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

MINERAL COMMODITY SUMMARIES 2019

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

USGS
science for a changing world

Cover: A solar evaporation pond at Albemarle Corp.'s lithium production site in Silver Peak, Nevada. Lithium compounds are used to manufacture many products. Lithium carbonate and lithium hydroxide are needed for lithium-ion-batteries in mobile devices such as smartphones, tablet computers, and laptops, or in electric or hybrid vehicles. Butyllithium is needed for the production of synthetic rubber for tires. Lithium organics are versatile tools for the synthesis of pharmaceuticals, agrochemicals, or flavors and fragrances. The glass industry requires lithium carbonate or spodumene to improve the properties of glass. Lithium bromide is used in industrial absorption refrigeration systems that are installed in large buildings and industrial plants for air-conditioning or process cooling. (Photograph courtesy of Albemarle Corp., copyright 2016 Albemarle Corp.)

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

MINERAL COMMODITY SUMMARIES 2019

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

USGS
science for a changing world

U.S. Department of the Interior
DAVID BERNHARDT, Acting Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2019

Manuscript approved for publication February 28, 2019.

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment—
visit https://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications,
visit https://store.usgs.gov/.
For sale by the Superintendent of Documents, U.S. Government Publishing Office
Mail: Stop IDCC; Washington, DC 20402–0001
Phone: (866) 512–1800 (toll-free); (202) 512–1800 (Washington, DC area)
Fax: (202) 512–2104
Internet: bookstore.gpo.gov

Suggested citation:
U.S. Geological Survey, 2019, Mineral commodity summaries 2019: U.S. Geological Survey, 200 p., https://doi.org/10.3133/70202434.

ISBN 978-1-4113-4283-5

CONTENTS

INSTANT INFORMATION

Information about the U.S. Geological Survey, its programs, staff, and products is available from the internet at https://www.usgs.gov or by calling (888) ASK–USGS [(888) 275–8747].

This publication has been prepared by the National Minerals Information Center. Information about the Center and its products is available from the internet at https://minerals.usgs.gov/minerals or by writing to Director, National Minerals Information Center, 988 National Center, Reston, VA 20192.

KEY PUBLICATIONS

Minerals Yearbook—These annual publications review the mineral industries of the United States and of more than 180 other countries. They contain statistical data on minerals and materials and include information on economic and technical trends and developments and are available at https://minerals.usgs.gov/minerals/pubs/myb.html. 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://minerals.usgs.gov/minerals/pubs/mcs/. Data sheets contain information on the domestic industry structure, Government programs, tariffs, and 5-year salient statistics for more than 90 individual minerals and materials.

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

Metal Industry Indicators—This monthly publication analyzes and forecasts the economic health of three metal industries (primary metals, steel, and copper) using leading and coincident indexes and is available at https://minerals.usgs.gov/minerals/pubs/mii/.

Nonmetallic Mineral Products Industry Indexes—This monthly publication analyzes the leading and coincident indexes for the nonmetallic mineral products industry (NAICS 327) and is available at https://minerals.usgs.gov/minerals/pubs/imii/.

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://minerals.usgs.gov/minerals/mflow/.

Recycling Reports—These studies illustrate the recycling of metal commodities and identify recycling trends and are available at https://minerals.usgs.gov/minerals/pubs/commodity/recycle/.

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://minerals.usgs.gov/minerals/pubs/historical-statistics/.

WHERE TO OBTAIN PUBLICATIONS

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

- All current and many past publications are available in PDF format (and some are available in XLS format) through https://minerals.usgs.gov/minerals.

INTRODUCTION

Each chapter of the 2019 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 and resources. The MCS is the earliest comprehensive source of 2018 mineral production data for the world. More than 90 individual minerals and materials are covered by two-page synopses.

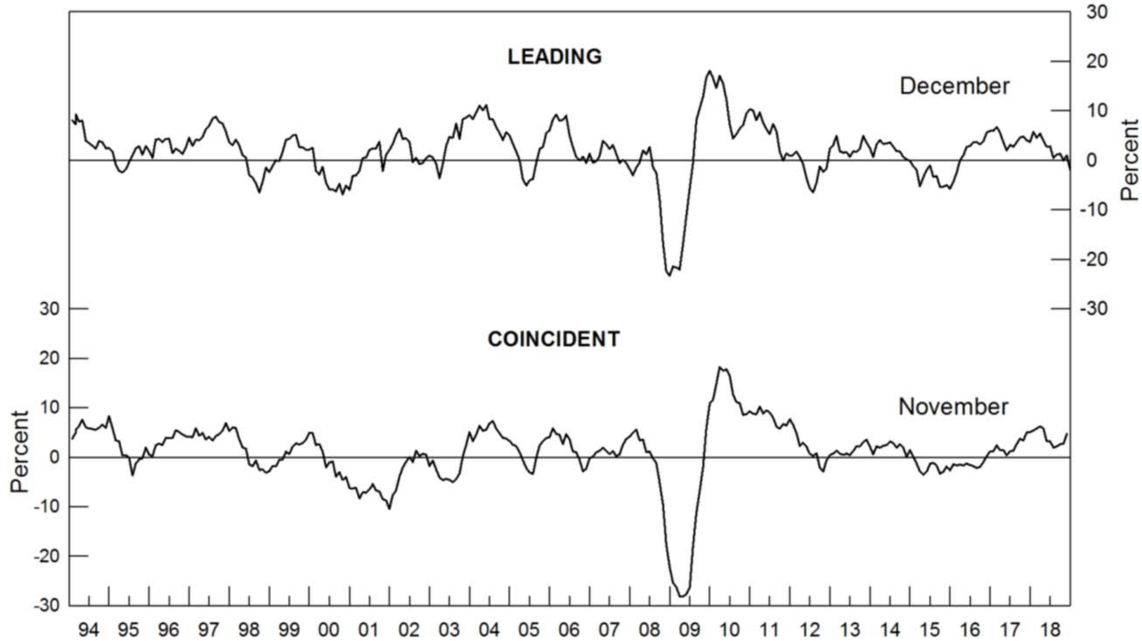
For mineral commodities for which there is a Government stockpile, detailed information concerning the stockpile status is included in the two-page synopsis.

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

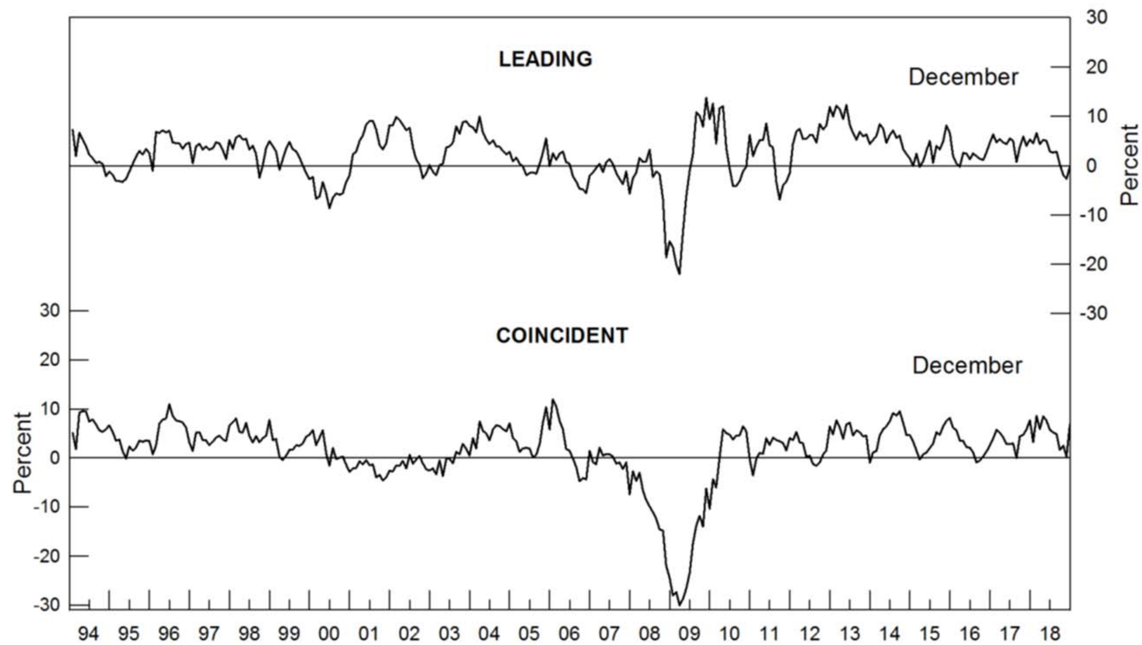
The USGS continually strives to improve the value of its publications to users. Constructive comments and suggestions by readers of the MCS 2019 are welcomed.

GROWTH RATES OF LEADING AND COINCIDENT INDEXES FOR MINERAL PRODUCTS

PRIMARY METALS: LEADING AND COINCIDENT GROWTH RATES, 1994–2018



NONMETALLIC MINERAL PRODUCTS: LEADING AND COINCIDENT GROWTH RATES, 1994–2018



The leading indexes historically give signals several months in advance of major changes in the corresponding coincident index, which measures current industry activity. The growth rates, which can be viewed as trends, are expressed as compound annual rates based on the ratio of the current month's index to its average level during the preceding 12 months.

Sources: U.S. Geological Survey, *Metal Industry Indicators and Nonmetallic Mineral Products Industry Indexes.*

THE ROLE OF NONFUEL MINERALS IN THE U.S. ECONOMY

(ESTIMATED VALUES IN 2018)

NET EXPORTS OF MINERAL RAW MATERIALS

GOLD, SODA ASH, ZINC CONCENTRATES, ETC.

Exports: $8.9 billion
Imports: $6.1 billion
Net exports: $2.8 billion

DOMESTIC MINERAL RAW MATERIALS FROM MINING

COPPER ORES, IRON ORE, SAND AND GRAVEL, STONE, ETC.

Value: $82.2 billion

METALS AND MINERAL PRODUCTS RECYCLED DOMESTICALLY

ALUMINUM, GLASS, STEEL, ETC.

Value of old scrap: $24.1 billion

NET EXPORTS OF OLD SCRAP

GOLD, STEEL, ETC.

Exports: $17.3 billion
Imports: $7.1 billion
Net exports: $10.2 billion

MINERAL MATERIALS PROCESSED DOMESTICALLY

ALUMINUM, BRICK, CEMENT, COPPER, FERTILIZERS, STEEL, ETC.

Value of shipments: $766 billion

NET IMPORTS OF PROCESSED MINERAL MATERIALS

METALS, CHEMICALS, ETC.

Imports: $152 billion
Exports: $95 billion
Net imports: $57 billion

VALUE ADDED TO GROSS DOMESTIC PRODUCT BY MAJOR INDUSTRIES THAT CONSUME PROCESSED MINERAL MATERIALS[1]

Value: $3,020 billion

U.S. ECONOMY

Gross Domestic Product: $20,500 billion

[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 the U.S. Department of Commerce.

2018 U.S. NET IMPORT RELIANCE[1]

Commodity	Percent	Major import sources (2014–17)[2]
ARSENIC (trioxide)	100	Morocco, China, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Canada
FLUORSPAR	100	Mexico, Vietnam, South Africa, China
GALLIUM	100	China, United Kingdom, Germany, Ukraine
GRAPHITE (natural)	100	China, Mexico, Canada, Brazil
INDIUM	100	China, Canada, Republic of Korea, Taiwan
MANGANESE	100	South Africa, Gabon, Australia, Georgia
MICA (sheet, natural)	100	China, Brazil, Belgium, Austria
NEPHELINE SYENITE	100	Canada
NIOBIUM (columbium)	100	Brazil, Canada, Russia, Germany
RARE EARTHS (compounds and metals)[3]	100	China, Estonia, France, Japan
RUBIDIUM	100	Canada
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	Brazil, Rwanda, Australia, Congo (Kinshasa)
THORIUM	100	India, United Kingdom
VANADIUM	100	Austria, Canada, Republic of Korea, Russia
GEMSTONES	99	India, Israel, Belgium, South Africa
BISMUTH	96	China, Belgium, Mexico, Republic of Korea
YTTRIUM	>95	China, Estonia, Japan, Republic of Korea
POTASH	92	Canada, Russia, Belarus, Israel
TITANIUM MINERAL CONCENTRATES	91	South Africa, Australia, Canada, Mozambique
DIAMOND (dust, grit, and powder)	89	China, Ireland, Republic of Korea, Romania
ANTIMONY (oxide)	85	China, Thailand, Belgium, Bolivia
ZINC	85	Canada, Mexico, Peru, Australia
BARITE	84	China, India, Mexico, Morocco
RHENIUM	84	Chile, Germany, Belgium, Poland
STONE (dimension)	82	Brazil, China, Italy, Turkey
TIN	78	Indonesia, Malaysia, Peru, Bolivia
ABRASIVES, fused Al oxide (crude)	>75	China, France, Hong Kong, Canada
ABRASIVES, silicon carbide (crude)	>75	China, Netherlands, South Africa, Romania
BAUXITE	>75	Jamaica, Brazil, Guinea, Guyana
TELLURIUM	>75	Canada, China, Germany
TITANIUM (sponge)	75	Japan, Kazakhstan, Ukraine, China
PLATINUM	73	South Africa, Germany, United Kingdom, Italy
CHROMIUM	71	South Africa, Kazakhstan, Russia
PEAT	70	Canada
GARNET (industrial)	68	Australia, India, South Africa, China
SILVER	65	Mexico, Canada, Peru, Republic of Korea
COBALT	61	Norway, China, Japan, Finland
NICKEL	52	Canada, Norway, Australia, Russia
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
IRON OXIDE PIGMENTS (natural)	>50	Cyprus, Spain, France, Austria
IRON OXIDE PIGMENTS (synthetic)	>50	China, Germany, Brazil, Canada
LITHIUM	>50	Argentina, Chile, China, Russia
TUNGSTEN	>50	China, Bolivia, Germany, Canada
ALUMINUM	50	Canada, Russia, United Arab Emirates, China
MAGNESIUM COMPOUNDS	48	China, Canada, Australia, Brazil
ALUMINA	45	Australia, Brazil, Suriname, Jamaica
SILICON	34	Russia, Brazil, Canada, China
PALLADIUM	33	South Africa, Russia, Italy, United Kingdom
COPPER	32	Chile, Canada, Mexico
VERMICULITE	30	South Africa, Brazil, China, Zimbabwe
LEAD	29	Canada, Mexico, Republic of Korea, India
PUMICE	29	Greece, Iceland, Mexico
SALT	28	Chile, Canada, Mexico, Egypt
MICA (scrap and flake, natural)	26	Canada, China, India, Japan
PERLITE	25	Greece, Mexico, Turkey
BROMINE	<25	Israel, Jordan, China
CADMIUM	<25	Canada, Australia, China, Belgium
MAGNESIUM METAL	<25	Israel, Canada, United Kingdom, Mexico
IRON and STEEL	24	Canada, Brazil, Republic of Korea

[1]Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (abrasives, metallic; boron; clays; diatomite; gold; helium; iron and steel scrap; iron ore; kyanite; molybdenum concentrates; sand and gravel, industrial; selenium; soda ash; titanium dioxide pigment; wollastonite; zeolites; and zirconium) or less than 24% import reliant (beryllium; cement; diamond, industrial stones; feldspar; gypsum; iron and steel slag; lime; nitrogen (fixed)–ammonia; phosphate rock; sand and gravel, construction; stone, crushed; sulfur; and talc and pyrophyllite). For some mineral commodities (hafnium; mercury; quartz crystal, industrial; and thallium), not enough information is available to calculate the exact percentage of import reliance.

[2]In descending order of import share.

[3]Data include lanthanides.

SIGNIFICANT EVENTS, TRENDS, AND ISSUES

In 2018, the estimated value of total nonfuel mineral production in the United States was $82.2 billion, a 3% increase from the revised total of $79.7 billion in 2017. The estimated value of metals production decreased by 4% to $25.9 billion. Lower average prices and lower production of many metals contributed to the reduced value. A zinc mine reopened in New York, having last been operational in 2008. The total value of industrial minerals production was $56.3 billion, a 7% increase from that of 2017. Of this total, $25.3 billion was construction aggregates production (construction sand and gravel and crushed stone). Increased construction activity resulted in the increased prices and production of some industrial minerals, especially those used in infrastructure, oil and gas drilling operations, and residential construction.

In March 2018, as a result of Department of Commerce findings of harm to national security under Section 232 of the Trade Expansion Act of 1962, as amended (19 U.S.C. 1862), additional import duties of 10% for aluminum articles from all countries of origin, except Canada and Mexico, and additional import duties of 25% for steel articles from all countries of origin, except Canada and Mexico, were implemented under Presidential Proclamations 9704 and 9705, respectively. Throughout the year, modifications and changes were made to the list of countries subject to the tariffs; for some countries, quotas were established in place of the additional duties, and exemptions for certain products were granted. Many countries responded to the increased import duties by increasing the duties for imports of aluminum and steel articles of United States origin, including European Union countries, Canada, China, India, Japan, Mexico, Russia, and Turkey.

As of December 2018, the additional import duty for aluminum articles remained at 10% for most countries of origin and 20% for Turkey. The only countries that did not have the increased import duty for aluminum were Argentina, on which import quotas were in place, and Australia. The additional import duty for steel articles remained at 25% for most countries of origin and was 50% for Turkey. The only countries that did not have the increased import duty for steel were Argentina, Brazil, and the Republic of Korea, all of which had import quotas in place, and Australia. As a result, U.S. aluminum imports were estimated to have decreased by 11% and steel mill product imports were estimated to have decreased by 8% in 2018.

Under Section 301 (b) of the Trade Act of 1974, as amended, the Office of the United States Trade Representative (USTR) determined that acts, policies and practices of China related to technology transfer, intellectual property, and innovation were discriminatory or unreasonable and those actions burdened or restricted United States commerce (83 FR 14906). An initial list of 818 tariff lines became subject to an additional import duty of 25% in July 2018. In response to this action, China imposed additional import duties for certain items originating in the United States. In August, the USTR imposed an additional 25% import duty on a second list of 279 tariff lines. China responded in kind and added more products of United States origin to its list of higher import duties. A third list of 5,745 full and partial tariff lines, including nonfuel mineral ores and concentrates and forms, became subject to an additional 10% import duty in late September. The duty rate for this third list was initially scheduled to increase to 25% on January 1, 2019, but that action was delayed. Most mineral commodities were subject to the Section 301 actions; however, a few commodities were removed from proposed lists, including some of those considered critical minerals.

Executive Order 13817, A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals (EO), was issued on December 20, 2017. Pursuant to the EO, the Secretary of the Interior, in coordination with the Secretary of Defense, and in consultation with the heads of other relevant executive departments and agencies, was tasked with developing and submitting to the Federal Register a list of minerals defined as critical minerals. The U.S. Geological Survey (USGS), in coordination with the Bureau of Land Management (BLM), developed the unranked list in cooperation with the U.S. Departments of Defense, Energy, State, Commerce, and other members of the National Science and Technology Council Subcommittee on Critical and Strategic Mineral Supply Chains. The final list of critical minerals was published in the Federal Register on May 18, 2018 (83 FR 23295).

A critical mineral, as defined by the EO, is a mineral identified to be (i) a nonfuel mineral or mineral material essential to the economic and national security of the United States, (ii) the supply chain of which is vulnerable to disruption, and (iii) that serves an essential function in the manufacturing of a product, the absence of which would have significant consequences for the U.S. economy or national security. Disruptions in supply may arise for any number of reasons, including natural disasters, labor strife, trade disputes, resource nationalism, conflict, and so forth. The assured supply of critical minerals and the resiliency of their supply chains are essential to the economic security and national defense of the United States.

Based on analysis and modeling using multiple factors, 35 minerals or mineral material groups were identified on the list of critical minerals. These were aluminum (bauxite), antimony, arsenic, barite, beryllium, bismuth, cesium, chromium, cobalt, fluorspar, gallium, germanium, graphite (natural), hafnium, helium, indium, lithium, magnesium, manganese, niobium, platinum group metals, potash, the rare earth elements group, rhenium, rubidium, scandium, strontium, tantalum, tellurium, tin, titanium, tungsten, uranium, vanadium, and zirconium.

One of the principle metrics used in the analysis and modeling of critical minerals was the Herfindahl-Hirschman index (HHI). The HHI is used by the

Department of Justice and the Federal Trade Commission to identify highly concentrated markets where a company may control market share above an established threshold of 2,500 on a scale that ranges from 0 to 10,000. Additional tools and sources of information used to produce the list were as follows: (i) U.S. net import reliance (NIR) statistics as published annually in the USGS Mineral Commodity Summaries; (ii) USGS Professional Paper 1802 “Critical Mineral Resources of the United States”; (iii) U.S. Defense Logistics Agency (DLA) reports produced in support of the management of the National Defense Stockpile; (iv) the National Defense Authorization Act for fiscal year 2018; (v) U.S. Energy Information Administration (EIA) uranium statistics in the 2016 Uranium Marketing Annual Report; and (vi) the judgment of subject matter experts. The methodology is summarized in a USGS publication released concurrently with the posting of the draft list in the Federal Register (Fortier and others, 2018).

The U.S. Geological Survey (USGS) generates composite leading and coincident indexes to track economic activity in the primary metals and the nonmetallic minerals industries. As shown in the charts on page 4, for each of the indexes, a growth rate is calculated to measure its change relative to the previous 12 months. The indexes’ growth rate is a 6-month smoothed compound annual rate, which measures near-term trend. Usually, a growth rate above +1.0% signals an increase in primary metals or nonmetallic minerals industry activity, and a growth rate below -1.0% indicates a downturn in activity. The primary metals leading index growth rate had been well above +1.0% from January through June 2018 and had been above +1.0% since April 2016; the July growth rate was below the +1.0% threshold; August and September growth rates increased barely above the +1.0% threshold; October turned slightly negative; November returned to +1.0% threshold growth; and December turned negative again. The nonmetallic mineral products industry’s leading index growth rate had been above the +1.0% growth rate threshold January through August; the September growth rate was below the +1.0% threshold but remained positive; and October, November, and December growth rates were negative.

As shown in the figure on page 5, 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 2018 was $82.2 billion. Domestic raw materials and domestically recycled materials were used to produce mineral materials worth $766 billion. These mineral materials were, in turn, consumed by downstream industries with an estimated value of $3.02 trillion in 2018, a 6% increase from the revised figure of $2.85 trillion in 2017.

The figure on page 6 illustrates the reliance of the United States on foreign sources for raw and processed mineral materials. In 2018, imports made up more than one-half of the U.S. apparent consumption for 48 nonfuel mineral commodities, and the United States was 100% net import reliant for 18 of those. Critical minerals comprised 14 of the 18 mineral commodities with 100% net import reliance, and comprised 15 of the 30 remaining mineral commodities with imports greater than 50 percent of annual consumption.

The figure on page 12 shows the countries from which the majority of these mineral commodities were imported and the number of mineral commodities for which each highlighted country was a leading supplier. China, followed by Canada, supplied the largest number of nonfuel mineral commodities. The United States was import reliant for an additional 29 commodities and was a net exporter of 18 nonfuel mineral commodities.

The estimated value of U.S. metal mine production in 2018 was $25.9 billion (table 1), 4% less than that of 2017. Principal contributors to the total value of metal mine production in 2018 were gold (33%), copper (31%), iron ore (16%), and zinc (9%). The estimated value of U.S. industrial minerals production in 2018, including construction aggregates, was $56.3 billion, about 7% more than the revised value of 2017. The value of industrial minerals production in 2018 was dominated by crushed stone (30%), cement (20%), and construction sand and gravel (15%).

In 2018, U.S. production of 13 mineral commodities was valued at more than $1 billion each. These were, in decreasing order of value, crushed stone, cement, construction sand and gravel, gold, copper, industrial sand and gravel, iron ore, zinc, lime, salt, phosphate rock, soda ash, and clays (all types).

In 2018, 12 States each produced more than $2 billion worth of nonfuel mineral commodities. These States were, in descending order of production value, Nevada, Arizona, Texas, California, Minnesota, Florida, Alaska, Utah, Missouri, Wisconsin, Michigan, and Wyoming (table 3).

The Defense Logistics Agency (DLA) Strategic Materials is responsible for providing safe, secure, and environmentally sound stewardship for strategic and critical materials in the U.S. National Defense Stockpile (NDS). DLA Strategic Materials stores 44 commodities at 10 locations in the United States. In fiscal year 2018, DLA Strategic Materials acquired approximately $11.6 million of new stock and sold $69.9 million of excess materials from the NDS. At the end of fiscal year 2018, materials valued at $1.2 billion remained in the NDS. Of the remaining material, portions are held in reserve, offered for sale, or sales were suspended. Additional detailed information can be found in the “Government Stockpile” sections in the mineral commodity chapters that follow. Under the authority of the Defense Production Act of 1950, the U.S. Geological Survey advises the DLA on acquisition and disposals of NDS mineral materials.

Reference Cited

Fortier, S.M., Nassar, N.T., Lederer, G.W., Brainard, Jamie, Gambogi, Joseph, and McCullough, E.A., 2018, Draft critical mineral list—Summary of methodology and background information: U.S. Geological Survey Open-File Report 2018–1021, 15 p.

TABLE 1.—U.S. MINERAL INDUSTRY TRENDS

	2014	2015	2016	2017	2018[e]
Total mine production (million dollars):					
Metals	28,900	24,400	23,800	27,000	25,900
Industrial minerals	49,500	48,800	47,600	52,600	56,300
Coal	34,800	28,500	22,300	26,100	25,700
Employment (thousands of production workers):					
Coal mining	62	54	42	43	44
Nonfuel mineral mining	100	99	95	97	101
Chemicals and allied products	497	507	516	525	548
Stone, clay, and glass products	280	296	306	305	310
Primary metal industries	310	307	293	292	294
Average weekly earnings of production workers (dollars):					
Coal mining	1,434	1,383	1,336	1,432	1,437
Chemicals and allied products	917	927	950	1,011	1,073
Stone, clay, and glass products	828	843	850	873	945
Primary metal industries	990	987	1,002	995	1,035

[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

	2014	2015	2016	2017	2018[e]
Gross domestic product (billion dollars)	17,522	18,219	18,707	19,485	20,500
Industrial production (2012=100):					
Total index:	105	104	102	104	108
Manufacturing:	102	102	101	103	105
Nonmetallic mineral products	109	110	111	114	120
Primary metals:	104	97	93	94	98
Iron and steel	101	92	87	92	97
Aluminum	106	107	106	103	108
Nonferrous metals (except aluminum)	108	98	95	92	92
Chemicals	96	95	95	96	99
Mining:	118	114	103	109	123
Coal	98	87	70	75	74
Oil and gas extraction	126	134	129	134	155
Metals	105	100	99	98	93
Nonmetallic minerals	112	116	114	114	117
Capacity utilization (percent):					
Total industry:	79	77	75	76	78
Mining:	90	84	78	84	92
Metals	77	75	75	73	69
Nonmetallic minerals	88	90	86	86	88
Housing starts (thousands)	999	1,107	1,177	1,208	1,264
Light vehicle sales (thousands)	16,452	17,396	17,465	17,136	17,214
Highway construction, value, put in place (billion dollars)	84	90	93	89	93

[e]Estimated.

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

TABLE 3.—VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 2018[e, 1]

State	Value (millions)	Rank[2]	Percent of U.S. total	Principal commodities[3]
Alabama	$1,450	20	1.76	Cement (masonry), cement (portland), lime, sand and gravel (construction), stone (crushed).
Alaska	3,440	7	4.18	Gold, lead, sand and gravel (construction), silver, zinc.
Arizona	6,690	2	8.15	Cement (portland), copper, molybdenum concentrates, sand and gravel (construction), stone (crushed).
Arkansas	903	30	1.10	Bromine, cement (portland), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
California	4,560	4	5.54	Boron minerals, cement (portland), gold, sand and gravel (construction), stone (crushed).
Colorado	1,380	21	1.68	Cement (portland), gold, molybdenum concentrates, sand and gravel (construction), stone (crushed).
Connecticut[4]	200	43	0.24	Clay (common), sand and gravel (construction), stone (crushed), stone (dimension).
Delaware[4]	31	50	0.04	Magnesium compounds, sand and gravel (construction), stone (crushed).
Florida	3,550	6	4.32	Cement (portland), phosphate rock, sand and gravel (construction), stone (crushed), zirconium mineral concentrates.
Georgia	1,960	13	2.39	Cement (portland), clay (kaolin and montmorillonite), sand and gravel (construction), stone (crushed).
Hawaii	141	47	0.17	Sand and gravel (construction), stone (crushed).
Idaho[4]	208	35	0.25	Lead, lime, phosphate rock, sand and gravel (construction), stone (crushed).
Illinois[4]	1,780	15	2.17	Cement (portland), sand and gravel (construction), sand and gravel (industrial), silica (tripoli), stone (crushed).
Indiana	1,060	27	1.29	Cement (portland), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Iowa[4]	680	29	0.83	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Kansas[4]	672	28	0.82	Cement (portland), helium (crude), helium (Grade-A), salt, stone (crushed).
Kentucky[4]	513	32	0.62	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Louisiana[4]	536	34	0.65	Clay (common), salt, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Maine[4]	135	44	0.16	Cement (portland), peat, sand and gravel (construction), stone (crushed), stone (dimension).
Maryland[4]	410	33	0.50	Cement (masonry), cement (portland), sand and gravel (construction), stone (crushed), stone (dimension).
Massachusetts[4]	340	40	0.41	Clay (common), lime, sand and gravel (construction), stone (crushed), stone (dimension).
Michigan	2,470	11	3.01	Cement (portland), iron ore, nickel, salt, sand and gravel (construction).
Minnesota[4]	4,050	5	4.93	Iron ore, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Mississippi	404	38	0.49	Clay (ball and montmorillonite), sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Missouri	2,930	9	3.57	Cement (portland), lead, lime, sand and gravel (industrial), stone (crushed).
Montana	1,130	24	1.37	Cement (portland), copper, palladium metal, platinum metal, sand and gravel (construction).

See footnotes at end of table.

TABLE 3.—VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 2018.[e, 1]—Continued

State	Value (millions)	Rank[2]	Percent of U.S. total	Principal commodities[3]
Nebraska[4]	$209	39	0.25	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Nevada	7,880	1	9.58	Copper, gold, lime, sand and gravel (construction), silver.
New Hampshire	162	45	0.20	Sand and gravel (construction), stone (crushed), stone (dimension).
New Jersey	295	42	0.36	Peat, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
New Mexico	1,160	23	1.42	Cement (portland), copper, potash, sand and gravel (construction), stone (crushed).
New York	1,790	16	2.18	Cement (portland), salt, sand and gravel (construction), stone (crushed), zinc.
North Carolina[4]	1,210	18	1.47	Clay (common), phosphate rock, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
North Dakota[4]	136	46	0.17	Clay (common), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Ohio[4]	1,200	17	1.46	Cement (portland), lime, salt, sand and gravel (construction), stone (crushed).
Oklahoma	894	31	1.09	Cement (portland), iodine, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Oregon	530	36	0.64	Cement (portland), diatomite, perlite (crude), sand and gravel (construction), stone (crushed).
Pennsylvania[4]	1,920	14	2.34	Cement (masonry), cement (portland), lime, sand and gravel (construction), stone (crushed).
Rhode Island[4]	56	49	0.07	Sand and gravel (construction), sand and gravel (industrial), stone (crushed).
South Carolina[4]	1,050	26	1.28	Cement (portland), clay (kaolin), gold, sand and gravel (construction), stone (crushed).
South Dakota	339	41	0.41	Cement (portland), gold, lime, sand and gravel (construction), stone (crushed).
Tennessee	1,460	19	1.77	Cement (portland), sand and gravel (construction), sand and gravel (industrial), stone (crushed), zinc.
Texas	6,030	3	7.34	Cement (portland), salt, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Utah	2,940	8	3.58	Cement (portland), copper, magnesium metal, salt, sand and gravel (construction).
Vermont[4]	104	48	0.13	Sand and gravel (construction), stone (crushed), stone (dimension), talc (crude).
Virginia	1,290	22	1.57	Cement (portland), lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed).
Washington	1,090	25	1.33	Cement (portland), diatomite, sand and gravel (construction), stone (crushed), zinc.
West Virginia[4]	263	37	0.32	Cement (masonry), cement (portland), lime, sand and gravel (construction), stone (crushed).
Wisconsin[4]	2,730	10	3.32	Lime, sand and gravel (construction), sand and gravel (industrial), stone (crushed), stone (dimension).
Wyoming	2,410	12	2.93	Cement (portland), clay (bentonite), helium (Grade-A), sand and gravel (construction), soda ash.
Undistributed	3,410	XX	4.15	
Total	82,200	XX	100.00	

[e]Estimated. XX Not applicable.

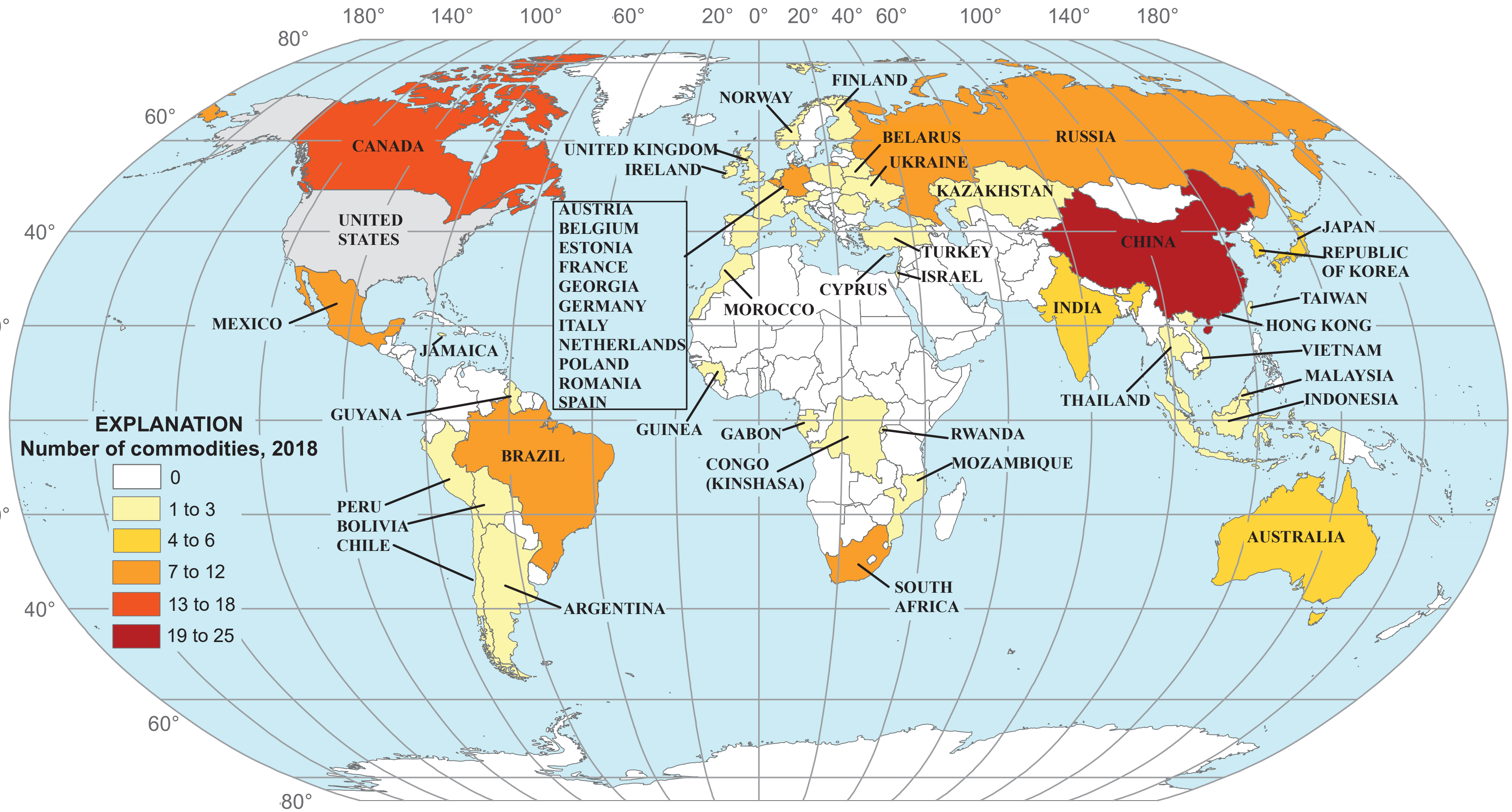
[1]Data are rounded to no more than three significant digits; may not add to totals shown.

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

[3]Listed in alphabetical order for each State.

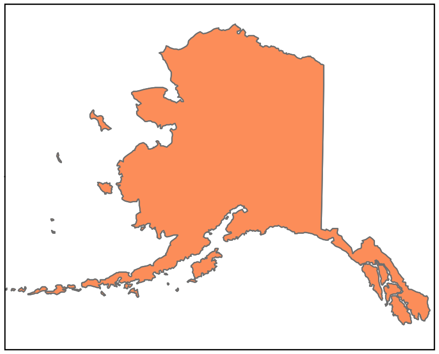
[4]Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included in "Undistributed."

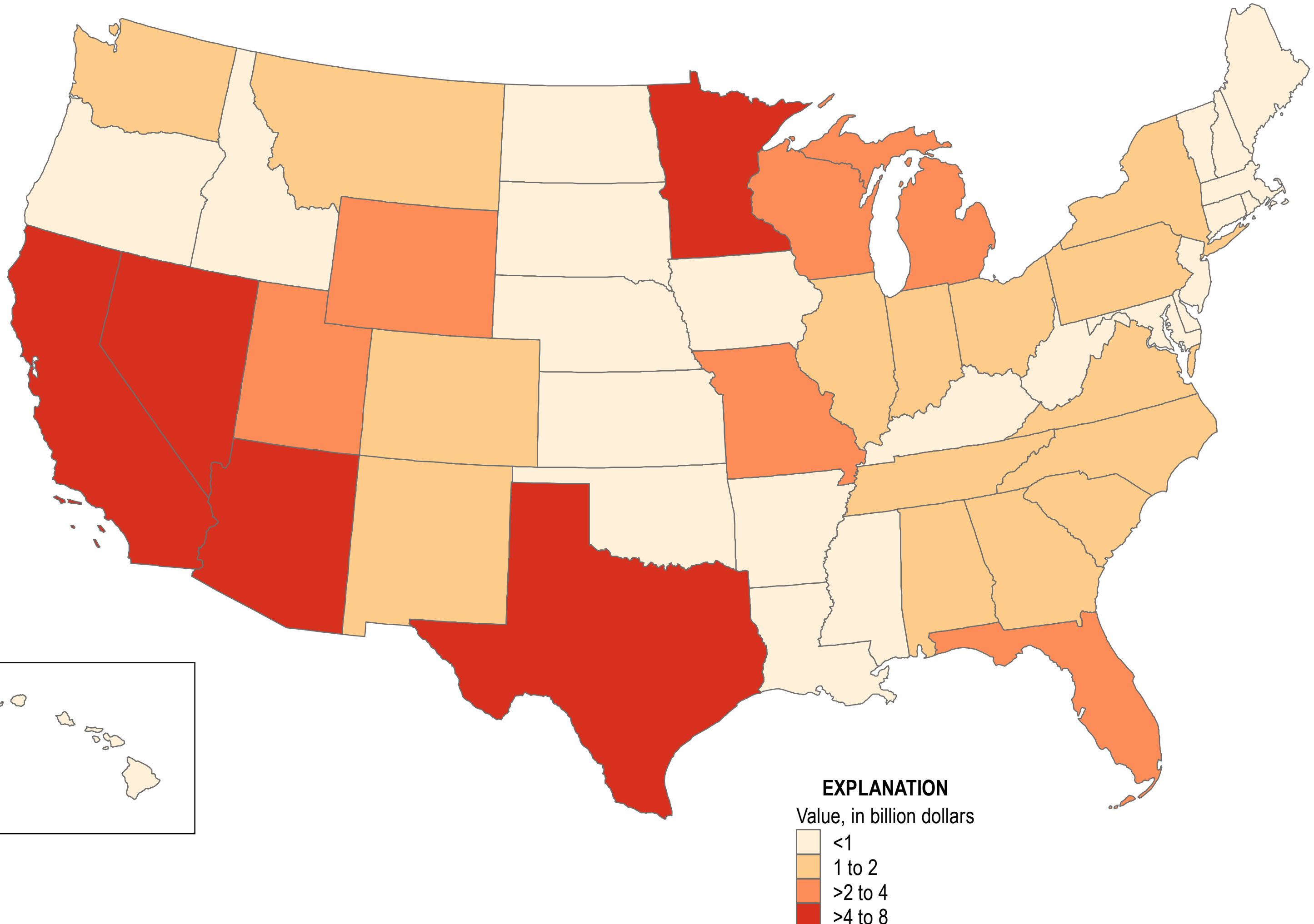
MAJOR IMPORT SOURCES OF NONFUEL MINERAL COMMODITIES FOR WHICH THE UNITED STATES WAS GREATER THAN 50% NET IMPORT RELIANT IN 2018

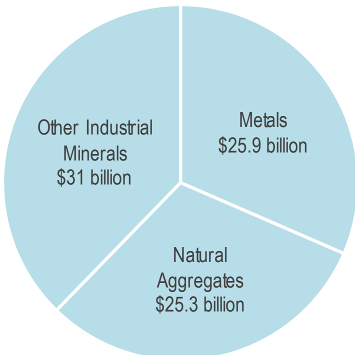


Source: U.S. Geological Survey

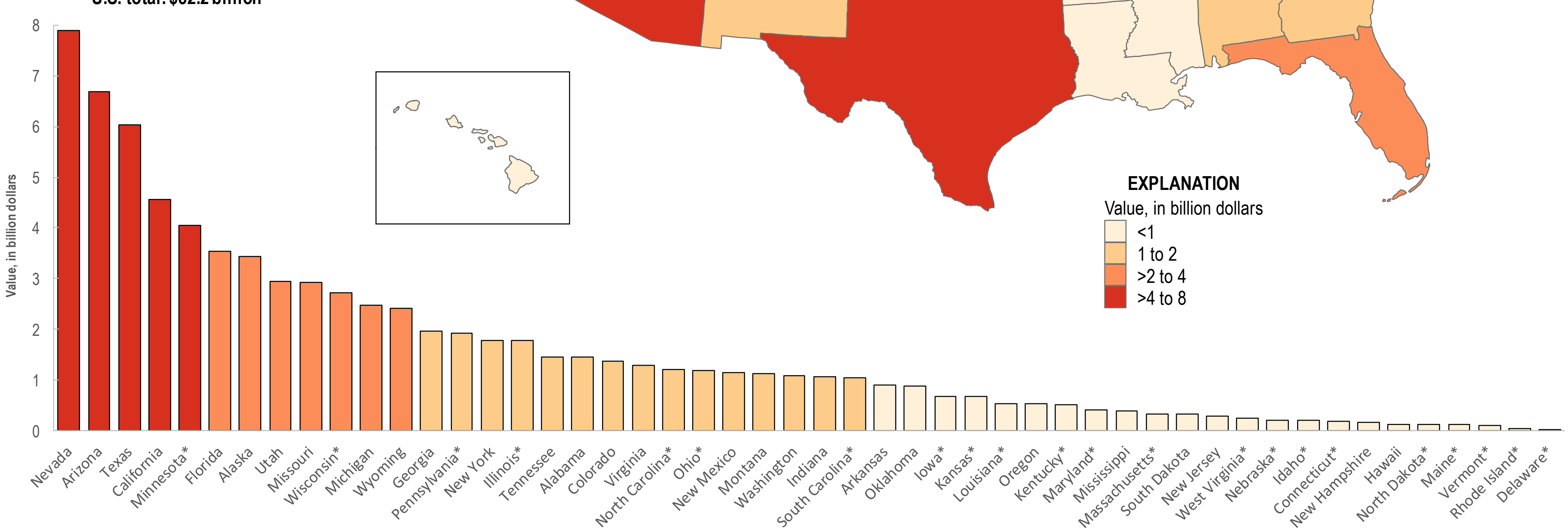
VALUE OF NONFUEL MINERALS PRODUCED IN 2018, BY STATE





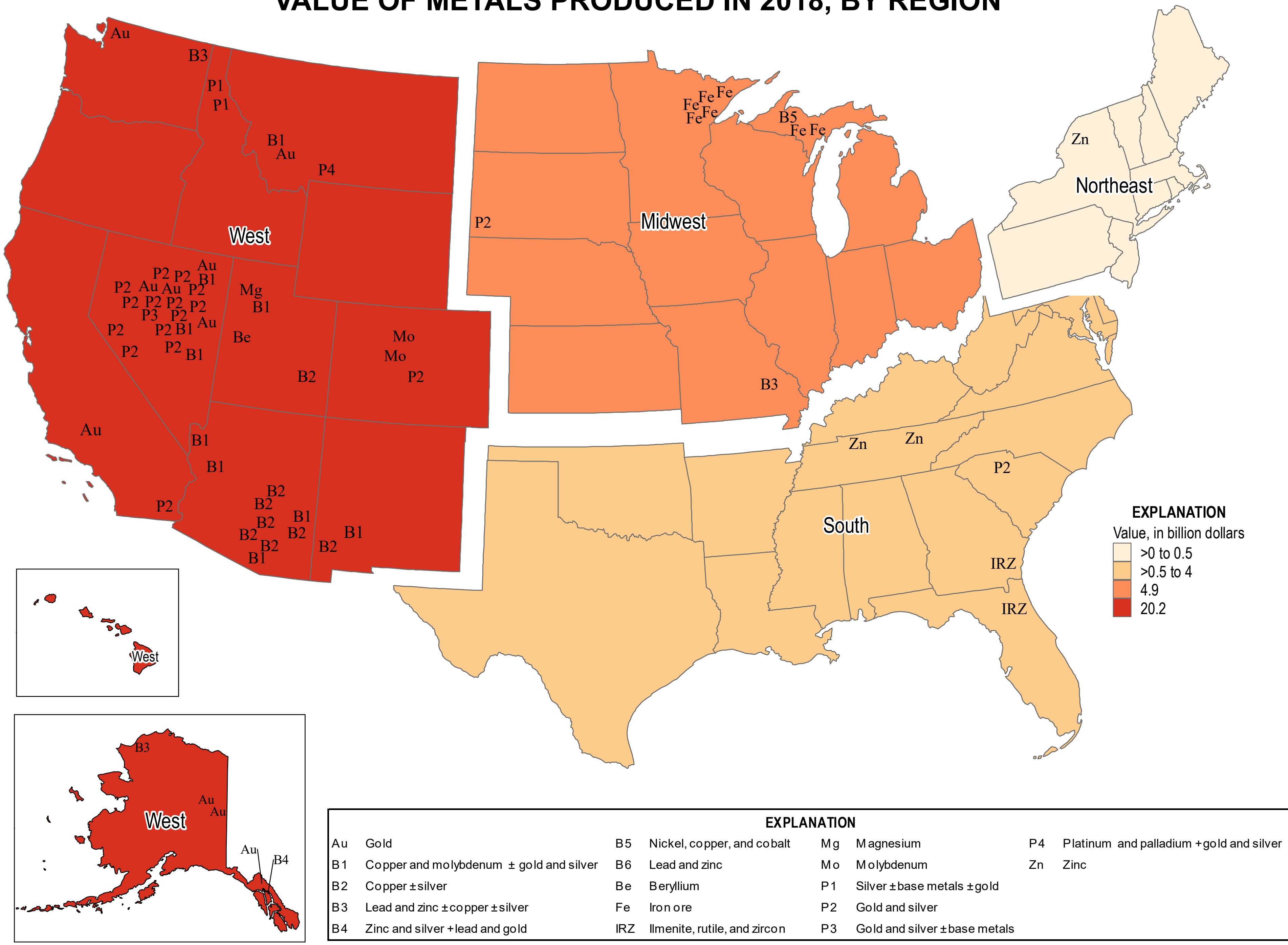


U.S. total: $82.2 billion

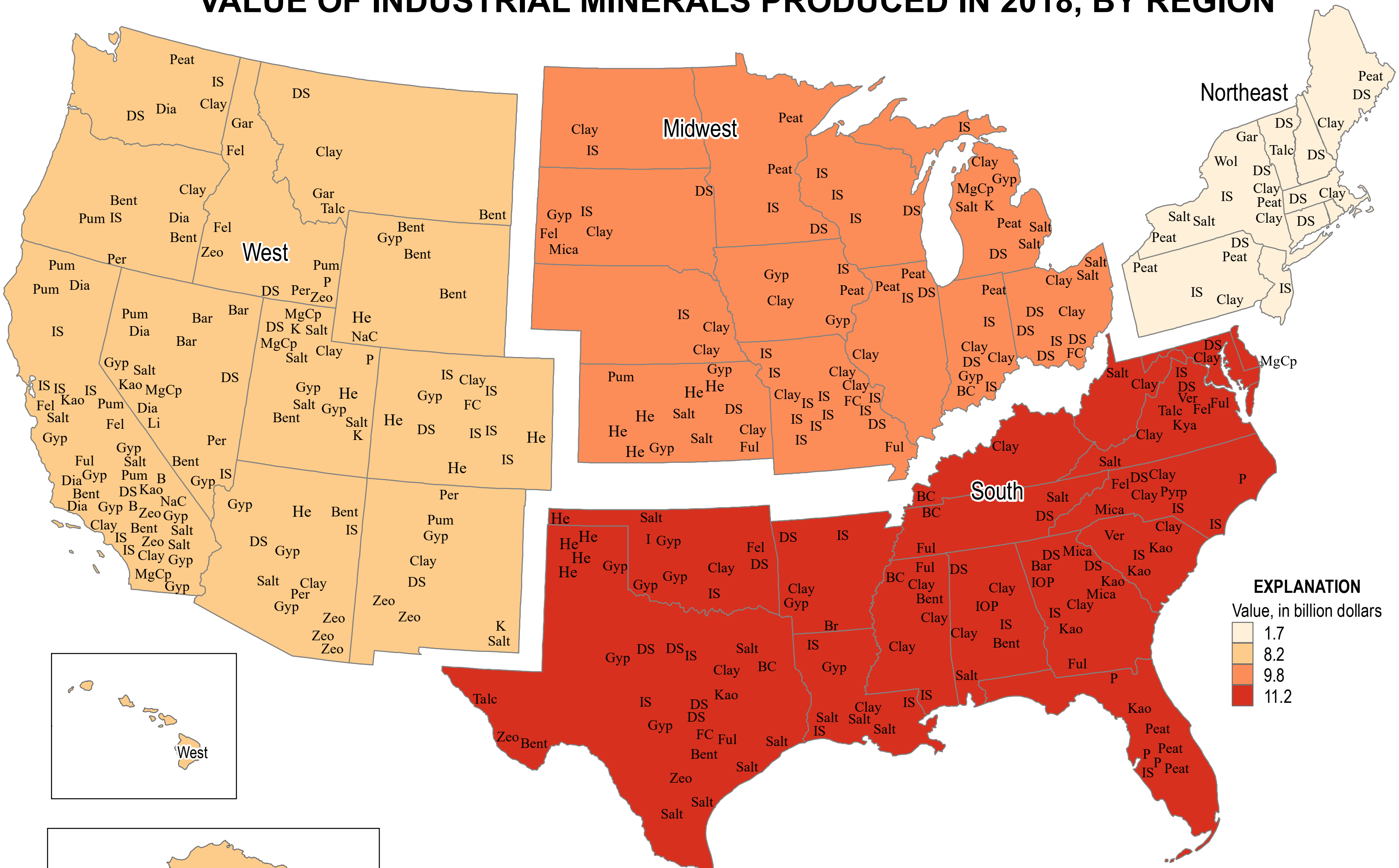


*Partial total; excludes values that must be withheld to avoid disclosing company proprietary data, which are included with "Undistributed" in table 3.

VALUE OF METALS PRODUCED IN 2018, BY REGION



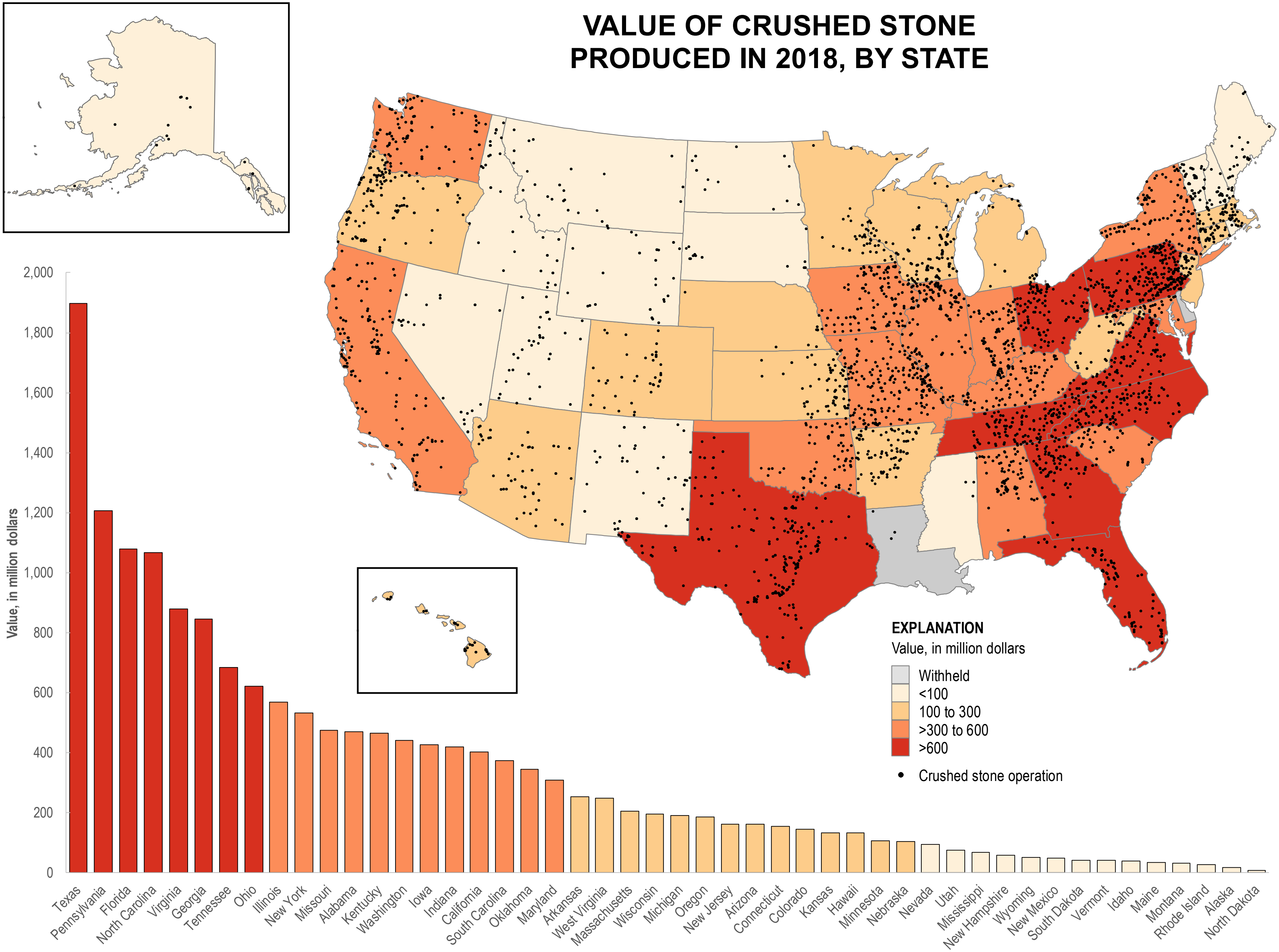
VALUE OF INDUSTRIAL MINERALS PRODUCED IN 2018, BY REGION



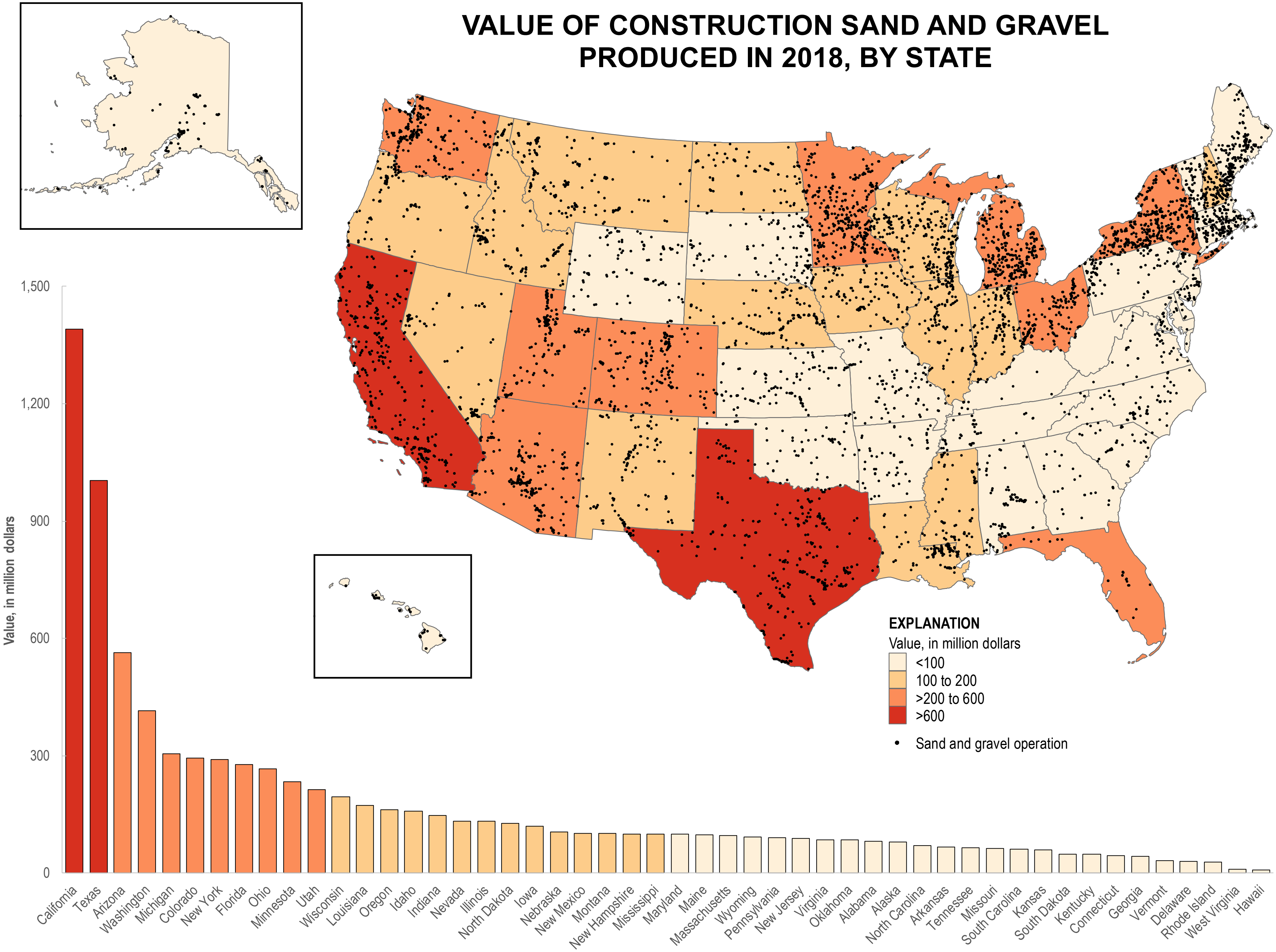
EXPLANATION

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

VALUE OF CRUSHED STONE PRODUCED IN 2018, BY STATE



VALUE OF CONSTRUCTION SAND AND GRAVEL PRODUCED IN 2018, BY STATE



ABRASIVES (MANUFACTURED)

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

Domestic Production and Use: Fused aluminum oxide was produced by two companies at three plants in the United States and Canada. Production of crude fused aluminum oxide had an estimated value of $2 million. Silicon carbide was produced by two companies at two plants in the United States. Domestic production of crude silicon carbide had an estimated value of about $26 million. Metallic abrasives were produced by 11 companies in 8 States. Production of metallic abrasives had an estimated value of about $114 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:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Fused aluminum oxide, crude[1, 2]	10,000	10,000	10,000	10,000	10,000
Silicon carbide[2]	35,000	35,000	35,000	35,000	35,000
Metallic abrasives	194,000	206,000	188,000	179,000	180,000
Shipments, metallic abrasives	211,000	224,000	204,000	197,000	195,000
Imports for consumption:					
Fused aluminum oxide	198,000	164,000	155,000	205,000	169,000
Silicon carbide	130,000	139,000	116,000	137,000	138,000
Metallic abrasives	23,500	52,800	54,200	29,700	31,000
Exports:					
Fused aluminum oxide	19,500	15,000	14,200	15,400	18,000
Silicon carbide	22,300	19,700	6,820	6,100	9,300
Metallic abrasives	41,000	35,900	28,600	31,000	34,000
Consumption, apparent:					
Fused aluminum oxide[3]	179,000	149,000	141,000	190,000	150,000
Silicon carbide[4]	143,000	154,000	144,000	166,000	166,000
Metallic abrasives[5]	194,000	241,000	230,000	196,000	190,000
Price, average unit value of imports, dollars per ton:					
Fused aluminum oxide, regular	659	579	418	489	680
Fused aluminum oxide, high-purity	1,420	1,290	1,370	1,220	1,300
Silicon carbide, crude	660	552	452	479	680
Metallic abrasives	1,020	584	543	1,020	750
Net import reliance[6] as a percentage of apparent consumption:					
Fused aluminum oxide	>75	>75	>75	>75	>75
Silicon carbide	>50	>75	>50	>75	>75
Metallic abrasives	E	8	12	E	E

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

Import Sources (2014–17): Fused aluminum oxide, crude: China, 75%; France, 7%; Hong Kong, 7%: Canada, 5%; and other, 6%. Fused aluminum oxide, grain: Austria, 20%; Brazil, 19%; Germany, 15%; Canada, 13%; and other, 33%. Silicon carbide, crude: China, 77%; Netherlands, 10%; South Africa, 9%; Romania, 2%; and other, 2%. Silicon carbide, grain: China, 52%; Brazil, 19%; Russia, 12%; Norway, 5%; and other, 12%. Metallic abrasives: Sweden, 33%; Canada, 27%; China, 12%; Germany, 8%; and other, 20%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–18**
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 val.
Artificial corundum, not elsewhere specified or included, fused aluminum oxide, grain	2818.10.2090	1.3% ad val.
Silicon carbide, crude	2849.20.1000	Free.
Silicon carbide, grain	2849.20.2000	0.5% ad val.
Iron, pig iron, or steel granules	7205.10.0000	Free.

Prepared by **David N. West [(703) 648–7751, dnwest@usgs.gov]**

ABRASIVES (MANUFACTURED)

Depletion Allowance: None.

Government Stockpile: None.

Events, Trends, and Issues: In 2018, China was the world's leading producer of abrasive fused aluminum oxide and abrasive silicon carbide, with producers operating nearly at capacity. Imports, especially from China where operating costs were lower, continued to challenge abrasives producers in the United States and Canada. Foreign competition, particularly from China, is expected to persist and continue to limit production in North America. Abrasives consumption in the United States is greatly influenced by activity in the manufacturing sectors, in particular 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[e]		Silicon carbide[e]	
	2017	2018	2017	2018
United States	60,000	60,000	43,000	43,000
Argentina	—	—	5,000	5,000
Australia	50,000	50,000	—	—
Austria	60,000	60,000	—	—
Brazil	50,000	50,000	43,000	43,000
China	800,000	800,000	455,000	455,000
France	40,000	40,000	16,000	16,000
Germany	80,000	80,000	36,000	36,000
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	190,000	190,000
World total (rounded)	1,300,000	1,300,000	1,000,000	1,000,000

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

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

[e]Estimated. E Net exporter. — Zero.
[1]Production data for aluminum oxide are combined production data from the United States and Canada to avoid disclosing company proprietary data.
[2]Rounded to the nearest 5,000 tons to avoid disclosing company proprietary data.
[3]Defined as imports – exports because production includes data from Canada; actual consumption is higher than that shown.
[4]Defined as production + imports – exports.
[5]Defined as shipments + imports – exports.
[6]Defined as imports – exports.

