania	57	60	420
Uzbekistan	[e]104	100	1,800
Other countries	726	700	9,200
World total (rounded)	3,060	3,000	59,000

World Resources:[10] An assessment of U.S. gold resources indicated 33,000 tons of gold—15,000 tons in identified and 18,000 tons in undiscovered 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 2023, 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]Large unreported investor stock purchases preclude calculation of a meaningful net import reliance.
[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 4,600 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 specified)

Domestic Production and Use: In 2023, natural graphite was not produced in the United States; however, approximately 95 companies, primarily in the Great Lakes and Northeast regions, consumed 76,000 tons valued at an estimated $180 million. The major uses of natural graphite were batteries, brake linings, lubricants, powdered metals, refractory applications, and steelmaking. During 2023, U.S. natural graphite imports were an estimated 84,000 tons, consisting of about 89.3% flake and high-purity, 10.4% amorphous, and 0.3% lump and chip graphite.

Graphite consumption is expected to continue to increase, owing largely to growth from the lithium-ion battery market. According to Benchmark Mineral Intelligence, global graphite consumption by the battery market has increased by 200% since 2019. The number of lithium-ion battery manufacturing facilities in the United States increased to 10 in 2023 from 3 in operation during 2019. An additional 28 facilities were under development.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production, mine	—	—	—	—	—
Imports for consumption	50,100	36,000	53,000	89,200	84,000
Exports	5,880	5,920	8,660	9,500	8,400
Consumption, apparent[1]	44,200	30,000	44,300	79,700	76,000
Price, average unit value of imports, dollars per metric ton at foreign ports:					
Flake	1,340	1,340	1,330	1,200	1,200
Lump and chip (Sri Lanka)	2,380	2,940	2,010	2,590	2,500
Amorphous	511	567	629	563	565
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 was increasing, with material being recycled into products such as brake linings and thermal insulation. 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 (2019–22): China,[2] 42%; Mexico, 16%; Canada, 15%; Madagascar, 12%; and other, 15%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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: None.

Events, Trends, and Issues: U.S. natural graphite imports, by tonnage, were 6% lower during the first 8 months of 2023, compared with those in the same period in 2022. Some companies announced that they increased orders in the fourth quarter in anticipation of reduced graphite supply from China. U.S. imports for consumption and U.S. apparent consumption increased by 68% and 72%, respectively, from 2019 to 2023.

In 2023, China was the world's leading graphite producer, producing an estimated 77% of total world production. Approximately 15% of graphite produced in China was amorphous and about 85% was flake. In October, China announced export restrictions to take effect on December 1 on certain goods, including flake graphite, spherical graphite (natural and synthetic), expandable graphite, and some synthetic graphite products. Exporters would need to apply for a license, which according to one graphite producer, required export contracts, technical product specifications, and the identity of the end user as well as the specific end use. During the first 9 months of the year, China exported 58,000 tons of flake graphite concentrate, less than the 81,000 tons exported in the same period in 2022. The leading recipients were the Republic of Korea (18%), Japan (17%), India (14%), and the United States (8%). During the same period in 2023, China exported 39,000 tons of natural spherical graphite, less than the 45,000 tons exported in 2022. The leading recipients were the Republic of Korea (56%), the United States (23%), and Japan (19%).

Five companies were exploring or developing graphite-mining projects in the United States—two in Alabama, one in Alaska, one in Montana, and one in New York. In July, the project in Alaska was awarded a grant of $37.5 million

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GRAPHITE (NATURAL)

through the Inflation Reduction Act. In November, a project in Alabama was awarded a grant of $3.2 million through the Defense Production Act.

Two spherical graphite plants, located in Kellyton, AL, and Vidalia, LA, were under construction in 2023; production was expected to begin during 2024. An additional five plants in the United States were under early development.

Production at a large graphite mine in Mozambique was paused for 4 months owing to unfavorable market conditions related to high anode production in China and lower prices. Operations resumed in the third quarter, but at a reduced rate. In September, the company was granted a conditional $150 million loan from the United States International Development Finance Corp. to help fund capital requirements at the mine.

A Canadian company continued to construct a graphite mine in Brazil. First production was on pace for early 2024; planned production during phase 1 was 5,000 tons per year, increasing to 50,000 tons in phase 3. In July, another Canadian company announced first production at its mine in Madagascar. Production capacity was planned to be 17,000 tons per year, potentially expanding to 150,000 tons per year in phase 2. An additional mine, with a capacity of 40,000 tons per year, was under construction in Tanzania.

Graphite production in Ukraine continued to face disruptions owing to the ongoing conflict with Russia, which began in 2022. After the winter season shutdown, production restarted in May but continued to face energy supply disruptions related to the conflict. Prior to Russian military action, graphite production in Ukraine was about 10,000 tons per year.

World Mine Production and Reserves: Reserves for Canada, China, India, Madagascar, and Turkey were revised based on company and Government reports.

	Mine production		Reserves[3]
	2022	2023[e]	
United States	—	—	([4])
Austria	500	500	([4])
Brazil	[e]72,000	73,000	74,000,000
Canada	13,000	3,500	5,700,000
China	1,210,000	1,230,000	78,000,000
Germany	170	150	([4])
India	11,000	11,500	8,600,000
Korea, North	[e]8,100	8,100	2,000,000
Korea, Republic of	23,800	27,000	1,800,000
Madagascar	[e]130,000	100,000	24,000,000
Mexico	2,000	2,000	3,100,000
Mozambique	166,000	96,000	25,000,000
Norway	10,380	7,200	600,000
Russia	[e]16,000	16,000	14,000,000
Sri Lanka	2,600	2,200	1,500,000
Tanzania	[e]6,120	6,000	18,000,000
Turkey	2,800	2,000	6,900,000
Ukraine	1,000	2,000	([4])
Vietnam	500	500	([4])
World total (rounded)	1,680,000	1,600,000	280,000,000

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]Includes Hong Kong.

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

[4]Included in "World total."

GYPSUM

(Data in thousand metric tons unless otherwise specified)

Domestic Production and Use: In 2023, domestic production of crude gypsum was estimated to be 22 million tons with a value of about $264 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 46 mines in 15 States. The majority of domestic consumption, which totaled approximately 45 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 2023, the production capacity gypsum panel manufacturing in the United States was about 34 billion square feet[1] per year. Total wallboard sales in 2023 were estimated to be 27 billion square feet.

Salient Statistics—United States:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production:					
Crude	21,600	21,300	20,800	22,300	22,000
Synthetic[2]	14,400	13,000	14,000	14,500	15,000
Calcined[3]	17,900	17,900	18,600	18,700	18,000
Wallboard products sold, million square feet[1]	25,900	26,200	27,300	28,200	27,000
Imports, crude, including anhydrite	6,140	6,030	6,520	6,870	8,100
Exports, crude, not ground or calcined	37	32	42	39	45
Consumption, apparent[4]	42,100	40,300	41,300	43,700	45,000
Price, average, dollars per metric ton:					
Crude, free on board (f.o.b.) mine	8.6	8.6	11	11	12
Calcined, f.o.b. plant	34	35	42	50	52
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	14	15	16	16	18

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 (2019–22): Spain, 34%; Mexico, 32%; Canada, 29%; Turkey, 4%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
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 2022. U.S. gypsum imports increased by an estimated 18% compared with those in 2022. Exports, although very low compared with imports, increased by an estimated 15%.

Demand for gypsum depends principally on construction industry activity, particularly in the United States, where most gypsum consumed is used for agriculture, building plasters, the manufacture of portland cement, and wallboard products. According to the U.S. Census Bureau, housing starts through September 2023 were at a seasonally adjusted annual rate of 1,358,000, 7% less than the 1,463,000 starts from January through September 2022.

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GYPSUM

The United States, the world's leading crude gypsum producer, produced an estimated 22 million tons (14%). Iran was the second-leading producer with an estimated 16 million tons (10%) of crude production, followed by China and Oman with 12 million tons (8%) each. 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, Iran, Pakistan, and Thailand were revised based on Government information.

	Mine production[e]		Reserves[6]
	2022	2023	
United States	[7]22,300	22,000	700,000
Algeria	2,500	2,500	NA
Brazil	2,900	2,900	450,000
Canada	2,400	2,400	450,000
China	12,000	12,000	2,100,000
France	2,000	2,400	350,000
Germany	5,200	5,200	NA
India	4,300	4,300	37,000
Iran	16,000	16,000	900,000
Japan	4,300	4,300	NA
Mexico	5,400	5,400	NA
Oman	12,000	12,000	NA
Pakistan	1,800	1,800	760,000
Russia	4,100	4,100	NA
Saudi Arabia	4,000	4,000	NA
Spain	11,000	11,000	NA
Thailand	10,400	10,000	910,000
Turkey	9,300	10,000	200,000
Ukraine	1,800	1,500	NA
Uzbekistan	2,000	2,000	NA
Other countries	19,000	19,000	NA
World total (rounded)	155,000	160,000	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 west coast. Large gypsum deposits occur in the Great Lakes region, the midcontinent region, and several Western States. Foreign resources are large and widely distributed; gypsum production was estimated for 77 countries in 2023.

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 2023, synthetic gypsum was estimated to account for about 33% of the total domestic gypsum supply.

[e]Estimated. NA Not available.

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

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

[3]From domestic crude and synthetic gypsum.

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

[5]Defined as imports – exports.

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

[7]Reported.

HELIUM

(Data in million cubic meters, helium gas[1] content, unless otherwise specified)

Domestic Production and Use: In 2023, the estimated sales of Grade-A helium (99.997% helium or greater) and gaseous helium (generally greater than 98% helium) was an estimated 79 million cubic meters (2.8 billion cubic feet) valued at an estimated $1.1 billion. Five plants (three in Texas and two in Kansas) extracted helium from natural gas and produced crude helium that generally ranged from 50% to 80% helium. Nine plants (two each in Arizona, Kansas, and New Mexico, and one each in Colorado, Oklahoma, and Utah) produced gaseous helium. Five plants (two in Colorado and one each in New Mexico, Utah, and Wyoming) extracted helium from natural gas and produced Grade-A helium. Four plants (three 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 2023, estimated domestic apparent consumption of Grade-A and gaseous helium was 59 million cubic meters (2.1 billion cubic feet), and it was used for, in decreasing quantity of use, analytical, engineering, lab, science, and specialty gases (21%); controlled atmospheres, fiber optics, and semiconductors (17%); magnetic resonance imaging (17%); lifting gas (16%); aerospace, pressuring, and purging (9%); welding (8%); leak detection (5%); diving (4%); and various other minor applications (3%).

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Helium extracted from natural gas[2]	64	72	69	65	60
Withdrawn from storage[3]	22	10	7	12	19
Grade-A and gaseous helium sales	86	82	76	77	79
Imports for consumption	7	7	9	9	12
Exports	58	35	33	32	32
Consumption, apparent[4]	[5]50	53	52	54	59
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 $14 per cubic meter ($390 per thousand cubic feet) in 2023, 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 (2019–22): Qatar, 47%; Canada, 31%; Algeria, 11%; Russia, 4%; and other, 7%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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] The Federal Helium System includes all operations of the Cliffside Crude Helium Enrichment Unit, the Cliffside Field helium storage reservoir, and the Government's crude helium pipeline system. The Helium Stewardship Act of 2013 (HSA) mandated the privatization of the Federal Helium System. The BLM was directed to sell at auction the 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) 2023, the remaining conservation helium was 51.5 million cubic meters (1.86 billion cubic feet). During FY 2023, the BLM's Amarillo Field Office, Helium Operations, accepted 5.7 million cubic meters (206 million cubic feet) of private helium for storage and redelivered 24.7 million cubic meters (891 million cubic feet). As of September 30, 2023, 41.4 million cubic meters (1.49 billion cubic feet) of privately owned helium remained in storage at Cliffside Field. On December 3, 2022, the management of the Federal Helium System was transferred from BLM to the General Services Administration (GSA) to dispose of all assets. The BLM will continue to deliver helium from private storage until all Federal Helium System assets are sold or disposed of. The Federal Helium System assets were being sold in two lots. Lot 1 included approximately 28 million cubic meters (1.0 billion cubic feet) of Federally owned crude helium. Lot 2 included the Federal Helium System and approximately 22 million cubic meters (800 million cubic feet) of crude helium. The GSA was accepting bids for the Federal Helium System assets until January 23, 2024. On September 7, 2023, a lawsuit was filed to prevent the Federal Government from selling the Federal Helium System. On November 2, 2023, the Court issued a decision that the sale of the Federal Helium System will continue as mandated in the HSA.

Material	Authorized for disposal	Disposal plan FY 2024
Helium	51.5	51.5

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HELIUM

Events, Trends, and Issues: In 2023, Grade-A and gaseous helium sales increased slightly, whereas helium extracted from natural gas decreased by 8% compared with those in 2022. The decrease in helium extracted from natural gas was mainly due to planned maintenance lasting about a month at one helium facility but was offset by a 58% increase of helium withdrawn from the Cliffside Field compared with that in 2022. In 2023, there were three new helium operations (one each in Arizona, Colorado, and New Mexico) that began producing helium in the United States. Total world helium production increased by 8%. Globally, several new helium facilities began operations—four in Canada, one in Russia, and one South Africa. A helium facility in Amur, Russia, restarted production from the first of its three trains in September 2023. The only helium facility in Australia ceased production in 2023 owing to reduced feedgas. Multiple companies were exploring for and developing helium deposits throughout the world. Some of these helium deposits that are being explored and developed are nonhydrocarbon sourced.

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

	Production		Reserves[8]
	2022	2023[e]	
United States (extracted from natural gas)	65	60	8,500
United States (from Cliffside Field)	12	19	52
Algeria	[e]8	10	[e]1,800
Australia	[e]3	1	NA
Canada	3	4	NA
Poland	3	3	24
Qatar	[e]59	66	[e]Large
Russia	[e]5	8	[e]1,700
South Africa	NA	([9])	NA
World total (rounded)	[e]158	170	NA

World Resources:[8] The U.S. Geological Survey (USGS) and the BLM coordinated efforts to complete a national helium gas 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 51.5 million cubic meters (1.86 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. Superconductors, including those in magnetic resonance imaging scanners, are being developed to operate at higher temperatures using nitrogen instead of helium as a coolant. Hydrogen can be substituted for helium in some lighter-than-air applications in which the flammable nature of hydrogen is not objectionable. Argon can be substituted for helium in welding. Hydrogen can be used as a substitute for helium in deep-sea diving applications.

[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]As Grade-A, gaseous, or crude helium.

[3]Extracted from natural gas in prior years.

[4]Grade-A and gaseous helium. Defined as sales + imports – exports.

[5]Consumption was estimated by the U.S. Geological Survey for 2019 because the data reported by the U.S. Census Bureau were unusually high and may have contained misclassified items.

[6]Defined as imports – exports.

[7]See Appendix B for definitions.

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

[9]Less than ½ unit.

[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 specified)

Domestic Production and Use: Indium was not recovered from ores in the United States in 2023. 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 300 tons in 2023 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 2023, based on the average U.S. warehouse price, was about $72 million.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production, refinery	—	—	—	—	—
Imports for consumption	95	115	158	202	300
Exports	NA	NA	NA	NA	NA
Consumption, estimated[1]	95	115	158	202	300
Price, annual average, dollars per kilogram:					
New York dealer[2]	390	395	NA	NA	NA
U.S. warehouse, free on board[3]	182	161	223	250	240
Rotterdam, duties unpaid[4]	177	158	217	252	240
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 (2019–22): Republic of Korea, 32%; Canada, 19%; Belgium, 11%; and other, 38%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
Unwrought indium, including powders	8112.92.3000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2023, the estimated annual average U.S. warehouse price (free on board) was $240 per kilogram, 4% less than the reported average price in 2022. The U.S. price, as reported by Argus Media Group, Argus Non-Ferrous Markets, began the year at $223 per kilogram and remained around $220 through midyear. By the end of September, tight feedstock availability caused prices to trend upward to $275.

In February, an Australian company completed the maiden resource estimate on its zinc-copper-silver-indium project in Utah. The resource estimate did not include indium owing to data gaps in historical drilling, but the company began a resampling program to include indium in the next resource update. The historical resource estimate, completed in 2014, included about 1,530 tons of contained indium.

A manufacturer of navigation and inertial sensing products announced that it would begin a restructuring program that would shut down its broadband business segment. The restructuring program would include closing down its indium phosphide (InP) wafer fabrication facility, located in Alhambra, CA.

In Bolivia, the Minister of Mining and Metallurgy announced that it was finalizing a $350 million loan from the Export-Import Bank of China to aid in the construction of a zinc refinery, also capable of processing indium. The refinery would be built in the city of Oruro. Bolivia has large indium deposits and has been exporting zinc ores to Europe for indium recovery.

An indium-producing zinc smelter in Auby, France, was placed on care-and-maintenance status in December 2022 owing to unfavorable market conditions. The company announced that it would use this period to apply planned investments to improve operations. The facility was reopened in March 2023, but with variable production.

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INDIUM

China, the leading producer and exporter of indium globally, exported 381 tons of indium in the first 8 months of 2023 according to international trade statistics. This was a 9% decrease compared with exports in the same period in 2022. Exports were primarily sent to the Republic of Korea, 57%; Hong Kong, 25%; and Singapore, 11%.

The advent of fifth-generation (5G) technologies continued to increase demand for indium. InP-based substrates are used in 5G fiber-optic telecommunications networks where InP lasers and receivers send data through fiber-optic lines, which allow for lower latency, reduced signal loss, and faster speeds.

The growing interest in artificial intelligence (AI) is expected to increase demand for specialized chip materials that allow for more advanced computation. One U.S.-based chipmaker announced in May that demand from data centers for AI chips was largely responsible for its second quarter revenue, which was 54% higher than expected. According to the consulting firm McKinsey, around two-thirds of the AI hardware demand will come from data centers for use in servers. Indium, as ITO, is used as a coating on data center fibers and cables to increase signal transmission and reduce loss. As InP, indium is used in high-speed photodetectors and laser diodes for optical communications. Additionally, some electrical components in data centers use indium-based solder alloys.

World Refinery Production and Reserves:

	Refinery production[e, 6]		Reserves[7]
	2022	2023	
United States	—	—	Quantitative estimates of reserves were not available.
Belgium	19	18	
Canada	39	37	
China	670	650	
France	19	12	
Japan	66	64	
Korea, Republic of	180	200	
Russia	5	5	
Uzbekistan	1	1	
World total (rounded)	999	990	

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

[4]Price is based on 99.99%-minimum-purity indium, duties unpaid in warehouse (Rotterdam). Source: Argus Media Group, Argus Non-Ferrous Markets.

[5]Defined as imports – exports.

[6]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.

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

IODINE

(Data in metric tons, elemental iodine, unless otherwise specified)

Domestic Production and Use: Iodine was produced from brines in 2023 by three companies operating in Oklahoma. U.S. iodine production in 2023 was withheld to avoid disclosing company proprietary data but was estimated to have decreased from that in 2022. The annual average cost, insurance, and freight unit value of iodine imports in 2023 was estimated to be $61 per kilogram, about 30% more than that in 2022.

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 2023. Worldwide, the leading uses of iodine and its compounds were X-ray contrast media (XRCM), pharmaceuticals, liquid crystal displays (LCDs), iodophors, animal feed, and fluorochemicals, in descending order of quantity consumed. Other applications of iodine included biocides, food supplements, and nylon.

Salient Statistics—United States:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production	W	W	W	W	W
Imports for consumption	4,300	4,570	4,120	4,270	3,600
Exports	1,230	1,130	1,280	1,140	1,300
Consumption:					
Apparent[1]	W	W	W	W	W
Reported	4,000	3,750	3,720	3,330	3,000
Price, crude iodine, average unit value of imports (cost, insurance, and freight), dollars per kilogram	26.38	31.57	32.72	45.81	61
Employment, number[e]	60	60	60	60	60
Net import reliance[2] as a percentage of apparent consumption	>50	>50	>50	>50	>50

Recycling: Small amounts of iodine were recycled.

Import Sources (2019–22): Chile, 89%; Japan, 10%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
Iodine, crude	2801.20.0000	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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IODINE

Events, Trends, and Issues: According to industry publications, spot prices for iodine crystal averaged about $73 per kilogram during the first 8 months of 2023. This was about 5% more than the 2022 annual average of $69.11 per kilogram. Iodine price increases were attributed to strong global demand and limited supply.

One U.S. producer opened a sixth iodine production plant in mid-2023. The new plant was expected to add an additional 100 to 150 metric tons per year of crystalline iodine to the company's annual production.

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 2023. 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.

World Mine Production and Reserves: Reserves data for Iran were revised based on Government reports. China also produces crude iodine, but output was 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]
	2022	2023	
United States	W	W	250,000
Azerbaijan	170	200	170,000
Chile	19,200	19,000	610,000
Indonesia	[4]29	30	NA
Iran	700	700	40,000
Japan	9,200	9,000	4,900,000
Russia	3	3	120,000
Turkmenistan	770	800	70,000
World total (rounded)	[5]30,100	[5]30,000	6,200,000

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

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

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Defined as production + imports – exports.
[2]Defined as imports – exports.
[3]See Appendix C for resource and reserve definitions and information concerning data sources.
[4]Reported.
[5]Excludes U.S. production.

IRON AND STEEL[1]

(Data in million metric tons, metal, unless otherwise specified)

Domestic Production and Use: The U.S. iron and steel industry produced raw steel in 2023 with an estimated value of about $110 billion, a 15% decrease from $128 billion in 2022. Pig iron and raw steel were produced by two companies operating integrated steel mills in 12 locations. Raw steel alone was produced by 49 companies at 105 minimills. Combined raw steel production capacity was about 104 million tons per year. Indiana accounted for an estimated 24% of total raw steel production, followed by Ohio, 12%, and Pennsylvania and Texas, 5% each; no other State accounted for more than 4% of total domestic raw steel production. Construction accounted for an estimated 30% of net shipments by market classification, followed by service centers, 24%; automotive, 14%; converting end uses, 8%; non-classified shipments, 4%; machinery and equipment, 3%; appliances, 3%; and other applications, 12%.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Pig iron production[2]	22.3	18.2	22.2	19.8	21
Raw steel production	87.8	72.7	85.8	80.5	80
Distribution of raw steel production, percent:					
Basic oxygen furnaces	30	29	29	28	29
Electric arc furnaces	70	71	71	72	71
Continuously cast steel, percent	99.8	99.8	99.8	99.7	99.7
Shipments, steel mill products	87.3	73.5	85.9	76.9	77
Imports, steel mill products:					
Finished	19.1	14.6	20.6	22.9	21
Semifinished	6.2	5.3	7.9	5.1	5
Total	25.3	20.0	28.5	28.0	25
Exports, steel mill products:					
Finished	6.6	6.1	7.4	7.5	8
Semifinished	0.1	0.1	0.1	0.1	0.1
Total	6.7	6.2	7.5	7.6	8
Stocks, service centers, yearend[3]	7.4	5.8	5.8	6.8	7
Consumption, apparent (steel mill products)[4]	100	82.9	98.9	96.9	93
Producer price index for steel mill products (1982=100)[5]	204	184	351	382	325
Employment, average, number:					
Iron and steel mills[5]	85,700	83,200	78,300	80,800	80,600
Steel product manufacturing[6]	57,800	54,900	52,700	55,400	54,900
Net import reliance[7] as a percentage of apparent consumption	12	12	13	17	13

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

Import Sources (2019–22): Canada, 21%; Mexico, 15%; Brazil, 13%; Republic of Korea, 9%; and other, 42%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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:[8]

	FY 2023		FY 2024	
Material	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Grain-oriented electrical steel	—	—	3,200	—

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IRON AND STEEL

Events, Trends, and Issues: In September, one company announced that it had launched a pilot program in coordination with the National Energy Technology Laboratory to use advanced membrane technology as a carbon capture and storage system at a steel mill in Pennsylvania. The same company also launched its new electrical steel line at a steel mill in Arkansas. Electrical steel has been in high demand and is a key component in certain green technologies. In October, the company also announced that it had indefinitely idled a steel mill in Illinois, with a steelmaking capacity of 2.5 million tons per year, laying off over 1,000 employees.

The World Steel Association[9] forecast global finished steel consumption to increase by 1.8% in 2023 and increase by 1.9% in 2024. End-use consumption of steel products was expected to only increase slightly in 2023 following concurrent events affecting consumer demand, including the conflict in Ukraine, monetary tightening, and rising interest rates, though inflation began to moderate owing to slowing economic conditions. In the United States, the apparent consumption of finished steel products was estimated to have decreased slightly in 2023 owing to interest rate increases that negatively affected manufacturing and residential construction; however, consumption was expected to increase by 1.6% in 2024. Increases in the commercial building and automotive sectors were attributed to the 2022 Inflation Reduction Act and the 2021 Bipartisan Infrastructure Law.

The economic conditions in China significantly affected steel production; Chinese finished steel production increased by 2% in 2023 and was expected to remain unchanged in 2024, owing to unexpected economic slowing related to real estate and property markets. The European Union's steel consumption was estimated to decrease by 5.1% in 2023 owing to the conflict in Ukraine and decreases in energy and manufacturing activities. In the Republic of Korea, an increase in steel demand from the construction sector was moderated by a decrease in nonautomotive manufacturing.

World Production:

	Pig iron		Raw steel	
	2022	2023[e]	2022	2023[e]
United States	19.8	21	80.5	80
Brazil	27	26	34	34
Canada	6	6	12	12
China	866	890	1,020	1,000
Germany	24	22	37	33
India	80	87	125	140
Iran	3	2	30	30
Italy	3	3	22	20
Japan	64	63	89	87
Korea, Republic of	42	44	66	68
Mexico	2	2	18	20
Russia	52	54	72	75
Taiwan	13	14	21	21
Turkey	9	11	35	42
Ukraine	6	7	6	7
Vietnam	12	13	20	21
Other countries	67	63	195	180
World total (rounded)	1,300	1,300	1,880	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. — Zero.
[1]U.S. production and shipments data source is the American Iron and Steel Institute; see also the Iron and Steel Scrap and the 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, May 2023.
[4]Defined as steel mill product shipments + imports of finished steel mill products – exports of steel mill products ± adjustments for 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]See Appendix B for definitions.
[9]Source: World Steel Association, 2023, Short range outlook October 2023: Brussels, Belgium, World Steel Association press release, October 7, 7 p.

IRON AND STEEL SCRAP[1]

(Data in million metric tons, metal, unless otherwise specified)

Domestic Production and Use: In 2023, 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) was an estimated $19.5 billion, a 19% decrease from $24.1 billion in 2022. 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 2023, estimated raw steel production was essentially unchanged at 80 million tons from 80.5 million tons in 2022, and net shipments of steel mill products in 2023 were an estimated 77 million tons, unchanged from those in 2022. U.S. apparent consumption of steel, the leading end use for iron and steel scrap, was estimated to have decreased by 4% to 93 million tons in 2023 from 96.9 million tons in 2022.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:					
Home scrap	5.3	5.1	4.7	[e]4.7	5.1
Purchased scrap[2]	55	50	59	[e]59	58
Imports for consumption[3]	4.3	4.5	5.3	4.7	4.7
Exports[3]	18	15	20	20	18
Consumption:					
Reported	47	45	48	[e]48	48
Apparent[4]	48	45	48	[e]48	50
Price, average, delivered, No. 1 heavy melting composite price, dollars per metric ton[5]	249	228	419	379	313
Stocks, consumer, yearend	3.9	4.0	4.4	[e]4.6	4.3
Employment, dealers, brokers, processors, number[e]	26,000	24,500	26,200	26,600	26,400
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 per year of steel is recycled from automobiles, 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 scrap (old, obsolete scrap), 24% new scrap (scrap produced in steel-product manufacturing plants), and 18% home scrap (recirculating scrap from current operations).

Import Sources (2018–21): Canada, 72%; Mexico, 12%; Netherlands, 5%; Sweden, 4%; and other, 7%.

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IRON AND STEEL SCRAP

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
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 the first 9 months of 2023, steel mills maintained normal operating rates of 73% to 78% of production capacity utilization, as compared with 70% to 80% in 2022 and more than the low monthly rate of 55% in May 2020 during the coronavirus disease 2019 (COVID-19) pandemic. Average composite prices published for No. 1 heavy melting steel scrap decreased from the previous high rate of $523.27 per ton in March 2022 to a low of $298.54 in June and July 2023. The annual average price delivered in the first 9 months of 2023 decreased to $334.45 per ton compared with the full-year annual average of $379.19 per ton in 2022.

In the first 9 months of 2023, Turkey was the primary destination for exports of ferrous scrap, by tonnage, accounting for 27% of total exports, followed by Mexico, 16%; Bangladesh, 10%; India, 10%; and Taiwan, 8%. The value of exported scrap decreased to an estimated $5.6 billion in 2023 from $7.4 billion in 2022. In the first 9 months of 2023, Canada was the leading source of imports of ferrous scrap, by tonnage, accounting for 71% of total imports, followed by Mexico, 14%; Sweden, 5%; and the Netherlands and Germany, 3% each.

