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

MINERAL COMMODITY SUMMARIES 2016

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

MINERAL COMMODITY SUMMARIES 2016

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

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U.S. Department of the Interior
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INSTANT INFORMATION

Information about the U.S. Geological Survey, its programs, staff, and products is available from the Internet at <http://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 <http://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. 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. 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 30 mineral commodities. 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.

Nonmetallic Mineral Products Industry Indexes—This monthly publication analyzes the leading and coincident indexes for the nonmetallic mineral products industry (NAICS 327).

Materials Flow Studies—These publications analyze global supply chains and characterize major components of mineral and material flows from ore extraction through processing to first-tier products to ultimate disposition to help better understand the economy, manage the use of natural resources, and protect the environment.

Recycling Reports—These studies illustrate the recycling of metal commodities and identify recycling trends.

Historical Statistics for Mineral and Material Commodities in the United States (Data Series 140)—These reports provides a compilation of statistics on production, trade, and use of approximately 90 mineral commodities since as far back as 1900.

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 <http://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 <http://minerals.usgs.gov/minerals/>.

INTRODUCTION

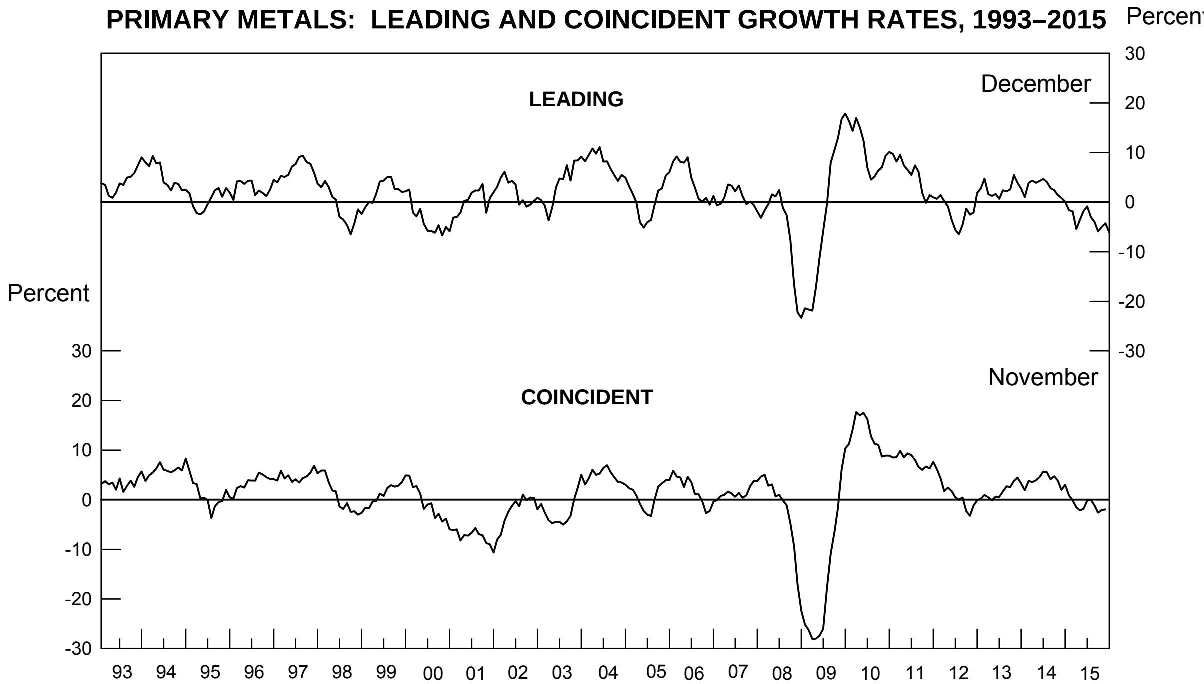
Each chapter of the 2016 edition of the U.S. Geological Survey (USGS) Mineral Commodity Summaries (MCS) includes information on events, trends, and issues for each mineral commodity as well as discussions and tabular presentations on domestic industry structure, Government programs, tariffs, 5-year salient statistics, and world production and resources. The MCS is the earliest comprehensive source of 2015 mineral production data for the world. More than 90 individual minerals and materials are covered by two-page synopses.

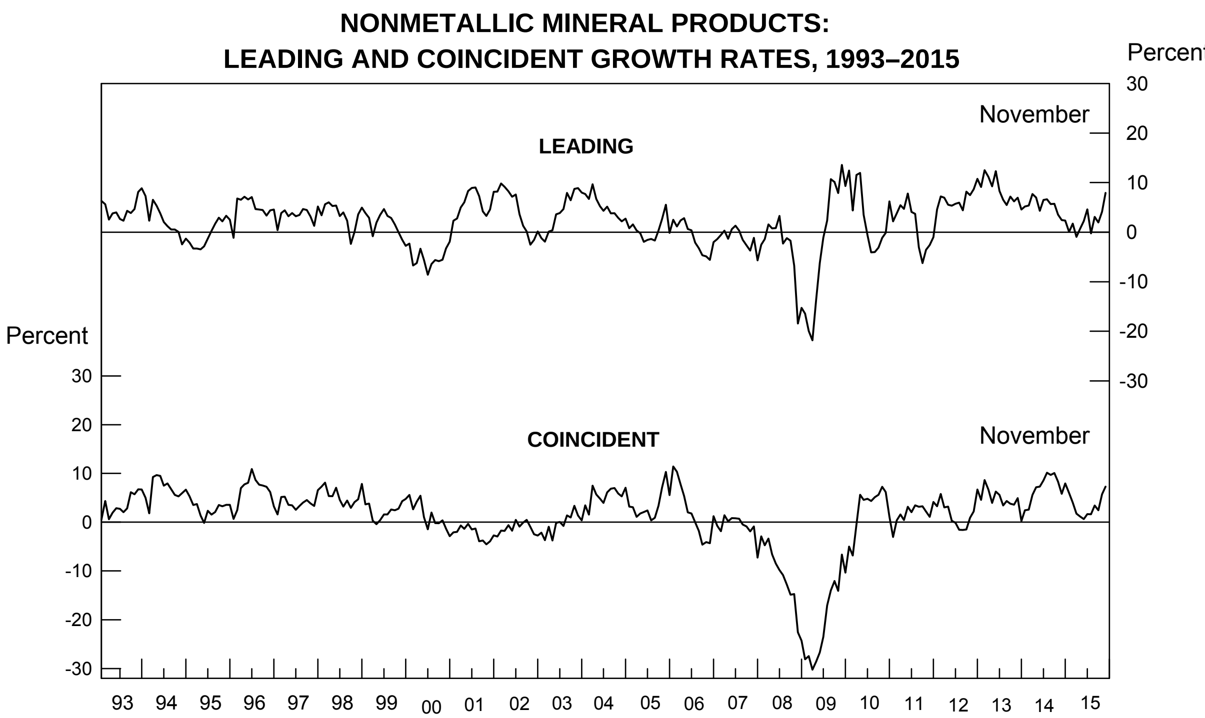
For mineral commodities for which there is a Government stockpile, detailed information concerning the stockpile status is included in the two-page synopsis.

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 assigned countries 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 2016 are welcomed.

GROWTH RATES OF LEADING AND COINCIDENT INDEXES FOR MINERAL PRODUCTS





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 2015)

NET EXPORTS OF MINERAL RAW MATERIALS

GOLD, SODA ASH, ZINC CONCENTRATES, ETC.

Imports: $6.1 billion
<u>Exports: $9.1 billion</u>
Net exports: $3.0 billion

DOMESTIC MINERAL RAW MATERIALS FROM MINING

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

Value: $78.3 billion

METALS AND MINERAL PRODUCTS RECYCLED DOMESTICALLY

ALUMINUM, GLASS, STEEL, ETC.

Value of old scrap: $25.3 billion

NET EXPORTS OF OLD SCRAP

GOLD, STEEL, ETC.

Imports: $4.9 billion
<u>Exports: $16.3 billion</u>
Net exports: $11.4 billion

MINERAL MATERIALS PROCESSED DOMESTICALLY

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

Value of shipments:
$630 billion

NET IMPORTS OF PROCESSED MINERAL MATERIALS

METALS, CHEMICALS, ETC.