ALUMINUM[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2018, three companies operated seven primary aluminum smelters in six States. During 2018, two smelters that were idle at yearend 2017 were restarted and capacity at one other smelter was restarted. Two smelters operated at reduced capacity throughout the year. One other smelter remained on standby throughout the year. Production increased for the first year since 2012. Domestic smelters were operating at about 55% of capacity of 1.79 million tons per year in October. Based on published prices, the value of primary aluminum production was about $2.3 billion, 41% more than the value in 2017. Transportation applications accounted for 40% of domestic consumption; in descending order of consumption, the remainder was used in packaging, 19%; building, 14%; electrical, 9%; consumer durables, 8%; machinery, 7%; and other, 3%.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Primary	1,710	1,587	818	741	890
Secondary (from old scrap)	1,690	1,560	1,570	1,590	1,600
Secondary (from new scrap)	1,870	2,000	2,010	2,050	2,100
Imports for consumption:					
Crude and semimanufactures	4,290	4,560	5,410	6,200	5,500
Scrap	559	521	609	700	730
Exports:					
Crude and semimanufactures	1,520	1,460	1,470	1,330	1,400
Scrap	1,720	1,550	1,350	1,570	1,700
Consumption, apparent[2]	5,070	5,300	5,090	5,670	4,900
Supply, apparent[3]	6,940	7,310	7,100	7,720	7,000
Price, ingot, average U.S. market (spot), cents per pound	104.5	88.2	80.4	98.3	115.0
Stocks, yearend:					
Aluminum industry	1,280	1,350	1,400	1,470	1,500
London Metal Exchange (LME), U.S. warehouses[4]	1,190	507	362	254	200
Employment, number[5]	30,900	31,000	31,900	31,700	32,000
Net import reliance[6] as a percentage of apparent consumption	33	41	53	59	50

Recycling: In 2018, aluminum recovered from purchased scrap in the United States was about 3.70 million tons, of which about 58% came from new (manufacturing) scrap and 42% from old scrap (discarded aluminum products). Aluminum recovered from old scrap was equivalent to about 28% of apparent consumption.

Import Sources (2014–17): Canada, 51%; Russia 9%; United Arab Emirates, 8%; China, 7%; and other, 25%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Aluminum, not alloyed:		
Unwrought (in coils)	7601.10.3000	2.6% ad val.
Unwrought (other than aluminum alloys)	7601.10.6000	Free.
Aluminum alloys:		
Unwrought (billet)	7601.20.9045	Free.
Aluminum waste and scrap:		
Used beverage container scrap	7602.00.0030	Free.
Other	7602.00.0090	Free.

Depletion Allowance: Not applicable.[1]

Government Stockpile: None.

Events, Trends, and Issues: Citing Government actions, three primary aluminum smelters restarted capacity. In January, a smelter in Evansville, IN, restarted 161,000 tons per year of its 269,000 tons per year of capacity. In June, a 263,000-ton-per-year smelter in New Madrid, MO, restarted 100,000 tons per year of its capacity, and a 252,000-ton-per-year smelter in Hawesville, KY, restarted 150,000 tons per year of its capacity. In May, power failures forced the shutdown of one potline at each of the smelters in Evansville, IN, and Sebree, KY, with capacities of 54,000 tons per year and 73,000 tons per year, respectively. Both potlines were restarted by yearend. In June, 38,000 tons per year of capacity at a smelter in Wenatchee, WA, that had not produced since 2001 was permanently shut down.

Prepared by **E. Lee Bray [(703) 648–4979, lbray@usgs.gov]**

ALUMINUM

On March 8, 2018, the President of the United States signed an order imposing a 10% tariff on aluminum imports under authority of Section 232 of the Trade Expansion Act of 1962. In May, the Governments of Argentina and Australia agreed to quotas at the average annual volume imported in 2015–17 and were exempted from the tariff. Effective April 2, the Government of China imposed a 25% tariff on aluminum scrap imports from the United States in response to the 10% tariff placed on aluminum imports by the United States.

In February 2018, the U.S. Department of Commerce issued the final determinations in the antidumping and countervailing duty investigations of imports of aluminum foil from China. The investigation, which was initiated in November 2017, concluded that foil produced in China was sold in the United States at less than fair value and that the Government of China provided subsidies to foil producers. Antidumping margins were set at 48.64% to 106.09% and countervailing margins were set at 17.14% to 80.97% on foil from China. In June, the U.S. Trade Representative imposed a 25% tariff on aluminum alloys, semifabricated aluminum products, and unwrought aluminum produced in China following its Section 301 investigation initiated in August 2017. In November, the U.S. Department of Commerce announced its determination of the antidumping and countervailing duty investigations of common aluminum alloy sheet, initiated in November 2017. Countervailing margins were set at 32.2% to 113.3% and the preliminary antidumping rate was set at 167.16% for all material produced in China covered by the investigation.

On April 6, 2018, the U.S. Department of the Treasury designated the sole primary aluminum producer in Russia for sanctions in response to activities of owners and the Government of the Russian Federation. After the primary owner of the company resigned operational control, the U.S. Department of the Treasury announced in September that in 2019, companies may import aluminum produced by that company in amounts similar to those imported in 2018.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including aluminum (bauxite). This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

World Smelter Production and Capacity:

	Production		Yearend capacity	
	2017	2018[e]	2017	2018[e]
United States	741	890	1,830	1,790
Australia	1,450	1,600	1,720	1,720
Bahrain	981	1,000	1,050	1,050
Brazil	801	660	1,400	1,400
Canada	3,210	2,900	3,270	3,270
China	32,300	33,000	45,200	47,800
Iceland	870	870	870	870
India	3,270	3,700	4,060	4,060
Norway	1,230	1,300	1,350	1,430
Russia	3,580	3,700	3,900	3,900
United Arab Emirates	2,600	2,600	2,600	2,600
Other countries	8,380	7,800	10,600	10,400
World total (rounded)	59,400	60,000	77,800	80,300

World Resources: Global resources of bauxite are estimated to be between 55 billion to 75 billion tons and are sufficient to meet world demand for metal well into the future.[1]

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

[e]Estimated.
[1]See also Bauxite and Alumina.
[2]Defined as domestic primary metal production + recovery from old aluminum scrap + net import reliance; excludes imported scrap.
[3]Defined as domestic primary metal production + recovery from all aluminum scrap + net import reliance; excludes imported scrap.
[4]Includes aluminum alloy.
[5]Alumina and aluminum production workers (North American Industry Classification System—3313). Source: U.S. Department of Labor, Bureau of Labor Statistics.
[6]Defined as imports – exports + adjustments for industry stock changes.

ANTIMONY

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

Domestic Production and Use: In 2018, no marketable antimony was mined in the United States. A mine in Nevada that had extracted about 800 tons of stibnite ore from 2013 through 2014 was placed on care-and-maintenance status in 2015 and had no reported production in 2018. Primary antimony metal and oxide were produced by one company in Montana using imported feedstock. Secondary antimony production was derived mostly from antimonial lead recovered from spent lead-acid batteries. The estimated value of secondary antimony produced in 2018, based on the average New York dealer price for antimony, was about $34 million. Recycling supplied about 14% of estimated domestic consumption, and the remainder came mostly from imports. The value of antimony consumption in 2018, based on the average New York dealer price, was about $251 million. The estimated distribution of domestic primary antimony consumption was as follows: nonmetal products, including ceramics and glass and rubber products, 33%; flame retardants, 36%; and metal products, including antimonial lead and ammunition, 31%.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Mine (recoverable antimony)	—	—	—	—	—
Smelter:					
Primary	519	627	645	602	400
Secondary	4,280	3,740	3,810	[e]4,000	4,000
Imports for consumption:					
Ore and concentrates	378	308	119	61	98
Oxide	17,600	16,700	16,200	17,900	21,000
Unwrought, powder, waste and scrap[1]	6,210	5,790	7,150	6,830	6,500
Exports:					
Ore and concentrates[1]	41	31	12	46	47
Oxide	1,670	1,760	1,330	1,600	1,960
Unwrought, powder, waste and scrap[1]	1,570	1,440	623	653	550
Consumption, apparent[2]	25,400	23,700	26,000	26,800	29,000
Price, metal, average, dollars per pound[3]	4.25	3.27	3.35	3.98	3.90
Stocks, yearend	1,400	1,290	1,090	1,360	1,400
Employment, plant, number (yearend)[e]	27	27	27	27	27
Net import reliance[4] as a percentage of apparent consumption	81	82	83	83	85

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 (2014–17): Metal: China, 58%; India, 17%; Vietnam, 6%; United Kingdom, 5%; and other, 14%. Ore and concentrate: Italy, 73%; China, 15%; India, 6%; Mexico, 3% and other, 3%. Oxide: China, 61%; Thailand, 11%; Belgium, 10%; Bolivia, 8%; and other, 10%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
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: None.

Prepared by **Kateryna Klochko [(703) 648–4977, kklochko@usgs.gov]**

ANTIMONY

Events, Trends, and Issues: In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including antimony. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ''A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" (82 FR 60835).

One company operated a smelter in Montana that produced antimony metal and oxides from imported intermediate products (antimony oxide and sodium antimonate), primarily from a smelter in Mexico that processed concentrates from mines in Australia and Mexico. The company reported successful testing of a new product, antimony trisulfide, which would be produced at the facility in Montana. The company also announced the reopening of two of its mines in Mexico.

China continued to be the leading global antimony producer in 2018 and accounted for more than 70% of global mine production. In 2016 and 2017, many large-scale producers reduced production and many small-scale producers closed in response to price declines in China and stricter environmental standards from Provincial and national governments. In 2018, producers in Hunan, Yunnan, and Guizhou Provinces maintained a steady production rate after their smelters completed upgrades to meet the environmental standards. In the next several years, antimony mining in the Guizhou Province was expected to be limited as a part of the Chinese Government's mining industry reforms aiming to reduce mine overproduction.

World Mine Production and Reserves:

	Mine production		Reserves[5]
	2017	2018[e]	
United States	—	—	[6]60,000
Australia	3,120	3,100	[7]140,000
Bolivia	2,700	2,700	310,000
Burma	1,000	1,000	NA
China	98,000	100,000	480,000
Guatemala	25	25	NA
Iran	300	300	NA
Kazakhstan	700	700	NA
Laos	340	300	NA
Mexico	243	240	18,000
Pakistan	60	60	NA
Russia (recoverable)	14,400	14,000	350,000
Tajikistan	14,000	14,000	50,000
Turkey	2,000	2,000	100,000
Vietnam	380	300	NA
World total (rounded)	137,000	140,000	1,500,000

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

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

[e]Estimated. NA Not available. — Zero.
[1]Gross weight.
[2]Defined as primary production + secondary production from old scrap + net import reliance.
[3]New York dealer price for 99.65% metal, cost, insurance, freight U.S. ports. Source: Platts Metal Week.
[4]Defined as imports of antimony in oxide, unwrought, powder, waste and scrap – exports of antimony in oxide, unwrought, powder, waste and scrap + adjustments for industry stock changes.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.
[6]Company-reported probable reserves for the Stibnite Gold Project in Idaho.
[7]For Australia, Joint Ore Reserves Committee-compliant reserves were 65,000 tons.

ARSENIC

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

Domestic Production and Use: Arsenic trioxide and primary arsenic metal have not been produced in the United States since 1985. The principal use for arsenic trioxide was for the production of arsenic acid used in the formulation of chromated copper arsenide (CCA) preservatives for the pressure treating of lumber used primarily in nonresidential applications. Three companies produced CCA preservatives in the United States in 2018. The grids in lead-acid storage batteries were strengthened by the addition of arsenic metal. Arsenic metal was also used as an antifriction additive for bearings, to harden lead shot, and in clip-on wheel weights. Arsenic compounds were used in herbicides and insecticides. High-purity arsenic (99.9999%) was used to produce gallium-arsenide (GaAs) semiconductors for solar cells, space research, and telecommunications. Arsenic also was used for germanium-arsenide-selenide specialty optical materials. Indium-gallium-arsenide (InGaAs) was used for short-wave infrared technology. The value of arsenic compounds and metal imported domestically in 2018 was estimated to be about $5.8 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 has been reported under this category reflects the gross weight of alloys, compounds, residues, scrap, and waste containing arsenic. Therefore, the estimated consumption reported under salient U.S. statistics reflects only imports of arsenic products.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Imports for consumption:					
Arsenic metal	688	514	793	942	630
Compounds	5,260	5,920	5,320	5,980	4,900
Exports, arsenic[2]	2,970	1,670	1,760	698	60
Estimated consumption[3]	5,940	6,430	6,120	6,920	5,500
Value, dollars per kilogram, average[4]					
Arsenic metal (China)	1.64	1.85	1.89	1.56	1.40
Trioxide (China)	0.45	0.45	0.46	0.45	0.42
Trioxide (Morocco)	0.66	0.64	0.68	0.68	0.75
Net import reliance[5] as a percentage of estimated consumption	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 (2014–17): Arsenic metal: China, 91%; Japan, 5%; Hong Kong, 3%, and other, 1%. Arsenic trioxide: Morocco, 50%; China, 47%; Belgium, 3%; and other, <1%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Arsenic	2804.80.0000	Free.
Arsenic acid	2811.19.1000	2.3% ad val.
Arsenic trioxide	2811.29.1000	Free.
Arsenic sulfide	2813.90.1000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Prepared by **Micheal W. George [(703) 648–4962, mgeorge@usgs.gov]**

ARSENIC

Events, Trends, and Issues: China and Morocco continued to be the leading global producers of arsenic trioxide, accounting for about 85% of estimated world production and supplied almost all of United States imports of arsenic trioxide in 2018. China was the leading world producer of arsenic metal and supplied about 90% of United States arsenic metal imports in 2018.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including arsenic. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

High-purity (99.9999%) arsenic metal was used to produce GaAs, indium-arsenide, and InGaAs semiconductors that were used in biomedical, communications, computer, electronics, and photovoltaic applications. Global GaAs wafer revenue was estimated to be $278 million in 2018, and almost one-half of GaAs wafer production took place in China. See the Gallium chapter for additional details.

World Production and Reserves:

	Production[6] (arsenic trioxide) 2017[e]	2018[e]	Reserves[7]
United States	—	—	
Belgium	1,000	1,000	World reserves data are unavailable but are thought to be more than 20 times world production.
Bolivia	40	40	
China	24,000	24,000	
Iran	110	110	
Japan	45	45	
Morocco	6,000	6,000	
Namibia	1,900	1,900	
Russia	1,500	1,500	
World total (rounded)	34,600	35,000	

World Resources: 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; has been recovered from copper-gold ores in Chile; and was associated with gold occurrences in Canada. Orpiment and realgar from gold mines in Sichuan Province, China, were stockpiled for later recovery of arsenic. Arsenic also may be recovered from enargite, a copper mineral. Arsenic trioxide was produced at the hydrometallurgical complex of Guemassa, near Marrakech, Morocco, from cobalt arsenide ore from the Bou-Azzer Mine.

Substitutes: Substitutes for CCA in wood treatment include alkaline copper quaternary, ammoniacal copper quaternary, ammoniacal copper zinc arsenate, alkaline copper quaternary boron-based preservatives, copper azole, copper citrate, and copper naphthenate. Treated wood substitutes include concrete, plastic composite material, plasticized wood scrap, or steel. Silicon-based complementary metal-oxide semiconductor power amplifiers compete with GaAs power amplifiers in midtier third generation cellular handsets. Indium phosphide components can be substituted for GaAs-based infrared laser diodes in some specific-wavelength applications, and helium-neon lasers compete with GaAs in visible laser diode applications. Silicon is the principal competitor with GaAs in solar-cell applications. GaAs-based integrated circuits are used in many defense-related applications because of their unique properties, and no effective substitutes exist for GaAs in these applications. GaAs in heterojunction bipolar transistors 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 calculated at 75.71%.
[2]Most of the materials reported to the U.S. Census Bureau as arsenic exports are thought to be arsenic-containing compounds or residues.
[3]Estimated to be the same as imports.
[4]Calculated from U.S. Census Bureau import data.
[5]Defined as imports.
[6]Chile, Mexico, and Peru were believed to be significant producers of commercial-grade arsenic trioxide but have reported no production in recent years.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.

ASBESTOS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: The last U.S. producer of asbestos ceased operations in 2002 as a result of the decline in domestic and international asbestos markets associated with health and liability issues. The United States has since been wholly dependent on imports to meet manufacturing needs. In 2018, all of the asbestos minerals imported into and used within the United States consisted of chrysotile and were predominantly shipped from Brazil. Domestic consumption of asbestos minerals in 2018 was estimated to be 750 tons. Actual consumption of asbestos may have been lower owing to stockpiling by companies for future use, but information regarding industry stocks was unavailable. The chloralkali industry, which uses asbestos to manufacture semipermeable diaphragms that prevent chlorine generated at the anode of an electrolytic cell from reacting with sodium hydroxide generated at the cathode, accounted for 100% of asbestos mineral consumption in 2018, based on bill of lading information obtained from a commercial trade database. In addition to asbestos minerals, an unknown quantity of asbestos was imported within manufactured products, including asbestos-containing brake materials, rubber sheets for gaskets, tile, wallpaper, and potentially asbestos-cement pipe and knitted fabrics.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Imports for consumption	406	325	747	332	[1]750
Exports[2]	—	—	—	—	—
Consumption, estimated[3]	406	325	747	332	750
Price, average U.S. Customs value, dollars per ton	1,830	1,880	1,910	1,870	1,900
Net import reliance[4] as a percentage of estimated consumption	100	100	100	100	100

Recycling: None.

Import Sources (2014–17): Brazil, >99%; and Russia, <1%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Crocidolite	2524.10.0000	Free.
Amosite	2524.90.0010	Free.
Chrysotile:		
Crudes	2524.90.0030	Free.
Milled fibers, group 3 grades	2524.90.0040	Free.
Milled fibers, group 4 and 5 grades	2524.90.0045	Free.
Other	2524.90.0055	Free.
Other, asbestos	2524.90.0060	Free.

Depletion Allowance: 22% (Domestic), 10% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of asbestos minerals in the United States has decreased during the past several decades, falling from a record high of 803,000 tons in 1973 to a record low of 325 tons in 2015. Annual consumption has since varied between roughly 330 tons and 750 tons. 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 accounted for all domestic consumption of asbestos minerals in 2018 compared with an estimated 35% in 2010.

Prepared by **Daniel M. Flanagan [(703) 648–7726, dflanagan@usgs.gov]**

ASBESTOS

Estimated worldwide consumption of asbestos minerals decreased from approximately 2 million tons in 2010 to slightly less than 1 million tons in 2017. Asbestos-cement products are expected to continue to be the leading global market for asbestos.

According to multiple news agencies, the Supreme Federal Court of Brazil enacted a comprehensive national ban on asbestos in November 2017. However, company documents indicate that the only asbestos producer in the country continued to operate during 2018. Pending a further court ruling, the company disputed the national nature of the ban and considered asbestos to be legal in those States without explicit laws that disallow its production, use, or exportation. Brazil accounted for an estimated 14% of global asbestos production and an estimated 7% of global asbestos mineral consumption in 2017.

The Frank R. Lautenberg Chemical Safety for the 21st Century Act, which amended the Toxic Substances Control Act of 1976, was signed into law in 2016. The legislation granted the U.S. Environmental Protection Agency (EPA) greater authority to evaluate the hazards posed by new chemicals as well as those already in the marketplace. In 2018, the EPA finalized the end uses and exposure pathways that will be considered in its asbestos evaluation and proposed a rule that would require manufacturers and importers to obtain EPA approval before starting or resuming the importation or processing of asbestos.

World Mine Production and Reserves: Two former asbestos mines in Zimbabwe were potentially in the process of restarting during 2018, but information regarding the status and production of these operations was unavailable. Reserves for Brazil were revised based on information from Government and industry sources.

	Mine production		Reserves[5]
	2017	2018[e]	
United States	—	—	Small
Brazil	[e]160,000	100,000	12,000,000
China	125,000	100,000	96,000,000
Kazakhstan	193,000	220,000	Large
Russia	[e]690,000	650,000	110,000,000
World total (rounded)	1,170,000	1,100,000	Large

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

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

[e]Estimated. — Zero.

[1]According to the U.S. Census Bureau and bill of lading information from a commercial trade database, U.S. imports of asbestos minerals (chrysotile) totaled approximately 540 tons through August 2018. Final 2018 imports may differ significantly from the provided estimate because imports of chrysotile typically do not follow a predictable pattern throughout the year.

[2]Exports of asbestos reported by the U.S. Census Bureau were 279 tons in 2014, 517 tons in 2015, 587 tons in 2016, 143 tons in 2017, and an estimated 490 tons in 2018. These shipments likely consisted of materials misclassified as asbestos, reexports, and (or) waste products because the United States no longer mines asbestos.

[3]Assumed to equal imports.

[4]Defined as imports – exports.

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

BARITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2018, domestic mine production increased by more than 40%, to an estimated 480,000 tons valued at an estimated $46 million. Most of the production came from Nevada and a single mine in Georgia. An estimated 2.4 million tons of barite (from domestic production and imports) was sold by crushers and grinders operating in seven States. More than 90% of the barite sold in the United States was 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. 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, automobile paint primer for metal protection and gloss, use 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:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Sold or used, mine	667	433	232	334	480
Ground and crushed[1]	3,410	2,010	1,420	2,030	2,400
Imports for consumption[2]	2,700	1,660	1,260	2,220	2,600
Exports[3]	161	147	78	116	74
Consumption, apparent (crude and ground)[4]	3,210	1,950	1,410	2,440	3,000
Estimated price, ground, average value, dollars per ton, f.o.b. mill	191	194	187	179	180
Employment, mine and mill, number	614	458	300	350	410
Net import reliance[5] as a percentage of apparent consumption	79	78	84	86	84

Recycling: None.

Import Sources (2014–17): China, 63%; India, 14%; Mexico, 11%; Morocco, 10%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Ground barite	2511.10.1000	Free.
Crude barite	2511.10.5000	$1.25 per metric ton.
Oxide, hydroxide, and peroxide	2816.40.2000	2% ad val.
Other chlorides	2827.39.4500	4.2% ad val.
Other sulfates of barium	2833.27.0000	0.6% ad val.
Carbonate	2836.60.0000	2.3% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Prepared by **Michele E. McRae [(703) 648–7743, mmcrae@usgs.gov]**

BARITE

Events, Trends, and Issues: In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including barite. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

Drilling rig counts have historically been an effective barometer of barite consumption. In January, the monthly average number of operating rigs was 937, which increased to 1,063 in October. Sales from grinding plants in all regions, including Louisiana, Texas, and all other States, increased by an estimated 18% compared with 2017. Sales from plants in Texas, which had increased by more than 110% in 2017, increased by more than 45% in 2018. These increases reflected continued recovery in U.S. drilling activity, which has been concentrated in the Permian Basin.

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 barite in 2010. This has likely stimulated exploration and expansion of global barite resources. Estimated reserves data are included only if developed since the adoption of the 4.1-specific-gravity standard. Reserves data for China, India, and Pakistan were revised based on Government information.

	Mine production		Reserves[6]
	2017	2018[e]	
United States	334	480	NA
China	3,200	3,200	36,000
India	1,560	2,000	51,000
Iran	550	550	24,000
Kazakhstan	620	620	85,000
Mexico	360	400	NA
Morocco	950	1,000	NA
Pakistan	106	110	30,000
Russia	221	220	12,000
Thailand	148	150	18,000
Turkey	200	290	35,000
Other countries	418	460	29,000
World total (rounded)	8,670	9,500	320,000

World Resources: In the United States, identified resources of barite are estimated to be 150 million tons, and undiscovered resources contribute an additional 150 million tons. The world’s barite resources in all categories are about 2 billion tons, but only about 740 million tons are identified resources. However, no known systematic assessment of either U.S. or global barite resources has been conducted since the 1980s.

Substitutes: In the drilling mud market, alternatives to barite include celestite, ilmenite, iron ore, and synthetic hematite that is manufactured in Germany. None of these substitutes, however, has had a major impact on the barite drilling mud industry.

[e]Estimated. NA Not available.

[1]Imported and domestic barite, crushed and ground, sold or used by domestic grinding establishments.

[2]Imports calculated from Harmonized Tariff Schedule of the United States codes 2511.10.1000, 2511.10.5000, and 2833.27.0000.

[3]Exports calculated from Schedule B numbers 2511.10.1000 and 2833.27.0000.

[4]Defined as sold or used by domestic mines + imports – exports.

[5]Defined as imports – exports.

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

BAUXITE AND ALUMINA[1]

(Data in thousand metric dry tons unless otherwise noted)

Domestic Production and Use: In 2018, the quantity of bauxite consumed, nearly all of which was imported, was estimated to be 3.9 million tons, 11% more than that in 2017, with an estimated value of about $120 million. About 80% 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, refractories, and as a slag adjuster in steel mills. Three domestic Bayer-process refineries had a combined alumina production capacity of 4 million tons per year. Two of the refineries produced an estimated 1.5 million tons in 2018, 5% more than that in 2017. One other refinery has been on care-and-maintenance status since 2016. About 70% 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:	2014	2015	2016	2017	2018[e]
Bauxite:					
Production, mine	W	W	W	W	W
Imports for consumption[2]	11,800	11,300	5,920	4,430	4,500
Exports[2]	15	21	40	29	23
Stocks, industry, yearend[2]	1,210	1,500	880	880	600
Consumption:					
Apparent[3]	W	W	W	W	W
Reported	9,840	9,660	5,360	3,510	3,900
Price, average value, U.S. imports (f.a.s.), dollars per ton	27	28	28	32	31
Net import reliance[4] as a percentage of apparent consumption	>75	>75	>75	>75	>75
Alumina:					
Production, refinery[5]	4,460	4,550	2,360	1,430	1,500
Imports for consumption[5]	1,630	1,570	1,140	1,330	1,700
Exports[5]	2,170	2,210	1,330	516	350
Stocks, industry, yearend[5]	276	274	320	264	400
Consumption, apparent[3]	3,930	3,920	2,130	2,300	2,700
Price, average value, U.S. imports (f.a.s.), dollars per ton	394	400	362	487	560
Net import reliance[4] as a percentage of apparent consumption	E	E	E	38	45

Recycling: None.

Import Sources (2014–17): Bauxite:[2] Jamaica, 46%; Brazil, 25%; Guinea, 15%; Guyana, 6%; and other, 8%. Alumina:[5] Australia, 36%; Brazil, 27%; Suriname, 14%; Jamaica, 7%; and other, 16%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
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 2018, two domestic alumina refineries produced alumina from imported bauxite. A 500,000-ton-per-year alumina refinery in Burnside, LA, produced specialty-grade alumina. A 1.2-million-ton-per-year alumina refinery in Gramercy, LA, produced alumina principally for aluminum smelting. A project at the Gramercy refinery was completed in the first half of 2018 that increased specialty-grade alumina capacity by 200,000 tons per year. The Gramercy refinery was also adding another production line for specialty-grade alumina. The average price free alongside ship (f.a.s.) for U.S. imports for consumption of metallurgical-grade alumina during the first 8 months of 2018 was $560 per ton, 22% higher than that of the same period in 2017, and ranged between $450 per ton and $900 per ton. For the first 8 months of 2018, the estimated average price (f.a.s.) for U.S. imports for consumption of crude-dry bauxite was $31 per ton, 3% less than that of the same period in 2017.

Prepared by **E. Lee Bray [(703) 648–4979, lbray@usgs.gov]**

BAUXITE AND ALUMINA

The Government of Malaysia continued its ban on bauxite mining through at least yearend 2018 but did permit exports of stockpiled bauxite. Media sources reported that some mines continued illegal mining. The ban was imposed in January 2016 because of concerns about pollution from mines and uncovered stockpiles at ports. In February, the Government of Brazil ordered a 6.3-million-ton-per-year alumina refinery and a nearby 10-million-ton-per-year bauxite mine to shut down one-half of their capacities, citing concerns that leaks from disposal areas may have taken place after heavy rainfall in the area. In June, an alumina refinery in Guinea that was shut down in 2012 was restarted and would be ramped up by midyear 2019. From August 8 to September 30, a labor dispute involving about 1,600 of 3,500 employees at two bauxite mines and three alumina refineries negatively affected production in Australia.

In April, the U.S. Department of the Treasury, in consultation with the U.S. Department of State, designated several Russian individuals and businesses for sanctions in response to activities of the Government of Russia. Among the designated companies was a producer of bauxite, alumina, and aluminum. A winddown period was granted to companies with contracts with the sanctioned company, through at least December 2018, and consumers in the United States may enter contracts for deliveries in 2019 in similar amounts purchased in 2018.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including aluminum (bauxite). This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

World Alumina Refinery and Bauxite Mine Production and Bauxite Reserves: Reserves data for India, Indonesia, and other countries were updated based on Government data and other sources.

	Alumina[5]		Bauxite		Reserves[6]
	2017	2018[e]	2017	2018[e]	
United States	1,430	1,500	W	W	20,000
Australia	20,500	19,000	87,900	75,000	[7]6,000,000
Brazil	10,900	7,900	38,500	27,000	2,600,000
Canada	1,570	1,600	—	—	—
China	69,000	72,000	70,000	70,000	1,000,000
Guinea	—	100	46,200	50,000	7,400,000
India	6,060	6,500	22,900	24,000	660,000
Indonesia	1,300	1,300	2,900	7,100	1,200,000
Jamaica	1,780	2,500	8,250	10,000	2,000,000
Malaysia	—	—	2,000	2,000	110,000
Russia	2,820	2,800	5,520	5,500	500,000
Vietnam	900	1,100	2,400	2,500	3,700,000
Other countries	12,700	13,200	22,500	22,000	5,200,000
World total (rounded)	129,000	130,000	309,000	300,000	30,000,000

World Resources: Bauxite resources are estimated to be 55 billion to 75 billion tons, 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 abrasives but cost more.

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

[1]See also Aluminum. As a general rule, 4 tons of dried bauxite is required to produce 2 tons of alumina, which, in turn, produces 1 ton of aluminum.

[2]Includes all forms of bauxite, expressed as dry equivalent weights.

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

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

[5]Calcined equivalent weights.

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

[7]For Australia, Joint Ore Reserves Committee-compliant reserves were about 2.3 billion tons.

BERYLLIUM

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

Domestic Production and Use: One company in Utah mined bertrandite ore and converted it, along with imported beryl, into beryllium hydroxide. Some of the beryllium hydroxide was shipped to the company's plant in Ohio, where it was converted into metal, oxide, and downstream beryllium-copper master alloy, and some was sold. Based on the estimated unit value for beryllium in imported beryllium-copper master alloy, beryllium apparent consumption of 220 tons was valued at about $110 million. Based on value-added sales revenues, approximately 22% of beryllium products were used in industrial components, 21% in consumer electronics, 16% in automotive electronics, 9% in defense applications, 8% in telecommunications infrastructure, 7% in energy applications, 1% in medical applications, and 16% in other applications. Beryllium alloy strip and bulk products, the most common forms of processed beryllium, were used in all application areas. The majority of unalloyed beryllium metal and beryllium composite products were used in defense and scientific applications.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, mine shipments	270	205	155	150	170
Imports for consumption[1]	68	66	68	62	86
Exports[2]	26	29	34	38	33
Shipments from Government stockpile[3]	1	1	3	2	—
Consumption:					
Apparent[4]	318	233	182	181	220
Reported, ore	280	220	160	160	190
Unit value, annual average, beryllium-copper master alloy, dollars per kilogram contained beryllium[5]	470	490	510	640	500
Stocks, ore, consumer, yearend	15	25	35	30	35
Net import reliance[6] as a percentage of apparent consumption	15	12	15	17	22

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

Import Sources (2014–17):[1] Kazakhstan, 44%; Japan, 14%; Brazil, 7%; United Kingdom, 7%; and other, 28%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Beryllium ores and concentrates	2617.90.0030	Free.
Beryllium oxide and hydroxide	2825.90.1000	3.7% ad val.
Beryllium-copper master alloy	7405.00.6030	Free.
Beryllium-copper plates, sheets, and strip:		
Thickness of 5 millimeters (mm) or more	7409.90.1030	3.0% ad val.
Thickness of less than 5 mm:		
Width of 500 mm or more	7409.90.5030	1.7% ad val.
Width of less than 500 mm	7409.90.9030	3.0% ad val.
Beryllium:		
Unwrought, including powders	8112.12.0000	8.5% ad val.
Waste and scrap	8112.13.0000	Free.
Other	8112.19.0000	5.5% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Prepared by **Brian W. Jaskula [(703) 648–4908, bjaskula@usgs.gov]**

BERYLLIUM

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

		FY2018		FY 2019	
Material	**Inventory As of 9–30–18**	**Potential Acquisitions**	**Potential Disposals**[8]	**Potential Acquisitions**	**Potential Disposals**[8]
Beryl ore (gross weight)	1	—	—	—	—
Metal	67	—	2	—	5
Structured powder	7	—	—	—	—

Events, Trends, and Issues: In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including beryllium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

Apparent consumption of beryllium-based products was estimated to have increased by about 20% in 2018 from that of 2017. During the first 6 months of 2018, 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 23% higher than those during the first 6 months of 2017. Sales of beryllium products to the consumer electronics, defense, energy, and industrial components markets increased owing to stronger demand.

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: Reserves for the United States were revised based on updated company information.

	Mine production[e] 2017	Mine production[e] 2018
United States	150	170
Brazil	3	3
China	50	50
Madagascar	6	6
Nigeria	4	4
Rwanda	1	1
World total (rounded)	210	230

Reserves[9]: The United States has very little beryl that can be economically hand sorted from pegmatite deposits. The Spor Mountain area in Utah, an epithermal deposit, contains a large bertrandite resource, which is being mined. Proven and probable bertrandite reserves in Utah total about 21,000 tons of contained beryllium. World beryllium reserves are not available.

World Resources: 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 size, the Spor Mountain area in Utah, the McCullough Butte area in Nevada, the Black Hills area in South Dakota, the Sierra Blanca area in Texas, the Seward Peninsula in Alaska, and the Gold Hill area in Utah account for most of the total.

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

[e]Estimated. — Zero.
[1]Includes estimated beryllium content of imported ores and concentrates, oxide and hydroxide, unwrought metal (including powders), beryllium articles, waste and scrap, beryllium-copper master alloy, and beryllium-copper plates, sheets, and strip.
[2]Includes estimated beryllium content of exported unwrought metal (including powders), beryllium articles, and waste and scrap.
[3]Change in total inventory level from prior yearend inventory.
[4]Defined as production + net import reliance.
[5]Calculated from gross weight and customs value of imports; beryllium content estimated to be 4%. Rounded to two significant figures.
[6]Defined as imports – exports + adjustments for Government and industry stock changes.
[7]See Appendix B for definitions.
[8]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.

BISMUTH

(Data in metric tons gross weight unless otherwise noted)

Domestic Production and Use: The United States ceased production of primary refined bismuth in 1997 and is highly import dependent for its supply. 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. In 2018, the estimated value of apparent consumption of bismuth was approximately $25 million.

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

Bismuth has a wide variety of metallurgical applications, including use as an additive to enhance metallurgical quality in the foundry industry and as a nontoxic replacement for lead in brass, free-machining steels, and solders. The Safe Drinking Water Act Amendment of 1996, which required that all new and repaired fixtures and pipes for potable water supply be lead free after August 1998, opened a wider market for bismuth as a metallurgical additive to lead-free pipe fittings, fixtures, and water meters. Bismuth is used as a triggering mechanism for fire sprinklers and in holding devices for grinding optical lenses. Bismuth-tellurium-oxide alloy film paste is used in the manufacture of semiconductor devices.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Refinery	—	—	—	—	—
Secondary (scrap)[e]	80	80	80	80	80
Imports for consumption, metal, alloys, and scrap	2,270	1,950	2,190	2,820	2,800
Exports, metal, alloys, and scrap	567	519	431	392	580
Consumption:					
Apparent[1]	1,750	1,490	1,780	2,530	2,300
Reported	655	621	710	756	680
Price, average, domestic dealer, dollars per pound[2]	11.14	6.43	4.53	4.93	4.90
Stocks, yearend, consumer	430	456	512	487	510
Net import reliance[3] as a percentage of apparent consumption	95	95	96	97	96

Recycling: Bismuth-containing alloy scrap was recycled and thought to compose less than 5% of U.S. bismuth apparent consumption, or about 110 tons.

Import Sources (2014–17): China, 80%; Belgium, 8%; Mexico, 4%; Republic of Korea, 2%; and other, 6%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–18**
Bismuth and articles thereof, including waste and scrap	8106.00.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Prepared by **Sheryl A. Singerling [(703) 648–4954, ssingerling@usgs.gov]**

BISMUTH

Events, Trends, and Issues: The U.S. domestic dealer average price of bismuth started 2018 at $5.25 per pound, increased slightly to a high of $5.30 per pound in March and April, and generally decreased throughout the remainder of the year. Bismuth reached a low of $4.15 per pound in late August and early September before it increased to $4.30 per pound in mid-September.

New environmental policies that came into effect in 2018 in China resulted in many bismuth smelters shutting down temporarily for inspections or permanently for infractions. However, smelters still in operation increased their output to offset the loss of production from the closures. Global bismuth prices decreased throughout most of 2018.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including bismuth. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

World Refinery Production and Reserves: Available information was inadequate to make reliable estimates for mine production and reserves data.

	Refinery production		Reserves[4]
	2017	2018[e]	
United States	—	—	Quantitative estimates of reserves are not available.
Bulgaria	50	50	
Canada	25	25	
China	13,500	13,000	
Japan	525	590	
Kazakhstan	270	270	
Laos	2,000	2,000	
Mexico	513	340	
World total (rounded)	16,900	16,000	

World Resources: Bismuth ranks 65th in elemental abundance in the Earth’s continental crust, at an estimated 85 parts per billion by weight, constituting much less than 0.001%. World reserves of bismuth are usually estimated based on the bismuth content of lead resources because bismuth production is most often a byproduct of processing lead ores. In China and Vietnam, bismuth production is a byproduct or coproduct of tungsten and other metal ore processing. Bismuth minerals rarely occur in sufficient quantities to be mined as principal products; the Tasna Mine in Bolivia and a mine in China are the only mines where bismuth has been the primary product. The Tasna Mine in Bolivia has been inactive since 1996.

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

[e]Estimated. — Zero.

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

[2]Source: American Metal Market.

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

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

BORON

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies in southern California produced borates in 2018, and most of the boron products consumed in the United States were manufactured domestically. 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 United States and the Eastern United States. In 2018, the glass and ceramics industries remained the leading domestic users of boron products, accounting for an estimated 80% 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:	2014	2015	2016	2017	2018[e]
Production	W	W	W	W	W
Imports for consumption:					
Refined borax	152	136	173	158	135
Boric acid	57	40	46	40	48
Colemanite (calcium borates)	45	35	35	58	79
Ulexite (sodium borates)	34	70	43	24	38
Exports:					
Boric acid	226	195	237	228	255
Refined borax	615	528	581	569	600
Consumption, apparent[1]	W	W	W	W	W
Price, average value of imports					
Cost, insurance, and freight, dollars per ton	373	327	352	392	390
Employment, number	1,410	1,380	1,340	1,310	1,300
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2014–17): All forms: Turkey, 78%; Bolivia, 15%; Chile, 3%; Argentina, 1%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Natural borates:		
Sodium (ulexite)	2528.00.0005	Free.
Calcium (colemanite)	2528.00.0010	Free.
Boric acids	2810.00.0000	1.5% ad val.
Borates:		
Refined borax:		
Anhydrous	2840.11.0000	0.3% ad val.
Non-anhydrous	2840.19.0000	0.1% ad val.

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

Government Stockpile: None.

Prepared by **Amanda S. Brioche [(703) 648–7747, abrioche@usgs.gov]**

BORON

Events, Trends, and Issues: Elemental boron is a metalloid with limited commercial applications. Although the term “boron” is commonly referenced, it does not occur in nature in an elemental state. Boron combines with oxygen and other elements to form boric acid, or inorganic salts called borates. Boron compounds, chiefly borates, are commercially important; therefore, boron products are priced and sold based on their boric oxide (B_2O_3) content, varying by ore and compound and by the absence or presence of calcium and sodium. The 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.

Canada, China, India, Japan, and Malaysia are the countries that imported the largest quantities of refined borates from the United States in 2018. Because China has low-grade boron reserves and demand for boron is anticipated to rise in that country, imports to China from Chile, Russia, Turkey, and the United States were expected to remain steady during the next several years. In Europe and developing countries, more stringent building standards with respect to heat conservation were being enacted. Consequently, increased consumption of borates for fiberglass insulation was expected.

An Australian-based mine developer confirmed that high-quality boric acid production is possible from its lithium-boron project in Nevada. The company has the potential to become a substantial producer of boric acid when the mine is constructed. Continued investment in new borate refineries and technologies and the continued rise in demand were expected to fuel growth in world production during the next several years.

World Production and Reserves: Reserves for China were updated based on Government information.

	Production—All forms		Reserves[3]
	2017	2018[e]	
United States	W	W	40,000
Argentina, crude ore	150	150	NA
Bolivia, ulexite	180	180	NA
Chile, ulexite	560	560	35,000
China, boric oxide equivalent	70	70	24,000
Kazakhstan, unspecified	500	500	NA
Peru, crude borates	—	—	4,000
Russia, datolite ore	75	75	40,000
Turkey, concentrate	1,800	1,800	950,000
World total[4]	XX	XX	XX

World Resources: Deposits of borates are associated with volcanic activity and arid climates, with the largest economically viable deposits located in the Mojave Desert of the United States, the Alpide belt in southern Asia, 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. — Zero.
[1]Defined as production + imports – exports.
[2]Defined as imports – exports.
[3]See Appendix C for resource and reserve definitions and information concerning data sources.
[4]World totals cannot be calculated because production and reserves are not reported in a consistent manner by all countries.

BROMINE

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

Domestic Production and Use: Bromine was recovered from underground brines by two companies in Arkansas. Bromine often is the leading mineral commodity, 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, and intermediates and industrial uses. Bromine compounds are also used in a variety of other applications, including drilling fluids and industrial water treatment. U.S. apparent consumption of bromine in 2018 was estimated to be greater than that in 2017.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production	W	W	W	W	W
Imports for consumption, elemental bromine and compounds[1]	59,400	61,200	58,400	52,700	59,700
Exports, elemental bromine and compounds[2]	31,500	29,600	28,200	43,400	34,400
Consumption, apparent[3]	W	W	W	W	W
Employment, number[e]	1,050	1,050	1,050	1,050	1,050
Net import reliance[4] as a percentage of apparent consumption	<25	<25	<25	<25	<25

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

Import Sources (2014–17):[5] Israel, 82%; Jordan, 8%; China, 7%; and other, 3%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–18**
Bromine	2801.30.2000	5.5% ad val.
Hydrobromic acid	2811.19.3000	Free.
Potassium or sodium bromide	2827.51.0000	Free.
Ammonium, calcium, or zinc bromide	2827.59.2500	Free.
Potassium bromate	2829.90.0500	Free.
Sodium bromate	2829.90.2500	Free.
Ethylene dibromide	2903.31.0000	5.4% ad val.
Methyl bromide	2903.39.1520	Free.
Dibromoneopentyl glycol	2905.59.3000	Free.
Tetrabromobisphenol A	2908.19.2500	5.5% ad val.
Decabromodiphenyl and octabromodiphenyl oxide	2909.30.0700	5.5% ad val.

Prepared by **Emily K. Schnebele [(703) 648–4945, eschnebele@usgs.gov]**

BROMINE

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. China, Israel, and Jordan also are major producers of elemental bromine. In 2018, U.S. imports of bromine and bromine compounds increased, whereas exports decreased.

Global consumption of brominated flame retardants, particularly in the automotive, construction, and electronics industries, was stable in 2018. The amount of clear brine fluids consumed in the oil-well and gas-well drilling industries continued to mirror global changes in oil prices and the number of active drilling rigs.

Bromine facilities in Shandong Province, China, remained closed in the first half of 2018 while rectifications and improvements were completed to meet new environmental regulations initiated by the Government of China in late 2017. The price of elemental bromine in China remained high in 2018, as a result of decreased bromine supply owing to the new environmental guidelines.

World Production and Reserves:

	Production		Reserves[6]
	2017	2018[e]	
United States	W	W	11,000,000
Azerbaijan	—	—	300,000
China	81,700	60,000	NA
India	1,700	1,700	NA
Israel	180,000	190,000	Large
Japan	20,000	20,000	NA
Jordan	100,000	100,000	Large
Ukraine	4,900	4,900	NA
World total (rounded)	[7]388,000	[7]380,000	Large

World Resources: 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 of 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-well 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. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Imports calculated from items shown in Tariff section.
[2]Exports calculated from Schedule B numbers 2801.30.2000, 2827.51.0000, 2827.59.0000, 2903.31.0000, and 2903.39.1520.
[3]Defined as production (sold or used) + imports – exports.
[4]Defined as imports – exports.
[5]Calculated using the gross weight of imports.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]Excludes U.S. production.

CADMIUM

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

Domestic Production and Use: Two companies in the United States produced refined cadmium in 2018. One company, operating in Tennessee, recovered primary refined cadmium as a byproduct of zinc leaching from roasted sulfide concentrates. The other company, operating in Ohio, recovered secondary cadmium metal from spent nickel-cadmium (NiCd) batteries. Domestic production and consumption of cadmium were withheld to avoid disclosing company proprietary data. Cadmium metal and compounds are mainly consumed for alloys, coatings, NiCd batteries, pigments, and plastic stabilizers. For the past 3 years, the United States has been a net importer of unwrought cadmium metal and cadmium metal powders and a net exporter of wrought cadmium products and cadmium pigments.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, refined[1]	W	W	W	W	W
Imports for consumption:					
Unwrought cadmium and powders	133	237	240	274	200
Wrought cadmium and other articles (gross weight)	6	18	([2])	2	([2])
Cadmium waste and scrap (gross weight)	—	71	52	20	([2])
Exports:					
Unwrought cadmium and powders	198	350	157	223	70
Wrought cadmium and other articles (gross weight)	72	246	371	205	150
Cadmium waste and scrap (gross weight)	—	([2])	12	([2])	([2])
Consumption, reported, refined	W	W	W	W	W
Price, metal, annual average, dollars per kilogram[3]	1.94	1.47	1.34	1.75	2.90
Stocks, yearend, producer and distributor	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption	E	E	<25	<25	<25

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

Import Sources (2014–17):[5] Canada, 36%; Australia, 21%; China, 14%; Belgium, 10%; and other, 19%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Cadmium oxide	2825.90.7500	Free.
Cadmium sulfide	2830.90.2000	3.1% ad val.
Pigments and preparations based on cadmium compounds	3206.49.6010	3.1% ad val.
Unwrought cadmium and powders	8107.20.0000	Free.
Cadmium waste and scrap	8107.30.0000	Free.
Wrought cadmium and other articles	8107.90.0000	4.4% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Prepared by **Amy C. Tolcin [(703) 648–4940, atolcin@usgs.gov]**

CADMIUM

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

The average monthly cadmium price began 2018 at $2.23 per kilogram in January 2018 and trended upward to $3.42 per kilogram in April. Prices then decreased during the next 4 months, falling to an average of $2.81 per kilogram in August.

In April 2018, a U.S.-based cadmium telluride thin-film solar-cell producer announced plans to build a second manufacturing plant in Ohio owing to strong domestic demand for solar technology and recent changes in U.S. corporate tax policy. Construction began in mid-2018, and the facility was expected to reach its full production rate by late 2019.

World Refinery Production and Reserves:

	Refinery production		Reserves[6]
	2017	2018[e]	
United States[1]	W	W	Quantitative estimates of reserves are not available. The cadmium content of typical zinc ores averages about 0.03%. See the Zinc chapter for zinc reserves.
Canada	1,800	1,800	
China	8,200	8,200	
Japan	2,140	2,100	
Kazakhstan	1,500	1,500	
Korea, Republic of	5,600	5,600	
Mexico	1,160	1,200	
Netherlands	600	900	
Peru	797	800	
Russia	1,200	1,200	
Other countries	2,370	2,400	
World total (rounded)	[7]25,400	[7]26,000	

World Resources: 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. Zinc-bearing coals of the Central United States and Carboniferous age coals of other countries also contain large subeconomic resources of cadmium.

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

[e]Estimated. E Net exporter. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Cadmium metal produced as a byproduct of zinc refining plus metal from recycling.
[2]Less than ½ unit.
[3]Average New York dealer price for 99.95% purity in 5-short-ton lots (2014–15). Source: Platts Metals Week. Average free market price for 99.95% purity in 10-ton lots; cost, insurance, and freight; global ports (2016–17). Source: Metal Bulletin.
[4]Defined as imports of unwrought metal and metal powders – exports of unwrought metal and metal powders + adjustments for industry stock changes.
[5]Imports for consumption of unwrought metal and metal powders (Harmonized Tariff Schedule of the United States code 8107.20.0000).
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]Excludes U.S. production.

CEMENT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Production of portland cement in 2018 in the United States increased slightly to about 85.4 million tons, and output of masonry cement continued to be stagnant at 2.4 million tons. Cement was produced at 98 plants in 34 States, and at 2 plants in Puerto Rico. Overall U.S. cement production continued to be well below the record level of 99 million tons reported in 2005, indicating continued full-time idle status at a few plants, underutilized capacity at many others, production disruptions from plant upgrades, plant closures over the interim, and relatively inexpensive imports in some recent years. Sales of cement increased by nearly 3% in 2018. Overall, shipments were 27.8 million tons lower than the record volume set in 2005. The overall value of shipments was nearly $12.7 billion. Most of the sales of cement were to make concrete, worth at least $66 billion. In recent years, about 70% to 75% of cement sales have been to ready-mixed concrete producers, 8% to 10% to contractors (mainly road paving; much contractor work also involves ready-mixed concrete), about 10% to concrete product manufacturers, and 7% to 10% to other customer types. Texas, California, Missouri, Florida, and Alabama were, in descending order of production, the five leading cement-producing States and accounted for nearly 50% of U.S. production.

Salient Statistics—United States:[1]	2014	2015	2016	2017	2018[e]
Production:					
Portland and masonry cement[2]	82,535	84,405	84,695	[e]86,100	87,800
Clinker	74,372	76,043	75,633	76,542	77,700
Shipments to final customers, includes exports	90,204	93,338	95,373	97,359	100,000
Imports of hydraulic cement for consumption	7,584	10,376	11,742	12,288	14,000
Imports of clinker for consumption	720	942	1,496	1,209	910
Exports of hydraulic cement and clinker	1,404	1,288	1,283	1,035	1,000
Consumption, apparent[3]	89,145	92,403	94,964	[e]97,400	100,200
Price, average mill value, dollars per ton	100.50	106.50	111.00	[e]121.00	126.50
Stocks, cement, yearend	6,140	7,230	7,420	[e]7,400	8,050
Employment, mine and mill, number[e]	11,500	11,300	11,000	10,500	10,000
Net import reliance[4] as a percentage of apparent consumption	8	11	13	13	14

Recycling: Cement kiln dust is routinely recycled to the kilns, which also can make use of a variety of waste fuels 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. Cement is not directly recycled, but significant quantities of concrete are recycled for use as construction aggregate.

Import Sources (2014–17):[5] Canada, 33%; Greece, 15%; China, 13%; Republic of Korea, 8%; and other, 31%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
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: Shipments of cement increased by nearly 3% overall in 2018, tempered by stagnant sales of masonry cement. Construction spending increased modestly during the year, largely owing to somewhat higher spending in the residential and public construction sectors; the nonresidential private building sector, however, declined slightly. Cement shipments into parts of the southeast and in Florida were lower than originally expected because of damage from hurricanes in 2017. In contrast, shipments into Puerto Rico were relatively strong because of reconstruction following devastating hurricanes in 2017. The leading cement-consuming States continued to be Texas, California, and Florida, in descending order by tonnage. Production of cement remained well below capacity, in part reflecting both the technical and environmental issues in returning long-idle kilns to full production at some plants, and the ready availability of imported cement in coastal markets.

Prepared by **Hendrik G. van Oss [Contact Kenneth C. Curry (703) 648–7793, kcurry@usgs.gov]**

CEMENT

Company mergers continued in 2018, with the final approval of the sale of a major U.S. cement company to a European cement company (the sales agreement had been announced in 2017). Completion of the sale required the consolidation of the European company's holdings (two cement plants) in Florida, and the sale by the European company of its newly acquired plant in Montana to a Mexican cement company.

A major upgrade to a cement plant in Michigan was completed during the year; minor upgrades were ongoing at a number of other plants in the country. Apart from increasing production efficiency, these upgrades were expected to improve the ability of individual plants to comply with the stringent emissions limits of the 2010 National Emissions Standards for Hazardous Air Pollutants (NESHAP) protocol for cement plants, which went into effect in September 2015. Many plants have installed emissions-reduction technologies to comply with the NESHAP protocol, but it remained unclear if such modifications would be economic for all individual kilns (some being of older technology) at multikiln plants. It remained possible that some kilns would be shut down, or used only sparingly, because of the NESHAP limits, and thus constrain U.S. clinker production capacity. Despite environmental permitting difficulties in recent years reducing the attractiveness of constructing new (greenfields) plants in the United States, a project to construct a greenfields white cement plant in Texas was announced during the year; currently, the United States has only two white cement plants.

World Production and Capacity:

	Cement production[e]		Clinker capacity[e]	
	2017	2018	2017	2018
United States (includes Puerto Rico)	86,600	88,500	107,000	108,000
Brazil	53,000	52,000	60,000	60,000
China	2,320,000	2,370,000	2,000,000	2,000,000
Egypt	53,000	55,000	48,000	48,000
India	290,000	290,000	280,000	280,000
Indonesia	65,000	67,000	78,000	78,000
Iran	54,000	53,000	80,000	80,000
Japan	55,200	55,500	53,000	53,000
Korea, Republic of	56,500	56,000	50,000	50,000
Russia	54,700	55,000	80,000	80,000
Saudi Arabia	47,100	45,000	75,000	75,000
Turkey	80,600	84,000	80,000	82,000
Vietnam	78,800	80,000	90,000	90,000
Other countries (rounded)	756,000	759,000	717,000	716,000
World total (rounded)	4,050,000	4,100,000	3,800,000	3,800,000

World Resources: Although reserves at individual plants are subject to exhaustion, limestone and other cement raw materials are geologically widespread and abundant, and overall shortages are unlikely in the future.

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 plus masonry cement unless otherwise noted; excludes Puerto Rico unless otherwise noted.

[2]Includes cement made from imported clinker.

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

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

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

CESIUM

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

Domestic Production and Use: In 2018, no cesium was mined domestically, and the United States was 100% import reliant for cesium minerals. The United States sourced the majority of its pollucite, the principal cesium mineral, from the largest known deposit in North America at Bernic Lake, Manitoba, Canada; however, that operation ceased mining at the end of 2015 and continued to supply cesium products from stocks.

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 production and exploration. Cesium nitrate is used as a colorant and oxidizer in the pyrotechnic industry, in petroleum cracking, in scintillation counters, and in x-ray phosphors. Cesium chloride is used in analytical chemistry applications as a reagent, in high-temperature solders, as an intermediate in cesium metal production, in isopycnic centrifugation, as a radioisotope in nuclear medicine, as an insect repellent in agricultural applications, and in specialty glasses.

Cesium metal is used in the production of cesium compounds and in photoelectric cells. Cesium carbonate is used in the alkylation of organic compounds and in energy conversion devices, such as fuel cells, magneto-hydrodynamic generators, and polymer solar cells. Cesium bromide is used in infrared detectors, optics, photoelectric cells, scintillation counters, and spectrophotometers. Cesium hydroxide is used as an electrolyte in alkaline storage batteries. Cesium iodide is used in fluoroscopy equipment—Fourier-transform infrared spectrometers—as the input phosphor of x-ray image intensifier tubes, and in scintillators.

Cesium isotopes, which are obtained as a byproduct in nuclear fission or formed from other isotopes, such as barium-131, are used in electronic, medical, 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 Time Scale, is based on 48 weighted atomic clocks, including 25 cesium fountain clocks.

A company in Richland, WA, produced a range of cesium-131 medical products for treatment of various cancers. Cesium-137 is widely used in industrial gauges, in mining and geophysical instruments, and for sterilization of food, sewage, and surgical equipment. Cesium isotopes can be used in metallurgy to remove gases and other impurities and in vacuum tubes.

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

In 2018, one company offered 1-gram ampoules of 99.8% (metal basis) cesium for $61.80, unchanged from that in 2017, and 99.98% (metal basis) cesium for $78.70, a slight increase from that in 2017.

In 2018, the prices for 50 grams of 99.9% (metal basis) cesium acetate, cesium bromide, cesium carbonate, and cesium chloride were $114.80, $69.80, $98.80, and $100.60, respectively. The price for a cesium-plasma standard solution (10,000 micrograms per milliliter) was $79.80 for 50 milliliters and $122.00 for 100 milliliters, and the price for 25 grams of cesium formate, 98% basis, was $38.70—the same prices as in 2017.

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. The formate brines are recycled with an estimated recovery rate of 85%, which can be reprocessed for further use.

Import Sources (2014–17): No reliable data has been available to determine the source of cesium ore imported by the United States since 1988. Previously, Canada was thought to be the primary supplier of cesium ore.

Prepared by **Christopher A. Tuck [(703) 648–4912, ctuck@usgs.gov]**

CESIUM

Tariff:

Item	Number	Normal Trade Relations 12–31–18
Alkali metals, other	2805.19.9000	5.5% ad val.
Chlorides, other	2827.39.9000	3.7% ad val.
Bromides, other	2827.59.5100	3.6% ad val.
Nitrates, other	2834.29.5100	3.5% ad val.
Carbonates, other	2836.99.5000	3.7% ad val.
Cesium-137, other	2844.40.0021	Free

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic cesium occurrences will likely remain uneconomic unless market conditions change. No known human health issues are associated with naturally occurring cesium, and its use has minimal environmental impact. Radioactive isotopes of cesium have been known to cause adverse health effects.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including cesium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ''A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" (82 FR 60835).

During 2018, projects that were primarily aimed at developing lithium resources with cesium content were at various stages of development, including eight subprojects at the King Col project in Australia, the Jubilee Lake lithium prospect in Canada, the Soris lithium project in Namibia, and the Winnipeg River pegmatite field in Canada. The status of these projects ranged from early feasibility studies to active exploration and drilling. No production has been reported at any sites. The projects focused on pegmatites containing pollucite and spodumene, which primarily contain lithium, tantalum, or both, but may also contain minor quantities of cesium and rubidium.

World Mine Production and Reserves: There were no official sources for cesium production data. Zimbabwe and Namibia were thought to have produced cesium in small quantities as a byproduct of lithium mining operations. Pollucite, mainly found in association with lithium-rich, lepidolite-bearing or petalite-bearing zoned granite pegmatites, is the principal cesium ore mineral. Cesium reserves are, therefore, estimated based on the occurrence of pollucite, which is mined as a byproduct of the lithium mineral lepidolite. Most pollucite contains 5% to 32% cesium oxide (Cs_2O). The main pollucite zone at Bernic Lake in Canada contains approximately 120,000 tons of contained cesium oxide in pollucite ore, with average ore grades of 23.3% Cs_2O. Cesium at the Manitoba, Canada, operation no longer was considered economically recoverable following a mine collapse in 2015.

	Reserves[1]
Namibia	30,000
Zimbabwe	60,000
Other countries	NA
World total (rounded)	90,000

World Resources: U.S. and world resources of cesium have not been estimated. Cesium is associated with lithium-bearing pegmatites worldwide, and cesium resources have been identified in Australia, Canada, Namibia, the United States, and Zimbabwe. In the United States, pollucite occurs in pegmatites in Alaska, Maine, and South Dakota. Lower concentrations occur in brines in Chile and China and in geothermal systems in Germany, India, and Tibet. China was believed to have cesium-rich deposits of geyserite, lepidolite, and pollucite, with concentrations highest in Yichun, Jiangxi Province, China, although no resource 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.

NA Not available.
[1]See Appendix C for resource and reserve definitions and information concerning data sources.

CHROMIUM

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

Domestic Production and Use: In 2018, the United States was expected to consume about 6% of world chromite ore production in various forms of imported materials, such as chromite ore, chromium chemicals, chromium ferroalloys, chromium metal, and stainless steel. Imported chromite ore was consumed by one chemical firm to produce chromium chemicals. One company produced chromium metal. Stainless-steel and heat-resisting-steel producers were the leading consumers of ferrochromium. Stainless steels and superalloys require chromium. The value of chromium material consumption in 2017 was $1.0 billion as measured by the value of net imports, excluding stainless steel, and was expected to be about $1.1 billion in 2018.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Mine	—	—	—	—	—
Recycling[1]	157	154	152	158	160
Imports for consumption	708	535	547	633	650
Exports	257	238	253	256	260
Shipments from Government stockpile	15	9	5	8	3
Consumption:					
Reported (includes recycling)	417	406	393	412	400
Apparent (includes recycling)[2]	622	461	451	542	550
Unit value, average annual import (dollars per ton):					
Chromite ore (gross weight)	243	216	198	259	280
Ferrochromium (chromium content)[3]	2,514	2,593	2,227	3,212	2,600
Chromium metal (gross weight)	11,048	11,386	9,827	9,682	9,000
Stocks, yearend, held by U.S. consumers	8	8	8	8	8
Net import reliance[4] as a percentage of apparent consumption	75	67	66	71	71

Recycling: In 2018, recycled chromium (contained in reported stainless steel scrap receipts) accounted for 29% of apparent consumption.

Import Sources (2014–17): Chromite (mineral): South Africa, 97%; Canada, 3%; and other, <1%. Chromium-containing scrap:[5] Canada, 51%; Mexico, 41%; and other, 8%. Chromium (primary metal):[6] South Africa, 36%; Kazakhstan, 10%; Russia, 7%; and other, 47%. Total imports: South Africa, 38%; Kazakhstan, 8%; Russia, 6%; and other, 48%.

Tariff:[7] Item	Number	Normal Trade Relations 12–31–18
Chromium ores and concentrates:		
Cr_2O_3 not more than 40%	2610.00.0020	Free.
Cr_2O_3 more than 40% and less than 46%	2610.00.0040	Free.
Cr_2O_3 more than or equal to 46%	2610.00.0060	Free.
Chromium oxides and hydroxides:		
Chromium trioxide	2819.10.0000	3.7% ad val.
Other	2819.90.0000	3.7% ad val.
Sodium dichromate	2841.30.0000	2.4% ad val.
Potassium dichromate	2841.50.1000	1.5% ad val.
Other chromates and dichromates	2841.50.9100	3.1% ad val.
Carbides of chromium	2849.90.2000	4.2% ad val.
Ferrochromium:		
Carbon more than 4%	7202.41.0000	1.9% ad val.
Carbon more than 3%	7202.49.1000	1.9% ad val.
Carbon more than 0.5%	7202.49.5010	3.1% ad val.
Other	7202.49.5090	3.1% ad val.
Ferrosilicon chromium	7202.50.0000	10% ad val.
Chromium metal:		
Unwrought, powder	8112.21.0000	3% ad val.
Waste and scrap	8112.22.0000	Free.
Other	8112.29.0000	3% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Prepared by **Ruth F. Schulte [(703) 648–4963, rschulte@usgs.gov]**

CHROMIUM

Government Stockpile:[8]

Material[9]	Inventory As of 9–30–18	FY2018 Potential Acquisitions	FY2018 Potential Disposals[10]	FY 2019 Potential Acquisitions	FY 2019 Potential Disposals[10]
Ferrochromium:					
High-carbon	44.5	—	[11]21.3	—	[11]21.3
Low carbon	27.6	—	—	—	—
Chromium metal	3.85	—	0.181	—	0.181

Events, Trends, and Issues: Chromium is consumed in the form of ferrochromium to produce stainless steel. China was the leading chromium-consuming country. China was also the leading stainless-steel- and ferrochromium-producing country. South Africa was the leading chromite ore producer. World stainless steel producers depend directly or indirectly on chromium supply. Ferrochromium production is electrical-energy intensive, so constrained electrical power supply results in constrained ferrochromium production.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including chromium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

From August 2017 to August 2018, ferrochromium prices did not change for charge grade and increased slightly for high carbon. Prices have remained relatively high compared with those prior to October 2016.