The World Steel Association[7] forecast global finished steel consumption to increase by 1.8% in 2023 and increase by 1.9% in 2024. End-use consumption of steel products was expected to only increase slightly in 2023 following concurrent events affecting consumer demand, including the conflict in Ukraine, monetary tightening, and rising interest rates. In the United States, the apparent consumption of finished steel products was estimated to have decreased slightly in 2023 owing to interest rate increases; however, consumption was expected to increase by 1.6% in 2024. The 2022 Inflation Reduction Act and the 2021 Bipartisan Infrastructure Law were attributed to increased activity in the commercial building and automotive sectors.

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 the Iron Ore chapters.

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

Substitutes: An estimated 5.3 million tons of direct-reduced iron was consumed in the United States in 2023 as a substitute for iron and steel scrap, up from 5.2 million tons in 2022.

[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, 2023, Short range outlook October 2023: Brussels, Belgium, World Steel Association press release, October 7, 7 p.

IRON AND STEEL SLAG

(Data in million metric tons unless otherwise specified)

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 2023 were estimated to be 16 million tons valued at about $900 million. Blast furnace slag was about 54% of the tonnage sold and accounted for 90% 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).

Iron slag and steel slag are used primarily as aggregates in concrete (air-cooled iron slag only) and as 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 $140 per ton or more for some GGBFS in 2023. 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:	2019	2020	2021	2022	2023[e]
Production (sales)[e, 1, 2]	16.3	15	16	16	16
Imports for consumption[e, 3]	1.4	1.7	2.1	1.7	2.1
Exports	([4])	([4])	([4])	([4])	([4])
Consumption, apparent[e, 5]	16	15	16	16	16
Price, average unit value, free on board plant, dollars per metric ton[6]	28.50	31.00	40.50	53	58
Employment, number[e]	1,500	1,500	1,500	1,500	1,500
Net import reliance[7] as a percentage of apparent consumption	9	11	13	10	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 (2019–22): Japan, 40%; China, 23%; Brazil, 18%; Canada, 7%; and other, 12%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 iron and steel slag is tied closely to the rates of pig iron and 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 71% of U.S. steel production in 2023 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 increase by 1.8% in 2023 and increase by 1.9% in 2024. Pig iron production in the United States was estimated to have increased by 6% to 21 million tons in 2023 from 19.8 million tons in 2022 despite the idling of one blast furnace in the fourth quarter. Raw steel production remained essentially unchanged at 80 million tons.

During 2023, domestic GGBFS remained in limited supply because granulation cooling was known to be available at only two active U.S. blast furnaces and only one other domestic plant produced pelletized slag in limited supply. Grinding of granulated blast furnace slag was only done domestically by cement companies. Much of the granulated blast furnace slag and some GGBFS was imported. Based on data through August, the quantity imported in 2023 was estimated to be 23% more than that in 2022.

The domestic supply of fly ash, which is used as an additive in concrete production, was expected to continue to decrease in upcoming years owing to restrictions on carbon dioxide (CO_2) and mercury emissions at coal-fired powerplants, closures of coal-fired powerplants, conversion of powerplants to natural gas, and increasing reliance on renewable energy sources. 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. In 2023, several large Federal building and infrastructure projects were initiated that would promote the use of such cement and other lower carbon materials under the Federal Buy Clean Initiative.

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 production from blast furnaces was estimated to be 25% to 30% of crude (pig) iron production, and steel furnace slag production was estimated to be 10% to 15% of raw steel production. In 2023, 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. Portland-limestone cement can be used instead of GGBFS for the same purpose. 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 the supplies of these metallurgical slags are generally much more restricted 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, 2023, Short range outlook October 2023: Brussels, Belgium, World Steel Association press release, October 17, 5 p.

IRON ORE[1]

(Data in thousand metric tons, usable ore, unless otherwise specified)

Domestic Production and Use: In 2023, 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 for consumption in the steel industry in the United States. The remaining 2% of domestic iron ore products were consumed in nonsteel end uses. In 2023, the United States produced iron ore with an estimated value of $7.5 billion, a 22% increase from $6.2 billion in 2022. 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 $2.1 billion. The United States was estimated to have produced 1.6% and consumed 1.4% of the world's iron ore output.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:					
Iron ore	46,900	38,100	47,500	39,000	44,000
Iron metallics	3,660	3,500	5,010	5,240	5,300
Shipments	47,000	38,000	43,400	39,000	45,000
Imports for consumption	3,980	3,240	3,750	3,040	3,500
Exports	11,400	10,400	14,400	11,400	11,000
Consumption:					
Reported	34,800	NA	NA	NA	NA
Apparent[2]	39,100	31,100	37,000	30,600	36,000
Price, average unit value reported by mines, dollars per metric ton	92.94	91.27	141.78	156.42	170
Stocks, mine, dock, and consuming plant, yearend	3,470	3,290	3,170	3,190	3,500
Employment, mine, concentrating and pelletizing plant, number	4,960	4,300	4,980	4,790	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 (2019–22): Brazil, 53%; Canada, 23%; Sweden, 9%; Bahrain, 4%; and other, 11%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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: Iron ore production and trade in 2023 were estimated to have increased likely owing to restocking and increased consumption for intermediate products. Domestic iron ore production was estimated to be 44 million tons in 2023, a 13% increase from 39 million tons in 2022. Pig iron production increased by 6% but total raw steel production was estimated to have remained essentially unchanged at 80 million tons in 2023 from 80.5 million tons in 2022. The World Steel Association[4] forecast global finished steel consumption to increase by 1.8% in 2023 and increase by 1.9% in 2024. Global end-use consumption of steel products was expected to increase slightly in 2023 owing to government measures to address inflation and infrastructure concerns, despite concurrent events affecting consumer demand, including the conflict in Ukraine, global inflation, and rising energy costs and interest rates.

Overall, global prices trended downward to an average year-to-date unit value of $117.76 per ton in the first 9 months of 2023, an 8% decrease from the 2022 average year-to-date unit value of $128.65 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 2023 was $128.37 per ton in March compared with the high of $152.07 per ton in March 2022. The lowest monthly average price during the same period in 2023 was $105.15 per ton in May compared with the low of $99.81 per ton in September 2022.

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IRON ORE

In April, one company restarted production, at a limited capacity, at a domestic mine that was idled in 2022, citing increases in steel production and attributing the plant as a "swing operation" to fill needed capacity. In May, one company received approval for State mineral leases that were expected to supplement iron ore for a domestic mine formerly anticipated to idle in 2025 and extend the mine life for an additional 20 years. In July, one iron ore and steel producer announced that it had made an offer to acquire 100% of the outstanding stock of its sole competitor in the domestic iron ore market, which rejected the offer. The purchase would have consolidated all domestic iron ore production under one company. In multiple announcements, the two iron ore companies in the United States made multiple improvements to processing, ran successful test trials for alternative fuel sources, and modified processes for efficiencies aimed at decreasing greenhouse gas emissions.

World Mine Production and Reserves: Reserves for Australia, Iran, South Africa, Turkey, and the United States were revised based on company and Government reports.

	Mine production				Reserves[5] (million metric tons)	
	Usable ore		Iron content			
	2022	2023[e]	2022	2023[e]	Crude ore	Iron content
United States	39,000	44,000	24,700	28,000	3,100	1,300
Australia	944,000	960,000	584,000	590,000	[6]58,000	[6]27,000
Brazil	435,000	440,000	276,000	280,000	34,000	15,000
Canada	69,000	70,000	41,400	42,000	6,000	2,300
Chile	17,700	18,000	11,100	11,000	NA	NA
China	272,000	280,000	170,000	170,000	20,000	6,900
India	251,000	270,000	156,000	170,000	5,500	3,400
Iran	78,300	77,000	51,300	50,000	3,300	1,500
Kazakhstan	53,600	53,000	8,890	8,800	2,500	900
Mauritania	12,700	13,000	7,950	8,100	NA	NA
Mexico	10,800	12,000	6,800	7,600	NA	NA
Peru	19,300	19,000	12,900	13,000	2,600	1,200
Russia	84,200	88,000	55,800	58,000	29,000	14,000
South Africa	63,700	61,000	40,500	39,000	990	620
Sweden	38,900	38,000	27,700	27,000	1,300	600
Turkey	17,700	17,000	10,700	10,000	152	99
Ukraine	34,100	36,000	21,300	22,000	[7]6,500	[7]2,300
Other countries	57,200	48,000	32,200	27,000	18,000	9,500
World total (rounded)	2,500,000	2,500,000	1,540,000	1,500,000	190,000	87,000

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 specified. 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, 2023, Short range outlook October 2023: Brussels, Belgium, World Steel Association press release, October 17, 7 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 specified)

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 lower in 2023 compared with that in 2022. Six companies, including the two producers of natural IOPs, processed and sold about 34,000 tons of finished natural and synthetic IOPs with an estimated value of $70 million. End uses for IOPs include, but are not limited to, concrete and other construction products, paint and coatings, ferrites, plastics, and rubber.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Mine production, crude	W	W	W	W	W
Sold or used, finished natural and synthetic IOPs	19,200	18,300	26,900	38,200	34,000
Imports for consumption	159,000	174,000	192,000	225,000	110,000
Exports, pigment grade	17,500	15,800	12,500	13,800	13,000
Consumption, apparent[1]	161,000	177,000	206,000	249,000	130,000
Price, average unit value, dollars per kilogram[2]	0.69	0.72	1.03	2.02	2.00
Employment, mine and mill, number	55	47	55	46	42
Net import reliance[3] as a percentage of apparent consumption	88	90	87	85	75

Recycling: None.

Import Sources (2019–22): Natural: Cyprus, 55%; France, 21%; Austria, 18%; and other, 6%. Synthetic: China,[4] 43%; Germany, 33%; Brazil, 8%; Canada, 6%; and other, 10%. Total: China,[4] 42%; Germany, 33%; Brazil, 8%; Canada, 6%; and other, 11%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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, decreased by 13% during the first 9 months of 2023 compared with that in the same period in 2022. IOPs are also used in paints and coatings for the aerospace, automotive, and marine industries. Vehicle production in the United States through August 2023 was 9.2% higher than that in the same period in 2022. 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.

Less than 2% of IOP imports were natural pigments, similar to all other years in the past decade. Imports of natural and synthetic pigments were estimated to have decreased by 53% in 2023, owing to the decrease in synthetic pigments imports from China. Global exports of synthetic pigments from China during the first 7 months in 2023 decreased by 73% and exports to the United States decreased by 53% compared with those during the same period in 2022. Exports of pigment-grade IOPs were estimated to have decreased by 5% in 2023 compared with those in 2022. Approximately 47% of pigment-grade IOPs exports went to Mexico; the other leading destination countries for exports were China (15%), Belgium (11%), and France (6%).

One IOP-producing company based in Singapore acquired the iron oxide business of a company based in the United Kingdom. The acquisition was completed in 2023 and included eight manufacturing sites and one administrative site across six countries.

World Mine Production and Reserves:

	Mine production[e]		Reserves[5]
	2022	2023	
United States	W	W	Moderate
Cyprus (umber)	3,500	3,500	Moderate
France	5,000	5,100	NA
Germany[6]	323,000	330,000	Moderate
India (ocher)	3,100,000	3,200,000	37,000,000
Italy	30,000	31,000	NA
Pakistan (ocher)	100,000	110,000	Large
Spain (ocher and red iron oxide)	12,000	13,000	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 specified)

Domestic Production and Use: In Virginia, one firm with integrated mining and processing operations produced an estimated 85,000 tons of kyanite worth $36 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 in 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:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production:					
Kyanite, mine	[1]91,300	[1]67,100	[1]105,000	[1]85,900	85,000
Synthetic mullite	W	W	W	W	W
Imports for consumption (andalusite)	6,960	714	1,390	7,630	6,500
Exports (kyanite)	40,100	37,400	48,000	51,800	52,000
Consumption, apparent[2]	W	W	W	W	W
Price, average unit value of exports (free alongside ship),[3, 4] dollars per metric ton	358	369	369	382	420
Employment, number:[e, 5]					
Kyanite, mine, office, and plant	150	140	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 (2019–22):[4] South Africa, 48%; Peru, 24%; France, 21%; United Kingdom, 7%; and other, <1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
Andalusite, kyanite, and sillimanite	2508.50.0000	Free.
Mullite	2508.60.0000	Free.

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

Government Stockpile: None.

Events, Trends, and Issues: Crude steel production in the United States, which ranked fourth in the world, decreased slightly in the first 8 months of 2023 compared with that in the same period in 2022, indicating a similar change in consumption of kyanite-mullite refractories. Global crude steel production was unchanged during the first 8 months of 2023 compared with that in the same period in 2022. Global crude steel production during the first 8 months of 2023 was disrupted by ongoing logistical issues and high input costs. The steel industry continued to be the leading consumer of refractories.

A company in South Africa that accounted for nearly one-third of global andalusite output was transferred to its new owner following the conclusion of business rescue proceedings in 2022. In mid-2019, the company entered business rescue proceedings attributed to financial problems in preparation to be transferred to a new owner. In January 2021, the company announced that a new investor and owner had been approved.

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KYANITE AND RELATED MINERALS

Andalusite production in 2023 remained constrained by challenging market conditions, such as availability of ore supply and increasing costs. In 2022, andalusite mines in South Africa were adversely affected by electricity supply disruptions, flooding, and shipping problems. In Peru, andalusite production in 2023 was estimated to have decreased from that in 2022 and output was not expected to meet demand. Andalusite exports from France were greater than those from Peru but exports from China were less than those reported from other andalusite-producing countries. 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. Some sillimanite was produced in association with kyanite-producing mines. If andalusite producers are unable to meet demand, market participants may consider alternatives such as bauxite and mullite. Development of and production from new refractory-grade bauxite sources in Brazil and Guyana continued to progress in 2023.

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

	Mine production[e]		Reserves[7]
	2022	2023	
United States (kyanite)	[1]85,900	85,000	Large
China (andalusite, crude ore)	100,000	100,000	5,000,000
France (andalusite)	65,000	65,000	NA
India (kyanite and sillimanite)	12,000	10,000	7,200,000
Peru (andalusite)	43,000	40,000	NA
South Africa (andalusite)	170,000	170,000	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 Iran may have produced kyanite and related minerals and China may have produced kyanite in addition to andalusite, but information was not available to make reliable estimates of output.

LEAD

(Data in thousand metric tons, lead content, unless otherwise specified)

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 recoverable lead from ore mined in 2023 was an estimated $660 million, unchanged from that in 2022. 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, 10% less than that in 2022. The lead-acid battery industry accounted for an estimated 85% of reported U.S. lead consumption during 2023. 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:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production:					
Mine, lead in concentrates	274	306	294	273	270
Mine, recoverable lead	266	297	286	264	260
Primary refinery	—	—	—	—	—
Secondary refinery, old scrap	1,150	1,090	1,050	1,010	1,000
Imports for consumption:					
Lead in concentrates	([1])	([1])	1	([1])	([1])
Refined metal, unwrought	501	382	614	651	570
Exports:					
Lead in concentrates	259	265	262	255	270
Refined metal, unwrought (gross weight)	25	17	22	26	25
Consumption, apparent[2]	1,630	1,450	1,640	1,630	1,600
Price, average, North American, cents per pound[3]	99.9	91.3	113.0	116.5	115
Employment, mine and mill (average), number[4]	1,600	1,790	1,830	1,870	1,800
Net import reliance[5] as a percentage of apparent consumption, refined metal	29	25	36	38	35

Recycling: In 2023, an estimated 1,000,000 tons of secondary lead was produced, an amount equivalent to 62% of apparent domestic consumption. Nearly all secondary lead was recovered from old scrap, mostly lead-acid batteries.

Import Sources (2019–22): Refined metal: Canada, 37%; Mexico, 16%; Republic of Korea, 14%; Australia, 8%; and other, 25%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–23**
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 2023, the average North American price for lead was 115 cents per pound, less than the annual average price of 116.5 cents per pound in 2022. Global stocks of lead in LME-approved warehouses were 128,350 tons at the end of October, which was five times more than those at yearend 2022.

In 2023, domestic mine production of recoverable lead decreased slightly, and production of secondary lead was essentially unchanged from that in 2022. Estimated U.S. apparent consumption of refined lead decreased slightly from that in 2022, and the net import reliance decreased to 35% from 38%. In the first 9 months of 2023, 31 million spent SLI lead-acid batteries were exported, a 26% increase from 24.6 million batteries exported in the same period in 2022. In August, a fire took place at an underground silver-lead-zinc mine in Idaho; no personnel were in the mine at the time of the fire. Production was suspended for the remainder of 2023 while work was carried out to bypass the damaged area.

According to the International Lead and Zinc Study Group,[6] global refined lead production in 2023 was forecast to increase by 2.7% to 12.8 million tons and refined lead consumption to increase by 1.1% to 12.8 million tons.

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

	Mine production		Reserves[7]
	2022	2023[e]	
United States	273	270	4,600
Australia	435	440	[8]35,000
Bolivia	90	90	1,600
China	1,950	1,900	20,000
India	220	220	1,900
Iran	[e]52	50	2,000
Mexico	273	270	5,600
Peru	255	250	5,000
Russia	[e]210	200	8,700
Sweden	75	70	1,700
Tajikistan	[e]53	50	NA
Turkey	[e]67	70	1,600
Other countries	507	610	5,900
World total (rounded)	4,460	4,500	95,000

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

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

[e]Estimated. NA Not available. — Zero.
[1]Less than ½ unit.
[2]Defined as primary refined production + secondary refined production from old scrap + refined imports – refined exports.
[3]Source: S&P Global Platts Metals Week.
[4]Includes lead and zinc-lead mines for which lead was either a principal product or significant byproduct. Data from the Mine Safety and Health Administration.
[5]Defined as refined imports – refined exports.
[6]Source: International Lead and Zinc Study Group, 2023, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 9, [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 10 million tons.

LIME[1]

(Data in thousand metric tons unless otherwise specified)

Domestic Production and Use: In 2023, an estimated 17 million tons of quicklime and hydrated lime was produced (excluding independent commercial hydrators[2]), valued at about $2.6 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 2023. Of the 28 companies, 5 operated only hydrating plants in nine States. In 2023, the five leading U.S. lime companies produced quicklime or hydrated in 22 States and accounted for about 80% of U.S. lime production. Principal producing States were Alabama, 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:	2019	2020	2021	2022	2023[e]
Production[2, 3]	16,900	15,800	16,800	17,000	17,000
Imports for consumption	342	308	323	354	340
Exports	347	266	335	303	350
Consumption, apparent[4]	16,900	15,900	16,800	17,000	17,000
Price, average value, dollars per metric ton at plant:					
Quicklime	128.3	131.4	133.4	151.3	155
Hydrated	154.6	156.0	159.6	183.1	185
Net import reliance[5] as a percentage of apparent consumption	E	<1	E	<1	E

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 to avoid double counting.

Import Sources (2019–22): Canada, 86%; Mexico, 10%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023, domestic lime production was estimated to be unchanged from that in 2022. However, some of the lime producers have increased product pricing owing to increased costs of production. Several companies were planning to accelerate their decarbonization efforts in the production of lime. In 2023, 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]
	2022	2023[e]	
United States	17,000	17,000	Adequate for all countries with listed production.
Australia	1,990	2,000	
Belgium[8]	1,710	1,200	
Brazil	8,300	8,300	
Bulgaria	1,420	1,400	
Canada (shipments)	1,680	1,700	
China	310,000	310,000	
France	2,500	3,000	
Germany	5,900	5,900	
India	16,000	16,000	
Iran	4,000	4,000	
Italy[8]	3,500	3,500	
Japan (quicklime only)	6,240	6,200	
Korea, Republic of	5,100	5,100	
Malaysia	1,500	1,500	
Poland (hydrated and quicklime)	1,800	1,800	
Romania	1,100	1,100	
Russia (industrial and construction)	11,400	11,000	
Slovenia	1,100	1,100	
South Africa	1,070	1,200	
Spain	1,700	1,700	
Turkey	4,600	4,600	
Ukraine	2,600	2,000	
United Kingdom	1,400	1,400	
Other countries	15,400	15,000	
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 or more of lime 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, lithium content, unless otherwise specified)

Domestic Production and Use: Commercial-scale lithium production in the United States was from a continental brine operation in Nevada and from 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 uses vary by location, global end uses were estimated as follows: batteries, 87%; ceramics and glass, 4%; lubricating greases, 2%; air treatment, 1%; continuous casting mold flux powders, 1%; medical, 1%; and other uses, 4%. Lithium consumption for batteries increased significantly in recent years because rechargeable lithium batteries have been used extensively in the growing market for electric vehicles, portable electronic devices, electric tools, and energy grid storage applications. Lithium minerals were used directly as mineral concentrates in ceramics and glass applications.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production	W	W	W	W	W
Imports for consumption	2,620	2,460	2,640	3,270	3,400
Exports	1,660	1,200	1,870	2,440	2,300
Consumption, apparent[1]	W	W	W	W	W
Price, annual average-nominal, battery-grade lithium carbonate, dollars per metric ton[2]	12,100	8,600	12,600	68,100	46,000
Employment, mine and mill, number	70	70	70	70	70
Net import reliance[3] as a percentage of apparent consumption	>25	>50	>25	>25	>25

Recycling: Construction of lithium battery recycling plants increased at a rapid pace. In 2023, about 40 companies in Canada and the United States and 50 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 (2019–22): Argentina, 51%; Chile, 43%; China, 3%; Russia, 2%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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: Not available.

Events, Trends, and Issues: Excluding U.S. production, worldwide lithium production in 2023 increased by 23% to approximately 180,000 tons from 146,000 tons in 2022 in response to strong demand from the lithium-ion battery market. Global consumption of lithium in 2023 was estimated to be 180,000 tons, a 27% increase from the revised consumption figure of 142,000 tons in 2022. However, concern of a short-term lithium oversupply, expiration of the Chinese Government's decade-long program of subsidies for electric vehicle (EV) purchases, and weaker-than-expected EV sales worldwide caused the price of lithium to decrease considerably in 2023.

Spot lithium carbonate prices in China [cost, insurance, and freight (c.i.f.)] decreased from approximately $76,000 per ton in January to about $23,000 per ton in November. For fixed contracts, the annual average U.S. lithium carbonate price was $46,000 per ton in 2023, a decrease of 32% from that in 2022. Spot lithium hydroxide prices in China (c.i.f. China) decreased from approximately $81,500 per ton in January to about $22,500 per ton in November. Spodumene (6% lithium oxide) prices in Australia (free on board) decreased from approximately $6,000 per ton in January to about $2,500 per ton in November.

Seven mineral operations in Australia, one mineral tailings operation in Brazil, two brine operations each in Argentina and Chile, two mineral operations in Canada, five mineral and four brine operations in China, and one mineral operation in Zimbabwe accounted for the majority of world lithium production. Additionally, smaller operations in Argentina, Australia, Brazil, China, Portugal, the United States, and Zimbabwe also contributed to world lithium

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LITHIUM

production. Owing to the rapid increase in demand of lithium in 2023, established lithium operations worldwide increased or were in the process of increasing production capacity.

In 2022, 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. The 2022 U.S. Inflation Reduction Act added tax incentives to consolidate sourcing of battery materials and manufacturing of EVs to North American and U.S.-partner countries.

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, Canada, 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, France, Finland, Germany, Ghana, India, Iran, Kazakhstan, Mali, Namibia, Nigeria, Peru, Portugal, Russia, Rwanda, Serbia, Spain, Thailand, Turkey, 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, China, the United States, and "Other countries" were revised based on company and Government reports.

	Mine production		Reserves[4]
	2022	2023[e]	
United States	W	W	1,100,000
Argentina	6,590	9,600	3,600,000
Australia	74,700	86,000	[5]6,200,000
Brazil	[e]2,630	4,900	390,000
Canada	[e]520	3,400	930,000
Chile	38,000	44,000	9,300,000
China	[e]22,600	33,000	3,000,000
Portugal	[e]380	380	60,000
Zimbabwe	[e]1,030	3,400	310,000
Other countries[6]	—	—	2,800,000
World total (rounded)	[7]146,000	[7]180,000	28,000,000

World Resources:[4] Owing to continuing exploration, measured and indicated lithium resources have increased substantially worldwide and total about 105 million tons. Measured and indicated lithium resources in the United States—from continental brines, claystone, geothermal brines, hectorite, oilfield brines, and pegmatites—are 14 million tons. Measured and indicated lithium resources in other countries have been revised to 91 million tons. Resources are distributed as follows: Bolivia, 23 million tons; Argentina, 22 million tons; Chile, 11 million tons; Australia, 8.7 million tons; China, 6.8 million tons; Germany, 3.8 million tons; Canada, 3 million tons; Congo (Kinshasa), 3 million tons; Mexico, 1.7 million tons; Czechia, 1.3 million tons; Serbia, 1.2 million tons; Peru, 1 million tons; Russia, 1 million tons; Mali, 890,000 tons; Brazil, 800,000 tons; Zimbabwe, 690,000 tons; Spain, 320,000 tons; Portugal, 270,000 tons; Namibia; 230,000 tons; Ghana, 200,000 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 industry stock changes.
[2]Lithium carbonate price assessments for spot and long-term contracts. Source: Benchmark Mineral Intelligence Ltd.
[3]Defined as imports – exports ± 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 4.8 million tons.
[6]Other countries with reported reserves: Austria, Congo (Kinshasa), Czechia, Finland, Germany, Ghana, Mali, Mexico, Namibia, Serbia, and Spain.
[7]Excludes U.S. production.

MAGNESIUM COMPOUNDS[1]

[Data in thousand metric tons, magnesium oxide (MgO) content,[2] unless otherwise specified]

Domestic Production and Use: In 2023, the majority of U.S. magnesium compounds were produced from seawater and natural brines. The value of shipments of all types of magnesium compounds was estimated to be $470 million, a slight increase from the revised value in 2022. 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. Olivine was mined and processed by one company in Washington.

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:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production	376	363	432	412	420
Shipments (gross weight)	563	547	634	606	620
Imports for consumption	564	480	655	598	570
Exports	88	66	86	104	100
Consumption, apparent[3]	852	777	1,001	906	880
Employment, plant, number[e]	270	260	270	280	270
Net import reliance[4] as a percentage of apparent consumption	56	53	57	55	52

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

Import Sources (2019–22): Caustic-calcined magnesia: China,[5] 75%; Canada, 20%; Israel, 2%; and other, 3%. Crude magnesite: China,[5] 85%; Singapore, 13%; and other, 2%. Dead-burned and fused magnesia: China,[5] 71%; Brazil, 16%; Turkey, 4%; Mexico, 3%; and other, 6%. Magnesium chloride: Israel, 59%; Netherlands, 24%; China,[5] 5%; and other, 12%. Magnesium hydroxide: Mexico, 57%; Netherlands, 15%; Israel, 12%; Austria, 6%; and other, 10%. Magnesium sulfates: China,[5] 54%; India, 13%; Germany, 11%; Vietnam, 7%; and other, 15%. Total imports: China,[5] 63%; Israel, 9%; Canada, 8%; Brazil, 6%; and other, 14%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
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 2023, consumption of dead-burned and fused magnesia was estimated to have decreased slightly in the United States, and global consumption remained unchanged compared with that in 2022 based on steel production data through August. Domestic consumption for all magnesium compounds has somewhat followed the general trend of the performance of the U.S. manufacturing industry. Globally, China was the leading producer of magnesia and magnesite and remained the principal exporter of magnesia to the United States and much of the world. Prices for Chinese fused magnesia reached a low in May 2023 and remained low as of September. China's domestic fused magnesia market weakened owing to high inventories and low demand. However, China's total fused magnesia exports to India increased by 9% from January through September compared with the same

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MAGNESIUM COMPOUNDS

period in 2022. This greater demand for refractories used in steelmaking, especially fused magnesia, was attributed to the increase in infrastructure construction in India.

In January 2023, an Austria-based magnesia and refractories company acquired a leading refractory producer in China, allowing it to expand production in China and the east Asia region. In May 2023, North America's largest producer of magnesium chloride acquired full ownership of a fire-retardant company with a supply agreement with the U.S. Forest Service. In June 2023, a Germany-based raw material producer opened a new subsidiary based near Hamburg, Germany, to supply magnesia and chromite to the refractory market. A Greece-based magnesia producer announced that its Turkish subsidiary would construct a new rotary kiln in 2024, doubling its current production capacity of caustic-calcined magnesia to around 50,000 tons per year. In July 2023, another U.S. magnesium chloride producer completed two additional drilling projects at their mine, maximizing brine availability and underground brine residence time thus enhancing their brine grade.

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 Australia, India, Iran, Saudi Arabia, and Slovakia were revised based on company and Government reports.

	Mine production[e]		Reserves[7]
	2022	2023	
United States	W	W	35,000
Australia	860	860	[8]280,000
Austria	810	810	49,000
Brazil	1,700	1,700	200,000
Canada	150	150	NA
China	13,000	13,000	580,000
Greece	380	380	280,000
India	100	100	66,000
Iran	270	270	10,000
Russia	960	960	2,300,000
Saudi Arabia	340	340	2,800
Slovakia	[9]512	510	1,200,000
Spain	670	670	35,000
Turkey	[9]1,820	1,800	110,000
Other countries	323	320	2,500,000
World total (rounded)	[10]21,900	[10]22,000	7,700,000

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. NA Not available. 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 magnesium oxide (MgO) content was determined to be more useful than reporting in terms of magnesium content. Calculations were made using 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]Reported.
[10]Excludes U.S. production.