Imports: $131 billion
<u>Exports: $99 billion</u>
Net imports: $32 billion

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

Value: $ 2,490 billion

U.S. ECONOMY

Gross Domestic Product:
$ 17,900 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

2015 U.S. NET IMPORT RELIANCE[1]

Commodity	Percent	Major import sources (2011–14)[2]
ARSENIC	100	Morocco, China, Belgium
ASBESTOS	100	Brazil, Canada
BAUXITE	100	Jamaica, Guinea, Brazil, Guyana
CESIUM	100	Canada
FLUORSPAR	100	Mexico, China, South Africa, Mongolia
GALLIUM	100	Germany, China, United Kingdom, Ukraine
GRAPHITE (natural)	100	China, Mexico, Canada, Brazil
INDIUM	100	Canada, China, Belgium, Republic of Korea
MANGANESE	100	South Africa, Gabon, Australia, Georgia
MICA, sheet (natural)	100	India, Brazil, China, Belgium
NIOBIUM (columbium)	100	Brazil, Canada
QUARTZ CRYSTAL (industrial)	100	China, Japan, Romania, United Kingdom
RUBIDIUM	100	Canada
SCANDIUM	100	China
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Germany, Indonesia, Kazakhstan
THALLIUM	100	Germany, Russia
THORIUM	100	India, France
VANADIUM	100	Czech Republic, Canada, Republic of Korea, Austria
GEMSTONES	99	Israel, India, Belgium, South Africa
BISMUTH	95	China, Belgium, Peru, United Kingdom
TITANIUM MINERAL CONCENTRATES	91	South Africa, Australia, Canada, Mozambique
PLATINUM	90	South Africa, Germany, United Kingdom, Canada
GARNET (industrial)	88	Australia, India, China
GERMANIUM	85	China, Belgium, Russia, Canada
ANTIMONY	84	China, Bolivia, Belgium, Thailand
DIAMOND (dust grit, and powder)	84	China, Ireland, Romania, Republic of Korea
POTASH	84	Canada, Russia, Israel, Chile
STONE (dimension)	83	China, Brazil, Italy,Turkey
ZINC	82	Canada, Mexico, Peru, Australia
RHENIUM	79	Chile, Poland, Germany
SILICON CARBIDE (crude)	77	China, South Africa, Netherlands, Romania
RARE EARTHS[3]	76	China, Estonia, France, Japan
COBALT	75	China, Norway, Finland, Russia
TIN	75	Peru, Indonesia, Bolivia, Malaysia
SILVER	72	Mexico, Canada, Poland, Peru
BARITE	70	China, India, Morocco, Mexico
PEAT	69	Canada
TITANIUM (sponge)	68	Japan, Kazakhstan, China
CHROMIUM	66	South Africa, Kazakhstan, Russia
PALLADIUM	58	Russia, South Africa, United Kingdom, Switzerland
TUNGSTEN	49	China, Bolivia, Canada, Germany
MAGNESIUM COMPOUNDS	43	China, Brazil, Canada, Australia
ALUMINUM	40	Canada, Russia, United Arab Emirates
MICA, scrap and flake (natural)	39	Canada, China, Finland, India
SILICON	38	Russia, Brazil, China, Canada
NICKEL	37	Canada, Australia, Russia, Norway
COPPER	36	Chile, Canada, Mexico
SALT	32	Chile, Canada, Mexico, The Bahamas
LEAD	31	Canada, Mexico, Peru, Australia, Kazakhstan
NITROGEN (fixed)—AMMONIA	29	Trinidad and Tobago, Canada, Russia, Ukraine
MAGNESIUM METAL	26	Israel, Canada, China, Mexico
IRON and STEEL	25	Canada, Republic of Korea, Brazil, Russia
PERLITE	21	Greece, Turkey
PUMICE	21	Greece, Iceland, Mexico
VERMICULITE	20	South Africa, Brazil, China
SULFUR	16	Canada, Mexico, Venezuela
GYPSUM	14	Mexico, Canada, Spain
TALC	13	Pakistan, Canada, China, Japan
FELDSPAR	12	Turkey, Mexico, Germany, India
BERYLLIUM	11	Kazakhstan, China, Nigeria, United Kingdom
IRON and STEEL SLAG	11	Canada, Japan, Spain, Italy
CEMENT	10	Canada, Republic of Korea, China, Greece

[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; alumina; boron; cadmium; clays; diatomite; gold; helium; iron and steel scrap; iron ore; kyanite; molybdenum; sand and gravel, industrial; selenium; soda ash; titanium dioxide pigment; wollastonite; zeolites) or less than 10% import reliant (diamond, industrial stones; lime; phosphate rock; sand and gravel, construction; stone, crushed). For some mineral commodities (abrasives, fused aluminum oxide; hafnium; mercury), not enough information is available to calculate the exact percentage of import reliance; for others (bromine; iodine; iron oxide pigments; lithium; tellurium; yttrium; zirconium), exact percentages may have been rounded to avoid disclosing company proprietary data.

[2]In descending order of import share.

[3]Data include lanthanides and yttrium but do not include most scandium.

SIGNIFICANT EVENTS, TRENDS, AND ISSUES

In 2015, the estimated value of total nonfuel mineral production in the United States decreased by 3% from that of 2014, mainly as a result of decreased metal prices, especially iron ore, copper, and precious metals. The value and quantity of industrial minerals production increased, especially for those used in the construction sector. Lower metal prices were attributed to decreased consumption, especially in China, reduced investment demand, and increased global inventories. Several U.S. metal mines were idled in 2015, including the only U.S. rare earth mine at Mountain Pass, CA. Downstream processors were also affected with smelters and refiners either shutting down or with idling production lines.

The U.S. Geological Survey (USGS) generates composite indexes to measure economic activity in the primary metals industry and the nonmetallic minerals, as shown in the charts of leading and coincident mineral industry indicators on page 4. For each of the indexes, a growth rate is calculated to measure its change relative to the previous 12 months. The primary metals leading index growth rate started 2015 just below the threshold that signals decreases in metals industry activity. It continued to decline throughout the year and at yearend, it settled deeper in negative territory. U.S. economic growth supported the domestic primary metals industry; however, weak global economic growth and the strong U.S. dollar limited U.S. exports. Meanwhile, low-priced metal imports increased during most of 2015 but decreased toward the end of the year as consumption decreased. Imports accounted for nearly 30% of U.S. steel consumption during 2015. Despite the highest number of domestic vehicles sold since 2001, metals consumption by the manufacturing sector decreased during the year. Similarly, metals consumption from the construction sector was strong at the beginning of 2015 but decreased as the year progressed. Construction spending increased by more than 10 percent compared with that in 2014. One of the leading nonresidential construction activities in early 2015 was manufacturing plant construction, but this decreased by the end of the year as decreased manufacturing activity did not merit new plant starts. The residential construction sector improved during the year, with the highest level of housing starts since the last recession began. The nonmetallic mineral products industry also benefitted from this increase in construction spending in 2015. Residential construction indicators, such as housing starts and building permits, point to continued increases in single-family home building, which is expected to be the largest portion of residential construction activity in 2016. At the end of 2015, the nonmetallic mineral products leading index growth rate indicated moderate growth in the nonmetallic mineral products industry in 2016.

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 mineral raw materials produced at mines in the United States in 2015 was $78.3 billion, a 3% decrease from $80.8 billion in 2014. Domestic raw materials and domestically recycled materials were used to process mineral materials worth $630 billion. These mineral materials were, in turn, consumed by downstream industries with an estimated value of $2.49 trillion in 2015, a slight decrease from $2.52 trillion in 2014.

The figure on page 6 illustrates the reliance of the United States on foreign sources for raw and processed mineral materials. In 2015, imports made up more than one-half of the U.S. apparent consumption of 47 nonfuel mineral commodities, including some reported only as greater than 50%. The United States was 100% import reliant for 19 of those. The figure on page 8 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. In 2015, the United States was a net exporter of 19 nonfuel mineral commodities, meaning that more of those domestically produced mineral commodities were exported than imported.