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

	Mine production[12] 2017	Mine production[12] 2018[e]	Reserves[13] (shipping grade)[14]
United States	—	—	620
India	3,500	3,500	100,000
Kazakhstan	4,580	4,600	230,000
South Africa	16,500	16,000	200,000
Turkey	6,500	6,500	26,000
Other countries	4,580	4,500	NA
World total (rounded)	35,700	36,000	560,000

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

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

[e]Estimated. NA Not available. — Zero.
[1]Recycling production is based on reported receipts of all types of stainless steel scrap.
[2]Defined as production (from mines and recycling) + imports – exports + adjustments for Government and industry stock changes.
[3]Excludes ferrochromium silicon.
[4]Defined as imports – exports + adjustments for Government and industry stock changes.
[5]Includes chromium metal scrap and stainless steel scrap.
[6]Includes chromium metal, ferrochromium, and stainless steel.
[7]In addition to the tariff items listed, certain imported chromium materials (see 26 U.S.C. sec. 4661, 4662, and 4672) are subject to excise tax.
[8]See Appendix B for definitions.
[9]Units are thousand tons of material by gross weight.
[10]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[11]High-carbon and low-carbon ferrochromium, combined.
[12]Mine production units are thousand tons, gross weight, of marketable chromite ore.
[13]See Appendix C for resource and reserve definitions and information concerning data sources.
[14]Reserves units are thousand 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.

CLAYS

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Production of clays (sold or used) in the United States was estimated to be 27 million tons valued at $1.6 billion in 2018, with about 145 companies operating clay and shale mines in 40 States. The leading 20 firms produced approximately 50% of the U.S. tonnage and 85% of the value for all types of clay. Principal uses for specific clays were estimated, in descending order, to be as follows: ball clay—50% floor and wall tile and 15% sanitaryware; bentonite—52% pet waste absorbents and 31% drilling mud; common clay—34% brick, 29% lightweight aggregate, and 24% cement; fire clay—70% heavy clay products (for example, brick and cement) and 30% refractory products and miscellaneous uses; fuller's earth—98% pet waste absorbents; and kaolin—60% paper coating and filling, 12% paint, and 9% catalysts. Lightweight ceramic proppants for use in hydraulic fracturing are also a significant market for kaolin, but available data were insufficient for a reliable estimate of the market size.

The United States accounted for 15% to 25% of the global production of refined clays, excluding common clay and shale. U.S. exports of bentonite decreased by an estimated 3% in 2018 relative to the prior year. Canada, Japan, and Mexico were, in decreasing order by tonnage, the leading destinations for United States bentonite and accounted for 67% of exports. Kaolin exports increased by an estimated 17% in 2018 relative to the prior year. Exports of kaolin went primarily to China, Mexico, Japan, Finland, and Canada, in decreasing order by tonnage.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production (sold or used):					
Ball clay	980	1,030	975	[e]900	1,000
Bentonite	4,580	4,050	3,600	[e]4,300	3,700
Common clay	10,900	11,300	11,700	[e]13,000	13,000
Fire clay	210	393	528	[e]440	460
Fuller's earth[1]	1,890	1,960	1,860	[e]1,700	1,600
Kaolin	5,960	5,810	5,320	[e]7,300	7,300
Total[1, 2]	24,500	24,500	23,900	[e]28,000	27,000
Imports for consumption:					
Artificially activated clays and earths	26	24	26	28	21
Kaolin	518	426	389	480	326
Other	47	70	58	86	63
Total[2]	591	520	473	594	410
Exports:					
Artificially activated clays and earths	175	173	143	147	170
Ball clay	33	48	41	83	100
Bentonite	901	938	801	961	930
Clays, not elsewhere classified	282	268	256	243	280
Fire clay[3]	237	217	184	225	280
Fuller's earth	92	77	86	78	82
Kaolin	2,640	2,420	2,290	2,310	2,700
Total[2]	4,360	4,140	3,800	4,050	4,500
Consumption, apparent[4]	21,900	21,000	20,700	[e]25,000	23,000
Price, ex-works, average, dollars per ton:					
Ball clay	44	46	45	46	46
Bentonite	67	74	75	75	77
Common clay	11	15	15	13	13
Fire clay	17	13	13	13	11
Fuller's earth[1]	86	86	89	96	83
Kaolin	144	151	157	160	140
Employment (excludes office workers):					
Mine (may not include contract workers)	1,150	1,130	1,120	1,220	1,110
Mill	4,930	4,730	4,440	4,370	4,360
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2014–17): All clay types combined: Brazil, 78%; Mexico, 7%; United Kingdom, 2%; and other, 13%.

Prepared by **David N. West [(703) 648–7751, dnwest@usgs.gov]**

CLAYS

Tariff: Item	Number	Normal Trade Relations 12–31–18
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 val.
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, flower pots, 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: Total U.S. sales of clay in 2018 were essentially unchanged compared with those in 2017. Increases in construction spending and housing starts led to a 3% increase in sales of common clay, but bentonite sales are estimated to have decreased by 13%. Higher kaolin production was likely a result of increased demand for ceramic proppants used by the oil and gas industry.

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

	Mine production					
	Bentonite		Fuller's earth		Kaolin	
	2017	2018[e]	2017	2018[e]	2017	2018[e]
United States	[e]4,300	3,700	[e, 1]1,700	[1]1,600	[e]7,300	7,300
Brazil (beneficiated)	405	400	—	—	2,100	2,000
China	5,600	5,590	—	—	3,200	3,200
Czechia	369	370	—	—	[7]3,500	[7]3,500
Germany	395	390	—	—	4,300	4,300
Greece	[7]1,100	[7]1,200	54	56	—	—
India	800	810	6	6	[7]4,110	[7]4,100
Iran	436	440	—	—	790	790
Mexico	470	460	260	260	330	310
Senegal	—	—	170	190	—	—
Spain	113	100	650	640	[7]247	[7]260
Turkey	3,140	3,090	—	—	1,900	1,900
Ukraine	210	200	—	—	1,820	1,800
United Kingdom	—	—	—	—	1,010	990
Other countries	3,300	3,800	640	550	6,400	6,600
World total (rounded)	20,600	21,000	[1]3,480	[1]3,300	37,000	37,000

World Resources: Resources of all clays are extremely large.

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

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

COBALT

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

Domestic Production and Use: In 2018, a nickel-copper mine in Michigan produced cobalt-bearing nickel concentrate. Most U.S. cobalt supply comprised imports and secondary (scrap) materials. Six companies were known to produce cobalt chemicals. About 46% of the cobalt consumed in the United States was used in superalloys, mainly in aircraft gas turbine engines; 8% in cemented carbides for cutting and wear-resistant applications; 15% in various other metallic applications; and 31% in a variety of chemical applications. The total estimated value of cobalt consumed in 2018 was $700 million.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Mine[e]	120	760	690	640	500
Secondary	2,200	2,750	2,750	2,750	2,800
Imports for consumption	11,300	11,400	12,800	11,900	12,000
Exports	4,500	3,830	4,160	5,730	7,700
Consumption:					
Reported (includes secondary)	8,650	8,830	9,010	9,240	9,500
Apparent (includes secondary)[1]	8,710	10,300	11,500	8,910	7,200
Price, average, dollars per pound:					
U.S. spot, cathode[2]	14.48	13.44	12.01	26.97	38.00
London Metal Exchange (LME), cash	14.00	12.90	11.57	25.28	33.00
Stocks, yearend:					
Industry[3]	1,410	1,320	1,220	1,270	1,200
LME, U.S. warehouse	9	165	195	160	130
Net import reliance[4] as a percentage of apparent consumption	75	73	76	69	61

Recycling: In 2018, cobalt contained in purchased scrap represented an estimated 29% of cobalt reported consumption.

Import Sources (2014–17): Cobalt contained in metal, oxide, and salts: Norway, 18%; China, 12%; Japan, 12%; Finland, 9%; and other, 49%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Cobalt ores and concentrates	2605.00.0000	Free.
Chemical compounds:		
Cobalt oxides and hydroxides	2822.00.0000	0.1% ad val.
Cobalt chlorides	2827.39.6000	4.2% ad val.
Cobalt sulfates	2833.29.1000	1.4% ad val.
Cobalt carbonates	2836.99.1000	4.2% ad val.
Cobalt acetates	2915.29.3000	4.2% ad val.
Unwrought cobalt, alloys	8105.20.3000	4.4% ad val.
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 val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

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

Material	Inventory As of 9–30–18	FY2018 Potential Acquisitions	FY2018 Potential Disposals[6]	FY 2019 Potential Acquisitions	FY 2019 Potential Disposals[6]
Cobalt	302	—	—	—	—
Cobalt alloys, gross weight	3	—	—	—	—

Prepared by **Kim B. Shedd [(703) 648–4974, kshedd@usgs.gov]**

COBALT

Events, Trends, and Issues: In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including cobalt. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

Congo (Kinshasa) continued to be the world’s leading source of mined cobalt, supplying more than 60% of world cobalt mine production. With the exception of production in Morocco and artisanally mined cobalt in Congo (Kinshasa), most cobalt is mined as a byproduct of copper or nickel. China was the world’s leading producer of refined cobalt and has been a leading supplier of cobalt imports to the United States. Most of China’s production was from partially refined cobalt imported from Congo (Kinshasa). China was the world’s leading consumer of cobalt, with more than 80% of its consumption being used by the rechargeable battery industry. In 2018, average annual cobalt prices were higher than those of 2017, owing to strong demand from consumers in the rechargeable battery and aerospace industries and to limited availability of cobalt metal.

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

	Mine production		Reserves[7]
	2017	2018[e]	
United States	640	500	38,000
Australia	5,030	4,700	[8]1,200,000
Canada	3,870	3,800	250,000
China	3,100	3,100	80,000
Congo (Kinshasa)	73,000	90,000	3,400,000
Cuba	5,000	4,900	500,000
Madagascar	3,500	3,500	140,000
Morocco	2,200	2,300	17,000
Papua New Guinea	3,310	3,200	56,000
Philippines	4,600	4,600	280,000
Russia	5,900	5,900	250,000
South Africa	2,300	2,200	24,000
Other countries	7,650	7,000	640,000
World total (rounded)	120,000	140,000	6,900,000

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

Substitutes: Depending on the application, substitution for cobalt could result in a loss in product performance or an increase in cost. The cobalt contents of lithium-ion batteries, the leading global use for cobalt, are expected to be reduced rather than eliminated; nickel contents of lithium-ion batteries will increase as cobalt contents decrease. Potential substitutes in other applications include barium or strontium ferrites, neodymium-iron-boron, 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, cermets, or ceramics in cutting and wear-resistant materials; nickel-based alloys or ceramics in jet engines; nickel in petroleum catalysts; rhodium in hydroformylation catalysts; and titanium-based alloys in prosthetics.

[e]Estimated. — Zero.

[1]Defined as net import reliance + secondary production, as estimated from consumption of purchased scrap.

[2]As reported by Platts Metals Week. Cobalt cathode is refined cobalt metal produced by an electrolytic process.

[3]Stocks held by consumers, processors, and trading companies.

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

[5]See Appendix B for definitions.

[6]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.

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

[8]For Australia, Joint Ore Reserves Committee-compliant reserves were about 390,000 tons.

COPPER

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

Domestic Production and Use: In 2018, U.S. mine production of recoverable copper decreased by 5% to an estimated 1.2 million tons and was valued at an estimated $8 billion, essentially unchanged from $7.92 billion in 2017. Arizona was the leading copper-producing State and was responsible for about 66% of domestic output, followed by Utah, New Mexico, Nevada, Montana, Michigan, and Missouri. Twenty-four mines recovered copper, 15 of which accounted for 99% of production. Three smelters, 3 electrolytic refineries, 4 fire refineries, and 14 electrowinning facilities operated during 2018. Refined copper and scrap were used at about 30 brass mills, 15 rod mills, and 500 foundries and miscellaneous consumers. Copper and copper alloy products were used in building construction, 44%; transportation equipment, 20%; electrical and electronic products, 19%; consumer and general products, 11%; and industrial machinery and equipment, 6%.[1]

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Mine, recoverable	1,360	1,380	1,430	1,260	1,200
Refinery:					
Primary (from ore)	1,050	1,090	1,180	1,040	1,100
Secondary (from scrap)	46	49	46	40	40
Copper recovered from old scrap[2]	173	166	149	146	150
Imports for consumption:					
Ores and concentrates	([3])	([3])	([3])	14	30
Refined	620	687	708	813	820
General imports, refined	614	665	701	820	780
Exports:					
Ores and concentrates	410	392	331	237	230
Refined	127	86	134	94	170
Consumption:					
Reported, refined	1,760	1,810	1,800	1,800	1,800
Apparent, refined[4]	1,780	1,820	1,880	1,870	1,850
Price, average, cents per pound:					
U.S. producer, cathode (COMEX + premium)	318.1	256.2	224.9	285.4	300.0
COMEX, high-grade, first position	312.0	250.8	219.7	280.4	295.0
London Metal Exchange, high-grade	311.1	249.5	220.6	279.5	300.0
Stocks, yearend, refined, held by U.S. producers, consumers, and metal exchanges	190	209	223	265	280
Employment, mine and mill, thousands	12.1	11.3	10.1	10.6	12.0
Net import reliance[5] as a percentage of apparent consumption	31	31	29	37	32

Recycling: Old scrap, converted to refined metal and alloys, provided an estimated 150,000 tons of copper, equivalent to 8% of apparent consumption. Purchased new scrap, derived from fabricating operations, yielded an estimated 720,000 tons of contained copper. Of the total copper recovered from scrap (including aluminum- and nickel-base scrap), brass and wire-rod mills recovered approximately 80%; copper smelters, refiners, and ingot makers, 15%; and miscellaneous chemical plants, foundries, and manufacturers, 5%. Copper in all scrap contributed about 35% of the U.S. copper supply.[6]

Import Sources (2014–17): Unmanufactured copper (refined copper and the copper content of blister and anodes; matte, ash, and precipitates; ore and concentrates; and unalloyed and alloyed scrap): Chile, 46%; Canada, 30%; Mexico, 16%; and other, 8%. Refined copper accounted for 86% of all unmanufactured copper imports.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Copper ores and concentrates	2603.00.0000	1.7¢/kg on lead content.
Unrefined copper anodes	7402.00.0000	Free.
Refined and alloys, unwrought	7403.00.0000	1.0% ad val.
Copper wire (rod)	7408.11.0000	1.0% or 3.0% ad val.

Depletion Allowance: 15% (Domestic), 14% (Foreign).

Government Stockpile: None.

Prepared by **Daniel M. Flanagan [(703) 648–7726, dflanagan@usgs.gov]**

COPPER

Events, Trends, and Issues: The International Copper Study Group projected that global mine and refined production of copper would increase slightly in 2018, owing to a decrease in supply disruptions, restarting of temporarily closed mines and electrowon plants in Congo (Kinshasa) and Zambia, and recovery from planned smelter maintenance shutdowns in 2017. Global consumption of refined copper was also expected to rise slightly and to exceed global refined production by roughly 90,000 tons.[7]

Domestic mine production of copper declined in 2018 primarily owing to reduced output from multiple mines in Arizona and New Mexico. One major copper producer operating in these States reported lower ore grades, and a landslide at the Mission Mine on March 21 significantly affected operations throughout the year. These production decreases were partially offset by higher output from the Bingham Canyon Mine in Utah, where mining activity progressed into higher grade ores. Refined production in the United States increased by an estimated 6% in 2018 compared with that in 2017, when output was affected by planned smelter maintenance shutdowns and a 6-week suspension of operations at one smelter following a fatal accident.

Through November 2018, the monthly average COMEX spot copper price varied between $2.69 per pound (August and September) and $3.19 per pound (January). It was projected to average roughly $2.95 per pound for the full year, an increase of 5% from $2.80 per pound in 2017. This increase was attributed primarily to rising global demand and was partially offset by uncertainty in trade policies between the United States and China, among other factors.

World Mine Production and Reserves: Reserves for multiple countries were revised based on reported company data and (or) information from the Governments of those countries.

	Mine production		Reserves[8]
	2017	2018[e]	
United States	1,260	1,200	48,000
Australia	860	950	[9]88,000
Chile	5,500	5,800	170,000
China	1,710	1,600	26,000
Congo (Kinshasa)	1,090	1,200	20,000
Indonesia	622	780	51,000
Mexico	742	760	50,000
Peru	2,450	2,400	83,000
Russia	705	710	61,000
Zambia	794	870	19,000
Other countries	4,250	4,400	210,000
World total (rounded)	20,000	21,000	830,000

World Resources: A 1998 U.S. Geological Survey (USGS) report estimated that 550 million tons of copper were contained in identified and undiscovered resources in the United States.[10] A 2014 USGS global assessment of copper deposits indicated that identified resources contained about 2.1 billion tons of copper (porphyry deposits accounted for 1.8 billion tons of those resources), and undiscovered resources contained an estimated 3.5 billion tons.[11]

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

[e]Estimated.
[1]Distribution reported by the Copper Development Association. Some electrical components are included in each end use.
[2]Includes copper recovered by brass and wire-rod mills, foundries, refineries, and other manufacturers. Old scrap refers to used copper items.
[3]Less than ½ unit.
[4]Primary refined production + copper from old scrap + refined imports (general) – refined exports (domestic) ± changes in refined stocks.
[5]Defined as imports – exports ± adjustments for industry stock changes of refined copper.
[6]Copper supply is defined as apparent consumption + copper recovered from new (manufacturing) scrap.
[7]International Copper Study Group, 2018, Copper market forecast 2018/2019: Lisbon, Portugal, International Copper Study Group press release, October 3, 2 p.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]For Australia, Joint Ore Reserves Committee-compliant reserves were about 24 million tons.
[10]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., https://pubs.er.usgs.gov/publication/cir1178.
[11]Johnson, K.M., Hammarstrom, J.M., Zientek, M.L., and Dicken, C.L., 2014, Estimate of undiscovered copper resources of the world, 2013: U.S. Geological Survey Fact Sheet 2014–3004, 3 p., *http://dx.doi.org/10.3133/fs20143004.*

DIAMOND (INDUSTRIAL)[1]

(Data in million carats unless otherwise noted)

Domestic Production and Use: In 2018, total domestic production of manufactured industrial diamond bort, girt, dust and powder, and stone was estimated to be 140 million carats with a value of $140 million. Domestic output was synthetic grit, powder, and stone. One firm in Ohio and one firm in Pennsylvania accounted for all of the production. At least nine firms produced polycrystalline diamond from diamond powder. Three companies recovered used industrial diamond as one of their principal operations. Total domestic secondary production of industrial diamond bort, grit, dust and powder, and stone was estimated to be 13 million carats with a value of $12 million. The United States was one of the world's leading markets. The major consuming sectors of industrial diamond are computer chip production; construction; drilling for minerals, natural gas, and oil; machinery manufacturing; stone cutting and polishing; and transportation (infrastructure and vehicles). Highway building, milling, and repair and stone cutting consumed most of the industrial diamond stone. About 99% of U.S. industrial diamond apparent consumption was synthetic industrial diamond because its quality can be controlled and its properties can be customized.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Bort, grit, and dust and powder; natural and synthetic:					
Production:					
Manufactured diamond[e]	53	40	42	41	43
Secondary	44	63	66	11	12
Imports for consumption	682	275	216	399	580
Exports	163	140	134	161	140
Consumption, apparent[2]	616	238	190	290	495
Price, value of imports, dollars per carat	0.11	0.20	0.23	0.16	0.12
Net import reliance[3] as a percentage of apparent consumption	84	57	43	82	89
Stones, natural and synthetic:					
Production:					
Manufactured diamond[e]	72	79	83	87	92
Secondary	0.52	0.19	0.36	0.39	0.37
Imports for consumption	2.16	1.31	1.37	1.23	0.85
Exports	—	—	—	—	—
Sales from Government stockpile excesses	—	—	—	—	—
Consumption, apparent[2]	74.6	80.7	84.9	88.6	93.0
Price, value of imports, dollars per carat	14.40	17.50	13.60	12.90	8.10
Net import reliance[3] as a percentage of apparent consumption	3	2	2	1	1

Recycling: In 2018, the amount of diamond bort, grit, and dust and powder recycled was estimated to be 12.0 million carats with an estimated value of $11.0 million. It was estimated that 370,000 carats of diamond stone was recycled with an estimated value of $860,000.

Import Sources (2014–17): Bort, grit, and dust and powder; natural and synthetic: China, 76%; Ireland, 8%; Republic of Korea, 4%; Romania, 4%; and other, 8%. Stones, primarily natural: Botswana, 21%; India, 20%; South Africa, 19%; Ghana, 14%; and other, 26%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Industrial Miners' diamonds, carbonados	7102.21.1010	Free.
Industrial Miners' diamonds, other	7102.21.1020	Free.
Industrial diamonds, simply sawn, cleaved, or bruted	7102.21.3000	Free.
Industrial diamonds, not worked	7102.21.4000	Free.
Grit or dust and powder of natural diamonds, 80 mesh or finer	7105.10.0011	Free.
Grit or dust and powder of natural diamonds, over 80 mesh	7105.10.0015	Free.
Grit or dust and powder of synthetic diamonds, coated with metal	7105.10.0020	Free.
Grit or dust and powder of synthetic diamonds, not coated with metal, 80 mesh or finer	7105.10.0030	Free.
Grit or dust and powder of synthetic diamonds, not coated with metal, over 80 mesh	7105.10.0050	Free.

Prepared by **Donald W. Olson [(703) 648–7721, dolson@usgs.gov]**

DIAMOND (INDUSTRIAL)

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2018, China was the world's leading producer of synthetic industrial diamond, with annual production exceeding 13 billion carats. The United States is likely to continue to be one of the world's leading markets for industrial diamond into the next decade and is expected to remain a significant producer and exporter of synthetic industrial diamond as well. U.S. demand for industrial diamond is likely to be strong in the construction sector as the United States continues building, milling, and repairing the Nation's highway system. Industrial diamond coats the cutting edge of saws used to cut concrete in highway construction and repair work.

Demand for synthetic diamond grit and powder is expected to remain greater than that for natural diamond material.

The operator of a diamond mine in the Northwest Territories, Canada, began commercial production from the A-21 kimberlite pipe during the fourth quarter of 2018. A diamond producer in Russia processed the first diamonds from the Verkhne-Munskoe deposit in the Republic of Sakha (Yakutia, Russia) during the fourth quarter of 2017. The next shipment of ore from the Verkhne-Munskoe deposit arrived for processing during the fourth quarter of 2018.

World Natural Industrial Diamond Mine Production and Reserves:[4]

	Mine production		Reserves[5]
	2017	2018[e]	
United States	—	—	NA
Australia	17	17	[6]120
Botswana	7	7	90
Congo (Kinshasa)	15	15	150
Russia	19	19	650
South Africa	2	2	70
Zimbabwe	2	2	NA
Other countries	1	1	90
World total (rounded)	63	63	1,200

World Resources: Natural diamond deposits have been discovered in more than 35 countries. Natural diamond accounts for about 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 about 99% of industrial applications.

[e]Estimated. NA Not available. — Zero.
[1]See Gemstones for information on gem quality diamond.
[2]Defined as manufactured diamond production + secondary diamond production + imports – exports.
[3]Defined as imports – exports.
[4]Natural industrial diamond only. Synthetic diamond production far exceeds natural industrial diamond output. Worldwide production of manufactured industrial diamond totaled at least 4.5 billion carats in 2018; the leading producers included China, France, Ireland, Japan, Russia, South Africa, Sweden, and the United States.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.
[6]For Australia, Joint Ore Reserves Committee-compliant reserves were about 67 million carats.

DIATOMITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2018, production of diatomite was estimated to be 790,000 tons with an estimated processed value of $300 million, f.o.b. plant. Six companies produced diatomite at 12 mining areas and 9 processing facilities in California, Nevada, Oregon, and Washington. Approximately 60% of diatomite is used in filtration products. The remaining 40% is used in absorbents, fillers, lightweight aggregates, and other applications. A small amount, less than 1%, is used for specialized pharmaceutical and biomedical purposes. The unit value of diatomite varied widely in 2018, from approximately $10 per ton when used as a lightweight aggregate in portland cement concrete to more than $1,000 per ton for limited specialty markets, including art supplies, cosmetics, and DNA extraction.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production[1]	901	832	686	768	790
Imports for consumption	4	7	8	9	10
Exports	82	75	66	87	72
Consumption, apparent[2]	823	765	628	690	728
Price, average value, dollars per ton, f.o.b. plant	300	290	280	360	380
Employment, mine and plant, number[e]	750	750	750	750	750
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None.

Import Sources (2014–17): Canada, 75%; Mexico, 11%; Germany, 7%; Japan, 3%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Siliceous fossil meals, including diatomite	2512.00.0000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Prepared by **Robert D. Crangle, Jr. [(703) 648–6410, rcrangle@usgs.gov]**

DIATOMITE

Events, Trends, and Issues: The amount of domestically produced diatomite sold or used by producers in 2018 increased by an estimated 3% compared with that of 2017. Apparent domestic consumption increased by 6% in 2018 to an estimated 728,000 tons; exports decreased by an estimated 17%. The United States remained the leading global consumer. Filtration (including the purification of beer, liquors, and wine and the cleansing of greases and oils) continued to be the leading end use for diatomite, also known as diatomaceous earth. An important application for diatomite is the removal of microbial contaminants, such as bacteria, protozoa, and viruses in public water systems. Other applications for diatomite include filtration of human blood plasma, pharmaceutical processing, and use as a nontoxic insecticide. Domestically, diatomite used in the production of cement was the second-ranked use.

In 2018, the United States was the leading producer of diatomite, accounting for 29% of total world production, followed by Denmark with 16%, China with 15%, South Africa with 10%, and Japan, Mexico, and Peru with 4% each. Smaller quantities of diatomite were mined in 20 additional countries.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2017	2018[e]	
United States[1]	768	790	250,000
Argentina	57	60	NA
China	420	420	110,000
Denmark[5] (processed)	440	440	NA
France	75	75	NA
Germany	52	50	NA
Japan	100	100	NA
Mexico	97	100	NA
Peru	110	110	NA
South Africa	NA	270	NA
Spain	50	50	NA
Turkey	62	60	44,000
Other countries	224	220	NA
World total (rounded)	2,460	2,700	Large

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

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

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

FELDSPAR AND NEPHELINE SYENITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: U.S. feldspar production in 2018 had an estimated value of $28 million. The three leading companies mined and processed about 80% of production; four other companies supplied the remainder. Producing States were North Carolina, Virginia, California, Idaho, South Dakota, and Oklahoma, in descending order of estimated tonnage. Feldspar processors reported joint product recovery of mica and silica sand. Nepheline syenite produced in the United States was not included in production figures because the material was not considered to be marketable as a flux and was mostly used in construction applications.

Feldspar is ground to about 20 mesh for glassmaking and to 200 mesh or finer for most ceramic and filler applications. It was estimated that domestically produced feldspar was transported by ship, rail, or truck to at least 30 States and to foreign destinations, including Canada and Mexico. In pottery and glass, feldspar and nepheline syenite function as a flux. The estimated 2018 end-use distribution of domestic feldspar and nepheline syenite was glass, about 60%, and ceramic tile, pottery, and other uses, 40%.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, marketable[1]	530	520	470	440	450
Imports for consumption:					
Feldspar	8	120	37	290	140
Nepheline syenite	503	449	572	1,460	1,200
Exports, feldspar	16	15	6	5	10
Consumption, apparent[1, 2]					
Feldspar only	520	630	500	730	580
Feldspar and nepheline syenite	1,000	1,100	1,100	2,200	1,800
Price, average value, dollars per ton:					
Feldspar only, marketable production,	66	73	69	64	64
Nepheline syenite, import value	127	150	128	61	70
Employment, mine, preparation plant, and office, number[e]	270	270	250	240	240
Net import reliance[3] as a percentage of apparent consumption:					
Feldspar	E	17	6	39	22
Nepheline syenite	100	100	100	100	100

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

Import Sources (2014–17): Feldspar: Turkey, 99%; and other, 1%. Nepheline syenite: Canada, 100%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
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 2018, domestic production and sales of feldspar decreased by 8% and the average unit value of sales was virtually unchanged from that of 2017. Although remaining uncharacteristically high, imports of feldspar and nepheline syenite decreased in 2018 following substantial increases to each in 2017 compared with those of 2016. A company based in Canada continued development of a feldspar-quartz-kaolin project in Idaho that contained high-grade potassium feldspar, with production expected to be about 45,000 tons per year of potassium feldspar during a 25-year mine life. For several years, the operation has produced a low-iron and trace-element feldspathic sand product from old mine tailings that it has marketed to ceramic tile producers.

Prepared by **Arnold O. Tanner [Contact Joyce A. Ober, (703) 648–7717, jober@usgs.gov]**

FELDSPAR AND NEPHELINE SYENITE

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

In the United States, residential construction, in which feldspar is a raw material commonly used in the manufacture of plate glass, ceramic tiles and sanitaryware, and insulation, increased during the first 9 months of 2018 compared with the same period in 2017; housing starts and completions each rose by about 6%. Use of feldspar and nepheline syenite from all sources was expected to increase in 2019, in part owing to an increase in construction and refurbishment projects resulting from the destruction of homes, buildings, and infrastructure that took place in 2017 and 2018 during active hurricane seasons along the Gulf Coast and the Southeastern States, and to a second consecutive year of significant wildfires in some Western States.

A company based in Canada continued development of its White Mountain high-purity calcium feldspar (anorthosite) deposit in southwestern Greenland; the construction of all necessary facilities was nearly finished in October 2018. Upon completion of the electrical components and the road to the port facility, the company expected to begin shipping products to customers during the first half of 2019. Owing to the feldspar's purity and tests, which indicate an alumina recovery of greater than 90%, the company is targeting its product as a replacement for bauxite as a primary source of alumina; kaolin in the production of electrical-grade glass (E-glass) fiberglass; and kaolin and premium nepheline syenite in the filler market for paint and clear-coating formulations and polymers.

World Mine Production and Reserves:[4] Reserves data for Brazil, Czechia, India, the Republic of Korea, and Thailand were revised based on Government information.

	Mine production (Feldspar)		Reserves[5]
	2017	2018[e]	
United States[1]	440	450	NA
Brazil (beneficiated marketable)	400	400	150,000
China	4,000	4,000	NA
Czechia	460	460	23,000
Egypt	400	400	1,000,000
India	1,500	1,500	320,000
Iran	1,000	1,000	630,000
Italy	3,500	3,000	NA
Korea, Republic of	600	600	240,000
Malaysia	350	350	NA
Poland (processed; includes imports)	500	500	16,000
Spain (includes pegmatites)	600	600	NA
Thailand	1,390	1,500	960
Turkey	7,150	7,500	240,000
Other countries	2,400	2,500	NA
World total (rounded)	24,700	25,000	Large

World Resources: 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. E Net exporter. NA Not available.

[1]Rounded to two significant digits to avoid disclosing company proprietary data.

[2]Defined as production + imports – exports.

[3]Defined as imports – exports.

[4]Feldspar only.

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

FLUORSPAR

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2018, 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. The same company also continued development work and stockpiling of ore for future processing at the Klondike II fluorspar mine in Kentucky. Synthetic fluorspar may have been recovered as a byproduct of petroleum alkylation, stainless steel pickling, or uranium processing, but no data were collected from any of these operations. An estimated 40,000 tons of fluorosilicic acid (FSA), equivalent to about 64,000 tons of fluorspar grading 100%, was recovered from five phosphoric acid plants processing phosphate rock. Fluorosilicic acid was used primarily in water fluoridation.

U.S. fluorspar consumption was satisfied by imports and small quantities of byproduct synthetic fluorspar. Domestically, production of hydrofluoric acid (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 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:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Finished, metallurgical grade	NA	NA	NA	NA	NA
Fluorspar equivalent from phosphate rock	114	105	72	64	64
Imports for consumption:					
Acid grade	291	328	328	331	350
Metallurgical grade	123	48	55	70	60
Total fluorspar imports	414	376	383	401	420
Hydrofluoric acid	125	120	126	123	130
Aluminum fluoride	38	32	20	21	23
Cryolite	16	19	16	10	14
Exports	13	14	12	11	10
Consumption:					
Apparent[1]	518	411	371	390	410
Reported	W	W	W	W	W
Price, average value of acid grade imports					
Cost, insurance, and freight, dollars per ton	254	284	267	262	270
Stocks, yearend, consumer and dealer[2]	195	[e]146	[e]147	NA	NA
Employment, mine, number[e]	6	5	4	4	3
Net import reliance[3] 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 (2014–17): Mexico, 69%; Vietnam, 10%; South Africa, 8%; China, 6%; and other, 7%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Metallurgical grade (less than 97% CaF_2)	2529.21.0000	Free.
Acid grade (97% or more CaF_2)	2529.22.0000	Free.
Natural cryolite	2530.90.1000	Free.
Hydrogen fluoride (hydrofluoric acid)	2811.11.0000	Free.
Aluminum fluoride	2826.12.0000	Free.
Synthetic cryolite	2826.30.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Prepared by **Michele E. McRae [(703) 648–7743, mmcrae@usgs.gov]**

FLUORSPAR

Events, Trends, and Issues: In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including fluorspar. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ''A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" (82 FR 60835).

A new mine in Canada that began operation in late 2017 reportedly sent its first shipment of 4,700 tons of fluorspar to the United States. According to U.S. Census Bureau trade statistics, these imports were received by the Houston-Galveston Customs District. Another new mine in South Africa was under construction and production was expected to begin in early 2019.

World Mine Production and Reserves: Reserves for Brazil, China, and Thailand were revised based on updated data from Government sources, and reserves for Mexico and Morocco were revised based on company-reported information.

	Mine production		Reserves[4, 5]
	2017	2018[e]	
United States	NA	NA	4,000
Argentina	14	14	NA
Brazil	24	24	1,500
China	3,500	3,500	42,000
Germany	55	55	NA
Iran	70	70	3,400
Mexico	1,020	1,100	68,000
Mongolia	220	220	22,000
Morocco	78	78	460
South Africa	257	260	41,000
Spain	142	170	6,000
Thailand	31	30	3,600
United Kingdom	12	12	4,000
Vietnam	236	220	5,000
Other countries	26	29	110,000
World total (rounded)	5,680	5,800	310,000

World Resources: No known systematic assessment of either U.S. or global resources has been conducted since the 1980s. Enormous 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 70 billion tons, equivalent to about 5 billion tons of 100% fluorspar equivalent.

Substitutes: Fluorosilicic acid is used to produce aluminum fluoride (AlF_3), but because of differing physical properties, AlF_3 produced from FSA is not readily substituted for AlF_3 produced from fluorspar. Fluorosilicic acid has been used to produce HF, but this practice has not been widely adopted. Synthetic fluorspar could potentially be recovered by the Department of Energy's two depleted uranium hexafluoride conversion plants in Paducah, KY, and Portsmouth, OH. However, the preferred product is currently aqueous HF rather than 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. W Withheld to avoid disclosing company proprietary data.
[1]Defined as imports – exports + adjustments for industry stock changes for fluorspar only. Adjustments for stocks changes are included for 2014–16 but were no longer available for 2017 and 2018 and are not included. Excludes fluorspar equivalent of FSA, HF, AlF_3, and cryolite.
[2]Industry stocks for leading consumers and fluorspar distributors.
[3]Defined as imports – exports + adjustments for industry stock changes for fluorspar only. Adjustments for stocks changes are included for 2014–16 but were no longer available for 2017 and 2018 and are not included.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]Measured as 100% calcium fluoride.

GALLIUM

(Data in kilograms of gallium content unless otherwise noted)

Domestic Production and Use: No domestic primary (low-grade, unrefined) gallium has been recovered since 1987. Globally, primary gallium is recovered as a byproduct of processing bauxite and zinc ores. One company in Utah recovered and refined high-purity gallium from imported low-grade primary gallium metal and new scrap. Imports of gallium metal and gallium arsenide (GaAs) wafers were valued at about $6 million and $230 million, respectively. GaAs was used to manufacture integrated circuits (ICs) and optoelectronic devices, which include laser diodes, light-emitting diodes (LEDs), photodetectors, and solar cells. Gallium nitride (GaN) principally was used to manufacture optoelectronic devices. ICs accounted for 68% of domestic gallium consumption, optoelectronic devices accounted for 30%, and research and development accounted for 2%. About 75% of the gallium consumed in the United States was contained in GaAs and GaN wafers. Gallium metal, triethyl gallium, and trimethyl gallium, used in the epitaxial layering process to fabricate epiwafers for the production of LEDs and ICs, 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:	2014	2015	2016	2017	2018[e]
Production, primary	—	—	—	—	—
Imports for consumption:					
Metal	53,900	28,600	10,500	20,200	33,000
Gallium arsenide wafers (gross weight)	391,000	2,690,000	1,290,000	804,000	630,000
Exports	NA	NA	NA	NA	NA
Consumption, reported	35,800	29,700	18,100	17,900	23,000
Price, imports, dollars per kilogram:					
High-purity, refined[1]	363	317	690	477	350
Low-purity, primary[2]	239	188	125	124	160
Stocks, consumer, yearend	3,980	3,280	2,720	2,840	2,940
Net import reliance[3] as a percentage of reported consumption	100	100	100	100	100

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

Import Sources (2014–17): China, 32%; United Kingdom, 28%; Germany, 15%; Ukraine, 14%; and other, 11%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Gallium arsenide wafers, doped	2853.90.9010	2.8% ad val.
Gallium arsenide wafers, doped	3818.00.0010	Free.
Gallium metal	8112.92.1000	3.0% ad val.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including gallium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

Imports of gallium metal and GaAs wafers continued to account for all U.S. consumption of gallium. In 2018, gallium metal imports increased by about 60% from those of 2017. However, owing to U.S.-based gallium consumers opening new facilities in Asia to be closer to the optoelectronics industry in that region, gallium metal imports in 2018 were still 39% lower than those in 2014.

Primary low-grade (99.99%-pure) gallium prices in China increased by about 40% in 2018, most likely due to restocking by consumers. Low-grade gallium prices worldwide increased after a more than 5-year decline as China's primary low-grade gallium production continued to exceed worldwide consumption. The average monthly price for low-grade gallium in China increased to $200 per kilogram throughout 2018 from approximately $140 per kilogram in 2017. China's primary low-grade gallium production capacity has expanded to approximately 600 tons per year since 2016 from 140 tons per year in 2010. China accounted for more than 80% of worldwide low-grade gallium capacity.

Prepared by **Brian W. Jaskula [(703) 648–4908, bjaskula@usgs.gov]**

GALLIUM

Low-grade primary gallium producers outside of China most likely restricted output owing to a large surplus of primary gallium. These producers included Japan, the Republic of Korea, Russia, and Ukraine. Germany and Kazakhstan ceased primary production in 2016 and 2013, respectively.

Primary high-purity refined gallium production in 2018 was estimated to be about 205 tons. China, Japan, Slovakia, the United Kingdom, and the United States were the known principal producers of high-purity refined gallium. Gallium was recovered from new scrap in Canada, China, Germany, Japan, the United Kingdom, and the United States. World primary low-grade gallium production capacity in 2018 was estimated to be 730 tons per year; high-purity refinery capacity, 320 tons per year; and secondary capacity, 270 tons per year.

In 2017, the value of worldwide radio frequency GaAs device consumption increased by 7% to $8.8 billion owing to a growing wireless telecommunications infrastructure in Asia; growth of third- and fourth-generation (3G and 4G) “smartphones,” which employ up to 10 times the amount of GaAs in standard cellular handsets; and robust use in military radar and communications applications. The value of worldwide GaAs wafer consumption increased by 13% to $790 million. Countries within the Asia and the Pacific region dominated the GaAs wafer market, with cellular, optoelectronics, and wireless manufacturers consuming an estimated 61% of the GaAs wafers. Owing to their large power-handling capabilities, high-switching frequencies, and higher voltage capabilities, GaN-based products, which historically have been used in defense applications, continued to be used in cable television transmission, commercial wireless infrastructure, power electronics, and satellite markets. In 2018, the GaN radio frequency device market was estimated to have increased by 23% to $467 million.

General lighting was the leading sector among LED applications and was expected to be the major share of the LED market for the rest of the decade. LED manufacturing capacity in Asia increased significantly owing to China’s Government-instituted incentives to increase LED production. In 2017, China accounted for 54% of global LED manufacturing capacity. In the first 9 months of 2018, China’s LED production outpaced worldwide consumption and LED prices declined. The global LED market was estimated to be $18.8 billion in 2018, an increase of 4% from that in 2017.

World Production and Reserves:

	Primary production		Reserves[4]
	2017	2018[e]	
United States	—	—	Quantitative estimates of reserves are not available.
China	300,000	390,000	
Japan	3,000	3,000	
Korea, Republic of	3,000	3,000	
Russia	7,000	6,000	
Ukraine	4,000	6,000	
World total (rounded)	320,000	410,000	

World Resources: 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 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. GaAs-based ICs are used in many defense-related applications because of their unique properties, and no effective substitutes exist for GaAs in these applications. GaAs in heterojunction bipolar transistors is being replaced in some applications by silicon-germanium.

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

[1]Estimated based on the average values of U.S. imports for 99.9999%- and 99.99999%-pure gallium.

[2]Estimated based on the average values of U.S. imports for 99.99%-pure gallium.

[3]Defined as imports – exports.

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

GARNET (INDUSTRIAL)[1]

(Data in metric tons of garnet unless otherwise noted)

Domestic Production and Use: In 2018, garnet for industrial use was mined by four firms—one in Idaho, one in Montana, and two in New York. The estimated value of crude garnet production was about $23 million, and refined material sold or used had an estimated value of $71 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:	2014	2015	2016	2017	2018[e]
Production (crude)	59,900	77,200	81,300	107,000	110,000
Production (refined, sold or used)	35,900	47,200	46,600	96,800	170,000
Imports for consumption[e, 2]	162,000	212,000	156,000	54,200	250,000
Exports[e]	15,400	14,700	13,400	23,300	18,000
Consumption, apparent[e, 3]	206,000	274,000	224,000	138,000	340,000
Price, average value, dollars per ton, import	280	250	190	260	210
Stocks, yearend	NA	NA	NA	NA	NA
Employment, mine and mill, number[e]	99	105	108	120	135
Net import reliance[4] as a percentage of apparent consumption	71	72	64	22	68

Recycling: Garnet was recycled in Pennsylvania with a recycling capacity of up to 25,000 tons per year and a new plant in Oregon, with a recycling capacity of up to 16,000 tons per year, opened in November 2018. Garnet can be recycled multiple times without degradation to its quality. Most used garnet is recycled from blast cleaning and water-jet-assisted cutting purposes.

Import Sources (2014–17):[e] Australia, 43%; India, 35%; South Africa, 13%; China, 7%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Emery, natural corundum, natural garnet, and other natural abrasives, crude	2513.20.1000	Free.
Emery, natural corundum, natural garnet, and other natural abrasives, other than crude	2513.20.9000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: During 2018, estimated domestic production of crude garnet concentrates increased by 5% compared with production in 2017. U.S. garnet production was estimated to be about 10% of total global garnet production. The 2018 estimated domestic sales or use of refined garnet increased by 76% compared with sales in 2017. This increase in domestic sales or use of refined garnet was mainly due to a garnet processing plant in Pennsylvania beginning full production and the opening of a new processing plant in Oregon. The two processing plants have a refined garnet production capacity of 422,000 tons per year.

Prepared by **Kenneth C. Curry [(703) 648–7793, kcurry@usgs.gov]**

GARNET (INDUSTRIAL)

Garnet imports in 2018 were estimated to have more than tripled compared with those of 2017. The significant increase in imports of garnet can be attributed to easing of supply restrictions of garnet from India and an increase in garnet required for the processing plants in Pennsylvania and Oregon. Imports from India increased in 2018 but were still significantly lower than in 2016, prior to the export restrictions in 2017. However, there was a substantial increase in imports from South Africa in 2018 to meet consumption requirements. In 2018, the average unit value of garnet imports was $210 per ton, which represents a decrease of 19% compared with the average unit value in 2017. In the United States, most domestically produced crude garnet concentrate was priced at about $205 per ton. Exports in 2018 were estimated to have decreased by 24%.

Over the past 5 years, U.S. production has increased steadily while imports have varied widely. It is thought that producer stocks have been able to augment supply to meet consumption requirements. The significant increase in imports in 2018 may be partially attributed to resupplying stocks that were used in 2017.

The United States consumed about 31% of global garnet production and world production of garnet increased by 13% in 2018. In India, garnet production continued to be limited. Garnet production in South Africa increased in 2018.

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 other salable mineral products that occur with garnet, such as kyanite, marble, metallic ores, mica minerals, sillimanite, staurolite, or wollastonite.

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

	Mine production		Reserves[5]
	2017	2018[e]	
United States	107,000	110,000	5,000,000
Australia	364,000	330,000	Moderate to Large
China	100,000	110,000	Moderate to Large
India	142,000	180,000	13,000,000
South Africa	211,000	270,000	NA
Other countries	50,000	60,000	6,500,000
World total (rounded)	974,000	1,100,000	Moderate to Large

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

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

[e]Estimated. NA Not Available.

[1]Excludes gem and synthetic garnet.

[2]It was assumed that 75% of imports under Harmonized Tariff Schedule codes 2513.20.1000 and 2513.20.9000 were industrial garnet.

[3]Defined as crude production + imports – exports.

[4]Defined as imports – exports.

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

GEMSTONES[1]

(Data in million dollars unless otherwise noted)

Domestic Production and Use: The combined value of U.S. natural and synthetic gemstone output in 2018 was an estimated $53 million, a 18% decrease compared with that of 2017. 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 decreasing order of production value, Arizona, Oregon, Nevada, California, Montana, Maine, Arkansas, Colorado, Utah, Idaho, Tennessee, North Carolina, and New York produced 95% of U.S. natural gemstones. Synthetic gemstones were manufactured by four firms in North Carolina, California, South Carolina, and Arizona, in decreasing order of production value. Major gemstone uses were carvings, gem and mineral collections, and jewelry. The apparent consumption in the table below is much lower than the actual consumption because the value of exports includes the value of reexports.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:[2]					
Natural[3]	9.5	8.5	11.7	9.2	10
Laboratory-created (synthetic)	51.0	55.1	54.9	55.1	43
Imports for consumption	26,400	25,100	25,200	25,100	28,000
Exports, including reexports[4]	21,300	18,500	19,500	21,100	23,000
Consumption, apparent[5]	5,160	6,660	5,770	4,060	5,100
Price	Variable, depending on size, type, and quality				
Employment, mine, number[e]	1,100	1,100	1,120	1,120	1,120
Net import reliance[6] 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 (2014–17 by value): India, 35%; Israel, 35%; Belgium, 15%; South Africa, 4%; and other, 11%. Diamond imports accounted for 91% of the total value of gem imports.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Coral and similar materials, unworked	0508.00.0000	Free.
Imitation gemstones	3926.90.4000	2.8% ad val.
Pearls, imitation, not strung	7018.10.1000	4.0% ad val.
Pearls, imitation, glass beads	7018.10.2000	Free.
Pearls, natural	7101.10.0000	Free.
Pearls, cultured	7101.21.0000	Free.
Diamonds, unworked or sawn	7102.31.0000	Free.
Diamonds, ½ carat or less	7102.39.0010	Free.
Diamonds, cut, more than ½ carat	7102.39.0050	Free.
Other nondiamond gemstones, unworked	7103.10.2000	Free.
Other nondiamond gemstones, uncut	7103.10.4000	10.5% ad val.
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 val.
Synthetic gemstones, cut but not set	7104.90.1000	Free.
Synthetic gemstones, other	7104.90.5000	6.4% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Prepared by **Donald W. Olson [(703) 648–7721, dolson@usgs.gov]**

GEMSTONES

Events, Trends, and Issues: In 2018, U.S. imports for consumption for gem-quality diamonds were estimated to be about $26 billion, which was a 13% increase compared with $22.7 billion in 2017. U.S. imports for consumption for natural, nondiamond gemstones was estimated to be about $2.0 billion, which was a 14% decrease compared with $2.30 billion in 2017. U.S. synthetic gemstone production decreased by 22% compared with that in 2017. Decreases in U.S. synthetic gemstone production were because the only U.S. cubic zirconia producer stopped producing at its U.S. production facility in November 2017.

The United States accounted for more than 35% of the world's diamond consumption and was once again the fastest-growing market in terms of consumer demand. The United States is expected to continue to dominate global gemstone demand. Demand also increased in China, but growth in the other main markets declined.

During the first half of 2018, worldwide rough diamond sales to cutting centers were higher than during the same period in 2017. Total world diamond production during 2018 fell slightly from 2017 levels, owing to a suspension of operations at a mine in Russia and reduced production in Canada. Production is expected to continue to decline, and new projects and expansions will not replace the output lost from closing mines. By 2025, several large mines are expected to reach the end of their mine life, and only a few new projects are in the pipeline.

World Gem Diamond Mine Production and Reserves:

	Mine production[7]	
	2017	2018[e]
United States	([9])	([9])
Angola	8,500	8,500
Australia	343	340
Botswana	16,000	16,000
Brazil	255	250
Canada	23,200	23,000
China	230	230
Congo (Kinshasa)	3,780	3,700
Guinea	145	140
Lesotho	1,130	1,100
Namibia	1,950	1,900
Russia	23,800	23,000
Sierra Leone	231	230
South Africa	7,750	7,700
Tanzania	260	260
Zimbabwe	251	250
Other countries	277	480
World total (rounded)	88,100	87,000

Reserves[8]

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

World Resources: Most diamond-bearing ore bodies have a diamond content that ranges from less than 1 carat per ton to about 6 carats per ton of ore. The major gem 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 gemstones) are common substitutes. Simulants (materials that appear to be gems but differ in chemical and physical characteristics) also are frequently substituted for natural gemstones.

[e]Estimated.
[1]Excludes industrial diamond and industrial garnet. See Diamond (Industrial) and Garnet (Industrial).
[2]Estimated minimum production.
[3]Includes production of freshwater shell.
[4]Reexports account for between 67% and 92% of the totals.
[5]Defined as production (natural and synthetic) + imports – exports (including reexports).
[6]Defined as imports – exports (including reexports).
[7]Data in thousands of carats of gem diamond.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]Less than ½ unit.

GERMANIUM

(Data in kilograms of germanium content unless otherwise noted)

Domestic Production and Use: In 2018, zinc concentrates containing germanium were produced at mines in Alaska, Tennessee, and Washington. Germanium-containing concentrates in Alaska and Washington were exported to a refinery in Canada for processing and germanium recovery. A zinc smelter in Clarksville, TN, produced and exported germanium leach concentrates recovered from processing zinc concentrates from the Middle Tennessee Mines. Germanium in the form of compounds and metal was imported into the United States for further processing by industry. A company in Utah produced germanium wafers for solar cells used in satellites from imported and recycled germanium. A refinery in Oklahoma recovered germanium from industry-generated scrap and produced germanium tetrachloride for the production of fiber optics. The estimated value of germanium consumed in 2018, based on the annual average price, was about $35 million, about 8% more than that in 2017.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Primary refinery	—	—	—	—	—
Secondary refinery	W	W	W	W	W
Imports for consumption:					
Germanium metal	23,700	20,100	11,000	11,100	8,000
Germanium dioxide[1]	12,500	14,300	15,200	12,000	13,000
Total exports[2]	12,000	5,000	4,780	3,670	4,900
Shipments from Government stockpile	[3]3,000	—	—	—	—
Consumption, estimated	32,000	34,000	30,000	30,000	27,000
Price, annual average, dollars per kilogram:[4]					
Germanium metal	1,918	1,792	1,087	1,082	1,300
Germanium dioxide	1,291	1,211	830	731	1,100
Net import reliance[5] as a percentage of estimated consumption	>75%	>75%	>50%	>50%	>50%

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

Import Sources (2014–17):[6] Germanium metal: China, 58%; Belgium, 26%; Germany, 7%; Russia, 6%; and other, 3%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–18**
Germanium oxides and zirconium dioxide	2825.60.0000	3.7% ad val.
Metal, unwrought	8112.92.6000	2.6% ad val.
Metal, powder	8112.92.6500	4.4% ad val.
Metal, wrought	8112.99.1000	4.4% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile:[7]

		FY2018		FY 2019	
Material	**Inventory As of 9–30–18**	**Potential Acquisitions**	**Potential Disposals[8]**	**Potential Acquisitions**	**Potential Disposals[8]**
Germanium metal	14,004	1,000	—	—	—
Germanium scrap (gross weight)	2,806	—	5,000	—	5,000
Germanium wafers (each)	76,454	—	—	—	—

Events, Trends, and Issues: The major global end uses for germanium were electronics and solar applications, fiber-optic systems, infrared optics, polymerization catalysts, and other uses (such as chemotherapy, metallurgy, and phosphors). Germanium-containing infrared optics were primarily for military use, but the commercial applications for thermal-imaging devices that use germanium lenses have increased during the past few years.

Prepared by **Christine L. Thomas [(703) 648–7713, clthomas@usgs.gov]**

GERMANIUM

Germanium dioxide and germanium metal prices gradually increased from the beginning of 2017 through to January 2018, and then sharply increased from January to March 2018 before stabilizing through to the end of July and decreasing in August. The prices of germanium dioxide and germanium metal increased by 29% and 15%, respectively, during the first 8 months of 2018. Sources attributed the price increases in 2018 to two main events: the partial force majeure at a refinery in Canada, and the implementation of stricter environmental standards in China. The decrease observed in August was attributed to lessened concern for supply availability.

In January 2018, germanium production at a lead-zinc refinery in Canada was disrupted after a breakdown of equipment during an explosion at a slag fuming furnace. The company announced a partial force majeure in January, and in July announced that the furnace would be operational during the fourth quarter of 2018. Germanium production was expected to begin after the furnace was back in operation.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including germanium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

In 2018, China remained the leading global producer of germanium. China’s germanium production growth rate in 2017 and 2018 were affected by the implementation of stricter environmental standards and restrictions. Germanium producers in China continued to integrate with downstream operations in order to sell more value-added germanium products. Germanium’s use in fiber optics, infrared, and photovoltaic products increased in China within the last year, which increased demand for the metal.

World Refinery Production and Reserves:[9]

	Refinery production[e]		Reserves[10]
	2017	2018	
United States	W	W	Data on the recoverable germanium content of zinc ores are not available.
China	60,000	75,000	
Russia	6,000	6,000	
Other countries[11]	40,000	35,000	
World total[12]	106,000	120,000	

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

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

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Data has been adjusted to exclude low value shipments, then multiplied by 69% to account for germanium content.
[2]Includes Schedule B numbers: 8112.92.6100, 8112.99.1000, and 2825.60.0000. Data have been adjusted to exclude low-value shipments. Oxide data have been multiplied by 69% to account for germanium content.
[3]Germanium metal from the National Defense Stockpile that was upgraded to epitaxial wafers.
[4]Average European price for minimum 99.99% purity. Source: Argus Media group-Argus Metals International.
[5]Defined as imports – exports + adjustments for Government stock changes.
[6]Import sources are based on gross weight of wrought and unwrought germanium metal and germanium metal powders.
[7]See Appendix B for definitions.
[8]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[9]Includes both primary and secondary production.
[10]See Appendix C for resource and reserve definitions and information concerning data sources.
[11]Includes Belgium, Canada, Germany, Japan, and Ukraine.
[12]Excludes U.S. production.

GOLD

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

Domestic Production and Use: In 2018, domestic gold mine production was estimated to be about 210 tons, 11% less than that in 2017, and the value was estimated to be about $8.6 billion. Gold was produced in 12 States at more than 40 lode mines, at several large placer mines in Alaska, and numerous smaller placer mines (mostly in Alaska and in the Western States). About 6% of domestic gold was recovered as a byproduct of processing domestic base-metal ores, chiefly copper ores. The top 28 operations yielded more than 99% of the mined gold produced in the United States. Commercial-grade gold was produced at about 15 refineries. A few dozen companies, out of several thousand companies and artisans, dominated the fabrication of gold into commercial products. U.S. jewelry manufacturing was heavily concentrated in the New York, NY, and Providence, RI, areas, with lesser concentrations in California, Florida, and Texas. Estimated domestic uses (excluding gold bullion bar) were jewelry, 46%; electrical and electronics, 40%; official coins, 9%; and other, 5%.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Mine	210	214	228	237	210
Refinery:					
Primary	253	248	248	212	200
Secondary (new and old scrap)	135	124	123	96	95
Imports for consumption[2]	308	265	374	255	220
Exports[2]	492	478	393	461	480
Consumption, reported	152	165	169	146	145
Stocks, yearend, Treasury[3]	8,140	8,140	8,140	8,140	8,140
Price, dollars per troy ounce[4]	1,269	1,163	1,252	1,261	1,270
Employment, mine and mill, number[5]	12,000	11,900	11,900	12,000	12,000
Net import reliance[6] as a percentage of apparent consumption	E	E	E	E	E

Recycling: In 2018, an estimated 95 tons of new and old scrap was recycled, about 66% of reported consumption. The domestic supply of gold from recycling decreased slightly compared with 2017.

Import Sources (2014–17):[2] Canada, 24%; Mexico, 23%; Colombia, 11%; Peru, 10%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
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.

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 2018 was slightly more than the price in 2017 but was 24% lower than the record-high annual price in 2012. The Engelhard daily price of gold in 2018 fluctuated through several cycles. Early in the year, the gold price reached a projected annual high of $1,363.96 per troy ounce on January 25. During this time, the weak U.S. dollar spurred investors to purchase more gold. Starting in late April, the price began a downward trend and reached $1,179.65 per troy ounce on August 16 as investors reportedly were investing in the strong U.S. dollar rather than in gold. The price was relatively flat for the rest of August and September but started to increase in October and into November. The price fell to the year-to-date low (and projected annual low) of $1,130.57 per troy ounce on October 19. The price quickly recovered and continued to trend upward to mid-November.

Prepared by **Micheal W. George [(703) 648–4962, mgeorge@usgs.gov]**

GOLD

The 11% decrease in domestic mine production in 2018 was attributed to decreases in production from the Cortez Mine in Nevada, the Cresson Mine in Colorado, the Fort Knox Mine in Alaska, and Newmont mines in Nevada, and to the shutdown of the Kettle River-Buckhorn Mine in Washington in 2017. In 2018, worldwide gold mine production was estimated to have increased slightly from that in 2017. New mine production in Canada and Russia and increased production from the Grasberg Mine in Indonesia more than offset decreased gold mine production in China, owing to increased environmental regulations, and in the United States.

In the first 9 months of 2018, domestic consumption of gold used in the production of coins and bars decreased by more than 19%; however, gold consumption for jewelry increased by 5% because of increased purchases by consumers, owing to the continually improved U.S. economic conditions in the first 9 months, evident by the 2.2%, 4.2%, and 3.5% increases in Gross Domestic Product in the first three quarters of 2018. Globally, gold consumption by the jewelry industry increased slightly and for gold coins and bars decreased slightly compared with that in the first 9 months of 2017. Investments in gold-based exchange-traded funds were significantly lower in the United States and slightly lower in the world during the same period.

World Mine Production and Reserves: Reserves for Canada, Peru, and Russia were revised based on Government or industry reports.

	Mine production		Reserves[7]
	2017	2018[e]	
United States	237	210	3,000
Australia	301	310	[8]9,800
Brazil	80	81	2,400
Canada	164	185	2,000
China	426	400	2,000
Ghana	128	130	1,000
Indonesia	75	85	2,500
Kazakhstan	85	85	1,000
Mexico	126	125	1,400
Papua New Guinea	64	65	1,300
Peru	151	145	2,600
Russia	270	295	5,300
South Africa	137	120	6,000
Uzbekistan	104	105	1,800
Other countries	883	920	12,000
World total (rounded)	3,230	3,260	54,000

World Resources: An assessment of U.S. gold resources indicated 33,000 tons of gold in identified (15,000 tons) and undiscovered (18,000 tons) resources.[9] 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 in electrical and electronic products, and in jewelry to economize on gold; 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.
[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.
[2]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 in Exchange Stabilization Fund. Stocks were valued at the official price of $42.22 per troy ounce.
[4]Engelhard's average gold price quotation for the year. In 2018, the price was estimated by the U.S. Geological Survey based on data from January through October.
[5]Data from 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]For Australia, Joint Ore Reserves Committee-compliant reserves were about 3,800 tons.
[9]U.S. Geological Survey National Mineral Resource Assessment Team, 2000, 1998 assessment of undiscovered deposits of gold, silver, copper, lead, and zinc in the United States: U.S. Geological Survey Circular 1178, 21 p.

GRAPHITE (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Although natural graphite was not produced in the United States in 2018, approximately 95 U.S. firms, primarily in the Great Lakes and Northeastern regions and Alabama and Tennessee, consumed 40,000 tons valued at an estimated $37 million. The major uses of natural graphite in 2018 were brake linings, lubricants, powdered metals, refractory applications, and steelmaking. During 2018, U.S. natural graphite imports were 52,000 tons, which were about 75% flake and high-purity, 24% amorphous, and 1% lump and chip graphite.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, mine	—	—	—	—	—
Imports for consumption	69,600	46,700	38,900	51,900	52,000
Exports	12,200	11,600	14,300	13,900	12,000
Consumption, apparent[1]	57,400	35,100	24,700	38,000	40,000
Price, imports (average dollars per ton at foreign ports):					
Flake	1,270	1,710	1,920	1,390	1,480
Lump and chip (Sri Lankan)	1,870	1,800	1,880	1,900	1,840
Amorphous	360	454	571	451	426
Net import reliance[1] as a percentage of apparent consumption	100	100	100	100	100

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

Import Sources (2014–17): China, 37%; Mexico, 29%; Canada, 17%; Brazil, 9%; and other, 8%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Crystalline flake (not including flake dust)	2504.10.1000	Free.
Powder	2504.10.5000	Free.
Other	2504.90.0000	Free.

Depletion Allowance: 22% (Domestic lump and amorphous), 14% (Domestic flake), and 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Worldwide consumption of graphite has steadily increased since 2013 and into 2018. U.S. consumption of natural graphite was at its highest point during the past 5 years in 2014. During 2015, U.S. consumption declined by 39% and continued declining into 2016; however, during 2017 and 2018, consumption increased by 54% and 5%, respectively.

In 2018, principal United States import sources of natural graphite were, in descending order of tonnage, China, Mexico, Canada, Brazil, Madagascar, Hong Kong, Sri Lanka, the United Kingdom, and Japan, which combined accounted for 99% of the tonnage and 98% of the value of total United States imports. Mexico provided most of the amorphous graphite, and Sri Lanka provided all the lump and chip dust variety.

During 2018, China produced 70% of the world's graphite. Approximately 44% of production in China was amorphous graphite and about 56% was flake. China does produce some large flake graphite, but the majority of its flake graphite production is very small, in the +200-mesh range.

New graphite deposits were being developed in Madagascar, Mozambique, Namibia, and Tanzania, and mines were projected to begin production in the near future. During 2017, some of the mines in Tanzania began sampling production. A graphite mine project in Mozambique commenced operations at the start of 2018 and was ramping up production at a high-grade graphite deposit. Reportedly the largest natural graphite mine globally, it is expected to operate for 50 years.

Prepared by **Donald W. Olson [(703) 648–7721, dolson@usgs.gov]**

GRAPHITE (NATURAL)

North America produced only 5% of the world's graphite supply with production in Canada and Mexico. No production of natural graphite was reported in the United States, but two companies were developing graphite projects—one in Alabama and one in Alaska.

A U.S. automaker was building a large plant to manufacture lithium-ion electric vehicle batteries. The plant's completion was projected for 2020. A portion of the plant was operational and battery packs were being assembled in 2018. When the plant is complete, it was expected to require 35,200 tons per year of spherical graphite for use as anode material for lithium-ion batteries.

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

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including graphite. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ''A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" (82 FR 60835).

World Mine Production and Reserves: The reserves data for Brazil, China, North Korea, Norway, and Vietnam were revised based on information reported by graphite-producing companies and the Governments of those countries.

	Mine production		Reserves[2]
	2017	2018[e]	
United States	—	—	(3)
Brazil	90,000	95,000	72,000,000
Canada	40,000	40,000	(3)
China	625,000	630,000	73,000,000
India	35,000	35,000	8,000,000
Korea, North	5,500	6,000	2,000,000
Madagascar	9,000	9,000	1,600,000
Mexico	9,000	9,000	3,100,000
Mozambique	300	20,000	17,000,000
Namibia	2,220	2,200	(3)
Norway	15,500	16,000	600,000
Pakistan	14,000	14,000	(3)
Russia	17,000	17,000	(3)
Sri Lanka	3,500	4,000	(3)
Tanzania	—	—	17,000,000
Turkey	2,300	2,000	90,000,000
Ukraine	20,000	20,000	(3)
Vietnam	5,000	5,000	7,600,000
Zimbabwe	1,580	2,000	(3)
Other	1,900	4,000	(3)
World total (rounded)	897,000	930,000	300,000,000

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

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

[e]Estimated. — Zero.

[1]Defined as imports – exports.

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

[3]Included with "World total."