MAGNESIUM METAL[1]

(Data in thousand metric tons unless otherwise specified)

Domestic Production and Use: In 2023, 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. 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 64% 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 18% of primary magnesium metal consumption; desulfurization of iron and steel, 4%; and all other uses, 14%. About 32% of secondary magnesium was consumed for structural uses, and about 68% was used in aluminum alloys.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:					
Primary	W	W	W	W	W
Secondary (new and old scrap)	102	95	103	107	100
Imports for consumption	59	61	54	89	95
Exports	10	15	10	9	4
Consumption:					
Reported, primary	57	54	51	50	55
Apparent[2]	W	W	W	W	W
Price, annual average:[3]					
U.S. spot Western, dollars per pound	2.47	2.48	3.73	7.59	5.00
European free market, dollars per metric ton	2,426	2,149	5,011	5,206	3,200
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	>50	>50

Recycling: In 2023, about 25,000 tons of secondary magnesium was recovered from old scrap and 75,000 tons was recovered from new scrap. Aluminum-base alloys accounted for about 52% of the secondary magnesium recovered, and magnesium-based castings, ingot, and other materials accounted for about 48%.

Import Sources (2019–22): Magnesium metal (99.8% purity): Turkey, 32%; Russia, 25%; Israel, 23%; Canada, 7%; and other, 13%. Magnesium alloys (magnesium content): Czechia, 23%; Taiwan, 23%; Hungary, 12%; Germany 9%; and other, 33%. Sheet, powder, and other (magnesium content): Mexico, 23%; Austria, 22%; China,[5] 17%; Taiwan, 14%; and other, 24%. Scrap: Canada, 35%; Mexico, 17%; China, 15%; India, 8%; and other, 25%. Combined total (includes magnesium content of alloys, metal, powder, scrap, sheet, and other): Canada, 18%; China,[5] 9%; Israel, 9%; Taiwan, 9%; and other, 55%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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. The shutdown of capacity was cited as the reason why the average annual U.S. spot Western price in 2022 nearly doubled from the annual average price in 2021, but in 2023 the annual average price decreased by about one-third as consumers contracted deliveries from new suppliers. Some aluminum smelters were reported to have switched from using primary magnesium to secondary magnesium alloys imported from Canada, Czechia, Hungary, the Republic of Korea, and Taiwan. Although imports of magnesium alloys decreased slightly in 2023 from those in 2022, they were more than double those in 2021 and increased by more than 200% since 2019.

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MAGNESIUM METAL

Domestic consumption of magnesium for castings used in the automotive industry decreased because of a 6-week-long labor dispute between three major automobile manufacturers and the union representing many of their employees. The trend of magnesium substituting for other materials in automobiles was expected to continue as manufacturers sought to decrease vehicle weight for increased fuel efficiency. Magnesium metal ingot imports were an estimated 39,000 tons in 2023 compared with 20,000 tons in 2022. Increased imports were attributed to the disruption of production at the sole primary magnesium producer since September 2021.

In August, the U.S. International Trade Commission completed a 5-year review of antidumping duties on magnesium imports from China. In 1995, antidumping duties were imposed on magnesium imports from China at a rate of 108.26%. The duties are to be reviewed every 5 years. The review concluded that revocation of the duties would likely lead to material injury to domestic magnesium producers; therefore, the antidumping duties were retained. Despite the duty on magnesium imports from China, some consumers in the United States were willing to pay the duty to obtain the magnesium that they needed owing to decreased domestic supply since 2021. More than 1,300 tons of unwrought magnesium metal was imported from China through the end of September 2023, and 3,900 tons was imported in the full year 2022; between 2009 and 2021, imports from China were less than 150 tons each year.

Magnesium prices in Europe generally decreased during the first half of the year compared with those in the last quarter of 2022 because demand decreased. Prices in Europe increased from a range of $3,050 to $3,150 per ton at the end of July to a range of $3,350 to $3,500 per ton at the end of September. The price increase in Europe was attributed to concerns of supply shortages after regulators in China ordered several coke facilities to shut down temporarily to address pollution concerns. Coke gas is the energy source used by many magnesium producers in China, the leading supplier of magnesium to consumers in Europe. Prices in Europe decreased to the prior range by October once producers in China were able to restart capacity. The 2023 annual average price range for magnesium in Europe was estimated to be 40% less than that in 2022.

World Primary Production and Reserves:

	Smelter production[e] 2022	Smelter production[e] 2023
United States	W	W
Brazil	22	22
China	[7]933	830
Iran	5	5
Israel	[7]22	22
Kazakhstan	27	25
Russia	21	20
Turkey	14	15
Ukraine	2	—
World total (rounded)[8]	1,050	940

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. — Zero.
[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]Reported.
[8]Excludes U.S. production.

MANGANESE

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

Domestic Production and Use: Manganese ore containing 20% or more manganese has not been produced domestically since 1970. Manganese ore was consumed mainly by six companies at seven 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]	2019	2020	2021	2022	2023[e]
Production, mine	—	—	—	—	—
Imports for consumption:					
Manganese ores and concentrates	434	367	497	566	500
Ferromanganese	332	223	329	330	300
Silicomanganese	351	269	313	420	250
Exports:					
Manganese ores and concentrates	1	1	1	1	1
Ferromanganese	5	5	9	3	2
Silicomanganese	2	2	5	3	3
Shipments from Government stockpile:[2]					
Manganese ore	—	—	2	—	NA
Ferromanganese and manganese metal, electrolytic	10	54	21	14	NA
Consumption, reported:					
Manganese ore[3]	442	378	399	357	350
Ferromanganese	336	325	335	339	340
Silicomanganese	[4]143	229	237	234	230
Consumption, apparent, manganese content[5]	748	621	717	804	690
Price, average, manganese content, cost, insurance, and freight, China, dollars per metric ton unit[6]	5.63	4.59	5.27	5.97	5.00
Stocks, producer and consumer, yearend:					
Manganese ore[3]	175	143	220	312	250
Ferromanganese	44	35	40	50	29
Silicomanganese	39	31	34	26	25
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 (2019–22): Manganese ore: Gabon, 62%; South Africa, 24%; Mexico, 13%; and other, 1%. Ferromanganese: Malaysia, 20%; Australia, 19%; South Africa, 15%; Norway, 14%; and other, 32%. Silicomanganese: Georgia, 27%; South Africa, 23%; Australia, 19%; Malaysia, 8%; and other, 23%. Manganese contained in principal manganese imports:[8] Gabon, 25%; South Africa, 21%; Australia, 10%; Georgia, 8%; and other, 36%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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	FY 2023 Potential acquisitions	FY 2023 Potential disposals	FY 2024 Potential acquisitions	FY 2024 Potential disposals
Manganese ore, metallurgical grade	—	150	—	150
Ferromanganese, high carbon	—	45	—	45
Manganese metal, electrolytic	5	—	5	—

Events, Trends, and Issues: Global production of manganese ore, on a manganese-content basis, was essentially unchanged from that in 2022. Exports of manganese ore, on a gross-weight basis, from Gabon decreased by 13% on account of a military coup, and exports from South Africa decreased by 7% because of weather-related transportation issues. A company based in Australia was developing a manganese mine in Arizona. Two manganese ore producers in Ukraine suspended operations. One of them suspended operations owing to rising operational costs, whereas the other suspended operations owing to Russian shelling that endangered operations.

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

	Mine production 2022	Mine production 2023[e]	Reserves[10]
United States	—	—	—
Australia	3,040	3,000	[11]500,000
Brazil	624	620	270,000
Burma	207	210	NA
China	743	740	280,000
Côte d'Ivoire	394	390	NA
Gabon	4,670	4,600	61,000
Georgia	166	160	NA
Ghana	844	840	13,000
India	721	720	34,000
Kazakhstan, concentrate	129	130	5,000
Malaysia	247	250	NA
Mexico	221	220	5,000
South Africa	7,300	7,200	600,000
Ukraine, concentrate	323	320	140,000
Vietnam	155	160	NA
Other countries	325	330	Small
World total (rounded)	19,800	20,000	1,900,000

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. Beginning in 2023, Government stock changes no longer available.

[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 for 2019–22 as imports – exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included. 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 for 2019–22 as imports – exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.

[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 110 million tons.

MERCURY

(Data in metric tons, mercury content, unless otherwise specified)

Domestic Production and Use: Mercury has not been produced as a principal mineral commodity in the United States since 1992. In 2023, 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 domestic production of 45 tons of mercury 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. On December 3, 2019, the U.S. Department of Energy (DOE) selected a site near Andrews, TX, to store up to 6,800 tons of mercury.

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 2023, 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:	2019	2020	2021	2022	2023[e]
Production:					
Mine (byproduct)	NA	NA	NA	NA	NA
Secondary	NA	NA	NA	NA	NA
Imports for consumption, metal (gross weight)	9	3	1	2	4
Exports, metal (gross weight)	—	—	—	—	—
Price, average unit value of imports, dollars per kilogram	23	26	29	33	6
Net import reliance[1] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: In 2023, eight facilities operated by six companies in the United States accounted for most of the secondary mercury produced and were authorized by the 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 (2019–22): Canada, 100%; and other, <1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
Mercury	2805.40.0000	1.7% ad valorem.
Amalgams	2843.90.0000	3.7% ad valorem.

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

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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] 2022	Mine production[e] 2023	Reserves[2]
United States	NA	NA	Quantitative estimates of reserves were not available. China, Kyrgyzstan, and Peru have the largest reserves.
China	1,000	1,000	
Kyrgyzstan	6	6	
Morocco	2	2	
Norway	20	20	
Peru (exports)	30	30	
Tajikistan	100	100	
World total (rounded)[3]	1,160	1,200	

World Resources:[2] 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 for 2019–22 as imports - exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.

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

[3]Excludes U.S. production.

MICA (NATURAL)

(Data in metric tons unless otherwise specified)

Domestic Production and Use: Scrap and flake mica production, excluding low-quality sericite, was estimated to be 38,000 tons valued at $3.9 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 65,000 tons of ground mica valued at about $20 million from domestic and imported scrap and flake mica. Most of the domestic production was processed into small-particle-size mica by either wet or dry grinding. Primary uses were joint compound, oil-well-drilling additives, paint, roofing, and rubber products.

A minor amount of sheet mica has been produced as incidental production from feldspar mining in North Carolina in the past several years. Data on sheet mica production were not available in 2023. 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:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Scrap and flake:					
Production:[e, 1]					
Sold or used	40,100	34,600	40,600	42,000	38,000
Ground	61,300	59,900	66,800	66,300	65,000
Imports[2]	27,300	20,400	24,100	22,600	19,000
Exports[3]	5,500	3,980	4,850	4,450	4,000
Consumption, apparent[e, 4]	61,900	50,000	59,600	60,200	53,000
Price, average, dollars per metric ton:[e]					
Scrap and flake	105	120	100	100	100
Ground:					
Dry	316	303	299	300	300
Wet	394	337	336	350	350
Net import reliance[5] as a percentage of apparent consumption	35	31	32	30	28
Sheet:					
Sold or used	W	W	NA	NA	NA
Imports[6]	3,150	2,840	3,980	5,410	4,100
Exports[7]	779	528	633	803	1,100
Consumption, apparent[e, 4]	2,370	2,310	3,350	4,610	3,000
Price, average value, muscovite and phlogopite mica, dollars per kilogram:[e]					
Block	W	W	W	W	W
Splittings	1.66	1.57	1.88	1.60	1.60
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2019–22): Scrap and flake: China, 39%; Canada, 36%; India, 10%; Finland, 4%; and other, 11%. Sheet: China, 77%; Brazil, 7%; India, 4%; Belgium, 3%; and other, 9%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
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 decreased by 10% in 2023 compared with that in 2022. Apparent consumption of scrap and flake mica decreased by 12% owing in part to lower use in oil and gas drilling and lower imports. The number of active oil- and gas-drilling rigs dropped by 20% from yearend 2022 to October 31, 2023. Apparent consumption of sheet mica was estimated to have been 35% lower than that in 2022, as imports were 24% lower than those in 2022. 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 and some from Brazil.

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

	Scrap and flake			Sheet		
	Mine production[e]		Reserves[8]	Mine production[e]		Reserves[8]
	2022	2023		2022	2023	
United States	42,000	38,000	Large	NA	NA	Very small
Canada	15,000	15,000	Large	NA	NA	NA
China	80,000	85,000	1,100,000	NA	NA	75,000
Finland	[9]58,200	60,000	Large	NA	NA	NA
France	15,000	10,000	Large	NA	NA	NA
India	14,000	14,000	Large	1,000	1,000	110,000
Korea, Republic of	[9]10,200	12,000	11,000,000	—	—	NA
Madagascar	35,000	50,000	Large	—	—	NA
Turkey	[9]6,070	4,000	620,000	—	—	NA
Other countries	42,500	39,000	Large	200	200	Moderate
World total (rounded)	318,000	330,000	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, polyvinyl chloride, styrene, 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, molybdenum content, unless otherwise specified)

Domestic Production and Use: Total estimated U.S. mine production of molybdenum concentrate decreased slightly to 34,000 tons of molybdenum content in 2023 compared with 34,600 tons in 2022. Molybdenum concentrate production at primary molybdenum mines continued at two U.S. operations in Colorado, and molybdenum concentrate production from mines where molybdenum was a byproduct continued at six U.S. operations (four in Arizona and one each in Montana and Utah). Three roasting plants converted molybdenum concentrate to molybdic oxide, from which intermediate products, such as ferromolybdenum, metal powder, and various chemicals, were produced. Molybdenum is a refractory metallic element used principally as an alloying agent in cast iron, steel, and superalloys and is also used in numerous chemical applications, including catalysts, lubricants, and pigments.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production, mine	43,600	51,100	41,100	34,600	34,000
Imports for consumption	34,200	24,700	30,200	28,800	31,000
Exports	67,200	62,600	59,900	51,100	51,000
Consumption:					
Reported[1]	16,400	16,000	16,100	15,900	16,000
Apparent[2]	10,400	13,100	11,200	12,400	14,000
Price, average value, dollars per kilogram[3]	26.50	19.90	35.30	41.35	55.60
Stocks, consumer materials	1,980	2,010	2,040	2,050	1,900
Employment, mine and plant, number	950	950	940	940	950
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Molybdenum is recycled as a component of catalysts, ferrous scrap, and superalloy scrap. Ferrous scrap consists of revert, new, and old scrap. Revert scrap refers to remnants manufactured in the steelmaking process. New scrap is generated by steel mill customers and recycled by scrap collectors and processors. Old scrap is largely molybdenum-bearing alloys recycled after serving their useful life. The amount of molybdenum recycled as part of new and old steel and other scrap may be as much as 30% of the apparent supply of molybdenum. There are no processes for the separate recovery and refining of secondary molybdenum from its alloys, but the molybdenum content of the recycled alloys is significant and is reused.

Import Sources (2019–22): Ferromolybdenum: Chile, 72%; Republic of Korea, 24%; and other, 4%. Molybdenum ores and concentrates: Peru, 60%; Mexico, 18%; Chile, 13%; Canada, 8%; and other, 1%. Total: Peru, 34%; Chile, 32%; Mexico, 11%; Republic of Korea, 7%; and other, 16%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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.

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

Government Stockpile: None.

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MOLYBDENUM

Events, Trends, and Issues: In 2023, the estimated average U.S. molybdic oxide price increased by 34% compared with that in 2022. Estimated U.S. imports for consumption increased by 8% compared with those in 2022. Estimated U.S. exports were unchanged from those in 2022. Estimated apparent consumption in 2023 increased by 14% compared with that in 2022. The decrease in North American molybdenum production owing to declining ore grades at copper-molybdenum mines as well as record-high molybdenum prices has caused some idled molybdenum mining companies to consider reopening. In 2023, a Canadian company completed a prefeasibility study to consider reopening its idled molybdenum mine in Idaho.

Estimated global molybdenum production in 2023 increased by 3% compared with that in 2022. In descending order of production, China, Chile, Peru, the United States, and Mexico provided 93% of total global production. Molybdenum producers in China continued to face difficulties because of the tightening of environmental regulations making mining permits more difficult to obtain. High molybdenum prices caused some consumers, especially in China, to purchase less material to avoid higher costs. However, molybdenum was expected to continue to have strong demand in global power generation and infrastructure projects as countries continue to prioritize clean energy to address climate change.

World Mine Production and Reserves: Reserves data for China, Peru, Russia, Turkey, and the United States were revised based on Government and industry reports.

	Mine production		Reserves[5]
	2022	2023[e]	(thousand metric tons)
United States	34,600	34,000	3,500
Argentina	—	—	100
Armenia	[e]7,800	7,800	150
Australia	277	500	[6]690
Canada	952	1,000	72
Chile	45,600	46,000	1,400
China	[e]106,000	110,000	5,800
Iran	[e]3,700	3,700	43
Korea, North	[e]700	700	NA
Korea, Republic of	367	400	8
Mexico	15,500	15,000	130
Mongolia	[e]3,000	3,100	NA
Peru	31,600	37,000	1,500
Russia	[e]1,700	1,700	1,100
Turkey	—	—	52
Uzbekistan	[e]1,700	1,700	21
World total (rounded)	253,000	260,000	15,000

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.
[6]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 250,000 tons.

NICKEL

(Data in metric tons, nickel content, unless otherwise specified)

Domestic Production and Use: In 2023, the underground Eagle Mine in Michigan produced approximately 17,000 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. 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:	2019	2020	2021	2022	2023[e]
Production:					
Mine	13,500	16,700	18,400	17,500	17,000
Refinery, byproduct	W	W	W	W	W
Imports:					
Ores and concentrates	4	95	18	([1])	1
Primary	119,000	105,000	108,000	127,000	120,000
Secondary	37,700	31,800	34,400	37,300	39,000
Exports:					
Ores and concentrates	14,300	13,400	14,900	15,200	10,000
Primary	12,800	11,300	11,600	11,100	11,000
Secondary	47,800	46,300	29,200	44,300	58,000
Consumption:					
Reported, primary[e]	120,000	97,000	92,000	100,000	100,000
Reported, secondary, purchased scrap	111,000	[e]110,000	[e]100,000	[e]97,000	80,000
Apparent, primary[2]	106,000	[e]94,000	[e]97,000	[e]110,000	110,000
Apparent, total[3]	217,000	[e]210,000	[e]200,000	[e]210,000	190,000
Price, average annual, London Metal Exchange (LME), cash:					
Dollars per metric ton	13,903	13,772	18,476	25,815	22,000
Dollars per pound	6.31	6.25	8.38	11.71	9.80
Stocks, yearend:					
Consumer	13,400	[e]14,000	[e]14,000	[e]29,000	29,000
LME U.S. warehouses	1,974	1,734	1,296	6	1,500
Net import reliance[4, 5] as a percentage of total apparent consumption	49	[e]46	[e]49	[e]54	[e]57

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 2023, recycled nickel in all forms accounted for approximately 57% of apparent consumption.

Import Sources (2019–22): Primary nickel: Canada, 46%; Norway, 9%; Finland, 7%; Russia, 7%; and other, 31%. Nickel-containing scrap, including nickel content of stainless-steel scrap: Canada, 40%; Mexico, 26%; United Kingdom, 9%; Russia, 5%, and other, 20%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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:[6] The U.S. Department of Energy is holding approximately 9,700 tons of radiologically contaminated nickel at Paducah, KY.

Events, Trends, and Issues: In 2023, the annual average LME nickel cash price was estimated to have decreased by 15% compared with that in 2022. The leading cause was an increasing surplus of nickel from Indonesia in the form of intermediate matte and mixed nickel-cobalt hydroxide (also called MHP by industry) that are used to produce battery-grade nickel sulfate, primarily in China, coupled with decreasing demand for stainless steel. The surplus first emerged in 2022, but the excess material was primarily in the form of Class II nickel pig iron, which is used

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NICKEL

predominately in the production of stainless steel in China and Indonesia. Any negative effect on price was counterbalanced by increased demand for nickel sulfate in lithium-ion battery precursors and concerns about continued availability of Class I metal from Russia after the conflict with Ukraine. By early 2023, however, the surplus had cascaded into an excess of nickel sulfate causing numerous companies in China to convert nickel sulfate to Class I metal, which was expected to add more than 150,000 tons of Class I metal capacity by yearend 2024.

In January, the LME released a report from an independent auditor that reviewed events that led to a 270% increase in nickel price and subsequent suspension of nickel trading on the exchange in March 2022. Contributing factors were found to include the existence of large, exposed, short positions; lack of transparency in over-the-counter trades, which were not subject to typical risk controls; a lack of liquidity and diversity of participants willing to take opposite positions; insufficient price volatility controls; and the use of LME nickel prices to hedge sales of Class II nickel, which is not approved for delivery on the exchange. In response to this report, the LME developed an action plan to reduce the likelihood of recurrent events that included mechanisms such as permanent daily price limits, mandatory reporting of over-the-counter positions, enhanced monitoring of member liquidity, off-warrant stock reporting, and releasing guidance for more efficiently listing new Class I metal brands.

In September, the U.S. Department of Defense awarded $20.6 million for further exploration and mineral resource definition at a nickel-copper-cobalt project in Minnesota under the Defense Production Act Title III authorities using funds from the Additional Ukraine Supplemental Appropriations Act.

World Mine Production and Reserves: Reserves for Australia, China, Indonesia, Russia, the United States, and "Other countries" were revised based on company and Government reports.

	Mine production		Reserves[7]
	2022	2023[e]	
United States	17,500	17,000	[8]340,000
Australia	155,000	160,000	[9]24,000,000
Brazil	88,500	89,000	16,000,000
Canada	143,000	180,000	2,200,000
China	[e]114,000	110,000	4,200,000
Indonesia	1,580,000	1,800,000	55,000,000
New Caledonia[10]	200,000	230,000	7,100,000
Philippines	[e]345,000	400,000	4,800,000
Russia	222,000	200,000	8,300,000
Other countries	404,000	380,000	>9,100,000
World total (rounded)	3,270,000	3,600,000	>130,000,000

World Resources:[7] Globally, nickel resources have been estimated to contain more than 350 million tons of nickel, with 54% in laterites and 35% in magmatic sulfide deposits. Hydrothermal systems such as iron-nickel alloy, sedimentary-hosted polymetallic, and volcanogenic massive sulfide deposits, as well as seafloor manganese crusts and nodules contain 10%, and miscellaneous resources such as tailings, 1%.

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. W Withheld to avoid disclosing company proprietary data.
[1]Less than ½ unit.
[2]Defined as primary imports – primary exports ± adjustments for industry stock changes, excluding secondary consumer stocks.
[3]Defined as apparent primary consumption + reported secondary consumption.
[4]Defined as imports – exports ± adjustments for consumer stock changes.
[5]Includes the nickel content of stainless steel and alloy scrap. Excluding scrap, net import reliance would be nearly 100%.
[6]See Appendix B for definitions.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]Includes reserve data for three projects. An additional three domestic projects have defined resources but have not yet defined reserves.
[9]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 8.6 million tons.
[10]Overseas territory of France.

NIOBIUM (COLUMBIUM)

(Data in metric tons, niobium content, unless otherwise specified)

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 57%, and superalloys, about 43%. The estimated value of niobium consumption was $430 million, as measured by the value of imports.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production, mine	—	—	—	—	—
Imports for consumption[1]	10,100	7,170	8,230	9,110	9,400
Exports[1]	655	787	992	687	980
Shipments from Government stockpile[2]	−84	−88	−1	—	NA
Consumption:[e]					
Apparent[3]	9,330	6,300	7,240	8,420	8,400
Reported[4]	6,680	6,040	6,160	3,540	3,000
Price, average unit value, ferroniobium, dollars per kilogram[5]	23	21	21	25	25
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 (2019–22): Niobium and tantalum ores and concentrates: Australia, 54%; Congo (Kinshasa), 11%; Rwanda, 9%; Mozambique, 7%; and other, 19%. Niobium oxide: Brazil, 76%; Thailand, 10%; Estonia, 5%; India, 3%; and other, 6%. Ferroniobium and niobium metal: Brazil, 66%; Canada, 28%; Russia, 3%, Germany, 1%, and other, 2%. Total imports: Brazil, 66%; Canada, 26%; and other, 8%. Of U.S. niobium material imports (by niobium content), 72% was ferroniobium, 18% was niobium metal, 9% was niobium oxide, and 1% was niobium ores and concentrates.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023		FY 2024	
Material	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Ferroniobium	—	—	136	—

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NIOBIUM (COLUMBIUM)

Events, Trends, and Issues: In 2023, U.S. niobium apparent consumption (measured in niobium content) was estimated to be 8,400 tons, a slight decrease from that in 2022. One domestic company developing its Elk Creek project in Nebraska continued to wait for financing in 2023. The project, which would be the only niobium mine and primary niobium-processing facility in the United States, has secured all necessary construction permits and contracted 75% of its planned ferroniobium production for the first 10 years of operation. According to the results of a 2022 feasibility study, the facility was projected to produce 7,350 tons per year of ferroniobium over a 38-year mine life.

Brazil continued to be the world's leading niobium producer, accounting for approximately 90% of global production, followed by Canada with about 8%. According to international trade statistics under the Harmonized System code 7202.93 (ferroniobium), Brazil's total exports were 50,566 tons from January through August 2023, 28% less than during the same period in 2022. Most of Brazil's exports were sent to China, followed by the Netherlands and Singapore.

In 2023, a leading niobium producer in Brazil reported that its most recent $60 million expansion project is set to initiate operations in 2024. The new facility is expected to broaden its niobium oxide production line, increasing production capacity by 3,000 tons per year of niobium oxide to target the battery market.

In 2023, another leading niobium producer in Brazil reported the approval for infrastructure construction focused on piling new waste ores to maintain mining operations. Preliminary operational licenses were obtained from Goias State environmental authorities, with final approvals expected in October 2023. Plans were also made for the relocation of niobium slag and facilities in the southern part of the phosphate mine.

World Mine Production and Reserves:

	Mine production		Reserves[8]
	2022	2023[e]	
United States	—	—	210,000
Brazil	75,600	75,000	16,000,000
Canada	6,700	7,000	1,600,000
Congo (Kinshasa)	710	540	NA
Russia	381	440	NA
Rwanda	199	190	NA
Other countries	127	150	NA
World total (rounded)	83,700	83,000	>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. Niobium content was estimated assuming the following: 28% niobium oxide (Nb_2O_5) content in niobium ores and concentrates; 16% Nb_2O_5 content in tantalum ores and concentrates and synthetic concentrates; 100% niobium content in unwrought niobium metal (powders and other); and 65% niobium content in ferroniobium. Nb_2O_5 is 69.904% niobium by weight.

[2]Defined for 2019–22 as change in total inventory from prior yearend inventory. If negative, increase in inventory. Beginning in 2023, Government stock changes no longer included.

[3]Defined for 2019–22 as imports – exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.

[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, nitrogen content, unless otherwise specified)

Domestic Production and Use: Ammonia was produced by 17 companies at 36 plants in 17 States in the United States during 2023; 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 2023, the U.S. plants actively producing ammonia operated at about 90% 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:	2019	2020	2021	2022	2023[e]
Production[1]	13,500	14,000	12,700	13,800	14,000
Imports for consumption	2,020	1,990	2,080	1,930	1,800
Exports	338	369	231	720	1,000
Consumption, apparent[2]	15,200	15,700	14,600	14,800	15,000
Stocks, producer, yearend	420	310	270	440	420
Price, average, free on board Gulf Coast,[3] dollars per short ton	232	213	578	1,070	480
Employment, plant, number[e]	1,600	1,600	1,600	1,600	1,600
Net import reliance[4] as a percentage of apparent consumption	11	11	13	7	6

Recycling: None.

Import Sources (2019–22): Trinidad and Tobago, 54%; Canada, 44%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 $1.70 and $3.80 per million British thermal units for most of the year, with an average of about $2.60 per million British thermal units. Natural gas prices in 2023 were lower than those in 2022—a result of above-average storage levels of natural gas and warmer-than-average winter weather. The Energy Information Administration, U.S. Department of Energy, projected that Henry Hub natural gas spot prices would average around $3.25 per million British thermal units in 2024.

The weekly average Gulf Coast ammonia price was $885 per short ton at the beginning of 2023, decreased to $259 per short ton in late June, and increased to $625 per short ton in late October. The average ammonia price for 2023 was estimated to be about $480 per short ton.

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NITROGEN (FIXED)—AMMONIA

A long period of generally 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 U.S. ammonia industry in the next 5 years is expected to increase capacity by about 2%, which includes decarbonized ammonia projects.

Global ammonia capacity is expected to increase by a total of 6% during the next 4 years. Capacity additions were expected in places with low-cost natural gas such as in central and eastern Asia, Eastern Europe, and North America. As part of the capacity increase, decarbonized ammonia plants have been proposed in several countries but mainly in North America. Consumption of ammonia for fertilizer is expected to increase by about 1% per year, depending on availability and cost, with the largest increases expected in Latin America and south Asia.