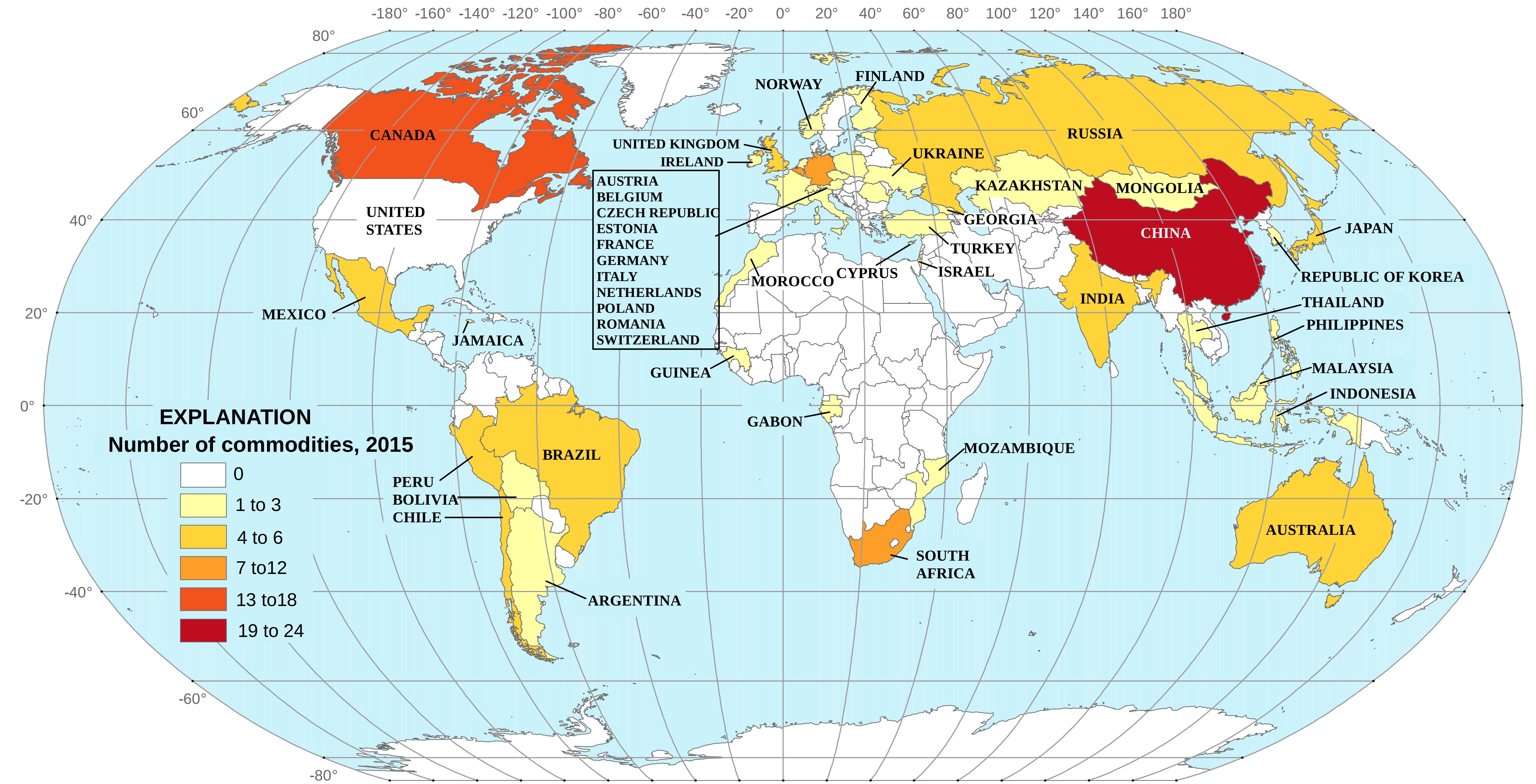
The estimated value of U.S. metal mine production in 2015 was $26.6 billion (table 1), 15% less than that of 2014. Principal contributors to the total value of metal mine production in 2015 were copper (29%), gold (29%), iron ore (14%), molybdenum concentrates (12%), and zinc (6%). The estimated value of U.S. industrial minerals production in 2015 was $51.7 billion, about 4% more than that of 2014. The value of industrial minerals production in 2015 was dominated by crushed stone (27%), cement (16%), and industrial sand and gravel (16%).

In 2015, U.S. production of 14 mineral commodities was valued at more than $1 billion each. These were, in decreasing order of value, crushed stone, cement, industrial sand and gravel, copper, gold, construction sand and gravel, iron ore (shipped), molybdenum concentrates, salt, lime, phosphate rock, zinc, soda ash, and clays (all types).

In 2015, 14 States each produced more than $2 billion worth of nonfuel mineral commodities. These States were, in descending order of value, Nevada, Arizona, Texas, Minnesota, Wisconsin, California, Alaska, Utah, Florida, Michigan, Missouri, Colorado, Wyoming, and Illinois (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 28 commodities at 12 locations in the United States. In fiscal year 2015, DLA Strategic Materials acquired $1.49 million of new materials and sold $66.9 million of excess materials from the NDS. At the end of the fiscal year, mineral materials valued at $1.3 billion remained in the NDS. Of the remaining material, some was being held in reserve, some was offered for sale, and sales of some of the materials 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.

MAJOR IMPORT SOURCES OF NONFUEL MINERAL COMMODITIES FOR WHICH THE UNITED STATES WAS GREATER THAN 50% NET IMPORT RELIANT IN 2015



Source: U.S. Geological Survey

TABLE 1.—U.S. MINERAL INDUSTRY TRENDS

	2011	2012	2013	2014	2015[e]
Total mine production (million dollars):					
Metals	36,000	34,700	32,100	31,200	26,600
Industrial minerals	38,800	41,100	43,000	49,600	51,700
Coal	44,900	40,600	36,700	35,700	31,300
Employment (thousands of production workers):					
Coal mining	78	74	67	63	58
Nonfuel mineral mining	98	101	100	100	100
Chemicals and allied products	480	491	490	497	510
Stone, clay, and glass products	278	273	275	282	299
Primary metal industries	301	317	306	311	310
Average weekly earnings of production workers (dollars):					
Coal mining	1,404	1,348	1,361	1,442	1,383
Chemicals and allied products	911	910	919	918	928
Stone, clay, and glass products	767	766	782	828	841
Primary metal industries	890	907	961	991	983

[e]Estimated.

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

TABLE 2.—U.S. MINERAL-RELATED ECONOMIC TRENDS

	2011	2012	2013	2014	2015[e]
Gross domestic product (billion dollars)	15,518	16,155	16,663	17,348	17,900
Industrial production (2012=100):					
Total index	97	100	102	106	107
Manufacturing:	97	100	101	103	105
Nonmetallic mineral products	97	100	104	109	113
Primary metals:	102	100	103	105	100
Iron and steel	100	100	102	105	92
Aluminum	96	100	107	110	110
Nonferrous metals (except aluminum)	112	100	105	104	105
Chemicals	101	100	98	100	103
Mining:	93	100	107	118	116
Coal	108	100	97	98	87
Oil and gas extraction	90	100	111	126	135
Metals	99	100	102	104	99
Nonmetallic minerals	98	100	103	110	115
Capacity utilization (percent):					
Total industry:	76	77	77	78	78
Mining:	87	88	89	91	84
Metals	74	72	73	76	72
Nonmetallic minerals	74	78	82	84	85
Housing starts (thousands)	612	784	928	1,001	1,102
Light vehicle sales (thousands)[1]	9,760	11,200	12,200	13,200	14,000
Highway construction, value, put in place (billion dollars)	80	80	81	84	89

[e]Estimated.
[1]Excludes imports.