GYPSUM

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2018, domestic production of crude gypsum was estimated to be 21 million tons with a value of about $168 million. The leading crude gypsum-producing States were Colorado, Iowa, Kansas, Nevada, Oklahoma, and Texas, which together accounted for an estimated 67% of total output. Overall, 47 companies produced or processed gypsum in the United States at 50 mines in 16 States. The majority of domestic consumption, which totaled approximately 48 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 2018, the production capacity of operating wallboard plants in the United States was about 33.4 billion square feet[1] per year. Total wallboard sales were estimated to be 25.5 billion square feet.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Crude	18,300	18,800	19,800	20,700	21,000
Synthetic[2]	15,200	15,500	16,700	20,700	22,000
Calcined[3]	16,100	16,500	17,900	17,800	18,000
Wallboard products sold (million square feet[1])	21,500	22,100	24,400	25,000	25,500
Imports, crude, including anhydrite	3,720	4,030	4,340	4,890	5,400
Exports, crude, not ground or calcined	67	63	43	36	34
Consumption, apparent[4]	37,100	38,200	40,700	46,300	48,000
Price:					
Average crude, free on board (f.o.b.) mine, dollars per metric ton	8.00	7.80	8.00	7.50	7.80
Average calcined, f.o.b. plant, dollars per metric ton	27.00	28.00	30.00	30.00	31.00
Employment, mine and calcining plant, number[e]	4,500	4,500	4,500	4,500	4,500
Net import reliance[5] as a percentage of apparent consumption	10	10	11	10	11

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

Import Sources (2014–17): Mexico, 41%; Canada, 30%; Spain, 27%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Gypsum; anhydrite	2520.10.0000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. gypsum production increased slightly compared with that of 2017. Apparent consumption increased by 4% compared with that of 2017. The world's leading crude gypsum producer, the United States, produced an estimated 21 million tons. Iran, tied for second with China in world production, supplied much of the gypsum needed for construction in the Middle East. China and Iran each produced an estimated 16 million tons. Spain, the leading European producer, ranked seventh in the world and supplied crude gypsum and gypsum products to much of Western Europe. Increased use of wallboard in Asia, coupled with new gypsum product plants, spurred increased production in that region. As wallboard becomes more widely used in other regions, worldwide production of gypsum is expected to increase.

Prior year chapters of this commodity included gypsum production for China that totaled as much as 130 million tons. However, recently acquired information revealed that the vast majority of that amount was likely synthetic gypsum, which is not "mine production." Hence, the large decrease in reported gypsum in China reflects a recategorization of gypsum material and should not be interpreted as a large decrease in the overall total world production of gypsum nor the production of gypsum in China.

Prepared by **Robert D. Crangle, Jr. [(703) 648–6410, rcrangle@usgs.gov]**

GYPSUM

Demand for gypsum depends principally on construction industry activity, particularly in the United States, where the majority of gypsum consumed is used for building plasters, the manufacture of portland cement, and wallboard products. If the construction of wallboard manufacturing plants designed to use synthetic gypsum from coal flue gas desulfurization (FGD) units as feedstock continues, this could result in less mining of natural gypsum. The availability of inexpensive natural gas, however, may limit the additional construction of FGD units and, therefore, the use of synthetic gypsum in wallboard. U.S. gypsum imports increased by 10% compared with those of 2017. Exports, although very low compared with imports and often subject to wide fluctuations, decreased by 6%.

World Mine Production and Reserves: Reserves for Brazil, India, and Turkey were revised based on Government and other public data.

	Mine production		Reserves[6]
	2017	2018[e]	
United States	20,700	21,000	700,000
Algeria	2,200	2,200	NA
Argentina	1,500	1,500	NA
Australia	*1,400	*1,400	NA
Brazil	3,400	3,400	340,000
Canada	1,700	1,700	450,000
China	15,500	16,000	NA
Egypt	2,200	2,200	NA
France	4,200	4,200	NA
Germany	3,100	3,100	NA
India	2,700	2,700	36,000
Iran	16,000	16,000	1,600
Japan	4,700	4,700	NA
Mexico	5,400	5,400	NA
Oman	5,500	5,500	4,900
Pakistan	2,000	2,000	NA
Russia	4,000	4,000	NA
Saudi Arabia	3,150	3,200	NA
Spain	7,000	7,000	NA
Thailand	9,250	9,300	NA
Turkey	9,000	9,000	200,000
Other countries	16,100	21,000	NA
World total (rounded)	*141,000	*150,000	Large

World Resources: 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 U.S. western seaboard. Large gypsum deposits occur in the Great Lakes region, the midcontinent region, and several Western States. Foreign resources are large and widely distributed; 82 countries were thought to produce gypsum in 2018.

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 FGD 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 2018, synthetic gypsum accounted for more than 50% 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]Data refer to the amount sold or used, not produced. Source: American Coal Ash Association.
[3]From domestic crude and synthetic.
[4]Defined as crude production + total synthetic reported used + imports – exports.
[5]Defined as imports – exports.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
*Corrections posted March 18, 2019.

HELIUM

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

Domestic Production and Use: The estimated value of Grade-A helium (99.997% or greater) extracted during 2018 by private industry was about $682 million. Fourteen plants (one in Arizona, two in Colorado, five in Kansas, one in Oklahoma, four in Texas, and one in Utah) extracted helium from natural gas and produced crude helium that ranged from 50% to 99% helium. One plant in Colorado and another in Wyoming extracted helium from natural gas and produced Grade-A helium. Three plants in Kansas and one in Oklahoma accepted crude helium from other producers and the Bureau of Land Management (BLM) pipeline and purified it to Grade-A helium. In 2018, estimated domestic consumption of Grade-A helium was 39 million cubic meters (1.4 billion cubic feet), and it was used for magnetic resonance imaging, 30%; lifting gas, 17%; analytical and laboratory applications, 14%; welding, 9%; engineering and scientific applications, 6%; leak detection and semiconductor manufacturing, 5% each; and various other minor applications, 14%.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Helium extracted from natural gas[2]	75	71	66	63	64
Withdrawn from storage[3]	27	20	23	28	26
Grade-A helium sales	102	91	89	91	90
Imports for consumption	7	16	24	21	22
Exports	67	65	61	69	73
Consumption, apparent[4]	42	42	52	43	39
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

In fiscal year (FY) 2018, the price for crude helium to Government users was $3.10 per cubic meter ($86.00 per thousand cubic feet) and to nongovernment users was $4.29 per cubic meter ($119.00 per thousand cubic feet). The price for the Government-owned helium is mandated by the Helium Stewardship Act of 2013 (Public Law 113–40) and determined through public auctions and industry surveys. The estimated price for private industry's Grade-A helium was about $7.57 per cubic meter ($210 per thousand cubic feet), with some producers posting surcharges to this price.

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

Import Sources (2014–17): Qatar, 79%; and other, 21%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Helium	2804.29.0010	3.7% ad val.

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

Government Stockpile: Under the Helium Stewardship Act of 2013, the BLM manages the Federal Helium Program, which includes all operations of the Cliffside Field helium storage reservoir, in Potter County, TX, and the Government's crude helium pipeline system. Private firms that sell Grade-A helium to Federal agencies are required to purchase a like amount of (in-kind) crude helium from the BLM. The law mandated that the BLM annually sell at auction Federal Conservation helium stored in Bush Dome at the Cliffside Field. The amounts sold are approximately equal to the amount that the Federal helium system can produce each year. The BLM will dispose of all helium-related assets when the remaining conservation helium falls below 83.2 million cubic meters or no later than 2021.
In FY 2018, privately owned companies purchased about 4.4 million cubic meters (158 million cubic feet) of in-kind crude helium. Privately owned companies also purchased 8.3 million cubic meters (300 million cubic feet) of open market sales helium. During FY 2018, the BLM's Amarillo Field Office, Helium Operations, accepted about 3.3 million cubic meters (119 million cubic feet) of private helium for storage and redelivered nearly 30.5 million cubic meters (1.1 billion cubic feet). As of September 30, 2018, about 85.9 million cubic meters (3.1 billion cubic feet) of privately owned helium remained in storage at Cliffside Field.

Stockpile Status—9–30–18[6]

Material	Inventory	Authorized for disposal	Disposal plan FY 2018	Disposals FY 2018
Helium	83.1	74.8	8.3	8.3

Prepared by **Joseph B. Peterson[7] [(806) 356–1030, jbpeters@blm.gov]**

HELIUM

Events, Trends, and Issues: In 2018, the BLM continued implementation of the Helium Stewardship Act of 2013 by conducting its fifth and final auction of helium from Federal helium storage at the Cliffside Field near Amarillo. In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including helium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835). By the end of the decade, international helium extraction facilities are likely to become the main source of supply for world helium users.

World Production and Reserves:[8]

	Production		Reserves[9]
	2017	2018[e]	
United States (extracted from natural gas)	63	64	3,900
United States (from Cliffside Field)	28	26	([10])
Algeria	14	14	1,800
Australia	4	4	NA
Canada	<1	<1	NA
China	NA	NA	NA
Poland	2	2	25
Qatar	45	45	NA
Russia	3	3	1,700
World total (rounded)	160	160	NA

World Resources: Section 16 of Public Law 113-40 requires the U.S. Geological Survey (USGS) to complete a national helium gas assessment. The USGS and the BLM have been coordinating efforts to complete this assessment. Completion of data integration, geologic review, data analysis, and probabilistic modeling for the resource assessment is expected in 2019. The USGS expects results to be published in 2020. The BLM plans to update its report of Helium Resources of the United States by midyear 2019. Until then, the following estimates are still the best available.

As of December 31, 2006, the total helium reserves and resources of the United States were estimated to be 20.6 billion cubic meters (744 billion cubic feet). This includes 4.25 billion cubic meters (153 billion cubic feet) of measured reserves, 5.33 billion cubic meters (192 billion cubic feet) of probable resources, 5.93 billion cubic meters (214 billion cubic feet) of possible resources, and 5.11 billion cubic meters (184 billion cubic feet) of speculative resources. Included in the measured reserves are 670 million cubic meters (24.2 billion cubic feet) of helium stored in the Cliffside Field Government Reserve, and 65 million cubic meters (2.3 billion cubic feet) of helium contained in Cliffside Field native gas. The Hugoton (Kansas, Oklahoma, and Texas), Panhandle West, Panoma, Riley Ridge in Wyoming, and Cliffside Fields are the depleting fields from which most U.S.-produced helium is extracted. These fields contained an estimated 3.9 billion cubic meters (140 billion cubic feet) of helium.

Helium resources of the world, exclusive of the United States, were estimated to be about 31.3 billion cubic meters (1.13 trillion cubic feet). The locations and volumes of the major deposits, in billion cubic meters, are Qatar, 10.1; Algeria, 8.2; Russia, 6.8; Canada, 2.0; and China, 1.1. As of December 31, 2018, the BLM had analyzed about 22,300 gas samples from 26 countries and the United States, in a program to identify world helium resources.

Substitutes: There is no substitute for helium in cryogenic applications if temperatures below –429 °F are required. Argon can be substituted for helium in welding, and hydrogen can be substituted for helium in some lighter-than-air applications in which the flammable nature of hydrogen is not objectionable. Hydrogen is also being investigated as a substitute for helium in deep-sea diving applications below 1,000 feet.

[e]Estimated. E Net exporter. NA Not available.
[1]Measured at 101.325 kilopascals absolute (14.696 psia) and 15 °C; 27.737 cubic meters of helium = 1,000 cubic feet of helium at 70 °F and 14.7 psia.
[2]Both Grade-A and crude helium.
[3]Extracted from natural gas in prior years.
[4]Grade-A helium. Defined as Grade-A helium sales + imports – exports.
[5]Defined as imports – exports + adjustments for Government and industry stock changes.
[6]See Appendix B for definitions.
[7]Supervisory General Engineer, Helium Resources Division, Bureau of Land Management, Amarillo Field Office, Helium Operations, Amarillo, TX.
[8]Production and reserves outside of the United States are estimated.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.
[10]Included in United States (extracted from natural gas) reserves.

INDIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Indium was not recovered from ores in the United States in 2018. 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 of global indium consumption. ITO thin-film coatings were primarily used for electrical 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. Based on an average of recent annual import levels, estimated domestic consumption of refined indium was 170 tons in 2018. The estimated value of refined indium consumed domestically in 2018, based on the average New York dealer price, was about $53 million.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, refinery	—	—	—	—	—
Imports for consumption	123	140	160	127	170
Exports	NA	NA	NA	NA	NA
Consumption, estimated[1]	123	140	160	127	170
Price, annual average, dollars per kilogram:					
New York dealer[2]	705	520	345	363	380
Free market[3]	NA	410	240	225	310
Net import reliance[4] as a percentage of estimated consumption	100	100	100	100	100

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

Import Sources (2014–17): China, 27%; Canada, 22%; Republic of Korea, 11%; Taiwan, 10%; and other, 30%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Unwrought indium, including powders	8112.92.3000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Prepared by **C. Schuyler Anderson [(703) 648–4985, csanderson@usgs.gov]**

INDIUM

<u>Events, Trends, and Issues</u>: The 2018 estimated average New York dealer price of indium was $380 per kilogram, 5% more than in 2017. The average monthly price began the year at $350 per kilogram in January and increased to a monthly average of $390 per kilogram in May, where it remained through October. The 2018 estimated average free market price of indium was $310 dollars per kilogram, 38% more than in 2017. The average monthly free market price began the year at $284 per kilogram, increased to an average of $349 per kilogram in April, and decreased through the year to an average of $258 per kilogram in September.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including indium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

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

	Refinery production		Reserves[5]
	2017	2018[e]	
United States	—	—	Quantitative estimates of reserves are not available.
Belgium	20	20	
Canada	67	70	
China	287	300	
France	30	50	
Japan	70	70	
Korea, Republic of	225	230	
Peru	10	10	
Russia	5	5	
World total (rounded)	714	750	

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

<u>Substitutes</u>: 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; PEDOT [poly(3,4-ethylene dioxythiophene)] has also been developed as a substitute for ITO in flexible displays and organic light-emitting diodes; and copper or silver nanowires have been explored as a substitute for ITO in touch screens. Graphene has been developed to replace ITO electrodes in solar cells and also has been explored as a replacement for ITO in flexible touch screens. Researchers have developed a more adhesive zinc oxide nanopowder to replace ITO in LCDs. Hafnium can replace indium in nuclear reactor control rod alloys.

[e]Estimated. NA Not available. — Zero.
[1]Estimated to equal imports.
[2]Price is based on 99.99%-minimum-purity indium; delivered duty paid U.S. buyers; in minimum lots of 50 kilograms. Source: Platts Metals Week.
[3]Price is based on 99.99%-minimum-purity indium at warehouse (Rotterdam). Source: Metal Bulletin.
[4]Defined as imports – exports.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.

IODINE

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

Domestic Production and Use: Iodine was produced from brines in 2018 by three companies operating in Oklahoma. U.S. iodine production in 2018 was withheld to avoid disclosing company proprietary data. The average cost, insurance, and freight value of iodine imports in 2018 was estimated to be $22 per kilogram, a 13% increase from that of 2017.

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. Organic iodine compounds, which included ethyl and methyl iodide, ethylenediamine dihydroiodide, and povidone iodine were thought to account for more than 50% of domestic iodine consumption in 2018. Worldwide, the leading uses of iodine and its compounds were x-ray contrast media, pharmaceuticals, and liquid-crystal-display (LCD) screens, in descending order of production quantity.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production	W	W	W	W	W
Imports for consumption	5,360	5,630	4,320	4,180	4,800
Exports	1,240	1,210	1,050	1,230	1,000
Consumption:					
Apparent[1]	W	W	W	W	W
Reported	3,910	3,800	4,610	4,500	4,600
Price, average value of imports, cost, insurance, and freight, dollars per kilogram	37.04	27.74	22.71	19.55	22
Employment, number[e]	60	60	60	60	60
Net import reliance[2] as a percentage of reported consumption	>50	>50	>50	>50	>50

Recycling: Small amounts of iodine were recycled.

Import Sources (2014–17): Chile, 88%; Japan, 11%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Iodine, crude	2801.20.0000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Prepared by **Emily K. Schnebele [(703) 648–4945, eschnebele@usgs.gov]**

IODINE

Events, Trends, and Issues: According to trade publications, spot prices for iodine crystal averaged about $25 per kilogram during the first half of 2018. Although this was an increase from the 2017 annual average of $21 per kilogram, prices were still considerably less than the historically high levels of $65 to $85 per kilogram in late 2012 and early 2013. The increase in the average spot price was attributed to an undersupply in the market, with consumption being greater than current production levels. In recent years, iodine producers decreased production in response to falling prices. One U.S. company opened a new plant in early 2018. The new plant was expected to increase the company's iodine production and reduce the unit cost of 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 62% of world production in 2018. Most of the world's iodine supply comes from three areas: the Chilean desert nitrate mines, the oil and gas fields in Japan, and iodine-rich brine wells in northwestern Oklahoma.

World Mine Production and Reserves: China also produces crude iodine, but output is not officially reported. Reserves for Chile were revised based on company and Government reports.

	Mine production		Reserves[3]
	2017	2018[e]	
United States	W	W	250,000
Azerbaijan	199	200	170,000
Chile	18,400	18,000	610,000
Indonesia	39	40	100,000
Japan	10,000	10,000	5,000,000
Russia	—	10	120,000
Turkmenistan	544	540	70,000
World total (rounded)	[4]29,200	[4]29,000	6,300,000

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

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

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

IRON AND STEEL[1]

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

Domestic Production and Use: The U.S. iron and steel industry and ferrous foundries produced goods in 2018 with an estimated value of about $137 billion, up from $127 billion in 2017. Pig iron and raw steel was produced by three companies operating integrated steel mills in nine locations. Fifty-one companies produced raw steel at 99 minimills. Combined production capacity was about 110 million tons. Indiana accounted for 27% of total raw steel production, followed by Ohio, 12%; Michigan, 6%; and Pennsylvania, 6%, with no other State having more than 5% of total domestic raw steel production. The distribution of steel shipments was estimated to be construction, 43%; transportation (predominantly automotive), 27%; machinery and equipment, 10%; energy, 7%; appliances, 5%; and other, 8%.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Pig iron production[2]	29.4	25.4	22.3	22.4	24
Raw steel production	88.2	78.8	78.5	81.6	87
Basic oxygen furnaces, percent	37.4	37.3	33.0	31.6	33
Electric arc furnaces, percent	62.6	62.7	67.0	68.4	67
Continuously cast steel, percent	98.5	99.0	99.6	99.6	98
Shipments, steel mill products	89.1	78.5	78.5	82.5	86
Imports:					
Steel mill products	40.2	35.2	30.0	34.6	32
Semifinished products	9.6	6.6	6.1	7.8	8
Exports, steel mill products	10.9	9.0	8.4	9.6	8
Consumption, apparent (steel)[3]	107	100	95	99	103
Producer price index for steel mill products (1982=100)[4]	200.2	177.1	167.8	187.4	207
Stocks, service centers, yearend[5]	9.0	7.5	6.6	6.9	6.8
Total employment, average, number:					
Blast furnaces and steel mills[4]	91,000	87,000	83,900	80,600	81,000
Iron and steel foundries[4]	67,600	64,900	65,000	65,000	64,000
Net import reliance[6] as a percentage of apparent consumption	30	22	24	25	24

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

Import Sources (2014–17): Canada, 15%; Brazil, 13%; Republic of Korea, 11%; and other, 61%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Carbon steel:		
Semifinished	7207.00.0000	Free.
Flat, hot-rolled	7208.00.0000	Free.
Flat, cold-rolled	7209.00.0000	Free.
Galvanized	7210.00.0000	Free.
Bars and rods, hot-rolled	7213.00.0000	Free.
Structural shapes	7216.00.0000	Free.
Stainless steel:		
Semifinished	7218.00.0000	Free.
Flat-rolled sheets	7219.00.0000	Free.
Bars and rods	7222.00.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Prepared by **Christopher A. Tuck [(703) 648–4912, ctuck@usgs.gov]**

IRON AND STEEL

Events, Trends, and Issues: In March 2018, the President of the United States issued a proclamation imposing a 25% tariff on steel imports from most countries of origin under the authority of Section 232 of the Trade Expansion Act of 1962 (83 FR 11625). Additional orders were issued during the year which modified the list of countries subject to the tariff and quotas. As of December, a 50% tariff was applicable to Turkey and the 25% tariff was applicable to all countries of origin, except Argentina, Australia, Brazil, and the Republic of Korea. Requests could be made for certain steel products to become eligible for relief from the quotas and tariff. The Producer Price Index series, published by the Bureau of Labor Statistics, indicated that the prices of steel products in the United States increased by about 10% during the second half of 2018.

Global raw steel production was forecast by one organization to increase by 3.9% in 2018 and 1.4% in 2019, spurred by investments in industrialized nations and economic improvement in emerging economies. China, which accounts for more than one-half of global raw steel production, increased steel consumption during the first half of 2018, owing to improvements in the global economy and the Chinese real estate market. The country's increased environmental enforcement and the impacts of U.S. tariffs were expected to slow steel output through 2019. The growth of the global economy was expected to slow, resulting in decreased demand in global steel. Steel consumption in developed economies was expected to increase by 1.0% in 2018 and 1.2% in 2019. In the United States, steel consumption increased owing to fiscal stimulus, tax and regulatory changes, and increased investment, partially as the result of moderate growth in the automotive and construction sectors.

World Production:

	Pig iron		Raw steel	
	2017	2018[e]	2017	2018[e]
United States	22	24	82	87
Brazil	28	29	34	35
Canada	6	7	14	15
China	711	723	832	890
France	11	12	16	17
Germany	28	29	43	44
India	66	69	101	110
Japan	78	82	105	110
Korea, Republic of	47	49	71	75
Russia	52	53	70	71
Taiwan	14	15	22	23
Turkey	11	11	38	38
Ukraine	20	21	21	22
Other countries	78	74	240	230
World total (rounded)	1,170	1,200	1,690	1,800

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

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

[e]Estimated.
[1]Production and shipments data source is the American Iron and Steel Institute; see also Iron and Steel Scrap and Iron Ore.
[2]More than 95% of iron made is transported in molten form to steelmaking furnaces located at the same site.
[3]Defined as steel shipments + imports of steel mill products – exports + adjustments for industry stock changes – imports of semifinished steel products.
[4]Source: U.S. Department of Labor, Bureau of Labor Statistics.
[5]Steel mill products. Source: Metals Service Center Institute.
[6]Defined as imports – exports + adjustments for industry stock changes.

IRON AND STEEL SCRAP[1]

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

Domestic Production and Use: In 2018, the total value of domestic purchases of iron and steel scrap (receipts of ferrous scrap by all domestic consumers from brokers, dealers, and other outside sources) and exports was estimated to be $19.7 billion, approximately 25% more than the $15.7 billion in 2017. U.S. apparent steel consumption, an indicator of economic growth, increased slightly to 103 million tons in 2018. Manufacturers of pig iron, raw steel, and steel castings accounted for about 92% of 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, such as machinery parts, motor blocks, and pipe. Relatively small quantities of steel scrap were used for producing ferroalloys, for the precipitation of copper, and by the chemical industry; these uses collectively totaled less than 1 million tons.

During 2018, raw steel production was an estimated 86.6 million tons, up by 6% from 81.6 million tons in 2017. Net shipments of steel mill products were an estimated 86 million tons, 4% higher than those in 2017.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Home scrap	7.1	6.3	5.9	5.5	4.4
Purchased scrap[2]	62	54	53	55	56
Imports for consumption[3]	4.2	3.5	3.9	4.6	4.8
Exports[3]	15	13	13	15	18
Consumption, reported	58	51	50	50	51
Consumption, apparent[4]	58	51	50	50	47
Price, average, dollars per metric ton delivered, No. 1 Heavy Melting composite price	351	213	196	265	325
Stocks, consumer, yearend	4.1	4.2	4.3	4.4	5.1
Employment, dealers, brokers, processors, number[e]	30,000	30,000	27,000	27,000	27,000
Net import reliance[5] 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. One ton of steel that is recycled conserves 1.1 tons of iron ore, 0.6 tons of coking coal, and 0.05 tons of limestone.

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

The recycling rate for 2014, the most recent year data was published, was approximately 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.

Prepared by **Christopher A. Tuck [(703) 648–4912, ctuck@usgs.gov]**

IRON AND STEEL SCRAP

Recycling of scrap plays an important role in the conservation of energy because the remelting of scrap requires much less energy than the production of iron or steel products from iron ore. Also, consumption of iron and steel scrap by remelting reduces the burden on landfill disposal facilities and prevents the accumulation of abandoned steel products in the environment. Recycled scrap consists of approximately 58% post-consumer (old, obsolete) scrap, 24% prompt scrap (produced in steel-product manufacturing plants), and 18% home scrap (recirculating scrap from current operations).

Import Sources (2014–17): Canada, 75%; Mexico, 7%; United Kingdom, 7%; Sweden, 5%; and other, 6%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Iron and steel waste and scrap:		
No. 1 Bundles	7204.41.0020	Free.
No. 1 Heavy Melting	7204.49.0020	Free.
No. 2 Heavy Melting	7204.49.0040	Free.
Shredded	7204.49.0070	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: Steel mill production capacity utilization last peaked at 80.9% in April 2012; however, that utilization rate was surpassed in November 2018 when the rate reached 81.2%. Scrap prices fluctuated during 2018, with a high of about $378 per ton in May and a low of about $299 per ton in September. Composite prices published by Scrap Price Bulletin for No. 1 Heavy Melting steel scrap delivered to purchasers in Chicago, IL, Philadelphia, PA, and Pittsburgh, PA, averaged about $329 per ton during the first 9 months of 2018. Exports of ferrous scrap increased in 2018 and primarily went to Turkey, Mexico, and Taiwan, in descending order of export tonnage. The value of exported scrap increased to an estimated $5.9 billion in 2018 from $4.0 billion in 2017.

Global raw steel production was forecast by one organization to increase by 3.9% in 2018 and by 1.4% in 2019, spurred by investments in industrialized nations and economic improvement in emerging economies. Steel demand in developed economies was expected to increase by only 1.0% in 2018 and 1.2% in 2019. In the United States, demand increased owing to tax and regulatory changes and increased investment. The automotive and construction sectors were expected to experience overall moderate growth.

World Mine Production and Reserves: Not applicable.

World Resources: Not applicable.

Substitutes: An estimated 2.0 million tons of direct-reduced iron was used in the United States in 2018 as a substitute for iron and steel scrap, up from 1.9 million tons in 2017.

[e]Estimated. E Net exporter.
[1]See also Iron and Steel and Iron Ore.
[2]Defined as receipts – shipments by consumers + 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]Defined as imports – exports + adjustments for industry stock changes.

IRON AND STEEL SLAG

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: When making crude (or pig) iron and crude steel, slagging agents are added to strip impurities from the iron ore in the blast furnaces and from the crude iron and scrap steel feeds to the steel furnaces. The impurities and slagging agents combine to form iron and steel (ferrous) slags, which are tapped separately from the metals and which, after cooling and processing, primarily find a ready market in the construction industry. Data are unavailable on actual U.S. ferrous slag production, but it is estimated to have been in the range of 14 to 19 million tons in 2018. Domestic slag sales[1] in 2018 amounted to an estimated 16 million tons, valued at about $470 million (ex-plant). Blast furnace slag accounted for about 50% of the tonnage sold and had a value of about $360 million; nearly 90% of this value was from sales of granulated slag. Steel slag produced from basic oxygen and electric arc furnaces accounted for almost all of the remainder.[2] Slag was processed by about 25 companies servicing active iron and steel facilities or reprocessing old slag piles at about 140 processing plants (including some iron and steel plants with more than one slag-processing facility) in 30 States; included in this tally are some facilities that grind and sell ground granulated blast furnace slag (GGBFS) based on imported unground feed.

Prices listed in the table below are weighted averages (rounded) for iron and steel slags sold for a variety of applications. Actual prices per ton ranged in 2018 from a few cents for some steel slags at a few locations to about $100 or more for some GGBFS. Air-cooled iron slag and steel slag are used primarily as aggregates in concrete (air-cooled iron slag only); asphaltic paving, fill, and road bases; and 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. Owing to low unit values, most slag types can be shipped only short distances by truck, but rail and waterborne transportation allow for greater distances. Because of much higher unit values, GGBFS can be shipped longer distances, so much of the GGBFS consumed in the United States is imported.

Salient Statistics—United States:	2014	2015	2016	2017[e]	2018[e]
Production (sales)[1, 3]	16.6	17.7	15.7	16	16
Imports for consumption[4]	1.8	1.5	2.0	2.1	2.2
Exports	0.1	([5])	([5])	([5])	([5])
Consumption, apparent[6]	16.5	17.7	15.7	16	16
Price, average value, dollars per ton, f.o.b. plant[7]	19.00	19.50	22.00	25.00	26.00
Employment, number[e]	1,700	1,700	1,600	1,500	1,500
Net import reliance[8] as a percentage of apparent consumption	10	8	13	13	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 the slag processors; data on metal returns are unavailable.

Import Sources (2014–17): Japan, 27%; Canada, 24%; Spain, 15%; Brazil, 6%; and other, 28%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Granulated slag	2618.00.0000	Free.
Slag, dross, scale, from manufacture of iron and steel	2619.00.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: The supply of blast furnace slag remains problematic in the United States because of the closure and (or) continued idling of some U.S. blast furnaces in recent years (including four in 2015, although at least one of these were restarted in 2018), the lack of construction of new furnaces, and the depletion of old slag piles.

Prepared by **Hendrik G. van Oss [Contact Kenneth C. Curry (703) 648–7793, kcurry@usgs.gov]**

IRON AND STEEL SLAG

Locally produced granulated blast furnace slag remained in limited supply because, at yearend 2018, granulation cooling was available at only two active U.S. blast furnaces. Installation of granulation cooling continued to be evaluated at a few blast furnaces, but it remained unclear if this would be cost-effective given the economic uncertainties in operating blast furnaces. Pelletized blast furnace slag was in very limited supply (one site only), and it was uncertain if any additional pelletizing capacity was planned. Domestic grinding of granulated blast furnace slag was only done by cement companies.

Basic oxygen furnace steel slag from domestic furnaces also has become less available recently because of the closure or idling of several integrated iron and steel complexes, although the existence at many sites of large slag stockpiles can allow for slag processing to continue even several years after the cessation of furnace operations. Nonetheless, the long-term supply of steel slag will increasingly rely on electric arc furnaces, which now contribute the majority of U.S. steel production. Domestic- and import-supply constraints appear to have limited domestic consumption of GGBFS in recent years. Although prices have increased, sales volumes for GGBFS have not matched the relative increases that have characterized the overall U.S. cement market since 2010. Long-term demand for GGBFS likely will increase because its use in concrete yields a superior product in many applications and reduces the unit carbon dioxide (CO_2) emissions footprint of the concrete related to the portland cement (clinker) content.

Recent regulations to restrict emissions of CO_2 and mercury by coal-fired powerplants, together with powerplant closures or conversion of others to natural gas, have led to a reduction in the supply of fly ash in some areas, including that of material for use as cementitious additive for concrete, with the result that fly ash imports have increased. Fly ash shortages have the potential to increase future demand for GGBFS, but the availability of granulated slag will increasingly depend on imports, either of ground or unground material. Imported slag availability may be constrained by increasing international demand for the same material and because not all granulated slag produced overseas is of high quality. Restrictions on mercury emissions by cement plants enacted in 2015 may reduce demand for fly ash as a raw material for clinker manufacture, and this could lead to use of air-cooled and steel slags as replacement raw materials.

World Mine Production and Reserves: Slag is not a mined material and thus the concept of reserves does not apply to this mineral commodity. Slag production data for the world are unavailable, but may be estimated as equivalent to 25% to 30% of crude (pig) iron production and steel furnace slag as about 10% to 15% of crude steel output. On this basis, it is estimated that global iron slag output in 2018 was on the order of 300 million to 360 million tons, and steel slag about 190 million to 290 million tons.

World Resources: Not applicable.

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

[e]Estimated.
[1]Processed slag sold rather than that processed or produced during the year. Excludes any entrained metal that may be recovered during slag processing and then sold separately or returned to iron and, especially, steel furnaces. Data are incomplete regarding slag returns to the furnaces.
[2]There were very minor sales of open hearth furnace steel slag from stockpiles but no domestic production of this slag type in 2014–18.
[3]Data include sales of imported granulated blast furnace slag, either after domestic grinding or still unground, and exclude sales of pelletized slag (proprietary but very small).
[4]Official (U.S. Census Bureau) data adjusted by the U.S. Geological Survey. In some years, the official data, which are reported as granulated blast furnace slag only, appear to have understated the true imports of this material by as much as 0.4–0.5 million tons annually for the period shown, and have included significant tonnages of 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.
[5]Less than 0.05 million tons.
[6]Defined as total sales of slag (including those from imported feed) − exports but does not significantly differ from total sales owing to the very small export tonnages.
[7]Rounded to the nearest $0.50 per ton.
[8]Defined as imports – exports.

IRON ORE[1]

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

Domestic Production and Use: In 2018, mines in Michigan and Minnesota shipped 98% of the usable iron ore products in the United States with an estimated value of $4.1 billion. The remaining 2% of domestic iron ore was produced for nonsteel end uses. Seven open-pit iron ore mines (each with associated concentration and pelletizing plants), and three iron metallic plants—one direct-reduced iron (DRI) plant and two hot-briquetted iron (HBI) plants—operated during the year to supply steelmaking raw materials. The United States was estimated to have produced 2.0% and consumed 1.6% of the world's iron ore output.

Salient Statistics—United States:[2]	2014	2015	2016	2017	2018[e]
Production:					
Iron ore	56,100	46,100	41,800	47,900	49,000
Iron metallics	1,950	1,450	2,070	3,250	3,400
Shipments	55,000	43,500	46,600	46,900	49,000
Imports for consumption	5,140	4,550	3,010	3,700	3,400
Exports	12,400	8,030	8,770	10,600	13,000
Consumption:					
Reported	44,400	38,500	34,500	34,400	35,000
Apparent[3]	46,700	39,300	39,200	39,500	38,000
Value, U.S. dollars per metric ton	84.43	81.19	73.11	80.15	82.00
Stocks, mine, dock, and consuming plant, yearend, excluding byproduct ore	4,460	7,860	4,660	6,120	7,600
Employment, mine, concentrating and pelletizing plant, number	6,270	4,800	4,710	4,630	4,800
Net import reliance[4] as a percentage of apparent consumption (iron content of ore)	E	E	E	E	E

Recycling: None. See Iron and Steel Scrap.

Import Sources (2014–17): Canada, 46%; Brazil, 38%; Sweden, 6%, Chile, 3%, and other, 7%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
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: U.S. iron ore production was estimated to have increased in 2018 owing to increased steel-mill-capacity utilization and higher steel demand. Raw steel production increased to 86.6 million tons in 2018 from 81.6 million tons in 2017. The share of steel produced by basic oxygen furnaces, the process that uses iron ore, continued to decline from 37.4% in 2014 to 33% in 2018 owing to increased use of electric arc furnaces because of their energy efficiency and reduced environmental impacts, the ready supply of scrap, and stable scrap prices.

Global spot prices in 2018 remained relatively steady throughout the year. Based on reported prices for iron ore fines (62% iron content) imported into China (cost and freight into Tianjin port), the highest monthly average price of the year was $76.34 in January compared with the high of $89.44 in 2017. The lowest monthly average price in 2018 was $64.56 in July, compared with the lowest price of $57.48 in 2017. Overall, global prices trended down slightly, but because China was working to increase efficiency and decrease pollution in steel production, prices for higher grade iron ore products increased.

Prepared by **Christopher A. Tuck [(703) 648–4912, ctuck@usgs.gov]**

IRON ORE

In July, a company, which was working to restart development of an iron ore project it had purchased following bankruptcy proceedings of the original owner, acquired the mineral leases from the State of Minnesota. The company secured financing and off-take agreements for the project, prerequisites for obtaining the leases, and could proceed with construction. Another company shut down four mines in Minnesota and a pelletizing plant in Indiana as it filed for bankruptcy and auctioned off all assets in October 2018. A third company began construction of a 1.6-million-ton-per-year hot-briquetted-iron plant in Toledo, OH, which was planned for completion by mid-2020.

Globally, iron ore production in 2018 was expected to increase slightly from that of 2017, primarily owing to increased production in Australia and the completion of a mine in Brazil. Global raw steel production was forecast by industry experts to increase by 3.9% in 2018 and by 1.4% in 2019, spurred by investments in industrialized nations and economic improvement in emerging economies. Increased pressure on steel producers around the world to increase efficiency, reduce energy consumption, and meet environmental benchmarks continued the slow decline in use of low-grade iron ore and spurred investment in the production of iron metallics and high-grade iron ore products, such as pellets.

World Mine Production and Reserves: Reserves for Brazil, China, India, and Sweden were revised based on Government and industry sources.

	Mine production				Reserves[5, 6]	
	Usable ore		Iron content			
	2017	2018[e]	2017	2018[e]	Crude ore	Iron content
United States	47,900	49,000	30,300	32,000	2,900	760
Australia	883,000	900,000	547,000	560,000	[7]50,000	[7]24,000
Brazil	425,000	490,000	269,000	310,000	32,000	17,000
Canada	49,000	49,000	29,400	29,000	6,000	2,300
China	360,000	340,000	223,000	210,000	20,000	6,900
India	202,000	200,000	125,000	130,000	5,400	3,200
Iran	40,100	40,000	26,300	26,000	2,700	1,500
Kazakhstan	39,100	40,000	10,900	12,000	2,500	900
Russia	95,000	95,000	61,200	61,000	25,000	14,000
South Africa	81,100	81,000	52,600	52,000	1,200	770
Sweden	27,200	27,000	16,900	17,000	1,300	600
Ukraine	60,500	60,000	37,800	38,000	[8]6,500	[8]2,300
Other countries	119,000	120,000	72,200	72,000	18,000	9,500
World total (rounded)	2,430,000	2,500,000	1,500,000	1,500,000	170,000	84,000

World Resources: 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, which allow hematite to be recovered from tailings basins and pelletized.

[e]Estimated. E Net exporter.

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

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

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

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

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

[6]Million metric tons.

[7]For Australia, Joint Ore Reserves Committee-compliant reserves were about 24 billion tons for crude ore and 10 billion tons for iron content.

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

IRON OXIDE PIGMENTS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Iron oxide pigments (IOPs) were mined domestically by three companies in three States. Production, which was withheld to avoid disclosing company proprietary data, decreased in 2018 from that of 2017. Six companies, including the three producers of natural IOPs, processed and sold about 52,000 tons of finished natural and synthetic IOPs with an estimated value of $74 million, significantly below the most recent sales peak of 88,100 tons in 2007. About 55% of natural and synthetic finished IOPs were used in concrete and other construction materials; 20% in coatings and paints; 5% in foundry sands and other foundry uses; 3% each in animal food and industrial chemicals; 2% each in cosmetics and plastics;1% in glass and ceramics; and 9% in other uses.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Mine production, crude	W	W	W	W	W
Sold or used, finished natural and synthetic IOP	45,300	53,500	48,500	47,900	52,000
Imports for consumption	175,000	176,000	179,000	179,000	180,000
Exports, pigment grade	8,790	8,930	15,800	13,500	12,000
Consumption, apparent[1]	212,000	221,000	212,000	213,000	220,000
Price, average value, dollars per kilogram[2]	1.58	1.46	1.46	1.44	1.41
Employment, mine and mill	50	55	60	60	60
Net import reliance[3] as a percentage of reported consumption	>50	>50	>50	>50	>50

Recycling: None.

Import Sources (2014–17): Natural: Cyprus, 46%; Spain, 27%; France, 13%; Austria, 12%; and other, 2%. Synthetic: China, 52%; Germany, 27%; Brazil, 7%, Canada, 6%, and other, 8%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Natural:		
Micaceous iron oxides	2530.90.2000	2.9% ad val.
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 val.
Red	2821.10.0020	3.7% ad val.
Yellow	2821.10.0030	3.7% ad val.
Other	2821.10.0040	3.7% ad val.
Earth colors	2821.20.0000	5.5% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2018, domestic mine production of crude natural IOPs decreased slightly owing to a major producer reducing mine output to draw down stocks after excess crude production in 2016 and 2017. Production and sales of finished natural and synthetic IOPs increased by about 9%. Domestic production of crude natural IOPs and production and sales of synthetic IOPs are expected to increase in 2019, owing in part to an increase in construction and refurbishment projects, resulting from the destruction of buildings, homes, and infrastructure that took place in 2017 and 2018 during hurricane seasons along the Gulf Coast and in southeastern States, and to a second consecutive year of significant wildfires in some Western States.

In the United States, residential construction, in which IOPs are commonly used to color concrete block and brick, ready-mixed concrete, and roofing tiles, increased during the first 9 months of 2018 compared with the same period in 2017; housing starts and completions each rose by about 6%. Spending on residential and nonresidential construction increased by 7% and 5%, respectively, during the first 9 months of 2018 compared with the same period in 2017.

Exports of pigment-grade IOPs decreased by about 13% during the first 9 months of 2018 compared with the same period in 2017, mostly owing to a significant decrease in exports to Belgium and China; more than 87% of pigment-grade IOPs went to Mexico, China, Belgium, Chile, Brazil, Thailand, the United Kingdom, and Germany, in

Prepared by **Arnold O. Tanner [Contact Joyce A. Ober, (703) 648–7717, jober@usgs.gov]**

IRON OXIDE PIGMENTS

descending order of quantity. Exports of other grades of iron oxides and hydroxides, nearly double those of pigment grade, decreased by about 40% during the first 9 months of 2018 compared with those of the same period in 2017. About 97% of exports of other grades of iron oxides and hydroxides went to Spain, Canada, China, Mexico, Israel, Australia, Argentina, and Belgium, in descending order of quantity. Total imports of natural and synthetic IOPs decreased slightly in 2018 compared with those in 2017.

A company in Utah continued to ramp up production and marketing of its high-purity "advanced natural" iron oxides, mostly composed of goethite and hematite. The company sold its natural IOP products to the paints and coatings industries, promoted its transparent IOP products to the woodstains market, and marketed IOP products to the energy and biogas industries as desulfurization catalysts to compete with costly synthetic iron oxide catalysts commonly used in scavenging the highly corrosive hydrogen sulfide gas produced in the anaerobic conversion of biomass.

A major international IOP-producing company, with production facilities in many countries, completed the acquisition of a U.S. company that historically was a significant producer of crude and synthetic IOPs. The U.S. company produced a variety of natural and blended IOPs and ecofriendly, transparent IOP products, mostly by recovering iron oxide from waste streams and drainage and iron-bearing waste piles from current and closed coal and iron ore mines, especially in the Eastern States. The same company, partnering with the State of Virginia, donated 100 hectares, including a site for walking and biking recreational use as an extension to an adjacent State park; newly constructed trails with naturally colorful cliffs opened in 2018.

A major iron-oxide-producing company based in Germany was planning to expand its synthetic IOP production capacities of black and red pigments in Germany; black, red, and yellow pigments in China; and yellow pigments in Brazil, reaching a total global production capacity of more than 400,000 tons per year by 2019.

World Mine Production and Reserves: Reserves data for India were revised based on Government information.

	Mine production		Reserves[4]
	2017	2018[e]	
United States	W	W	Moderate
Austria (micaceous IOP)	3,500	3,500	NA
Cyprus (umber)	4,000	4,000	Moderate
France	1,000	1,000	NA
Germany[5]	200,000	200,000	Moderate
India (ocher)	2,200,000	2,300,000	37,000,000
Pakistan (ocher)	80,000	80,000	Moderate
Spain (ocher and red iron oxide)	16,000	16,000	Large
World total	[6]NA	[6]NA	Large

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

KYANITE AND RELATED MINERALS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In Virginia, one firm with integrated mining and processing operations produced kyanite from two hard-rock open pit mines and synthetic mullite by calcining kyanite. Two other companies, one in Alabama and another in Georgia, produced synthetic mullite from materials mined from four sites; each company sourced materials from one site in Alabama and one site in Georgia. Synthetic mullite production data are withheld to avoid disclosing company proprietary data. Commercially produced synthetic mullite is made by sintering or fusing such feedstock materials as kyanite, kaolin, bauxite, or bauxitic kaolin. Natural mullite occurrences typically are rare and uneconomic 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 65% of the refractory use was by the iron and steel industries, and the remainder was by industries that manufacture 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.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Mine	[1]88,600	[1]109,000	[1]79,700	[1]91,300	95,000
Synthetic mullite	W	W	W	W	W
Imports for consumption (andalusite)	4,020	11,500	2,510	7,430	9,000
Exports (kyanite)	40,000	39,900	37,100	42,400	45,000
Consumption, apparent	W	W	W	W	W
Price, average, dollars per metric ton:[2]					
U.S. kyanite, raw concentrate	260	270	270	270	270
U.S. kyanite, calcined	370	410	410	420	420
Andalusite, Transvaal, South Africa	340	330	330	340	360
Employment, kyanite mine, office, and plant, number[e]	150	155	150	140	150
Employment, mullite plant, office, and plant, number[e]	230	220	210	200	200
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2014–17): South Africa, 75%; Peru, 19%; France, 4%; China 1%, and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Andalusite, kyanite, and sillimanite	2508.50.0000	Free.
Mullite	2508.60.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Prepared by **Arnold O. Tanner [Contact Joyce A. Ober, (703) 648–7717, jober@usgs.gov]**

KYANITE AND RELATED MINERALS

Events, Trends, and Issues: Crude steel production in the United States, which ranked fourth in the world, increased by about 4% in the first 8 months of 2018 compared with that of the same period in 2017, indicating a similar change in consumption of kyanite-mullite refractories. Total world steel production increased by nearly 5% during the first 8 months of 2018 compared with that of the same period in 2017. The increase in world steel production during the first 8 months of 2018 was the result of incremental to small increases in production in developed and developing countries, especially in Asia. Despite a continuing deceleration in growth, China still led with the largest increase in steel production and continued to be the largest market for refractories. Of the total world refractories market, which was estimated to be approximately 40 million tons, crude steel manufacturing consumed more than 70% of refractories production.

The availability of inexpensive refractory-grade bauxite from China, which accounted for about three-quarters of the refractories market share worldwide, continued to decrease, in part owing to inspections by the Government of China and the shutdown of some operations during the past few years because of environmental problems. Andalusite and mullite could receive increased consideration as alternative aluminosilicate refractory minerals to refractory bauxite, if the availability of andalusite in 2019 can meet the rising demand for the mineral. The mine disruptions caused by heavy rain during 2017 at major andalusite operations in South Africa and Peru followed prolonged rampup to full capacity and resulted in shortages of andalusite to supply existing and future orders. Contracts for orders for andalusite of shorter than traditional duration, typically with an increase in prices, began in 2018 and were expected to continue in 2019. Higher consumption of refractories in iron and steel production is expected in countries with higher rates of growth in steel production.

Although still recovering from the adverse weather conditions of 2017, andalusite projects in Peru continued to progress. At one andalusite project, the company continued exploration and construction of a processing facility as it sought a joint-venture investment partner, which was deemed necessary to proceed with production.

World Mine Production and Reserves: Reserves data for India were revised based on Government information.

	Mine production		Reserves[4]
	2017	2018[e]	
United States (kyanite)	91,300	95,000	Large
India (kyanite and sillimanite)	68,000	70,000	7,190,000
Peru (andalusite)	35,000	40,000	NA
South Africa (andalusite)	200,000	200,000	NA
World total (rounded)	[5]NA	[5]NA	NA

World Resources: 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 economic to mine at present. The characteristics of kyanite resources in the rest of the world are thought to be similar to those in the United States. Significant resources of andalusite are known to exist in China, France, Peru, and South Africa; kyanite resources have been identified in Brazil, India, and Russia; and sillimanite has been identified in India.

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

[e]Estimated. E Net exporter. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Source: Virginia Department of Mines, Minerals and Energy.
[2]Source: Average of prices reported in Industrial Minerals.
[3]Defined as imports – exports.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]In addition to the countries listed, France continued production of andalusite and Cameroon and China produced kyanite and related minerals. Output is not reported quantitatively, and no reliable basis is available for estimation of output levels.

LEAD

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

Domestic Production and Use: Five lead mines in Missouri, plus five mines in Alaska, Idaho, and Washington that produced lead as a principal product or byproduct, accounted for all domestic lead mine production. The value of the lead in concentrates mined in 2018, based on the average North American Market price for refined lead, was about $660 million. It was estimated that the lead-acid battery industry accounted for more than 85% of reported U.S. lead consumption during 2018. Lead-acid batteries were primarily used as starting-lighting-ignition (SLI) batteries for automobiles, as industrial-type batteries for standby power for computer and telecommunications networks, and for motive power. During the first 10 months of 2018, 116 million lead-acid automotive batteries were shipped by North American producers, a 3% increase from those shipped in the same period of 2017.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Mine, lead in concentrates	378	370	346	310	260
Primary refinery	—	—	—	—	—
Secondary refinery, old scrap	1,020	1,050	986	1,130	1,300
Imports for consumption:					
Lead in concentrates	—	—	([1])	—	—
Refined metal, unwrought	593	521	533	658	580
Exports:					
Lead in concentrates	357	350	341	269	270
Refined metal, unwrought (gross weight)	55	56	43	24	54
Consumption:					
Reported	1,510	1,630	1,470	NA	NA
Apparent[2]	1,560	1,520	1,480	1,760	1,800
Price, average, cents per pound:[3]					
North American market	106.2	91.2	94.4	114.5	115.0
London Metal Exchange (LME), cash	95.0	81.0	84.8	105.1	104.0
Stocks, metal, producers, consumers, yearend	66	64	101	NA	NA
Employment, number:					
Mine and mill (average)[4]	1,890	1,970	1,970	1,890	1,870
Primary smelter, refineries	—	—	—	—	—
Secondary smelters, refineries	1,800	1,800	1,850	1,850	1,850
Net import reliance[5] as a percentage of apparent consumption, refined lead	35	31	33	36	29

Recycling: In 2018, about 1.3 million tons of secondary lead was produced, an amount equivalent to 71% of apparent domestic consumption. Nearly all secondary lead was recovered from old scrap, mostly lead-acid batteries.

Import Sources (2014–17): Refined metal: Canada, 45%; Mexico, 18%; Republic of Korea, 14%; India, 5%; and other, 18%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
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.

Prepared by **Kateryna Klochko [(703) 648–4977, kklochko@usgs.gov]**

LEAD

Events, Trends, and Issues: During the first 10 months of 2018, the average LME cash price for lead was $1.04 per pound, essentially unchanged from that in the same period of 2017. In the second half of 2017, prices reached a 6-year high owing to a tight supply of concentrate and increased demand for refined lead. During the first 10 months of 2018, prices decreased by 23%, bringing down the year average. Global stocks of lead in LME-approved warehouses were 106,950 tons in mid-December, which was 25% less than those at yearend 2017.

In 2018, domestic mine production was estimated to have decreased from that in the previous year in all four lead-producing States. Production at one mine in Idaho continued to be relatively low owing to an employee strike, which began in March 2017. The United States has become more reliant on imported refined lead in recent years owing to the closure of the last primary lead smelter in 2013. Exports of spent SLI batteries had been decreasing since 2014. During the first 10 months of 2018, however, 22.9 million spent SLI lead-acid batteries were exported, which was 44% more than exports in 2017.

In November 2018, an industrial conglomerate, which was a leading lead-acid automotive battery manufacturer and secondary lead producer in the United States, announced the sale of its battery-making component.

According to the International Lead and Zinc Study Group,[6] global refined lead production in 2018 increased by 0.4% to 11.59 million tons, and metal consumption increased by 0.2% to 11.71 million tons, resulting in a production-to-consumption deficit of about 120,000 tons of refined lead.

World Mine Production and Reserves: Reserves estimates for Australia, China, India, and Turkey were revised based on new information from company or Government reports.

	Mine production		Reserves[7]
	2017	2018[e]	
United States	310	260	5,000
Australia	459	450	[8]24,000
Bolivia	110	100	1,600
China	2,150	2,100	18,000
India	170	170	2,500
Kazakhstan	112	100	2,000
Mexico	243	240	5,600
Peru	307	300	6,000
Russia	200	200	6,400
Sweden	74	70	1,100
Turkey	68	60	6,100
Other countries	379	380	5,000
World total (rounded)	4,580	4,400	83,000

World Resources: 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 (old scrap) + refined imports – refined exports.
[3]Source: Platts Metal Week.
[4]Includes lead and zinc-lead mines for which lead was either a principal product or significant byproduct.
[5]Defined as imports – exports.
[6]International Lead and Zinc Study Group, 2018, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group news release, October 8, 5 p.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]For Australia, Joint Ore Reserves Committee-compliant reserves were about 12 million tons.

LIME[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2018, an estimated 19 million tons of quicklime and hydrate was produced (excluding independent commercial hydrators[2]), valued at about $2.4 billion. At yearend, 29 companies were producing lime, which included 18 companies with commercial sales and 10 companies that produced lime strictly for internal use (for example, sugar companies). These companies had 74 primary lime plants (plants operating quicklime kilns) in 28 States and Puerto Rico. Six of these 29 companies operated only hydrating plants in 11 States. In 2018, the five leading U.S. lime companies produced quicklime or hydrate in 20 States and accounted for 79% of U.S. lime production. Principal producing States were, in alphabetical order, Alabama, Kentucky, Missouri, Ohio, and Texas. Major markets for lime were, in descending order of consumption, steelmaking, chemical and industrial applications (such as the manufacture of fertilizer, glass, paper and pulp, and precipitated calcium carbonate, and in sugar refining), flue gas treatment, construction, water treatment, and nonferrous mining.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production[3]	19,500	18,300	17,700	17,800	19,000
Imports for consumption	414	391	376	367	330
Exports	320	346	329	391	350
Consumption, apparent[4]	19,600	18,300	17,700	17,800	19,000
Quicklime average value, dollars per ton at plant	119.10	121.50	121.00	121.80	120.00
Hydrate average value, dollars per ton at plant	142.20	146.40	145.50	146.70	150.00
Employment, mine and plant, number	5,100	NA	NA	NA	NA
Net import reliance[5] as a percentage of apparent consumption	1	<1	<1	<1	<1

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

Import Sources (2014–17): Canada, 94%; Mexico, 5%; and other, 1%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–18**
Calcined dolomite	2518.20.0000	3% ad val.
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 2018, domestic lime production was estimated to increase by 7% from that of 2017, owing primarily to an increase in hydrated lime output. This also led to the slight increase in estimated value of production year over year.

In 2017, one sugar cooperative reversed an earlier decision made in 2016 to close its sugar beet facility in Torrington, WY, thereby keeping one quicklime kiln in production. Another company shut down quicklime production at one plant in Green Bay, WI; since then, only hydrated lime has been produced at this location. As a result, the total number of operating quicklime plants stayed at 74 in 2018. 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. In 2018, the leading uses of hydrated lime were chemical and industrial, and construction applications; flue gas desulfurization; and water treatment.

Prepared by **Lisa A. Corathers [(703) 648–4973, lcorathers@usgs.gov]**

LIME

World Lime Production and Limestone Reserves:

	Production[e, 6] 2017	Production[e, 6] 2018	Reserves[7]
United States	17,800	19,000	Adequate for all countries listed.
Australia	2,000	2,100	
Belgium[8]	1,500	1,500	
Brazil	8,300	8,400	
Bulgaria	1,400	1,400	
Canada (shipments)	1,830	1,800	
China	290,000	300,000	
Czechia	1,100	1,100	
France	2,600	2,600	
Germany	7,000	7,200	
India	16,000	16,000	
Iran	3,100	3,300	
Italy[8]	3,600	3,600	
Japan (quicklime only)	7,300	7,300	
Kazakhstan	1,040	1,000	
Korea, Republic of	5,200	5,200	
Malaysia	1,600	1,600	
Poland (hydrated and quicklime)	1,840	1,900	
Romania	2,130	2,100	
Russia (industrial and construction)	11,000	11,000	
Slovenia	1,060	1,100	
South Africa	1,130	1,100	
Spain	1,830	1,800	
Turkey	4,700	4,700	
Ukraine	2,500	2,500	
United Kingdom	1,500	1,500	
Other countries	13,500	14,000	
World total (rounded)	413,000	420,000	

World Resources: 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. NA Not available.
[1]Data are for quicklime, hydrated lime, and refractory dead-burned dolomite. Includes Puerto Rico.
[2]To avoid double counting quicklime production, excludes independent commercial hydrators that purchase quicklime for hydration.
[3]Sold or used by producers.
[4]Defined as production + imports – exports. Includes some double counting based on nominal, undifferentiated reporting of company export sales as U.S. production.
[5]Defined as imports – exports.
[6]Only countries that produced 1 million tons of lime or more are listed separately.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]Includes hydraulic lime.

LITHIUM

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

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

Although lithium markets vary by location, global end-use markets are estimated as follows: batteries, 56%; ceramics and glass, 23%; lubricating greases, 6%; polymer production, 4%; continuous casting mold flux powders, 3%; air treatment, 2%; and other uses, 6%. Lithium consumption for batteries has increased significantly in recent years because rechargeable lithium batteries are used extensively in the growing market for portable electronic devices and increasingly are used in electric tools, electric vehicles, and grid storage applications. Lithium minerals were used directly as ore concentrates in ceramics and glass applications.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production	W	W	W	W	W
Imports for consumption	2,130	2,750	3,140	3,330	4,000
Exports	1,420	1,790	1,520	1,960	1,600
Consumption, estimated	[1]2,000	[1]2,000	[1]3,000	[1]3,000	[1]3,000
Price, annual average, battery-grade lithium carbonate, dollars per metric ton[2]	6,690	6,500	8,650	15,000	17,000
Employment, mine and mill, number	70	70	70	70	70
Net import reliance[3] as a percentage of estimated consumption	>25	>25	>50	>50	>50

Recycling: One domestic company has recycled lithium metal and lithium-ion batteries since 1992 at its facility in British Columbia, Canada. In 2015, the company began operating the first U.S. recycling facility for lithium-ion vehicle batteries in Lancaster, OH.

Import Sources (2014–17): Argentina, 51%; Chile, 44%; China, 3%; Russia, 1%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Other alkali metals	2805.19.9000	5.5% ad val.
Lithium oxide and hydroxide	2825.20.0000	3.7% ad val.
Lithium carbonate:		
U.S. pharmaceutical grade	2836.91.0010	3.7% ad val.
Other	2836.91.0050	3.7% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[4]

		FY2018		FY 2019	
Material	**Inventory As of 9–30–18**	**Potential Acquisitions**	**Potential Disposals[5]**	**Potential Acquisitions**	**Potential Disposals[5]**
Lithium cobalt oxide (kilograms, gross weight)	600	600	—	—	—
Lithium nickel cobalt aluminum oxide (kilograms, gross weight)	1,620	2,160	—	—	—
Lithium-ion precursors (kilograms, gross weight)	—	—	—	19,000	—

Events, Trends, and Issues: In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including lithium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

Excluding U.S. production, worldwide lithium production in 2018 increased by 22% to 84,000 tons of lithium content from 69,000 tons of lithium content in 2017 in response to increased lithium demand for battery applications. This follows an increase of 74% in worldwide production in 2017 from that of 2016, owing primarily to a threefold increase in Australia’s spodumene production, including more than 11,000 tons of lithium content in direct shipping ore that

Prepared by **Brian W. Jaskula [(703) 648–4908, bjaskula@usgs.gov]**

LITHIUM

was exported to China for processing. Consumption of lithium in 2018 was projected to be about 47,600 tons of lithium content, an increase of 20% from 39,700 tons of lithium content in 2017. Worldwide lithium production capacity was estimated to be 91,000 tons of lithium content per year.

Spot lithium carbonate prices in China decreased from approximately $21,000 per ton at the beginning of the year to about $12,000 per ton in the third quarter owing to worldwide lithium production exceeding worldwide lithium consumption. For large fixed contracts, however, Industrial Minerals reported an annual average U.S. lithium carbonate price of $17,300 per metric ton in 2018, a 15% increase from that of 2017.

Five spodumene operations in Australia and two brine operations each in Argentina and Chile accounted for the majority of world lithium production. The leading spodumene operation in Australia increased its spodumene concentrate production by about 40% in 2018 and remained the world's largest lithium producer. Two new Australian spodumene operations ramped up production in 2017, and five additional spodumene operations ramped up production in 2018.

Lithium supply security has become a top priority for technology companies in the United States and Asia. 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 operations were under development in Argentina, Bolivia, Chile, China, and the United States; pegmatite mining operations were under development in Australia, Austria, Canada, China, Czechia, Finland, Mali, Namibia, Portugal, Serbia, and Spain; and lithium-clay mining operations were under development in Mexico and the United States.

World Mine Production and Reserves: Reserves for Brazil, Chile, China, and Zimbabwe were revised based on new information from Government and industry sources.

	Mine production		Reserves[6]
	2017	2018[e]	
United States	W	W	35,000
Argentina	5,700	6,200	2,000,000
Australia	40,000	51,000	[7]2,700,000
Brazil	200	600	54,000
Chile	14,200	16,000	8,000,000
China	6,800	8,000	1,000,000
Portugal	800	800	60,000
Namibia	—	500	NA
Zimbabwe	800	1,600	70,000
World total (rounded)	[8]69,000	[8]85,000	14,000,000

World Resources: Owing to continuing exploration, lithium resources have increased substantially worldwide and total about 62 million tons. Identified lithium resources in the United States—from continental brines, geothermal brines, hectorite, oilfield brines, and pegmatites—are 6.8 million tons. Identified lithium resources in other countries have been revised to 55 million tons. Identified lithium resources in Argentina are 14.8 million tons; Bolivia, 9 million tons; Chile, 8.5 million tons; Australia, 7.7 million tons; China, 4.5 million tons; Canada, 2 million tons; Mexico, 1.7 million tons; Czechia, 1.3 million tons; Congo (Kinshasa), Russia, and Serbia, 1 million tons each; Zimbabwe, 540,000 tons; Mali and Spain, 400,000 tons each; Brazil and Germany, 180,000 tons each; Peru and Portugal, 130,000 tons each; Austria, 75,000 tons; Finland and Kazakhstan, 40,000 tons each; and Namibia, 9,000 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. NA Not available. — Zero.
[1]Defined as production + imports – exports. Rounded to one significant digit to avoid disclosing company proprietary data.
[2]Source: Industrial Minerals, IM prices: Lithium carbonate, large contracts, delivered continental United States.
[3]Defined as imports – exports + adjustments for Government and industry stock changes.
[4]See Appendix B for definitions.
[5]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]For Australia, Joint Ore Reserves Committee-compliant reserves were about 1.4 million tons.
[8]Excludes U.S. production.

MAGNESIUM COMPOUNDS[1]

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

Domestic Production and Use: Seawater and natural brines accounted for about 57% of U.S. magnesium compound production in 2018. The value of production of all types of magnesium compounds was estimated to be $257 million. Magnesium oxide and other compounds were recovered from seawater by one company in California and another company in Delaware, from well brines by one company in Michigan, and from lake brines by two companies in Utah. Magnesite was mined by one company in Nevada. One company in Washington processed olivine that was mined previously for use as foundry sand. About 60% of the magnesium compounds consumed in the United States were used in agricultural, chemical, construction, environmental, and industrial applications in the form of caustic-calcined magnesia, magnesium chloride, magnesium hydroxide, and magnesium sulfates. The remaining 40% was used for refractories in the form of dead-burned magnesia, fused magnesia, and olivine.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production (shipments)	395	394	408	438	460
Shipments (gross weight)	560	561	579	616	640
Imports for consumption	471	602	370	436	530
Exports	65	71	88	103	110
Consumption, apparent[3]	801	925	690	771	880
Employment, plant, number[e]	250	260	260	260	270
Net import reliance[4] as a percentage of apparent consumption	51	57	41	43	48

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

Import Sources (2014–17): Caustic-calcined magnesia: China, 57%; Canada, 22%; Australia, 9%; Brazil, 4%; and other, 8%. Dead-burned and fused magnesia: China, 60%; Brazil, 19%; Ukraine, 6%; Turkey, 6%; and other, 9%. Magnesium chloride: Israel, 63%; Netherlands, 27%; China, 4%; India, 3%; and other, 3%. Magnesium hydroxide: Mexico, 42%; Israel, 18%; Netherlands, 14%; Austria, 13%; and other, 13%. Magnesium sulfates: Germany, 42%; China, 41%; Canada, 6%; Mexico, 5%; and other, 6%.

Tariff:[5] **Item**	**Number**	**Normal Trade Relations 12–31–18**
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	2816.10.0000	3.1% ad val.
Magnesium chloride	2827.31.0000	1.5% ad val.
Magnesium sulfate (synthetic)	2833.21.0000	3.7% ad val.