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 38.1 million hectares of corn in crop-year 2023 (July 1, 2022, through June 30, 2023), which was 6% more than the area planted in crop-year 2022. Corn acreage in crop-year 2024 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]
	2022	2023[e]	
United States	13,800	14,000	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	1,500	1,500	
Canada	3,410	3,400	
China	43,000	43,000	
Egypt	4,100	4,000	
Germany	1,460	1,500	
India	13,700	14,000	
Indonesia	6,000	6,000	
Iran	4,400	4,400	
Malaysia	1,400	1,400	
Netherlands	2,000	2,000	
Nigeria	1,600	1,600	
Oman	1,720	1,700	
Pakistan	3,400	3,400	
Poland	1,820	1,800	
Qatar	3,110	3,100	
Russia	14,000	14,000	
Saudi Arabia	4,000	4,000	
Trinidad and Tobago	3,710	3,700	
Uzbekistan	1,200	1,200	
Vietnam	1,180	1,200	
Other countries	13,700	14,000	
World total (rounded)	145,000	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 specified)

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 $16 million in 2023. Peat was harvested and processed by 26 companies in 10 of the conterminous United States. Two companies were idle in 2023. The top five producing States were Florida, Illinois, Maine, Michigan, and Minnesota, which accounted for 98% of the peat sold. Reed-sedge peat accounted for approximately 87% of the total volume produced, followed by sphagnum moss with an estimated 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:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production	366	354	324	[e]350	360
Sales by producers	420	388	386	[e]510	510
Imports for consumption	1,160	1,390	1,630	1,440	1,100
Exports	46	46	37	43	46
Consumption, apparent[1]	1,400	1,690	1,970	1,750	1,400
Price, average unit value, f.o.b. mine, dollars per metric ton	25.77	26.07	38.52	27.49	31.70
Stocks, producer, yearend	280	288	235	235	240
Employment, mine and plant, number[e]	520	510	510	510	500
Net import reliance[2] as a percentage of apparent consumption	74	79	84	80	74

Recycling: None.

Import Sources (2019–22): Canada, 96%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
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. Imports in 2023 were estimated to have decreased to 1.1 million tons from 1.4 million tons in 2022, and exports were estimated to have increased by 7% to an estimated 46,000 tons from 43,000 tons in 2022. In 2023, peat stocks were estimated to have increased to 240,000 tons from 235,000 tons in 2022. The world's leading peat producers in 2023 were estimated to be, in descending order of production, Finland, Germany, Sweden, Canada, Latvia, and Belarus.

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. In 2023, the National Oceanic and Atmospheric Administration (NOAA) distributed $35 million from the Bipartisan Infrastructure Law and the Inflation Reduction Act to fund conservation and restoration projects. NOAA announced the awarded projects in April, one of which was a peatland conservation project in Alaska that planned to purchase 55 acres of peatland and recharge its water levels. Doing so was expected to also alleviate coastal erosion and safeguard the water quality of the area.

Other projects in the United States were done in partnership among conservation institutions and local and Federal governments to restore peatlands in Minnesota and North Carolina. In Minnesota, research on how to restore peatlands was done in partnership with a conservation institute, the U.S. Department of Agriculture's Forest Service, the Minnesota Department of Natural Resources, the Minnesota Board of Water and Soil Resources, two local universities, and a local nonprofit organization. In North Carolina, work was done with various Federal and State agencies and institutions to install water management infrastructure, including water control structures, to restore degraded peatlands.

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 the first half of 2023, only about 2% of Finland's energy consumption was supplied by peat. Approximately 42% of Finland's energy supply was generated using renewable energy sources, whereas 26% was produced by nuclear energy.

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PEAT

Ireland announced the end of its peat harvesting in 2021, as the country transitioned to alternative fuel sources, but peat briquet production was expected to continue until 2024. In 2023, the country released a 30-year climate plan that aims to phase out coal and peat-fired electricity generation. Instead, renewable energy sources were expected to generate approximately 80% of its electricity needs by 2030.

In March 2023, the United Kingdom announced a delay on the ban of peat-based growing media sales to amateur gardeners that had been expected to start by 2024. Owing to concerns from the peat sector, the ban will be delayed until 2026, with some exemptions delayed until 2030 to prepare for the phaseout.

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]
	2022	**2023[e]**	
United States	[e]350	360	150,000
Belarus	[e]2,300	2,300	2,600,000
Canada	2,390	2,400	720,000
Estonia	1,130	1,100	570,000
Finland	5,870	5,800	6,000,000
Germany	[e]2,600	2,600	([4])
Latvia	2,440	2,400	150,000
Lithuania	473	470	210,000
Poland	[e]1,100	1,100	([4])
Russia	[e]1,400	1,400	1,000,000
Sweden	2,560	2,500	([4])
Ukraine	440	440	([4])
Other countries[e]	580	600	1,400,000
World total (rounded)	23,600	23,000	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.
[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 specified)

Domestic Production and Use: In 2023, the quantity of domestic processed crude perlite sold and used was estimated to be 450,000 tons with a value of $30 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 610,000 tons. Processed crude perlite was expanded at 51 plants in 27 States. The applications for expanded perlite were building construction products, 47%; horticultural aggregate, 16%; fillers, 15%; filter aids, 14%; and other, 8%. Other applications included specialty insulation and miscellaneous uses.

Salient Statistics—United States:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Mine production, crude ore	629	853	879	672	650
Sold and used, processed crude perlite	397	501	491	458	450
Imports for consumption[1]	180	160	170	240	170
Exports[1]	19	25	27	22	15
Consumption, apparent[2]	560	640	630	680	610
Price, average value, free on board mine, dollars per metric ton	64	61	64	68	68
Employment, mine and mill, number	140	140	150	150	150
Net import reliance[3] as a percentage of apparent consumption	29	21	23	32	26

Recycling: Not available.

Import Sources (2019–22): Greece, 92%; China, 5%; Mexico, 2%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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. Construction applications for expanded perlite are numerous because it is fire resistant, an excellent insulator, and lightweight. 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. Perlite has replaced vermiculite in some horticulture products owing to producer obstacles in acquiring vermiculite. Cosmetics, environmental remediation, and personal care products have become increasing markets for perlite.

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PERLITE

The amount of processed perlite sold or used from U.S. mines dropped to its lowest level since 2019. Imports also decreased from those in 2022, as apparent consumption dropped to about 610,000 tons. The value of total construction put in place in the United States increased by about 4% during the first 8 months of 2023 compared with that of the same period in 2022, indicating a stable consumption of perlite for construction products despite a decrease in apparent consumption for 2023.

Based on estimated world production for 2023, the world's leading producers were, in descending order of production, China, Turkey, Greece, and the United States, accounting for about 30%, 28%, 22%, and 9%, 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, Greece, Hungary, Iran, Slovakia, and Turkey were revised based on company and Government reports.

	Production		Reserves[4]
	2022	2023[e]	
United States	[5]458	[5]450	50,000
Argentina[e]	18	20	NA
Armenia[e]	170	180	NA
China[e]	1,500	1,500	32,000
Georgia	20	20	NA
Greece[e]	1,100	1,100	180,000
Hungary[e]	77	80	NA
Iran[e]	77	80	15,000
Mexico[e]	24	20	NA
New Zealand[e]	18	20	NA
Philippines	25	20	NA
Slovakia[e]	35	40	30,000
Turkey[e]	1,400	1,400	NA
Other countries[e]	14	10	NA
World total (rounded)	4,940	4,900	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, marketable phosphate rock, unless otherwise specified)

Domestic Production and Use: In 2023, phosphate rock ore was mined by five companies at nine mines in four States and processed into an estimated 20 million tons of marketable product, valued at $2 billion, free on board (f.o.b.) mine. Phosphate rock was produced in Florida, Idaho, North Carolina, 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), monoammonium phosphate (MAP) fertilizer, merchant-grade phosphoric acid, and other phosphate fertilizer products. 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:	2019	2020	2021	2022	2023[e]
Production, marketable	23,300	23,500	21,600	[e]19,800	20,000
Sold or used by producers	23,400	22,600	21,900	[e]19,800	21,000
Imports for consumption	2,140	2,520	2,460	2,500	2,600
Consumption, apparent[1]	25,500	25,100	24,400	[e]22,300	24,000
Price, average value, f.o.b. mine,[2] dollars per metric ton	67.90	75.50	82.40	[e]98	100
Stocks, producer, yearend	9,940	11,000	10,700	[e]10,600	10,000
Employment, mine and beneficiation plant, number[e]	1,900	1,800	2,000	1,900	1,900
Net import reliance[3] as a percentage of apparent consumption	11	5	10	12	14

Recycling: None.

Import Sources (2019–22): Peru, 98%; and Morocco, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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, sales, imports, and consumption of phosphate rock all were estimated to have increased in 2023, owing to increased phosphoric acid and fertilizer production. Favorable weather conditions in the planting seasons helped to boost fertilizer consumption and reduce phosphate fertilizer stocks that had accumulated in 2022.

In 2023, a U.S. Federal judge canceled permits issued by the Bureau of Land Management (BLM) for construction of a new phosphate rock mine in Caribou County, ID. The judge ruled that the BLM failed to analyze the effects of the mine and associated infrastructure on the habitat of the greater sage grouse. The mine was intended to be a replacement for an existing mine and was planned to start production within the next decade. The two other mining companies in Idaho were not affected by the ruling and remained on schedule with development of new mines to replace their existing mines.

Global production of phosphate rock was estimated to have been lower in 2023 than that in 2022. World consumption of P_2O_5 contained in fertilizers was estimated to have been 45.7 million tons in 2023 compared with 43.8 million tons in 2022. World consumption of P_2O_5 in fertilizers was projected to increase to 50 million tons by 2027. The leading regions for growth were expected to be Asia and South America.

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PHOSPHATE ROCK

Global phosphate production capacity, in terms of P_2O_5 content, was projected to increase to 69.1 million tons by 2027 compared with 63.6 million tons in 2023. Capacity expansions to phosphate rock production that were expected to be completed by 2026 were ongoing in Brazil, Kazakhstan, Mexico, Morocco, and Russia. Significant new mining projects that were planned to be completed after 2027 were under development in Australia, Canada, Congo (Brazzaville), Guinea-Bissau, and Senegal. The new mines in Australia and Canada were planned to be primarily used to supply the manufacturing of lithium-iron-phosphate battery cathode active material.

World Mine Production and Reserves: Reserves for China, India, Russia, and Turkey were revised based on Government reports. Reserves for South Africa were revised based on company reports.

	Mine production		Reserves[4]
	2022	2023[e]	
United States	[e]19,800	20,000	1,000,000
Algeria	[e]1,800	1,800	2,200,000
Australia	[e]2,500	2,500	[5]1,100,000
Brazil	[e]6,200	5,300	1,600,000
China[6]	[e]93,000	90,000	3,800,000
Egypt	[e]5,000	4,800	2,800,000
Finland	923	950	1,000,000
India	[e]1,740	1,500	31,000
Israel	2,170	2,500	60,000
Jordan	11,300	12,000	1,000,000
Kazakhstan	[e]1,500	2,000	260,000
Mexico	442	500	30,000
Morocco	39,000	35,000	50,000,000
Peru	4,200	4,200	210,000
Russia	[e]14,000	14,000	2,400,000
Saudi Arabia	[e]9,000	8,500	1,400,000
Senegal	[e]2,600	2,500	50,000
South Africa	1,990	1,600	1,500,000
Syria	[e]1,100	800	250,000
Togo	[e]1,500	1,500	30,000
Tunisia	3,560	3,600	2,500,000
Turkey	[e]900	800	71,000
Uzbekistan	[e]900	900	100,000
Vietnam	[e]2,000	2,000	30,000
Other countries	750	800	800,000
World total (rounded)	228,000	220,000	74,000,000

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 120 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, platinum-group-metal (PGM) content, unless otherwise specified]

Domestic Production and Use: One company in Montana produced PGMs with an estimated value of about $510 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:	2019	2020	2021	2022	2023[e]
Mine production:[1]					
Palladium	14,300	14,600	13,700	10,100	9,800
Platinum	4,150	4,200	4,020	3,000	2,900
Imports for consumption:[2]					
Palladium	84,300	76,400	72,600	65,200	64,000
Platinum	42,300	64,900	67,900	64,200	70,000
PGM waste and scrap	35,200	185,000	160,000	41,500	32,000
Iridium	875	1,620	2,310	1,610	1,900
Osmium	([3])	1	1	1	([3])
Rhodium	15,000	20,700	16,500	13,200	11,000
Ruthenium	11,200	13,900	18,000	13,300	11,000
Exports:[4]					
Palladium	55,500	48,600	43,900	42,200	34,000
Platinum	17,400	28,900	29,400	23,100	12,000
PGM waste and scrap	20,800	33,200	37,800	35,200	13,000
Rhodium	1,210	1,480	1,350	677	180
Other PGMs	1,330	1,440	2,180	906	620
Consumption, apparent:[5, 6]					
Palladium	85,100	82,300	82,400	74,100	82,000
Platinum	37,000	47,300	51,500	53,100	70,000
Price, dollars per troy ounce:[7]					
Palladium	1,544.31	2,205.27	2,419.18	2,133.81	1,500
Platinum	866.94	886.02	1,094.31	966.54	1,000
Iridium	1,485.80	1,633.51	5,158.40	4,581.93	4,600
Rhodium	3,918.78	11,205.06	20,254.10	15,585.00	7,700
Ruthenium	262.59	271.83	576.12	577.02	470
Employment, mine, number	1,379	1,475	1,598	1,555	1,500
Net import reliance[6, 8] as a percentage of apparent consumption:					
Palladium	34	34	35	31	37
Platinum	67	76	75	77	83

Recycling: About 120,000 kilograms of palladium and platinum were recovered globally from new and old scrap in 2023, including about 42,000 kilograms of palladium and 9,000 kilograms of platinum recovered from automobile catalytic converters in the United States.

Import Sources (2019–22): Palladium: Russia, 32%; South Africa, 31%; Italy, 8%; Canada, 7%; and other, 22%. Platinum: South Africa, 33%; Switzerland, 15%; Germany, 14%; Belgium, 9%; and other, 29%.

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]

	FY 2023		FY 2024	
Material	**Potential acquisitions**	**Potential disposals**	**Potential acquisitions**	**Potential disposals**
Iridium	—	15	—	15
Platinum	—	261	—	261

Events, Trends, and Issues: Production at a domestic mine continued but was constrained owing to an incident that occurred in March 2023 and damaged equipment in a vertical shaft. Production of PGMs in South Africa, the world's leading producer of PGM-containing mined material, decreased compared with that in 2022 owing to disruptions to the supply of electricity and multiple issues related to rail transport. Declining prices also contributed to decreased production. Production in Russia, the world's leading producer of palladium, increased owing to higher metal grades and ore recovery as well as increased processing of inventory. Estimated domestic automobile production increased by 10%, which could increase the demand for palladium, platinum, and rhodium used in catalytic converters. Demand for iridium, platinum, rhodium, and ruthenium in the chemical and electrochemical industries also increased.

The estimated annual average price for platinum in 2023 increased by 3%, and that for iridium was unchanged compared with the average prices in 2022. The estimated annual average price for other PGMs in 2023 decreased—by 51% for rhodium, by 30% for palladium, and by 19% for ruthenium—compared with annual average prices in 2022. Price decreases were attributed to oversupply and decreased demand.

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

	Mine production				PGM reserves[10]
	Palladium		Platinum		
	2022	2023[e]	2022	2023[e]	
United States	10,100	9,800	3,000	2,900	820,000
Canada	16,100	16,000	5,400	5,500	310,000
Russia[e]	87,000	92,000	20,000	23,000	5,500,000
South Africa	73,100	71,000	124,000	120,000	63,000,000
Zimbabwe	14,300	15,000	17,000	19,000	1,200,000
Other countries	2,700	2,700	4,580	4,600	NA
World total (rounded)	203,000	210,000	174,000	180,000	71,000,000

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 used as a substitute 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, and 7118.90.0020 (2019–23); 7112.92.0000 (2019–21); and 7112.92.0100 (2022–23).

[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, and 7110.49.0000 (2019–23); 7112.92.0000 (2019–21); and 7112.92.0100 (2022–23).

[5]Defined as primary production + secondary production + imports – exports.

[6]Excludes imports and (or) exports of waste and scrap.

[7]Engelhard unfabricated metal average annual prices. Source: S&P Global Platts Metals Week.

[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, potassium oxide (K_2O) equivalent, unless otherwise specified]

Domestic Production and Use: In 2023, the estimated sales value of marketable potash, free on board (f.o.b.) mine, was $570 million, which was 20% lower than that in 2022. 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:	2019	2020	2021	2022	2023[e]
Production, marketable[1]	510	460	480	430	400
Sales by producers, marketable[1]	480	500	490	400	470
Imports for consumption	5,150	5,370	6,480	4,940	5,000
Exports	145	147	112	267	160
Consumption, apparent[1, 2]	5,500	5,700	6,900	5,100	5,300
Price, average, f.o.b. mine, dollars per metric ton of K_2O equivalent:					
All products[3]	820	850	1,120	1,790	1,210
MOP	480	450	650	980	640
Employment, mine and mill, number	900	900	900	900	900
Net import reliance[4] as a percentage of apparent consumption	91	92	93	92	91

Recycling: None.

Import Sources (2019–22): Canada, 77%; Russia, 11%; Belarus, 6%; and other, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
Potassium nitrate	2834.21.0000	Free.
Potassium chloride	3104.20.0000	Free.
Potassium chloride, less than or equal to 62% K_2O	3104.20.0010	Free.
Potassium chloride, greater than 62% K_2O	3104.20.0050	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 2023, domestic production of potash was lower than that in 2022, owing to lower MOP and SOPM production. Consumption of potash was estimated to have increased over that in 2022, as sales increased owing to lower potash prices and good weather conditions in the planting season compared with those in 2022.

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POTASH

World production was lower in 2023 owing to producers drawing down potash inventories that had increased in 2022, after supply uncertainty from economic sanctions on Belarus and Russia caused potash prices to rise in the first half of 2022. Prices began to fall in the second half of 2022 as stocks increased, and this trend carried into 2023.

Production in Canada was lower in part owing to a dock workers strike in July 2023 that curtailed shipments of potash from the port of Vancouver, British Columbia. This led to temporary closures of some mines in Canada. Production resumed at those mines after the strike was settled in August. Production and exports from Belarus were lower than those in 2022. Belarus shifted to exporting potash by rail to China and from ports in Russia, but its exports remained well below the levels in prior to 2022 when it had been one of the leading exporters. World consumption of potash in fertilizers was estimated to have increased to 37.1 million metric tons in 2023 from 35.7 million tons in 2022. Asia and South America remained the leading regions for potash consumption.

World annual potash production capacity was projected to increase to about 67.6 million tons of K_2O by 2026 from 64.3 million tons of K_2O in 2023. Most of the increase would be MOP from new mines and expansion projects in Laos and Russia. New MOP mines in Belarus, Brazil, Canada, Ethiopia, Morocco, Spain, and the United States were planned to begin operation past 2026.

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

	Mine production		Reserves[5]	
	2022	2023[e]	Recoverable ore	K_2O equivalent
United States[1]	430	400	970,000	220,000
Belarus	[e]4,000	3,800	3,300,000	750,000
Brazil	[e]200	200	10,000	2,300
Canada	14,600	13,000	4,500,000	1,100,000
Chile	[e]600	600	NA	100,000
China	[e]6,000	6,000	NA	180,000
Germany	[e]2,700	2,600	NA	150,000
Israel	2,450	2,400	NA	[6]Large
Jordan	1,640	1,800	NA	[6]Large
Laos	[e]700	1,400	1,000,000	75,000
Russia	[e]6,800	6,500	NA	650,000
Spain	[e]420	250	NA	68,000
Other countries	400	400	1,500,000	300,000
World total (rounded)	40,900	39,000	>11,000,000	>3,600,000

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 billion 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 specified)

Domestic Production and Use: In 2023, 10 operations in five States produced pumice and pumicite. Estimated production[1] was 310,000 tons with an estimated processed value of about $21 million, free on board (f.o.b.) plant. That represented an increase in both quantity and value from the 2022 reported production of 295,000 tons valued at $19.2 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:	2019	2020	2021	2022	2023[e]
Production, mine[1]	565	578	504	295	310
Imports for consumption	136	90	87	102	81
Exports	11	8	11	14	11
Consumption, apparent[2]	690	660	580	383	380
Price, average unit value, f.o.b. mine or mill, dollars per metric ton	28	31	46	65	68
Employment, mine and mill, number	140	140	140	140	140
Net import reliance[3] as a percentage of apparent consumption	18	12	13	23	18

Recycling: Little to no known recycling.

Import Sources (2019–22): Greece, 90%; Iceland, 7%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023 was estimated to be 5% more than that in 2022. Imports and exports were estimated to have decreased compared with those in 2022. An estimated 75% of all imported pumice originated from Greece in 2023 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 2023 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 18 million tons (rounded) in 2023, which was slightly less than that in 2022. Turkey was the leading global producer of pumice and pumicite, followed by Uganda. 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[e]		Reserves[4]
	2022	2023	
United States[1]	[5]295	310	Large in the United States. Quantitative estimates of reserves for most countries were not available.
Algeria[6]	900	900	
Cameroon[6]	280	280	
Chile[6]	720	720	
Ecuador[6]	800	800	
Ethiopia	510	510	
France[6]	280	200	
Greece[6]	1,010	1,000	
Guadeloupe	200	200	
Guatemala	570	570	
Indonesia	200	200	
Saudi Arabia[6]	980	980	
Spain	240	240	
Syria[6]	200	200	
Tanzania	220	230	
Turkey	8,700	8,700	
Uganda	1,300	1,500	
Other countries[6]	750	700	
World total (rounded)	18,200	18,000	

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 (HIGH-PURITY AND INDUSTRIAL CULTURED CRYSTAL)

(Data in metric tons unless otherwise specified)

Domestic Production and Use: Ground high-purity quartz (HPQ) is typically defined as ground natural quartz with less than 100 parts per million of impurities and has further defined standards for the concentrations of specific impurities allowed. HPQ has specialized end uses including electronics, fiber optic cables, fused quartz crucibles (for manufacturing silicon metal ingots that are later processed into silicon wafers for the photovoltaic cell and semiconductor markets), high-temperature lamp tubing, and specialty glass. In 2023, there were two companies that produced HPQ in the United States around Spruce Pine, NC. The HPQ in Spruce Pine was sourced from pegmatite rocks that were concurrently mined to produce feldspar and mica. The pegmatite rocks were processed through a number of procedures which include being crushed, washed and scrubbed, and sorted. Additional processing for the HPQ included being physically processed, chemically processed, and thermally processed. At least one of these companies sent their product overseas for further processing.

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 2023, 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:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Ground high-purity quartz:					
Production[e, 2]	100,000	100,000	100,000	200,000	200,000
Imports[3]	NA	NA	NA	NA	NA
Exports[3]	NA	NA	NA	NA	NA
Price, range of value, dollars per metric ton[e, 4, 5]	500–14,000	500–15,000	500–16,000	500–17,000	500–20,000
Net import reliance[6] as a percentage of apparent consumption	NA	NA	NA	NA	NA
Industrial cultured quartz crystal:					
Production	W	W	W	W	W
Imports, piezoelectric	55	114	69	76	77
Exports, piezoelectric	41	37	39	77	120
Price, as-grown cultured quartz, dollars per kilogram[e, 4]	200	200	200	200	200
Price, lumbered quartz, dollars per kilogram[e, 4, 7]	500	400	300	300	300
Net import reliance[6] 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 (2019–22): Import statistics specific to lascas and HPQ were not available because they were combined with other types of quartz. Cultured quartz crystal (piezoelectric quartz, unmounted): China,[8] 90%; Japan, 3%; Denmark, 2%; and other, 5%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
Sand containing 95% or more silica and not more than 0.6% iron oxide (including HPQ)	2505.10.1000	Free.
Quartz (including lascas and HPQ)	2506.10.0050	Free.
Piezoelectric quartz, unmounted	7104.10.0000	3% ad valorem.

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QUARTZ (HIGH-PURITY AND INDUSTRIAL CULTURED CRYSTAL)

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

Government Stockpile:[9]

	FY 2023		FY 2024	
Material	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Quartz crystal, kilograms	—	7,148	—	7,148

Events, Trends, and Issues: Increased global manufacturing of silicon metal ingots that are later processed into silicon wafers for the photovoltaic cell and semiconductor markets has increased the demand for HPQ needed to make fused quartz crucibles. Growth of the electronics, fiber optic, and specialty glass markets are also likely to remain a factor in sustaining and increasing global demand for HPQ.

Increased trade of piezoelectric quartz in the past several years was 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 demand for cultured quartz crystal.

World Mine Production and Reserves:[10] This information was not available. Global reserves of HPQ were thought to be limited to a few locations. The United States was estimated to be the leader in production of HPQ with other sources being in Australia, Brazil, Canada, China, India, and Russia. The global reserves for lascas were estimated to be large.

World Resources:[10] Limited resources of HPQ exist throughout the world. Limited resources of natural quartz crystal suitable for direct electronic or optical use exist throughout the world. World dependence on natural quartz crystal 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: No economic substitutes or alternatives for HPQ exist for most applications. Cultured quartz can be used as a substitute for HPQ, although it is not commonly done owing to the high price of cultured quartz.

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. Lascas data are not included in this publication.
[2]Production is estimated from a combination of publicly available data, published sources, and industry trends. Data are rounded to the nearest hundred thousand metric tons to avoid disclosing company proprietary data.
[3]Trade data for ground high-purity quartz are included in Harmonized Tariff Schedule of the United States (HTS) codes 2505.10.1000 and 2505.10.1050 but are mixed with other types of sand and quartz. A reliable estimate cannot be made.
[4]Price is estimated from a combination of reported prices, trade data prices, and industry trends.
[5]Prices vary based on the percentage of quartz, percentage and type of impurities, and end use of the ground high-purity quartz.
[6]Defined as imports – exports.
[7]As-grown cultured quartz that has been processed by sawing and grinding.
[8]Includes Hong Kong.
[9]See Appendix B for definitions.
[10]See Appendix C for resource and reserve definitions and information concerning data sources.

RARE EARTHS[1]

[Data in metric tons, rare-earth-oxide (REO) equivalent, unless otherwise specified]

Domestic Production and Use: Rare earths were mined domestically in 2023. 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 stockpiled 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 2023 was $190 million, a 7% decrease from $208 million in 2022. The estimated leading domestic end use of rare earths was catalysts. Significant amounts 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:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production:[e]					
Mineral concentrates	28,000	39,000	[e]42,000	[e]42,000	43,000
Compounds and metals	—	—	120	95	250
Imports:[e, 2]					
Compounds	12,200	6,510	7,690	10,700	8,800
Metals:					
Ferrocerium, alloys	330	270	330	396	300
Rare-earth metals, scandium, and yttrium	627	363	580	487	580
Exports:[e, 2]					
Ores and compounds	28,300	40,000	46,000	46,000	40,000
Metals:					
Ferrocerium, alloys	1,290	625	825	1,500	950
Rare-earth metals, scandium, and yttrium	83	25	20	24	64
Consumption, apparent, compounds and metals[3]	11,800	6,490	[e]7,900	[e]10,200	8,800
Price, average, dollars per kilogram:[4]					
Cerium oxide, 99.5% minimum	2	2	2	1	1
Dysprosium oxide, 99.5% minimum	239	261	410	382	323
Europium oxide, 99.99% minimum	35	31	31	30	27
Lanthanum oxide, 99.5% minimum	2	2	2	1	1
Mischmetal, 65% cerium, 35% lanthanum	6	5	6	7	5
Neodymium oxide, 99.5% minimum	45	49	98	134	80
Terbium oxide, 99.99% minimum	507	670	1,346	2,051	1,300
Employment, mine and mill, annual average, number	202	185	293	350	450
Net import reliance[5] as a percentage of apparent consumption:[6]					
Compounds and metals	100	100	>95	>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 (2019–22): Rare-earth compounds and metals: China,[7] 72%; Malaysia, 11%; Japan, 6%; Estonia, 5%; and other, 6%. 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 12–31–23**
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); bastnaesite and xenotime, 14% (domestic and foreign).

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RARE EARTHS

Government Stockpile:[8] In the addition to the materials listed below, the fiscal year (FY) 2023 potential acquisitions included 100 tons of rare-earth magnet block, and FY 2024 potential acquisitions include 300 tons of neodymium-praseodymium oxide, 286 tons of neodymium-iron-boron magnet block, and 200 tons of samarium-cobalt alloy.

	FY 2023		FY 2024	
Material	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Cerium	550	—	550	—
Lanthanum	1,300	—	1,300	—
Neodymium	600	—	600	—
Praseodymium	70	—	70	—

Events, Trends, and Issues: Global mine production was estimated to have increased to 350,000 tons of REO equivalent. China's Ministry of Industry and Information Technology raised 2023 quotas for rare-earth mining and separation to 240,000 tons and 230,000 tons of REO equivalent, respectively. In 2023, mine production quotas were allocated to 220,850 tons of light rare earths and 19,150 tons of ion-adsorption clays.