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

TABLE 3.—VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 2015[p, 1]

State	Value (millions)	Rank[2]	Percent of U.S. total	Principal minerals, in order of value
Alabama	$1,250	22	1.60	Cement (portland), stone (crushed), lime, sand and gravel (construction), sand and gravel (industrial).
Alaska	3,090	7	3.95	Zinc, gold, lead, silver, sand and gravel (construction).
Arizona	6,800	2	8.69	Copper, molybdenum concentrates, sand and gravel (construction), cement (portland), stone (crushed).
Arkansas	991	26	1.27	Bromine, sand and gravel (industrial), stone (crushed), cement (portland), sand and gravel (construction).
California	3,300	6	4.22	Sand and gravel (construction), cement (portland), boron minerals, stone (crushed), gold.
Colorado	2,410	12	3.09	Molybdenum concentrates, sand and gravel (construction), cement (portland), gold, stone (crushed).
Connecticut[3]	232	43	0.30	Stone (crushed), sand and gravel (construction), clays (common), stone (dimension), gemstones (natural).
Delaware[3]	15	50	0.02	Stone (crushed), sand and gravel (construction), magnesium compounds, gemstones (natural).
Florida	2,840	9	3.63	Phosphate rock, stone (crushed), cement (portland), sand and gravel (construction), cement (masonry).
Georgia	1,700	17	2.18	Clays (kaolin), stone (crushed), cement (portland), clays (fuller's earth), cement (masonry).
Hawaii	129	46	0.17	Stone (crushed), sand and gravel (construction), gemstones (natural).
Idaho	713	33	0.91	Phosphate rock, sand and gravel (construction), silver, lead, stone (crushed).
Illinois	2,150	14	2.75	Sand and gravel (industrial), stone (crushed), sand and gravel (construction), cement (portland), tripoli.
Indiana	916	28	1.17	Stone (crushed), cement (portland), lime, sand and gravel (construction), stone (dimension).
Iowa	817	30	1.04	Stone (crushed), cement (portland), sand and gravel (industrial), sand and gravel (construction), lime.
Kansas	1,050	25	1.34	Helium (Grade–A), cement (portland), salt, stone (crushed), helium (crude).
Kentucky[3]	571	29	0.73	Stone (crushed), lime, cement (portland), sand and gravel (construction), sand and gravel (industrial).
Louisiana[3]	689	31	0.88	Salt, sand and gravel (construction), sand and gravel (industrial), stone (crushed), lime.
Maine[3]	96	45	0.12	Sand and gravel (construction), cement (portland), stone (crushed), stone (dimension), cement (masonry).
Maryland[3]	306	35	0.39	Cement (portland), stone (crushed), sand and gravel (construction), cement (masonry), stone (dimension).
Massachusetts[3]	305	39	0.38	Stone (crushed), sand and gravel (construction), stone (dimension), lime, clays (common).
Michigan	2,790	10	3.56	Iron ore (usable shipped), cement (portland), nickel concentrates, stone (crushed), sand and gravel (construction).
Minnesota[3]	959	4	1.23	Iron ore (usable shipped), sand and gravel (industrial), sand and gravel (construction), stone (crushed), stone (dimension).
Mississippi	192	44	0.25	Sand and gravel (construction), stone (crushed), clays (fuller's earth), clays (ball), sand and gravel (industrial).
Missouri	2,560	11	3.27	Cement (portland), stone (crushed), lead, lime, sand and gravel (industrial).
Montana	1,340	21	1.71	Palladium, molybdenum concentrates, copper, platinum, gold.

See footnotes at end of table.

TABLE 3.—VALUE OF NONFUEL MINERAL PRODUCTION IN THE UNITED STATES AND PRINCIPAL NONFUEL MINERALS PRODUCED IN 2015[p, 1]—Continued

State	Value (millions)	Rank[2]	Percent of U.S. total	Principal minerals, in order of value
Nebraska	382	38	0.49	Cement (portland), sand and gravel (industrial), stone (crushed), sand and gravel (construction), lime.
Nevada	6,940	1	8.87	Gold, copper, silver, lime, diatomite.
New Hampshire	111	48	0.14	Sand and gravel (construction), stone (crushed), stone (dimension), gemstones (natural).
New Jersey[3]	309	40	0.40	Stone (crushed), sand and gravel (construction), sand and gravel (industrial), greensand marl, peat.
New Mexico	1,760	15	2.25	Copper, potash, sand and gravel (construction), cement (portland), salt.
New York	1,530	19	1.95	Salt, stone (crushed), sand and gravel (construction), cement (portland), wollastonite.
North Carolina[3]	943	20	1.21	Stone (crushed), phosphate rock, sand and gravel (construction), sand and gravel (industrial), stone (dimension).
North Dakota[3]	243	42	0.31	Sand and gravel (construction), stone (crushed), lime, clays (common), sand and gravel (industrial).
Ohio[3]	1,310	18	1.68	Stone (crushed), salt, sand and gravel (construction), lime, sand and gravel (industrial).
Oklahoma	744	32	0.95	Stone (crushed), cement (portland), sand and gravel (industrial), sand and gravel (construction), helium (Grade–A).
Oregon	398	36	0.51	Stone (crushed), sand and gravel (construction), cement (portland), diatomite, perlite (crude).
Pennsylvania[3]	1,700	16	2.18	Stone (crushed), cement (portland), lime, sand and gravel (construction), cement (masonry).
Rhode Island[3]	70	49	0.09	Sand and gravel (construction), stone (crushed), sand and gravel (industrial), gemstones (natural).
South Carolina[3]	679	34	0.87	Cement (portland), stone (crushed), sand and gravel (construction), sand and gravel (industrial), cement (masonry).
South Dakota	293	41	0.37	Gold, cement (portland), sand and gravel (construction), stone (crushed), lime.
Tennessee	1,130	24	1.44	Stone (crushed), zinc, cement (portland), sand and gravel (construction), sand and gravel (industrial).
Texas	5,270	3	6.74	Stone (crushed), sand and gravel (industrial), cement (portland), sand and gravel (construction), salt.
Utah	2,930	8	3.74	Molybdenum concentrates, copper, magnesium metal, potash, salt.
Vermont[3]	118	47	0.15	Stone (crushed), sand and gravel (construction), stone (dimension), talc (crude), gemstones (natural).
Virginia	1,160	23	1.49	Stone (crushed), cement (portland), sand and gravel (construction), lime, zirconium concentrates.
Washington	936	27	1.20	Sand and gravel (construction), stone (crushed), gold, cement (portland), zinc.
West Virginia	395	37	0.51	Stone (crushed), cement (portland), lime, sand and gravel (industrial), cement (masonry).
Wisconsin	3,600	5	4.59	Sand and gravel (industrial), sand and gravel (construction), stone (crushed), lime, stone (dimension).
Wyoming	2,370	13	3.03	Soda ash, helium (Grade–A), clays (bentonite), sand and gravel (construction), cement (portland).
Undistributed	4,690	XX	6.00	
Total	78,300	XX	100.00	

[p]Preliminary. 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; ranking includes values that must be withheld to avoid disclosing company proprietary data.