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: Consumption of dead-burned and fused magnesia increased by 6% in the United States in the first 8 months of 2018 compared with that of the same period in 2017 and was expected to continue to increase at a similar rate in the foreseeable future. Global consumption of dead-burned and fused magnesia increased by about 7% during the first 8 months of 2018 compared with that in the same period of 2017, as world steel production increased in 2018. Prices for dead-burned magnesia and caustic-calcined magnesia remained high after increasing in the second half of 2017 as demand was strong and supplies from China were constrained.

Consumption of caustic-calcined magnesia continued to increase for animal feed supplements and fertilizer as the importance of magnesium as a nutrient gained recognition. Environmental applications, such as wastewater treatment, also accounted for increasing consumption of magnesium compounds, including caustic-calcined magnesia and magnesium hydroxide.

Prepared by **E. Lee Bray [(703) 648–4979, lbray@usgs.gov]**

MAGNESIUM COMPOUNDS

Because China was the leading producing country for magnesite and magnesia, policy changes in China affected prices and availability of all grades of magnesia in the world market. Prices for all types of magnesia surged during 2017 and prices generally remained at these higher levels in 2018. Magnesia plant shutdowns in 2017 and 2018, ordered by the Government of China for environmental concerns, resulted in limited supplies and price increases. The Government of China also restricted the use of explosives and certain equipment in magnesite mines in some areas, resulting in shortages of raw material for some magnesia producers. The prices for high-grade dead-burned magnesia (97.5% MgO) produced in China increased as demand was strong, but supplies were limited. Prices in China for lower grade dead-burned magnesia (94%–95% MgO) declined as demand for lower grade material decreased. Prices for caustic-calcined magnesia from China remained stable but were generally higher than those in other countries, and many consumers switched to suppliers from other countries. Environmental concerns in China were expected to continue to affect production and prices. In the main magnesia-producing regions of China, Provincial government-owned companies previously announced plans to consolidate small producers; however, the consolidation was not completed as of mid-2018.

Magnesia exports from North Korea to China and other countries were restricted in 2017. Exports to China resumed in 2018 but not to other countries, accounting for a significant decline of magnesite production in North Korea in 2018 compared with that of 2017. A fused magnesia producer in Norway, which had shut down production in August 2016 citing low prices, restarted production in December 2017 and ramped up production in the first half of the year.

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

	Mine production		Reserves[7]
	2017	2018[e]	
United States	W	W	35,000
Australia	470	500	[8]320,000
Austria	600	600	50,000
Brazil	1,800	1,900	390,000
China	19,000	19,000	1,000,000
Greece	400	400	280,000
India	188	200	82,000
Korea, North	380	270	2,300,000
Russia	1,500	1,500	2,300,000
Slovakia	450	470	120,000
Spain	300	330	35,000
Turkey	3,300	3,400	230,000
Other countries	700	830	1,400,000
World total (rounded)	[9]29,100	[9]29,000	8,500,000

World Resources: 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 12 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 believed to be very large.

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

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]See also Magnesium Metal.
[2]Previously reported as magnesium content. Based on input from consumers, producers, and others involved in the industry, it was determined that reporting magnesium compound data in terms of contained magnesia was more useful than reporting in terms of magnesium content. Conversion factors used: magnesite, 47.8% MgO; magnesium chloride, 42.3% MgO; magnesium hydroxide, 69.1% MgO; and magnesium sulfate, 33.5% MgO.
[3]Defined as shipments + imports – exports.
[4]Defined as imports – exports.
[5]Tariffs are based on gross weight.
[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 reserves were about 38 million tons.
[9]Excludes U.S. production.

MAGNESIUM METAL[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2018, primary magnesium was produced by one company in Utah at an electrolytic process plant that recovered magnesium from brines from the Great Salt Lake. Secondary magnesium was recovered from scrap at plants that produced magnesium ingot and castings, and from aluminum alloy scrap at secondary aluminum smelters. Primary magnesium production in 2018 was estimated to have been unchanged from that of 2017. Information regarding U.S. primary magnesium production was withheld to avoid disclosing company proprietary data. The leading use for primary magnesium metal, which accounted for 45% of reported consumption, was in castings, principally used for the automotive industry. Aluminum-base alloys that were used for packaging, transportation, and other applications accounted for 25% of primary magnesium metal consumption; desulfurization of iron and steel, 11%; reduction agent for metals production, 10%; and other uses, 9%. About 35% of the secondary magnesium was consumed for structural uses and about 65% was used in aluminum alloys.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Primary	W	W	W	W	W
Secondary (new and old scrap)	81	88	102	114	100
Imports for consumption	52	49	46	42	49
Exports	17	15	19	14	12
Consumption:					
Reported, primary	64	64	69	65	70
Apparent[2]	W	W	W	W	W
Price, yearend:					
U.S. spot Western, dollars per pound, average	2.15	2.15	2.15	2.15	2.15
China, free on board, dollars per metric ton, average	2,325	1,825	2,390	2,350	2,530
Stocks, producer, yearend	W	W	W	W	W
Employment, number[e]	420	420	420	400	400
Net import reliance[3] as a percentage of apparent consumption	<50	<50	<25	<25	<25

Recycling: In 2018, about 30,000 tons of secondary magnesium was recovered from old scrap and 70,000 tons were recovered from new scrap. Aluminum-base alloys accounted for 64% of the secondary magnesium recovered, and magnesium-based castings, ingot, and other materials accounted for about 36%.

Import Sources (2014–17): Israel, 27%; Canada, 22%; United Kingdom, 10%; Mexico, 9%; and other, 32%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Unwrought metal	8104.11.0000	8.0% ad val.
Unwrought alloys	8104.19.0000	6.5% ad val.
Scrap	8104.20.0000	Free.
Powders and granules	8104.30.0000	4.4% ad val.
Wrought metal	8104.90.0000	14.8¢/kg on Mg content + 3.5% ad val.

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

Government Stockpile: None.

Events, Trends, and Issues: The sole U.S. producer of primary magnesium temporarily shut down some capacity at the end of 2016 citing the shutdown of a titanium sponge plant that had been a major customer, and this capacity was not expected to restart in the foreseeable future. An explosion and fire occurred in the scrap melting area of a magnesium diecasting plant in Michigan in May. Production was temporarily shut down for several months during the year while repairs were made to the facility.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including magnesium metal. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

Prepared by **E. Lee Bray [(703) 648–4979, lbray@usgs.gov]**

MAGNESIUM METAL

In China, a new 100,000-ton-per-year plant in Qinghai Province that was completed in 2017 started producing magnesium from lake brines and was expected to ramp up to full capacity in 2019. Estimated production in China in 2018 decreased by approximately 15% compared with that in 2017, owing to shutdowns in the second half of the year ordered by regulators in an effort to decrease pollution and conserve energy. Some plants producing magnesium using the Pidgeon (silicothermic reduction) process were shut down, owing to energy cost increases and to comply with environmental regulations ordered by the Government of China and more are expected to shut down in 2019.

Producers in China dominate global magnesium metal production, but several projects were under development to increase primary magnesium metal capacity elsewhere. One company conducted laboratory testing to recover magnesium from its dolomite deposit in Nevada and was planning to conduct a feasibility study for a proposed plant. A company in Quebec, Canada, produced a limited amount of magnesium from serpentine contained in asbestos tailings at its 200-ton-per-year pilot plant and was planning to construct a 50,000-ton-per-year plant. Another company was testing its process for producing magnesium from serpentine-bearing asbestos tailings in the same region of Quebec. A company in Australia was conducting a feasibility study for a 5,000-ton-per-year plant to recover magnesium from coal fly ash.

The use of magnesium in automobile parts continued to increase as automobile manufacturers sought to decrease vehicle weight in order to comply with fuel-efficiency standards. Magnesium castings have substituted for aluminum, iron, and steel in some automobiles. The substitution of aluminum for steel in automobile sheet was expected to increase consumption of magnesium in aluminum alloy sheet. Although some magnesium sheet applications have been developed for automobiles, these were generally limited to expensive sports cars and luxury vehicles, automobiles where the higher price of magnesium is not a deterrent to its use.

World Primary Production and Reserves:

	Primary production	
	2017	**2018[e]**
United States	W	W
Brazil	15	15
Canada	(5)	(5)
China	930	800
Iran	3	5
Israel	23	25
Kazakhstan	9	23
Korea, Republic of	10	10
Russia	40	65
Turkey	14	10
Ukraine	8	19
World total (rounded)	[6]1,050	[6]970

Reserves[4]

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

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

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]See also Magnesium Compounds.
[2]Defined as primary production + secondary production from old scrap + imports – exports + adjustments for industry stock changes.
[3]Defined as imports – exports + adjustments for industry stock changes.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]Less than ½ unit.
[6]Excludes U.S. production.

MANGANESE

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

Domestic Production and Use: Manganese ore containing 20% or more manganese has not been produced domestically since 1970. Manganese ore was consumed mainly by eight firms with plants principally in the East and Midwest. Most ore consumption was related to steel production, either directly in pig iron manufacture or indirectly through upgrading the ore to ferroalloys. Additional quantities of ore were used for such nonmetallurgical purposes as production of dry cell batteries, in fertilizers and animal feed, and as a brick colorant. Manganese ferroalloys were produced at two plants. Construction, transportation, and machinery end uses accounted for about 34%, 12%, and 11%, respectively, of manganese consumption on a manganese-content basis. Most of the rest went to a variety of other iron and steel applications. In 2018, the value of domestic consumption, estimated from foreign trade data on a manganese-content basis, was about $1.3 billion.

Salient Statistics—United States:[1]	2014	2015	2016	2017	2018[e]
Production, mine	—	—	—	—	—
Imports for consumption:					
Manganese ore	387	441	282	297	430
Ferromanganese	365	292	229	331	460
Silicomanganese[2]	448	301	264	351	420
Exports:					
Manganese ore	1	1	1	1	4
Ferromanganese	6	5	7	9	9
Silicomanganese	3	1	2	8	4
Shipments from Government stockpile:[3]					
Manganese ore	—	—	—	—	—
Ferromanganese	19	32	42	12	9
Consumption, reported:					
Manganese ore[4]	508	451	410	378	390
Ferromanganese	360	344	342	345	360
Silicomanganese	146	138	139	141	150
Consumption, apparent, manganese[5]	835	693	545	715	860
Price, average, 46% to 48% Mn metallurgical ore, dollars per metric ton unit, contained Mn:					
Cost, insurance, and freight (c.i.f.), U.S. ports[e]	4.49	3.53	3.41	6.19	9.60
China spot market (c.i.f.)	4.72	3.22	4.48	[6]5.62	[7]7.16
Stocks, producer and consumer, yearend:[4]					
Manganese ore	189	187	207	148	180
Ferromanganese	23	21	21	17	18
Silicomanganese	10	21	10	11	11
Net import reliance[8] as a percentage of apparent consumption	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 (2014–17): Manganese ore: Gabon, 74%; South Africa, 13%; Australia, 8%; Mexico, 4%; and other, 1%. Ferromanganese: South Africa, 41%; Australia, 18%; Norway, 14%; Republic of Korea, 12%; and other, 15%. Silicomanganese: Georgia, 29%; South Africa, 26%; Australia, 18%; Mexico, 9%; and other, 18%. Manganese contained in principal manganese imports:[9] South Africa, 27%; Gabon, 21%; Australia, 14%; Georgia, 11%; and other, 27%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Ores and concentrates	2602.00.0040/60	Free.
Manganese dioxide	2820.10.0000	4.7% ad val.
High-carbon ferromanganese	7202.11.5000	1.5% ad val.
Ferrosilicon manganese (silicomanganese)	7202.30.0000	3.9% ad val.
Metal, unwrought	8111.00.4700/4900	14% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Prepared by **Lisa A. Corathers [(703) 648–4973, lcorathers@usgs.gov]**

MANGANESE

Government Stockpile:[10]

Material	Inventory As of 9–30–18	FY2018 Potential Acquisitions	FY2018 Potential Disposals[11]	FY 2019 Potential Acquisitions	FY 2019 Potential Disposals[11]
Manganese ore, metallurgical grade	292	—	292	—	292
Ferromanganese, high-carbon	203	—	45	—	45
Manganese metal, electrolytic	—	3	—	3	—

Events, Trends, and Issues: U.S. manganese apparent consumption was estimated to increase by 20% to 860,000 tons in 2018 compared with that in 2017. This was primarily a result of increases in U.S. ferromanganese and silicomanganese imports in response to the 6% increase in domestic steel production. In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including manganese. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

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

	Mine production 2017	Mine production 2018[e]	Reserves[12]
United States	—	—	—
Australia	2,820	3,100	[13]99,000
Brazil	1,160	1,200	110,000
China	1,700	1,800	54,000
Gabon	2,190	2,300	65,000
Ghana	810	850	13,000
India	734	770	33,000
Kazakhstan, concentrate	168	170	5,000
Malaysia	478	510	NA
Mexico	212	220	5,000
South Africa	5,400	5,500	230,000
Ukraine, concentrate	735	740	140,000
Other countries	898	940	Small
World total (rounded)	17,300	18,000	760,000

World Resources: Land-based manganese resources are large but irregularly distributed; those in the United States are very low grade and have potentially high extraction costs. South Africa accounts for about 74% of the world’s identified manganese resources, and Ukraine accounts for about 10%.

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]Imports more nearly represent amount consumed than does reported consumption.
[3]Defined as stockpile shipments – receipts, thousand tons, manganese content. If receipts, a negative quantity is shown.
[4]Exclusive of ore consumed directly at iron and steel plants and associated yearend stocks.
[5]Defined as imports – exports + adjustments for Government and industry stock changes, thousand tons, manganese content. To avoid double counting, manganese consumption is not calculated as the sum of manganese ore, ferromanganese, and silicomanganese consumption because manganese in ore is used to produce ferromanganese and silicomanganese.
[6]For average metallurgical-grade ore containing 44% manganese, as reported by CRU Group.
[7]Average weekly price through October 2018 for average metallurgical-grade ore containing 44% manganese, as reported by CRU Group.
[8]Defined as imports – exports + adjustments for Government and industry stock changes, thousand tons, manganese content.
[9]Includes imports of ferromanganese, manganese ore, silicomanganese, synthetic manganese dioxide, and unwrought manganese metal.
[10]See Appendix B for definitions.
[11]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[12]See Appendix C for resource and reserve definitions and information concerning data sources.
[13]For Australia, Joint Ore Reserves Committee-compliant reserves were about 46 million tons of manganese content.

MERCURY

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

Domestic Production and Use: Mercury has not been produced as a principal mineral commodity in the United States since 1992. In 2018, 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. It was estimated that less than 40 tons per year of mercury was consumed domestically. The leading domestic end users of mercury were the chlorine-caustic soda (chloralkali), dental, electronics, and fluorescent-lighting manufacturing industries. Only two mercury cell chloralkali plants operated in the United States in 2018. 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 additional mercury compounds will be banned. The U.S. Environmental Protection Agency (EPA) issued the final rule for mercury reporting requirements for the Toxic Substances Control Act. The requirements applied to anyone who manufactured (including imports) mercury or mercury-added products, or otherwise intentionally used mercury in a manufacturing process. The EPA plans to use the reported information to prepare an inventory of mercury supply, trade, and use in the United States.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Mine (byproduct)	NA	NA	NA	NA	NA
Secondary	NA	NA	NA	NA	NA
Imports for consumption (gross weight), metal	49	26	24	20	10
Exports (gross weight), metal	—	([1])	—	—	—
Price, average value, dollars per flask 99.99%, European Union[2, 3]	3,037	1,954	1,402	1,041	[4]2,800
Net import reliance[5] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: In 2018, eight facilities operated by six companies in the United States accounted for the majority of secondary mercury produced and were authorized by the U.S Department of Energy to temporarily store mercury. Mercury-containing automobile convenience switches, barometers, compact and traditional fluorescent bulbs, computers, dental amalgam, medical devices, and thermostats were collected by smaller companies and shipped to the refining companies for retorting to reclaim the mercury. In addition, many collection companies recovered mercury when retorting was not required. With the rapid phasing out of compact and traditional fluorescent lighting for light-emitting-diode (LED) lighting, there has been an increased amount of mercury being recycled.

Import Sources (2014–17): Germany, 35%; Canada, 29%; France, 20%; Switzerland, 8%; and other, 8%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Mercury	2805.40.0000	1.7% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[6] An inventory of 4,437 tons of mercury was held in storage at the Hawthorne Army Depot, in Hawthorne, NV. The Mercury Export Ban Act of 2008 required the U.S. Department of Energy to establish long-term management and storage capabilities for domestically produced elemental mercury. Sales of mercury from the stockpiles remained suspended.

		FY2018		FY 2019	
Material	Inventory As of 9–30–18	Potential Acquisitions	Potential Disposals[7]	Potential Acquisitions	Potential Disposals[7]
Mercury	4,437	—	—	—	—

Prepared by **Micheal W. George [(703) 648–4962, mgeorge@usgs.gov]**

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. Mercury continues to be released to the environment from numerous sources, including mercury-containing car switches when automobiles are scrapped without recovering them for recycling, coal-fired powerplant emissions, incineration of mercury-containing medical devices, and from naturally occurring sources. Mercury is no longer used in most batteries and paints manufactured in the United States. Some button-type batteries, cleansers, fireworks, folk medicines, grandfather clocks, pesticides, and skin-lightening creams and soaps may still contain mercury. Mercury compounds were used as catalysts in the coal-based manufacture of vinyl chloride monomer in China. In some parts of the world, mercury was used in the recovery of gold in 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, storage. Because of global export restrictions and decreasing domestic consumption, domestic imports of mercury have continued to decline, and in the first 7 months of 2018, China was the only country from which the United States imported mercury.

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 nonmercury-containing products in control, dental, and measuring applications.

World Mine Production and Reserves:

	Mine production		Reserves[8]
	2017	2018[e]	
United States	NA	NA	Quantitative estimates of reserves are not available. China, Kyrgyzstan, and Peru are thought to have the largest reserves.
Argentina	25	30	
China	3,380	3,000	
Kyrgyzstan	20	20	
Mexico (net exports)	197	200	
Norway	20	20	
Peru (exports)	40	40	
Tajikistan	100	100	
Other countries	12	10	
World total (rounded)	3,790	3,400	

World Resources: 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, there are mercury occurrences in Alaska, Arkansas, California, Nevada, and Texas; however, mercury has not been mined as a principal mineral commodity since 1992. 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. "Galistan," 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 have been substituted for mercury fungicides in latex paint.

[e]Estimated. NA Not available. — Zero.
[1]Less than ½ unit.
[2]Some international data and dealer prices are reported in flasks. One metric ton (1,000 kilograms) = 29.0082 flasks, and 1 flask = 76 pounds, or 34.47 kilograms, or 0.03447 ton.
[3]For 2014–17, average annual price of minimum 99.99% mercury published by Argus Media group–Argus Metals International.
[4]Estimated 2018 price based on free market mercury in warehouse price published by Metal Bulletin.
[5]Defined as imports – exports + adjustments for Government stock changes.
[6]See Appendix B for definitions.
[7]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.

MICA (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Scrap and flake mica production, excluding low-quality sericite, was estimated to be 44,000 tons valued at $5.3million. 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 feldspar, industrial sand beneficiation, and kaolin. Eight companies produced an estimated 65,000 tons of ground mica valued at about $23 million from domestic and imported scrap and flake mica. The majority of 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 was produced as incidental production from feldspar mining in North Carolina. Data was withheld to avoid disclosing company proprietary data. 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:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Scrap and flake:					
Production:[1]					
Sold and used	48,200	32,600	28,000	40,000	44,000
Ground	81,600	65,800	59,500	69,700	65,000
Imports[2]	33,400	33,200	31,500	29,700	21,000
Exports[3]	8,080	7,440	6,340	6,790	4,800
Consumption, apparent[4]	73,500	58,300	53,200	62,900	60,000
Price, average, dollars per metric ton, reported:					
Scrap and flake	117	142	152	165	120
Ground:					
Dry	278	304	326	289	330
Wet	458	423	435	424	450
Employment, mine, number	NA	NA	NA	NA	NA
Net import reliance[5] as a percentage of apparent consumption	34	44	47	36	26
Sheet:					
Sold and used	([6])	W	W	W	W
Imports[7]	2,470	2,130	2,060	1,850	1,200
Exports[8]	868	911	689	704	530
Consumption, apparent[4]	1,600	1,210	1,370	1,150	680
Price, average value, dollars per kilogram, muscovite and phlogopite mica, reported:					
Block	278	W	W	W	W
Splittings	1.70	1.61	1.61	1.66	1.70
Stocks, fabricator and trader, yearend	NA	NA	NA	NA	NA
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2014–17): Scrap and flake: Canada, 45%; China, 31%; India, 11%; Japan, 4%; and other, 9%. Sheet: China, 44%; Brazil, 24%; Belgium, 9%; Austria, 5%; and other, 18%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
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 reconstructed mica	6814.10.0000	2.7% ad val.
Worked mica and articles of mica, other	6814.90.0000	2.6% ad val.

Prepared by **Kenneth C. Curry [(703) 648–7793, kcurry@usgs.gov]**

MICA (NATURAL)

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic production of scrap and flake mica was estimated to have increased by 10% in 2018. Apparent consumption of scrap and flake mica decreased slightly because of a decrease in imports. Apparent consumption of sheet mica was estimated to have decreased by 41% in 2018 as a result of decreased imports of sheet mica from China and Brazil. No environmental concerns are associated with the manufacture and use of mica products. Future supplies of sheet mica for United States consumption were expected to come increasingly from imports, primarily from Austria, Belgium, Brazil, China, and India.

World Mine Production and Reserves: Estimates of production of scrap and flake mica in China were revised significantly upward based on new information from a Government source. China is the leading global producer of natural mica, accounting for 24% of estimated worldwide production. World production of sheet mica is shown to have remained steady; however, reliable production numbers for some countries that may influence that world total were unavailable.

	Scrap and flake			Sheet		
	Mine production		Reserves[9]	Mine production[e]		Reserves[9]
	2017	2018[e]		2017	2018	
United States	40,000	44,000	Large	W	W	Very small
Canada	24,000	22,000	Large	NA	NA	NA
China	100,000	80,000	Large	NA	NA	NA
Finland	57,900	55,000	Large	NA	NA	NA
France	21,000	21,000	Large	NA	NA	NA
India	14,000	19,000	Large	1,000	1,000	110,000
Korea, Republic of	14,600	15,000	12,000,000	—	—	NA
Madagascar	23,000	23,000	Large	—	—	NA
Turkey	12,000	12,000	620,000	—	—	NA
Other countries	50,000	50,000	Large	200	200	Moderate
World total (rounded)	360,000	340,000	Large	[10]1,200	[10]1,200	Very large

World Resources: 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 are uneconomic 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 thermal and electrical properties of mica. Many materials can be substituted for mica in numerous electrical, electronic, and insulation uses. Substitutes include acrylic, cellulose acetate, fiberglass, fishpaper, nylatron, nylon, phenolics, polycarbonate, polyester, styrene, polyvinyl chloride, and vulcanized fiber. Mica paper made from scrap mica can be substituted for sheet mica in electrical and insulation applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Excludes low-quality sericite used primarily for brick manufacturing.
[2]Includes Harmonized Tariff Schedule of the United States codes: 2525.10.0050, <$1.00/kg; 2525.20.0000; and 2525.30.0000.
[3]Includes Schedule B numbers: 2525.10.0000, <$1.00/kg; 2525.20.0000; and 2525.30.0000.
[4]Defined as sold or used by producing companies + imports – exports.
[5]Defined as imports – exports.
[6]Less than ½ unit.
[7]Includes Harmonized Tariff Schedule of the United States codes: 2525.10.0010; 2525.10.0020; 2525.10.0050, >$1.00/kg; 6814.10.0000; and 6814.90.0000.
[8]Includes Schedule B numbers: 2525.10.0000, >$1.00/kg; 6814.10.0000; and 6814.90.0000.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.
[10]Excludes U.S. production.

MOLYBDENUM

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

Domestic Production and Use: U.S. mine production of molybdenum in 2018 increased by 3% to 42,000 tons compared with the previous year. Molybdenum ore was produced as a primary product at two mines—both in Colorado—whereas seven copper mines (four in Arizona and one each in Montana, Nevada, and Utah) recovered molybdenum as a byproduct. Three roasting plants converted molybdenite concentrate to molybdic oxide, from which intermediate products, such as ferromolybdenum, metal powder, and various chemicals, were produced. Metallurgical applications accounted for about 88% of the total molybdenum consumed.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, mine	68,200	47,400	36,200	40,700	42,000
Imports for consumption	25,300	17,500	22,800	36,000	37,000
Exports	65,200	41,500	31,200	43,200	45,000
Consumption:					
Reported[1]	19,500	17,600	15,800	17,300	16,000
Apparent[2]	28,000	23,800	27,400	33,300	34,000
Price, average value, dollars per kilogram[3]	25.84	15.10	14.40	18.06	27
Stocks, consumer materials	2,010	1,880	1,910	2,010	2,050
Employment, mine and plant, number	1,000	950	920	940	940
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

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

Import Sources (2014–17): Ferromolybdenum: Chile, 58%; Republic of Korea, 25%; Canada, 10%; and other, 7%. Molybdenum ores and concentrates: Peru, 44%; Chile, 28%; Canada, 16%; Mexico, 10%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Molybdenum ore and concentrates, roasted	2613.10.0000	12.8¢/kg + 1.8% ad val.
Molybdenum ore and concentrates, other	2613.90.0000	17.8¢/kg.
Molybdenum chemicals:		
Molybdenum oxides and hydroxides	2825.70.0000	3.2% ad val.
Molybdates of ammonium	2841.70.1000	4.3% ad val.
Molybdates, all others	2841.70.5000	3.7% ad val.
Molybdenum pigments, molybdenum orange	3206.20.0020	3.7% ad val.
Ferroalloys, ferromolybdenum	7202.70.0000	4.5% ad val.
Molybdenum metals:		
Powders	8102.10.0000	9.1¢/kg + 1.2% ad val.
Unwrought	8102.94.0000	13.9¢/kg + 1.9% ad val.
Wrought bars and rods	8102.95.3000	6.6% ad val.
Wrought plates, sheets, strips, etc.	8102.95.6000	6.6% ad val.
Wire	8102.96.0000	4.4% ad val.
Waste and scrap	8102.97.0000	Free.
Other	8102.99.0000	3.7% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Prepared by **Désirée E. Polyak [(703) 648–4909, dpolyak@usgs.gov]**

MOLYBDENUM

Events, Trends, and Issues: In 2018, the average molybdic oxide price was 50% higher than that of 2017, and U.S. estimated mine output of molybdenum increased by 3% from that of 2017. The increase in production was seen at both primary and byproduct mines. Primary molybdenum production continued at the Climax Mine in Lake County and Summit County, CO, and at the Henderson Mine in Clear Creek County, CO. The Thompson Creek Mine in Custer County, ID, continued to be on care-and-maintenance status in 2018. Byproduct molybdenum production continued at the Bagdad, Morenci, Pinto Valley, and Sierrita Mines in Arizona; the Continental Pit Mine in Montana; the Robinson Mine in Nevada; and the Bingham Canyon Mine in Utah.

U.S. imports for consumption slightly increased from those of 2017. Ferromolybdenum imports increased by 57% in 2018, and imports of roasted molybdenum ores and concentrates decreased by 27% in 2018. Total U.S. exports increased by 4% from those of 2017. Apparent consumption increased slightly from that of 2017.

Global molybdenum production in 2018 increased slightly compared with 2017. In descending order of production, China, Chile, the United States, Peru, and Mexico provided approximately 93% of total global production.

World Mine Production and Reserves: The reserves estimate for Canada was revised based on new information from the Mining Association of Canada. The reserves estimate for Peru was revised based on new information from the Ministry of Energy and Mines of Peru. The reserves estimates for Chile, Mongolia, and Turkey were revised based on company and Government reports.

	Mine production		Reserves[5]
	2017	2018[e]	(thousand metric tons)
United States	40,700	42,000	2,700
Argentina	450	450	100
Armenia	5,800	5,000	150
Canada	5,290	5,100	100
Chile	62,500	61,000	1,400
China[e]	130,000	130,000	8,300
Iran	3,500	3,500	43
Mexico	14,000	15,000	130
Mongolia	1,800	1,800	210
Peru	28,100	28,000	2,400
Russia[e]	3,100	3,100	1,000
Turkey	900	900	700
Uzbekistan[e]	450	450	60
World total (rounded)	297,000	300,000	17,000

World Resources: 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.
[1]Reported consumption of primary molybdenum products.
[2]Defined as production + imports – exports + adjustments for stock changes
[3]Time-weighted average price per kilogram of molybdenum contained in technical-grade molybdic oxide, as reported by CRU Group.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.

NICKEL

(Data in metric tons of nickel content unless otherwise noted)

Domestic Production and Use: In 2018, the underground Eagle Mine in Michigan produced approximately 19,000 tons of nickel in concentrate, which was exported to smelters in Canada and overseas. The mine continued development of the Eagle East extension, with first production expected in 2020. In November, the Minnesota Department of Natural Resources announced that it had issued permits for a mining project in the northeastern part of the State. Nickel in crystalline sulfate was produced as a byproduct of smelting and refining platinum-group-metal ores mined in Montana.

Approximately 47% of the primary nickel consumed went into stainless and alloy steel products, 41% into nonferrous alloys and superalloys, 7% into electroplating, and 5% into other uses. The U.S. steel industry produced approximately 2.4 million tons of nickel-bearing stainless steel in 2018, an estimated 20% more than in 2017. Sales of nickel-base superalloys for use in jet engines also continued to increase.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Mine	4,300	27,200	24,100	22,100	19,000
Refinery, byproduct	W	W	W	W	W
Shipments of purchased scrap[1]	132,000	132,000	151,000	135,000	140,000
Imports:					
Ores and concentrates	92	24	([2])	64	5
Primary	156,000	130,000	111,000	150,000	150,000
Secondary	39,000	27,100	32,300	38,100	50,000
Exports:					
Ores and concentrates	3,320	25,400	22,400	20,000	19,000
Primary	10,400	9,610	10,300	11,000	10,000
Secondary	56,300	51,900	63,700	51,500	80,000
Consumption:					
Reported, primary metal	113,000	105,000	96,000	101,000	110,000
Reported, secondary	115,000	108,000	120,000	122,000	130,000
Apparent, primary metal[3]	149,000	118,000	104,000	140,000	140,000
Apparent, total[4]	264,000	226,000	224,000	262,000	270,000
Price, average annual, London Metal Exchange (LME):					
Cash, dollars per metric ton	16,865	11,831	9,594	10,403	14,000
Cash, dollars per pound	7.650	5.367	4.352	4.719	6.200
Stocks:					
Consumer, yearend	23,300	19,200	15,100	14,700	15,000
LME U.S. warehouses	1,560	4,212	5,232	3,780	2,400
Net import reliance[5] as a percentage of total apparent consumption	56	52	46	53	52

Recycling: Nickel in alloyed form was recovered from the processing of nickel-containing waste, including flue dust, grinding swarf, mill scale, and shot blast generated during the manufacturing of stainless steel; filter cakes, plating solutions, spent catalysts, spent pickle liquor, sludges, and all types of spent nickel-containing batteries. Nickel-containing alloys and stainless steel scrap were also melted and used to produce new alloys and stainless steel. In 2018, recycled nickel in all forms accounted for approximately 52% of apparent consumption.

Import Sources (2014–17): Nickel contained in ferronickel, metal, oxides, and salt: Canada, 41%; Norway, 11%; Australia, 8%; Russia, 8%; and other, 32%. Nickel-containing scrap, including nickel content of stainless steel scrap: Canada, 40%; Mexico, 28%; United Kingdom, 8%; and other, 24%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Nickel ores and concentrates	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.
Unwrought nickel, powders and flakes	7504.00.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Prepared by **Michele E. McRae [(703) 648–7743, mmcrae@usgs.gov]**

NICKEL

Government Stockpile:[6] The U.S. Department of Energy is holding nickel ingot contaminated by low-level radioactivity at Paducah, KY, and shredded nickel scrap at Oak Ridge, TN. Ongoing decommissioning activities at former nuclear defense sites were expected to generate additional nickel in scrap. See the Lithium chapter for statistics on lithium-nickel-cobalt-aluminum oxide.

Material	Inventory As of 9–30–18	FY2018 Potential Acquisitions	FY2018 Potential Disposals[7]	FY 2019 Potential Acquisitions	FY 2019 Potential Disposals[7]
Nickel alloys, gross weight	307	—	68	—	68

Events, Trends, and Issues: In recent years, production of refined nickel decreased as stainless steel producers, primarily in Asia, preferred lower cost nickel pig iron. Mine production in countries that supply direct shipping ore to nickel pig iron operations increased, while mine production supplying refineries tended to decrease. Production of nickel chemicals, however, has increased, particularly nickel sulfate used in the production of batteries. Industry analysts project a significant increase in global nickel consumption in batteries for energy storage and electric vehicles.

World Mine Production and Reserves: Reserves for Brazil, China, Colombia, Indonesia, and the United States were revised based on new information from company or Government reports.

	Mine production 2017	Mine production 2018[e]	Reserves[8]
United States	22,100	19,000	110,000
Australia	179,000	170,000	[9]19,000,000
Brazil	78,600	80,000	11,000,000
Canada	214,000	160,000	2,700,000
China	103,000	110,000	2,800,000
Colombia	45,500	43,000	440,000
Cuba	52,800	53,000	5,500,000
Finland	34,600	46,000	NA
Guatemala	53,700	49,000	1,800,000
Indonesia	345,000	560,000	21,000,000
Madagascar	41,700	39,000	1,600,000
New Caledonia[10]	215,000	210,000	—
Philippines	366,000	340,000	4,800,000
Russia	214,000	210,000	7,600,000
South Africa	48,400	44,000	3,700,000
Other countries	146,000	180,000	6,500,000
World total (rounded)	2,160,000	2,300,000	89,000,000

World Resources: Identified land-based resources averaging 1% nickel or greater contain at least 130 million tons of nickel, with about 60% in laterites and 40% in sulfide deposits. Extensive nickel resources also are found in manganese crusts and nodules on the ocean floor. The decline in discovery of new sulfide deposits in traditional mining districts has led to exploration in more challenging locations such as east-central Africa and the subarctic.

Substitutes: Low-nickel, duplex, or ultrahigh-chromium stainless steels are being 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. Lithium-ion batteries may be used instead of nickel metal hydride batteries in certain applications.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Scrap receipts – shipments by consumers + exports – imports + adjustments for consumer stock changes.
[2]Less than ½ unit.
[3]Defined as primary imports – primary exports + adjustments for industry stock changes, excluding secondary consumer stocks.
[4]Defined as apparent primary metal consumption + reported secondary consumption.
[5]Defined as imports – exports + adjustments for consumer stock changes.
[6]See Appendix B for definitions.
[7]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]For Australia, Joint Ore Reserves Committee-compliant reserves were about 6.0 million tons.
[10]Overseas territory of France. Although nickel-cobalt mining and processing continued, the leading producing company reported zero reserves owing to recent nickel prices.

NIOBIUM (COLUMBIUM)

(Data in metric tons of niobium content unless otherwise noted)

Domestic Production and Use: Significant U.S. niobium mine production has not been reported since 1959. Domestic niobium resources are of low grade, some are mineralogically complex, and most are not commercially recoverable. Companies in the United States produced niobium-containing materials from imported niobium minerals, 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 reported niobium consumption was as follows: steels, about 75%, and superalloys, about 25%. In 2018, the estimated value of niobium consumption was $310 million, as measured by the value of imports.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, mine	—	—	—	—	—
Imports for consumption[1]	11,100	8,520	8,250	9,370	11,000
Exports[1]	1,110	1,430	1,480	1,490	1,000
Shipments from Government stockpile	—	—	—	—	—
Consumption:[e]					
Apparent[2]	10,000	7,080	6,730	7,820	10,000
Reported[3]	8,210	7,510	7,370	7,510	9,000
Unit value, ferroniobium, dollars per kilogram[4]	26	24	21	20	21
Net import reliance[2] 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 (2014–17): Niobium ore and concentrate: Brazil, 35%; Rwanda, 31%; Australia, 15%; Congo (Kinshasa), 8%; and other, 11%. Niobium oxide: Brazil, 44%; Russia, 30%; Thailand, 9%; Estonia, 7%; and other, 10%. Ferroniobium and niobium metal: Brazil, 76%; Canada, 21%; Germany, 2%; and other, 1%. Total imports: Brazil, 72%; Canada, 18%; Russia, 3%; Germany, 2%; and other, 5%. Of the U.S. niobium material imports, 99% (by gross weight) was ferroniobium, niobium metal, and niobium oxide.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Niobium ores and concentrates	2615.90.6030	Free.
Niobium oxide	2825.90.1500	3.7% ad val.
Ferroniobium:		
Less than 0.02% P or S, or less than 0.4% Si	7202.93.4000	5% ad val.
Other	7202.93.8000	5% ad val.
Niobium:		
Waste and scrap[5]	8112.92.0600	Free.
Powders and unwrought metal	8112.92.4000	4.9% ad val.
Niobium, other[5]	8112.99.9000	4% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[6]

		FY2018		FY 2019	
Material	Inventory As of 9–30–18	Potential Acquisitions	Potential Disposals[7]	Potential Acquisitions	Potential Disposals[7]
Ferroniobium (gross weight)	278	209	—	209	—
Niobium metal (gross weight)	10	—	—	—	—

Prepared by **Abraham J. Padilla [(703) 648–4965, apadilla@usgs.gov]**

NIOBIUM (COLUMBIUM)

Events, Trends, and Issues: Niobium principally was imported in the form of ferroniobium. Based on data through July 2018, U.S. niobium apparent consumption (measured in contained niobium) was estimated to be 10,000 metric tons, 27% more than that of 2017. Brazil continued to be the world's leading niobium producer with 88% of global production, followed by Canada with 10%.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including niobium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ''A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" (82 FR 60835).

One domestic company continued to make progress developing its Elk Creek project in Nebraska by securing all major Federal permits and completing a proposed engineering design for its underground mine. The project would be the only niobium mine and primary niobium processing facility in the United States. It was expected to begin production after 2019.

In July 2018, a company from Japan acquired all shares of the niobium-tantalum business of a company from Germany. The business was headquartered in Munich, Germany, and included niobium processing and manufacturing facilities in Baden-Wurttemberg and Lower Saxony States, Germany, as well as Ibaraki Prefecture, Japan, and Rayong Province, Thailand.

World Mine Production and Reserves: The reserves data for the United States, Brazil, and Canada were revised based on information reported by niobium-producing companies and the Governments of those countries.

	Mine production		Reserves[8]
	2017	2018[e]	
United States	—	—	180,000
Brazil	60,700	60,000	7,300,000
Canada	6,980	7,000	1,600,000
Other countries	1,410	1,000	NA
World total (rounded)	69,100	68,000	>9,100,000

World Resources: 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. The United States has approximately 868,000 tons of niobium in identified resources, most of which were considered subeconomic at 2018 prices for niobium.

Substitutes: The following materials can be substituted for niobium, but a performance loss or higher cost may ensue: ceramic matrix composites, molybdenum, tantalum, and tungsten in high-temperature (superalloy) applications; molybdenum, tantalum, and titanium as alloying elements in stainless and high-strength steels; and molybdenum and vanadium as alloying elements in high-strength low-alloy steels.

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

[1]Imports and exports include the estimated niobium content of ferroniobium, niobium and tantalum ores and concentrates, niobium oxide, and niobium powders and unwrought metal.

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

[3]Only includes ferroniobium and nickel niobium.

[4]Unit value is weighted average unit value of gross weight of U.S. ferroniobium trade. (Trade is imports plus exports.)

[5]This category includes niobium-containing material and other material.

[6]See Appendix B for definitions.

[7]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.

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

NITROGEN (FIXED)—AMMONIA

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

Domestic Production and Use: Ammonia was produced by 15 companies at 34 plants in 16 States in the United States during 2018; 2 additional plants were idle for the entire year. About 50% of total U.S. ammonia production capacity was located in Louisiana, Oklahoma, and Texas because of their large reserves of natural gas, the dominant domestic feedstock for ammonia. In 2018, U.S. producers operated at about 75% of rated capacity. The United States was one of the world's leading producers and consumers of ammonia. Urea, ammonium nitrate, ammonium phosphates, nitric acid, and ammonium sulfate were, in descending order of importance, 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:	2014	2015	2016	2017	2018[e]
Production	[1]9,330	[1]9,590	[1]10,200	[1]11,600	12,500
Imports for consumption	4,150	4,320	3,840	3,090	2,600
Exports	111	93	183	612	430
Consumption, apparent[2]	13,300	13,700	13,800	14,100	14,600
Stocks, producer, yearend	280	420	400	320	400
Price, dollars per short ton, average, f.o.b. Gulf Coast[3]	531	481	267	247	280
Employment, plant, number[e]	1,200	1,200	1,300	1,500	1,600
Net import reliance[4] as a percentage of apparent consumption	30	30	26	18	14

Recycling: None.

Import Sources (2014–17): Trinidad and Tobago, 66%; Canada, 23%; Russia, 4%; Venezuela, 4%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Ammonia, anhydrous	2814.10.0000	Free.
Urea	3102.10.0000	Free.
Ammonium sulfate	3102.21.0000	Free.
Ammonium nitrate	3102.30.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: The Henry Hub spot natural gas price ranged between $2.48 and $6.88 per million British thermal units for most of the year, with an average of about $3.00 per million British thermal units. Natural gas prices in 2018 were relatively stable; slightly higher prices were a result of increased demand for natural gas owing to cold temperatures and associated increased demand for power generation. The U.S. Department of Energy, Energy Information Administration, projected that Henry Hub natural gas spot prices would average $3.12 per million British thermal units in 2019.

The weekly average Gulf Coast ammonia price was $290 per short ton at the beginning of 2018, decreased to $210 per short ton in early June, and then increased to $322 per short ton in October. The average ammonia price for 2018 was estimated to be $280 per short ton. Increased ammonia prices were a result of an improved urea market and rising production costs in Europe.

A long period of stable and low natural gas prices in the United States has made it economical for companies to upgrade existing ammonia plants and plan for the construction of new nitrogen projects. The additional capacity has reduced ammonia imports. In 2017, ammonia facilities in Iowa, Louisiana, and Texas became operational. In 2018, one new ammonia facility in Texas became operational. No other ammonia plants are expected to be commissioned before 2022. Two U.S. ammonia producers completed their merger in January 2018. The new company accounted for 18% of the U.S. ammonia production capacity.

Prepared by **Lori E. Apodaca [(703) 648–7724, lapodaca@usgs.gov]**

NITROGEN (FIXED)—AMMONIA

Global ammonia capacity is expected to increase by a total of 6% during the next 3 years. In addition to increases in North America, capacity additions are expected in Africa, Central Asia, Eastern Europe, and Southeast Asia. Increased demand for ammonia is expected in Latin America and South Asia as a result of regional nitrogen deficits.

Large corn plantings maintain the continued demand for nitrogen fertilizers. According to the U.S. Department of Agriculture, U.S. corn growers planted 36.1 million hectares of corn in the 2018 crop-year (July 1, 2017, through June 30, 2018), which was slightly less than the area planted in 2017. Corn acreage in the 2019 crop-year is expected to remain about the same in most States because of anticipated higher returns for corn compared with other crops.

World Ammonia Production and Reserves:

	Plant production		Reserves[5]
	2017	2018[e]	
United States	11,600	12,500	Available atmospheric nitrogen and sources of natural gas for production of ammonia are considered adequate for all listed countries.
Algeria	2,100	2,100	
Australia	1,300	1,300	
Belarus	1,050	1,100	
Brazil	1,000	1,000	
Canada	3,750	3,800	
China	43,600	44,000	
Egypt	2,800	2,800	
France	1,010	1,000	
Germany	2,500	2,500	
India	10,800	11,000	
Indonesia	5,000	6,000	
Iran	2,640	2,600	
Netherlands	2,300	2,300	
Oman	1,700	1,700	
Pakistan	3,300	3,300	
Poland	2,340	2,300	
Qatar	3,220	3,200	
Russia	14,000	14,000	
Saudi Arabia	3,820	4,000	
Trinidad and Tobago	4,140	4,100	
Uzbekistan	1,100	1,100	
Vietnam	1,100	1,100	
Other countries	15,400	15,000	
World total (rounded)	142,000	140,000	

World Resources: The availability of nitrogen from the atmosphere for fixed nitrogen production is unlimited. Mineralized occurrences of sodium and potassium nitrates, found in the Atacama Desert of Chile, contribute minimally to the global nitrogen supply.

Substitutes: Nitrogen is an essential plant nutrient that has no substitute. No practical substitutes for nitrogen explosives and blasting agents are known.

[e]Estimated.
[1]Source: The Fertilizer Institute; data adjusted by the U.S. Geological Survey.
[2]Defined as production + imports – exports + adjustments for industry stock changes.
[3]Source: Green Markets.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.

PEAT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The estimated free on board (f.o.b.) mine value of marketable peat production in the conterminous United States was $13 million in 2018. Peat was harvested and processed by about 31 companies in 12 conterminous States. Florida, Minnesota, and Michigan were the leading producing States, in order of quantity harvested. Reed-sedge peat accounted for approximately 85% of the total volume produced, followed by sphagnum moss with 13%. 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:	2014	2015	2016	2017	2018[e]
Production	468	455	441	498	500
Commercial sales	479	460	443	515	530
Imports for consumption	994	1,150	1,130	1,150	1,200
Exports	29	28	30	30	33
Consumption, apparent[1]	1,390	1,620	1,590	1,520	1,700
Price, average value, f.o.b. mine, dollars per ton	24.97	28.39	31.97	27.55	24.00
Stocks, producer, yearend	222	179	125	222	200
Employment, mine and plant, number[e]	550	550	550	540	540
Net import reliance[2] as a percentage of apparent consumption	66	72	72	67	70

Recycling: None.

Import Sources (2014–17): Canada, 95%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Peat	2703.00.0000	Free.

Depletion Allowance: 5% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Peat is an important component of plant-growing media, and the demand for peat generally follows that of horticultural applications. In the United States, the short-term outlook is for production to average about 500,000 tons per year and imported peat from Canada is expected to continue to account for more than 70% of domestic consumption.

Prepared by **Amanda S. Brioche [(703) 648–7747, abrioche@usgs.gov]**

PEAT

Based on estimated world production for 2018, the world's leading producers were, in descending order of production, Finland, Belarus, Germany, Ireland, and Sweden, with about 35%, 9%, 9%, 9%, and 8%, respectively. Belarus' 2018 peat production increased significantly when compared to the previous year's production, making it Europe's second leading producer. Ireland's peat production is expected to decrease over the coming years owing to the country's transition to alternative fuel sources.

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

	Mine production		Reserves[3]
	2017	2018[e]	
United States	498	500	150,000
Belarus	1,520	2,600	2,600,000
Canada	1,670	1,700	720,000
Estonia	588	600	60,000
Finland	9,970	9,900	6,000,000
Germany	3,300	2,500	([4])
Ireland	2,500	2,500	([4])
Latvia	1,740	1,700	150,000
Lithuania	418	400	210,000
Poland	900	900	([4])
Russia	960	960	1,000,000
Sweden	2,240	2,200	([4])
Ukraine	600	600	([4])
United Kingdom	700	700	([4])
Other countries[e]	540	540	1,400,000
World total (rounded)	28,100	28,000	12,000,000

World Resources: Peat is a renewable resource, continuing to accumulate on 60% of global peatlands. However, the volume of global peatlands has been decreasing at a rate of 0.05% annually owing to harvesting and land development. Many countries evaluate peat resources based on volume or area because the variations in densities and thickness of peat deposits make it difficult to estimate tonnage. Volume data have been converted using the average bulk density of peat produced in that country. Reserves data were estimated based on data from International Peat Society publications and the percentage of peat resources available for peat extraction. 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 noted)

Domestic Production and Use: In 2018, the quantity of domestic processed crude perlite sold and used was estimated to be 510,000 tons with a value of $37 million. Crude ore production was from seven mines operated by six companies in five Western States. New Mexico and Oregon continued to be the leading producing States. Processed crude perlite was expanded at 60 plants in 27 States. Domestic apparent consumption was 680,000 tons. The applications for expanded perlite were building construction products, 58%; fillers, 15%; horticultural aggregate, 12%; filter aid, 9%; and other, 6%. Other applications included specialty insulation and miscellaneous uses.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Mine production, crude ore	462	501	521	570	560
Sold and used, processed crude perlite	462	444	437	479	510
Imports for consumption[1]	144	143	188	156	200
Exports[1]	36	30	21	32	30
Consumption, apparent[2]	570	557	604	603	680
Price, average value, dollars per ton, f.o.b. mine	55	61	65	73	70
Employment, mine and mill, number	119	142	135	139	140
Net import reliance[3] as a percentage of apparent consumption	19	20	28	21	25

Recycling: Not available.

Import Sources (2014–17): Greece, 95%; Mexico, 2%; Turkey, 2%; and other, 1%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–18**
Vermiculite, perlite and chlorites, unexpanded	2530.10.0000	Free.

Depletion Allowance: 10% (Domestic and foreign).

Government Stockpile: None.

Prepared by **Shawnna M. Bennett [(703) 648–7715, smbennett@usgs.gov]**

PERLITE

Events, Trends, and Issues: Perlite is a siliceous volcanic glass that expands up to 20 times its original volume when rapidly heated. In horticultural uses, expanded perlite is used to provide moisture retention and aeration without compaction when added to soil. Owing primarily to cost, some commercial greenhouse growers in the United States have recently switched to a wood fiber material over perlite. Perlite, however, remained a preferred soil amendment for segments of the greenhouse growers because it does not degrade or compact over lengthy growing times and is inert. Construction applications for expanded perlite are numerous because it is lightweight, fire resistant, and an excellent insulator. Novel and small markets for perlite have increased during the past 10 years; cosmetics, environmental remediation, and personal care products have become increasing markets for perlite. Throughout 2017 and 2018, a new perlite deposit in Nevada was being actively explored and developed as a potential supplier of crude perlite ore for industrial and household applications. The estimated amount of processed crude perlite sold or used from U.S. mines increased to the highest level since 2005.

Domestic perlite mining generally takes place in remote areas, and its environmental impact is not severe. The mineral fines, overburden, and reject ore produced during ore mining and processing are used to reclaim the mined-out areas, and, therefore, little waste remains. Airborne dust is captured by baghouses, and virtually no runoff contributes to water pollution.

Based on estimated world production for 2018, the world's leading producers were, in descending order of production, China, Turkey, Greece, and the United States, with about 41%, 22%, 21%, and 12%, respectively, of world production. Although China was the leading producer, most of its perlite production was thought to be consumed internally. Greece and Turkey remained the leading exporters of perlite.

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

	Production		Reserves[4]
	2017	2018[e]	
United States	[5]570	[5]560	50,000
Armenia	45	45	NA
China	1,930	1,900	NA
Greece	930	950	120,000
Hungary	35	35	49,000
Iran	20	20	NA
Mexico	20	20	NA
New Zealand	25	25	NA
Turkey	1,000	1,000	57,000
Other countries	78	60	NA
World total (rounded)	4,650	4,600	NA

World Resources: Perlite occurrences in Arizona, Idaho, Nevada, New Mexico, and Oregon contain estimated large resources. Significant deposits have been reported in China, Greece, and Turkey, and some other countries. Insufficient information is available to make reliable estimates of resources in many perlite-producing countries.

Substitutes: In construction applications, diatomite, expanded clay and shale, pumice, and slag can be substituted for perlite. For horticultural uses, vermiculite, coco coir, wood pulp, and pumice are alternative soil additives and are sometimes used in conjunction with perlite.

[e]Estimated. NA Not available.
[1]Exports and imports were estimated by the U.S. Geological Survey from U.S. Census Bureau combined data for vermiculite, perlite, and chlorites, unexpanded.
[2]Defined as sold or used processed perlite + imports – exports.
[3]Defined as imports − exports.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]Mine production of crude ore.

PHOSPHATE ROCK

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2018, phosphate rock ore was mined by five firms at 10 mines in four States and processed into an estimated 27 million tons of marketable product, valued at $1.8 billion, free on board (f.o.b.) mine. Florida and North Carolina accounted for more than 75% of total domestic output; the remainder was produced in Idaho and Utah. Marketable product refers to beneficiated phosphate rock with phosphorus pentoxide (P_2O_5) content suitable for phosphoric acid or elemental phosphorus production. More than 95% of the phosphate rock mined in the United States was used to manufacture wet-process phosphoric acid and superphosphoric acid, which were used as intermediate feedstocks in the manufacture of granular and liquid ammonium phosphate fertilizers and animal feed supplements. Approximately 50% of the wet-process phosphoric acid produced was exported in the form of upgraded granular diammonium (DAP) and monoammonium phosphate (MAP) fertilizer, and merchant-grade phosphoric acid. The balance of the phosphate rock mined was for the manufacture of elemental phosphorus, which was used to produce phosphorus compounds for industrial applications, primarily glyphosate herbicide.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production, marketable	25,300	27,400	27,100	27,900	27,000
Used by producers	26,700	26,200	26,700	26,300	23,000
Imports for consumption	2,380	1,960	1,590	2,520	3,000
Consumption, apparent[1]	29,100	28,100	28,200	28,800	27,000
Price, average value, dollars per ton, f.o.b. mine[2]	78.59	72.41	76.90	73.67	68.00
Stocks, producer, yearend	5,880	6,730	7,450	8,440	11,000
Employment, mine and beneficiation plant, number[e]	2,100	2,000	2,000	2,000	2,000
Net import reliance[3] as a percentage of apparent consumption	18	4	4	5	5

Recycling: None.

Import Sources (2014–17): Peru, 68%; Morocco, 31%; and other, 1%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–18**
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 phosphate rock production and consumption in 2018 were estimated to be lower than those in 2017, owing to a decrease in phosphoric acid production caused in part by the temporary closure of a phosphate plant in Florida. Production of DAP and MAP were lower in 2018 because of lower export sales.

In early 2018, the leading United States phosphate rock producer completed its purchase of the phosphate and potash assets of the leading fertilizer producer in Brazil. The acquisition included five phosphate rock mines, one potash mine, and four phosphate fertilizer plants in Brazil, and potash mine projects in Argentina and Canada. The company also acquired the Brazilian company's 40% stake in their joint-venture mine in Peru, which increased its stake to 75%.

U.S. annual mine production capacity was expected to remain steady at 32.5 million tons during the next 5 years. All three producers in Idaho were developing new mines to replace existing mines as they become exhausted over the next decade.

According to industry analysts, world mine production rated capacity was projected to increase to 169 million tons in 2022 from 148 million tons in 2018, excluding official capacity data for China. Production of marketable phosphate rock in China was believed to be between 80 to 85 million tons per year, compared with official production statistics that included some crude ore production, according to industry analysts. Most of the increases are planned for Africa and the Middle East, where expansion projects were in progress in Egypt, Jordan, Morocco, Saudi Arabia, and South Africa.

Prepared by **Stephen M. Jasinski [(703) 648–7711, sjasinsk@usgs.gov]**

PHOSPHATE ROCK

World consumption of P_2O_5, contained in phosphoric acid, fertilizers, and other uses, was projected to increase to 50.5 million tons in 2022 from 47.0 million tons in 2018. Africa, India, and South America would account for about 75% of the projected growth. U.S. consumption of P_2O_5 was expected to remain at nearly 5 million tons per year.

World Mine Production and Reserves: Reserves for China, India, and Russia were updated with official Government data. Reserves for Israel and Jordan were updated with information from company reports.

	Mine production		Reserves[4]
	2017	2018[e]	
United States	27,900	27,000	1,000,000
Algeria	1,300	1,300	2,200,000
Australia	3,000	3,000	[5]1,100,000
Brazil	5,200	5,400	1,700,000
China[6]	144,000	140,000	3,200,000
Egypt	4,400	4,600	1,300,000
Finland	980	1,000	1,000,000
India	1,590	1,600	46,000
Israel	3,850	3,900	67,000
Jordan	8,690	8,800	1,000,000
Kazakhstan	1,500	1,600	260,000
Mexico	1,930	2,000	30,000
Morocco and Western Sahara	30,000	33,000	50,000,000
Peru	3,040	3,100	400,000
Russia	13,300	13,000	600,000
Saudi Arabia	5,000	5,200	1,400,000
Senegal	1,390	1,500	50,000
South Africa	2,080	2,100	1,500,000
Syria	100	100	1,800,000
Togo	825	850	30,000
Tunisia	4,420	3,300	100,000
Uzbekistan	900	900	100,000
Vietnam	3,000	3,300	30,000
Other countries	1,100	1,300	770,000
World total (rounded)	269,000	270,000	70,000,000

World Resources: 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, China, the Middle East, 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 used by producers + imports - exports. U.S. producers stopped exporting phosphate rock in 2003.
[2]Marketable phosphate rock, weighted value, all grades.
[3]Defined as imports – exports + adjustments for industry stock changes. U.S. producers stopped exporting phosphate rock in 2003.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]For Australia, Joint Ore Reserves Committee-compliant reserves were about 290 million tons.
[6]Production data for large mines only, as reported by National Bureau of Statistics of China.

PLATINUM-GROUP METALS

(Palladium, platinum, iridium, osmium, rhodium, and ruthenium)
(Data in kilograms of platinum-group-metal content unless otherwise noted)

Domestic Production and Use: One company in Montana produced about 18,100 kilograms of platinum-group metals (PGMs) with an estimated value of about $570 million. Small quantities of primary PGMs also were recovered as byproducts of copper-nickel mining in Minnesota; 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. Platinum-group metals 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:	2014	2015	2016	2017	2018[e]
Mine production:[1]					
Palladium	12,400	12,500	13,100	13,600	14,000
Platinum	3,660	3,670	3,890	3,980	4,100
Imports for consumption:[2]					
Palladium	92,900	85,300	80,400	86,000	89,000
Platinum	45,400	42,700	42,300	53,200	59,000
PGM waste and scrap	112,000	123,000	159,000	363,000	43,000
Iridium	1,960	1,010	1,300	1,420	940
Osmium	322	8	27	856	38
Rhodium	11,100	10,600	10,700	11,600	14,000
Ruthenium	11,000	8,230	8,410	14,500	17,000
Exports:[3]					
Palladium	22,100	23,000	17,500	52,300	61,000
Platinum	14,800	14,400	14,000	16,700	18,000
PGM waste and scrap	254,000	246,000	273,000	195,000	34,000
Rhodium	433	759	794	844	4,000
Other PGMs	887	781	736	939	2,500
Price, dollars per troy ounce:[4]					
Palladium	809.89	694.99	617.39	874.30	990.00
Platinum	1,387.89	1,056.09	989.52	951.23	900.00
Iridium	556.19	544.19	586.90	908.35	1,200.00
Rhodium	1,174.23	954.90	696.84	1,112.59	2,100.00
Ruthenium	65.13	47.63	42.00	76.86	240.00
Employment, mine, number[1]	1,622	1,439	1,432	1,513	1,500
Net import reliance[5, 6] as a percentage of apparent consumption:					
Palladium	57	53	53	38	33
Platinum	69	66	66	71	73

Recycling: About 120,000 kilograms of palladium and platinum was recovered globally from new and old scrap in 2018, including about 51,000 kilograms recovered from automobile catalytic converters in the United States.

Import Sources (2014–17):[6] Palladium: South Africa, 31%; Russia, 28%; Italy, 12%; United Kingdom, 6%; and other, 23%. Platinum: South Africa, 44%; Germany, 15%; United Kingdom, 10%; Italy, 7%; and other, 24%.

Tariff: All unwrought and semimanufactured forms of PGMs are imported duty free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[7]

		FY 2018		FY 2019	
Material	Inventory As of 9–30–18	Potential Acquisitions	Potential Disposals[8]	Potential Acquisitions	Potential Disposals[8]
Iridium	15	—	15	—	15
Platinum	261	—	261	—	261

Prepared by **Sheryl A. Singerling [(703) 648–4954, ssingerling@usgs.gov]**

PLATINUM-GROUP METALS

Events, Trends, and Issues: Progress continued on the domestic company's mine expansion project; full production was expected by the end of 2021. Production of PGMs in South Africa, the world's leading supplier of mined material, decreased compared with 2017 owing to job cuts and mine-shaft closures. Production was expected to continue decreasing as the world's third-leading PGM-mining company, by production volume, announced plans to cut 13,000 jobs over the next 2 years at some of its mines in South Africa.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including platinum-group metals. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ''A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" (82 FR 60835).

Annual average prices of iridium, palladium, rhodium, and ruthenium increased by 32%, 13%, 89%, and 212%, respectively, compared with those of 2017. The average annual price of platinum was 5% lower than that of 2017. Since October 2017, the average price of palladium has been higher than that of platinum, which had not been the case previously since 2001.

World Mine Production and Reserves:

	Mine production				PGMs
	Palladium		Platinum		Reserves[9]
	2017	2018[e]	2017	2018[e]	
United States	13,600	14,000	3,980	4,100	900,000
Canada	17,000	17,000	9,500	9,500	310,000
Russia	85,200	85,000	21,800	21,000	3,900,000
South Africa	86,800	68,000	143,000	110,000	63,000,000
Zimbabwe	12,000	12,000	14,000	14,000	1,200,000
Other countries	10,800	11,000	6,510	6,100	NA
World total (rounded)	225,000	210,000	199,000	160,000	69,000,000

World Resources: World resources of PGMs are estimated to total more than 100 million kilograms. The largest reserves are in the Bushveld Complex in South Africa.

Substitutes: Palladium has been substituted for platinum in most gasoline-engine catalytic converters because of the historically lower price for palladium relative to that of platinum. About 25% of palladium can routinely be substituted for platinum in diesel catalytic converters; the proportion can be as much as 50% in some applications. For some industrial end uses, one PGM can substitute for another, but with losses in efficiency.

[e]Estimated. NA Not available. — Zero.
[1]Estimates from published sources.
[2]Includes data for the following Harmonized Tariff Schedule of the United States codes: 7110.11.0010, 7110.11.0020, 7110.11.0050, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0010, 7110.41.0020, 7110.41.0030, 7110.49.0010, 7112.92.0000, and 7118.90.0020.
[3]Includes data for the following Schedule B codes: 7110.11.0000, 7110.19.0000, 7110.21.0000, 7110.29.0000, 7110.31.0000, 7110.39.0000, 7110.41.0000, 7110.49.0000, and 7112.92.0000.
[4]Engelhard Corp. unfabricated metal.
[5]Defined as imports – exports + adjustments for industry stock changes.
[6]Excludes imports and (or) exports of waste and scrap.
[7]See Appendix B for definitions.
[8]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.

POTASH

(Data in thousand metric tons of K_2O equivalent unless otherwise noted)

Domestic Production and Use: In 2018, the estimated sales value of marketable potash, f.o.b. mine, was $400 million, which was 5% more than that in 2017. Potash denotes a variety of mined and manufactured salts, which contain the element potassium in water-soluble form. In agriculture, the term potash refers to potassic fertilizers, which are potassium chloride (KCl), potassium sulfate or sulfate of potash (SOP), and potassium magnesium sulfate (SOPM) or langbeinite. Muriate of potash (MOP) is an agriculturally acceptable mix of KCl (95% pure or greater) and sodium chloride for fertilizer use. The majority of U.S. production was from southeastern New Mexico, where two companies operated two underground mines and one deep-well solution mine. Sylvinite and langbeinite ores in New Mexico were beneficiated by flotation, dissolution-recrystallization, heavy-media separation, solar evaporation, and (or) combinations of these processes, and accounted for about 50% of total U.S. producer sales. In Utah, two companies operated three facilities. One company extracted underground sylvinite ore by deep-well solution mining. Solar evaporation crystallized the sylvinite ore from the brine solution, and a flotation process separated the MOP from byproduct sodium chloride. The firm also processed subsurface brines by solar evaporation and flotation to produce MOP at its other facility. Another company processed brine from the Great Salt Lake by solar evaporation to produce SOP and other byproducts.

The fertilizer industry used about 85% of U.S. potash sales, and the remainder was used for chemical and industrial applications. About 65% of the potash produced was SOPM and SOP, which are required to fertilize certain chloride-sensitive crops. Muriate of potash accounted for the remaining 35% of production and was used for agricultural and chemical applications.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, marketable[1]	850	740	510	480	500
Sales by producers, marketable[1]	930	620	600	490	550
Imports for consumption	4,970	5,000	4,550	5,870	5,900
Exports	100	106	96	128	110
Consumption, apparent[1, 2]	5,800	5,500	5,000	6,200	6,300
Price, dollars per ton of K_2O, average, all products, f.o.b. mine[3]	735	880	680	775	740
Price, dollars per ton of K_2O, average, muriate, f.o.b. mine	560	580	350	410	415
Employment, number, mine and mill	1,400	1,300	1,150	900	900
Net import reliance[4] as a percentage of apparent consumption	85	87	90	92	92

Recycling: None.