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

	Mine production[e]		Reserves[9]
	2022	2023	
United States	42,000	43,000	1,800,000
Australia	18,000	18,000	[10]5,700,000
Brazil	80	80	21,000,000
Burma	12,000	38,000	NA
Canada	—	—	830,000
China	[11]210,000	[11]240,000	44,000,000
Greenland	—	—	1,500,000
India	2,900	2,900	6,900,000
Madagascar	960	960	NA
Malaysia	80	80	NA
Russia	2,600	2,600	10,000,000
South Africa	—	—	790,000
Tanzania	—	—	890,000
Thailand	7,100	7,100	4,500
Vietnam	1,200	600	22,000,000
World total (rounded)	300,000	350,000	110,000,000

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 Non-Ferrous Metals.
[5]Defined as imports – exports.
[6]In 2019 and 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 3.3 million tons.
[11]Production quota; does not include undocumented production.

RHENIUM

(Data in kilograms, rhenium content, unless otherwise specified)

Domestic Production and Use: During 2023, 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. Total estimated U.S. primary production was approximately 9,100 kilograms in 2023, a 3% increase from that in 2022. 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:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production[1]	8,360	8,830	9,290	8,870	9,100
Imports for consumption					
Rhenium, unwrought and powders[2]	31,500	15,900	15,900	11,900	11,000
Ammonium perrhenate[3]	12,800	9,320	6,020	8,920	5,000
Exports	—	—	—	267	2,100
Consumption, apparent[4]	52,600	34,000	31,200	29,500	23,000
Price, average value, gross weight, dollars per kilogram:[5]					
Metal pellets, 99.99% pure	1,300	1,030	977	1,120	1,070
Ammonium perrhenate	1,280	1,090	866	911	920
Employment, number	Small	Small	Small	Small	Small
Net import reliance[6] as a percentage of apparent consumption	84	74	70	70	60

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 (2019–22): Ammonium perrhenate: Kazakhstan, 27%; Canada, 17%; Poland, 15%; Germany, 12%; and other, 29%. Rhenium metal powder: Chile, 78%; Germany, 9%; Canada, 8%; Poland, 4%; and other, 1%. Total imports: Chile, 56%; Canada, 11%; Germany, 10%; Kazakhstan, 9%; and other, 14%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
Salts of peroxometallic acids, other, ammonium perrhenate	2841.90.2000	3.1% ad valorem.
Rhenium, unwrought, waste and scrap	8112.41.1000	Free.
Rhenium, unwrought, powders	8112.41.5000	3% ad valorem.
Rhenium, other	8112.49.0000	4% ad valorem.
Rhenium (and other metals), wrought	8112.99.9100	4% ad valorem.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

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RHENIUM

Events, Trends, and Issues: In 2023, the estimated price for catalytic-grade APR averaged $920 per kilogram, more than the annual average price of $911 per kilogram in 2022. The estimated rhenium metal pellet price averaged $1,070 per kilogram in 2023, a 5% decrease from the annual average price in 2022.

In 2023, apparent consumption in the United States was about 22% less than that in 2022. During 2023, 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 decreased by an estimated 44% in 2023 compared with those in 2022. Imports of rhenium metal decreased by an estimated 8% in 2023 compared with those in 2022. Estimated world rhenium production in 2023 increased slightly compared with that in 2022.

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 2023. There were no primary rhenium projects in 2023 that were expected to significantly contribute to rhenium availability in the immediate future.

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

	Mine production[e, 7]		Reserves[8]
	2022	2023	
United States	8,870	9,100	400,000
Armenia	260	280	95,000
Chile[9]	29,000	30,000	1,300,000
China	2,500	2,500	19,200
Kazakhstan	500	500	190,000
Korea, Republic of	2,800	2,800	NA
Poland	6,310	6,300	NA
Russia	NA	NA	310,000
Uzbekistan	4,900	4,900	NA
World total (rounded)	55,100	56,000	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; one such application using iridium and tin has achieved commercial success. 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. — Zero.

[1]Based on 80% recovery of estimated rhenium contained in molybdenum disulfide concentrates. Secondary rhenium production not included.

[2]Includes data for the following Harmonized Tariff Schedule of the United States (HTS) codes: 8112.92.5000 (2019–21) and 8112.41.5000 and 8112.49.0000 (2022–23). 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 Non-Ferrous Markets.

[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, rubidium oxide, unless otherwise specified)

Domestic Production and Use: In 2023, 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.

At the end of September 2023, one company offered 1-gram ampoules of 99.75% (metal basis) rubidium for $121.00, a 20% increase from $100.80 in 2022, and 100-gram ampoules of the same material for $2,160, a 19% increase from $1,818.60 in 2022. The price for 10-gram ampoules of 99.8% (metal basis) rubidium formate hydrate was $290.00, a 4% increase from $278.25. in 2022.

In 2023, the prices for 10 grams of 99.8% (metal basis) rubidium acetate, rubidium bromide, rubidium carbonate, rubidium chloride, and rubidium nitrate were $65.60, $93.60, $63.10, $80.10, and $60.20, respectively, with increases ranging from 15% to 20% compared to prices in 2022.

The price for a rubidium-plasma standard solution (10,000 micrograms per milliliter) was $65.00 for 50 milliliters and $115.00 for 100 milliliters, 6% and 5% increases, respectively, from those in 2022.

Recycling: None.

Import Sources (2019–22): No reliable data have been available to determine the source of rubidium ore or compounds imported by the United States since 1988. The United States was 100% net import reliant for its rubidium needs, and the primary global producers were estimated to include China, Germany, and Russia.

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RUBIDIUM

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023, no rubidium production was reported globally but rubidium was estimated 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. 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 2023, 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. Pollucite mining at the Tanco Mine in Canada ended in 2015; however, mining resumed intermittently in recent years with most of the ore and preexisting stockpiles processed on site but rubidium was not present in mined ore and not produced.

World Mine Production and Reserves:[1] There were no official sources for rubidium production data in 2023. 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 estimated 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 specified)

Domestic Production and Use: Domestic production of salt was an estimated 42 million tons in 2023. The quantity of salt sold or used in 2023 was an estimated 41 million tons with a total estimated value of $2.6 billion. Salt was produced by 25 companies that operated 63 plants in 16 States. The top producing States were Kansas, Louisiana, Michigan, New York, Ohio, Texas, and Utah. These seven States produced about 95% of the salt in the United States in 2023. The estimated percentage of salt sold or used was, by type, rock salt, 46%; salt in brine, 33%; vacuum pan salt, 11%; and solar salt, 10%.

Highway deicing accounted for about 41% of total salt consumed. The chemical industry accounted for about 38% of total salt sales, with salt in brine accounting for 86% 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, 10%; food processing, 4%; agricultural, 3%; general industrial, 2%; miscellaneous, 1%, and primary water treatment, 1%.

Salient Statistics—United States:[1]	2019	2020	2021	2022	2023[e]
Production	44,800	42,600	39,300	[e]41,000	42,000
Sold or used by producers	44,900	39,600	39,800	[e]40,000	41,000
Imports for consumption	18,700	15,800	17,700	17,800	16,000
Exports	1,020	1,250	1,010	890	2,300
Consumption:					
Apparent[2]	62,500	54,200	56,400	[e]57,000	55,000
Reported	51,800	44,000	47,100	[e]47,000	48,000
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	211.57	212.21	203.72	[e]210	220
Solar salt	126.18	122.77	153.52	[e]150	150
Rock salt	59.90	61.71	59.88	[e]60	61
Salt in brine	7.56	8.36	8.14	[e]8.40	8.50
Employment, mine and plant, number[e]	4,100	4,000	4,000	4,100	4,100
Net import reliance[3] as a percentage of apparent consumption	28	27	30	30	25

Recycling: None.

Import Sources (2019–22): Canada, 29%; Chile, 28%; Mexico, 12%; Egypt, 11%; and other, 20%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
Salt (sodium chloride)	2501.00.0000	Free.

Depletion Allowance: 10% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of salt in 2023 remained lower than 2019 levels after the coronavirus disease 2019 (COVID-19) pandemic affected production and consumption of salt throughout the world since 2020. 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 2022–23 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 imports in 2023 were estimated to have decreased compared with those in 2022 because demand from many local and State transportation departments was essentially unchanged from the previous year and stockpiles of domestically sourced salt were sufficient to meet demand in many areas.

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SALT

For the 2023–24 winter, the National Oceanic and Atmospheric Administration (NOAA) predicted a El Niño weather pattern for the first time in 4 years. A strong El Niño historically favors a warmer-than-average temperature pattern in the northern tier of the continental United States. NOAA forecasted wetter-than-average conditions for the Gulf Coast, lower Middle Atlantic, the southern Plains, and the Southeast, but drier-than-average conditions across the northern tier of the United States. These forecasts indicate that demand for rock salt could decrease in many locales in the United States.

Demand for salt brine used in the chloralkali industry was expected to increase in 2024 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, as salt production in China has decreased.

World Production and Reserves:

	Mine production[e]		Reserves[4]
	2022	**2023**	
United States[1]	41,000	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	13,000	14,000	
Belarus	2,000	2,100	
Brazil	6,600	6,600	
Bulgaria	3,300	3,300	
Canada	12,000	12,000	
Chile	9,000	9,200	
China	54,000	53,000	
Egypt	2,300	2,300	
France	5,500	5,600	
Germany	15,000	15,000	
India	30,000	30,000	
Iran	2,700	2,700	
Italy	1,900	2,000	
Mexico	8,700	9,000	
Netherlands	5,900	6,000	
Pakistan	3,000	3,000	
Poland	4,300	4,200	
Russia	8,000	7,000	
Saudi Arabia	2,400	2,500	
Spain	3,900	4,000	
Turkey	9,100	9,000	
United Kingdom	2,400	2,300	
Other countries	26,000	27,000	
World total (rounded)	270,000	270,000	

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 specified)

Domestic Production and Use: In 2023, 920 million tons of construction sand and gravel valued at $11 billion was produced by an estimated 3,400 companies operating 6,500 pits and over 200 sales and (or) distribution yards in 50 States. Leading producing States were, in order of decreasing tonnage, Texas, California, Minnesota, Michigan, Arizona, Colorado, Ohio, Utah, Washington, and Nevada, which together accounted for about 53% of total output. An estimated 43% of construction sand and gravel was used as portland cement concrete aggregates, 25% for road base and coverings, 12% for construction fill, 12% for asphaltic concrete aggregate and for other bituminous mixtures, and 4% for other miscellaneous uses. The remaining amount 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 2023 was 698 million tons, a decrease of 5% compared with that in the same period in 2022. Third-quarter shipments for consumption decreased by 4% compared with those in the same period in 2022. 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:	2019	2020	2021	2022	2023[e]
Sold or used by producers	930	925	943	953	920
Imports for consumption	5	5	5	4	4
Exports	([2])	([2])	([2])	([2])	([2])
Consumption, apparent[3]	935	929	948	956	920
Price, average unit value, dollars per metric ton	9.63	9.96	10.35	11.25	12.20
Employment, mine and mill, number[4]	39,600	37,900	37,800	36,900	37,000
Net import reliance[5] as a percentage of apparent consumption	1	1	([2])	([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 2023, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2019–22): Canada, 95%; Mexico, 2%; The Bahamas, 1%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 920 million tons in 2023, a decrease of 4% compared with that in 2022. Apparent consumption also decreased to 920 million tons. Consumption of construction sand and gravel decreased in 2023 because of decreases in residential housing demand caused by interest rates increasing to the highest levels in 20 years. 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 an increase in prices for construction sand and gravel are expected to be present in 2024, especially in and near metropolitan areas.

The construction sand and gravel industry continued to address health and safety regulations, permitting and zoning issues, and environmental restrictions in 2023. The 2021 Infrastructure Investment and Jobs Act reauthorizes surface transportation programs for 5 years and invests billions in additional funding to repair roads and bridges and support major, transformational projects. This included $118 billion to the Highway Trust Fund—$90 billion to the highway account and $28 billion to the transit account. 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]
	2022	2023[e]	
United States	953	920	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 2023.

[e]Estimated. NA Not available.
[1]See also the Sand and Gravel (Industrial) and the Stone (Crushed) chapters.
[2]Less than ½ unit.
[3]Defined as sold or used by producers + 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 specified)

Domestic Production and Use: In 2023, industrial sand and gravel production was an estimated 130 million tons valued at an estimated $7.0 billion. The quantity of industrial sand and gravel sold or used increased by 14%, and the value increased by 36% compared with that in 2022. Industrial sand and gravel was produced by 106 companies from 199 operations in 33 States. The leading producing States were, in descending order of production, Texas, Wisconsin, Illinois, Louisiana, Oklahoma, Missouri, Arkansas, Michigan, California, and Iowa. Combined production from these States accounted for about 89% of total domestic sales and use. Approximately 81% of the U.S. tonnage was used as hydraulic-fracturing sand (frac sand) and well-packing and cementing sand, and 8% 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 7% combined. Other minor uses were, in decreasing quantity of use, chemicals, roofing granules, abrasives, silicon and ferrosilicon, ceramics, fillers, traction, filtration gravel, and metallurgic flux, which accounted for 2% combined. Other unspecified uses accounted for 2% combined.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Sold or used	108,000	75,800	91,200	114,000	130,000
Imports for consumption	389	417	350	338	290
Exports	5,590	4,070	5,400	6,350	7,500
Consumption, apparent[2]	103,000	72,100	86,200	108,000	120,000
Price, average value, dollars per metric ton	46.00	29.50	40.80	45.30	54.00
Employment, quarry and mill, number[e]	7,500	4,500	5,300	6,000	6,100
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 (2019–22): Canada, 86%; Vietnam, 4%; Taiwan, 3%; Brazil, 2%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 120 million tons in 2023, an 11% increase from that in 2022. The most important driving force in the industrial sand and gravel industry remained the production and sale of frac sand. In recent years, the consumption of frac sand increased as hydrocarbon extraction from shale deposits increased and the quantity of frac sand used per well increased in the United States. In 2023, industrial sand and gravel consumption increased as demand for frac sand increased and also led to higher prices for frac sand. Increased apparent consumption for other end uses in 2023 resulted from continued economic recovery from the effects of the global coronavirus disease 2019 (COVID-19) pandemic. Imports of industrial sand and gravel in 2023 were an estimated 290,000 tons, a 14% decrease from those in 2022. The United States remained a net exporter of industrial sand and gravel; U.S. exports of industrial sand and gravel were an estimated 7,500,000 tons, an 18% increase from those in 2022.

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 2023, especially those concerning crystalline silica exposure.

Local shortages of industrial sand and gravel were expected to continue to increase owing to land development priorities, local zoning regulations, and logistical issues. 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."

World Mine Production and Reserves:

	Mine production 2022	Mine production 2023[e]	Reserves[4]
United States	114,000	130,000	Large. Industrial sand and gravel deposits are widespread.
Argentina	[e]3,900	4,000	
Australia	[e]5,000	5,500	
Bulgaria	[e]8,450	8,500	
Canada	[e]5,000	5,500	
China	[e]87,700	88,000	
France	[e]13,000	14,000	
Germany	[e]11,100	11,000	
India	[e]11,900	12,000	
Indonesia	[e]3,540	3,500	
Italy	[e]14,000	33,000	
Japan	2,010	2,000	
Malaysia	[e]4,500	7,000	
Mexico	[e]2,700	2,700	
Netherlands	[e]10,000	12,000	
Poland	[e]5,570	5,800	
Russia	[e]7,300	7,300	
Spain	[e]6,600	6,600	
Turkey	14,500	15,000	
United Kingdom	[e]4,200	4,200	
Other countries	[e]24,000	25,000	
World total (rounded)	359,000	400,000	

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, foundry, and molding sands are chromite, olivine, staurolite, and zircon sands. Alternative materials that can be used for abrasive sands are garnet, olivine, and slags. 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, scandium oxide equivalent, unless otherwise specified)

Domestic Production and Use: Domestically, scandium was neither mined nor recovered from process streams or mine tailings in 2023. 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 2023 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:	2019	2020	2021	2022	2023[e]
Price, yearend:					
Compounds, dollars per gram:					
Acetate, 99.9% purity, 5-gram lot size[2]	45	45	43	46	70
Chloride, 99.9% purity, 5-gram lot size[2]	129	133	137	140	166
Fluoride, 99.9% purity (99.99% purity in 2022), 1- to 5-gram lot size[3]	209	214	216	250	1,080
Iodide, 99.999% purity, 5-gram lot size[2]	157	161	161	170	200
Oxide, 99.99% purity, 5-kilogram lot size[4]	3.9	3.8	2.2	2.1	NA
Metal:					
Scandium, dollars per gram:[2]					
Distilled dendritic, 2-gram lot size	233	233	238	260	269
Ingot, 5-gram lot size	134	134	137	150	153
Scandium-aluminum alloy, dollars per kilogram:[4]					
1-kilogram lot size	300	340	350	350	NA
1,000-kilogram lot size	NA	NA	NA	98	NA
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2019–22): Although there are no trade codes for scandium materials exclusively, shipping records indicated imported material was mostly from Japan, China, Germany, and Philippines.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 30 to 40 tons per year with a global capacity estimate of 80 tons per year. Scandium was recovered from cobalt, nickel, titanium, and zirconium process streams. China was the leading producer. Prices quoted for scandium oxide in the United States generally decreased over a 5-year period. Global consumption has increased considerably driven by its use in aluminum-scandium alloys and SOFCs.

In 2023, a metallurgical complex in southwestern Quebec extracted scandium from waste streams and was planning to increase capacity from the current 3 tons per year to 12 tons per year; the increase in capacity was expected to be completed by yearend 2024. An Australia-United Kingdom mining company entered into a binding agreement to purchase the Platina Scandium Project in New South Wales in first half of 2023; the project was expected to produce up to 40 tons per year of scandium oxide once operational.

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SCANDIUM

In Europe, a company started the ScaVanger project in France to produce scandium. Currently there is no production of scandium in the European Union and is 100% dependent on imports. The major European Union import sources for scandium are China (from the titanium dioxide industry and rare-earth-element production); the Philippines; Kazakhstan; and Ukraine (from nickel-laterite tailings and uranium production waste). Beginning in 2026, the ScaVanger project is projected to produce 21 tons per year of scandium oxide from titanium dioxide coproduction.

In the United States, there is no current mine production of scandium but, based on the 2022 Elk Creek Technical Report estimates, a scandium oxide resource of 11,000 tons is present in Nebraska. The company had successful pilot-scale production of 1 kilogram of aluminum-scandium ingot at its testing facility.

In Australia, several polymetallic projects were under development and seeking permitting, financing, and offtake agreements including the Nyngan, Owendale, Sconi, and Sunrise projects.

In the Philippines, the Taganito high-pressure acid-leach nickel commercial plant recovered 7 to 8 tons per year of scandium oxide.

In Tangshan, Hebei Province, China, a new production plant was being built and expected to produce 20 tons per year of high-purity scandium oxide from feedstock from Papua New Guinea. The pilot plant production started November 2023.

The global scandium market is small compared to most commodities, and according to industry estimates, global production totaled less than 40 tons in 2022. Global consumption has increased considerably driven by its use in SOFCs and aluminum alloys.

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 2022 and 2023 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. Australia’s reserves were about 37,000 tons of scandium as accessible Economic Demonstrated Resources (EDR) as of December 2022.[7]

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. NA Not available.
[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.
[7]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 12,000 tons.

SELENIUM

(Data in metric tons, selenium content, unless otherwise specified)

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 2023, 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 in agriculture as a fertilizer additive to increase plant tolerance to environmental stressors; as an active ingredient in antidandruff shampoos; 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:	2019	2020	2021	2022	2023[e]
Production, refinery[1]	W	W	W	W	W
Imports for consumption:					
Selenium	465	366	346	351	290
Selenium dioxide	5	18	71	10	5
Exports[2]	361	147	227	192	110
Consumption, apparent[3]	W	W	W	W	W
Price, average, dollars per kilogram:					
United States[4]	20.17	14.58	18.18	23.07	23
Europe[5]	20.44	14.71	18.47	19.82	19
Stocks, producer, yearend	W	W	W	W	W
Net import reliance[6] as a percentage of apparent consumption	>50	>75	>50	>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 (2019–22): Selenium: Philippines, 22%; Mexico, 17%; Germany, 13%; Canada, 9%; and other, 39%. Selenium dioxide: Republic of Korea, 86%; China, 7%; Germany, 5%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 supply of selenium is directly affected by the supply of materials of which it is a byproduct, primarily copper. In 2023, the selenium content of domestic copper anode slimes was estimated to have decreased from that in 2022, reflecting lower output of copper cathode from electrolytic refineries in the United States. The annual average price for selenium in U.S. warehouses was an estimated $23 per kilogram, unchanged from that in 2022. Higher production costs were offset by increased global supply and stable global demand.

China was the leading producer of refined selenium in 2023 and accounted for 42% of estimated global output. Production in China increased significantly over the past 10 years, correlating with an increase of approximately 60% in the production capacity of electrolytically refined copper. The leading global end use for selenium in 2023 was estimated to be for the production of electrolytic manganese in China. 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 reflect the estimated selenium content of copper reserves except for those for China, which represent reported reserves of selenium. Reserves for China were revised based on Government reports, and reserves for Finland, Peru, Russia, the United States, and "Other countries" were revised based on company reports.

	Refinery production[e, 7]		Reserves[8]
	2022	2023	
United States	W	W	11,000
Belgium	200	200	—
Canada	110	120	6,000
China	1,290	1,500	5,000
Finland	[9]130	100	300
Germany	300	300	—
India	14	14	500
Japan	710	780	—
Peru	[9]57	57	19,000
Poland	[9]82	95	3,000
Russia	340	360	26,000
Sweden	10	8	500
Turkey	50	50	NA
Other countries[10]	14	15	24,000
World total (rounded)	[11]3,310	[11]3,600	95,000

World Resources:[8] 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 99.5%-minimum-purity selenium powder, free on board, U.S. warehouse. Source Argus Media Group, Argus Non-Ferrous Markets.
[5]Average annual price for 99.5%-minimum-purity selenium powder, in warehouse, Rotterdam. Source: Argus Media Group, Argus Non-Ferrous Markets.
[6]Defined as imports (excluding selenium dioxide) – exports ± adjustments for industry stock changes.
[7]Insofar as possible, data relate to refinery output only; countries that produced selenium contained in blister copper, copper anodes, copper concentrates, copper ores, and (or) refinery residues but did not recover selenium from these materials were excluded.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]Reported.
[10]Includes Serbia, South Africa, and Uzbekistan. In addition to the countries listed, Australia, Chile, Iran, Kazakhstan, the Republic of Korea, Mexico, the Philippines, and Zimbabwe may have produced refined selenium, but available information was inadequate to make reliable estimates of output.
[11]Excludes U.S. production.

SILICON

(Data in thousand metric tons, silicon content, unless otherwise specified)

Domestic Production and Use: Silicon materials were produced at six facilities in 2023, 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, respectively, from high-purity silicon also consumed silicon metal.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production, ferrosilicon[1] and silicon metal[2]	310	W	W	265	W
Imports for consumption:					
Ferrosilicon, all grades	127	140	125	175	160
Silicon metal	124	97	96	117	80
Exports:					
Ferrosilicon, all grades	8	4	7	9	6
Silicon metal	40	32	53	47	40
Consumption, apparent,[3] ferrosilicon[1] and silicon metal[2]	517	W	W	495	W
Price, average, cents per pound of silicon:					
Ferrosilicon, 50% silicon[4]	102.35	103.38	137.94	NA	NA
Ferrosilicon, 75% silicon[5]	89.15	87.40	192.28	312.10	150
Silicon metal[2, 5]	105.70	96.84	220.31	361.86	190
Stocks, producer, ferrosilicon[1] and silicon metal,[2] yearend	15	W	11	17	19
Net import reliance[6] as a percentage of apparent consumption:					
Ferrosilicon, all grades	<50	>50	<50	>50	>50
Silicon metal[2]	<50	<50	<25	<50	<50
Total	40	<50	<50	46	<50

Recycling: Insignificant.

Import Sources (2019–22): Ferrosilicon: Russia, 38%; Brazil, 13%; Canada, 13%; Malaysia, 9%; and other, 27%. Silicon metal: Brazil, 35%; Canada, 25%; Norway, 13%; Australia, 6%; and other, 21%. Total: Brazil, 23%; Russia, 21%; Canada, 18%; Norway, 7%; and other, 31%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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.

Events, Trends, and Issues: Combined domestic ferrosilicon and silicon metal production in 2023 was withheld to avoid disclosing proprietary information but was estimated to be less than that in 2022. By September 2023, average U.S. spot market prices decreased by approximately 50% for both 75%-grade ferrosilicon and silicon metal compared with the annual average prices in 2022.

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SILICON

Excluding the United States, ferrosilicon accounted for almost 60% of world silicon production on a silicon-content basis in 2023. 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 more than 70% of total global estimated production of silicon materials in 2023. Global production of silicon materials, on a silicon-content basis, was estimated to be essentially unchanged from that in 2022.

In January, a company announced plans to build a $2.5 billion fully integrated silicon-based solar supply chain facility in Georgia that would manufacture silicon ingots, wafers, cells, and modules. Production was expected to commence in late 2024 and would be the first production of solar-grade wafers in the United States since 2016. Another U.S. company planned to restart an idled solar-grade polysilicon production facility in Washington in late 2023.

In support of the CHIPS and Science Act of 2022, the U.S. Department of Commerce, through the National Institute of Standards and Technology, issued a final rule in September to prevent funding from being used directly or indirectly to benefit foreign countries of concern. Countries of concern are determined to be those engaged in conduct that is detrimental to the national security or foreign policy of the United States.

World Production:

	Ferrosilicon[e]		Silicon metal[e]	
	2022	2023	2022	2023
United States[7]	W	W	W	W
Australia	—	—	48	50
Bhutan	75	80	—	—
Brazil	189	190	202	200
Canada	20	20	29	30
China	3,770	3,600	2,900	3,000
France	25	20	96	90
Germany	—	—	62	60
Iceland	79	80	49	50
India	59	60	—	—
Kazakhstan	96	120	5	5
Malaysia	91	80	—	—
Norway	195	200	144	140
Poland	47	50	—	—
Russia	572	570	54	50
Spain	46	50	6	6
Ukraine	28	2	—	—
Other countries	144	100	79	80
World total (rounded)[8]	5,440	5,200	3,670	3,800

World Resources:[9] 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. W Withheld to avoid disclosing company proprietary data. — Zero.

[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. Estimated 2023 price is the mean based on monthly average of January through September 2023.

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

[7]To avoid disclosing proprietary data, U.S. ferrosilicon and silicon production are not reported separately. See Salient Statistics for U.S. combined ferrosilicon and silicon metal production.

[8]Excludes U.S. production.

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

SILVER

(Data in metric tons,[1] silver content, unless otherwise specified)

Domestic Production and Use: In 2023, U.S. mines produced approximately 1,000 tons of silver with an estimated value of $760 million. Silver was produced at 4 silver mines and as a byproduct or coproduct from 31 domestic base- and precious-metal operations. Silver was produced in 12 States, and 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 3,000 tons from domestic and foreign ores and concentrates and from new and old scrap. The physical properties of silver include high ductility, electrical conductivity, malleability, and reflectivity. In 2023, 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; wood treatment; and processing of spent ethylene oxide catalysts. Mercury and silver, the main components of dental amalgam, are biocides, and their use in amalgam inhibits recurrent decay.

Salient Statistics—United States:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production:					
Mine	981	1,080	1,020	1,010	1,000
Refinery:					
Primary	1,360	1,360	1,920	1,850	1,900
Secondary (new and old scrap)	627	582	908	1,090	1,100
Imports for consumption[2]	4,760	6,730	6,160	4,490	4,700
Exports[2]	220	141	137	275	80
Consumption, apparent[3]	6,150	8,250	7,950	6,320	6,700
Price, bullion, average, dollars per troy ounce[4]	16.24	20.58	25.23	21.88	23.40
Stocks, yearend:					
Industry	52	55	56	55	58
Treasury[5]	498	498	498	498	498
New York Commodities Exchange—COMEX	9,865	12,334	11,064	9,300	8,400
Employment, mine and mill, number[6]	990	1,180	1,440	1,400	1,500
Net import reliance[7] as a percentage of apparent consumption	74	80	76	67	69

Recycling: In 2023, approximately 1,100 tons of silver was recovered from new and old scrap, accounting for about 16% of apparent consumption.

Import Sources (2019–22):[2] Mexico, 44%; Canada, 18%; Poland, 5%; Switzerland, 4%; and other, 29%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
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 2023 was $23.40 per troy ounce, 7% higher than the average price in 2022. The price began the year at $24.70 per troy ounce and decreased to the low of $20.15 per troy ounce in March, it then increased to a high of $26.00 per troy ounce in May. It fluctuated between $21.00 per troy ounce and $26.00 from May to November.