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

MAJOR METAL-MINING AREAS

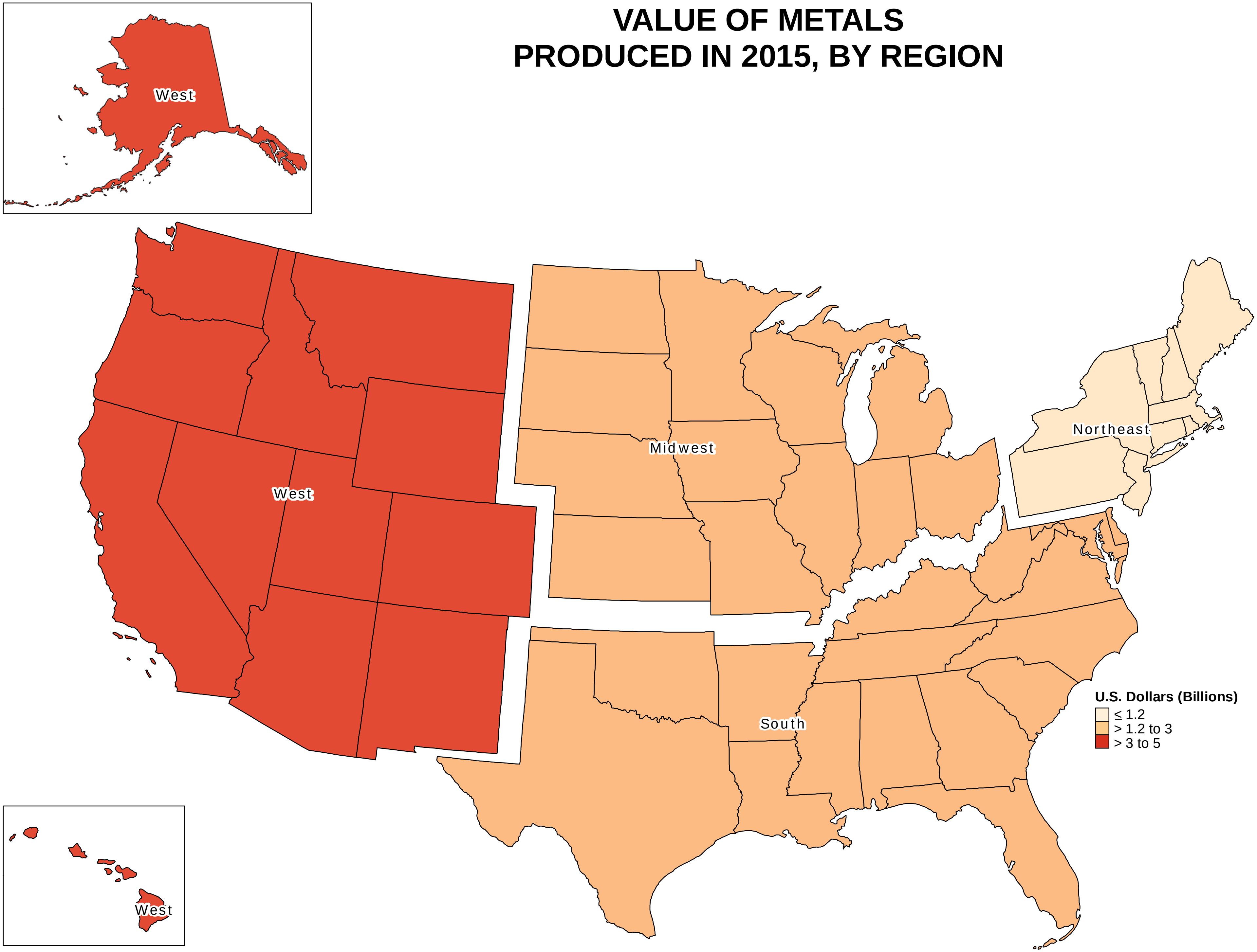
MAJOR INDUSTRIAL MINERAL-PRODUCING AREAS—PART I

SYMBOLS

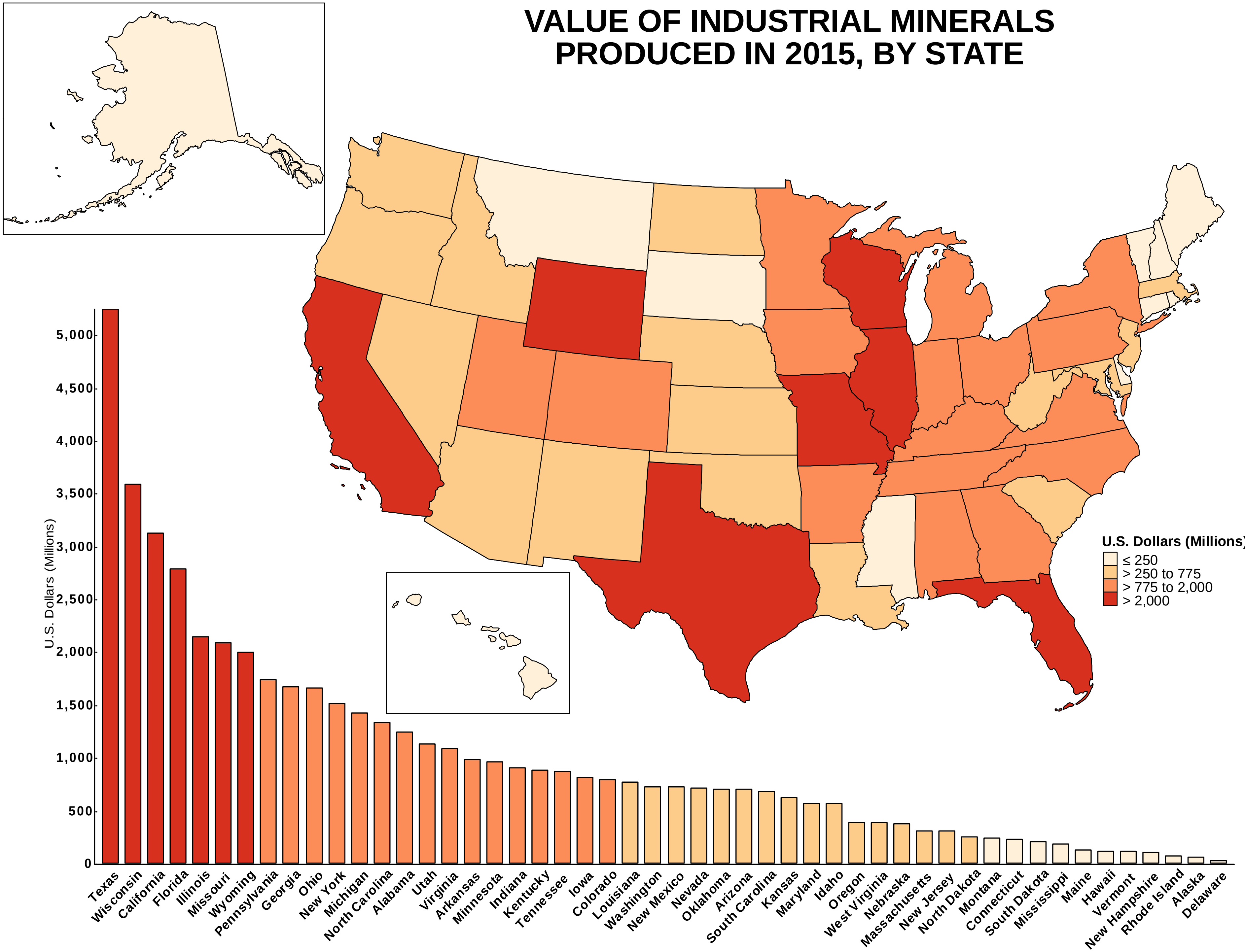
Ba	Barite
B	Borates
Br	Bromine
Chr	Chromite
Dia	Diatomite
Gar	Garnet
Gyp	Gypsum
He	Helium
Irz	Ilmenite, rutile, and zircon
I	Iodine
Ky	Kyanite
MgCp	Magnesium compounds
Mica	Mica
O	Olivine
Peat	Peat
P	Phosphate rock
K	Potash
Pyrp	Pyrophyllite
Salt	Salt
NaC	Soda ash
S	Sulfur
Talc	Talc
Vm	Vermiculite
Wol	Wollastonite
Zeo	Zeolites