Import Sources (2014–17): Canada, 84%; Russia, 7%; Belarus, 3%; Israel, 3%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Potassium nitrate	2834.21.0000	Free.
Potassium chloride	3104.20.0000	Free.
Potassium sulfate	3104.30.0000	Free.
Potassic fertilizers, other	3104.90.0100	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. production of potash was slightly higher in 2018, owing to increased output of SOP and SOPM. Apparent consumption of potash was estimated to have increased slightly because of stronger demand for fertilizers and for oil-well-drilling-fluid additives. Imports of MOP from Canada increased by about 3% over those of 2017.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including potash. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

Prepared by **Stephen M. Jasinski [(703) 648–7711, sjasinsk@usgs.gov]**

POTASH

Two of the four Canadian potash producers completed their merger in January 2018. The new company accounts for 24% of world MOP capacity, making it the leading world producer. Canada led the world in potash production, with about 38% of global production capacity.

In 2018, one company opened two new potash mines in Russia. Each mine had a production capacity of 2.3 million tons per year of MOP. The company planned to ramp up to full production by 2021, depending on economic conditions.

Between 2019 and 2022, other new mines were planned to start production in Belarus, China, Laos, and Spain, and expansion projects at existing facilities were ongoing in Belarus, China, and Russia. These new projects would increase world production capacity to 64.6 million tons of K_2O in 2022 from 58.7 million tons of K_2O in 2018. Other new potash mine projects in Argentina, Australia, Canada, Congo (Brazzaville), Eritrea, Ethiopia, Peru, and the United Kingdom were delayed until after 2023, owing to financing difficulties and low potash prices. Canada, Russia, and Belarus were expected to remain the leading world producers and suppliers, by quantity. World potash consumption for all uses was projected to increase to 46.2 million tons in 2022 from 42.2 million tons in 2018, with the largest consumption in Asia and South America.

World Mine Production and Reserves: Reserves for the United States, Canada, Chile, China, Spain, and the United Kingdom were revised with information contained in individual company reports. Reserves for Russia were revised based on official Government data.

	Mine production		Reserves[5]	
	2017	2018[e]	Recoverable ore	K_2O equivalent
United States[1]	480	500	970,000	220,000
Belarus	7,100	7,100	3,300,000	750,000
Brazil	290	300	310,000	24,000
Canada	12,200	12,000	4,900,000	1,200,000
Chile	1,100	1,000	NA	100,000
China	5,510	5,500	NA	350,000
Germany	2,700	2,900	NA	150,000
Israel	2,000	2,000	NA	[6]270,000
Jordan	1,390	1,400	NA	[6]270,000
Russia	7,300	7,500	NA	2,000,000
Spain	610	560	NA	41,000
United Kingdom	250	190	NA	170,000
Other countries	500	600	1,500,000	280,000
World total (rounded)	41,400	42,000	NA	5,800,000

World Resources: Estimated domestic potash resources total about 7 billion tons. Most of these lie at depths between 1,800 and 3,100 meters in a 3,110-square-kilometer area of Montana and North Dakota as an extension of the Williston Basin deposits in Manitoba and Saskatchewan, Canada. The Paradox Basin in Utah contains resources of about 2 billion tons, mostly at depths of more than 1,200 meters. The Holbrook basin of Arizona contains resources of about 0.7 to 2.5 billion tons. A large potash resource lies about 2,100 meters under central Michigan and contains more than 75 million tons. Estimated world resources total about 250 billion tons.

Substitutes: No substitutes exist for potassium as an essential plant nutrient and as an essential nutritional requirement for animals and humans. Manure and glauconite (greensand) are low-potassium-content sources that can be profitably transported only short distances to crop fields.

[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]Total reserves in the Dead Sea are divided equally between Israel and Jordan for inclusion in this tabulation.

PUMICE AND PUMICITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2018, 10 operations in five States produced pumice and pumicite. Estimated production[1] was 400,000 tons with an estimated processed value of about $16 million, free on board (f.o.b.) plant. Pumice and pumicite were mined in Oregon, California, Idaho, New Mexico, and Kansas, in descending order of production. 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:	2014	2015	2016	2017	2018[e]
Production, mine[1]	269	310	374	383	400
Imports for consumption	60	64	170	166	180
Exports[e]	14	11	9	11	12
Consumption, apparent[2]	315	363	535	538	570
Price, average value, dollars per ton, f.o.b. mine or mill	39	33	38	39	40
Employment, mine and mill, number	140	140	140	140	140
Net import reliance[3] as a percentage of apparent consumption	15	15	30	29	29

Recycling: Little to no known recycling.

Import Sources (2014–17): Greece, 93%; Iceland, 5%; and Mexico, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
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 2018 was estimated to be 4% more than that in 2017. Imports and exports increased compared with those of 2017. Since 2015, average unit value, apparent consumption, and quantity of pumice that was sold or used have followed an upward trend. Almost all imported pumice originated from Greece in 2018, and primarily supplied markets in the eastern and Gulf Coast regions of the United States. Turkey and Italy are the leading global producers of pumice and pumicite. While the domestic mill price for pumice is approximately $40 per ton, the average imported value of pumice was approximately $30 per ton.

Although pumice and pumicite are plentiful in the Western United States, legal challenges and public land designations could limit access to known deposits. Pumice and pumicite production is sensitive to mining and transportation costs. Although unlikely in the short term, an increase in fuel prices would likely lead to increases in production costs; imports and competing materials could become attractive substitutes for domestic products.

Prepared by **Robert D. Crangle, Jr. [(703) 648–6410, rcrangle@usgs.gov]**

PUMICE AND PUMICITE

All known domestic pumice and pumicite mining in 2018 was accomplished through open pit methods, generally in remote areas, away from major population centers. Although the generation and disposal of reject fines in mining and milling may result in local dust issues at some operations, such environmental impacts are thought to be restricted to relatively small geographic areas.

World production of pumice and related material was estimated to be 18 million tons in 2018, which represented a slight increase from that of 2017. 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 significantly less gypsum wallboard because stone and concrete are the preferred building materials. Prefabricated lightweight concrete walls, which may contain pumice as lightweight aggregate, are often produced and shipped to construction locations. Because of their cementitious properties, light weight, and strength, pumice and pumicite perform well in European-style construction.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2017	2018[e]	
United States[1]	383	400	Large in the United States. Quantitative estimates of reserves for most countries are not available.
Algeria[5]	350	350	
Cameroon[5]	360	360	
Chile[5]	840	840	
Ecuador[5]	830	850	
Ethiopia	800	800	
France[5]	280	280	
Greece[5]	950	1,000	
Guadeloupe	200	200	
Guatemala	570	570	
Italy[5]	4,040	4,000	
Saudi Arabia[5]	480	480	
Spain	200	200	
Syria[5]	200	200	
Tanzania	350	350	
Turkey	5,600	5,600	
Uganda	720	720	
Other countries[5]	460	900	
World total (rounded)	17,600	18,000	

World Resources: The identified U.S. resources of pumice and pumicite are concentrated in the Western States and estimated to be more than 25 million tons. The estimated total resources (identified and undiscovered) in the Western and Great Plains States are at least 250 million tons and may total more than 1 billion tons. Large resources of pumice and pumicite have been identified on all continents.

Substitutes: The costs of transportation determine the maximum economic distance pumice and pumicite can be shipped and still remain competitive with alternative materials. Competitive materials that may be substituted for pumice and pumicite include crushed aggregates, diatomite, expanded shale and clay, and vermiculite.

[e]Estimated.
[1]Quantity sold and used by producers.
[2]Defined as production + imports – exports.
[3]Defined as imports – exports.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.
[5]Includes pozzolan and (or) volcanic tuff.

QUARTZ CRYSTAL (INDUSTRIAL)

(Data in kilograms unless otherwise noted)

Domestic Production and Use: Industrial cultured quartz crystal is electronic-grade quartz crystal that is manufactured, not mined. In the past, cultured quartz crystal was primarily produced using lascas[1] as raw quartz feed material. Lascas mining and processing in Arkansas ended in 1997. Cultured quartz crystal is produced in the United States, but production statistics were not available. 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 may use a mix of cultured quartz and imported lascas as feed material. In the past several years, cultured quartz crystal has been increasingly produced overseas, primarily in Asia. Electronic applications accounted for most industrial uses of quartz crystal; other uses included special optical applications.

Virtually all quartz crystal used for electronics was cultured, rather than natural, crystal. Electronic-grade quartz crystal is used to make frequency filters, frequency controls, and timers in electronic circuits employed for a wide range of products, such as communications equipment, computers, and many consumer goods, such as electronic games and television receivers.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Mine (lascas)	—	—	—	—	—
Cultured quartz crystal	NA	NA	NA	NA	NA
Imports for consumption:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	4,180	3,400	6,280	7,210	4,860
Exports:					
Quartz (lascas)	NA	NA	NA	NA	NA
Piezoelectric quartz, unmounted	46,800	43,600	60,500	57,900	50,000
Price, dollars per kilogram:					
As-grown cultured quartz	280	280	280	280	280
Lumbered quartz[2]	400	160	890	300	300
Net import reliance[3] as a percentage of apparent consumption	NA	NA	NA	NA	NA

Recycling: An unspecified amount of rejected cultured quartz crystal was used as feed material for the production of cultured quartz crystal.

Import Sources (2014–17): Import statistics specific to lascas are not available because they are combined with other types of quartz. Cultured quartz crystal is thought to be mostly imported from China, Italy, Japan, and Taiwan.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Quartz (including lascas)	2506.10.0050	Free.
Piezoelectric quartz, unmounted	7104.10.0000	3% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Prepared by **Thomas P. Dolley [(703) 648–7710, tdolley@usgs.gov]**

QUARTZ CRYSTAL (INDUSTRIAL)

Government Stockpile:[4] As of September 30, 2018, the National Defense Stockpile (NDS) contained 7,148 kilograms of natural quartz crystal. The stockpile has 11 weight classes for natural quartz crystal that range from 0.2 kilogram to more than 10 kilograms. The stockpiled crystals, however, are primarily in the larger weight classes. The larger pieces are suitable as seed crystals, which are very thin crystals cut to exact dimensions, to produce cultured quartz crystal. In addition, many of the stockpiled crystals could be of interest to the specimen and gemstone industry. Little, if any, of the stockpiled material is likely to be used in the same applications as cultured quartz crystal. No natural quartz crystal was sold from the NDS in 2018. Previously, the only individual crystals from the stockpile that were sold were those that weighed 10 kilograms or more and that could be used as seed material.

		FY2018		FY 2019	
Material	Inventory As of 9–30–18	Potential Acquisitions	Potential Disposals[5]	Potential Acquisitions	Potential Disposals[5]
Quartz crystal	7,148	—	—	—	—

Events, Trends, and Issues: Demand for cultured quartz crystal for frequency-control oscillators and frequency filters in a variety of electronic devices is expected to remain stable. However, silicon has replaced quartz crystal in two very important markets—cellular telephones and other mobile devices and automotive stability control applications. Growth of the consumer electronics market, for products such as personal computers, electronic games, and tablet computers, is likely to continue to sustain global production of cultured quartz crystal.

World Mine Production and Reserves:[6] This information is unavailable, but the global reserves for lascas are thought to be large.

World Resources: Limited resources of natural quartz crystal suitable for direct electronic or optical use are available throughout the world. World dependence on these resources will continue to decline because of the increased acceptance of cultured quartz crystal as an alternative material. Additionally, techniques using rejected cultured quartz crystal as feed material could mean a decreased dependence on lascas for growing cultured quartz.

Substitutes: Silicon is increasingly being used as a substitute for quartz crystal for frequency-control oscillators in electronic circuits. Other materials, such as aluminum orthophosphate (the very rare mineral berlinite), langasite, lithium niobate, and lithium tantalate, which have larger piezoelectric coupling constants, have been studied and used. The cost competitiveness of these materials, as opposed to cultured quartz crystal, is dependent on the type of application that the material is used for and the processing required.

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

[1]Lascas is a nonelectronic-grade quartz used as a feedstock for growing cultured quartz crystal and for production of fused quartz.

[2]As-grown cultured quartz that has been processed by sawing and grinding.

[3]Defined as imports - exports.

[4]See Appendix B for definitions.

[5]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.

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

RARE EARTHS[1]

[Data in metric tons of rare-earth oxide (REO) equivalent content unless otherwise noted]

Domestic Production and Use: Rare earths were mined domestically in 2018. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined as a primary product at a mine in Mountain Pass, CA, which was restarted in the first quarter of 2018 after being put on care-and-maintenance status in the fourth quarter of 2015. Monazite, a phosphate mineral, also may have been produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. The estimated value of rare-earth compounds and metals imported by the United States in 2018 was $160 million, an increase from $137 million in 2017. The estimated distribution of rare earths by end use was as follows: catalysts, 60%; ceramics and glass, 15%; metallurgical applications and alloys, 10%; polishing, 10%; and other, 5%.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, bastnaesite concentrates	5,400	5,900	—	—	15,000
Imports:[2]					
Compounds	12,300	9,160	11,500	11,000	9,800
Metals:					
Ferrocerium, alloys	371	356	268	309	330
Rare-earth metals, scandium, and yttrium	348	385	404	524	1,000
Exports:[2]					
Compounds	4,390	4,980	590	1,740	15,000
Metals:					
Ferrocerium, alloys	1,640	1,220	943	982	1,300
Rare-earth metals, scandium, and yttrium	140	60	103	55	30
Consumption, apparent[3]	12,200	9,550	10,500	9,060	9,500
Price, dollars per kilogram, average:[4]					
Cerium oxide, 99.5% minimum	5	3	2	2	2
Dysprosium oxide, 99.5% minimum	395	279	198	187	180
Europium oxide, 99.99% minimum	822	344	74	77	56
Lanthanum oxide, 99.5% minimum	5	3	2	2	2
Mischmetal, 65% cerium, 35% lanthanum	10	7	5	6	6
Neodymium oxide, 99.5% minimum	63	48	40	50	51
Terbium oxide, 99.99% minimum	713	564	415	501	461
Employment, mine and mill, annual average	391	351	—	24	150
Net import reliance[5] as a percentage of apparent consumption:[6]					
Compounds and metals	56	38	100	100	100
Mineral concentrates	NA	NA	NA	NA	E

Recycling: Limited quantities, from batteries, permanent magnets, and fluorescent lamps.

Import Sources (2014–17): Rare-earth compounds and metals: China, 80%; Estonia, 6%; France and Japan, 3% each; and other, 8%. Imports of compounds and metals from Estonia, France, and Japan were derived from mineral concentrates and chemical intermediates produced in China and elsewhere.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Rare-earth metals, scandium, and yttrium, whether or not intermixed or interalloyed	2805.30.0000	5.0% ad val.
Cerium compounds:		
Oxides	2846.10.0010	5.5% ad val.
Other	2846.10.0050	5.5% ad val.
Other rare-earth compounds:		
Lanthanum oxides	2846.90.2005	Free.
Other oxides	2846.90.2040	Free.
Lanthanum carbonates	2846.90.8070	3.7% ad val.
Other carbonates	2846.90.8075	3.7% ad val.
Other rare-earth compounds	2846.90.8090	3.7% ad val.
Ferrocerium and other pyrophoric alloys	3606.90.3000	5.9% ad val.

Depletion Allowance: Monazite, 22% on thorium content and 14% on rare-earth content (Domestic), 14% (Foreign); bastnäsite and xenotime, 14% (Domestic and foreign).

Prepared by **Joseph Gambogi [(703) 648–7718, jgambogi@usgs.gov]**

RARE EARTHS

Government Stockpile:[7]

Material	Inventory As of 9–30–18	FY2018 Potential Acquisitions	FY2018 Potential Disposals[8]	FY 2019 Potential Acquisitions	FY 2019 Potential Disposals[8]
Dysprosium	0.1	0.5	0.5	0.5	—
Europium	7.1	18	—	35	—
Ferrodysprosium, gross weight	0.5	—	—	—	—
Rare earths	—	416	—	416	—
Rare-earth-magnet feedstock	—	—	—	100	—
Yttrium oxide	25	10	—	10	—

Events, Trends, and Issues: Mining of rare earths increased with renewed production in the United States supplemented with new and or increased production in Australia, Burma (Myanmar), and Burundi. In China, mine production quotas for the first and second halves of 2018 were set at 73,500 tons and 46,500 tons, respectively—an annual increase of 14% compared with the combined quota in 2017. According to China's Ministry of Commerce, production of rare-earth-oxide equivalent in China was estimated to be at least 180,000 tons based on magnet material production. Illegal and undocumented production in China continued despite Government efforts.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including rare earths. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ''A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" (82 FR 60835).

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

	Mine production[e] 2017	Mine production[e] 2018	Reserves[9]
United States	—	15,000	1,400,000
Australia	19,000	20,000	[10]3,400,000
Brazil	1,700	1,000	22,000,000
Burma (Myanmar)	NA	5,000	NA
Burundi	—	1,000	NA
China	[11]105,000	[11]120,000	44,000,000
India	1,800	1,800	6,900,000
Malaysia	180	200	30,000
Russia	2,600	2,600	12,000,000
Thailand	1,300	1,000	NA
Vietnam	200	400	22,000,000
Other countries	—	—	4,400,000
World total (rounded)	132,000	170,000	120,000,000

World Resources: Rare earths are relatively abundant in the Earth's crust, but minable concentrations are less common than for most other ores. Resources are primarily in four geologic environments: carbonatites, alkaline igneous systems, ion-adsorption clay deposits, and monazite-xenotime-bearing placer deposits. Carbonatites and placer deposits are the leading sources of production of light rare-earth elements. Ion-adsorption clays are the leading source of production of heavy rare-earth elements.

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 Scandium and Yttrium.
[2]REO equivalent or content of various materials were estimated. Source: U.S. Census Bureau.
[3]Defined as production + imports – exports.
[4]Price range from Argus Media group – Argus Metals International.
[5]Defined as imports – exports.
[6]In 2014–15, domestic production of mineral concentrates was included with apparent consumption of compounds and metals. In 2018, domestic production of mineral concentrates was exported and consumers of compounds and metals were reliant on imports and stockpiled inventory.
[7]See Appendix B for definitions.
[8]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.
[10]For Australia, Joint Ore Reserves Committee-compliant reserves were about 2.1 million tons.
[11]Production quota does not include undocumented production.

RHENIUM

(Data in kilograms of rhenium content unless otherwise noted)

Domestic Production and Use: During 2018, ores containing 8,300 kilograms of rhenium were mined at six operations (four in Arizona and one each in Montana and Utah). Rhenium compounds are included in molybdenum concentrates derived from porphyry copper deposits, and rhenium is recovered as a byproduct from roasting such molybdenum concentrates. Rhenium-containing products included ammonium perrhenate (APR), metal powder, and perrhenic acid. 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 °C) strength properties of some nickel-base superalloys. Rhenium alloys were used in crucibles, electrical contacts, electromagnets, electron tubes and targets, heating elements, ionization gauges, mass spectrographs, metallic coatings, semiconductors, temperature controls, thermocouples, vacuum tubes, and other applications. The value of rhenium consumed in 2018 was about $83 million as measured by the value of imports of rhenium metal and APR.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production[1]	8,510	7,900	8,440	8,200	8,300
Imports for consumption[2]	25,000	31,800	31,900	34,500	42,000
Exports	NA	NA	NA	NA	NA
Consumption, apparent[3]	33,500	39,700	40,300	42,700	51,000
Price, average value, dollars per kilogram, gross weight:[4]					
Metal pellets, 99.99% pure	2,980	2,670	2,030	1,550	1,500
Ammonium perrhenate	3,080	2,820	2,510	1,530	1,400
Employment, number	Small	Small	Small	Small	Small
Net import reliance[5] as a percentage of apparent consumption	75	80	79	81	84

Recycling: Nickel-base superalloy scrap and scrapped turbine blades and vanes continued to be recycled hydrometallurgically to produce rhenium metal for use in new superalloy melts. The scrapped parts were also processed to generate engine revert—a high-quality, lower cost superalloy meltstock—by an increasing number of companies, mainly in the United States, Canada, Estonia, Germany, and Russia. Rhenium-containing catalysts were also recycled.

Import Sources (2014–17): Ammonium perrhenate: Kazakhstan, 34%; Canada, 19%; Republic of Korea, 13%; Germany, 10%; and other, 24%. Rhenium metal powder: Chile, 85%; Germany, 6%; Belgium, 4%; Poland, 3%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Salts of peroxometallic acids, other, ammonium perrhenate	2841.90.2000	3.1% ad val.
Rhenium (and other metals), waste and scrap	8112.92.0600	Free.
Rhenium, unwrought and powders	8112.92.5000	3% ad val.
Rhenium (and other metals), wrought	8112.99.9000	4% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: During 2018, the United States continued to rely on imports for much of its supply of rhenium. Canada, Chile, Germany, Kazakhstan, and the Republic of Korea supplied most of the imported rhenium. Rhenium imports for consumption increased by 22% from those of 2017. Primary rhenium production in the United States slightly increased compared with that in 2017. Germany and the United States continued to be the leading secondary rhenium producers. Secondary rhenium production also took place in Canada, Estonia, France, Japan, Poland, and Russia. Reliable secondary production estimates were not available. For the seventh year in a row, rhenium metal and catalytic-grade APR prices declined. In 2018, catalytic-grade APR prices averaged $1,400 per kilogram, an 8% decrease from 2017 prices. Rhenium metal pellet prices averaged $1,500 per kilogram in 2018, a slight decrease from 2017 prices.

Prepared by **Désirée E. Polyak [(703) 648–4909, dpolyak@usgs.gov]**

RHENIUM

Consumption of catalyst-grade APR by the petroleum industry was expected to remain at high levels. Demand for rhenium in the aerospace industry, although more unpredictable, was expected to continue to increase. The major aerospace companies, however, were expected to continue testing superalloys that contain one-half the quantity of rhenium used in engine blades as currently designed, as well as testing rhenium-free alloys for other engine components.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including rhenium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

World Mine Production and Reserves: The reserves estimate for the United States was revised based on company reports.

	Mine production[6]		Reserves[7]
	2017	2018[e]	
United States	8,200	8,300	400,000
Armenia	300	260	95,000
Canada	—	—	32,000
Chile[8]	27,000	27,000	1,300,000
China	2,500	2,500	NA
Kazakhstan	1,000	1,200	190,000
Peru	—	—	45,000
Poland	9,300	9,300	NA
Russia	NA	NA	310,000
Uzbekistan	460	500	NA
World total (rounded)	48,800	49,000	2,400,000

World Resources: Most rhenium occurs with molybdenum in porphyry copper deposits. Identified U.S. resources are estimated to be about 5 million kilograms, and the identified resources of the rest of the world are approximately 6 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 being evaluated continually. Iridium and tin have achieved commercial success in one such application. Other metals being evaluated for catalytic use include gallium, germanium, indium, selenium, silicon, tungsten, and vanadium. The use of these and other metals in bimetallic catalysts might decrease rhenium’s share of the existing catalyst market; however, this would likely be offset by rhenium-bearing catalysts being considered for use in several proposed gas-to-liquid projects. Materials that can substitute for rhenium in various end uses are as follows: cobalt and tungsten for coatings on copper x-ray targets, rhodium and rhodium-iridium for high-temperature thermocouples, tungsten and platinum-ruthenium for coatings on electrical contacts, and tungsten and tantalum for electron emitters.

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

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

[2]Does not include wrought forms or waste and scrap. The rhenium content of ammonium perrhenate is 69.42%.

[3]Defined as production + imports – exports.

[4]Average price per kilogram of rhenium in pellets or catalytic-grade ammonium perrhenate, from Argus Media group–Argus Metals International.

[5]Defined as imports – exports.

[6]Estimated amount of rhenium recovered in association with copper and molybdenum production. Secondary rhenium production not included.

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

[8]Estimated rhenium recovered from roaster residues from Belgium, Chile, and Mexico.

RUBIDIUM

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

Domestic Production and Use: In 2018, no rubidium was mined in the United States; however, occurrences 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; it is produced in small quantities as a byproduct of cesium, lithium, and strontium mining. 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. The United States sourced the majority of its pollucite from the largest known deposit in North America at Bernic Lake, Manitoba, Canada; however, that operation ceased mining at the end of 2015.

Applications for rubidium and its compounds include biomedical research, electronics, specialty glass, and pyrotechnics. Specialty glasses are the leading market for rubidium; rubidium carbonate is used to reduce electrical conductivity, which improves stability and durability in fiber optic telecommunications networks. Biomedical applications include rubidium salts used in antishock agents and the treatment of epilepsy and thyroid disorder; rubidium-82, a radioactive isotope used as a blood-flow tracer in positron emission tomographic imaging; and rubidium chloride, used as an antidepressant. Rubidium atoms are used in academic research, including the development of quantum-mechanics-based computing devices, a future application with potential for relatively high consumption of rubidium. Quantum computing research uses ultracold rubidium atoms in a variety of applications. Quantum computers, which have the ability to perform more complex computational tasks than traditional computers by calculating in two quantum states simultaneously, were expected to be in prototype phase by 2025.

Rubidium's photoemissive properties make it ideal for electrical-signal generators in motion-sensor devices, night-vision devices, photoelectric cells (solar panels), and photomultiplier tubes. Rubidium is used as an atomic resonance-frequency-reference oscillator for telecommunications network synchronization, playing a vital role in global positioning systems. Rubidium-rich feldspars are used in ceramic applications for spark plugs and electrical insulators because of their high dielectric constant. Rubidium hydroxide is used in fireworks to oxidize mixtures of other elements and produce violet hues. The U.S. military frequency standard, the United States Naval Observatory (USNO) timescale, is based on 48 weighted atomic clocks, including 4 USNO rubidium fountain clocks.

Salient Statistics—United States: U.S. salient statistics, such as consumption, exports, and imports, are not available. Some concentrate was imported to the United States for further processing. Industry information during the past decade suggests a domestic consumption rate of approximately 2,000 kilograms per year. The United States was 100% import reliant for rubidium minerals.

In 2018, one company offered 1-gram ampoules of 99.75%-grade rubidium (metals basis) for $84.40, a slight increase from $82.70 in 2017, and 100-gram ampoules of the same material for $1,546.00, a slight increase from $1,516.00 in 2017. The price for 10-gram ampoules of 99.8% rubidium formate hydrate (metals basis) was $48.40, a 12% decrease from $55.10 in 2017.

In 2018, the prices for 10 grams of 99.8% (metals basis) rubidium acetate, rubidium bromide, rubidium carbonate, rubidium chloride, and rubidium nitrate were $48.40, $63.80, $55.20, $58.10, and $45.00, respectively. The price for a rubidium-plasma standard solution (10,000 micrograms per milliliter) was $54.30 for 50 milliliters and $80.80 for 100 milliliters, a slight decrease from that of 2017.

Recycling: None.

Import Sources (2014–17): No reliable data has been available to determine the source of rubidium ore imported by the United States since 1988. Previously, Canada was thought to be the primary supplier of rubidium ore.

Prepared by **Christopher A. Tuck [(703) 648–4912, ctuck@usgs.gov]**

RUBIDIUM

Tariff:

Item	Number	Normal Trade Relations 12–31–18
Alkali metals, other	2805.19.9000	5.5% ad val.
Chlorides, other	2827.39.9000	3.7% ad val.
Bromides, other	2827.59.5100	3.6% ad val.
Nitrates, other	2834.29.5100	3.5% ad val.
Carbonates, other	2836.99.5000	3.7% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic rubidium occurrences will remain uneconomic unless market conditions change, such as the development of new end uses or increased consumption for existing end uses, which in turn could lead to increased prices. No known human health issues are associated with exposure to naturally occurring rubidium, and its use has minimal environmental impact.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including rubidium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

During 2018, projects that were primarily aimed at developing lithium resources were at various stages of development, including eight subprojects at the King Col project in Australia, the Jubilee Lake lithium prospect in Canada, the Soris lithium project in Namibia, and the Winnipeg River pegmatite field in Canada. The status of these projects ranged from early feasibility studies to active exploration and drilling. No production has been reported at any sites. The projects focused on pegmatites containing pollucite and spodumene, which primarily contain lithium, tantalum, or both, but may also contain minor quantities of cesium and rubidium.

World Mine Production and Reserves: There were no official sources for rubidium production data. Production is known to take place periodically in Namibia and Zimbabwe, but production data are not available. Production of pollucite ceased at the Bernic Lake operation in Manitoba, Canada, at the end of 2015; however, it was expected that rubidium concentrate would continue to be produced as a byproduct of processing from pollucite stocks. Rubidium is thought to be mined in China, but information regarding reserves and production is unavailable. 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 cost prohibitive. Rubidium at the Manitoba, Canada, operation no longer was considered economically recoverable following a mine collapse in 2015.

	Reserves[1]
Namibia	50,000
Zimbabwe	30,000
Other countries	10,000
World total	90,000

World Resources: Significant rubidium-bearing pegmatite occurrences have been identified in the United States, Afghanistan, Australia, Canada, China, Denmark, Germany, Japan, Kazakhstan, Namibia, Peru, Russia, the United Kingdom, and Zambia. Minor quantities of rubidium are reported in brines in northern Chile and China and in evaporites in the United States (New Mexico and Utah), France, and Germany.

Substitutes: Rubidium and cesium can be used interchangeably in many applications because they have similar physical properties and atomic radii. Cesium, however, is more electropositive than rubidium, making it a preferred material for some applications.

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

SALT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Domestic production of salt was estimated to have increased by 5% in 2018 to 42 million tons. The total value of salt sold or used was estimated to be about $2.3 billion. Twenty-six companies operated 62 plants in 16 States. The top producing States were, in alphabetical order, Kansas, Louisiana, Michigan, New York, Ohio, Texas, and Utah. These seven States produced about 92% of the salt in the United States in 2018. The estimated percentage of salt sold or used was, by type, rock salt, 43%; salt in brine, 40%; vacuum pan salt, 10%; and solar salt, 7%.

Highway deicing accounted for about 43% of total salt consumed. The chemical industry accounted for about 39% of total salt sales, with salt in brine accounting for 87% 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, in declining order of use, distributors, 7%; agricultural and food processing, 3% each; other uses combined with exports and general industrial, 2% each; and primary water treatment, 1%.

Salient Statistics—United States:[1]	2014	2015	2016	2017	2018[e]
Production	45,300	45,100	41,700	[e]40,000	42,000
Sold or used by producers	46,000	42,800	40,200	[e]38,000	41,000
Imports for consumption	20,200	21,600	12,100	12,600	17,000
Exports	935	830	716	1,120	950
Consumption:					
Apparent[2]	65,300	63,600	51,600	[e]49,000	57,000
Reported	55,600	52,300	48,400	[e]48,000	51,000
Price, average value of bulk, pellets and packaged salt, dollars per ton, f.o.b. mine and plant:					
Vacuum and open pan salt	180.61	188.87	197.78	[e]200.00	200.00
Solar salt	75.35	102.04	99.69	[e]100.00	100.00
Rock salt	48.11	56.32	56.74	[e]55.00	58.00
Salt in brine	9.08	10.27	8.29	[e]10.00	10.00
Employment, mine and plant, number[e]	4,200	4,200	4,000	4,100	4,100
Net import reliance[3] as a percentage of apparent consumption	29	33	22	23	28

Recycling: None.

Import Sources (2014–17): Chile, 38%; Canada, 28%; Mexico, 11%; Egypt, 4%; and other, 19%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Salt (sodium chloride)	2501.00.0000	Free.

Depletion Allowance: 10% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The winter was slightly colder than average in 2017–18 after several warmer than average winters. The total amount of frozen precipitation was about average, but the number of winter weather events was greater than the last few years in many parts of the United States, requiring more salt for highway deicing. Rock salt production and imports in 2018 increased from the levels in 2017 because demand from many local and State transportation departments increased. The majority of local and State governments in cold regions reportedly had depleted stockpiles and had to replenish supplies of rock salt for the winter of 2018–19. Because winter weather started relatively early in November 2018, many consumers of rock salt had already begun to use stockpiles of salt and considered increasing salt purchases for the remainder of the winter season. Owing to the increased demand for deicing salt, coupled with production interruptions at mines in the United States and Canada, many buyers were experiencing increased unit prices for rock salt.

Prepared by **Wallace P. Bolen [(703) 648–7727, wbolen@usgs.gov]**

SALT

For the winter of 2018–19, the National Oceanic and Atmospheric Administration predicted a weak El Niño weather pattern. This pattern normally leads to cooler weather in the Southeast with more precipitation in the Southern United States and drier and warmer conditions in the northern States, particularly in the Great Plains and Great Lakes region. Weather conditions in the northeastern United States were predicted to be near average. Because the effects of a weak El Niño are less predictable, forecasting is more difficult for 2018–19. The early part of the ongoing season was noticeably cooler and wetter than normal, and if this were to continue, as some meteorologists were predicting, salt demand could continue to increase throughout the winter.

Demand for salt brine used in the chloralkali industry was expected to increase as demand for caustic soda increased globally, especially in Asia. Exports from Australia and especially India increased to supply the increasing demand for caustic soda in China.

World Production and Reserves:

	Mine Production[e]		Reserves[4]
	2017	2018	
United States[1]	40,000	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	11,000	12,000	
Austria	4,600	4,600	
Brazil	7,400	7,500	
Canada	12,000	13,000	
Chile	8,500	9,500	
China	67,000	68,000	
France	4,500	4,500	
Germany	13,000	13,000	
India	28,000	29,000	
Mexico	9,000	9,000	
Netherlands	6,940	7,000	
Pakistan	3,600	3,600	
Poland	4,450	4,500	
Russia	5,800	5,800	
Spain	4,500	4,500	
Turkey	5,500	5,500	
United Kingdom	5,100	5,100	
Other countries	47,200	47,000	
World total (rounded)	288,000	300,000	

World Resources: World continental resources of salt are vast, and the salt content in the oceans is nearly unlimited. Domestic resources of rock salt and salt from brine are primarily in Kansas, Louisiana, Michigan, New York, Ohio, and Texas. Saline lakes and solar evaporation salt facilities are in Arizona, California, Nevada, New Mexico, Oklahoma, and Utah. Almost every country in the world has salt deposits or solar evaporation operations of various sizes.

Substitutes: No economic substitutes or alternatives for salt exist in most applications. Calcium chloride and calcium magnesium acetate, hydrochloric acid, and potassium chloride can be substituted for salt in deicing, certain chemical processes, and food flavoring, but at a higher cost.

[e]Estimated.
[1]Excludes production from Puerto Rico.
[2]Defined as sold or used by producers + imports – exports.
[3]Defined as imports – exports.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.

SAND AND GRAVEL (CONSTRUCTION)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2018, 970 million tons of construction sand and gravel valued at $8.7 billion was produced by an estimated 3,800 companies operating 9,350 pits and 340 sales and distribution yards in 50 States. Leading producing States were California, Texas, Arizona, Washington, Michigan, Minnesota, Colorado, Ohio, Wisconsin, and Utah, in order of decreasing tonnage, which together accounted for about 55% of total output. It is estimated that about 44% of construction sand and gravel was used as concrete aggregates; 24%, for road base and coverings and road stabilization; 12%, as asphaltic concrete aggregates and other bituminous mixtures; 12%, as construction fill; and 4%, for other miscellaneous uses. The remaining 4% was used for concrete products, filtration, golf course maintenance, plaster and gunite sands, railroad ballast, road stabilization, roofing granules, and snow and ice control.

The estimated output of construction sand and gravel in the United States shipped for consumption in the first 9 months of 2018 was 720 million tons, an increase of 7% compared with that of the same period of 2017. Third quarter shipments for consumption increased by 8% compared with those of the same period of 2017. Additional production information by quarter for each State, geographic region, and the United States is published by the U.S. Geological Survey (USGS) in its quarterly Mineral Industry Surveys for Crushed Stone and Sand and Gravel.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017[e]**	**2018[e]**
Production	830	881	888	900	970
Imports for consumption	4	4	3	7	6
Exports	([2])	([2])	([2])	([2])	([2])
Consumption, apparent[3]	833	885	892	910	980
Price, average value, dollars per metric ton	8.04	8.28	8.40	8.64	8.94
Employment, mine and mill, number[4]	34,600	34,800	35,300	36,500	36,200
Net import reliance[5] as a percentage of apparent consumption	([2])	([2])	([2])	1	1

Import Sources (2014–17): Canada, 94%; Mexico, 3%; China, 1%; Norway, 1%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Sand, other	2505.90.0000	Free.
Pebbles and gravel	2517.10.0015	Free.

Depletion Allowance: Common varieties, 5% (Domestic and foreign).

Government Stockpile: None.

Prepared by **Jason Christopher Willett [(703) 648–6473, jwillett@usgs.gov]**

SAND AND GRAVEL (CONSTRUCTION)

Events, Trends, and Issues: Construction sand and gravel production was about 970 million tons in 2018, an increase of 8% compared with that of 2017. Apparent consumption also increased by 7% to 980 million tons. Demand for construction sand and gravel increased in 2018 because of growth in the private and public construction markets, especially after this segment being flat during the past 2 years. Commercial and heavy-industrial construction activity, infrastructure funding, new single-family housing unit starts, and weather affect growth in sand and gravel production and consumption. Long-term increases in construction aggregates demand will be influenced by activity in the public and private construction sectors, as well as by construction work related to security measures being implemented around the Nation. The underlying factors that would support a rise in prices of construction sand and gravel are expected to be present in 2019, especially in and near metropolitan areas.

The construction sand and gravel industry remained concerned with environmental, health, permitting, safety, and zoning regulations. Movement of sand and gravel operations away from densely populated regions was expected to continue where regulations and local sentiment discouraged them. Resultant regional shortages of construction sand and gravel would likely result in higher-than-average price increases in industrialized and urban areas.

World Mine Production and Reserves:

	Mine production[e]		Reserves[6]
	2017	2018	
United States	900	970	Reserves are controlled largely by land use and (or) environmental concerns.
Other countries[7]	NA	NA	
World total	NA	NA	

World Resources: 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 uneconomic 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 2018.

[e]Estimated. NA Not available.
[1]See also Sand and Gravel (Industrial) and Stone (Crushed).
[2]Less than ½ unit.
[3]Defined as production + imports – exports.
[4]Including office staff. Source: Mine Safety and Health Administration.
[5]Defined as imports – exports.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]No reliable production information is available for most countries owing to the wide variety of ways in which countries report their sand and gravel production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the USGS Minerals Yearbook, Volume III, Area Reports: International.

SAND AND GRAVEL (INDUSTRIAL)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2018, industrial sand and gravel valued at about $6.2 billion was produced by about 191 companies from 321 operations in 35 States. The value of production of industrial sand and gravel in 2018 increased by 22% compared with that of the previous year, and by 130% compared with 2016, owing primarily to increased demand for hydraulic-fracturing sand for the oil and gas sector. Leading States were Wisconsin, Texas, Illinois, Missouri, Minnesota, Oklahoma, North Carolina, Mississippi, Iowa, and Arkansas, in order of tonnage produced. Combined production from these States accounted for 87% of the domestic total. About 73% of the U.S. tonnage was used as hydraulic-fracturing sand and well-packing and cementing sand; as glassmaking sand and other whole-grain silica, 7% each; as foundry sand, 4%; as other ground silica, and whole-grain fillers and building products, 2% each; as ground and unground sand for chemicals, filtration sand, and recreational sand, 1% each; and for other uses, 2%.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Sold or used	110,000	102,000	79,400	102,000	120,000
Imports for consumption	245	289	281	365	370
Exports	4,470	3,910	2,780	4,680	7,000
Consumption, apparent[2]	106,000	98,400	76,900	97,700	110,000
Price, average value, dollars per ton	74.80	47.30	35.40	52.60	53.10
Employment, quarry and mill, number[e]	4,000	3,500	3,500	4,000	4,000
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Some foundry sand is recycled, and recycled cullet (pieces of glass) represents a significant proportion of reused silica. About 34% of glass containers are recycled.

Import Sources (2014–17): Canada, 86%; Mexico, 1%; and other, 13%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
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 an estimated 110 million tons in 2018, a 13% increase from that of the previous year, owing primarily to increased activity in the oil and gas sector. Mine output was sufficient to accommodate many uses, which included abrasives, ceramics, chemicals, fillers (ground and whole-grain), glassmaking sand, filtration sand for swimming pools, foundry sand, other ground silica, recreational sand, roofing granules and fillers, and sand for well packing and cementing. Increased oil and gas drilling in North America and oil well completion activity triggered a corresponding increase in the production of hydraulic-fracturing sand in 2018 compared with that of the previous year. More efficient hydraulic-fracturing techniques, which require more silica sand use per well (mostly for secondary recovery at mature wells) also led to increased demand for hydraulic-fracturing sand. Imports of industrial sand and gravel in 2018 were about 370,000 tons—essentially unchanged from those of 2017. Imports of silica are generally of two types—small shipments of very high-purity silica or a few large shipments of lower grade silica shipped only under special circumstances (for example, very low freight rates). The United States remains a net exporter of industrial sand and gravel; U.S. exports of industrial sand and gravel increased by 50% in 2018 compared with those of 2017.

The United States was the world's leading producer and consumer of industrial sand and gravel based on estimated world production figures. It is difficult to collect definitive data on silica sand and gravel production in most nations because of the wide range of terminology and specifications found among different countries. The United States remained a major exporter of silica sand and gravel, shipping it to almost every region of the world. The high level of exports was attributed to the high quality and advanced processing techniques used in the United States for many grades of silica sand and gravel, meeting virtually every specification.

Prepared by **Thomas P. Dolley [(703) 648–7710, tdolley@usgs.gov]**

SAND AND GRAVEL (INDUSTRIAL)

The industrial sand and gravel industry continued to be concerned with safety and health regulations and environmental restrictions in 2018, especially those concerning crystalline silica exposure. The Occupational Safety and Health Administration finalized new regulations to further restrict exposure to crystalline silica at mine sites and other industries that use it. Phased implementation of the new regulations is scheduled to take effect through 2021. Most provisions of the new regulations became enforceable on June 23, 2018, for general industry and maritime operations. Local shortages of industrial sand and gravel were expected to continue to increase owing to land development priorities, local zoning regulations, and logistical issues, including ongoing development and permitting of operations producing hydraulic-fracturing sand. Natural gas and petroleum operations that use hydraulic fracturing may also undergo increased scrutiny. These factors may result in future sand and gravel operations being located farther from high-population centers.

World Mine Production and Reserves:

	Mine production[e]		Reserves[4]
	2017	2018	
United States	102,000	120,000	Large. Industrial sand and gravel deposits are widespread.
Australia	3,000	3,000	
Bulgaria	7,250	7,300	
Canada	2,300	2,300	
France	9,310	9,300	
Germany	7,500	7,500	
India	8,500	8,500	
Italy	14,000	14,000	
Japan	2,700	2,700	
Korea, Republic of	4,480	4,500	
Malaysia	10,000	10,000	
Mexico	2,400	2,400	
Netherlands	54,000	54,000	
New Zealand	2,320	2,300	
Poland	4,800	4,800	
South Africa	1,900	2,200	
Spain	6,300	6,300	
Turkey	10,500	15,000	
United Kingdom	4,000	4,000	
Other countries	15,700	16,000	
World total (rounded)	273,000	300,000	

World Resources: 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 uneconomic. Quartz-rich sand and sandstone, the main sources of industrial silica sand, occur throughout the world.

Substitutes: Alternative materials that can be used for glassmaking and for foundry and molding sands are chromite, olivine, staurolite, and zircon sands. Although costlier and mostly used in deeper wells, alternative materials that can be used as proppants are sintered bauxite and kaolin-based ceramic proppants.

[e]Estimated. E Net exporter.
[1]See also Sand and Gravel (Construction).
[2]Defined as production + imports – exports.
[3]Defined as imports – exports.
[4]See Appendix C for resource and reserve definitions and information concerning data sources.

SCANDIUM[1]

(Data in metric tons of scandium oxide equivalent unless otherwise noted)

Domestic Production and Use: Domestically, scandium-bearing minerals were neither mined nor recovered from mine tailings in 2018. Previously, scandium was produced domestically primarily from the scandium-yttrium silicate mineral thortveitite and from byproduct leach solutions from uranium operations. Limited capacity to produce ingot and distilled scandium metal existed at facilities in Ames, IA; Tolleson, AZ; and Urbana, IL. The principal source for scandium metal and scandium compounds was imports from China. The principal uses for scandium in 2018 were in aluminum-scandium alloys and solid oxide fuel cells (SOFCs). Other uses for scandium included ceramics, electronics, lasers, lighting, and radioactive isotopes. In SOFCs, electricity is generated directly from oxidizing a fuel. For metal applications, scandium metal is typically produced by reducing scandium fluoride with calcium metal. Aluminum-scandium alloys are produced for sporting goods, aerospace, and other high-performance applications. Aluminum-magnesium-scandium alloys have been developed for use in additive manufacturing. Scandium is added to a zirconia-base electrolyte to improve the power density and to lower the reaction temperature of the SOFC. Scandium is used in small quantities in a number of electronic applications. Some lasers that contain scandium are used in defense applications and in medical treatments. In lighting, scandium iodide is used in high-intensity lights to simulate natural light. Scandium isotopes are used as a tracing agent in oil refining.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Price, yearend, dollars:					
Compounds, per gram:					
Acetate, 99.9% purity, 5-gram sample size[2]	43.00	43.00	44.00	44.00	44.00
Chloride, 99.9% purity, 5-gram sample size[2]	123.00	123.00	126.00	124.00	125.00
Fluoride, 99.9% purity, 1-to-5-gram sample size	[2]263.00	[2]263.00	[3]270.00	[3]277.00	[3]206.00
Iodide, 99.999% purity, 5-gram sample size[2]	187.00	187.00	149.00	183.00	165.00
Oxide, 99.99% purity, 5-kilogram lot size[4]	5.00	5.10	4.60	4.60	4.60
Metal:					
Scandium, distilled dendritic, per gram, 2-gram sample size[2]	221.00	221.00	228.00	226.00	226.00
Scandium, ingot, per gram, 5-gram sample size[2]	134.00	134.00	107.00	132.00	132.00
Scandium-aluminum alloy, per kilogram, metric-ton lot size[4]	386.00	220.00	340.00	350.00	360.00
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2014–17): Although no definitive data exist listing import sources, imported material is mostly from Europe, China, Japan, and Russia.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–18**
Rare-earth metals, unspecified, whether or not intermixed or interalloyed	2805.30.0090	5.0% ad val.
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 val.
Mixtures of other rare-earth compounds, including scandium	2846.90.8090	3.7% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Prepared by **Joseph Gambogi [(703) 648–7718, jgambogi@usgs.gov]**

SCANDIUM

Events, Trends, and Issues: The global supply and consumption of scandium was estimated to be about 10 tons to 15 tons per year. Consumption of scandium contained in SOFCs and nonferrous alloys was reported to be within this same range. Prices quoted for most scandium products in the United States were generally unchanged or decreased compared with those in 2017. In China, ex-works prices for scandium oxide were significantly less than domestic quoted prices.

Although global exploration and development projects continued in anticipation of increased demand, the global scandium market remained small relative to most other metals. In the United States, following the completion of a feasibility study in 2017 for the polymetallic Elk Creek project in Nebraska, permitting and engineering studies were ongoing. Other domestic projects that included scandium recovery in their process plans were the Bokan project in Alaska and the Round Top project in Texas. The U.S. Department of Energy was funding the development of methods to separate scandium from coal and coal byproducts. In Australia, the Nyngan project and Syerston project in New South Wales were under development while seeking project financing and offtake agreements. Reserves at Nyngan were estimated to be 1.44 million tons containing about 590 tons of scandium using an effective cutoff grade of 155 parts per million scandium. Subject to financing, the developer expected to begin production in 2020 and was expected to produce as much as 38.5 tons per year of scandium oxide. The Syerston project's measured and indicated scandium resources increased 63% to 45.7 million tons containing 19,200 tons of scandium oxide equivalent using a 300-parts-per-million scandium cutoff grade. In Queensland, the Scandium-Cobalt-Nickel (SCONI) Project was nearing completion of a bankable feasibility study and updated resource estimate at yearend. The prior measured and indicated resources of the SCONI Project were estimated at 12 million tons containing about 3,000 tons of scandium oxide using a 162-parts-per-million scandium cutoff grade. In India, a project to construct a 2.4-ton-per-year scandium oxide plant awaited environmental approval. In the Philippines, a plant to recover 7.5 tons per year of scandium oxide equivalent was being commissioned at the Taganito high-pressure acid-leach nickel operation. Production of an intermediate concentrate was expected to increase in 2019. In Russia, an aluminum producer was commercializing a hybrid technology for producing scandium-aluminum master alloy and developing new aluminum alloy formulations for additive manufacturing. Feasibility studies for making scandium oxide as a byproduct of alumina refining in the Ural Mountains were ongoing. The pilot plant was reported to have produced scandium oxide with purity greater than 99%. Based on pilot test results, plans were in place for a 3-ton-per-year scandium oxide plant. In Dalur, Kurgan region, development of scandium recovery as a byproduct of uranium production continued, and a 1.5-ton-per-year plant produced finished scandium oxide in 2018. In the European Union, recovery methods were being developed to produce scandium compounds and aluminum alloys from ores and byproducts. Globally, several projects were underway to commercialize new aluminum-scandium alloys for casting and additive manufacturing.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including scandium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

World Mine Production and Reserves:[6] No scandium was mined 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. In recent years, scandium was produced as byproduct material in China (iron ore, rare earths, titanium, and zirconium), Kazakhstan (uranium), Russia (apatite and uranium), and Ukraine (uranium). Foreign mine production data for 2018 were not available.

World Resources: Resources of scandium are abundant. Scandium's crustal abundance is greater than that of lead. Scandium lacks affinity for the common ore-forming anions; therefore, it is widely dispersed in the lithosphere and forms solid solutions with low concentrations in more than 100 minerals. There are identified scandium resources in Australia, Canada, China, Kazakhstan, Madagascar, Norway, the Philippines, Russia, Ukraine, and the United States.

Substitutes: Titanium and aluminum high-strength alloys, as well as carbon-fiber materials, may substitute in high-performance scandium-alloy applications. Light-emitting diodes displace mercury-vapor high-intensity lights in some industrial and residential applications. In some applications that rely on scandium's unique properties, substitution is not possible.

[e]Estimated.
[1]See also Rare Earths. Scandium is one of the 17 rare-earth elements.
[2]Prices from Alfa Aesar, a Johnson Matthey company.
[3]Prices from Sigma-Aldrich, a part of Millipore Sigma.
[4]Prices from Stanford Materials Corp.
[5]Defined as imports – exports. Quantitative data are not available.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.

SELENIUM

(Data in metric tons of selenium content unless otherwise noted)

Domestic Production and Use: Primary selenium was refined from anode slimes recovered from the electrolytic refining of copper. Of the two electrolytic copper refineries operating in the United States, only one in Texas reported production of primary selenium.

In glass manufacturing, selenium is used to decolorize the green tint caused by iron impurities in container glass and other soda-lime silica glass and is used in architectural plate glass to reduce solar heat transmission. Cadmium sulfoselenide pigments are used in ceramics, glass, and plastics to produce a ruby-red color. Selenium is used in blasting caps; in catalysts to enhance selective oxidation; in copper, lead, and steel alloys to improve machinability; in the electrolytic production of manganese to increase yields; in gun bluing to improve cosmetic appearance and provide corrosion resistance; in plating solutions, where it improves appearance and durability; in rubber compounding chemicals to act as a vulcanizing agent; and in thin-film photovoltaic copper-indium-gallium-diselenide (CIGS) solar cells.

Selenium is an essential micronutrient and is used as a human dietary supplement, a dietary supplement for livestock, and as a fertilizer additive to enrich selenium-poor soils. Selenium is also used as an active ingredient in antidandruff shampoos.

Estimates for world consumption are as follows: metallurgy (including manganese production), 40%; glass manufacturing, 25%; agriculture, 10%; chemicals and pigments, 10%; electronics, 10%; and other uses, 5%.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production, refinery	W	W	W	W	W
Imports for consumption:					
Selenium metal	467	444	411	450	390
Selenium dioxide	8	14	21	19	13
Exports,[1] metal	521	468	150	268	160
Consumption, apparent[2]	W	W	W	W	W
Price, average, dollars per pound[3]	26.78	22.09	23.69	10.78	20.00
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

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

Import Sources (2014–17): China, 19%; Philippines 13%; Germany, 13%; Japan, 12%; and other, 43%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Selenium metal	2804.90.0000	Free.
Selenium dioxide	2811.29.2000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The supply of selenium is directly affected by the supply of the materials from which it is a byproduct—copper and, to a lesser extent, nickel—and it is directly affected by the number of facilities that recover selenium. The estimated annual average price for selenium was $20.00 per pound in 2018, about 86% more than the annual average price in 2017. In the first quarter of 2018, average monthly prices increased from $12.50 per pound to $20.00 per pound. Prices then increased slightly to $20.50 per pound in June and remained level through September.

Prepared by **C. Schuyler Anderson [(703) 648–4985, csanderson@usgs.gov]**

SELENIUM

Electrolytic manganese production was the main metallurgical end use for selenium in China, where selenium dioxide was used in the electrolytic process to increase current efficiency and the metal deposition rate. Selenium consumption in China was thought to have increased in recent years; 51 electrolytic manganese producers were reported to have been operating and consuming selenium in 2017 (latest information available), up from 47 reported in 2016.

World Refinery Production and Reserves:

	Refinery production[5]		Reserves[6]
	2017	2018[e]	
United States	W	W	10,000
Belgium	200	200	—
Canada	49	50	6,000
China	930	950	26,000
Finland	105	100	—
Germany	300	300	—
Japan	729	750	—
Peru	45	45	13,000
Poland	88	90	3,000
Russia	150	150	20,000
Sweden	20	20	—
Turkey	50	50	—
Other countries	47	50	21,000
World total (rounded)	[7]2,710	[7]2,800	99,000

World Resources: Reserves for selenium are based on identified copper deposits and average selenium content. Coal generally contains between 0.5 and 12 parts per million of selenium, or about 80 to 90 times the average for copper deposits. The recovery of selenium from coal fly ash, although technically feasible, does not appear likely to be economical in the foreseeable future.

Substitutes: Silicon is the major substitute for selenium in low- and medium-voltage rectifiers. Organic pigments have been developed as substitutes for cadmium sulfoselenide pigments. Other substitutes include cerium oxide as either a colorant or decolorant in glass; tellurium in pigments and rubber; bismuth, lead, and tellurium in free-machining alloys; and bismuth and tellurium in lead-free brasses. Sulfur dioxide can be used as a replacement for selenium dioxide in the production of electrolytic manganese metal, but it is not as energy efficient.

The selenium-tellurium photoreceptors used in some plain paper copiers and laser printers have been replaced by organic photoreceptors in newer machines. Amorphous silicon and cadmium telluride are the two principal competitors with CIGS in thin-film photovoltaic solar cells.

[e]Estimated. E Net exporter. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]There was no exclusive domestic export classification code for selenium dioxide.
[2]Defined as production + imports – exports + adjustments for industry stock changes.
[3]U.S. spot market price for selenium metal powder, minimum 99.5% purity, in 5-ton lots. Source: Platts Metals Week.
[4]Defined as imports – exports + adjustments for industry stock changes; export data incomplete for common forms of selenium, and may be exported under unexpected or misidentified forms, such as copper selenide or zinc selenide.
[5]Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in blister copper, copper concentrates, copper ores, and (or) refinery residues, but did not recover refined selenium from these materials indigenously, were excluded to avoid double counting.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]Excludes U.S. production. Australia, Iran, Kazakhstan, Mexico, the Philippines, and Uzbekistan are known to produce refined selenium, but output was not reported, and information was inadequate to make reliable production estimates.

SILICON

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

Domestic Production and Use: Six companies produced silicon materials at eight plants, 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. The semiconductor and solar energy industries, which manufacture chips for computers and photovoltaic cells from high-purity silicon, respectively, accounted for only a small percentage of silicon demand.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Ferrosilicon and silicon metal[1, 2]	401	411	384	415	430
Imports for consumption:					
Ferrosilicon, all grades[1]	186	162	155	147	158
Silicon metal	139	140	122	136	118
Exports:					
Ferrosilicon, all grades[1]	9	9	7	11	12
Silicon metal	45	37	60	71	41
Consumption, apparent:[3]					
Ferrosilicon, all grades[1]	W	W	W	W	W
Silicon metal[2]	W	W	W	W	W
Total	670	661	601	616	660
Price, average, cents per pound of silicon:					
Ferrosilicon, 50% Si[4]	108	101	83	94	104
Ferrosilicon, 75% Si[5]	98	88	71	87	108
Silicon metal[2, 5]	140	127	91	117	138
Stocks, producer, yearend:					
Ferrosilicon and metal[1, 2]	27	33	26	26	25
Net import reliance[6] as a percentage of apparent consumption:					
Ferrosilicon, all grades[1]	<50	>50	>50	<50	<50
Silicon metal[2]	<50	<50	<50	<50	<50
Total	42	38	36	33	34

Recycling: Insignificant.

Import Sources (2014–17): Ferrosilicon: Russia, 35%; China, 20%; Canada, 12%; Iceland, 7%; and other, 26%. Silicon metal: Brazil, 28%; South Africa, 18%; Canada, 15%; Australia, 14%; and other, 25%. Total: Russia, 19%; Brazil, 16%; Canada, 14%; China, 11%; and other, 40%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Silicon, more than 99.99% Si	2804.61.0000	Free.
Silicon, 99.00%–99.99% Si	2804.69.1000	5.3% ad val.
Silicon, other	2804.69.5000	5.5% ad val.
Ferrosilicon, 55%–80% Si:		
More than 3% Ca	7202.21.1000	1.1% ad val.
Other	7202.21.5000	1.5% ad val.
Ferrosilicon, 80%–90% Si	7202.21.7500	1.9% ad val.
Ferrosilicon, more than 90% Si	7202.21.9000	5.8% ad val.
Ferrosilicon, other:		
More than 2% Mg	7202.29.0010	Free.
Other	7202.29.0050	Free.

Prepared by **Emily K. Schnebele [(703) 648–4945, eschnebele@usgs.gov]**

SILICON

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 2018, expressed in terms of contained silicon, increased from that of 2017. Domestic production during the first 9 months of 2018 was about 7% greater than that during the same period in 2017. By September 2018, average U.S. ferrosilicon spot market prices had increased by 11% and 25% for 50%-grade and 75%-grade ferrosilicon, respectively, and the average silicon metal spot market price had increased by 19% compared with the annual average spot price in 2017.

Excluding the United States, ferrosilicon accounted for about 62% of world silicon production on a silicon-content basis. The leading countries for ferrosilicon production were, in descending order and on a contained-weight basis, China, Russia, and Norway. For silicon metal, the leading producers were China, Norway, and Brazil. China accounted for approximately 60% of total global estimated production of silicon materials in 2018.

World Production and Reserves:

	Production[e, 7]		Reserves[8]
	2017	2018	
United States	415	430	The reserves in most major producing countries are ample in relation to demand. Quantitative estimates are not available.
Bhutan[9]	55	65	
Brazil	170	190	
Canada	54	54	
China	4,000	4,000	
France	126	130	
Iceland[9]	76	76	
India[9]	59	62	
Malaysia[9]	113	140	
Norway	375	380	
Russia	670	670	
South Africa	65	65	
Spain	69	69	
Ukraine[9]	60	52	
Other countries	274	300	
World total (rounded)	6,580	6,700	

World Resources: 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. W Withheld to avoid disclosing company proprietary data.
[1]Ferrosilicon grades include the two standard grades of ferrosilicon—50% and 75% silicon—plus miscellaneous silicon alloys.
[2]Metallurgical-grade silicon metal.
[3]Defined as production + imports – exports + adjustments for industry stock changes.
[4]CRU Group transaction prices based on weekly averages.
[5]S&P Global Platts mean import prices based on monthly averages.
[6]Defined as imports – exports + adjustments for industry stock changes.
[7]Production quantities are the silicon content of combined totals for ferrosilicon and silicon metal, except as noted.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.
[9]Silicon content of ferrosilicon only.

SILVER

(Data in metric tons[1] of silver content unless otherwise noted)

Domestic Production and Use: In 2018, U.S. mines produced approximately 900 tons of silver with an estimated value of $440 million. Silver was produced at 4 silver mines and as a byproduct or coproduct from 38 domestic base- and precious-metal mines. 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 1,800 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 2018, the estimated domestic uses for silver were electrical and electronics, 26%; jewelry and silverware, 26%; coins and medals, 13%; photography, 4%; and other, 31%. 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; photovoltaic solar cells; water purification; and wood treatment. Mercury and silver, the main components of dental amalgam, are biocides, and their use in amalgam inhibits recurrent decay.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production:					
Mine	1,180	1,090	1,140	1,030	900
Refinery:					
Primary	800	800	800	800	800
Secondary (new and old scrap)	1,400	1,200	1,300	1,150	1,000
Imports for consumption[2]	5,000	5,930	6,160	5,040	5,400
Exports[2]	380	818	289	157	160
Consumption, apparent[3]	6,930	8,000	7,590	5,180	5,500
Price, average, dollars per troy ounce[4]	19.09	15.72	17.20	17.07	15.30
Stocks, yearend:					
Industry	120	130	140	150	170
Treasury[5]	498	498	498	498	498
New York Commodities Exchange—COMEX	5,610	5,000	5,710	7,570	9,150
Employment, mine and mill, number[6]	1,185	1,204	1,189	896	946
Net import reliance[7] as a percentage of apparent consumption	63	71	68	58	65

Recycling: In 2018, approximately 1,000 tons of silver was recovered from new and old scrap, about 18% of apparent consumption.

Import Sources (2014–17):[2] Mexico, 50%; Canada, 27%; Peru, 5%; Republic of Korea, 4%; and other, 14%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Silver ores and concentrates, silver content	2616.10.0040	0.8 ¢/kg on lead content.
Bullion, silver content	7106.91.1010	Free.
Dore, silver content	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 2018 was $15.30 per troy ounce, 10% lower than the average price in 2017. The price began the year at $17.15 per troy ounce, increased to a high of $17.52 per troy ounce on January 25, and then fell to a low of $14.00 per troy ounce on November 14. The silver price range over the course of 2018 remained consistent compared with that in 2017 from January through June when prices began declining into mid-November where they settled around $14.50 per troy ounce for the remainder of the year.

Prepared by **Shawnna M. Bennett [(703) 648–7715, smbennett@usgs.gov]**

SILVER

In 2018, global consumption of silver was estimated to have decreased slightly from that of 2017. Coin and bar consumption was projected to decrease significantly for the second year in a row. This comes after record high sales in 2015. Jewelry and silverware, photography, and photovoltaics were also estimated to decrease in 2018. Of the industrial uses, consumption of silver for brazing and alloys, and electronics was expected to increase in 2018.[8] Global yearend stocks of refined silver continued to increase and were projected to be at a 10-year high for a third consecutive year owing to a reduction of consumption in physical silver.

World silver mine production increased slightly in 2018 to an estimated 27,000 tons, principally as a result of increased production from mines in Argentina, China, and Russia. The world's top silver-producing companies experienced reductions in production owing to governmental issues with licensing, illegal mining operations, increasing tariffs, reduced ore grades, and worker strikes at various projects. Domestic silver mine production decreased by 12% in 2018 compared with that in 2017 owing to a strike at one of the four primary silver mines in the United States, which began in the second quarter of 2017, and to decreased production at mining operations in Alaska. With physical demand down and a moderate price for silver, the development of new projects has slowed as well.

World Mine Production and Reserves: Reserves for Chile, China, Peru, Poland, and Russia were revised based on new information from official Government sources.

	Mine production		Reserves[9]
	2017	2018[e]	
United States	1,030	900	25,000
Argentina	1,020	1,100	NA
Australia	1,200	1,200	[10]89,000
Bolivia	1,240	1,200	22,000
Chile	1,260	1,300	26,000
China	3,500	3,600	41,000
Mexico	6,110	6,100	37,000
Peru	4,300	4,300	110,000
Poland	1,290	1,300	110,000
Russia	1,120	1,200	45,000
Other countries	4,770	4,800	57,000
World total (rounded)	26,800	27,000	560,000

World Resources: Although silver was a principal product at several mines, silver was primarily obtained as a byproduct from lead-zinc mines, copper mines, and gold mines, in descending order of production. The polymetallic ore deposits from which silver was recovered account for more than two-thirds of U.S. and world resources of silver. Most recent silver discoveries have been associated with gold occurrences; however, copper and lead-zinc occurrences that contain byproduct silver will continue to account for a significant share of reserves and resources in the future.