In 2023, global consumption of silver was an estimated 36,000 tons, a 6% decrease from that in 2022 but still higher than consumption before the coronavirus disease 2019 (COVID-19) pandemic. Coin and bar consumption decreased by 7% in 2023 owing to most key markets declining after a strong 2022. In 2023, consumption of silver for industrial uses was estimated to have increased by 4% compared with that in 2022 owing to the installation of fifth-generation (5G) telecommunications infrastructure and power grids, gross domestic product (GDP) growth, increased production of PV, growth for consumer electronics and continued rising vehicle output. Consumption of silver in jewelry and silverware was estimated to have decreased by 15% and 24%, respectively. The decline was due to demand reverting to pre-pandemic levels for both.[8]

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SILVER

World silver mine production increased slightly in 2023 to an estimated 26,000 tons, principally as a result of increased production from mines in Mexico and Chile as new silver mines were starting or ramping up. Domestic silver mine production was estimated to have remained essentially unchanged in 2023. In August, a fire took place at an underground silver-lead-zinc mine in Idaho; no personnel were in the mine at the time of the fire. Production was suspended for the remainder of 2023 while work was carried out to bypass the damaged area.

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

	Mine production		Reserves[9]
	2022	2023[e]	
United States	1,010	1,000	23,000
Argentina	913	910	6,500
Australia	1,167	1,200	[10]94,000
Bolivia	1,214	1,200	22,000
Chile	1,274	1,400	26,000
China	3,480	3,400	72,000
India	694	690	8,000
Kazakhstan	1,053	990	NA
Mexico	6,195	6,400	37,000
Peru	3,079	3,100	110,000
Poland	1,316	1,300	*63,000
Russia	1,280	1,200	92,000
Other countries	2,940	3,000	57,000
World total (rounded)	25,600	26,000	*610,000

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. NA Not available.

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

[2]Silver content of base metal ores and concentrates, ash and residues, refined bullion, and dore; excludes coinage and waste and scrap material.

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

[4]Engelhard's industrial bullion quotations. Source: S&P Global Platts Metals Week.

[5]Source: U.S. Mint. Balance in U.S. Mint only; includes deep storage and working stocks.

[6]Source: U.S. Department of Labor, Mine Safety and Health Administration (MSHA). Only includes mines where silver is the primary product.

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

[8]Source: Metals Focus, 2023, World silver survey 2023: Silver Institute, prepared by Metals Focus, 84 p. (Accessed July 1, 2023, at https://www.silverinstitute.org/wp-content/uploads/2023/04/World-Silver-Survey-2023.pdf.)

[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.

*Correction posted on March 5, 2024.

SODA ASH

(Data in thousand metric tons unless otherwise specified)

Domestic Production and Use: The total value of domestic soda ash (sodium carbonate) produced in 2023 was an estimated $1.9 billion[1] and the quantity produced was an estimated 11 million tons, slightly less than that in 2022. The U.S. soda ash industry consisted of 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 2023 quarterly reports, the estimated distribution of soda ash by end use was glass, 47%; chemicals, 29%; miscellaneous uses, 9%; distributors, 5%; soap and detergents, 5%; flue gas desulfurization, 3%; pulp and paper, 1%; and water treatment, 1%.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production[2]	11,700	9,990	11,300	11,300	11,000
Imports for consumption	115	98	130	61	8
Exports	7,020	5,590	6,840	6,490	6,600
Consumption:					
Apparent[3]	4,830	4,470	4,580	4,740	4,100
Reported	4,720	4,440	4,640	4,640	4,500
Price, average unit value of sales (natural source), free on board (f.o.b.) mine or plant:					
Dollars per metric ton	153.24	140.70	133.37	178.52	180
Dollars per short ton	139.02	127.64	120.99	161.95	160
Stocks, producer, yearend	289	317	278	364	300
Employment, mine and plant, number[e]	2,600	2,400	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 (2019–22): Turkey, 92%; Mexico, 2%; United Kingdom, 2%; Bulgaria, 1%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
Disodium carbonate	2836.20.0000	1.2% ad valorem.

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

Government Stockpile: None.

Events, Trends, and Issues: Estimates for production, exports, and consumption in 2023 were still at levels lower than those before the global coronavirus disease 2019 (COVID-19) pandemic. Production was slightly lower than that in 2022 whereas estimated exports increased slightly. Reported and apparent consumption both decreased, by 3% and 13%, respectively, compared with those in 2022. More than one-half of U.S. soda ash production was exported in 2023.

China produced an estimated 29 million tons of soda ash in 2023 (most of which was synthetic) and was the leading producing country followed by, in descending order, Turkey and the United States. These three countries accounted for 78% of world production in 2023.

Relatively low production costs and lower environmental impacts provide natural soda ash producers in Turkey and the United States 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.

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SODA ASH

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

	Mine production 2022	Mine production 2023[e]	Reserves[5, 6]
Natural:			
United States	11,300	11,000	[7]23,000,000
Botswana	285	270	16,000
Ethiopia	[e]18	20	400,000
Kenya	[e]280	280	7,000
Turkey	[e]11,500	11,000	840,000
Other countries[8]	NA	NA	280,000
World total, natural	23,400	23,000	25,000,000
World total, synthetic	42,100	42,000	XX
World total, natural and synthetic	65,500	65,000	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 estimated 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 specified)

Domestic Production and Use: In 2023, 1.5 billion tons of crushed stone valued at more than $24 billion was produced by an estimated 1,400 companies operating 3,500 quarries and over 180 sales and (or) distribution yards in 50 States. Leading States were, in descending order of production, Texas, Florida, Missouri, Pennsylvania, Ohio, Georgia, North Carolina, Kentucky, Illinois, and Tennessee, which together accounted for about 54% of total crushed stone output. Of the total domestic crushed stone produced in 2023, about 69% was limestone and dolomite; 15%, granite; 6%, traprock; 6%, miscellaneous stone; and 3%, sandstone and quartzite; the remaining 1% was divided, in descending order of tonnage, among marble, volcanic cinder and scoria, calcareous marl, shell, and slate. An estimated 70% of crushed stone was used as a construction aggregate, mostly for road construction and maintenance; 20% for cement manufacturing; 7% for lime manufacturing; 1% for agricultural uses; and the remaining 2% 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 2023 was 1.17 billion tons, essentially unchanged compared with that in the same period in 2022. Third-quarter shipments for consumption decreased by 3% compared with those in the same period in 2022. 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:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Sold or used by producers	1,470	1,460	1,510	1,550	1,500
Recycled material	32	31	33	33	33
Imports for consumption	24	20	19	16	13
Exports	([2])	([2])	([2])	([2])	([2])
Consumption, apparent[3]	1,530	1,510	1,560	1,600	1,600
Price, average unit value, dollars per metric ton	12.36	12.69	13.19	14.23	15.60
Employment, quarry and mill, number[4]	69,000	68,000	68,900	70,400	70,000
Net import reliance[5] as a percentage of apparent consumption	2	1	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 2023, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2019–22): Mexico, 47%; Canada, 31%; The Bahamas, 13%; Honduras, 7%; and other, 2%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–23**
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 1.5 billion tons in 2023, essentially unchanged compared with 1.55 billion tons in 2022. Apparent consumption was essentially unchanged at 1.6 billion tons. Consumption of crushed stone for residential construction decreased in 2023 because of decreases in residential housing demand caused by interest rates increasing to the highest levels in 20 years. 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 an increase in prices for crushed stone are expected to be present in 2024, especially in and near metropolitan areas.

The crushed stone industry continued address health and safety regulations, permitting and zoning issues, and environmental restrictions in 2023. The 2021 Infrastructure Investment and Jobs Act reauthorizes surface transportation programs for 5 years and invests billions in additional funding to repair roads and bridges and support major, transformational projects. This included $118 billion to the Highway Trust Fund—$90 billion to the highway account and $28 billion to the transit account. 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]
	2022	2023[e]	
United States	1,550	1,500	Adequate, except where special types are needed or where local shortages exist.
Other countries[7]	NA	NA	
World total	NA	NA	

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 2023.

[e]Estimated. NA Not available.
[1]See also the Sand and Gravel (Construction) and the Stone (Dimension) chapters.
[2]Less than ½ unit.
[3]Defined as sold or used by producers + 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 specified)

Domestic Production and Use: Approximately 2.3 million tons of dimension stone, valued at $410 million, was sold or used by U.S. producers in 2023. Dimension stone was produced by 176 companies operating 224 quarries in 33 States. Leading producing States were, in descending order by tonnage, Texas, Wisconsin, Indiana, Vermont, and Georgia. These five States accounted for about 70% of the production quantity and contributed about 60% of the value of domestic production.

Approximately 51%, by tonnage, of dimension stone sold or used was limestone, followed by granite (20%), sandstone (14%), and dolomite (4%); the remaining 11% was divided, in descending order of tonnage, among miscellaneous stone, quartzite, marble, traprock, and slate. By value, the leading sales or uses were for limestone (49%), granite (25%), sandstone (9%), and dolomite and quartzite (4% each); the remaining 9% was divided, in descending order of total value, among slate, marble, miscellaneous stone, and traprock.

Rough stone represented 58% of the tonnage and 51% 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 (62%) and in irregular-shaped stone (29%). The leading uses and distribution of dressed stone, by tonnage, were in ashlars and partially squared pieces (47%); curbing (12%); slabs and blocks for building and construction, and flagging (11% each).

Salient Statistics—United States:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Sold or used by producers:[2]					
Quantity	2,510	2,120	2,290	2,380	2,300
Value, million dollars	415	397	413	421	410
Imports for consumption, value, million dollars	1,890	1,750	2,200	2,320	2,600
Exports, value, million dollars	61	48	50	54	50
Consumption, apparent, value, million dollars[3]	2,250	2,100	2,560	2,680	3,000
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	3,900	3,800	3,700	3,800	3,700
Net import reliance[5] as a percentage of apparent consumption (based on value)	82	81	84	84	86
Granite only:					
Quantity, sold or used by producers	430	436	445	491	450
Value, sold or used by producers, million dollars	108	105	108	102	130
Imports, value, million dollars	913	859	900	902	880
Exports, value, million dollars	17	13	12	13	13
Consumption, apparent, value, million dollars[3]	1,000	951	996	991	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	89	90	87

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

Import Sources (2019–22, by value): All dimension stone: Brazil, 22%; China,[6] 19%; Italy, 16%; Turkey, 14%; and other, 29%. Granite only: Brazil, 45%; India, 23%; China,[6] 17%; Italy, 5%; 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 2023. In 2023, the value of domestic sales of dimension stone was estimated to have decreased by 3% compared with that in 2022. The funding of construction projects continued through the 2021 Infrastructure Investment and Jobs Act with over $370 billion in awards announced. In 2023, U.S construction spending increased by an estimated 6% from that in 2022. However, there was an estimated 13% decrease in new housing starts.

The Dimension Stone Committee of the standard development organization named ASTM International has proposed a new standard that tests the physical properties of dimension and other natural building stone under freeze-thaw conditions. The testing procedures would produce additional data on the mechanical performance of different building stones that are subjected to especially cold and harsh environments.

The dimension stone industry continued to address safety and health regulations and environmental restrictions in 2023, 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]
	2022	2023[e]	
United States	2,380	2,300	Adequate, except for certain special types and local shortages.
Other countries	NA	NA	
World total	NA	NA	

World Resources:[7] Dimension stone resources of the world are sufficient. Resources can be limited on a local level or occasionally on a regional level by the lack of a particular kind of stone that is suitable for dimension purposes.

Substitutes: Substitutes for dimension stone include aluminum, brick, ceramic tile, concrete, glass, plastics, resin-agglomerated stone, and steel.

[e]Estimated. NA Not available.
[1]See also 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, strontium content, unless otherwise specified)

Domestic Production and Use: Although deposits of strontium minerals occur widely throughout the United States, none have been mined since 1959. Large-scale 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 estimated to have been used as an additive in drilling fluids for oil and natural-gas wells. A few domestic companies manufactured and (or) distributed small quantities of downstream strontium chemicals from imported strontium carbonate.

Based on import data, the estimated end-use distribution in the United States for strontium, including celestite and strontium compounds, was ceramic ferrite magnets, 29%; pyrotechnics and signals, 29%; drilling fluids, 23%; and other uses, including electrolytic production of zinc, master alloys, pigments and fillers, and other applications, including glass, 19%.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production	—	—	—	—	—
Imports for consumption:					
Celestite[1]	7,960	1,060	106	7,200	1,100
Strontium compounds[2]	5,560	4,440	5,020	5,850	3,700
Exports, strontium compounds[3]	20	32	6	15	79
Consumption, apparent:[4]					
Celestite	7,960	1,060	106	7,200	1,100
Strontium compounds	5,540	4,410	5,010	5,840	3,600
Total	13,500	5,470	5,120	13,000	4,700
Price, average unit value of celestite imports at port of exportation, dollars per ton	82	90	210	114	79
Net import reliance[4] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2019–22): Celestite: Mexico, 100%. Strontium compounds: Germany, 50%; Mexico, 43%; China, 3%; and other, 4%. Total imports: Mexico, 68%; Germany, 28%; China, 2%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 decreased by 64% in 2023 compared with that in 2022. Apparent consumption of strontium compounds decreased by 38%, and apparent consumption of celestite decreased by 85%. The decrease in 2023 was likely the result of decreased drilling activity as well as decreased consumption of strontium compounds for various end uses, owing to economic considerations such as inflation and ongoing supply chain logistical issues. World celestite production in 2023 was estimated to have remained essentially unchanged from that in 2022.

The final 2022 U.S critical minerals list published in the Federal Register (87 FR 10381) did not include strontium as a critical mineral. The list is to be updated every 3 years and revised as necessary consistent with available data. The U.S. Department of Energy evaluated strontium for the 2023 final critical materials list, but strontium did not meet the threshold for criticality assessment and was considered a lower risk material. After similar evaluations, strontium was variously considered critical or not critical on minerals lists developed by several other countries and regions. In 2023, strontium was identified as a critical raw material by the European Union, and strontium was also included on the first critical minerals list released by India.

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STRONTIUM

Imports of celestite decreased by 85%, likely the result of decreased use of celestite in natural-gas- and oil-well-drilling fluids. The average active rig count[5] was essentially unchanged in the first 9 months in 2023 compared with that in the same period in 2022 but remained 28% lower than that in the same period in 2019 before the global coronavirus disease 2019 (COVID-19) pandemic in 2020. 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; however, barite is preferred over celestite for drilling mud. 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 strontium carbonate was not produced in the United States, in July, an Australia-based company announced its acquisition of an 80% interest in a strontium deposit in California and planned to undertake an exploration program for mineralization. Celestite is the raw material from which strontium carbonate and other strontium compounds are produced.

Strontium carbonate is the most 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 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 decreased by 37% in 2023.

World Mine Production and Reserves:[6] Reserves for China and Iran were revised based on Government reports.

	Mine production[e]		Reserves[7]
	2022	2023	
United States	—	—	NA
Argentina	700	700	NA
China	80,000	80,000	12,000,000
Iran	200,000	200,000	7,100,000
Mexico	[8]33,800	35,000	NA
Spain	200,000	200,000	NA
World total (rounded)	514,000	520,000	Large

World Resources:[7] World resources of strontium may exceed 1 billion tons.

Substitutes: Barium can be substituted for strontium in ceramic ferrite 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%); oxide, hydroxide, and peroxide (70%); 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 number 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]Source: Baker Hughes Co., 2023, Rig count overview & summary count: Baker Hughes Co., accessed October 20, 2023, at https://rigcount.bakerhughes.com/na-rig-count.

[6]Gross weight of celestite in metric tons.

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

[8]As reported by the National Statistical and Geographic Information System (INEGI).

SULFUR

(Data in thousand metric tons, sulfur content, unless otherwise specified)

Domestic Production and Use: In 2023, recovered elemental sulfur and byproduct sulfuric acid were produced at 86 operations in 26 States. Total shipments were valued at about $860 million. Elemental sulfur production was estimated to be 8.0 million tons; Louisiana and Texas accounted for about 52% of domestic production. Elemental sulfur was recovered, in descending order of tonnage, at petroleum refineries, natural-gas-processing plants, and coking plants by 31 companies at 81 plants in 25 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 66% of domestic consumption, and byproduct sulfuric acid accounted for about 6%. The remaining 28% 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:	2019	2020	2021	2022	2023[e]
Production:					
Recovered elemental	8,110	7,310	7,460	8,000	8,000
Other forms	596	581	600	636	600
Total (rounded)	8,710	7,890	8,060	8,640	8,600
Shipments, all forms	8,700	7,900	8,050	8,620	8,600
Imports for consumption:					
Recovered elemental[e]	1,850	2,230	2,370	1,670	1,500
Sulfuric acid	971	1,190	1,070	1,060	1,100
Exports:					
Recovered elemental	2,200	1,330	1,900	1,740	1,800
Sulfuric acid	72	64	129	123	60
Consumption, apparent, all forms[1]	9,250	9,940	9,460	9,480	9,400
Price, average unit value, free on board, mine and (or) plant, dollars per metric ton of elemental sulfur	51.10	24.60	90.90	178.5	100
Stocks, producer, yearend	124	109	113	126	100
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	6	21	15	9	8

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 (2019–22): Elemental: Canada, 77%; Russia, 10%; Kazakhstan, 9%; and other, 4%. Sulfuric acid: Canada, 57%; Mexico, 20%; Spain, 7%; and other, 16%. Total sulfur imports: Canada, 70%; Mexico, 7%; Russia, 7%; Kazakhstan, 6%; and other, 10%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023 was estimated to be unchanged from that in 2022, and shipments to be essentially unchanged from those in 2022. Domestic production of elemental sulfur from petroleum refineries and recovery from natural gas operations was estimated to have remained the same. 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 2023 was estimated to have increased from that in 2022, which resulted in the higher 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 west Asia.

World sulfur production was unchanged compared with that in 2022. Starting in 2023, sulfur production from the Middle East owing to upgrades and new refining projects will begin to increase sulfur availability. Also, an increase in nickel production from high-pressure acid leach projects to produce battery materials will begin to increase sulfur demand.

Contract sulfur prices in Tampa, FL, began 2023 at around $90 per long ton. The sulfur price increased to $130 per long ton in mid-January, and then decreased to $55 per long ton in mid-July. Fourth quarter 2023 prices were $102 per long ton. In the past few years, sulfur prices have been variable, a result of the volatility in the demand for sulfur.

World Production and Reserves:

	Production, all forms	
	2022	2023[e]
United States	8,640	8,600
Australia	900	900
Canada	4,900	4,900
Chile	1,400	1,400
China[4]	18,800	19,000
Finland	640	640
Germany	610	610
India	3,540	3,500
Iran	1,600	1,600
Japan	3,140	3,100
Kazakhstan	4,300	4,300
Korea, Republic of	3,080	3,100
Kuwait	600	600
Poland	1,050	1,100
Qatar	2,100	2,100
Russia	7,530	7,000
Saudi Arabia	7,500	8,000
Turkmenistan	860	860
United Arab Emirates	5,400	5,400
Other countries	5,600	5,600
World total (rounded)	82,000	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 specified)

Domestic Production and Use: Three companies operated five talc-producing mines in three States during 2023, and domestic production of crude talc was estimated to have decreased to 450,000 tons valued at $22 million. Talc was mined in Montana, Texas, and Vermont. Total sales (domestic and export) of talc by U.S. producers were estimated to be 460,000 tons valued at about $140 million. Talc produced and sold in the United States was used in plastics, 30%; ceramics (including automotive catalytic converters), 27%; paint, 17%; paper, 9%; roofing, 8%; and rubber, 5%. The remaining 4% was for agriculture, cosmetics, export, insecticides, and other miscellaneous uses.

Two companies in North Carolina mined and processed pyrophyllite in 2023. Domestic production data were withheld to avoid disclosing company proprietary data and were estimated to have decreased from those in 2022. Pyrophyllite was sold for ceramic, paint, and refractory products.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production, mine	578	491	577	511	450
Sold by producers	515	461	556	548	460
Imports for consumption	280	189	278	346	230
Exports	229	186	232	196	200
Consumption, apparent[2]	566	464	602	698	490
Price, average, milled, dollars per metric ton[3]	240	265	321	303	300
Employment, mine and mill, number:[4]					
Talc	208	187	334	316	350
Pyrophyllite	30	31	32	35	38
Net import reliance[5] as a percentage of apparent consumption	9	1	8	21	6

Recycling: Insignificant.

Import Sources (2019–22): Pakistan, 52%; Canada, 25%; China,[6] 13%; and other, 10%. 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 12–31–23
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 of United States talc imports in recent years. Imports of talc and related materials were estimated to have decreased by about 33% in 2023 compared with those in 2022. Imports from Pakistan decreased by more than 50% in 2023 and accounted for about 33% of total imports. Imports from Canada were about the same as those in 2022 and supplied 24% of the total. Imports from China doubled and accounted for approximately 23% of total imports. Mexico, Canada, and Belgium, in descending order of quantity, were the primary destinations for United States talc exports, collectively receiving about 70% of exports. Exports were estimated to have remained essentially the same as those in 2022. U.S. talc consumption, imports, production, and sales were estimated to have decreased in 2023.

A talc mining company headquartered in New York announced in June that its subsidiary planned to end talc mining in the next few years. The subsidiary had talc mining and processing facilities in Montana and Texas. In October, it announced that its subsidiary filed for Chapter 11 bankruptcy. These decisions were made in part owing to the talc industry's multiple legal disputes and concerns about the safety of talc used to manufacture certain products, such as baby powder and cosmetics.

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TALC AND PYROPHYLLITE

In August 2022, a consumer products company headquartered in New Jersey announced plans to discontinue sales of talc-based baby powder globally in 2023, 3 years after it ended sales of the product in North America. The company is following an industry trend to substitute cornstarch for talc in baby powder and cosmetics.

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.

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

	Mine production[e]		Reserves[7]
	2022	2023	
United States (crude)	[8]511	450	140,000
Afghanistan	370	370	Large
Brazil (crude and beneficiated)[9]	600	600	45,000
Canada (unspecified minerals)[9]	200	200	NA
China (unspecified minerals)	1,100	1,100	72,000
Finland	[8]242	240	Large
France (crude)	350	400	Large
India[9]	1,630	1,600	110,000
Italy (includes steatite)	180	180	NA
Japan[9]	136	140	100,000
Korea, Republic of[9]	[8]323	320	81,000
Pakistan	[8]300	300	NA
South Africa[9]	[8]439	370	NA
Turkey	[8]43	40	15,000
Other countries (includes crude)[9]	707	700	Large
World total (rounded)	7,130	7,000	Large

World Resources:[7] The United States is self-sufficient in most grades of talc and related minerals, but lower priced imports have replaced domestic minerals for some uses. Talc occurs in the United States from New England to Alabama in the Appalachian Mountains and the Piedmont region, as well as in California, Montana, Nevada, Texas, and Washington. Domestic and world identified resources are estimated to be approximately five times the quantity of reserves.

Substitutes: Substitutes for talc include bentonite, chlorite, feldspar, kaolin, and pyrophyllite in ceramics; chlorite, kaolin, and mica in paint; calcium carbonate and kaolin in paper; bentonite, kaolin, mica, and wollastonite in plastics; and kaolin and mica in rubber.

[e]Estimated. NA Not available.
[1]All statistics do not include pyrophyllite unless otherwise specified.
[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]Reported.
[9]Includes pyrophyllite.

TANTALUM

(Data in metric tons, tantalum content, unless otherwise specified)

Domestic Production and Use: Tantalum has not been mined in the United States since 1959. Domestic tantalum resources are 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. The value of tantalum consumed in 2023 was estimated to exceed $205 million as measured by the value of imports.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:					
Mine	—	—	—	—	—
Secondary	NA	NA	NA	NA	NA
Imports for consumption[1]	1,350	1,200	1,330	1,720	1,100
Exports[1]	427	434	655	662	680
Shipments from Government stockpile[2]	—	−16	−10	—	NA
Consumption, apparent[3]	919	753	663	1,060	[4]370
Price, tantalite, annual average, dollars per kilogram of Ta_2O_5 content[5]	161	158	158	214	190
Net import reliance[6] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Tantalum was recycled mostly from new scrap 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 (2019–22): Tantalum ores and concentrates: Australia, 54%; Congo (Kinshasa), 11%; Rwanda, 9%; Mozambique, 7%; and other, 19%. Tantalum metal and powder: China,[7] 42%; Germany, 27%; Kazakhstan, 13%; Thailand, 7%; and other, 11%. Tantalum waste and scrap: Indonesia, 26%; China,[7] 15%; Japan, 14%; Republic of Korea, 7%; and other, 38%. Total: China,[7] 24%; Germany, 13%; Australia, 11%; Indonesia, 9%; and other, 43%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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	2825.90.9000	3.7% ad valorem.
Potassium fluorotantalate	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, wrought:		
Crucibles	8103.91.0000	4.4% ad valorem.
Other	8103.99.0000	4.4% ad valorem.

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

Government Stockpile:[8]

	FY 2023		FY 2024	
Material	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Tantalum metal	—	0.09	24.00	0.09

Events, Trends, and Issues: U.S. tantalum apparent consumption was estimated to be 370 tons, a 65% decrease from that in 2022, and estimated U.S. imports for consumption decreased by 39% compared with those in 2022. The significant decrease in U.S. tantalum imports in 2023 is a reflection of a broader trend in the global market, primarily owing to a decrease in consumer electronics and data center demand. Additionally, the trade has been affected by increased stockpiles after the global coronavirus disease 2019 (COVID-19) pandemic, owing to double ordering influenced by logistics and lead times during the pandemic. Concurrently, estimated U.S. exports increased by 3% in 2023, highlighting a disparity between import and export trends. The value of waste and scrap imports had the most significant increase of 24% compared with that in 2022. In 2023, the average monthly price for tantalum ore was valued at $190 per kilogram of Ta_2O_5 content, a decrease of 8% compared with that in 2022.

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TANTALUM

In October, the United States updated the Export Administration Regulations, which introduced new classifications and broadened restrictions on controlled semiconductor manufacturing items. It also added new license exceptions and detailed compliance guidance, refined controls on United States persons in technology development in China, and expanded geographical destination controls.

Also in October, the United States and several additional entities signed an agreement on the development of the Lobito Corridor and the Zambia-Lobito Rail Line connecting Congo (Kinshasa) and Zambia to Angola's Port of Lobito. When complete, the project is expected to reduce transportation time, lower costs, and decrease the carbon footprint associated with exporting metals and other products.

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

	Mine production		Reserves[9]
	2022	2023[e]	
United States	—	—	—
Australia	46	43	[10]110,000
Brazil	[e]370	360	40,000
Burundi	[e]59	36	NA
China	[e]78	79	240,000
Congo (Kinshasa)	[e]890	980	NA
Nigeria	[e]110	110	NA
Russia	[e]31	20	NA
Rwanda	[e]347	520	NA
Other	[e]120	260	NA
World total (rounded)	1,990	2,400	NA

World Resources:[9] 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 2023 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 50% Ta_2O_5. Tantalum ores and concentrates were assumed to contain 32% Ta_2O_5. Niobium ores and concentrates were assumed to contain 28% 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. Beginning in 2023, Government stock changes no longer available.
[3]Defined for 2019–22 as production + imports – exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.
[4]Decrease in apparent consumption is due to a decline in imports for consumption caused by stockpiling in 2022.
[5]Sources: CRU Group (2019–21) and the Institute for Rare Earths and Metals (2022–23).
[6]Defined for 2019–22 as imports – exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.
[7]Includes Hong Kong.
[8]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 28,000 tons.

TELLURIUM

(Data in metric tons, tellurium content, unless otherwise specified)

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 2023, 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 both domestic facilities was exported for further processing. 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 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:	2019	2020	2021	2022	2023[e]
Production, refinery[1]	W	W	W	W	W
Imports for consumption	59	12	42	37	10
Exports	1	([2])	2	1	3
Consumption, apparent[3]	W	W	W	W	W
Price, average, dollars per kilogram:					
United States[4]	68.11	59.37	69.72	70.34	80
Europe[5]	60.45	56.05	67.26	68.10	78
Stocks, producer, yearend	W	W	W	W	W
Net import reliance[6] as a percentage of apparent consumption	>95	>75	>95	>75	>25

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 (2019–22): Canada, 38%; Germany, 34%; Philippines, 15%; Japan, 6%; and other, 7%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
Tellurium	2804.50.0020	Free.

Depletion Allowance: 14% (domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The supply of tellurium is directly affected by the supply of materials from which it is a byproduct, primarily copper. In 2023, recovery of copper telluride from domestic copper anode slimes was estimated to have decreased from that in 2022, reflecting lower output of copper cathode from electrolytic refineries in the United States. In July 2023, the leading U.S. producer of solar modules announced plans to build a fifth plant in the United States that would increase the company's domestic manufacturing capacity to 14 gigawatts (GW) of solar modules by 2026. The annual average price for tellurium in U.S. warehouses increased by 14% to an estimated $80 per kilogram in 2023 from $70.34 per kilogram in 2022, primarily owing to strong global demand.