MAJOR INDUSTRIAL MINERAL-PRODUCING AREAS—PART II

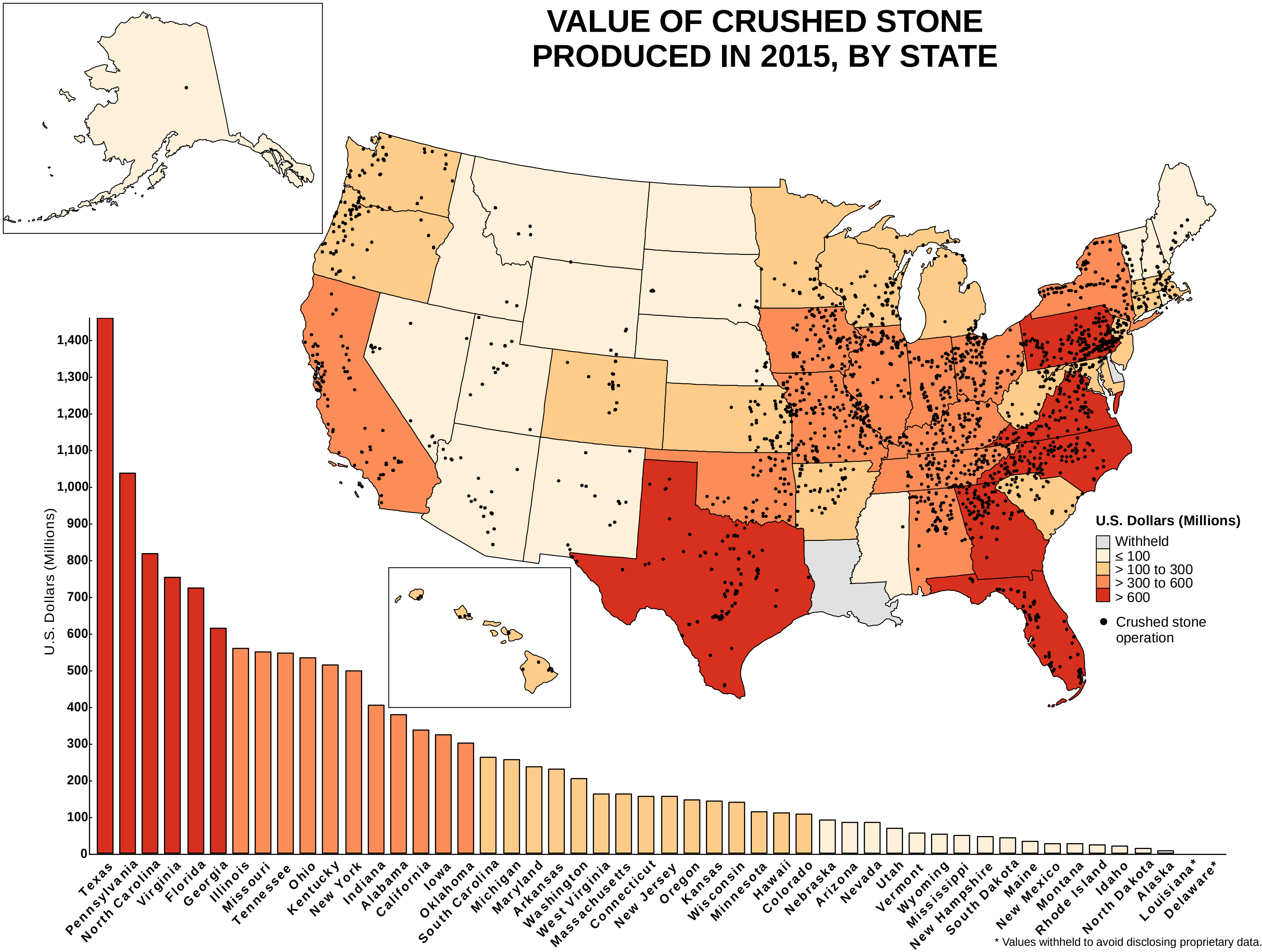
VALUE OF METALS PRODUCED IN 2015, BY REGION



VALUE OF INDUSTRIAL MINERALS PRODUCED IN 2015, BY STATE

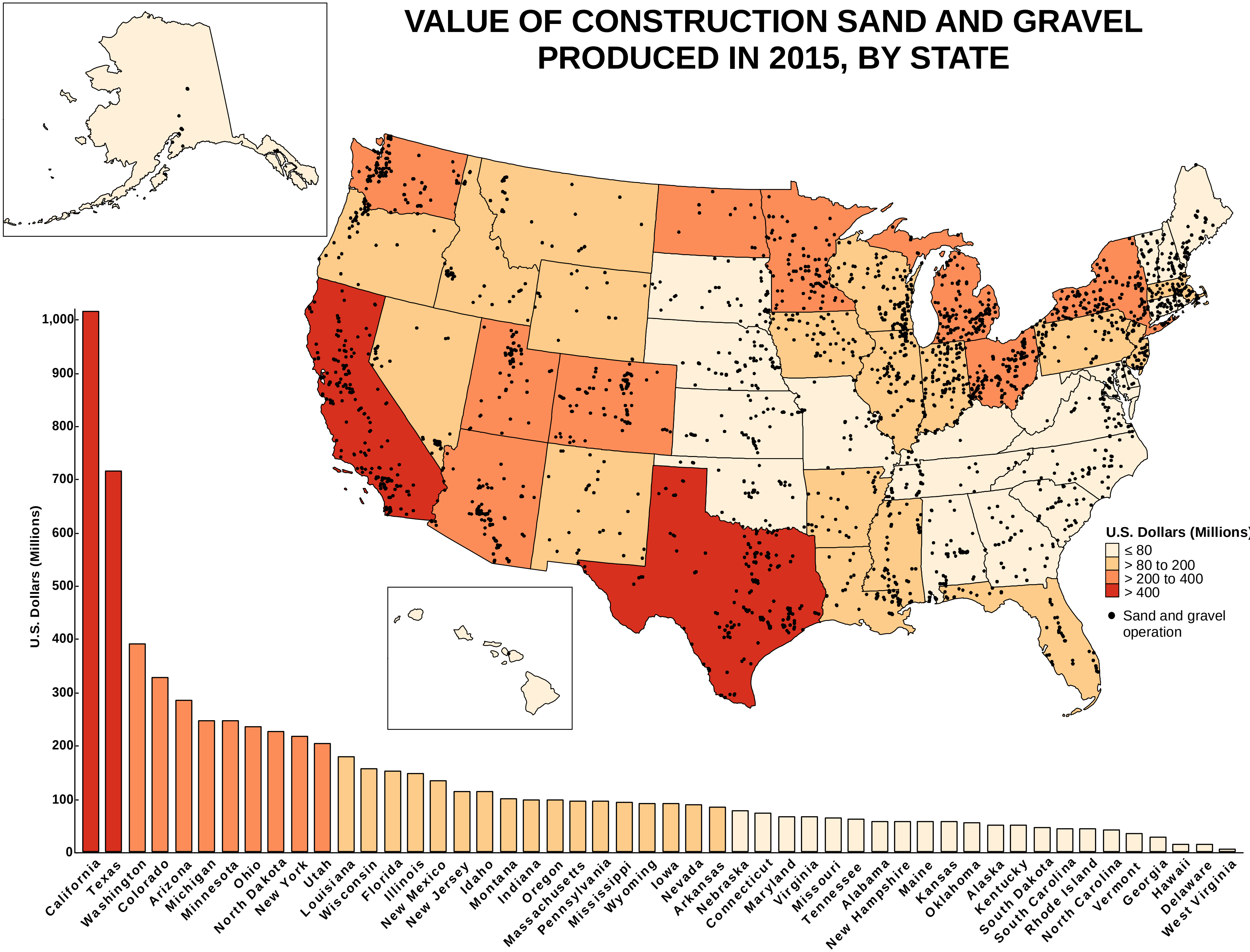


VALUE OF CRUSHED STONE PRODUCED IN 2015, BY STATE



* Values withheld to avoid disclosing proprietary data.