Substitutes: Digital imaging, film with reduced silver content, silverless black-and-white film, and xerography substitute for traditional photographic applications for silver. Surgical pins and plates may be made with stainless steel, tantalum, and titanium in place of silver. Stainless steel may be substituted for silver flatware. Nonsilver batteries may replace silver batteries in some applications. Aluminum and rhodium may be used to replace silver that was traditionally used in mirrors and other reflecting surfaces. Silver may be used to replace more costly metals in catalytic converters for off-road vehicles.

[e]Estimated. NA Not available.
[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.
[2]Silver content of base metal ores and concentrates, refined bullion, and dore; excludes coinage, and waste and scrap material.
[3]Defined as mine production + secondary production + imports – exports + adjustments for COMEX, Government, and industry stock changes.
[4]Engelhard's industrial bullion quotations. Source: Platts Metals Week.
[5]Balance in U.S. Mint only; includes deep storage and working stocks.
[6]Source: U.S. Department of Labor, Mine Safety and Health Administration. Only includes mines where silver is the primary product.
[7]Defined as imports – exports + adjustments for COMEX, Government, and industry stock changes.
[8]Wiebe, Johann, 2018, Silver survey update 2018—The Silver Institute—2018 interim report: GFMS, Thompson Reuters, November 15, 2 p.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.
[10]For Australia, Joint Ore Reserves Committee-compliant reserves were about 26,000 tons.

SODA ASH

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The total value of domestic natural soda ash (sodium carbonate) produced in 2018 was estimated to be about $1.8 billion.[1] U.S. production of 12 million tons was equal to that of the previous year but about 900,000 tons higher than production in 2012. The U.S. soda ash industry comprised four companies in Wyoming operating five plants and one company in California with one plant. The five producing companies have a combined annual nameplate capacity of 13.9 million tons (15.3 million short tons). Borax, salt, and sodium sulfate were produced as coproducts of sodium carbonate production in California. Chemical caustic soda, sodium bicarbonate, and sodium sulfite were manufactured as coproducts at several of the Wyoming soda ash plants. Sodium bicarbonate was produced at an operation in Colorado using soda ash feedstock shipped from the company's Wyoming facility.

Based on 2018 quarterly reports, the estimated distribution of soda ash by end use was glass, 48%; chemicals, 30%; distributors, 6%; miscellaneous uses, 6%; soap and detergents, 5%; flue gas desulfurization, 3%; pulp and paper, 1%; and water treatment, 1%.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production[2]	11,700	11,600	11,800	12,000	12,000
Imports for consumption	39	40	35	19	16
Exports	6,670	6,400	6,760	6,990	6,900
Consumption:					
Apparent[3]	5,100	5,200	5,010	5,040	5,100
Reported	5,170	4,990	5,120	4,910	4,900
Price:					
Average sales value (natural source):					
f.o.b. mine or plant, dollars per metric ton	148.67	155.30	149.83	146.26	149.00
f.o.b. mine or plant, dollars per short ton	134.87	140.88	135.92	132.68	135.00
Stocks, producer, yearend	271	285	336	293	300
Employment, mine and plant, number[e]	2,500	2,500	2,500	2,600	2,600
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 (2014–17): Germany, 48%; Italy, 16%; United Kingdom, 13%; Mexico, 7%; and other, 16%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Disodium carbonate	2836.20.0000	1.2% ad val.

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

Government Stockpile: None.

Prepared by **Wallace P. Bolen [(703) 648–7727, wbolen@usgs.gov]**

SODA ASH

Events, Trends, and Issues: Relatively low production costs and lower environmental impacts provide natural soda ash producers some advantage over producers of synthetic soda ash. The production of synthetic soda ash normally consumes more energy and releases more carbon dioxide than that of natural soda ash. In recent years, U.S. producers of natural soda ash were able to expand their markets when several synthetic soda ash plants were closed or idled around the world.

Soda ash production in Turkey rose in 2018 when a 2.5-million-ton-per-year plant opened all of its production lines after several months of operational delays. Total production capacity in Turkey is estimated to be between 4 million and 5 million tons and soda ash shipments, especially for export, are expected to increase significantly over the next few years.

Three groups dominate production and have become the world's leading suppliers of soda ash—American National Soda Ash Corp., which represented three of the five domestic producers in 2018; multiple producers in China; and Solvay S.A. of Belgium. The United States likely will remain competitive with producers in China for markets elsewhere in Asia. Asia and South America remain the most likely areas for increased soda ash consumption in the near future. U.S. producers expect modest growth in production and exports through 2020.

World Production and Reserves:

	Mine production		Reserves[5, 6]
Natural:	2017	2018[e]	
United States	12,000	12,000	[7]23,000,000
Botswana	227	230	400,000
Ethiopia	8	8	NA
Kenya	310	320	7,000
Turkey	2,000	2,200	840,000
Other countries	NA	NA	280,000
World total, natural (rounded)	14,500	15,000	25,000,000
World total, synthetic (rounded)	39,500	40,000	XX
World total (rounded)	54,000	55,000	XX

World Resources: Natural soda ash is obtained from trona and sodium carbonate-rich brines. The world's largest deposit of trona is in the Green River Basin of Wyoming. About 47 billion tons of identified soda ash resources could be recovered from the 56 billion tons of bedded trona and the 47 billion tons of interbedded or intermixed trona and halite, which are in beds more than 1.2 meters thick. Underground room-and-pillar mining, using conventional and continuous mining, is the primary method of mining Wyoming trona ore. This method has an average 45% mining recovery, whereas average recovery from solution mining is 30%. Improved solution-mining techniques, such as horizontal drilling to establish communication between well pairs, could increase this extraction rate and enable companies to develop some of the deeper trona beds. Wyoming trona resources are being depleted at the rate of about 15 million tons per year (8.3 million tons of soda ash). Searles Lake and Owens Lake in California contain an estimated 815 million tons of soda ash reserves. At least 95 natural sodium carbonate deposits have been identified in the world, 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 yields 1 ton of sodium carbonate.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]From trona, nahcolite, and dawsonite deposits.

STONE (CRUSHED)[1]

(Data in million metric tons unless otherwise noted)

Domestic Production and Use: In 2018, 1.40 billion tons of crushed stone valued at more than $16.6 billion was produced by an estimated 1,465 companies operating 3,710 quarries and 176 sales and (or) distribution yards in 50 States. Leading States were, in descending order of production, Texas, Pennsylvania, Florida, North Carolina, Ohio, Missouri, Georgia, Virginia, Tennessee, and Illinois, which together accounted for more than one-half of the total crushed stone output. Of the total domestic crushed stone produced in 2018, about 68% was limestone and dolomite; 15%, granite; 6%, traprock; 5%, miscellaneous stone; 4%, sandstone and quartzite; and the remaining 2% was divided, in descending order of tonnage, among marble, volcanic cinder and scoria, calcareous marl, slate, and shell. It is estimated that of the 1.5 billion tons of crushed stone consumed in the United States in 2018, 75% was used as construction material, mostly for road construction and maintenance; 13% for cement manufacturing; 7% for lime manufacturing; 3% for other chemical, special, and miscellaneous uses and products; and 2% for agricultural uses.

The estimated output of crushed stone in the United States shipped for consumption in the first 9 months of 2018 was 1.0 billion tons, an increase of 3% compared with that of the same period of 2017. Third quarter shipments for consumption increased by 4% compared with those of the same period of 2017. Additional production information, by quarter for each State, geographic division, and the United States, is reported in the U.S. Geological Survey quarterly Mineral Industry Surveys for Crushed Stone and Sand and Gravel.

Salient Statistics—United States:	2014	2015	2016	2017[e]	2018[e]
Production	1,250	1,340	1,360	1,350	1,400
Recycled material	40	48	49	49	50
Imports for consumption	18	20	20	19	22
Exports	(2)	(2)	1	1	(2)
Consumption, apparent[3]	1,310	1,410	1,430	1,420	1,470
Price, average value, dollars per metric ton	10.19	10.56	11.14	11.50	11.90
Employment, quarry and mill, number[4]	65,600	67,100	68,100	68,600	67,200
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 2018, asphalt and portland cement concrete road surfaces were recycled in all 50 States.

Import Sources (2014–17): Mexico, 56%; Canada, 28%; The Bahamas, 10%; Honduras, 5%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
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.

Prepared by **Jason Christopher Willett [(703) 648–6473, jwillett@usgs.gov]**

STONE (CRUSHED)

Depletion Allowance: (Domestic) 14% for some special uses; 5%, if used as ballast, concrete aggregate, riprap, road material, and similar purposes.

Government Stockpile: None.

Events, Trends, and Issues: Crushed stone production was about 1.40 billion tons in 2018, an increase of 3% compared with that of 2017. Apparent consumption also increased to about 1.47 billion tons. Consumption of crushed stone increased in 2018 because of growth in the private and public construction markets, following 2 years of little growth in the segment. Commercial and heavy industrial construction activity, infrastructure funding, new single-family housing unit starts, and weather, affect growth in crushed stone production and consumption. Long-term increases in construction aggregates demand are influenced by activity in the public and private construction sectors, as well as by construction work related to security measures being implemented around the Nation. The underlying factors that would support a rise in prices of crushed stone are expected to be present in 2019, especially in and near metropolitan areas.

The crushed stone industry continued to be concerned with environmental, health, and safety regulations. 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 locate away from large population centers.

World Mine Production and Reserves:

	Mine production[e]		Reserves[6]
	2017	2018	
United States	1,350	1,400	Adequate, except where special
Other countries[7]	NA	NA	types are needed or where
World total	NA	NA	local shortages exist.

World Resources: Stone resources are plentiful throughout the world. 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 2018.

[e]Estimated. NA Not available.
[1]See also Sand and Gravel (Construction) and Stone (Dimension).
[2]Less than ½ unit.
[3]Defined as production + recycled material + imports – exports.
[4]Including office staff. Source: Mine Safety and Health Administration.
[5]Defined as imports – exports.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]Consistent production information is not available for other countries owing to a wide variety of ways in which countries report their crushed stone production. Some countries do not report production for this mineral commodity. Production information for some countries is available in the U.S. Geological Survey Minerals Yearbook, Volume III, Area Reports: International.

STONE (DIMENSION)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Approximately 2.8 million tons of dimension stone, valued at $450 million, was sold or used by U.S. producers in 2018. Dimension stone was produced by 195 companies operating 251 quarries in 34 States. Leading producer States were, in descending order by tonnage, Texas, Indiana, Wisconsin, Massachusetts, and Georgia. These five States accounted for about 69% of the production quantity and contributed about 59% of the value of domestic production. Approximately 48%, by tonnage, of dimension stone sold or used was limestone, followed by sandstone (23%), granite (18%), miscellaneous stone (7%), and marble and slate (2% each). By value, the leading sales or uses were for limestone (46%), followed by granite (25%), sandstone (12%), miscellaneous stone (8%), slate (5%), and marble (4%). Rough stone represented 58% of the tonnage and 45% 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 (51%) and in irregular-shaped stone (38%). The leading uses and distribution of dressed stone, by tonnage, were in ashlars and partially squared pieces (43%), flagging (14%), and slabs and blocks for building and construction (11%).

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Sold or used by producers:[2]					
Tonnage	2,470	2,630	2,790	2,810	2,800
Value, million dollars	470	461	445	446	450
Imports for consumption, value, million dollars	2,230	2,380	2,170	2,110	2,100
Exports, value, million dollars	70	75	66	70	71
Consumption, apparent, value, million dollars[3]	2,630	2,760	2,550	2,490	2,500
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	4,000	4,000	4,000	3,900	3,900
Net import reliance[5] as a percentage of apparent consumption (based on value)	82	84	83	82	82
Granite only, sold or used by producers:					
Tonnage	519	585	593	504	500
Value, million dollars	117	130	130	110	110
Imports, value, million dollars	1,330	1,330	1,100	1,010	1,000
Exports, value, million dollars	32	27	21	22	22
Consumption, apparent, value, million dollars[3]	1,420	1,430	1,210	1,100	1,100
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	880	880	880	800	800
Net import reliance[5] as a percentage of apparent consumption (based on value)	91	91	89	89	90

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

Import Sources (2014–17 by value): All dimension stone: Brazil, 25%; China, 25%; Italy, 22%; Turkey, 14%; and other, 14%. Granite only: Brazil, 47%; China, 24%; India, 16%; Italy, 9%; and other, 4%.

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 2018. Most crude or roughly trimmed stone was imported at 3.7% ad valorem or less.

Depletion Allowance: 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.

Prepared by **Thomas P. Dolley [(703) 648–7710, tdolley@usgs.gov]**

STONE (DIMENSION)

Events, Trends, and Issues: The United States remained one of the world's leading markets for dimension stone. In 2018, total imports of dimension stone were unchanged in value compared with those in 2017. In 2018, mixed to steady activity in new residential construction resulted in essentially unchanged domestic production of dimension stone compared with the previous year. Dimension stone for construction and refurbishment was used in commercial and residential markets; in 2018, the renovation market for existing homes remained steady and unchanged compared with that in the previous year. These factors contributed to a slight decline in dimension stone imports. Dimension stone exports increased to about $71 million. Apparent consumption, by value, was estimated to be $2.5 billion in 2018—about the same as that of 2017.

The dimension stone industry continued to be concerned with safety and health regulations and environmental restrictions in 2018, 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 industries that use materials containing it. Phased implementation of the new regulations was scheduled to take effect through 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.

Although some small-scale production was likely in many nations, dimension granite and marble was produced and officially reported in 27 countries. The leading five producing countries, in descending order by tonnage, were thought to be China, India, Turkey, Iran, and Italy.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2017	2018[e]	
United States	2,810	2,800	Adequate, except for certain
Other countries	NA	NA	special types and local
World total	NA	NA	shortages.

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

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

[e]Estimated. NA Not available.
[1]See also Stone (Crushed).
[2]Includes granite, limestone, and other types of dimension stone.
[3]Defined as sold or used (value) + imports (value) – exports (value).
[4]Excludes office staff.
[5]Defined as imports – exports.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.

STRONTIUM

(Data in metric tons of strontium content unless otherwise noted)

Domestic Production and Use: Although deposits of strontium minerals occur widely throughout the United States, none have been mined in the United States since 1959. Domestic production of strontium carbonate, the principal strontium compound, ceased in 2006. It is thought that virtually all of the strontium mineral celestite consumed in the United States since 2006 has been used as an additive in drilling fluids for oil and natural gas wells. A few domestic companies produced small quantities of downstream strontium chemicals from imported strontium carbonate.

Based on import data, the estimated end-use distribution in the United States for strontium, including celestite and strontium compounds, was, in descending order, drilling fluids, 70%; ceramic ferrite magnets, and pyrotechnics and signals, 9% each; electrolytic production of zinc, master alloys, pigments and fillers, and other applications, including glass, 3% each.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production	—	—	—	—	—
Imports for consumption:					
Celestite[1]	24,200	24,500	4,420	11,300	21,000
Strontium compounds[2]	7,600	7,100	6,420	6,660	6,800
Exports, strontium compounds	104	86	91	36	37
Consumption, apparent:					
Celestite	24,200	24,500	4,420	11,300	21,000
Strontium compounds	7,500	7,020	6,330	6,620	6,800
Total	31,700	31,500	10,700	17,900	28,000
Price, average value of celestite imports at port of exportation, dollars per ton	50	51	78	74	75
Net import reliance[3] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2014–17): Celestite: Mexico, 100%. Strontium compounds: Mexico, 52%; Germany, 39%; China, 6%; and other, 3%. Total imports: Mexico, 86%; Germany, 12%; and China, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Celestite	2530.90.8010	Free.
Strontium compounds:		
Strontium metal	2805.19.1000	3.7% ad val.
Strontium oxide, hydroxide, peroxide	2816.40.1000	4.2% ad val.
Strontium nitrate	2834.29.2000	4.2% ad val.
Strontium carbonate	2836.92.0000	4.2% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Prepared by **Sheryl A. Singerling [(703) 648–4954, ssingerling@usgs.gov]**

STRONTIUM

Events, Trends, and Issues: For the second year in a row, imports of celestite, the most commonly used strontium mineral, increased significantly. Imports increased by an estimated 88% in 2018 from those in 2017 and by 155% from those in 2016. The decrease in 2016 was likely the result of decreased natural gas- and oil-drilling activity owing to low gas and oil prices in 2014 and 2015. The imports of celestite correlated with the number of active drilling rigs in 2016 through 2018. Nearly all of the celestite is imported from Mexico, with the exception of a small amount of specimen samples, and is thought to be used exclusively as an additive in drilling fluids for oil and natural gas exploration and production. For these applications, celestite is ground but undergoes no chemical processing. Outside the United States, celestite is the raw material used for production of strontium compounds.

Strontium compounds include strontium carbonate, which is sintered with iron oxide to produce permanent ceramic ferrite magnets, and strontium nitrate, which contributes a brilliant red color to fireworks and signal flares. Smaller quantities of these and other strontium compounds were consumed in several other applications, including electrolytic production of zinc, glass production, master alloys, and pigments and fillers.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including strontium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

World Mine Production and Reserves:[4] Production data for celestite in Iran was added owing to a new source of Government data. Output from Iran was previously not estimated and not included in world totals.

	Mine production		Reserves[5]
	2017	2018[e]	
United States	—	—	—
Argentina	5,000	5,000	All other:
China	50,000	50,000	6,800,000
Iran	40,000	37,000	
Mexico	70,000	70,000	
Spain	90,000	100,000	
World total (rounded)	255,000	260,000	6,800,000

World Resources: World resources of strontium are thought to exceed 1 billion tons.

Substitutes: Barium can be substituted for strontium in ferrite ceramic magnets; however, the resulting barium composite will have 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. — Zero.

[1]The strontium content of celestite is 43.88%, assuming an ore grade of 92%, which was used to convert units of celestite to strontium content.

[2]Strontium compounds, with their respective strontium contents, in descending order, include metal (100.00%); oxide, hydroxide, and peroxide (70.00%); carbonate (59.35%); and nitrate (41.40%). These factors were used to convert gross weight of strontium compounds to strontium content.

[3]Defined as imports − exports.

[4]Gross weight of celestite in tons.

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

SULFUR

(Data in thousand metric tons of sulfur unless otherwise noted)

Domestic Production and Use: In 2018, recovered elemental sulfur and byproduct sulfuric acid were produced at 95 operations in 27 States. Total shipments were valued at about $670 million. Elemental sulfur production was 9.0 million tons; Louisiana and Texas accounted for about 55% of domestic production. Elemental sulfur was recovered, in descending order of tonnage, at petroleum refineries, natural-gas-processing plants, and coking plants by 35 companies at 90 plants in 26 States. Byproduct sulfuric acid, representing about 7% of production of sulfur in all forms, was recovered at five nonferrous smelters in four States by four companies. Domestic elemental sulfur provided 67% of domestic consumption, and byproduct acid accounted for about 5%. 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:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Recovered elemental	9,050	8,890	9,070	9,070	9,000
Other forms	587	646	673	575	670
Total (rounded)	9,630	9,540	9,740	9,640	9,700
Shipments, all forms	9,670	9,560	9,750	9,700	9,700
Imports for consumption:					
Recovered, elemental[e]	2,370	2,240	1,820	1,860	1,900
Sulfuric acid, sulfur content	1,000	1,160	1,050	954	1,000
Exports:					
Recovered, elemental	2,010	1,840	2,060	2,340	2,300
Sulfuric acid, sulfur content	53	58	59	83	100
Consumption, apparent, all forms[1]	11,000	11,000	10,500	10,000	10,000
Price, reported average value, dollars per ton of elemental sulfur, f.o.b., mine and (or) plant	80.07	87.62	37.88	46.40	70.00
Stocks, producer, yearend	141	138	144	124	110
Employment, mine and (or) plant, number	2,600	2,600	2,500	2,400	2,400
Net import reliance[2] as a percentage of apparent consumption	12	14	7	4	5

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 (2014–17): Elemental: Canada, 78%; Mexico, 8%; Kazakhstan, 4%; Russia, 4%; and other, 6%. Sulfuric acid: Canada, 62%; Mexico, 20%; and other, 18%. Total sulfur imports: Canada, 73%; Mexico 12%; Kazakhstan, 3%; Russia, 3%; and other, 9%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
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 2018 was estimated to have increased slightly from that of 2017 and shipments were slightly less than those of 2017. Domestic production of elemental sulfur from petroleum refineries and recovery from natural gas operations decreased slightly. Domestically, refinery sulfur production is expected to remain relatively constant as well as byproduct sulfuric acid, unless one or more of the remaining nonferrous-metal smelters close.

Domestic phosphate rock consumption in 2018 was estimated to be 9% lower than that in 2017, which resulted in decreased demand for sulfur to process the phosphate rock into phosphate fertilizers.

Prepared by **Lori E. Apodaca [(703) 648–7724, lapodaca@usgs.gov]**

SULFUR

World sulfur production was about the same as it was in 2017 but is likely to steadily increase for the foreseeable future. The largest increases in sulfur production during the next 5 years are expected to take place in India, Kuwait, and Saudi Arabia. New sulfur demand associated with phosphate fertilizer projects is expected in Brazil, China, Egypt, India, and Turkey.

Contract sulfur prices in Tampa, FL, began 2018 at around $110 per ton. The sulfur price continued to increase throughout the year and increased to about $140 per ton in mid-October. Export prices were higher than domestic prices. In the past few years, sulfur prices have been variable, a result of the volatility of the demand for sulfur.

World Production and Reserves:

	Production—All forms	
	2017	2018[e]
United States	9,640	9,700
Australia	900	900
Brazil	530	530
Canada	5,460	5,500
Chile	1,800	1,800
China[4]	17,400	17,000
Finland	940	940
Germany	888	890
India	3,430	3,400
Iran	2,200	2,200
Italy	511	510
Japan	3,490	3,500
Kazakhstan	3,520	3,500
Korea, Republic of	3,080	3,100
Kuwait	850	850
Mexico	551	550
Netherlands	520	520
Poland	1,240	1,200
Qatar	2,100	2,100
Russia	7,080	7,100
Saudi Arabia	6,000	6,000
Turkmenistan	610	610
United Arab Emirates	3,300	3,300
Venezuela	700	700
Other countries	3,460	3,500
World total (rounded)	80,200	80,000

Reserves[3]

Reserves of sulfur in crude oil, natural gas, and sulfide ores are large. Because most sulfur production is a result of the processing of fossil fuels, supplies should 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: Resources of elemental sulfur in evaporite and volcanic deposits, and sulfur associated with natural gas, petroleum, tar sands, and metal sulfides, amount to 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 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 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]China sulfur production includes byproduct elemental sulfur recovered from natural gas and petroleum, the estimated sulfur content of byproduct sulfuric acid from metallurgy, and the sulfur content of sulfuric acid from pyrite.

TALC AND PYROPHYLLITE[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Three companies operated five talc-producing mines in three States during 2018, and domestic production of crude talc was estimated to have increased slightly to 620,000 tons valued at $22.8 million. Montana was the leading producer State, followed by Texas and Vermont. Total sales (domestic and export) of talc by U.S. producers were estimated to be 540,000 tons valued at $117 million, a slight increase from those in 2017. Talc produced and sold in the United States was used in ceramics (including automotive catalytic converters) (22%), paint (21%), paper (21%), plastics (8%), roofing (4%), rubber (4%), and cosmetics (2%). The remaining 18% was for export, insecticides, refractories, and other miscellaneous uses.

One company in North Carolina mined and processed pyrophyllite in 2018. Domestic production was withheld in order to avoid disclosing company proprietary data and was estimated to have increased from that in 2017. Pyrophyllite was sold for refractory, paint, and ceramic products.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, mine	608	615	578	610	620
Sold by producers	551	535	528	528	540
Imports for consumption	308	322	378	354	300
Exports	190	206	238	220	230
Consumption, apparent[2]	669	651	668	662	610
Price, average, milled, dollars per metric ton[3]	171	186	197	214	216
Employment, mine and mill, talc[4]	230	239	223	206	208
Employment, mine and mill, pyrophyllite[4]	26	29	30	31	30
Net import reliance[5] as a percentage of apparent consumption	21	22	27	20	11

Recycling: Insignificant.

Import Sources (2014–17): Pakistan, 40%; Canada, 27%; China, 22%; and other, 11%. Large quantities of crude talc are mined in Afghanistan before being milled in and exported from Pakistan.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Natural steatite and talc:		
Not crushed, not powdered	2526.10.0000	Free.
Crushed or powdered	2526.20.0000	Free.
Talc, steatite, and soapstone; cut or sawed	6815.99.2000	Free.

Depletion Allowance: Block steatite talc: 22% (Domestic), 14% (Foreign). Other talc and pyrophyllite: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Canada, China, and Pakistan were the principal sources for United States talc imports in recent years. Imports from Pakistan increased significantly in recent years and imports from China dropped to about one-third of what they had been. In 2018, imports from China recovered and imports from Pakistan declined. Canada and Mexico continued to be the primary destinations for United States talc exports, collectively receiving about one-half of exports.

Prepared by **Wallace P. Bolen [(703) 648–7727, wbolen@usgs.gov]**

TALC AND PYROPHYLLITE

U.S. talc production has increased for the past 2 years after decreasing in 2016. Apparent consumption was relatively flat for 4 consecutive years through 2017 but is estimated to decrease in 2018 owing to decreased imports and increased exports. Production and apparent consumption in 2018 were still about 42% and 32% lower, respectively, than in 1995. Several domestic talc markets have declined over this 23-year period, with the largest decreases taking place in the ceramics (talc use fell by an estimated 58%), cosmetics (57%), roofing (47%), paint (24%), and paper (21%) industries. Ceramic tile and sanitaryware formulations and the technology for firing ceramic tile changed, 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. Paper manufacturing began to decrease beginning in the 1990s, and some talc used for pitch control was replaced by chemical agents. For cosmetics, manufacturers of body dusting powders shifted some of their production from talc-based to corn-starch-based products. In contrast, sales of domestic talc for plastics increased by an estimated 34% from 1995 to 2018, primarily as the result of increased use in automotive plastics, but a significant share of the increased demand has been met with imported talc. The quantity of talc used in rubber production increased by 11% in 2018 compared with that in 1995.

The paper industry has traditionally been the largest consumer of talc worldwide; however, plastics are expected to overtake paper as the predominant end use within the next several years, as papermakers in Asia make greater use of talc substitutes and as the use of talc in automobile plastics increases.

World Mine Production and Reserves:

	Mine production[e]		**Reserves[6]**
	2017	**2018**	
United States (crude)	[7]610	620	140,000
Brazil (crude and beneficiated)[8]	850	850	44,000
China (unspecified minerals)	1,800	1,800	82,000
Finland	350	360	Large
France (crude)	450	450	Large
India[8]	900	900	110,000
Japan[8]	365	370	100,000
Korea, Republic of[8]	[7]603	610	8,100
Other countries (includes crude)[8]	1,340	1,500	Large
World total (rounded)[8]	7,270	7,500	Large

World Resources: 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 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.
[1]All statistics exclude pyrophyllite unless otherwise noted.
[2]Defined as sold by producers + imports – exports.
[3]Average ex-works unit value of milled talc sold by U.S. producers, based on data reported by companies.
[4]Includes only companies that mine talc or pyrophyllite. Excludes office workers and mills that process imported or domestically purchased material.
[5]Defined as imports – exports.
[6]See Appendix C for resource and reserve definitions and information concerning data sources.
[7]Reported figure.
[8]Includes pyrophyllite.

TANTALUM

(Data in metric tons of tantalum content unless otherwise noted)

Domestic Production and Use: Significant U.S. tantalum mine production has not been reported since 1959. Domestic tantalum resources are of low grade, some are mineralogically complex, and most are not commercially recoverable. Companies in the United States produced tantalum alloys, capacitors, compounds, and tantalum metal from imported tantalum ores and concentrates and tantalum-containing materials. Tantalum metal and alloys were recovered from foreign and domestic scrap. Domestic tantalum consumption was not reported by consumers. Major end uses for tantalum capacitors included automotive electronics, mobile phones, and personal computers. Tantalum oxide (Ta_2O_5) was used in glass lenses to make lighter weight lenses that produce a brighter image. Tantalum carbide was used in cutting tools. The value of tantalum consumed in 2018 was estimated to exceed $310 million as measured by the value of imports.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Mine	—	—	—	—	—
Secondary	NA	NA	NA	NA	NA
Imports for consumption[1]	1,230	1,240	1,060	1,460	1,820
Exports[1]	725	657	604	549	654
Shipments from Government stockpile	—	—	—	—	—
Consumption, apparent[2]	508	587	460	907	1,170
Price, tantalite, dollars per kilogram of Ta_2O_5 content[3]	221	193	193	193	218
Net import reliance[4] as a percentage of apparent consumption	100	100	100	100	100

Recycling: Tantalum was recycled mostly from new scrap that was generated during the manufacture of tantalum-containing electronic components, and from tantalum-containing cemented carbide and superalloy scrap. The amount of tantalum recycled was not available, but it may be as much as 10% of apparent consumption.

Import Sources (2014–17): Tantalum ore and concentrate: Brazil, 35%; Rwanda, 31%; Australia, 15%; Congo (Kinshasa), 8%; and other, 11%. Tantalum metal and powder: China, 40%; Germany, 18%; Kazakhstan, 17%; Thailand, 11%; and other, 14%. Tantalum waste and scrap: Austria, 16%; Mexico, 14%; China, 11%; Indonesia, 10%; and other 49%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Synthetic tantalum-niobium concentrates	2615.90.3000	Free.
Tantalum ores and concentrates	2615.90.6060	Free.
Tantalum oxide[5]	2825.90.9000	3.7% ad val.
Potassium fluorotantalate[5]	2826.90.9000	3.1% ad val.
Tantalum, unwrought:		
Powders	8103.20.0030	2.5% ad val.
Alloys and metal	8103.20.0090	2.5% ad val.
Tantalum, waste and scrap	8103.30.0000	Free.
Tantalum, other	8103.90.0000	4.4% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[6]

		FY 2018		FY 2019	
Material	**Inventory As of 9–30–18**	**Potential Acquisitions**	**Potential Disposals[7]**	**Potential Acquisitions**	**Potential Disposals[7]**
Tantalum carbide powder	1.71	—	1.71	—	1.71
Tantalum metal (gross weight)	0.084	15.4	0.09	15.4	0.09
Tantalum alloy (gross weight)	0.001	—	—	—	—

Prepared by **Abraham J. Padilla [(703) 648–4965, apadilla@usgs.gov]**

TANTALUM

Events, Trends, and Issues: U.S. tantalum apparent consumption (measured in contained tantalum) was estimated to have increased by 27% from that of 2017. U.S. imports for consumption increased by 24% from those of 2017. The increase was largely attributed to the increase in imports of tantalum wrought metal (40%) and tantalum unwrought metal (35%). U.S. exports increased by 19% from those of 2017. In 2018, the average monthly price of tantalum ore increased to about $224 per kilogram of Ta_2O_5 content in September from about $193 per kilogram of Ta_2O_5 content in January. This represented an increase of about 16% from the average price in 2017. Congo (Kinshasa) and Rwanda accounted for 66% of estimated global tantalum production in 2018.

Two companies in Western Australia began producing tantalite concentrates as byproducts of lithium operations in 2018. One company operated its Bald Hill lithium and tantalum mine and began production in April, and the other operated its Pilgangoora lithium tantalum project and completed its first shipment of concentrates in September.

The Government of Venezuela exported columbite-tantalite concentrates for the first time in the country's history in May 2018. Approximately 5 metric tons of columbite-tantalite concentrate from artisanal mining were exported to Italy.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including tantalum. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ''A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals'' (82 FR 60835).

In July 2018, a company from Japan acquired all shares of the niobium-tantalum business of a company from Germany. The business was headquartered in Munich, Germany, and included niobium-processing and niobium-manufacturing facilities in Baden-Wurttemberg and Lower Saxony States, Germany, as well as in Ibaraki Prefecture, Japan, and Rayong Province, Thailand.

World Mine Production and Reserves: Reserves for Australia and Brazil were revised based on Government and industry information.

	Mine production		Reserves[8]
	2017	2018[e]	
United States	—	—	—
Australia	83	90	[9]76,000
Brazil	110	100	34,000
China	110	120	NA
Congo (Kinshasa)	760	710	NA
Ethiopia	65	70	NA
Nigeria	153	150	NA
Rwanda	441	500	NA
Other	83	100	NA
World total (rounded)	1,810	1,800	>110,000

World Resources: Identified world resources of tantalum, most of which are in Australia, Brazil, and Canada, are considered adequate to supply projected needs. The United States has about 55,000 tons of tantalum resources in identified deposits, most of which were considered uneconomic at 2018 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 niobium and tantalum ores and concentrates, unwrought tantalum alloys and powder, tantalum waste and scrap, and other tantalum articles. Synthetic concentrates and niobium ores and concentrates were assumed to contain 32% Ta_2O_5. Tantalum ores and concentrates were assumed to contain 37% Ta_2O_5. Ta_2O_5 is 81.897% Ta.

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

[3]Price is annual average price reported by CRU Group. Estimate for 2018 includes data through September 2018.

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

[5]This category includes tantalum-containing material and other material.

[6]See Appendix B for definitions.

[7]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.

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

[9]For Australia, Joint Ore Reserves Committee-compliant reserves were 37,000 tons.

TELLURIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2018, one firm in Texas produced commercial-grade tellurium as a byproduct from domestic copper anode slimes. The primary producer and downstream producers further refined domestic and imported commercial-grade metal to produce tellurium dioxide, high-purity tellurium, and tellurium compounds for specialty applications. To avoid disclosing company proprietary data, U.S. tellurium production in 2018 was withheld.

Tellurium was used in the production of cadmium telluride (CdTe) for CdTe thin-film solar cells. Other uses were as an alloying additive in steel to improve machining characteristics, as a minor additive in copper alloys to improve machinability without reducing conductivity, in lead alloys to improve resistance to vibration and fatigue, in cast iron to help control the depth of chill, and in malleable iron as a carbide stabilizer. It was used in the chemical industry as a vulcanizing agent and accelerator in the processing of rubber and as a component of catalysts for synthetic fiber production. Other uses included those in photoreceptor and thermoelectric devices, blasting caps, and as a pigment to produce various colors in glass and ceramics.

Global consumption estimates of tellurium by end use are solar, 40%; thermoelectric production, 30%; metallurgy, 15%; rubber applications, 5%; and other, 10%.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production, refinery	W	W	W	W	W
Imports for consumption	109	76	73	163	230
Exports	28	41	3	2	10
Consumption, apparent[1]	W	W	W	W	W
Price, dollars per kilogram[2]	113	79	36	38	79
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[3] as a percentage of apparent consumption	>75	>75	>75	>75	>75

Recycling: For traditional metallurgical and chemical uses, there was little or no old scrap from which to extract secondary tellurium because these uses of tellurium are highly dispersive or dissipative. A very small amount of tellurium was recovered from scrapped selenium-tellurium photoreceptors employed in older plain-paper copiers in Europe. A plant in the United States recycled tellurium from CdTe solar cells; however, the amount recycled was limited because most CdTe solar cells were relatively new and had not reached the end of their useful life.

Import Sources (2014–17): Canada, 66%; China, 27%; Germany, 3%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Tellurium	2804.50.0020	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including tellurium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

Domestic tellurium production was estimated to have remained essentially unchanged from that in 2017. The sole domestic producer shipped at least a portion of its anode slimes to Mexico for treatment and refining. World production of tellurium in 2018 was estimated to be about 440 tons. In 2018, the domestic average monthly price of tellurium generally increased in the first 7 months of the year, from around $52 per kilogram in January to $100 per kilogram in July. The average monthly price then decreased slightly through September to an average of $82 per kilogram through mid-October.

Prepared by **C. Schuyler Anderson [(703) 648–4985, csanderson@usgs.gov]**

TELLURIUM

Domestic imports of tellurium were estimated to have increased by about 41% in 2018 from those of 2017, mostly as a result of a significant increase in imports from Canada, Germany, and the Philippines. During the first 9 months of 2018, the United States imported 119 tons of tellurium from Canada, 32 tons from China, 24 tons from Germany, and 5 tons from the Philippines—an increase of 56 tons, a decrease of 5 tons, and an increase of 21 tons and 4 tons, respectively, compared with imports during the same period of the prior year. In 2017, 93% of the tellurium imports from China were imported between August and November, and for the past several years, most of the annual tellurium imports from China took place in 1 or 2 months of the year. In September 2018, imports from China were 25 tons, representing 78% of imports from China in 2018. China was the leading producer of refined tellurium, recovering tellurium from copper anode slimes and from residues generated during the lead, nickel, precious metals, and zinc smelting processes.

Subsidies and tax credits for new solar construction that were aimed at encouraging domestic solar projects continued in the United States. The subsidies had been set to expire at the end of 2016, but legislation passed by Congress in December 2015 extended the 30% Solar Energy Credit until January 1, 2019. After this date, the credit will begin to decrease incrementally, until it reaches 10% on January 1, 2022.

World Refinery Production and Reserves: The figures shown for reserves include only tellurium contained in copper reserves. These estimates assume that more than one-half of the tellurium contained in unrefined copper anodes is recoverable.

	Refinery production[e]		Reserves[4]
	2017	2018	
United States	W	W	3,500
Bulgaria	5	5	NA
Canada	49	30	800
China	290	300	6,600
Japan	38	36	—
Russia	44	35	NA
South Africa	7	7	—
Sweden	35	32	670
Other countries[5]	NA	NA	16,000
World total (rounded)	[6]470	[6]440	31,000

World Resources: Data on tellurium resources were not available. More than 90% of tellurium has been produced from anode slimes collected from electrolytic copper refining, and the remainder was derived from skimmings at lead refineries and from flue dusts and gases generated during the smelting of bismuth, copper, and lead-zinc ores. Potential sources of tellurium include bismuth telluride and gold telluride ores.

Substitutes: Several materials can replace tellurium in most of its uses, but usually with losses in efficiency or product characteristics. Bismuth, calcium, lead, phosphorus, selenium, and sulfur can be used in place of tellurium in many free-machining steels. Several of the chemical process reactions catalyzed by tellurium can be carried out with other catalysts or by means of noncatalyzed processes. In rubber compounding, sulfur and (or) selenium can act as vulcanization agents in place of tellurium. The selenides and sulfides of niobium and tantalum can serve as electrical-conducting solid lubricants in place of tellurides of those metals.

The selenium-tellurium photoreceptors used in some plain paper photocopiers and laser printers have been replaced by organic photoreceptors in newer devices. Amorphous silicon and copper indium gallium selenide were the two principal competitors of CdTe in thin-film photovoltaic solar cells.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Defined as production + imports – exports + adjustments for industry stock changes.
[2]Average price published by Argus Media group–Argus Metals International for 99.95% tellurium, free on board, U.S. warehouses.
[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]In addition to the countries listed, Australia, Belgium, Chile, Colombia, Germany, Kazakhstan, Mexico, the Philippines, and Poland produce refined tellurium, but output was not reported and available information was inadequate to make reliable production and reserves estimates.
[6]Excludes U.S. production.

THALLIUM

(Data in kilograms unless otherwise noted)

Domestic Production and Use: Thallium has not been recovered in the United States since 1981. Consumption of thallium metal and thallium compounds was valued at $258,600. The primary end uses included the following: radioactive thallium-201 used for medical purposes in cardiovascular imaging; thallium as an activator (sodium iodide crystal doped with thallium) in gamma radiation detection equipment (scintillometer); thallium-barium-calcium-copper oxide high-temperature superconductor used in filters for wireless communications; thallium in lenses, prisms, and windows for infrared detection and transmission equipment; thallium-arsenic-selenium crystal filters for light diffraction in acousto-optical measuring devices; and thallium in mercury alloys for low-temperature measurements. Other uses include: as an additive in glass to increase its refractive index and density, a catalyst for organic compound synthesis, and a component in high-density liquids for gravity separation of minerals.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, refinery	—	—	—	—	—
Imports for consumption:					
Unwrought metal and metal powders	44	—	—	—	—
Waste and scrap	—	—	—	—	23
Other articles	53	334	193	—	41
Exports:					
Unwrought metal and metal powders	51	104	56	34	100
Waste and scrap	1,430	1,450	286	364	150
Other articles	1,050	1,070	973	1,560	2,000
Consumption, estimated[1]	97	334	193	—	64
Price, metal, dollars per kilogram[2]	7,200	7,400	7,400	4,200	4,000
Net import reliance[3] as a percentage of estimated consumption	NA	NA	NA	NA	NA

Recycling: None.

Import Sources (2014–17): United Kingdom, 100%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Unwrought and powders	8112.51.0000	4.0% ad val.
Waste and scrap	8112.52.0000	Free.
Other	8112.59.0000	4.0% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: In 2018, the price for thallium metal declined for the second year by 5%, likely owing to decreased use and domestic availability from scrap and waste. In 2018, China maintained its policy of eliminating toll-trading tax benefits on exports of thallium that began in 2006, thus contributing to the reduced supply to markets outside of China. In September 2018, the United States Trade Representative released a list of approximately $200 billion worth of Chinese imports that would be subject to an additional 10% tariff beginning in late September. Further tariffs of 25% will be imposed in January of 2019. Thallium (unwrought), powders, waste and scrap, and other articles were included in the list of Chinese imports that will be subjected to additional tariffs.

Demand for thallium for use in cardiovascular-imaging applications has declined, owing to superior performance and availability of alternatives, such as the medical isotope technetium-99. A global shortage of technetium-99 from 2009 to 2011 had contributed to an increase in thallium consumption during that time period. Since 2011, consumption of thallium has declined significantly. Small quantities of thallium are used for research.

Prepared by **Shawnna M. Bennett [(703) 648–7715, smbennett@usgs.gov]**

THALLIUM

Two of the leading global markets for thallium were glass lenses, prisms, and windows for fiber optics, and optics for digital cameras. The majority of producers of these products were in China, Japan, and the Republic of Korea. A search of the U.S. Patent and Trademark office shows that patents were filed in 2018 to use thallium as a metal plating enhancer in batteries and as a variable resistance layer in memory devices to increase thermal and electrical conductivity. Other applications were for antibody detection labels with radioactive isotopes for research, and for quantum dots and solder.

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. The leading sources of thallium released into the environment are coal-burning powerplants and smelters of copper, lead, and zinc ores. The major sources of thallium in drinking water are ore-processing sites and discharges from drugs, electronics, and glass factories. 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 of thallium in drinking water.

World Refinery Production and Reserves:[4] Thallium is produced commercially in only a few countries as a byproduct in the roasting of copper, lead, and zinc ores and is recovered from flue dust. Because most producers withhold thallium production data, global production data are limited. In 2018, global production of thallium was estimated to be less than 8,000 kilograms. China, Kazakhstan, and Russia were believed to be leading producers of primary thallium. Since 2005, substantial thallium-rich deposits have been identified in Brazil, China, Macedonia, and Russia.

World Resources: 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 the trace amounts found in copper, lead, zinc, and other sulfide ores. Quantitative estimates of reserves are not available, owing to the difficulty in identifying deposits where thallium can be extracted economically. Previous estimates of reserves were based on the thallium content of zinc ores. World resources of thallium contained in zinc resources could be as much as 17 million kilograms; most are in Canada, Europe, and the United States. Global resources of coal contain an estimated 630 million kilograms of thallium.

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-99 can be used in cardiovascular-imaging applications instead of thallium.

Nonpoisonous substitutes, such as tungsten compounds, are being marketed as substitutes for thallium in high-density liquids for gravity separation of minerals.

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

[1]Estimated to be equal to imports.

[2]Estimated price of 99.99%-pure granules or rods in 100- to 250-gram or larger lots.

[3]Defined as imports – exports. Consumption and exports of unwrought thallium were from imported material or from a drawdown in unreported inventories.

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

THORIUM

[Data in kilograms unless otherwise noted]

Domestic Production and Use: The world's primary source of thorium is the rare-earth and thorium phosphate mineral monazite. In 2018, monazite may have been produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. Essentially, all thorium compounds and alloys consumed by the domestic industry were derived from imports. The number of companies that processed or fabricated various forms of thorium for commercial use was not available. Thorium's use in most products was generally limited because of concerns over its naturally occurring radioactivity. Imports of thorium compounds are sporadic owing to changes in consumption and fluctuations in consumer inventory levels. The estimated value of thorium compounds imported for consumption by the domestic industry in 2018 was about $260,000, compared with $731,000 in 2017.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, mine[1]	—	—	NA	NA	NA
Imports for consumption:					
Thorium ore and concentrates (monazite), gross weight	—	—	16,000	—	1,000
Thorium ore and concentrates (monazite)[e]	—	—	800	—	50
Thorium compounds (oxide, nitrate, etc.), gross weight	11,000	2,740	3,120	8,510	3,800
Thorium compounds (oxide, nitrate, etc.)[e]	5,200	1,400	1,600	4,200	1,800
Exports:					
Thorium ore and concentrates (monazite), gross weight	—	—	—	—	1,000
Thorium ore and concentrates (monazite)[e]	—	—	—	—	50
Thorium compounds (oxide, nitrate, etc.), gross weight	[2]14,800	2,160	[2]63,900	[2]88,600	[2]12,000
Thorium compounds (oxide, nitrate, etc.)[e]	[3]7,000	1,600	[3]3,400	[3]1,100	2,000
Consumption, apparent[4]	([5])	([5])	([5])	3,100	([5])
Value, thorium compounds, gross weight, dollars per kilogram,[6] India	65	63	65	73	72
Net import reliance[7] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2014–17): Monazite: Canada, 100%. Thorium compounds: India, 96%; United Kingdom, 3%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Thorium ores and concentrates (monazite)	2612.20.0000	Free.
Thorium compounds	2844.30.1000	5.5% ad val.

Depletion Allowance: Monazite, 22% on thorium content, and 14% on rare-earth and yttrium content (Domestic); 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Domestic demand for thorium alloys, compounds, and metals was limited. Imports and existing stocks supplied essentially all thorium consumed in the United States in 2018. 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.

Prepared by **Joseph Gambogi [(703) 648–7718, jgambogi@usgs.gov]**

THORIUM

Estimated imports of unspecified thorium compounds were thought to contain about 1,800 kilograms of ThO_2 equivalent in 2018. India maintained its position as the primary source of imported thorium compounds in 2018. The unit value of imports from India decreased slightly to $72 per kilogram compared with $73 per kilogram in 2017.

Exports of unspecified thorium compounds were 12,000 kilograms in 2018; however, 83% of the exports were reported to have a unit value less than $50 per kilogram and may have been misclassified. Owing to potentially misclassified material and variations in the type and purity of thorium compound, the unit value of exports varied widely by month and exporting district, from a low of $7 per kilogram to a high of $9,100 per kilogram.

Globally, monazite was produced primarily for its rare-earth-element content, and only a small fraction of the byproduct thorium produced was consumed. India was the leading producer of monazite. Thorium consumption worldwide is relatively small compared with that of most other mineral commodities. In regard to international trade, China was the leading importer of monazite, and Brazil and Thailand were China's leading import sources. Some concentrates from Thailand may be beneficiated concentrates from other sources. According to export statistics from Australia, 17,500 tons of thorium ores and concentrates, with a unit value of $122 per ton, were exported from Australia to Thailand in 2017.

Several companies and countries were active in the pursuit of commercializing thorium as a fuel material for a new generation of nuclear reactors. Thorium-based nuclear research and development programs have been or are underway in Belgium, Brazil, Canada, China, Czechia, France, Germany, India, Israel, Japan, the Netherlands, Norway, Russia, the United Kingdom, and the United States.

The U.S. Environmental Protection Agency (EPA) withdrew proposed revisions to the EPA's "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings." The new standards would have been applicable to byproduct materials produced by uranium in situ recovery.

World Refinery Production and Reserves:[8] Production and reserves are associated with the recovery of monazite in heavy-mineral-sand deposits. Without demand for the rare earths, monazite would probably not be recovered for its thorium content under current market conditions.

World Resources: The world's leading thorium resources are found in placer, carbonatite, and vein-type deposits. Thorium is found in several minerals, including monazite, thorite, and thorianite. According to a report by the Organisation for Economic Co-operation and Development's Nuclear Energy Agency and the International Atomic Energy Agency, worldwide thorium resources were estimated to total more than 6 million tons of thorium. Thorium resources are found throughout the world, most notably in Australia, Brazil, and India. India's Department of Atomic Energy estimated that 12 million tons of monazite was contained in heavy-mineral sands in India. India's monazite was reported to have an average thorium oxide content of 9% to 10%. Geoscience Australia estimated Australia's inferred resources to be about 0.6 million tons of thorium. Most of the identified thorium resources in Australia are within heavy-mineral-sand deposits. None of Australia's thorium resources were classified as economically recoverable. Brazil's thorium resources were estimated to be 0.6 million tons.

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 and lanthanum can substitute for thorium in welding electrodes.

[e]Estimated. NA Not Available.— Zero.
[1]All domestically consumed thorium was thought to be derived from imported materials; however, monazite may have been produced as a separate concentrate or included as an accessory mineral in heavy-mineral concentrates.
[2]Includes material that may have been misclassified.
[3]Low unit-value exports were excluded from ThO_2 content estimate because they were believed to have been misclassified.
[4]Defined as production + imports – exports. Excludes ores and concentrates.
[5]The apparent consumption calculation yields a negative value from 2014 through 2016 and 2018.
[6]Based on U.S. Census Bureau customs value.
[7]Defined as imports – exports; however, all exports of refined compounds and alloys were derived from imported materials, and net import reliance is assumed to be 100%.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.

TIN

(Data in metric tons of tin content unless otherwise noted)

Domestic Production and Use: Tin has not been mined or smelted in the United States since 1993 and 1989, respectively. Twenty-five firms accounted for about 90% of the primary tin consumed domestically in 2018. The major uses for tin in the United States were tinplate, 21%; chemicals, 17%; solder, 14%; alloys, 10%; babbitt, bronze and brass, and tinning, 11%; and other, 27%. Based on the average Platts Metals Week New York dealer price for tin, the estimated value of imported refined tin was $703 million, and the estimated value of tin recovered from old scrap domestically was $213 million.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, secondary:					
Old scrap[e]	10,100	10,100	10,300	10,300	10,000
New scrap	1,900	1,120	1,080	900	900
Imports for consumption:					
Tin, refined	35,600	33,600	32,200	34,300	37,000
Tin, alloys, gross weight	1,570	2,720	1,910	1,550	1,300
Tin, waste and scrap, gross weight	49,700	32,700	27,200	52,100	48,000
Exports:					
Tin, refined	2,920	807	1,150	1,560	1,000
Tin, alloys, gross weight	2,790	2,540	1,040	966	920
Tin, waste and scrap, gross weight	7,480	2,530	4,570	3,460	4,200
Shipments from Government stockpile	—	—	—	2	10
Consumption, reported:					
Primary	24,200	23,900	22,500	23,500	22,000
Secondary	3,240	2,940	2,920	3,140	2,400
Consumption, apparent, refined[1]	42,400	42,700	42,100	43,000	46,000
Price, average, cents per pound:[2]					
New York dealer	1,023	756	839	937	930
London Metal Exchange, cash	994	729	815	911	910
Kuala Lumpur	993	NA	NA	NA	NA
Stocks, consumer and dealer, yearend	6,970	7,090	6,370	6,570	6,300
Net import reliance[3] as a percentage of apparent consumption	76	76	76	76	78

Recycling: About 11,000 tons of tin from old and new scrap was estimated to have been recycled in 2018. Of this, about 10,000 tons was recovered from old scrap at 2 detinning plants and about 75 secondary nonferrous metal-processing plants, accounting for 22% of apparent consumption. This decrease was attributed to a decrease in lead-base scrap.

Import Sources (2014–17): Indonesia, 23%; Malaysia, 23%; Peru, 22%; Bolivia, 17%; and other, 15%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Unwrought tin:		
Tin, not alloyed	8001.10.0000	Free.
Tin alloys, containing, by weight:		
5% or less lead	8001.20.0010	Free.
More than 5% but not more than 25% lead	8001.20.0050	Free.
More than 25% lead	8001.20.0090	Free.
Tin waste and scrap	8002.00.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[4]

		FY2018		FY 2019	
Material	Inventory As of 9–30–18	Potential Acquisitions	Potential Disposals[5]	Potential Acquisitions	Potential Disposals[5]
Tin (gross weight)	4,040	—	804	—	—

Prepared by **C. Schuyler Anderson [(703) 648–4985, csanderson@usgs.gov]**

TIN

Events, Trends, and Issues: Apparent consumption of tin in the United States was estimated to have increased slightly in 2018 compared with consumption in 2017. Indonesia was the primary supplier of tin to the United States, and the estimated amount of tin recycled in 2018 decreased slightly from that in 2017. Estimated average tin prices for the first 10 months in 2018 were 945 and 923 cents per pound for the New York dealer price and London Metal Exchange price, respectively—a slight increase from both of the average prices in 2017.The monthly average New York dealer tin price in 2018 peaked in February at 1,004 cents per pound, then steadily decreased through September to a monthly average price of 882 cents per pound, before recovering slightly to a monthly average price of 889 cents per pound in October.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including tin. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

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

	Mine production		Reserves[6]
	2017	2018[e]	
United States	—	—	—
Australia	7,200	7,000	[7]370,000
Bolivia	18,500	18,000	400,000
Brazil	18,000	18,000	700,000
Burma	47,000	45,000	110,000
China	93,000	90,000	1,100,000
Congo (Kinshasa)	9,500	9,000	150,000
Indonesia	83,000	83,000	800,000
Malaysia	3,810	4,000	250,000
Nigeria	5,960	6,000	NA
Peru	17,800	18,000	110,000
Russia	1,300	1,300	350,000
Rwanda	2,860	2,900	NA
Thailand	100	100	170,000
Vietnam	4,560	5,000	11,000
Other countries	200	300	180,000
World total (rounded)	313,000	310,000	4,700,000

World Resources: Identified resources of tin in the United States, primarily in Alaska, were insignificant compared with those of the rest of the world. World resources, principally in western Africa, southeastern Asia, Australia, Bolivia, Brazil, Indonesia, and Russia, are extensive and, if developed, could sustain recent annual production rates well into the future.

Substitutes: Aluminum, glass, paper, plastic, or tin-free steel substitute for tin content in cans and containers. Other materials that substitute for tin are epoxy resins for solder; aluminum alloys, alternative copper-base alloys, and plastics for bronze; plastics for bearing metals that contain tin; and compounds of lead and sodium for some tin chemicals.

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

[1]Defined as production (old scrap) + refined tin imports – refined tin exports + adjustments for Government and industry stock changes. Excludes imports and exports of alloys, and waste and scrap.

[2]Source: Platts Metals Week.

[3]Defined as imports – exports + adjustments for Government and industry stock changes, excluding imports and exports of waste and scrap.

[4]See Appendix B for definitions.

[5]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.

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

[7]For Australia, Joint Ore Reserves Committee-compliant reserves were about 260,000 tons.

TITANIUM AND TITANIUM DIOXIDE[1]

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Titanium sponge metal was produced by two operations in Nevada and 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, used the Armstrong method to produce high-purity titanium for use in electronics. The operations in Nevada, with an estimated capacity of 12,600 tons per year, used the Kroll method, the dominant process of titanium sponge production for use in aerospace, industrial, and all other applications. A third facility, in Rowley, UT, which produced titanium sponge using the Kroll method, was idled and placed on care-and-maintenance status in 2016 owing to low titanium sponge prices.

In 2018, an estimated 80% of titanium metal was used in aerospace applications; the remaining 20% was used in armor, chemical processing, marine hardware, medical implants, power generation, and consumer and other applications. Assuming an average purchase price of $9.10 per kilogram, the value of sponge metal consumed was about $309 million.

In 2018, titanium dioxide (TiO_2) pigment production, by four companies operating five facilities in four States, was valued at about $3.0 billion. The estimated end-use distribution of TiO_2 pigment consumption was paints (including lacquers and varnishes), 69%; plastics, 25%; paper, 5%; and other, 1%. Other uses of TiO_2 included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Titanium sponge metal:					
Production	W	W	W	W	W
Imports for consumption	17,700	20,700	16,200	24,100	23,000
Exports	2,590	1,700	724	3,130	600
Consumption, reported	26,400	31,200	34,100	37,400	34,000
Price, dollars per kilogram, yearend	10.00	9.40	9.50	9.70	9.10
Stocks, industry, yearend[e]	22,900	25,000	25,100	13,200	10,000
Employment, number[e]	300	300	150	150	150
Net import reliance[2] as a percentage of reported consumption	57	61	45	88	75
Titanium dioxide pigment:					
Production	1,260,000	1,220,000	1,240,000	1,260,000	1,200,000
Imports for consumption	224,000	221,000	247,000	239,000	270,000
Exports	685,000	649,000	651,000	634,000	550,000
Consumption, apparent[3]	802,000	792,000	840,000	870,000	920,000
Producer price index (1982=100), yearend[4]	224	176	175	205	217
Employment, number[e]	3,400	3,110	3,110	3,110	3,050
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: About 61,500 tons of titanium scrap metal was consumed in 2018—50,000 tons by the titanium industry, 9,800 tons by the steel industry, 600 tons by the superalloy industry, and 1,100 tons by other industries.

Import Sources (2014–17): Sponge metal: Japan, 81%; Kazakhstan, 7%; Ukraine, 7%; China, 3%; and other, 2%. Titanium dioxide pigment: Canada, 34%; China, 24%; Germany, 10%; Mexico, 4%; and other, 28%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Titanium oxides (unfinished TiO_2 pigments)	2823.00.0000	5.5% ad val.
TiO_2 pigments, 80% or more TiO_2	3206.11.0000	6.0% ad val.
TiO_2 pigments, other	3206.19.0000	6.0% ad val.
Ferrotitanium and ferrosilicon titanium	7202.91.0000	3.7% ad val.
Unwrought titanium metal	8108.20.0010	15.0% ad val.
Titanium waste and scrap metal	8108.30.0000	Free.
Other titanium metal articles	8108.90.3000	5.5% ad val.
Wrought titanium metal	8108.90.6000	15.0% ad val.

Prepared by **George M. Bedinger [(703) 648–6183, gbedinger@usgs.gov]**

TITANIUM AND TITANIUM DIOXIDE

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: Domestic consumption of titanium sponge in 2018 was estimated to have decreased by about 9% from that of 2017, owing to continued demand from the aerospace industry. Additive manufacturing (3D printing) techniques for aerospace applications continued to progress.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including titanium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

In Yanbu, Saudi Arabia, the first batch of titanium sponge was produced in August. The Yanbu facility was jointly owned by a Saudi Arabian industrial company and a Japanese titanium producer. The plant was expected to have a capacity of 15,600 tons per year.

Domestic production of TiO_2 pigment in 2018 was estimated to be about 1.2 million tons, a decrease from that of 2017. A proposed merger between two major TiO_2 pigment producers was delayed pending approval from U.S. regulators. If approved, the combined company operations would have a capacity of 1.3 million tons per year and would be the largest global producer of TiO_2 pigments. In Pori, Finland, a 130,000-ton-per-year pigment plant was shut down after experiencing fire damage in 2017. In 2018, the plant resumed operations and was producing at a rate of approximately 25,000 tons per year. In September, the owner announced its intention to close the facility by yearend 2021.

World Sponge Metal Production and Sponge and Pigment Capacity:

	Sponge production		Capacity 2018[5]	
	2017	2018[e]	Sponge	Pigment
United States	W	W	13,100	1,370,000
Australia	—	—	—	260,000
Canada	—	—	—	104,000
China[e]	72,000	70,000	110,000	3,250,000
Germany	—		—	472,000
India	500	500	500	108,000
Japan[e]	51,000	52,000	68,800	314,000
Kazakhstan[e]	9,000	9,000	26,000	1,000
Mexico	—	—	—	300,000
Russia[e]	40,000	40,000	46,500	55,000
Saudi Arabia	—	500	15,600	210,000
Ukraine[e]	8,000	8,000	12,000	120,000
United Kingdom	—	—	—	315,000
Other countries	—	—	—	784,000
World total (rounded)	[6]181,000	[6]180,000	293,000	7,660,000

World Resources: Reserves and resources of titanium minerals are discussed in the Titanium Mineral Concentrates chapter.

Substitutes: Few materials possess titanium metal’s strength-to-weight ratio and corrosion resistance. In high-strength applications, titanium competes with aluminum, composites, intermetallics, steel, and superalloys. Aluminum, nickel, specialty steels, and zirconium alloys may be substituted for titanium for applications that require corrosion resistance. Ground calcium carbonate, precipitated calcium carbonate, kaolin, and talc compete with titanium dioxide as a white pigment.

[e]Estimated. E Net exporter. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]See also Titanium Mineral Concentrates.
[2]Defined as imports – exports.
[3]Defined as production + imports – exports.
[4]U.S. Department of Labor, Bureau of Labor Statistics.
[5]Yearend operating capacity.
[6]Excludes U.S. production.

TITANIUM MINERAL CONCENTRATES[1]

(Data in thousand metric tons of TiO_2 content unless otherwise noted)

Domestic Production and Use: In 2018, two companies recovered ilmenite and rutile concentrates from surface-mining operations near Nahunta, GA, and Starke, FL, and a third company processed existing mineral sands tailings in Florida. Based on reported data through August 2018, the estimated value of titanium mineral concentrates imported in the United States in 2018 was $654 million. Zircon was a coproduct of mining from ilmenite and rutile deposits. About 90% of titanium mineral concentrates were consumed by domestic titanium dioxide (TiO_2) pigment producers. The remaining 10% was used in welding-rod coatings and for manufacturing carbides, chemicals, and metal.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production[2]	100	200	100	100	100
Imports for consumption	1,110	1,100	1,020	1,180	1,100
Exports, all forms[e]	1	2	5	6	30
Consumption, apparent[3]	1,210	1,300	1,120	1,270	1,100
Price, dollars per metric ton:					
Rutile, bulk, minimum 95% TiO_2, f.o.b. Australia[4]	950	840	740	740	990
Ilmenite, bulk, minimum 54% TiO_2, f.o.b. Australia[4]	155	110	105	173	NA
Ilmenite, import, dollars per ton	172	215	142	172	220
Slag, 80%–95% TiO_2[5]	679–761	687–742	612–682	621–700	690–720
Employment, mine and mill, number	234	285	156	264	270
Net import reliance[6] as a percentage of apparent consumption	92	85	91	92	91

Recycling: None.

Import Sources (2014–17): South Africa, 35%; Australia, 27%; Canada, 12%; Mozambique, 11%; and other, 15%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Synthetic rutile	2614.00.3000	Free.
Ilmenite and ilmenite sand	2614.00.6020	Free.
Rutile concentrate	2614.00.6040	Free.
Titanium slag	2620.99.5000	Free.

Depletion Allowance: Ilmenite and rutile; 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Events, Trends, and Issues: Consumption of titanium mineral concentrates is tied to production of TiO_2 pigments that are primarily used in paint, paper, and plastics. Domestic apparent consumption of titanium mineral concentrates in 2018 was estimated to have decreased by about 13 percent from that of 2017. Although exports were estimated to have increased fivefold in 2018, they were a result of an intracompany transfer that moved 27,000 tons of stockpiled ilmenite from its former operations in Virginia to its synthetic rutile kiln in Western Australia in February. Prices for ilmenite, rutile, and titanium slag all increased through 2018.

A company was conducting a feasibility study of the Dundas ilmenite project on the northwest coast of Greenland. Large-scale production was expected to begin in 2019 contingent upon obtaining customer offtake agreements. A major producer of titanium minerals was restarting its Jacinth-Ambrosia Mine in South Australia and was further developing its operations in Sierra Leone in order to increase its production of natural rutile. Other projects were being developed in Australia, Mozambique, and Tanzania.

Prepared by **George M. Bedinger [(703) 648–6183, gbedinger@usgs.gov]**

TITANIUM MINERAL CONCENTRATES

World Mine Production and Reserves: Reserves for China were revised based on data from the National Bureau of Statistics of China.