In 2023, China was the leading producer of refined tellurium and accounted for 67% of estimated global output. A new refinery in China with a production capacity of 50 tons per year of tellurium was expected to begin operating in October. The Government of India selected 11 companies to construct approximately 40 GW of photovoltaic manufacturing capacity, a fourfold increase from current capacity. Estimated end uses for tellurium in global consumption were solar power cells, 40%; thermoelectric production, 30%; metallurgy, 15%; rubber applications, 5%; and other, 10%.

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TELLURIUM

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, which represent reported reserves of tellurium. Reserves for China and Russia were revised based on Government reports, and reserves for Sweden, the United States, and "Other countries" were revised based on company reports.

	Refinery production[e, 7]		Reserves[8]
	2022	2023	
United States	W	W	4,000
Bulgaria	3	3	NA
Canada	24	27	800
China	380	430	3,100
Japan	68	75	—
Russia	70	75	5,800
South Africa	4	5	800
Sweden	[9]33	25	700
Uzbekistan	[9]3	3	NA
Other countries[10]	NA	NA	21,000
World total (rounded)	[11]584	[11]640	36,000

World Resources:[8] 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]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 Non-Ferrous Markets.
[5]Average annual price for 99.99%-maximum-purity tellurium, in warehouse, Rotterdam. Source: Argus Media Group, Argus Non-Ferrous Markets.
[6]Defined as imports – exports ± adjustments for industry stock changes.
[7]Insofar as possible, data relate to refinery output only; countries that produced tellurium contained in blister copper, copper anodes, copper concentrates, copper ores, and (or) refinery residues but did not recover tellurium from these materials were excluded.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]Reported.
[10]In addition to the countries listed, Australia, Belgium, Chile, Germany, Indonesia, Kazakhstan, Mexico, and the Philippines may have produced refined tellurium, but available information was inadequate to make reliable estimates of output.
[11]Excludes U.S. production.

THALLIUM

(Data in kilograms unless otherwise specified)

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, a component in high-density liquids for gravity separation of minerals, and a component in wear-resistant nanocoatings such as that used on jet engine thrust vector bearings.

Salient Statistics—United States:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production, refinery	—	—	—	—	—
Imports for consumption:					
Unwrought metal and metal powders	—	57	—	—	13
Waste and scrap	27	—	—	13	—
Other articles	38	—	7	—	[1]300
Exports:					
Unwrought metal and powders	290	300	190	—	—
Waste and scrap	133	359	—	—	—
Other articles	[1]79,100	580	378	2,150	4,000
Consumption, estimated[2]	65	57	7	13	13
Price, metal, dollars per kilogram[e, 3]	7,600	8,200	8,400	9,400	8,800
Net import reliance[4] as a percentage of estimated consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2019–2022): Russia, 40%; China, 25%; Norway, 19%; France, 9%; Israel, 5%; and United Kingdom, 2%.

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.

Events, Trends, and Issues: In 2023, Oak Ridge National Laboratory announced the development of a safe method of producing thallium metal foils, which it had begun producing at their facility in Tennessee. Commercially sourced metal was consolidated into an ingot in a special furnace and used to produce 40 non-isotopic foils. In the United States, thallium foils were last produced in 2007 at Oak Ridge National Laboratory but discontinued because of safety issues. No commercial sources are available because of the safety risks. The initiative began in 2021 with the goal to supply national laboratories across the United States with thallium foils for applications in the production of radioisotopes.

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THALLIUM

As of September 2023, there were no imports or exports of unwrought thallium metal or of waste and scrap. Data on inventory drawdown of thallium for domestic use were not available. In 2023, estimated exports of thallium articles increased from those in 2022 and were significantly more than estimated imports. Although not an import source in the previous 4 years, all imports as of September 2023 were from Mexico. The minor quantities of imports suggest that inventories of thallium remain adequate for domestic needs and for production of articles for export. In 2019, reported exports of thallium articles had been unusually high in quantity; these exports had likely been misclassified material.

The leading global uses for thallium were gamma radiation detection equipment, high-temperature superconductors, infrared optical materials, low-melting glass, 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. 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.

World Refinery Production and Reserves:[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 2023, 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.

World Resources:[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 from 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.

Substitutes: 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 for 2019–2022. In 2023, consumption estimated to be equal to imports of unwrought metal and metal powders.

[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 unless otherwise specified)

Domestic Production and Use: The world's primary source of thorium is the rare-earth and thorium phosphate mineral monazite. In 2023, 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 2023 was $921,000 (based on data through August 2023), compared with $56,800 in 2022.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production, mine (monazite)[1]	[2]1,700,000	[2]960,000	W	W	W
Imports for consumption:					
Ore and concentrates (monazite)	—	3,000	16,000	—	—
Compounds (oxide, nitrate, and so forth)	3,970	1,920	5,790	1,930	13,000
Exports:					
Ore and concentrates (monazite)	1,680,000	958,000	—	22,000	—
Compounds (oxide, nitrate, and so forth)[3]	154,000	60,300	45,600	25,900	67,000
Consumption, apparent:[4]					
Ore and concentrates (monazite)	—	3,000	W	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	NA	NA	NA	74
France	29	29	29	26	29
Net import reliance[6] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2019–22): Ores and concentrates (monazite): China, 84%, and United Kingdom, 16%. Thorium compounds: France, 85%; India, 15%; and other, <1%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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.

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THORIUM

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.

Exports of unspecified thorium compounds were 63,200 kilograms through August 2023 with average unit values ranging from $29 per kilogram to $74 per kilogram and averaged $69 per kilogram. Owing to 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. Australia, Madagascar, and Thailand were the leading producing countries of monazite, in descending order of gross weight 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; Madagascar, Thailand, Nigeria, and Vietnam were China's leading import sources, in descending order of quantity.

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, thorianite, and thorite. 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, tin content, unless otherwise specified)

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 93% of the primary tin consumed domestically in 2023. The uses for tin in the United States were tinplate, 23%; chemicals, 22%; alloys and solder, 11% each; babbitt, brass and bronze, and tinning, 7%; bar tin, 2%; and other, 24%. Based on the average S&P Global Platts Metals Week New York dealer price for tin, the estimated value of imported refined tin in 2023 was $840 million, and the estimated value of tin recovered from old scrap domestically in 2023 was $280 million.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production, secondary:[e]					
Old scrap	10,500	9,550	9,860	9,430	10,000
New scrap	8,100	8,000	7,600	3,900	6,900
Imports for consumption:					
Refined	34,100	31,600	38,100	33,200	30,000
Tin alloys, gross weight	1,020	840	1,110	740	990
Tin waste and scrap, gross weight	30,400	20,700	18,600	11,600	9,200
Exports:					
Refined	1,300	519	1,290	1,310	1,100
Tin alloys, gross weight	1,200	1,130	630	530	700
Tin waste and scrap, gross weight	2,470	1,200	2,800	30,400	38,000
Shipments from Government stockpile, gross weight[1]	18	–7	437	—	NA
Consumption, apparent, refined[2]	43,200	40,600	48,500	41,400	39,000
Price, average, cents per pound:[3]					
New York dealer	868	799	1,580	1,546	1,300
London Metal Exchange (LME), cash	846	777	1,478	1,423	1,200
Stocks, consumer and dealer, yearend	10,200	10,400	9,010	8,930	8,800
Net import reliance[4] as a percentage of apparent consumption, refined	76	76	81	77	74

Recycling: About 17,000 tons of tin from old and new scrap was estimated to have been recycled in 2023. Of this, about 10,000 tons was recovered from old scrap at 1 detinning plant and about 29 secondary nonferrous-metal-processing plants, accounting for 25% of apparent consumption.

Import Sources (2019–22): Refined tin: Peru, 27%; Bolivia, 21%; Indonesia, 20%; Malaysia, 11%; and other, 21%. Waste and scrap: Canada, 96%; Mexico, 3%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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]

	FY 2023		FY 2024	
Material	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Tin (gross weight)	—	688	—	640

Events, Trends, and Issues: The estimated amount of new and old scrap tin recycled domestically in 2023 increased by 27% compared with that in 2022. The estimated annual average New York dealer price for refined tin in 2023 was 1,300 cents per pound, a 18% decrease compared with that in 2022. The estimated annual average LME

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TIN

cash price for refined tin in 2023 was 1,200 cents per pound, a 16% decrease compared with that in 2022. In 2023, the monthly average New York dealer tin price decreased from January to October, apart from June and July, when the price increased by 4% and 7%, respectively.

In March, energy supply troubles led a Bolivian tin producer to declare force majeure. The company was unable to secure sufficient coal from Peru to fully power its primary tin smelter, decreasing tin production by up to 200 tons per week. Protests along the Peruvian border have reportedly impeded trade of coal into Bolivia. In April, Burma's self-administered Wa State announced that beginning in August it would halt mining operations in areas under its control. The suspension is expected to protect mineral resources until new mining regulations are implemented. In August, all mining, processing, and raw ore transportation activities ceased. Most of Burma's tin was mined within areas administered by the Wa State.

In October 2023, Indonesia's Ministry of Energy and Mineral Resources added tin to its list of critical minerals owing to its supply, economic significance, and applications in high-tech industries. The strategic move is expected to strengthen and prioritize the sustainable management of its mineral resources, streamline the industry's regulatory framework, and improve processing practices within the sector.

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

	Mine production		Reserves[6]
	2022	2023[e]	
United States	—	—	—
Australia	9,000	9,100	[7]620,000
Bolivia	17,600	18,000	400,000
Brazil	[e]17,000	18,000	420,000
Burma	[e]47,000	54,000	700,000
China	[e]71,000	68,000	1,100,000
Congo (Kinshasa)	[e]18,600	19,000	120,000
Indonesia	[e]70,000	52,000	NA
Laos	2,510	2,300	NA
Malaysia	[e]5,000	6,100	NA
Nigeria	[e]7,000	8,100	NA
Peru	28,200	23,000	130,000
Russia	[e]3,700	2,700	460,000
Rwanda	[e]3,300	3,800	NA
Vietnam	[e]5,900	5,300	11,000
Other countries	1,160	1,300	310,000
World total (rounded)	307,000	290,000	4,300,000

World Resources:[6] Identified resources of tin in the United States, primarily in Alaska, were insignificant compared with those in 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. Beginning in 2023, Government stock changes no longer available.

[2]Defined for 2019–22 as production from old scrap + refined tin imports – refined tin exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.

[3]Source: S&P Global Platts Metals Week.

[4]Defined for 2019–22 as refined imports – refined exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.

[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 320,000 tons.

TITANIUM AND TITANIUM DIOXIDE[1]

(Data in metric tons unless otherwise specified)

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 idle since 2016.

Although detailed 2023 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 $420 million, a significant increase compared with $273 million in 2022.

In 2023, titanium dioxide (TiO_2) pigment production, by four companies operating five facilities in four States, was valued at about $3 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:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Titanium sponge metal:					
Production	W	W	W	W	W
Imports for consumption[e]	30,000	19,200	16,000	30,900	42,000
Exports	869	711	117	105	200
Consumption, apparent[2]	W	W	[3]15,900	[3]30,800	[3]42,000
Consumption, reported	W	W	W	W	W
Price, dollars per kilogram[4]	10.70	10.60	11.20	11.10	12
Stocks, industry, yearend[e]	W	W	W	W	W
Employment, number[e]	150	150	20	20	20
Net import reliance[5] as a percentage of apparent consumption	>50	>50	>95	>95	>95
TiO_2 pigment:					
Production	1,000,000	1,000,000	1,150,000	1,150,000	920,000
Imports for consumption	226,000	262,000	251,000	265,000	240,000
Exports	401,000	386,000	494,000	378,000	280,000
Consumption, apparent[2]	825,000	880,000	906,000	1,040,000	880,000
Price, dollars per metric ton[4]	2,750	2,710	2,920	3,450	3,300
Employment, number[e]	3,050	3,100	3,200	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 for titanium scrap metal for the titanium metal industry were withheld. Consumption data for titanium scrap for the steel, superalloy, and other industries were not available.

Import Sources (2019–22): Sponge metal: Japan, 86%; Kazakhstan, 10%; Saudi Arabia, 2%; Ukraine, 1%; and other, 1%. TiO_2 pigment: Canada, 45%; China, 10%; Germany, 8%; Spain, 5%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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:[6]

Material	FY 2023 Potential acquisitions	FY 2023 Potential disposals	FY 2024 Potential acquisitions	FY 2024 Potential disposals
Titanium	15,000	—	15,000	—

Events, Trends, and Issues: The 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. Demand from the aerospace and other industries resulted in a 35% increase in imports compared with those in 2022, a record-high 42,000 tons. Japan (77%), Saudi Arabia (13%), and Kazakhstan (9%) were the leading import sources for titanium sponge in 2023.

U.S. imports of titanium scrap were about 26,000 tons. The United Kingdom (16%), France, Germany, and Japan (13% each), Canada (9%), and Mexico (7%) were the leading import sources for titanium waste and scrap in 2023. In 2023, the annual average duty-paid unit value of scrap imports was about \$9.30 per kilogram compared with \$7.90 per kilogram in 2022. China led a global increase in sponge production and capacity. Sponge production in Zaporozhye, Ukraine, was idled because of the conflict with Russia. Although limited data were available for 2023, in 2022, global imports of unwrought and wrought titanium metal from Russia were 4,000 and 14,000 metric tons, respectively.

Domestic production of TiO_2 pigment in 2023 was an estimated 920,000 tons. Although heavily reliant on imports of titanium mineral concentrates, the United States was a net exporter of TiO_2 pigments. Owing to reduced global and domestic demand, both exports and imports of TiO_2 pigments decreased in 2023. China continued an unprecedented expansion in TiO_2 production and capacity.

World Sponge Metal Production and Sponge and Pigment Capacity:

	Sponge production[e]		Capacity, 2023[7]	
	2022	2023	Sponge	Pigment
United States	W	W	500	1,360,000
Australia	—	—	—	260,000
Canada	—	—	—	108,000
China	180,000	220,000	260,000	5,500,000
Germany	—	—	—	339,000
India	300	300	500	91,000
Japan	47,000	60,000	65,200	322,000
Kazakhstan	15,000	14,000	26,000	—
Mexico	—	—	—	350,000
Russia	20,000	20,000	46,500	55,000
Saudi Arabia	9,700	12,000	15,600	200,000
Ukraine	1,000	—	—	122,000
United Kingdom	—	—	—	315,000
Other countries	—	—	—	820,000
World total (rounded)	[8]270,000	[8]330,000	410,000	9,800,000

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. 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]See Appendix B for definitions.
[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, titanium dioxide (TiO_2) content, unless otherwise specified]

Domestic Production and Use: In 2023, 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. Abrasive sands, monazite, and zircon were coproducts of domestic titanium minerals mining operations. Based on trade data through August, the estimated value of titanium mineral and synthetic concentrates imported into the United States in 2023 was $600 million. 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:	2019	2020	2021	2022	2023[e]
Production[2]	100	100	100	200	200
Imports for consumption	1,160	807	969	950	670
Exports, all forms[e]	8	18	30	110	70
Consumption, apparent[2, 3]	1,300	900	1,000	1,000	800
Price, dollars per metric ton:					
Rutile, bulk, minimum 95% TiO_2, free on board (f.o.b.) Australia[4]	1,110	1,170	1,300	1,470	1,490
Ilmenite and leucoxene, bulk, f.o.b. Australia[5]	478	459	595	530	330
Ilmenite, average unit value of imports[6]	186	215	240	285	390
Slag, 80%–95% TiO_2, average unit value of imports[6]	792	757	774	867	1,000
Employment, mine and mill, number	310	315	290	305	410
Net import reliance[7] as a percentage of apparent consumption	92	89	90	81	75

Recycling: None.

Import Sources (2019–22): South Africa, 37%; Madagascar, 16%; Australia, 12%; Canada, 10%; and other, 25%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 closely 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. Although inventory changes were not included in the apparent consumption calculation, domestic apparent consumption of titanium mineral concentrates in 2023 was estimated to have decreased significantly from that in 2022. The decrease in apparent consumption was the result of a reduction in imports. Exports of titanium mineral concentrates also decreased significantly and were primarily in the form of mixed concentrates derived from mine tailings.

In 2023, as of August, Canada (60%) and South Africa (30%) were the leading sources of titanium slag imports into the United States. Mozambique (43%), Madagascar (22%), and Senegal (20%) were leading sources of ilmenite, and South Africa (61%), Australia (32%), and Kenya (7%) were the leading sources of rutile. There were no imports of synthetic rutile.

In 2023, China continued to be the leading producer and consumer of titanium mineral concentrates, accounting for approximately 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 4.4 million tons in gross weight, a 27% increase compared with those in 2022. As of September, Mozambique (49%), Norway (10%), and Vietnam (7%) were the leading sources of titanium mineral concentrates to China.

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TITANIUM MINERAL CONCENTRATES

World Mine Production and Reserves: Reserves for Australia, Canada, China, Kenya, Madagascar, Mozambique, South Africa, and "Other countries" were revised based on company and Government reports.

	Mine production		Reserves[8]
	2022	2023[e]	
Ilmenite:			
United States[2, 9]	200	200	2,000
Australia	400	400	[10]180,000
Brazil	28	54	43,000
Canada[11]	520	500	52,000
China	3,140	3,100	210,000
India	210	210	85,000
Kenya	190	140	130
Madagascar[11]	320	320	27,000
Mozambique	1,400	1,600	22,000
Norway	410	430	37,000
Senegal	410	340	NA
South Africa[11]	1,100	1,000	28,000
Ukraine	190	60	5,900
Vietnam	170	140	1,600
Other countries	110	110	1,200
World total (ilmenite, rounded)[9]	8,800	8,600	690,000
Rutile:			
United States	([9])	([9])	([9])
Australia	200	200	[10]35,000
India	13	13	7,400
Kenya	73	58	70
Madagascar	—	—	520
Mozambique	8	9	720
Senegal	9	8	NA
Sierra Leone	130	110	2,900
South Africa	100	100	6,100
Ukraine	95	50	2,500
Other countries	10	10	20
World total (rutile, rounded)[9]	640	560	55,000
World total (ilmenite and rutile, rounded)	9,400	9,200	750,000

World Resources:[8] Ilmenite accounts for about 90% of the world's consumption of titanium minerals. World resources of anatase, ilmenite, and rutile total more than 2 billion tons.

Substitutes: Ilmenite, leucoxene, rutile, slag, and synthetic rutile compete as feedstock sources for producing TiO_2 pigment, titanium metal, and welding-rod coatings.

[e]Estimated. NA Not available. — 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; annual average.
[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]United States rutile production and reserves data are included with ilmenite.
[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were estimated to be 43 million tons for ilmenite and 11 million tons for rutile, respectively, TiO_2 content.
[11]Mine production of titaniferous magnetite is primarily used to produce titaniferous slag.

TUNGSTEN

(Data in metric tons, tungsten content, unless otherwise specified)

Domestic Production and Use: Tungsten has not been mined commercially in the United States 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 2023 was withheld to avoid disclosing company proprietary data.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production:					
Mine	—	—	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Ores and concentrates	2,760	2,020	1,600	2,130	1,500
Other forms[1]	11,100	8,660	10,500	12,300	10,000
Exports:					
Ores and concentrates	583	480	441	614	550
Other forms[2]	2,780	2,470	2,970	3,680	3,300
Shipments from Government stockpile:[3]					
Concentrate	663	728	1,030	689	NA
Other forms	—	34	93	—	NA
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]	198	172	225	275	260
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 2023 were withheld to avoid disclosing company proprietary data.

Import Sources (2019–22): Ores, concentrates, and other forms:[1] China,[8] 27%; Germany, 12%; Bolivia, 9%; Vietnam, 8%; and other, 44%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023		FY 2024	
Material	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Ores and concentrates	—	1,130	—	907
Tungsten	—	—	266	—

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TUNGSTEN

Events, Trends, and Issues: World tungsten supply was dominated by production in China and exports from China. Production of tungsten concentrate outside China was estimated to have increased in 2023 but remained less than 20% of world production. The increase was from existing operations and from the restart of production from a historic mine in Australia. Additional production, primarily from mines in the Republic of Korea, Russia, Spain, and the United Kingdom, was forecast to begin within a year or two. 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 2023, global tungsten consumption was forecast to decrease slightly from that in 2022.

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

	Mine production[e]		Reserves[10]
	2022	2023	
United States	—	—	NA
Australia	200	800	[11]570,000
Austria	910	910	10,000
Bolivia	1,360	1,500	NA
China	66,000	63,000	2,300,000
Korea, North	1,520	1,700	29,000
Portugal	500	500	4,000
Russia	2,000	2,000	400,000
Rwanda	1,400	1,400	NA
Spain	800	1,500	66,000
Vietnam	4,000	3,500	74,000
Other countries	1,080	1,100	950,000
World total (rounded)	79,800	78,000	4,400,000

World Resources:[10] 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 carbide powders; 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 carbide powders, 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. Beginning in 2023, Government stock changes no longer available.
[4]Defined for 2019–22 as mine production + secondary production + imports − exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.
[5]Source: Argus Media Group, Argus Tungsten Analytics.
[6]A metric ton unit of tungsten trioxide contains 7.93 kilograms of tungsten.
[7]Defined for 2019–22 as imports − exports ± adjustments for Government and industry stock changes. Beginning in 2023, Government stock changes no longer included.
[8]Includes Hong Kong.
[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 220,000 tons.

VANADIUM

(Data in metric tons, vanadium content, unless otherwise specified)

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 2023. 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. Estimated U.S. apparent consumption of vanadium in 2023 increased by 27% from that in 2022. Metallurgical use, primarily as an alloying agent for iron and steel, accounted for about 94% of domestic reported vanadium consumption in 2023. Of the other uses for vanadium, the major nonmetallurgical use was in catalysts to produce maleic anhydride and sulfuric acid.

Salient Statistics—United States:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production from primary ore and concentrate	460	17	—	—	—
Production from ash, residues, and spent catalysts[e]	3,000	2,900	3,200	4,400	5,700
Imports for consumption:					
Aluminum-vanadium master alloy	222	101	35	104	300
Ash and residues[1, 2]	2,120	1,550	1,680	2,240	3,100
Ferrovanadium	2,280	1,360	2,170	2,650	2,400
Oxides and hydroxides, other	105	67	69	222	100
Vanadium chemicals[3]	734	382	846	804	900
Vanadium metal[4]	45	([5])	([5])	18	35
Vanadium ores and concentrates[1]	108	2	4	492	500
Vanadium pentoxide	3,620	1,670	1,710	1,980	2,100
Exports:					
Aluminum-vanadium master alloy	29	14	72	28	30
Ash and residues[1]	1,280	503	930	1,130	1,000
Ferrovanadium	295	210	173	172	200
Oxides and hydroxides, other	750	51	235	309	200
Vanadium metal[4]	27	1	4	8	100
Vanadium ores and concentrates[1]	95	92	81	185	10
Vanadium pentoxide	423	50	17	143	5
Consumption:					
Apparent[6]	9,790	7,110	8,200	11,000	14,000
Reported	9,900	7,920	8,030	7,510	8,000
Price, average, vanadium pentoxide,[7] dollars per pound	12.17	6.68	8.17	9.25	9.25
Stocks, yearend[8]	257	269	271	248	250
Net import reliance[9] as a percentage of apparent consumption	65	59	61	60	58

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 (2019–22): Ferrovanadium: Canada, 46%; Austria, 33%; Russia, 8%; and other, 13%. Vanadium pentoxide: Brazil, 49%; South Africa, 36%; Germany, 4%; and other, 11%. Total: Canada, 28%; Brazil, 15%; Austria, 10%; Russia, 8%; and other, 39%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–23**
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: The estimated average Chinese vanadium pentoxide price in both 2022 and 2023 was $9.25 per pound. The estimated United States ferrovanadium price decreased by 25% to $17.89 per pound in 2023 compared with that in 2022. The World Steel Association forecast global steel consumption to increase by 2.3% in 2023 and by 1.7% in 2024. Total world steel production was unchanged during the first 8 months of 2023 compared with that in the same period in 2022. Like most ferroalloys, vanadium is largely dependent on the market characteristics of steel and specifically the Chinese steel industry. In 2023, China continued to be the world's top vanadium producer, producing most of its vanadium from vanadiferous iron ore processed for steel production.

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 continued to increase worldwide as energy companies looked to support renewable energy projects as many countries attempt to lower their carbon emissions. Project Blue and other analysts projected that the VRFB market would account for approximately 17% of vanadium consumption in 2033 compared with only 3% in 2021. The new supply of high-purity vanadium pentoxide needed to support the VRFB market was expected to come from either existing producers or from projects which are, for the vast majority, still in their very early phases of development. Despite the anticipated growth of VRFBs, there will be continued competition from a variety of alternative battery technologies looking to capture a portion of the energy storage market share.

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

	Mine production 2022	Mine production 2023[e]	Reserves[11] (thousand metric tons)
United States	—	—	45
Australia	—	—	[12]8,500
Brazil	5,840	6,400	120
China	66,900	68,000	4,400
Russia	[e]20,000	20,000	5,000
South Africa	8,870	9,100	750
World total (rounded)	102,000	100,000	19,000

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 kilograms of vanadium pentoxide. To convert vanadium pentoxide content to vanadium content, multiply by 0.56.
[2]Includes estimates for data suppressed by the U.S. Census Bureau in the years 2020 through 2023.
[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), vanadates (2841.90.1000), vanadium chlorides (2827.39.1000), and vanadium sulfates (2833.29.3000).
[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-compliant or equivalent reserves were 3 million tons.

VERMICULITE

(Data in thousand metric tons unless otherwise specified)

Domestic Production and Use: Two companies with mining and processing facilities in South Carolina and Virginia produced approximately 100,000 tons of vermiculite concentrate; data have been rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data. Flakes of raw vermiculite concentrate are micaceous in appearance and contain interlayer water in their structure. When the flakes are heated rapidly to a temperature above 870 degrees Celsius, the water flashes into steam, and the flakes expand into accordionlike particles. This process is called exfoliation or expansion, and the resulting ultralightweight material is chemically inert, fire resistant, and odorless. Most vermiculite concentrate, 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, 30%; lightweight concrete aggregates (including cement premixes, concrete, and plaster), 21%; insulation, 14%; and other, 35%.

Salient Statistics—United States:	2019	2020	2021	2022	2023[e]
Production[1, 2]	100	100	100	100	100
Imports for consumption[e]	39	40	33	24	40
Exports[e]	8	8	10	8	9
Consumption:					
Apparent, concentrate[e, 3]	130	130	120	120	130
Reported, exfoliated	76	74	68	67	74
Price, range of value, concentrate, ex-plant, dollars per metric ton	NA	NA	NA	NA	NA
Employment, number[e]	70	70	70	70	70
Net import reliance[4] as a percentage of apparent consumption[e, 5]	20	20	20	10	20

Recycling: Insignificant.

Import Sources (2019–22): South Africa, 60%; Brazil, 37%; Zimbabwe, 2%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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.

Events, Trends, and Issues: 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 an estimated 40,000 tons in 2023, compared with 24,000 tons in 2022. In 2023, most imports came from Brazil and South Africa.

A company in Brazil continued to develop an additional mine and production facility. The project, which is in Catalao, Goias State, is expected to begin production in 2024 with an initial production capacity of 20,000 tons per year of ore and with production capacity eventually reaching 60,000 tons per year, equaling that of their other operation. The majority of vermiculite from this new location is expected to be super fine grade.

Demand for all grades of vermiculite remained strong. 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. Producers are expected to continue investigating ways to increase the use of the finer grades in existing products and as a substitute for coarser grade vermiculite while continuing to develop new and innovative applications.

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VERMICULITE

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

	Mine production[e]		Reserves[6]
	2022	2023[e]	
United States	[1, 2]100	[1, 2]100	25,000
Brazil	70	70	6,600
Bulgaria	10	10	NA
China	39	39	2,900
India	4	4	1,600
Mexico	([7])	([7])	NA
Russia	29	29	NA
South Africa	[8]183	160	14,000
Turkey	3	10	11,000
Uganda	30	30	NA
Uzbekistan	3	3	NA
Zimbabwe	45	45	NA
World total (rounded)	516	500	NA

World Resources:[6] In addition to the producing mines in South Carolina and Virginia, there are vermiculite occurrences in Colorado, Nevada, North Carolina, Texas, and Wyoming that contain estimated resources of 2 million to 3 million tons. Significant deposits have been reported in Australia, Russia, Uganda, and some other countries, but reserve and resource information comes from many sources, and in most cases, it is not clear whether the numbers refer to vermiculite alone or vermiculite plus other minerals and host rock and overburden.

Substitutes: Expanded perlite is a substitute for exfoliated vermiculite in lightweight concrete and plaster. Other denser but less costly alternatives in these applications include expanded clay, shale, slag, and slate. Alternate materials for loose-fill fireproofing insulation include fiberglass, perlite, and slag wool. In agriculture, substitutes include bark and other plant materials, peat, perlite, sawdust, and synthetic soil conditioners.

[e]Estimated. NA Not available.
[1]Concentrate sold or used by producers.
[2]Data are rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data.
[3]Defined as concentrate sold or used by producers + imports – exports.
[4]Defined as imports – exports.
[5]Data are rounded to one significant digit to avoid disclosing company proprietary data.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]Less than ½ unit.
[8]Reported.