VALUE OF CONSTRUCTION SAND AND GRAVEL PRODUCED IN 2015, BY STATE



ABRASIVES (MANUFACTURED)

(Fused aluminum oxide and silicon carbide)
(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 $1.65 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 $25.9 million. Domestic production of metallic abrasives had an estimated value of about $88.1 million. Bonded and coated abrasive products accounted for most abrasive uses of fused aluminum oxide and silicon carbide.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Fused aluminum oxide, crude[1, 2]	10,000	10,000	10,000	10,000	10,000
Silicon carbide[1, 2]	35,000	35,000	35,000	35,000	35,000
Metallic abrasives (U.S.)[3]	202,000	193,000	191,000	190,000	196,000
Imports for consumption (U.S.):					
Fused aluminum oxide	223,000	231,000	222,000	198,000	157,000
Silicon carbide	129,000	100,000	129,000	130,000	137,000
Metallic abrasives	49,600	22,000	23,900	23,500	27,000
Exports (U.S.):					
Fused aluminum oxide	19,900	19,100	24,500	19,600	15,800
Silicon carbide	27,800	20,000	18,400	22,300	21,700
Metallic abrasives	39,500	39,000	35,900	41,000	37,000
Consumption, apparent (U.S.):					
Fused aluminum oxide[4]	203,000	212,000	197,000	177,000	141,000
Silicon carbide[5]	136,000	115,000	145,000	142,000	151,000
Metallic abrasives[5]	212,000	176,000	179,000	173,000	186,000
Price, value of imports, dollars per ton:					
Fused aluminum oxide, regular	627	560	663	659	598
Fused aluminum oxide, high-purity	1,360	1,080	847	1,420	1,280
Silicon carbide, crude	1,260	877	638	660	583
Metallic abrasives	700	988	1,030	1,020	903
Net import reliance[6] as a percentage of apparent consumption (U.S.):					
Fused aluminum oxide	NA	NA	NA	NA	NA
Silicon carbide	74	70	76	75	77
Metallic abrasives	5	E	E	E	E

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

Import Sources (2011–14): Fused aluminum oxide, crude: China, 83%; Canada, 11%; Venezuela, 5%; and other, 1%. Fused aluminum oxide, grain: Germany, 15%; Austria, 14%; Brazil, 13%; China, 9%; and other, 49%. Silicon carbide, crude: China, 60%; South Africa, 18%; the Netherlands, 12%; Romania, 6%; and other, 4%. Silicon carbide, grain: China, 42%; Brazil, 22%; Russia, 11%; Germany, 6%; and other, 19%. Metallic abrasives: Canada, 36%; Sweden, 24%; Germany, 9%; China, 8%; and other, 23%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–15**
Artificial corundum, crude	2818.10.1000	Free.
White, pink, ruby artificial corundum, greater than 97.5% fused 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.

Depletion Allowance: None.

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

ABRASIVES (MANUFACTURED)

Government Stockpile: None.

Events, Trends, and Issues: In 2015, China was the world's leading producer of abrasive fused aluminum oxide and abrasive silicon carbide, with production 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, all of which experienced increased production during 2015. The U.S. abrasive markets also are influenced by technological trends.

World Production Capacity:

	Fused aluminum oxide		Silicon carbide	
	2014	2015[e]	2014	2015[e]
United States and Canada	60,400	60,400	42,600	42,600
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	25,000	25,000	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)	1,290,000	1,290,000	1,010,000	1,010,000

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. NA Not available. — Zero.
[1]Production data for aluminum oxide and silicon carbide are combined Canadian and United States production data to avoid disclosing company proprietary data.
[2]Rounded to the nearest 5,000 tons to avoid disclosing company proprietary data.
[3]Production data for metallic abrasives does not include Canadian production data.
[4]Estimate of apparent consumption for aluminum oxide defined as imports – exports to avoid disclosing company proprietary data.
[5]Apparent consumption for silicon carbide and metallic abrasives defined as production + imports – exports.
[6]Net import reliance defined as imports – exports.

ALUMINUM[1]

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

Domestic Production and Use: In 2015, three companies operated eight primary aluminum smelters in six States, primarily east of the Mississippi River. One additional smelter remained on standby throughout the year, and two other nonoperating smelters were permanently shut down during 2015. Based on published market prices, the value of primary aluminum production was $3.11 billion. Aluminum consumption was centered in the East Central United States. Transportation accounted for an estimated 39% of domestic consumption; in descending order of consumption, the remainder was used in packaging, 20%; building, 14%; electrical, 9%; consumer durables, 8%; machinery, 7%; and other, 3%.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production:					
Primary	1,986	2,070	1,946	1,710	1,600
Secondary (from old scrap)	1,470	1,440	1,630	1,700	1,640
Imports for consumption (crude and semimanufactures)	3,710	3,760	4,160	4,290	4,700
Exports, total	3,420	3,480	3,390	3,230	3,020
Consumption, apparent[2]	3,570	3,950	4,530	5,080	5,390
Price, ingot, average U.S. market (spot), cents per pound	116.1	101.0	94.2	104.5	88.0
Stocks:					
Aluminum industry, yearend	1,060	1,140	1,130	1,280	1,350
LME, U.S. warehouses, yearend[3]	2,360	2,120	1,950	1,190	650
Employment, number[4]	30,300	31,500	30,100	30,900	30,000
Net import reliance[5] as a percentage of apparent consumption	3	11	21	33	40

Recycling: In 2015, aluminum recovered from purchased scrap in the United States was about 3.61 million tons, of which about 54% came from new (manufacturing) scrap and 46% from old scrap (discarded aluminum products). Aluminum recovered from old scrap was equivalent to about 30% of apparent consumption.

Import Sources (2011–14): Canada, 65%; Russia and United Arab Emirates, 6% each; and other, 23%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Aluminum, not alloyed:		
Unwrought (in coils)	7601.10.3000	2.6% ad val.
Unwrought (other than aluminum alloys)	7601.10.6000	Free.
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: Owing to permanent smelter closures and temporary potline closures, U.S. production of primary aluminum decreased for the third consecutive year, declining by about 6% in 2015. Despite an employee lockout for about 4 weeks in May and June at a 252,000-ton-per-year smelter in Hawesville, KY, production continued at full capacity until a new labor contract was ratified. However, in September, one of the five potlines at the smelter was temporarily shut down and two other potlines were shut down in October owing to low aluminum prices. In December, the same company shut down 112,000 tons per year of capacity in Mount Holly, SC. One company announced that it would temporarily shut down 373,000 tons per year of smelting capacity in Ferndale, WA, and Wenatchee, WA, at yearend or early in 2016. New power contracts were obtained by primary smelters in Missouri, New York, and South Carolina. In October, domestic smelters were operating at about 74% of capacity of 2 million tons per year. World primary aluminum production increased by about 10% in 2015 compared with production in 2014, and total (primary plus secondary) production increased by 16%. New capacity built in recent years in China, where primary production increased by 18% and total production increased by 31%, accounted for most of the increased production.

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ALUMINUM

U.S. import reliance increased in 2015 as primary production and exports decreased and U.S. manufacturers were supplied by increased imports and a drawdown of domestic stocks. Total U.S. imports of aluminum (crude, semimanufactures, and scrap) increased by 8% in 2015 compared with those in 2014. Canada was the leading supplier of imported aluminum, accounting for 65% of crude aluminum, 21% of semimanufactures, 64% of scrap, and 54% of total aluminum imports. Imports of crude aluminum (metal and alloys) and semimanufactures in 2015 were 5% and 26% higher, respectively, than the quantities imported in 2014, but imports of scrap were 4% lower. Imports of semimanufactures from China increased by 57% in 2015 compared with those in 2014; China accounted for 54% of semimanufactures imported in 2015 compared with 29% in 2014. Total aluminum exports (crude, semimanufactures, and scrap) from the United States decreased by 7% in 2015 compared with those in 2014.

The monthly average U.S. market price for primary ingot quoted by Platts Metals Week remained at about $1.06 per pound through February, then gradually decreased throughout the year to $0.80 per pound in September, the lowest price since 2009. U.S. market prices generally followed the trend of prices on the London Metal Exchange (LME). However, during the first 4 months of 2015, the U.S. market price averaged about 25% higher than the LME price, similar to the 23% average premium in 2014, but significantly higher than the average premium in 2013 (13%) and May to September 2015 (12%). The higher market price premium during 2014 and the first part of 2015 was attributed to uncertainty about proposed LME warehouse rules. In 2014, the LME proposed rule changes to increase the allowable outflows of aluminum stored in LME-bonded warehouses. The proposed changes were struck down by a court in the United Kingdom in March 2014, but that ruling was overturned on appeal in October 2014. Global inventories of primary aluminum metal held by LME-bonded warehouses decreased to 3.04 million tons in mid-November 2015 from 5.59 million tons at yearend 2013.