	Mine production 2017	Mine production 2018[e]	Reserves[7]
Ilmenite:			
United States[2]	[8]100	[8]100	[8]2,000
Australia	730	700	[9]250,000
Brazil	50	50	43,000
Canada[10]	880	850	31,000
China	840	850	230,000
India	300	300	85,000
Kenya	280	280	54,000
Madagascar	110	100	40,000
Mozambique	600	600	14,000
Norway	220	200	37,000
Senegal	300	250	NA
South Africa[10]	550	500	63,000
Ukraine	230	230	5,900
Vietnam	200	200	1,600
Other countries	150	150	26,000
World total (ilmenite, rounded)	[8]5,540	[8]5,400	[8]880,000
Rutile:			
United States	([8])	([8])	([8])
Australia	290	250	[9]29,000
India	10	10	7,400
Kenya	87	90	13,000
Mozambique	9	8	880
Senegal	10	8	NA
Sierra Leone	160	170	490
South Africa	95	100	8,300
Ukraine	95	100	2,500
Other countries	13	10	400
World total (rutile, rounded)	[8]770	[8]750	[8]62,000
World total (ilmenite and rutile, rounded)	6,300	6,100	940,000

World Resources: Ilmenite accounts for about 89% of the world's consumption of titanium minerals. World resources of anatase, ilmenite, and rutile total more than 2 billion tons.

Substitutes: Ilmenite, leucoxene, rutile, slag, and synthetic rutile compete as feedstock sources for producing TiO_2 pigment, titanium metal, and welding-rod coatings.

[e]Estimated. NA Not available.
[1]See also Titanium and Titanium Dioxide.
[2]Rounded to the nearest 100,000 tons to avoid disclosing company proprietary data.
[3]Defined as production + imports – exports.
[4]Source: Industrial Minerals; average of yearend price. Prices of ilmenite from Australia were discontinued at yearend 2017.
[5]Landed duty-paid value based on U.S. imports for consumption. Data series revised to reflect annual average unit value range of significant importing countries.
[6]Defined as imports – exports.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]U.S. rutile production and reserves data are included with ilmenite.
[9]For Australia, Joint Ore Reserves Committee-compliant reserves for ilmenite and rutile were about 57 million and 7 million tons, respectively.
[10]Mine production is primarily used to produce titaniferous slag.

TUNGSTEN

(Data in metric tons of tungsten content unless otherwise noted)

Domestic Production and Use: There has been no known domestic commercial production of tungsten concentrates since 2016. Approximately six companies in the United States processed tungsten concentrates, ammonium paratungstate, tungsten oxide, and (or) scrap to make tungsten metal powder, tungsten carbide powder, and (or) tungsten chemicals. Nearly 60% of the tungsten used 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 remaining tungsten 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 2018 was approximately $900 million.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Mine	NA	NA	—	—	—
Secondary	W	W	W	W	W
Imports for consumption:					
Concentrate	4,080	3,970	3,580	3,930	4,000
Other forms	8,820	6,270	6,300	9,790	10,000
Exports:					
Concentrate	1,230	398	183	532	370
Other forms	5,490	3,360	3,200	3,010	3,100
Shipments from Government stockpile:					
Concentrate	282	—	—	1,460	1,200
Other forms	([1])	—	—	—	—
Consumption:					
Reported, concentrate	W	W	W	W	W
Apparent, all forms[2]	W	W	W	W	W
Price, concentrate, dollars per mtu WO_3,[3] average, U.S. spot market, Platts Metals Week	348	302	148	245	330
Stocks, industry, yearend, concentrate and other forms	W	W	W	W	W
Net import reliance[4] as a percentage of apparent consumption	>25	>25	>25	>50	>50

Recycling: The estimated quantity of tungsten consumed from secondary sources by processors and end users in 2018 was withheld to avoid disclosing company proprietary data.

Import Sources (2014–17): Tungsten contained in ores and concentrates, intermediate and primary products, wrought and unwrought tungsten, and waste and scrap: China, 32%; Bolivia, 9%; Germany, 9%; Canada, 8%; and other, 42%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–18**
Ores	2611.00.3000	Free.
Concentrates	2611.00.6000	37.5¢/kg tungsten content.
Tungsten oxides	2825.90.3000	5.5% ad val.
Ammonium tungstates	2841.80.0010	5.5% ad val.
Tungsten carbides	2849.90.3000	5.5% ad val.
Ferrotungsten	7202.80.0000	5.6% ad val.
Tungsten powders	8101.10.0000	7.0% ad val.
Tungsten waste and scrap	8101.97.0000	2.8% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[5]

		FY 2018		**FY 2019**	
Material	**Inventory As of 9–30–18**	**Potential Acquisitions**	**Potential Disposals[6]**	**Potential Acquisitions**	**Potential Disposals[6]**
Metal powder	125	—	125	—	125
Ores and concentrates	9,170	—	1,360	—	1,360
Tungsten alloys, gross weight[7]	6	5	—	5	—

Prepared by **Kim B. Shedd [(703) 648–4974, kshedd@usgs.gov]**

TUNGSTEN

Events, Trends, and Issues: In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including tungsten. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

World tungsten supply was dominated by production in China and exports from China. China's Government regulated its tungsten industry by limiting the number of mining and export licenses, imposing quotas on concentrate production, and placing constraints on mining and processing. From 2016 through 2018, environmental and safety inspections at Chinese mines and downstream ammonium paratungstate plants resulted in intermittent periods of reduced supply. Production of tungsten concentrate outside China in 2018 was expected to be less than that of 2017, owing to lower ore grades being mined in Vietnam and the closure of the sole tungsten mine in the United Kingdom after the owner entered voluntary administration in October 2018. Near-term new concentrate production was anticipated in the Republic of Korea and Spain. Scrap continued to be an important source of raw material for the tungsten industry worldwide.

China was the world's leading tungsten consumer. Beginning in 2017, economic conditions improved in China and elsewhere, resulting in increased tungsten consumption. In early to mid-2018, prices of tungsten concentrate and downstream tungsten materials trended upward and then stabilized or decreased during the remainder of the year.

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

	Mine production		Reserves[8]
	2017	2018[e]	
United States	—	—	NA
Austria	975	980	10,000
Bolivia	994	1,000	NA
China	67,000	67,000	1,900,000
Portugal	724	770	3,100
Russia	2,090	2,100	240,000
Rwanda	720	830	NA
Spain	564	750	54,000
United Kingdom	1,090	900	43,000
Vietnam	6,600	6,000	95,000
Other countries	1,300	1,400	1,000,000
World total (rounded)	82,100	82,000	3,300,000

World Resources: World tungsten resources are geographically widespread. China ranks first in the world in terms of tungsten resources and reserves and has some of the largest deposits. Canada, Kazakhstan, Russia, and the United States also have significant tungsten resources.

Substitutes: Potential substitutes for cemented tungsten carbides include cemented carbides based on molybdenum carbide, niobium carbide, or titanium carbide; ceramics; ceramic-metallic composites (cermets); and tool steels. Most of these options reduce, rather than replace, the amount of tungsten used. Potential substitutes for other applications are as follows: molybdenum for certain tungsten mill products; molybdenum steels for tungsten steels, although most molybdenum steels still contain tungsten; lighting based on carbon nanotube filaments, induction technology, and light-emitting diodes for lighting based on tungsten electrodes or filaments; depleted uranium or lead for tungsten or tungsten alloys in applications requiring high-density or the ability to shield radiation; and depleted uranium alloys or hardened steel for cemented tungsten carbides or tungsten alloys in armor-piercing projectiles. In some applications, substitution would result in increased cost or a loss in product performance.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Less than ½ unit.
[2]Defined as mine production + secondary production + imports – exports + adjustments for Government and industry stock changes.
[3]A metric ton unit (mtu) of tungsten trioxide (WO_3) contains 7.93 kilograms of tungsten.
[4]Defined as imports – exports + adjustments for Government and industry stock changes.
[5]See Appendix B for definitions.
[6]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[7]Inventory includes tungsten alloys and tungsten rhenium metal; acquisitions are tungsten rhenium metal only.
[8]See Appendix C for resource and reserve definitions and information concerning data sources.

VANADIUM

(Data in metric tons of vanadium content unless otherwise noted)

Domestic Production and Use: In 2018, secondary vanadium production continued primarily in Arkansas, Delaware, Ohio, Pennsylvania, and Texas, where processed waste materials (petroleum residues, spent catalysts, utility ash, and vanadium-bearing pig iron slag) were used to produce ferrovanadium, vanadium-bearing chemicals or specialty alloys, vanadium metal, and vanadium pentoxide. In 2009–13, small quantities of vanadium were produced as a byproduct from the mining of uraniferous sandstones on the Colorado Plateau. All byproduct vanadium production has been suspended since 2014. Metallurgical use, primarily as an alloying agent for iron and steel, accounted for about 93% of domestic vanadium consumption in 2018. Of the other uses for vanadium, the major nonmetallurgical use was in catalysts for the production of maleic anhydride and sulfuric acid.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production, mine, mill	—	—	—	—	—
Imports for consumption:					
Vanadium ores and concentrates	—	72	18	1	18
Ferrovanadium	3,230	1,980	1,590	2,810	3,000
Vanadium pentoxide, anhydride	3,410	2,870	2,460	3,400	4,700
Oxides and hydroxides, other	104	94	660	148	160
Aluminum-vanadium master alloys	320	143	157	288	300
Ash and residues	3,450	4,600	2,820	2,540	2,400
Sulfate	19	13	12	4	3
Vanadates	197	173	313	349	340
Vanadium metal[1]	117	135	33	54	20
Exports:					
Vanadium ores and concentrates	40	276	433	60	21
Ferrovanadium	253	122	400	229	280
Vanadium pentoxide, anhydride	171	303	4	108	400
Oxides and hydroxides, other	231	66	53	98	50
Aluminum-vanadium master alloys	248	128	53	132	140
Ash and residues	258	41	123	322	290
Vanadium metal[1]	25	4	15	45	40
Consumption:					
Apparent[2]	9,650	9,340	7,400	8,670	9,800
Reported	4,070	3,930	3,830	3,880	3,800
Price, average, dollars per pound vanadium pentoxide[3]	5.61	4.16	3.38	7.61	14
Stocks, yearend[4]	170	166	168	155	180
Net import reliance[5] as a percentage of apparent consumption	100	100	100	100	100

Recycling: The quantity of vanadium recycled from spent chemical process catalysts was significant and may compose as much as 40% of total vanadium catalysts.

Import Sources (2014–17): Ferrovanadium: Austria, 34%; Canada, 22%; Republic of Korea, 16%; Russia, 13%; and other, 15%. Vanadium pentoxide: South Africa, 46%; Russia, 18%; Brazil, 13%; China, 10%; and other, 13%.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Vanadium ores and concentrates	2615.90.6090	Free.
Vanadium bearing ash and residues	2620.40.0030	Free.
Vanadium bearing ash and residues, other	2620.99.1000	Free.
Chemical compounds:		
Vanadium pentoxide anhydride	2825.30.0010	5.5% ad val.
Vanadium oxides and hydroxides, other	2825.30.0050	5.5% ad val.
Vanadium sulfates	2833.29.3000	5.5% ad val.
Vanadates	2841.90.1000	5.5% ad val.
Hydrides & nitrides, of vanadium	2850.00.2000	5.5% ad val.
Ferrovanadium	7202.92.0000	4.2% ad val.
Vanadium metal	8112.92.7000	2.0% ad val.
Vanadium and articles thereof[6]	8112.99.2000	2.0% ad val.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Prepared by **Désirée E. Polyak [(703) 648–4909, dpolyak@usgs.gov]**

VANADIUM

Government Stockpile: None.

Events, Trends, and Issues: U.S. apparent consumption of vanadium in 2018 increased by 13% from that of 2017. Among the major uses for vanadium, production of carbon, full-alloy, and high-strength low-alloy steels accounted for 18%, 44%, and 33%, respectively, of domestic consumption. Average 2018 vanadium pentoxide prices almost doubled compared with 2017 prices, and ferrovanadium prices more than doubled to $33 per pound in 2018 compared with 2017. In September 2018, ferrovanadium prices averaged $39.60 per pound. Prices had not been this high since March 2008. Byproduct vanadium production in the United States was expected to resume by early 2019 at the White Mesa mill in Utah. An iron and vanadium mine in South Africa remained closed and left South Africa with only two major producers of vanadium. Few new vanadium operations have been commissioned in recent years, with the exception of a producer in Brazil that started production in 2014. The producer began construction on an expansion plan in June 2018 that would further increase capacity.

In February 2018, the Standardization Administration of China released a new high-strength rebar standard that would decrease the use of substandard steels in construction. The implementation date was expected to be November 1, 2018. The increase of vanadium in rebar was expected to increase overall consumption of vanadium in China by approximately 10,000 tons per year, depending on the degree of enforcement.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including vanadium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ‘‘A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals” (82 FR 60835).

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

	Mine production		Reserves[7]
	2017	2018[e]	(thousand metric tons)
United States	—	—	45
Australia	—	—	[8]2,100
Brazil	5,210	6,300	130
China	40,000	40,000	9,500
Russia	18,000	18,000	5,000
South Africa	7,960	9,100	3,500
World total (rounded)	71,200	73,000	20,000

World Resources: World resources of vanadium exceed 63 million tons. Vanadium occurs in deposits of phosphate rock, titaniferous magnetite, and uraniferous sandstone and siltstone, in which it constitutes less than 2% of the host rock. Significant quantities are also present in bauxite and carboniferous materials, such as coal, crude oil, oil shale, and tar sands. Because vanadium is typically recovered as a byproduct or coproduct, demonstrated world resources of the element are not fully indicative of available supplies. Although domestic resources and secondary recovery are adequate to supply a large portion of domestic needs, all of U.S. demand is currently met by foreign sources.

Substitutes: Steels containing various combinations of other alloying elements can be substituted for steels containing vanadium. Certain metals, such as manganese, molybdenum, niobium (columbium), titanium, and tungsten, are to some degree interchangeable with vanadium as alloying elements in steel. Platinum and nickel can replace vanadium compounds as catalysts in some chemical processes. Currently, no acceptable substitute for vanadium is available for use in aerospace titanium alloys.

[e]Estimated. — Zero.
[1]Vanadium metal includes waste and scrap.
[2]Defined as production + net import reliance.
[3]Prices for 2014–2016 are U.S. annual average vanadium pentoxide prices. The 2017 annual average vanadium pentoxide price includes U.S. monthly averages for January 2017–June 2017 and Chinese monthly average prices for July 2017–December 2017. The price for 2018 is the Chinese annual average vanadium pentoxide price.
[4]Includes chlorides, ferrovanadium, vanadates, vanadium-aluminum alloy, other vanadium alloys, vanadium metal, vanadium pentoxide, and other specialty chemicals.
[5]Defined as imports – exports + adjustments for industry stock changes.
[6]Aluminum-vanadium master alloy consisting of 35% aluminum and 64.5% vanadium.
[7]See Appendix C for resource and reserve definitions and information concerning data sources.
[8]For Australia, Joint Ore Reserves Committee-compliant reserves were about 1.3 million tons.

VERMICULITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Two companies with mining and processing facilities in South Carolina and Virginia produced vermiculite concentrate and reported production of approximately 100,000 tons. Flakes of raw vermiculite concentrate are micaceous in appearance and contain interlayer water in their structure. When the flakes are heated rapidly at a temperature above 870 °C, the water flashes into steam, and the flakes expand into accordionlike particles. This process is called exfoliation or expansion, and the resulting lightweight material is chemically inert, fire resistant, and odorless. Most of the vermiculite concentrate produced in the United States was shipped to 17 exfoliating plants in 11 States. The end uses for exfoliated vermiculite were estimated to be agriculture and horticulture, 46%; lightweight concrete aggregates (including cement premixes, concrete, and plaster), 19%; insulation, 8%; and other, 27%.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production[e, 1]	100	100	100	100	100
Imports for consumption[e, 2]	52	33	46	53	50
Exports[e]	3	2	2	2	2
Consumption, apparent, concentrate[3]	150	130	140	150	150
Consumption, reported, exfoliated	63	65	68	72	70
Price, range of value, concentrate, dollars per ton, ex-plant	145–565	140–575	140–575	140–575	140–575
Employment, number[e]	68	69	69	70	70
Net import reliance[4] as a percentage of apparent consumption	30	20	30	30	30

Recycling: Insignificant.

Import Sources (2014–17): South Africa, 36%; Brazil, 34%; China, 24%; Zimbabwe, 4%; and other, 2%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–18**
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: U.S. exports and imports of vermiculite are not collected as a separate category by the U.S. Census Bureau. However, according to an independent industry trade information source, United States imports, excluding any material from Canada and Mexico, were estimated to be about 50,000 tons in 2018, slightly less than those of 2017. Coarse-grade vermiculite remained in short supply; however, prices were unchanged in 2018. Most imports, excluding any material from Canada and Mexico, came from China, South Africa, and Zimbabwe in 2018.

A company based in Australia withdrew from its joint venture in developing the Namekara vermiculite mine in Uganda, citing inconsistent sales of vermiculite that resulted in reduced cash flow and the company's inability to service its debt obligations. A local mining company, which became the 100% owner of the project, continued mining operations and honored existing contracts to supply vermiculite concentrate to customers in Japan, the United Kingdom, and other countries in Europe. The deposit was considered to be one of the world's largest vermiculite deposits with significant portions of medium- and coarse-grade material. Capacity at the 30,000-ton-per-year mine may be expanded to 80,000 tons per year during the next several years. The Namekara deposit has sufficient resources for more than 50 years of production at previously announced rates.

Prepared by **Arnold O. Tanner [Contact Joyce A. Ober, (703) 648–7717, jober@usgs.gov]**

VERMICULITE

A company based in France, in cooperation with the Government of Zimbabwe and local governments, produced vermiculite concentrate, including a significant portion of coarse-grade vermiculite, at the Shawa deposit in Zimbabwe. The mine had an expected life of more than 30 years. The deposit also was considered to be one of the world's largest vermiculite deposits with significant portions of medium- and coarse-grade material. A company in Brazil expanded production capacity at its vermiculite mine in central Brazil and continued with the development of another deposit near Brasilia with the goal of bringing the company's total production capacity to 200,000 tons per year. Companies in China with significant vermiculite resources also were ramping up production, although processing operations continued to be somewhat constrained by increased enforcement of environmental regulations. Specific production data were not available for China.

World Mine Production and Reserves: Reserves data for Brazil and India were revised based on Government information.

	Mine production		Reserves[5]
	2017	2018[e]	
United States[e]	[1]100	[1]100	25,000
Brazil	55	50	6,200
Bulgaria	10	10	NA
China	NA	NA	NA
Egypt	8	8	NA
India	5	10	1,600
Russia	13	10	NA
South Africa	176	180	14,000
Uganda	5	20	NA
Zimbabwe	30	30	NA
Other countries	2	12	NA
World total	400	430	NA

World Resources: Vermiculite occurrences in Colorado, Nevada, North Carolina, Texas, and Wyoming contain estimated resources of 2 million to 3 million tons. Significant deposits have been reported in Australia, China, Russia, Uganda, and some other countries, but reserves 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 substitutes in these applications are 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. Data are rounded to one significant digit to avoid disclosing company proprietary data.
[2]Excludes Canada and Mexico.
[3]Defined as concentrate sold or used by producers + imports – exports.
[4]Defined as imports – exports. Data are rounded to one significant digit to avoid disclosing company proprietary data.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.

WOLLASTONITE

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Wollastonite was mined by two companies in New York during 2018. U.S. production of wollastonite (sold or used by producers) was withheld to avoid disclosing company proprietary data but was estimated to have increased from that of 2017. Economic resources of wollastonite typically form as a result of thermal metamorphism of siliceous limestone during regional deformation or chemical alteration of limestone by siliceous hydrothermal fluids along faults or contacts with magmatic intrusions. Deposits of wollastonite have been identified in Arizona, California, Idaho, Nevada, New Mexico, New York, and Utah; however, New York is the only State where long-term continuous mining has taken place.

The U.S. Geological Survey does not collect consumption statistics for wollastonite, but consumption was estimated to have increased in 2018 as compared with that of the previous year. Ceramics (frits, sanitaryware, and tile), friction products (primarily brake linings), metallurgical applications (flux and conditioner), paint (architectural and industrial paints), plastics and rubber markets (thermoplastic and thermoset resins and elastomer compounds), and miscellaneous uses (including adhesives, concrete, glass, and sealants) accounted for wollastonite sales in the United States.

In ceramics, wollastonite decreases shrinkage and gas evolution during firing; increases green and fired strength; maintains brightness during firing; permits fast firing; and reduces crazing, cracking, and glaze defects. In metallurgical applications, wollastonite serves as a flux for welding, a source for calcium oxide, a slag conditioner, and protects the surface of molten metal during the continuous casting of steel. As an additive in paint, it improves the durability of the paint film, acts as a pH buffer, improves resistance to weathering, reduces gloss and pigment consumption, and acts as a flatting and suspending agent. In plastics, wollastonite improves tensile and flexural strength, reduces resin consumption, and improves thermal and dimensional stability at elevated temperatures. Surface treatments are used to improve the adhesion between wollastonite and the polymers to which it is added. As a substitute for asbestos in floor tiles, friction products, insulating board and panels, paint, plastics, and roofing products, wollastonite is resistant to chemical attack, stable at high temperatures, and improves flexural and tensile strength.

Salient Statistics—United States: The United States was thought to be a net exporter of wollastonite in 2018. Comprehensive trade data were not available for wollastonite because it is imported and exported under a generic Harmonized Tariff Schedule of the United States code that includes multiple mineral commodities. Ex-works prices for domestic wollastonite were reported in trade literature to range from approximately $210 to $445 per ton, and free-on-board prices for wollastonite from China, which tends to be minimally refined, ranged from $80 to $105 per ton. Products with finer grain sizes and acicular (highly elongated) particles sold for higher prices. Surface treatment, when necessary, also increased the selling price. Approximately 82 people were employed at wollastonite mines and mills in **2018** (excluding office workers).

Recycling: None.

Import Sources (2014–17): Comprehensive trade data were not available, but wollastonite was primarily imported from China, Finland, India, and Mexico.

Tariff:

Item	Number	Normal Trade Relations 12–31–18
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 10% (Domestic and foreign).

Government Stockpile: None.

Prepared by **Kenneth C. Curry [(703) 648–7793, kcurry@usgs.gov]**

WOLLASTONITE

Events, Trends, and Issues: U.S. construction spending in 2018 increased by 5.2% through July compared with that in the same time period during 2017, suggesting that sales of wollastonite to domestic construction-related markets, such as adhesives, caulks, cement board, ceramic tile, paints, stucco, and wallboard, might have increased. The major markets, in which wollastonite is used, increased: plastics increased slightly and primary iron and steel products increased. Production of motor vehicles and parts, which contain wollastonite in friction products and plastic and rubber components, and rubber, remained about the same.

Globally, ceramics, polymers (such as plastics and rubber), and paint accounted for most wollastonite sales. Lesser global uses for wollastonite included miscellaneous construction products, friction materials, metallurgical applications, and paper.

The leading U.S. producer of wollastonite continued to pursue a potential new mine within the Adirondack Forest Preserve of New York. This land became available for development as part of a land swap transaction approved by the State of New York in 2013. According to a company representative, the project was still in the development stage as of late 2018. Previous estimates suggest that the 81-hectare property contains 1.2 million to 1.5 million tons of wollastonite reserves.

World Mine Production and Reserves: U.S. production of wollastonite ranks fourth globally. Many countries either do not publish wollastonite production or production is reported with a 2- to 3-year lag time.

	Mine production[e]	
	2017	2018
United States	W	W
Canada	11,000	10,000
China	500,000	530,000
Finland	10,000	11,000
India	156,000	150,000
Mexico	88,000	90,000
Other countries	6,000	6,000
World total (rounded)[2]	770,000	800,000

Reserves[1]

World reserves of wollastonite exceed 100 million tons. Many deposits, however, have not been surveyed, precluding accurate reserves estimates.

World Resources: 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 it to compete with other acicular materials, such as ceramic fiber, glass fiber, steel fiber, and several organic fibers, such as aramid, polyethylene, polypropylene, and polytetrafluoroethylene, in products where improvements in dimensional stability, flexural modulus, and heat deflection are sought. Wollastonite also competes with several nonfibrous minerals or rocks, such as kaolin, mica, and talc, which are added to plastics to increase flexural strength, and such minerals as barite, calcium carbonate, gypsum, and talc, which impart dimensional stability to plastics. In ceramics, wollastonite competes with carbonates, feldspar, lime, and silica as a source of calcium and silica. Its use in ceramics depends on the formulation of the ceramic body and the firing method.

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]See Appendix C for resource and reserve definitions and information concerning data sources.
[2]Excludes U.S. production.

YTTRIUM[1]

[Data in metric tons of yttrium oxide (Y_2O_3) equivalent content unless otherwise noted]

Domestic Production and Use: Yttrium is one of the rare-earth elements. Bastnaesite (or bastnäsite), a rare-earth fluorocarbonate mineral, was mined in 2018 as a primary product at the Mountain Pass Mine in California, which was restarted in the first quarter after being put on care-and-maintenance status in the fourth quarter of 2015. Monazite, a rare-earth phosphate mineral, also may have been produced as a separated concentrate or included as an accessory mineral in heavy-mineral concentrates. Yttrium was estimated to represent about 0.12% of the rare-earth elements in the Mountain Pass bastnaesite ore.

The leading end uses of yttrium were in ceramics, 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 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. 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. Yttrium was used in phosphor compounds for flat-panel displays and various lighting applications.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production, mine[2]	NA	NA	—	—	NA
Imports for consumption:					
Yttrium, alloys, compounds, and metal[e, 3]	200	360	340	380	390
Exports, compounds[e, 4]	NA	39	2	2	14
Consumption, estimated[5]	200	300	300	400	400
Price, dollars per kilogram, average:					
Yttrium oxide, minimum 99.999 purity[6]	16	8	4	3	3
Yttrium metal, minimum 99.9% purity[6]	60	48	35	35	36
Net import reliance[2, 7] as a percentage of apparent consumption	>95	>95	100	100	>95

Recycling: Insignificant.

Import Sources (2014–17):[8] Yttrium compounds: China, 76%; Estonia, 13%; Japan, 4%; Republic of Korea, 3%; and other, 4%. 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 12–31–18**
Rare-earth metals, unspecified, whether or not intermixed or interalloyed	2805.30.0090	5.0% ad val.
Mixtures of rare-earth oxides containing yttrium or scandium as the predominant metal	2846.90.2015	Free.
Mixtures of rare-earth chlorides containing yttrium or scandium as the predominant metal	2846.90.2082	Free.
Yttrium-bearing materials and compounds containing by weight >19% to <85% Y_2O_3	2846.90.4000	Free.
Other rare-earth compounds, including yttrium and other compounds	2846.90.8000	3.7% ad val.

Depletion Allowance: Monazite, thorium content, 22% (Domestic), 14% (Foreign); yttrium, rare-earth content, 14% (Domestic and foreign); and xenotime, 14% (Domestic and foreign).

Government Stockpile:[9]

		FY2018		FY 2019	
Material	**Inventory As of 9–30–18**	**Potential Acquisitions**	**Potential Disposals[10]**	**Potential Acquisitions**	**Potential Disposals[10]**
Yttrium oxide	25	10	—	10	—

Prepared by **Joseph Gambogi [(703) 648–7718, jgambogi@usgs.gov]**

YTTRIUM

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 Provinces. Processing was primarily at facilities in Guangdong, Jiangsu, and Jiangxi Provinces. China's mining quota was estimated to include about 4,800 tons of yttrium, but illegal mining in China may have added significantly to the available supply. Programs to stem the undocumented production of rare earths in China were ongoing.

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. Prices for yttrium metal and oxide remained nearly unchanged in 2018.

In Nebraska, a rare-earth separation facility was being commissioned whose primary feedstock was expected to be recycled fluorescent lamp phosphors. The plant's initial production capacity was reported to be 430 tons per year, including 144 tons per year of yttrium oxide. An expansion plan was expected to raise the production capacity to 3,500 tons per year of separated oxides using mineral feedstocks. Ionic clays from Chile and domestic monazite mineral concentrates were being evaluated as potential sources.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including the rare-earth-elements group. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, ''A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" (82 FR 60835).

World Mine Production and Reserves:[11] World production of yttrium oxide was almost entirely from China in 2018 and was estimated to be 5,000 to 7,000 tons. Reserves of yttrium are associated with those of rare earths. Global reserves of yttrium oxide were estimated to be more than 500,000 tons. The leading countries for these reserves included Australia, Brazil, Canada, China, and India. Although reserves may be sufficient to satisfy near-term demand at current rates of production, economics, environmental issues, and permitting and trade restrictions could affect the mining or availability of many of the rare-earth elements, including yttrium.

World Resources: 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, nonplacer 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, yttrium oxide may be substituted with calcium oxide or magnesium oxide, but the substitutes generally impart lower toughness.

[e]Estimated. NA Not available. — Zero.
[1]See also Rare Earths; trade data for yttrium are included in the data shown for rare earths.
[2]Includes yttrium contained in rare-earth ores and mineral concentrates.
[3]Estimated from Trade Mining LLC shipping records.
[4]Estimated from Harmonized Tariff System-based Schedule B code: 2846.90.2015.
[5]Rounded to one significant digit. Yttrium consumed domestically was imported or refined from imported materials.
[6]Free on board China. Source: Argus Media group-Argus Metals International, London, United Kingdom.
[7]Defined as imports – exports. In 2014, insufficient data were available to determine exports and were excluded from the calculation.
[8]Includes estimated yttrium oxide equivalent content from the following Harmonized Tariff Schedule codes: 2846.90.2015, 2846.90.2082, 2846.90.4000, 2846.90.8050, and 2846.90.8060.
[9]See Appendix B for definitions.
[10]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[11]See Appendix C for resource and reserve definitions and information concerning data sources.

ZEOLITES (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2018, six companies in the United States operated nine zeolite mines and produced an estimated 95,000 tons of natural zeolites, a 15% increase from that of 2017. Two mines operated by an additional company were idle during the year. Chabazite was mined in Arizona, and clinoptilolite was mined in California, Idaho, New Mexico, Oregon, and Texas. Minor quantities of ferrierrite, mordenite, and phillipsite were also likely produced. New Mexico was estimated to be the leading natural zeolite-producing State in 2018, followed by California, Idaho, Texas, Oregon, and Arizona. The top three U.S. companies accounted for approximately 90% of total domestic production.

An estimated 93,000 tons of natural zeolites were sold in the United States during 2018, an increase of 14% compared with sales in 2017. Domestic uses were, in decreasing order by estimated quantity, animal feed, odor control, water purification, oil and grease absorbent, unclassified end uses, fertilizer carrier, gas absorbent (and air filtration), pet litter, desiccant, wastewater treatment, soil amendment, traction control (ice melt), synthetic turf, aquaculture, and fungicide or pesticide carrier. Animal feed, odor control, and water purification applications likely accounted for about 75% of the domestic sales tonnage.

Salient Statistics—United States:	2014	2015	2016	2017	2018[e]
Production, mine	62,800	75,100	75,200	82,400	95,000
Sales, mill	62,500	73,200	71,300	81,300	93,000
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[e, 1]	62,500	73,200	71,300	81,300	93,000
Price, range of value, dollars per metric ton[2]	110–440	110–950	100–400	100–300	100–300
Employment, mine and mill[e, 3]	95	100	115	110	110
Net import reliance[4] as a percentage of estimated consumption	E	E	E	E	E

Recycling: Zeolites used for desiccation, gas absorbance, wastewater cleanup, and water purification may be reused after reprocessing of the spent zeolites. Information about the quantity of recycled natural zeolites was unavailable.

Import Sources (2014–17): Comprehensive trade data were not available for natural zeolite minerals because they were imported and exported under a generic U.S. Census Bureau Harmonized Tariff Schedule code that includes multiple mineral commodities or under codes for finished products. Nearly all imports and exports consisted of synthetic zeolites.

Tariff: Item	Number	Normal Trade Relations 12–31–18
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: Prior to the 1990s, annual output of natural zeolites in the United States was less than 15,000 tons. Production rose more than sixfold from 1990 through 2018 owing predominantly to increases in sales for animal feed applications, although sales for odor control and water purification also increased significantly. In contrast, sales for pet litter declined substantially during this period as a result of competition from other products.

According to Mine Safety and Health Administration records, one domestic natural zeolite mine halted operations in March 2018; information about whether or when mining would recommence was unavailable. A major U.S. company finished construction of a new processing plant in 2017. The annual capacity of the mill was upgraded to more than 35,000 tons, a tenfold increase in comparison to the former plant. In early 2018, the company began a project to further expand its production capacity.

Prepared by **Daniel M. Flanagan [(703) 648–7726, dflanagan@usgs.gov]**

ZEOLITES (NATURAL)

World Mine Production and Reserves: Most countries either do not report production of natural zeolites or production is reported with a 2- to 3-year lag time. End uses for natural zeolites in countries that mine large tonnages of zeolite minerals typically include low-value, high-volume construction applications, such as dimension stone, lightweight aggregate, and pozzolanic cement. As a result, production data for some countries do not accurately indicate the quantities of natural zeolites used in the high-value applications that are reflected in the domestic data.

World reserves of natural zeolites have not been estimated. Deposits occur in many countries, but companies rarely, if ever, publish reserves data. Further complicating estimates of reserves is the fact that much of the reported world production includes altered volcanic tuffs with low to moderate concentrations of zeolites that are typically used in high-volume construction applications. Some deposits should, therefore, be excluded from reserves estimates because it is the rock itself and not its zeolite content that makes the deposit valuable.

Production data for multiple countries were revised based on information from Government and industry sources.

	Mine production[e]		Reserves[5]
	2017	2018	
United States	[6]82,400	95,000	World reserves data are unavailable but are estimated to be large.
China	300,000	300,000	
Cuba	[6]56,500	57,000	
Jordan	20,000	20,000	
Korea, Republic of	120,000	120,000	
New Zealand	[6]100,000	100,000	
Turkey	70,000	70,000	
Other countries	350,000	350,000	
World total (rounded)	1,100,000	1,100,000	

World Resources: Recent estimates for domestic and global resources of natural zeolites are not available. Resources of chabazite and clinoptilolite within the Basin and Range province 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 zeolite 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.
[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 $150 in 2014 and 2015 and $140 in 2016, 2017, and 2018. 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 office staff.
[4]Defined as imports – exports.
[5]See Appendix C for resource and reserve definitions and information concerning data sources.
[6]Reported figure.

ZINC

(Data in thousand metric tons of zinc content unless otherwise noted)

Domestic Production and Use: The value of zinc mined in 2018, based on zinc contained in concentrate, was about $2.5 billion. Zinc was mined in six States at 15 mines operated by five companies. Two smelter facilities, one primary and one secondary, operated by two companies, produced commercial-grade zinc metal. Of the total reported zinc consumed, most was used in galvanizing, followed by brass and bronze, zinc-based alloys, and other uses.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production:					
Zinc in ore and concentrate	831	825	805	774	790
Refined zinc[1]	180	172	126	132	130
Imports for consumption:					
Zinc in ore and concentrate	([2])	([2])	([2])	7	40
Refined zinc	805	771	713	729	770
Exports:					
Zinc in ore and concentrate	644	708	597	682	870
Refined zinc	20	13	47	32	22
Shipments from Government stockpile	—	—	—	—	—
Consumption, apparent, refined zinc[3]	965	931	792	829	880
Price, average, cents per pound:					
North American[4]	107.1	95.5	101.4	139.3	145.0
London Metal Exchange (LME), cash	98.1	87.6	94.8	131.3	137.0
Reported producer and consumer stocks, refined zinc, yearend	88	87	80	120	100
Employment:					
Mine and mill, number[5]	2,620	2,670	2,350	2,420	2,660
Smelter, primary, number	259	250	246	240	250
Net import reliance[6] as a percentage of apparent consumption (refined zinc)	81	81	84	84	85

Recycling: In 2018, about 25% (32,000 tons) of the refined zinc produced in the United States was recovered from secondary materials at both primary and secondary smelters. Secondary materials included galvanizing residues and crude zinc oxide recovered from electric arc furnace dust.

Import Sources (2014–17): Ore and concentrate: Peru, 99%; and other, 1%. Refined metal: Canada, 71%; Mexico, 14%; Peru, 8%; Australia, 6%; and other, 1%. Waste and scrap: Canada, 72%; Mexico, 27%; and other, 1%. Combined total: Canada, 70%; Mexico, 14%; Peru, 8%; Australia, 6%; and other, 2%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–18**
Zinc ores and concentrates, Zn content	2608.00.0030	Free.
Zinc oxide; zinc peroxide	2817.00.0000	Free.
Unwrought zinc, not alloyed:		
Containing 99.99% or more zinc	7901.11.0000	1.5% ad val.
Containing less than 99.99% zinc:		
Casting-grade	7901.12.1000	3% ad val.
Other	7901.12.5000	1.5% ad val.
Zinc alloys	7901.20.0000	3% ad val.
Zinc waste and scrap	7902.00.0000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile:[7]

		FY2018		**FY 2019**	
Material	**Inventory As of 9–30–18**	**Potential Acquisitions**	**Potential Disposals[8]**	**Potential Acquisitions**	**Potential Disposals[8]**
Zinc	7.25	—	7.25	—	7.25

Prepared by **Christine L. Thomas [(703) 648–7713, clthomas@usgs.gov]**

ZINC

Events, Trends, and Issues: Global zinc mine production in 2018 was estimated to be 13 million tons, a slight increase from that of 2017. Notable zinc mine production increases took place in Australia with the opening of the Dugald River Mine in late 2017 and the commissioning of two tailings projects; in Cuba, with the opening of the Castellanos Mine in late 2017; and in Peru, with increased production at the Antamina Mine.

In 2018, the zinc metal market continued the deficit observed in 2017, with consumption exceeding production. According to the International Lead and Zinc Study Group,[9] global refined zinc production in 2018 was estimated to be 13.42 million tons, and metal consumption was estimated to be 13.74 million tons, resulting in a production-to-consumption deficit of 322,000 tons of refined zinc.

Domestic zinc mine production increased slightly in 2018, owing to the addition of production from a reopened mine in New York. Refined zinc production decreased slightly owing to maintenance outages at the Clarksville, TN, smelter. Despite the slight decrease in refined zinc production, calculated apparent consumption for 2018 increased by 6% to 880,000 tons owing to an increase of imports.

The monthly average North American Special High Grade (SHG) zinc price decreased by about 28% in the first 9 months of 2018 to an average of $1.19 per pound in September from $1.64 per pound in January.

World Mine Production and Reserves: Reserves for the United States, Canada, India, and Sweden were revised based on company data. The reserves estimates for China and Peru were revised based on data from Government reports.

	Mine production[10]		Reserves[11]
	2017	2018[e]	
United States	774	790	11,000
Australia	842	940	[12]64,000
Bolivia	473	520	4,800
Canada	344	340	3,000
China	4,400	4,300	44,000
India	833	800	10,000
Kazakhstan	330	390	13,000
Mexico	674	650	20,000
Peru	1,470	1,600	21,000
Sweden	251	220	1,400
Other countries	2,140	2,300	33,000
World total (rounded)	12,500	13,000	230,000

World Resources: Identified zinc resources of the world are about 1.9 billion tons.

Substitutes: Aluminum and plastics substitute for galvanized sheet in automobiles; and aluminum alloys, cadmium, paint, and plastic coatings replace zinc coatings in other applications. Aluminum- and magnesium-base alloys are major competitors for zinc-base die-casting alloys. Many elements are substitutes for zinc in chemical, electronic, and pigment uses.

[e]Estimated. — Zero.
[1]Includes primary and secondary refined production.
[2]Less than ½ unit.
[3]Defined as refined production + refined imports – refined exports + adjustments for Government stock changes.
[4]Platts Metals Week price for North American SHG zinc; based on the LME cash price plus premium.
[5]Includes mine and mill employment at all zinc-producing mines. Source: Mine Safety and Health Administration.
[6]Defined as imports – exports + adjustments for Government stock changes.
[7]See Appendix B for definitions.
[8]Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock.
[9]International Lead and Zinc Study Group, 2018, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 8, 6 p.
[10]Zinc content of concentrate and direct shipping ore.
[11]See Appendix C for resource and reserve definitions and information concerning data sources.
[12]For Australia, Joint Ore Reserves Committee-compliant reserves were about 24 million tons.

ZIRCONIUM AND HAFNIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2018, two firms recovered zircon (zirconium silicate) from surface-mining operations in Florida and Georgia as a coproduct from the mining of heavy-mineral sands and the processing of titanium and zirconium mineral concentrates, and a third company processed existing mineral sands tailings in Florida. Zirconium metal and hafnium metal were produced from zirconium chemical intermediates by one producer in Oregon and one in Utah. Zirconium and hafnium are typically contained in zircon at a ratio of about 36 to 1. Zirconium chemicals were produced by the metal producer in Oregon and by at least 10 other companies. Ceramics, foundry sand, opacifiers, and refractories are the leading end uses for zircon. Other end uses of zircon include abrasives, chemicals (predominantly, zirconium basic sulfate and zirconium oxychloride octohydrate as intermediate chemicals), metal alloys, and welding rod coatings. The leading consumers of zirconium metal are the chemical process and nuclear energy industries. The leading use of hafnium metal is in superalloys.

Salient Statistics—United States:	**2014**	**2015**	**2016**	**2017**	**2018[e]**
Production, zircon, ores and concentrates (ZrO_2 content)[1]	W	[2]50,000	W	[2]50,000	[2]100,000
Imports:					
Zirconium ores and concentrates (ZrO_2 content)	32,800	20,800	24,900	24,300	31,000
Zirconium, unwrought, powder, and waste and scrap	843	1,140	1,040	900	2,600
Zirconium, wrought	257	188	195	282	300
Hafnium, unwrought, powder, and waste and scrap	21	72	180	113	36
Exports:					
Zirconium ores and concentrates (ZrO_2 content)	4,850	3,200	3,280	31,500	80,000
Zirconium, unwrought, powder, and waste and scrap	534	515	363	627	620
Zirconium, wrought	913	1,020	788	972	1,200
Consumption, apparent, zirconium ores and concentrates, (ZrO_2 content)[3]	W	[2]70,000	W	[2]40,000	[2]30,000
Prices:					
Zircon, dollars per metric ton (gross weight):					
Australia, free on board[4]	1,025	1,025	975	975	NA
China, cost insurance and freight[4]	NA	NA	NA	1,125	1,500
Imported[5]	1,133	1,061	877	916	1,200
Zirconium, unwrought, import, China, dollars per kilogram[6]	55	15	33	12	13
Hafnium, unwrought, dollars per kilogram[7]	NA	1,250	930	900	775
Net import reliance[8] as a percentage of apparent consumption:					
Zircon, ores and concentrates	<50	<25	<50	E	E
Hafnium	NA	NA	NA	NA	NA

Recycling: Companies in Oregon and Utah recycled zirconium from new scrap generated during metal production and fabrication and (or) from post-commercial old scrap. Zircon foundry mold cores and spent or rejected zirconia refractories are often recycled. Hafnium metal recycling was insignificant.

Import Sources (2014–17): Zirconium ores and concentrates: South Africa, 55%; Australia, 23%; Senegal, 18%; and other, 4%. Zirconium, unwrought, including powder: China, 70%; Germany, 17%; Japan, 9%; France, 3%; and other, 1%. Hafnium, unwrought: Germany, 47%; France, 30%; United Kingdom, 11%; China, 11%; and other, 1%.

Tariff:

Item	**Number**	**Normal Trade Relations 12–31–18**
Zirconium ores and concentrates	2615.10.0000	Free.
Ferrozirconium	7202.99.1000	4.2% ad val.
Zirconium, unwrought and powder	8109.20.0000	4.2% ad val.
Zirconium waste and scrap	8109.30.0000	Free.
Other zirconium articles	8109.90.0000	3.7% ad val.
Hafnium, unwrought, powder, and waste and scrap	8112.92.2000	Free.

Depletion Allowance: 22% (Domestic), 14% (Foreign).

Government Stockpile: None.

Prepared by **George M. Bedinger [(703) 648–6183, gbedinger@usgs.gov]**

ZIRCONIUM AND HAFNIUM

Events, Trends, and Issues: Domestic production of zircon concentrates increased sharply in 2018 owing to process improvements and year-round operations of the third company reprocessing mineral sands tailings in Starke, FL. Prices for zircon concentrate imports rose slightly during the year; however, export unit values decreased. Apparent consumption was estimated to have increased in 2018, and exports were estimated to have more than doubled in 2018.

In May 2018, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals (83 FR 23295), including hafnium and zirconium. This list was developed to serve as an initial focus, pursuant to Executive Order 13817, "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" (82 FR 60835).

In New South Wales, Australia, construction at the Dubbo Zirconia Project (DZP) at yearend 2018 remained on hold pending financing. The DZP was projected to produce zirconium carbonate (equivalent to 16,300 tons per year of ZrO_2) and more than 200 tons per year of hafnium (IV) oxide (HfO_2), as well as niobium, rare-earth, and tantalum products. Production of hafnium metal from HfO_2 would be independent of zirconium metal production for the nuclear industry where it is a byproduct.

World Mine Production and Reserves: World primary hafnium production data are not available and quantitative estimates of hafnium reserves are not available. The zirconium reserves estimate for Australia was revised based on data from Geoscience Australia. Reserves for Kenya were revised based on company reporting.

	Zirconium ores and concentrates, mine production (thousand metric tons, gross weight)		Zirconium reserves[9] (thousand metric tons, ZrO_2 content)
	2017	2018[e]	
United States	[2]80	[2]100	500
Australia	505	500	42,000
China	140	150	500
Indonesia	110	100	NA
Kenya	44	45	3,600
Mozambique	74	80	1,800
Senegal	82	80	NA
South Africa	377	350	14,000
Other countries	138	125	10,600
World total (rounded)	1,550	1,500	73,000

World Resources: 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 are not available.

Substitutes: Chromite and olivine can be used instead of zircon for some foundry applications. Dolomite and spinel refractories can also substitute for zircon in certain high-temperature applications. Niobium (columbium), stainless steel, and tantalum provide limited substitution in nuclear applications, and titanium and synthetic materials may substitute in some chemical processing plant applications. Silver-cadmium-indium control rods are used in lieu of hafnium at numerous nuclear powerplants. Zirconium can be used interchangeably with hafnium in certain superalloys.

[e]Estimated. E Net Exporter. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Contained ZrO_2 content calculated at 65% of gross production.
[2]Rounded to one significant digit to avoid disclosing company proprietary data.
[3]Defined as production + imports – exports.
[4]Source: Industrial Minerals, average of yearend price. Prices of zircon from Australia were discontinued at yearend 2017.
[5]Unit value based on annual United States imports for consumption from Australia, Senegal, and South Africa.
[6]Unit value based on annual United States imports for consumption from China.
[7]Source: Argus Media group–Argus Metals International, minimum 99% hafnium, at warehouse (Rotterdam), average of yearend price.
[8]Defined as imports – exports.
[9]See Appendix C for resource and reserve definitions and information concerning data sources.

APPENDIX A

Abbreviations and Units of Measure

1 carat (metric) (diamond)	= 200 milligrams
1 flask (fl)	= 76 pounds, avoirdupois
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
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 Helium Stockpile

Inventory refers to the quantity of mineral materials held in the National Defense Stockpile or in the Federal Helium Reserve. Nonstockpile-grade materials may be included in the table; where significant, the quantities of these stockpiled materials are specified in the text accompanying the table.

Potential disposals indicate the total amount of a material in the National Defense Stockpile that the U.S. Department of Defense is permitted to dispose of under the Annual Materials Plan approved by Congress for the fiscal year. Congress has authorized disposal over the long term at rates designed to maximize revenue but avoid undue disruption to the usual markets and financial loss to the United States. Fiscal year (FY) 2018 is the period from October 1, 2017, through September 30, 2018. FY 2019 is the period from October 1, 2018, through September 30, 2019. Disposals are defined as any barter, rotation, sale, or upgrade of National Defense Stockpile stock. For mineral commodities that have a disposal plan greater than the inventory, the actual quantity will be limited to the remaining disposal authority or inventory. Note that, unlike the National Defense Stockpile, helium stockpile sales by the Bureau of Land Management under the Helium Privatization Act of 1996 are permitted to exceed disposal plans.

Potential acquisitions indicate the maximum amount of a material that may be acquired by the U.S. Department of Defense for the National Defense Stockpile under the Annual Materials Plan approved by Congress for the fiscal year. FY 2018 is the period from October 1, 2017, through September 30, 2018. FY 2019 is the period from October 1, 2018, through September 30, 2019.

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, almost 540 million tons of copper have been produced worldwide, but world copper reserves in 2018 were estimated to be 830 million tons of copper, almost triple those of 1970, despite the depletion by mining of more than the original 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/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 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/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 1 and 2; its components and their usage are described in the text. The classification of mineral and energy resources is necessarily arbitrary because definitional criteria do not always coincide with natural boundaries. The system can be used to report the status of mineral and energy-fuel resources for the Nation or for specific areas.[1]

RESOURCE/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 whose 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.

Demonstrated.—A term for the sum of measured plus indicated.

Measured.—Quantity is computed from dimensions revealed in outcrops, trenches,

[1]Based on U.S. Geological Survey Circular 831, 1980.

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 measurement 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 which 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/Reserves.—That part of any resource/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 1 and 2. In figure 1, 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, percent extractable, 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 1 and 2. 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 1.—Major Elements of Mineral-Resource Classification, Excluding *Reserve Base* and *Inferred Reserve Base*

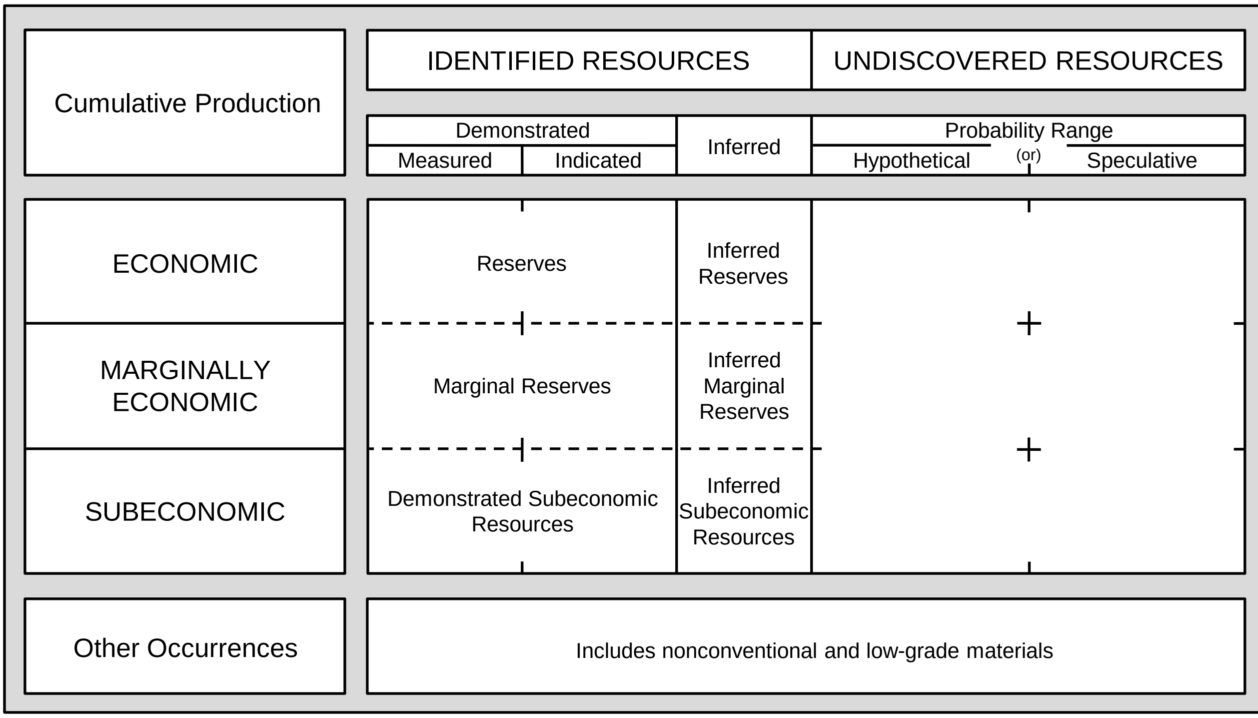
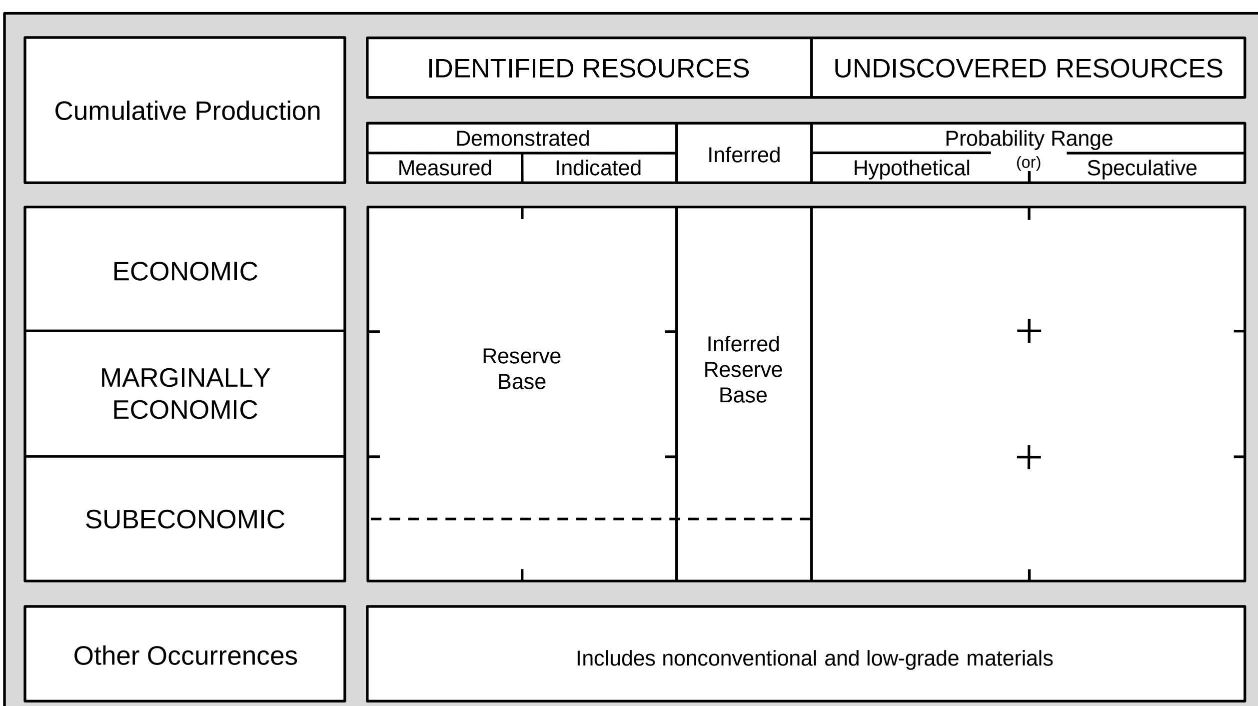


Figure 2.—*Reserve Base* and *Inferred Reserve Base* Classification Categories



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 information about the quantity and quality of mineral resources but does not directly measure reserves, and companies or governments do not directly report reserves to the USGS. Reassessment of reserves is a continuing process, and the intensity of this process differs for mineral commodities, countries, 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 (the 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 (https://www.jorc.org/).

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 Mineral Commodity Summaries 2019 are Accessible EDR. For more information, see table 3. Australia's Identified Mineral Resources as of December 2016 can be found at https://www.ga.gov.au/scientific-topics/minerals/mineral-resources-and-advice/aimr/table-3-mineral-resources.

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://web.cim.org/standards/MenuPage.cfm?sections=177&menu=178.

Russian reserves for most minerals, which had been withheld, have been released with increasing frequency within the past few years and can appear in a number of sources, although no systematic list of Russian reserves is published. Russian reserves data for various minerals appear at times in journal articles, such as those in the journal Mineral'nye Resursy Rossii (Mineral Resources of Russia), which is published by the Russian Ministry of Natural Resources. Russian reserves data are often published according to the Soviet reserves classification system, which is still used in many countries of the former Soviet Union, but also at times published according to the JORC system based on analyses made by Western firms. 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, as 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 reserves that are included. 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 (economic reserves or balansovye zapasy) and outside the balance reserves (uneconomic reserves or zabalansovye zapasy), as well as categories that include explored, industrial, and proven reserves, and the reserves totals can vary significantly, depending on the specific definition of reserves being reported.

APPENDIX D

Country Specialists Directory

Minerals information country specialists at the U.S. Geological Survey collect and analyze information on the mineral industries of more than 170 nations throughout the world. The specialists are available to answer minerals-related questions concerning individual countries.

Africa and the Middle East

Algeria	Mowafa Taib
Angola	Meralis Plaza-Toledo
Bahrain	Philip A. Szczesniak
Benin	Meralis Plaza-Toledo
Botswana	Thomas R. Yager
Burkina Faso	Alberto A. Perez
Burundi	Thomas R. Yager
Cameroon	Philip A. Szczesniak
Cabo Verde	Meralis Plaza-Toledo
Central African Republic	James J. Barry
Chad	Philip A. Szczesniak
Comoros	James J. Barry
Congo (Brazzaville)	James J. Barry
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	James J. Barry
Ethiopia	Meralis Plaza-Toledo
Gabon	Alberto A. Perez
The Gambia	Meralis Plaza-Toledo
Ghana	Meralis Plaza-Toledo
Guinea	Alberto A. Perez
Guinea-Bissau	Meralis Plaza-Toledo
Iran	Philip A. Szczesniak
Iraq	Philip A. Szczesniak
Israel	Philip A. Szczesniak
Jordan	Mowafa Taib
Kenya	Thomas R. Yager
Kuwait	Philip A. Szczesniak
Lebanon	Mowafa Taib
Lesotho	James J. Barry
Liberia	Meralis Plaza-Toledo
Libya	Mowafa Taib
Madagascar	Thomas R. Yager
Malawi	Thomas R. Yager
Mali	Alberto A. Perez
Mauritania	Mowafa Taib
Mauritius	James J. Barry
Morocco & Western Sahara	Mowafa Taib
Mozambique	Meralis Plaza-Toledo
Namibia	James J. Barry
Niger	Alberto A. Perez
Nigeria	Thomas R. Yager
Oman	Philip A. Szczesniak
Qatar	Philip A. Szczesniak
Reunion	James J. Barry
Rwanda	Thomas R. Yager
São Tomé & Principe	Meralis Plaza-Toledo
Saudi Arabia	Mowafa Taib
Senegal	Alberto A. Perez
Seychelles	James J. Barry
Sierra Leone	Alberto A. Perez
Somalia	Philip A. Szczesniak
South Africa	Thomas R. Yager
South Sudan	Alberto A. Perez
Sudan	Mowafa Taib
Syria	Mowafa Taib
Tanzania	Thomas R. Yager
Togo	Alberto A. Perez
Tunisia	Mowafa Taib
Uganda	Thomas R. Yager
United Arab Emirates	Philip A. Szczesniak
Yemen	Mowafa Taib
Zambia	James J. Barry
Zimbabwe	James J. Barry

Asia and the Pacific

Afghanistan	Karine M. Renaud
Australia	Spencer Buteyn
Bangladesh	Ji Won Moon
Bhutan	Ji Won Moon
Brunei	Spencer Buteyn
Burma (Myanmar)	Ji Won Moon
Cambodia	Ji Won Moon
China	Sean Xun
East Timor	Jaewon Chung
Fiji	Spencer Buteyn
India	Karine M. Renaud
Indonesia	Jaewon Chung
Japan	Jaewon Chung
Korea, North	Jaewon Chung
Korea, Republic of	Jaewon Chung
Laos	Ji Won Moon
Malaysia	Spencer Buteyn
Mongolia	Jaewon Chung
Nauru	Spencer Buteyn
Nepal	Ji Won Moon
New Caledonia	Spencer Buteyn
New Zealand	Spencer Buteyn
Pakistan	Ji Won Moon
Papua New Guinea	Spencer Buteyn
Philippines	Ji Won Moon
Singapore	Spencer Buteyn
Solomon Islands	Jaewon Chung
Sri Lanka	Ji Won Moon
Taiwan	Jaewon Chung
Thailand	Ji Won Moon
Vietnam	Ji Won Moon

Europe and Central Eurasia

Albania	Sinan Hastorun
Armenia	Elena Safirova
Austria	Sinan Hastorun
Azerbaijan	Elena Safirova
Belarus	Elena Safirova
Belgium	Sinan Hastorun

Europe and Central Eurasia—Continued

Bosnia and Herzegovina	Lindsey Abdale
Bulgaria	Karine M. Renaud
Croatia	Lindsey Abdale
Cyprus	Sinan Hastorun
Czechia	Lindsey Abdale
Denmark, Faroe Islands, and Greenland	Joanna Goclawska
Estonia	Lindsey Abdale
Finland	Joanna Goclawska
France	Lindsey Abdale
Georgia	Elena Safirova
Germany	Elena Safirova
Greece	Sinan Hastorun
Hungary	Sinan Hastorun
Iceland	Joanna Goclawska
Ireland	Joanna Goclawska
Italy	Lindsey Abdale
Kazakhstan	Elena Safirova
Kosovo	Sinan Hastorun
Kyrgyzstan	Karine M. Renaud
Latvia	Lindsey Abdale
Lithuania	Lindsey Abdale
Luxembourg	Sinan Hastorun
Macedonia	Lindsey Abdale
Malta	Sinan Hastorun
Moldova	Elena Safirova
Montenegro	Sinan Hastorun
Netherlands	Sinan Hastorun
Norway	Joanna Goclawska
Poland	Joanna Goclawska
Portugal	Joanna Goclawska
Romania	Lindsey Abdale
Russia	Elena Safirova
Serbia	Karine M. Renaud
Slovakia	Lindsey Abdale
Slovenia	Lindsey Abdale
Spain	Lindsey Abdale
Sweden	Joanna Goclawska
Switzerland	Sinan Hastorun
Tajikistan	Karine M. Renaud
Turkey	Sinan Hastorun
Turkmenistan	Karine M. Renaud
Ukraine	Elena Safirova
United Kingdom	Lindsey Abdale
Uzbekistan	Elena Safirova

North America, Central America, and the Caribbean

Aruba	Yadira Soto-Viruet
The Bahamas	Yadira Soto-Viruet
Belize	Jesse J. Inestroza
Canada	James J. Barry
Costa Rica	Jesse J. Inestroza
Cuba	Yadira Soto-Viruet
Dominican Republic	Yadira Soto-Viruet
El Salvador	Jesse J. Inestroza
Guatemala	Jesse J. Inestroza
Haiti	Yadira Soto-Viruet
Honduras	Jesse J. Inestroza
Jamaica	Yadira Soto-Viruet
Mexico	Alberto A. Perez
Nicaragua	Jesse J. Inestroza
Panama	Jesse J. Inestroza
Trinidad and Tobago	Yadira Soto-Viruet

South America

Argentina	Jesse J. Inestroza
Bolivia	Yolanda Fong-Sam
Brazil	Yolanda Fong-Sam
Chile	Yadira Soto-Viruet
Colombia	Jesse J. Inestroza
Ecuador	Jesse J. Inestroza
French Guiana	Yolanda Fong-Sam
Guyana	Yolanda Fong-Sam
Paraguay	Yadira Soto-Viruet
Peru	Yadira Soto-Viruet
Suriname	Yolanda Fong-Sam
Uruguay	Yadira Soto-Viruet
Venezuela	Yolanda Fong-Sam

Country specialist	Telephone	E-mail
Lindsey Abdale	(703) 648–7716	labdale-beadle@usgs.go
James J. Barry	(703) 648–7752	jbarry@usgs.gov
Spencer Buteyn	(703) 648–7738	sbuteyn@usgs.gov
Jaewon Chung	(703) 648–4793	jchung@usgs.go
Yolanda Fong-Sam	(703) 648–7756	yfong-sam@usgs.gov
Joanna Goclawska	(703) 648–7973	jgoclawska@usgs.gov
Sinan Hastorun	(703) 648–7744	shastorun@usgs.gov
Jesse J. Inestroza	(703) 648–7779	jinestroza@usgs.gov
Ji Won Moon	(703) 648–7791	jmoon@usgs.gov
Alberto A. Perez	(703) 648–7749	aperez@usgs.gov
Meralis Plaza-Toledo	(703) 648–7759	mplaza-toledo@usgs.gov
Karine M. Renaud	(703) 648–7748	krenaud@usgs.gov
Elena Safirova	(703) 648–7731	esafirova@usgs.gov
Yadira Soto-Viruet	(703) 648–4957	ysoto-viruet@usgs.gov
Philip A. Szczesniak	(703) 648–7728	pszczesniak@usgs.gov
Mowafa Taib	(703) 648–4986	mtaib@usgs.gov
Sean Xun	(703) 648–7746	sxun@usgs.gov
Thomas R. Yager	(703) 648–7739	tyager@usgs.gov