WOLLASTONITE

(Data in metric tons unless otherwise specified)

Domestic Production and Use: Wollastonite was mined by two companies in New York during 2023. 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 2022. 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 been essentially unchanged in 2023 compared with that in 2022. 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 a net exporter of wollastonite in 2023. 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 $380 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 75 people were employed at wollastonite mines and mills in 2023 (excluding office workers) in the United States.

Recycling: None.

Import Sources (2019–22): Comprehensive trade data were not available, but wollastonite was primarily imported from China and India.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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: The production of motor vehicles and parts, which contain wollastonite in friction products and plastic and rubber components, increased by 10% in the first 7 months of 2023. However, construction starts of new housing units through August 2023 decreased by 11% compared with those during the same period in 2022. Sales of wollastonite to domestic construction-related markets, such as adhesives, caulks, cement board, ceramic tile, paints, stucco, and wallboard, were estimated to have decreased. Sales of wollastonite were estimated to be slightly lower for primary iron and steel production, which decreased slightly in the first 7 months of 2023 compared with production during the same period in 2022.

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 800,000 to 1,000,000 tons, the same as those in 2022.

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]
	2022	2023	
United States	W	W	World resources of wollastonite are estimated 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	900,000	900,000	
India	100,000	100,000	
Mexico	85,000	80,000	
Other countries	15,000	15,000	
World total (rounded)[2]	1,120,000	1,100,000	

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, yttrium oxide (Y_2O_3) equivalent, unless otherwise specified]

Domestic Production and Use: Yttrium is one of the rare-earth elements. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined in 2023 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 the bastnaesite ore production. Monazite, a rare-earth phosphate mineral, was produced as a separated concentrate that includes yttrium-rich xenotime as part of the heavy-mineral concentrate. Both are accessory minerals in heavy-mineral-sand concentrates. There is no fully commercial rare-earth 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:	2019	2020	2021	2022	2023[e]
Production, mine	NA	NA	NA	NA	NA
Imports for consumption, yttrium, alloys, compounds, and metal[e, 2]	360	650	670	1,200	250
Exports, compounds[e, 3]	6	1	9	4	23
Consumption, apparent[e, 4]	400	600	700	1,000	200
Price, average, dollars per kilogram:[5]					
Y_2O_3, minimum 99.999% purity	3	3	6	12	8
Yttrium metal, minimum 99.9% purity	34	34	39	41	33
Net import reliance[6, 7] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Insignificant.

Import Sources (2019–22):[8] Yttrium compounds: China,[9] 94%; Germany, 2%; France, 1%; Republic of Korea, 1%; and other, 2%. 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 12–31–23
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] Not available.

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. In 2023, the average prices for yttrium metal and Y_2O_3 each decreased compared with those in 2022. China's Ministry of Industry and Information Technology raised quotas in 2023 for rare-earth mining and separation to 240,000 tons and 230,000 tons of rare-earth-oxide equivalent, respectively. The yttrium content of the production quota was not specified. Mine production quotas allocated 220,850 tons to light rare earths and 19,150 tons to ion-adsorption clays.

In 2023, China's exports of yttrium compounds and metal were estimated to be 2,900 tons of Y_2O_3 equivalent, and the leading export destinations were, in descending order, Japan, Italy, the United States, and the Republic of Korea. In 2022, China's exports of yttrium compounds and metal were 3,400 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.
[1]See also the Rare Earths chapter; trade data for yttrium are included in the data shown for rare earths.
[2]Estimated from USATrade, Trade Mining LLC, and Zen Innovations 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 Rare Earths.
[6]Defined as imports – exports.
[7]Domestic production of mineral concentrates was stockpiled or exported. Consumers of compounds and metals were reliant on imports and stockpiled inventory of compounds and metals.
[8]Includes estimated Y_2O_3 equivalent from the following Harmonized Tariff Schedule of the United States codes: 2846.90.2015, 2846.90.2082, 2846.90.4000, 2846.90.8050, and 2846.90.8060 (2019–21); and 2846.90.8075 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 specified)

Domestic Production and Use: In 2023, seven companies operated nine zeolite mines in six States and produced an estimated 84,000 tons of natural zeolites. Total production increased slightly compared with production in 2022. 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 74% of total domestic production.

An estimated 85,000 tons of natural zeolites were sold in the United States during 2023, 6% more than the sales in the previous year. Domestic uses were, in descending order of estimated quantity, animal feed, odor control, unspecified end uses (such as ice melt, soil amendment, and synthetic turf), water purification, wastewater treatment, oil and grease absorbent, gas absorbent, pet litter, fertilizer carrier, aquaculture, fungicide or pesticide carrier, and desiccant. Animal feed, odor control, and water purification applications accounted for about 67% of the domestic sales tonnage.

Salient Statistics—United States:	**2019**	**2020**	**2021**	**2022**	**2023[e]**
Production, mine	87,800	86,700	87,000	77,400	84,000
Sales, mill	77,100	75,300	73,900	79,800	85,000
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]	77,100	75,300	73,900	79,800	85,000
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]	120	120	120	120	110
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Zeolites used for desiccation, gas absorbance, wastewater treatment, and water purification may be reused after reprocessing of the spent zeolites. Information about the quantity of recycled natural zeolites was unavailable.

Import Sources (2019–22): 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 12–31–23**
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 and sales of natural zeolites have more than doubled from 1993 through 2023 owing to increased sales for animal feed, odor control, soil amendment, and water purification applications. Domestic natural zeolite production fluctuated in recent years. Natural zeolite production in 2023 increased by 9% after reaching a 5-year low in 2022. Several natural zeolite companies in the United States made improvements to their storage capacity and crushing operations in 2023. Sales for natural zeolites had been waning over the last few years owing to decreased use in pet litter and wastewater treatment applications as a result of competition from other products such as clays and synthetic zeolites. The increase in sales over the past 2 years was the result of the expansion of natural zeolites into the traction control, pool filter media, soil amendment, and artificial turf infill markets.

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ZEOLITES (NATURAL)

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 time delay. 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.

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 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]	
	2022	2023
United States	77,400	84,000
Chile	297	400
China	200,000	200,000
Cuba	77,500	78,000
Georgia	4,810	5,000
Hungary	32,000	31,000
Indonesia	100,000	100,000
Jordan	1,000	1,000
Korea, Republic of	16,000	130,000
Philippines	6,900	7,100
New Zealand	100,000	100,000
Russia	35,000	35,000
Slovakia	221,000	220,000
Turkey	74,500	70,000
World total (rounded)	900,000	1,100,000

Reserves[5]

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.

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 2019, 2020, and 2021; $130 in 2022; and $150 in 2023. Prices vary with the percentage of zeolite present in the product, the chemical and physical properties of the zeolite mineral(s), particle size, surface modification and (or) activation, and end use.
[3]Excludes administration and office staff. Estimates based on data from the Mine Safety and Health Administration.
[4]Defined as imports – exports.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.

ZINC

(Data in thousand metric tons, zinc content, unless otherwise specified)

Domestic Production and Use: The estimated value of zinc mined in 2023 was about $2.4 billion. Zinc was mined in five States at seven mining operations by five companies. Two smelter facilities, one primary and one secondary, operated by two companies, accounted for most of the commercial-grade zinc metal produced in the United States. 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:	2019	2020	2021	2022	2023[e]
Production:					
Mine, zinc in concentrates	753	723	704	761	750
Refined zinc[e, 1]	115	180	220	220	220
Imports for consumption:					
Zinc in ores and concentrates	([2])	3	13	5	20
Refined zinc	830	700	701	762	750
Exports:					
Zinc in ores and concentrates	792	546	644	644	730
Refined zinc	5	2	13	8	5
Shipments from Government stockpile[3]	—	—	—	1	NA
Consumption, apparent, refined zinc[4]	939	878	908	975	970
Price, average, cents per pound:					
North American[5]	124.1	110.8	145.8	190.2	152
London Metal Exchange (LME), cash	115.6	102.7	136.3	158.1	120
Stocks, reported producer and consumer, refined zinc, yearend	116	120	120	100	100
Employment, number:					
Mine and mill[6]	2,470	2,360	2,480	2,500	2,600
Smelter, primary	250	220	220	220	340
Net import reliance[7] as a percentage of apparent consumption:					
Ores and concentrates	E	E	E	E	E
Refined zinc	88	79	76	77	77

Recycling: 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 (2019–22): Ores and concentrates: Peru, 67%; Canada, 19%; China, 7%, Taiwan, 3%; and other, 4%. Refined metal: Canada, 62%; Mexico, 16%; Peru, 6%; Republic of Korea, 5%; and other, 11%. Waste and scrap (gross weight): Canada, 61%; Mexico, 37%; and other, 2%. Combined total (includes gross weight of waste and scrap): Canada, 62%; Mexico, 16%; Peru, 7%; Republic of Korea, 5%; and other, 10%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
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 2023		FY 2024	
Material	Potential acquisitions	Potential disposals	Potential acquisitions	Potential disposals
Zinc	—	2.27	—	2.27

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ZINC

Events, Trends, and Issues: U.S. zinc mine production was estimated to have decreased slightly in 2023 compared with that in 2022. Production was suspended at two zinc-producing mines in the second half of the year. In August, a fire took place at an underground silver-lead-zinc mine in Idaho; no personnel were in the mine at the time of the fire. Production was suspended for the remainder of 2023 while work was carried out to bypass the damaged area. In late November, production was temporarily paused at the Middle Tennessee zinc mines in response to decreasing zinc prices and the effect of inflation on input costs. During the closure, drilling work would be conducted to define additional zinc, germanium, and gallium resources. Domestic refined production was estimated to have remained unchanged in 2023 compared with that in the previous year, and apparent consumption was essentially unchanged alongside an estimated slight decrease in net imports of refined zinc.

The annual average LME cash price for Special High Grade (SHG) zinc was projected to decrease by 24% in 2023 from that in 2022. Average monthly prices decreased particularly during the first half of the year. High interest rates in the United States and Europe, the relative strength of the United States dollar, high energy prices in Europe, and concerns over a downturn in China's real estate sector were cited as factors contributing to the price decrease. The monthly average North American premium to the LME cash price decreased during 2023, but remained high compared with historical levels. According to the International Lead and Zinc Study Group,[9] estimated global refined zinc production in 2023 was forecast to increase by 3.7% to 13.8 million tons and estimated metal consumption to increase by 1.1% to 13.6 million tons, resulting in a production-to-consumption surplus of 248,000 tons.

World Mine Production and Reserves: Reserves for Australia, China, India, Kazakhstan, Mexico, Peru, Russia, Sweden, the United States, and "Other countries" were revised based on company and Government reports.

	Mine production[10]		Reserves[11]
	2022	2023[e]	
United States	761	750	6,600
Australia	1,240	1,100	[12]64,000
Bolivia	518	490	NA
China	4,040	4,000	44,000
India	840	860	7,400
Kazakhstan	312	330	6,700
Mexico	744	690	14,000
Peru	1,370	1,400	21,000
Russia	[e]300	310	25,000
South Africa	238	230	6,200
Sweden	234	220	4,100
Other countries	1,940	1,800	25,000
World total (rounded)	12,500	12,000	220,000

World Resources:[11] Identified zinc resources of the world are about 1.9 billion tons.

Substitutes: Aluminum and plastics substitute for galvanized sheet in automobiles; aluminum alloys, cadmium, paint, and plastic coatings replace zinc coatings in other applications. Aluminum- and magnesium-base alloys are major 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. Beginning in 2023, Government stock changes no longer available.
[4]Defined for 2019–22 as refined production + refined imports – refined exports ± adjustments for Government stock changes. Beginning in 2023, Government stock changes no longer included.
[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 for 2019–22 as imports – exports ± adjustments for Government stock changes. Beginning in 2023, Government stock changes no longer included.
[8]See Appendix B for definitions.
[9]Source: International Lead and Zinc Study Group, 2023, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 9, [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 21 million tons.

ZIRCONIUM AND HAFNIUM

(Data in metric tons unless otherwise specified)

Domestic Production and Use: In 2023, 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 a second company processed existing mineral sands tailings in California. Abrasive sands, monazite, and titanium mineral concentrates were coproducts of domestic heavy-mineral-sand operations. 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 from domestic and imported materials 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, and other end uses included abrasives, 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:	2019	2020	2021	2022	2023[e]
Production, zirconium ores and concentrates [zirconium oxide (ZrO_2) content]	<100,000	<100,000	<100,000	<100,000	<100,000
Imports					
Zirconium ores and concentrates (ZrO_2 content)[1]	22,600	15,600	18,500	35,400	16,000
Zirconium, unwrought, powder, and waste and scrap	1,820	2,030	746	346	490
Zirconium, wrought	289	302	265	286	310
Hafnium, unwrought, powder, and waste and scrap	32	16	23	43	68
Hafnium, wrought	NA	NA	NA	2	5
Exports:					
Zirconium ores and concentrates (ZrO_2 content)[1, 2]	40,500	12,200	10,000	11,200	14,000
Zirconium, unwrought, powder, and waste and scrap	897	664	589	1,090	1,000
Zirconium, wrought	816	838	966	805	680
Consumption, apparent,[3] zirconium ores and concentrates (ZrO_2 content)[1]	<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]	1,620	1,490	1,580	2,170	2,280
Imported[5]	1,490	1,380	1,440	1,940	2,100
Zirconium, sponge, ex-works China,[4] dollars per kilogram	34	25	25	30	28
Hafnium, unwrought, dollars per kilogram	832	778	781	1,590	6,200
Net import reliance[6] as a percentage of apparent consumption:					
Zirconium ores and concentrates	E	<25	<25	<50	<25
Hafnium	NA	NA	NA	NA	NA

Recycling: Companies in Oregon and Utah recycled zirconium from new scrap generated during metal production and fabrication and (or) from post-commercial old scrap. Zircon foundry mold cores and spent or rejected zirconia refractories are often recycled but could not be quantified. Hafnium metal recycling was limited.

Import Sources (2019–22): Zirconium ores and concentrates: South Africa, 46%; Australia, 34%; Senegal, 18%; Russia, 1%; and other, 1%. Zirconium, unwrought, including powder: China, 91%; Germany, 6%; France, 1%; and other, 2%. Zirconium, wrought: France, 66%; Germany, 17%; Belgium, 6%; China, 4%; and other, 7%. Hafnium, unwrought: Germany, 41%; France, 25%; China, 22%; Russia, 5%; and other, 7%.

Tariff: Item	Number	Normal Trade Relations 12–31–23
Zirconium ores and concentrates	2615.10.0000	Free.
Ferrozirconium	7202.99.1000	4.2% ad valorem.
Zirconium, unwrought and powder	8109.21.0000, 8109.29.0000	4.2% ad valorem.
Zirconium waste and scrap	8109.31.0000, 8109.39.0000	Free.
Other zirconium articles	8109.91.0000, 8109.99.0000	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:[7] The fiscal year (FY) 2024 potential acquisitions include 230 tons of zirconium.

Events, Trends, and Issues: Global mine production of zirconium mineral concentrates increased to about 1.6 million tons in 2023. Advanced exploration and development projects with planned production of zirconium mineral concentrates were ongoing in Australia, Madagascar, Mozambique, Senegal, Tanzania, and elsewhere. U.S. imports of zirconium mineral concentrates decreased significantly in 2023. Australia, Senegal, and South Africa continued to be the leading import sources of zirconium mineral concentrates. The leading global exporters of zirconium mineral concentrates were Australia and South Africa. China was the leading importer of zirconium mineral concentrates. Zircon imports into China included zircon in mixed heavy-mineral concentrates. Global producers of zirconium sponge included China, France, India, Russia, and the United States. The United States was a net exporter of zirconium metal.

Hafnium metal is produced as a byproduct of hafnium-free zirconium metal. Constricted supply combined with increasing demand for hafnium in aerospace alloys and electronics has resulted in an unprecedent increase in hafnium prices.

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, China, Mozambique, South Africa, and "Other countries" were revised based on company and Government reports.

	Zirconium mineral concentrates, mine production[e] (thousand metric tons, gross weight)		Zirconium reserves[8] (thousand metric tons, ZrO_2 content)[1]
	2022	2023	
United States	[9]100	[9]100	500
Australia	500	500	[10]55,000
China	140	140	72
Indonesia	97	90	NA
Kenya	27	30	18
Madagascar	27	30	2,300
Mozambique	104	90	1,500
Senegal	57	50	2,600
Sierra Leone	34	30	290
South Africa	300	400	5,600
Other countries	57	140	5,700
World total (rounded)	1,440	1,600	74,000

World Resources:[8] 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. Boron or cadmium-silver-indium alloys are sometimes used in lieu of hafnium metal in control rods at 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 weight.
[2]Excludes zircon in mixed mineral concentrates.
[3]Defined as production + imports – exports.
[4]Source: Argus Media Group, Argus Non-Ferrous Markets, annual average
[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 B for definitions.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]Data are rounded to the nearest hundred thousand tons to avoid disclosing company proprietary data.
[10]For Australia, Joint Ore Reserves Committee-compliant or equivalent reserves were 20 million tons, ZrO_2 content.

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) 2023 is from October 1, 2022, through September 30, 2023. FY 2024 is from October 1, 2023, through September 30, 2024.

Inventory refers to the quantity of mineral materials held in the National Defense Stockpile or in the Federal Helium Reserve. Beginning in 2023, National Defense Stockpile shipments and inventory levels no longer included.

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. 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 2024.

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 670 million tons of copper have been produced worldwide, but world copper reserves in 2023 were estimated to be 1 billion tons of copper, more than 3.5 times 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 C1 and 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*

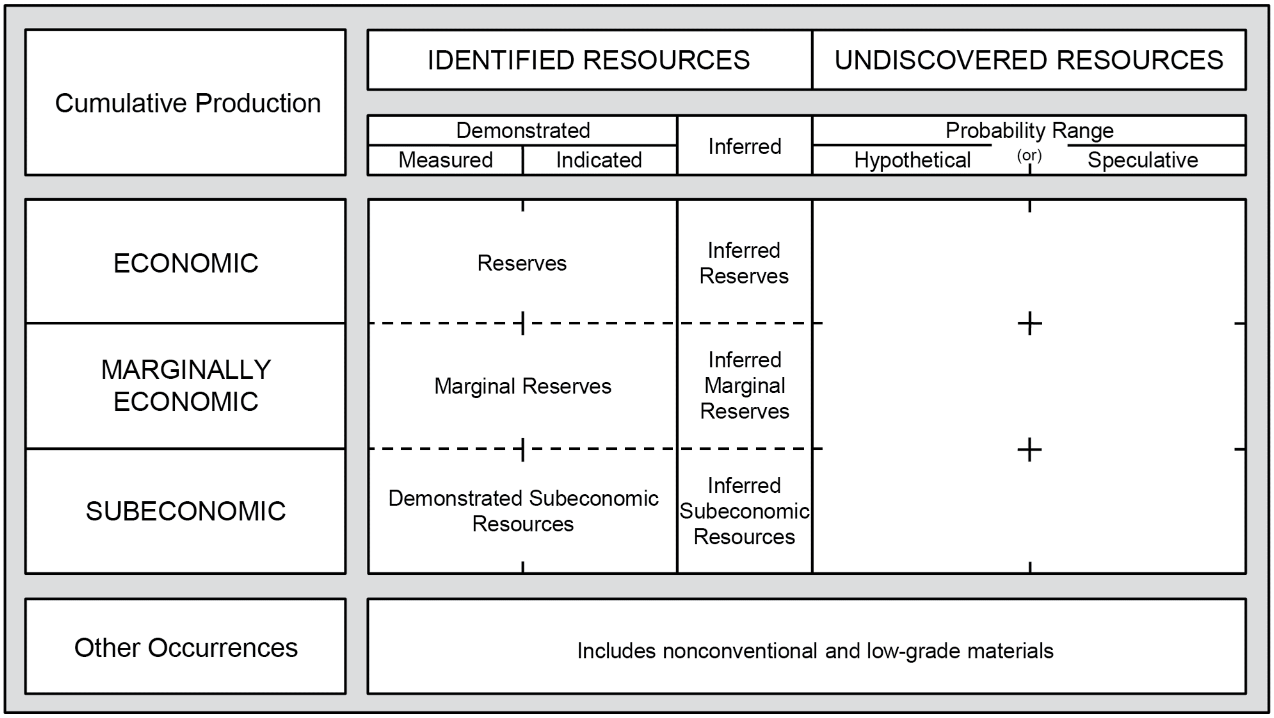
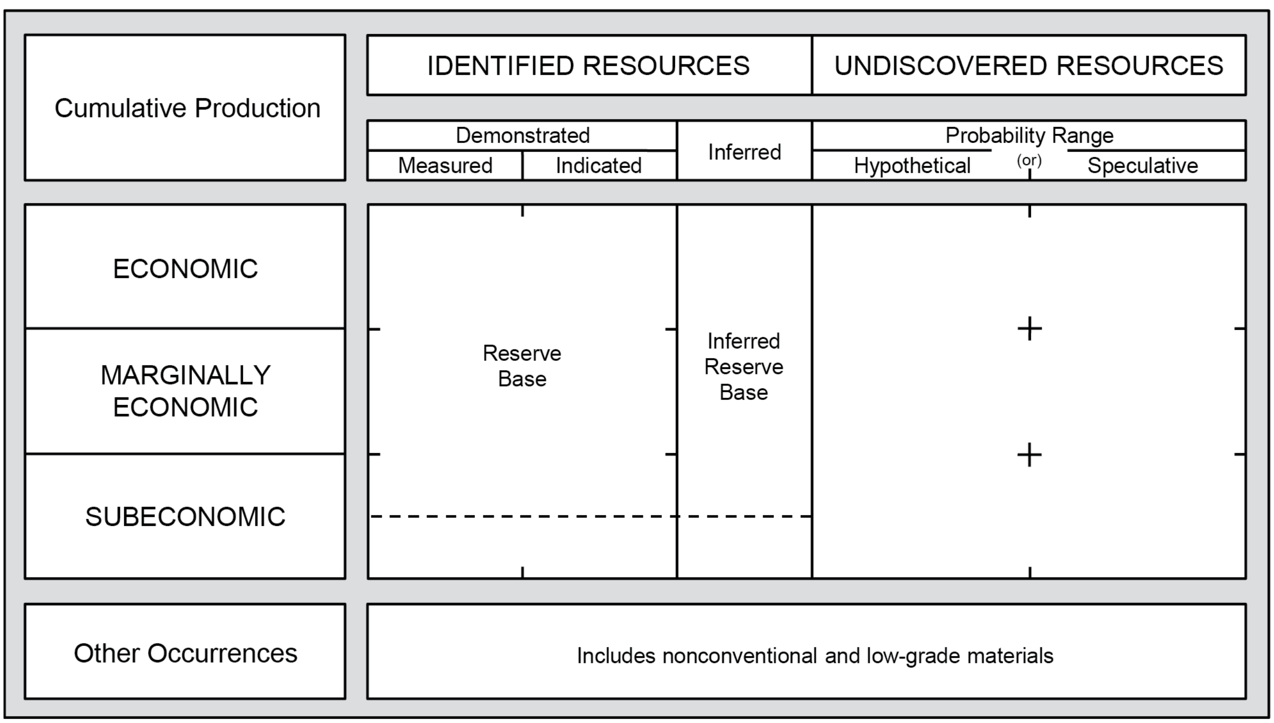


Figure C2.—*Reserve Base* and *Inferred Reserve Base* Classification Categories



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 2024 are Accessible EDR. For more information, see “Australia’s Identified Mineral Resources 2023—Preliminary Tables” (https://www.ga.gov.au/digital-publication/aimr2022/aimr-2023-preliminary-tables).

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	Iman Salehihikouei
Benin	Meralis Plaza-Toledo
Botswana	Thomas R. Yager
Burkina Faso	Alberto A. Perez
Burundi	Thomas R. Yager
Cabo Verde	Meralis Plaza-Toledo
Cameroon	Edgardo J. Pujols
Central African Republic	Edgardo J. Pujols
Chad	Edgardo J. Pujols
Comoros	Edgardo J. Pujols
Congo (Brazzaville)	Edgardo J. Pujols
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	Edgardo J. Pujols
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	Iman Salehihikouei
Iraq	Iman Salehihikouei
Israel	Iman Salehihikouei
Jordan	Mowafa Taib
Kenya	Thomas R. Yager
Kuwait	Iman Salehihikouei
Lebanon	Mowafa Taib
Lesotho	Edgardo J. Pujols
Liberia	Meralis Plaza-Toledo
Libya	Mowafa Taib
Madagascar	Thomas R. Yager
Malawi	Thomas R. Yager
Mali	Alberto A. Perez
Mauritania	Meralis Plaza-Toledo
Mauritius	Edgardo J. Pujols
Morocco and Western Sahara	Mowafa Taib
Mozambique	Meralis Plaza-Toledo
Namibia	Edgardo J. Pujols
Niger	Alberto A. Perez
Nigeria	Thomas R. Yager
Oman	Iman Salehihikouei
Qatar	Iman Salehihikouei
Reunion	Edgardo J. Pujols
Rwanda	Thomas R. Yager

Africa and the Middle East—Continued

São Tomé & Principe	Meralis Plaza-Toledo
Saudi Arabia	Mowafa Taib
Senegal	Alberto A. Perez
Seychelles	Edgardo J. Pujols
Sierra Leone	Alberto A. Perez
Somalia	Edgardo J. Pujols
South Africa	Thomas R. Yager
South Sudan	Alberto A. Perez
Sudan	Alberto A, Perez
Syria	Mowafa Taib
Tanzania	Thomas R. Yager
Togo	Alberto A. Perez
Tunisia	Mowafa Taib
Uganda	Thomas R. Yager
United Arab Emirates	Iman Salehihikouei
Yemen	Iman Salehihikouei
Zambia	Edgardo J. Pujols
Zimbabwe	Edgardo J. Pujols

Asia and the Pacific

Afghanistan	Keita F. DeCarlo
Australia	Loyd M. Trimmer III
Bangladesh	Keita F. DeCarlo
Bhutan	Keita F. DeCarlo
Brunei	Kathleen D. Gans
Burma (Myanmar)	Kathleen D. Gans
Cambodia	Kathleen D. Gans
China	Ji Won Moon
Fiji	Loyd M. Trimmer III
India	Keita F. DeCarlo
Indonesia	Jaewon Chung
Japan	Keita F. DeCarlo
Korea, North	Jaewon Chung
Korea, Republic of	Jaewon Chung
Laos	Kathleen D. Gans
Malaysia	Jaewon Chung
Mongolia	Jaewon Chung
Nauru	Loyd M. Trimmer III
Nepal	Keita F. DeCarlo
New Caledonia	Loyd M. Trimmer III
New Zealand	Loyd M. Trimmer III
Pakistan	Kathleen D. Gans
Papua New Guinea	Loyd M. Trimmer III
Philippines	Ji Won Moon
Singapore	Kathleen D. Gans
Solomon Islands	Jaewon Chung
Sri Lanka	Keita F. DeCarlo
Taiwan	Jaewon Chung
Thailand	Kathleen D. Gans
Timor-Leste	Loyd M. Trimmer III
Vietnam	Ji Won Moon

Europe and Central Eurasia

Albania	Kristian A. Macias
Armenia	Elena Safirova
Austria	Kathleen R. Trafton
Azerbaijan	Elena Safirova
Belarus	Elena Safirova
Belgium	Elizabeth R. Neustaedter
Bosnia and Herzegovina	Karine M. Renaud
Bulgaria	Karine M. Renaud
Croatia	Kathleen R. Trafton
Cyprus	Kristian A. Macias
Czechia	Elizabeth R. Neustaedter
Denmark, Faroe Islands, and Greenland	Joanna Goclawska
Estonia	Alexandru Hostiuc
Finland	Joanna Goclawska
France	Kathleen R. Trafton
Georgia	Elena Safirova
Germany	Karine M. Renaud
Greece	Kristian A. Macias
Hungary	Elizabeth R. Neustaedter
Iceland	Joanna Goclawska
Ireland	Joanna Goclawska
Italy	Alexandru Hostiuc
Kazakhstan	Karine M. Renaud
Kosovo	Kristian A. Macias
Kyrgyzstan	Karine M. Renaud
Latvia	Alexandru Hostiuc
Lithuania	Alexandru Hostiuc
Luxembourg	Alexandru Hostiuc
Malta	Kristian A. Macias
Moldova	Elena Safirova
Montenegro	Kristian A. Macias
Netherlands	Elizabeth R. Neustaedter
North Macedonia	Kathleen R. Trafton
Norway	Joanna Goclawska
Poland	Joanna Goclawska
Portugal	Kristian A. Macias
Romania	Alexandru Hostiuc
Russia	Elena Safirova
Serbia	Karine M. Renaud
Slovakia	Elizabeth R. Neustaedter
Slovenia	Elizabeth R. Neustaedter

Europe and Central Eurasia—Continued

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Sweden	Joanna Goclawska
Switzerland	Kathleen R. Trafton
Tajikistan	Karine M. Renaud
Turkey	Alexandru Hostiuc
Turkmenistan	Karine M. Renaud
Ukraine	Elena Safirova
United Kingdom	Kathleen R. Trafton
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

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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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