World Smelter Production and Capacity:

	Production		Yearend capacity	
	2014	2015[e]	2014	2015[e]
United States	1,710	1,600	2,340	2,000
Australia	1,700	1,650	1,720	1,720
Bahrain	931	960	970	970
Brazil	962	780	1,700	1,600
Canada	2,860	2,900	3,130	3,270
China	24,400	32,000	35,000	36,000
Iceland	800	820	840	840
India	1,940	2,350	2,890	3,850
Norway	1,330	1,320	1,550	1,550
Qatar	640	640	640	640
Russia	3,490	3,500	4,180	4,180
Saudi Arabia	665	740	740	740
South Africa	745	690	715	715
United Arab Emirates	2,330	2,340	2,400	2,400
Other countries	6,000	6,010	8,130	8,320
World total (rounded)	50,500	58,300	66,900	68,800

World Resources: Global resources of bauxite are estimated to be between 55 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. Magnesium, steel, and titanium can substitute for aluminum in ground transportation and structural 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]Includes aluminum alloy.
[4]Alumina and aluminum production workers (North American Industry Classification System—3313). Source: U.S. Department of Labor, Bureau of Labor Statistics.
[5]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 2015, no marketable antimony was mined in the United States. A mine in Nevada, which had the potential to produce antimony and had extracted about 1 metric ton of stibnite ore from 2013 to 2014, was on care-and-maintenance status in 2015 and had no reported production. 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 2015, based on the average New York dealer price, was about $30 million. Recycling supplied about 17% of estimated domestic consumption, and the remainder came from imports. The value of antimony consumption in 2015, based on the average New York dealer price, was about $185 million. The estimated domestic distribution of primary antimony consumption was as follows: nonmetal products, including ceramics and glass and rubber products, 36%; flame retardants, 34%; and metal products, including antimonial lead and ammunition, 30%.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production:					
Mine (recoverable antimony)	—	—	—	—	—
Smelter:					
Primary	W	W	W	W	W
Secondary	2,860	3,050	4,400	4,230	4,000
Imports for consumption, ores and concentrates, oxide, and metal	23,500	22,600	24,700	24,200	23,600
Exports of metal, alloys, oxide, and waste and scrap[1]	4,170	4,710	3,980	3,240	3,100
Consumption, apparent[2]	22,300	21,000	25,100	25,200	24,500
Price, metal, average, cents per pound[3]	650	565	463	425	344
Stocks, yearend	1,430	1,430	1,470	1,400	1,400
Employment, plant, number (yearend)[e]	24	24	24	27	27
Net import reliance[4] as a percentage of apparent consumption	87	85	82	83	84

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

Import Sources (2011–14): Metal: China, 68%; India, 14%; Mexico, 4%; and other, 14%. Ore and concentrate: Italy, 64%; China, 20%; India, 12%; and other, 4%. Oxide: China, 63%; Bolivia, 9%; Belgium, 8%; Thailand, 8%; Mexico, 6%; and other, 6%. Total: China, 63%; Bolivia, 8%; Belgium, 7%; Thailand, 6%; and other, 16%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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.

Events, Trends, and Issues: U.S. Antimony Corp. (USAC) operated a smelter in Montana that produced antimony metal and oxides from imported concentrates, primarily from Canada and Mexico, and a smelter in Mexico that processed concentrates from mines in Mexico and imports from Australia. USAC planned to produce about 2,000 tons of antimony in 2015, more than double that produced in 2014.[5] In late 2013, an historically productive antimony mine in Nevada was restarted and by yearend 2014, had produced about 800 tons of stibnite (antimony trisulfide) ore for upgrade. In 2015, the company was reorganized and the project was placed on care-and-maintenance status. At the end of 2014, a Canadian mining company completed an independent preliminary feasibility study for the Stibnite Gold Project (formerly known as the Golden Meadows Project) in the Stibnite-Yellow Pine mining district in Idaho. Mining had occurred at project sites intermittently in the past and, according to the study, antimony production at the mines could be about 6,350 tons per year in the first 4 years of operation.

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ANTIMONY

Antimony metal price declined during 2015, averaging $3.71 per pound in the first quarter, $3.45 per pound in the second quarter, and $3.00 per pound in August. The average price during the first 8 months of 2015 was about 20% less than that during the same period of 2014. Reports indicated that elevated producer stocks in China and lower than expected consumption in Europe contributed to the price decline in 2015. Some consumers were thought to be purchasing smaller quantities of antimony, owing to the possibility that some or all of the 18,660 tons of antimony metal reportedly held in the Fanya Metal Exchange in China could enter the market and lead to price declines.

China was the leading global antimony producer. The National Bureau of Statistics in China reported that mine and smelter production declined during the first half of 2015 when compared with that in the same period in 2014, owing to temporary closures and curtailments. In April, the government in Hunan Province forced one mine and eight smelters to close and consolidate their operations as part of a plan to control pollution and protect resources, contributing to a decline in production. In late September, it was reported that more than 50% of antimony metal production capacity had been idled in Hunan Province. The Government of China set export quotas of 59,400 tons (metal content) of antimony metal and antimony trioxide for 2015, unchanged from that in 2014.

In Oman, a producer, which planned to construct an antimony smelter with a 20,000-ton-per-year capacity for antimony metal and antimony oxide, acquired adequate funding and was proceeding with development. In Russia, a company announced plans to build a new 6,000-ton-per-year primary antimony smelter. Early in 2015, South Africa’s only antimony producer was placed into provisional liquidation after it failed to sell its assets, and the future of the mine was uncertain.

Global antimony consumption was estimated to be about 184,000 tons in 2015, a slight increase from that in 2014. Consumption of antimony trioxide was essentially unchanged from that in 2014 but had declined by about 9% from 2010, owing to some consumers opting for substitute materials that were less expensive. Flame retardants were estimated to account for about one-half of global primary antimony consumption, followed by lead-acid batteries and plastics. Asia accounted for more than 50% of global antimony consumption in 2015.

World Mine Production and Reserves: Reserves for Australia were updated with data from Geoscience Australia.

	Mine production[e]		Reserves[6]
	2014	2015	
United States	—	—	[7]60,000
Australia	5,800	5,500	[8]140,000
Bolivia	5,500	5,000	310,000
Burma	3,300	3,500	NA
China	120,000	115,000	950,000
Russia (recoverable)	9,000	9,000	350,000
South Africa	1,600	—	27,000
Tajikistan	4,700	4,700	50,000
Turkey	4,500	4,500	NA
Other countries	4,000	4,000	100,000
World total (rounded)	158,000	150,000	2,000,000

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. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Gross weight, for metal, alloys, waste, and scrap.
[2]Domestic mine production + secondary production from old scrap + net import reliance.
[3]New York dealer price for 99.5% to 99.6% metal, c.i.f. U.S. ports.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]U.S. Antimony Corp., 2015, U.S. Antimony reports all-time record production: Thompson Falls, MT, U.S. Antimony Corp. news release, March 12.
[6]See Appendix C for resource/reserve definitions and information concerning data sources.
[7] For United States, company-reported probable reserves for Stibnite Gold Project in Idaho.
[8] For Australia, Joint Ore Reserves Committee-compliant reserves were 63,000 tons.

ARSENIC

(Data in metric tons of arsenic unless otherwise noted)

Domestic Production and Use: Arsenic trioxide and primary arsenic metal have not been produced in the United States since 1985. However, limited quantities of arsenic metal have been recovered from gallium-arsenide (GaAs) semiconductor scrap. 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 2015. Ammunition used by the U.S. military was hardened by the addition of less than 1% arsenic metal, and 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 by the electronics industry for GaAs semiconductors that are used for solar cells, space research, and telecommunications. Arsenic also was used for germanium-arsenide-selenide specialty optical materials. Indium-gallium-arsenide was used for short-wave infrared technology. The value of arsenic compounds and metal imported domestically in 2015 was estimated to be about $5.6 million.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Imports for consumption:					
Arsenic	628	883	514	688	600
Compounds	4,990	5,740	6,290	5,260	6,200
Exports, arsenic[1]	705	439	1,630	2,950	1,900
Consumption, estimated [2]	5,620	6,620	6,810	5,940	6,800
Value, cents per pound, average[3]					
Arsenic (China)	74	75	72	75	80
Trioxide (Morocco)	22	24	27	30	29
Net import reliance[4] as a percentage of estimated consumption	100	100	100	100	100

Recycling: Arsenic metal was recycled from GaAs semiconductor manufacturing. Arsenic contained in the process water at wood treatment plants where CCA was used was also recycled. Although electronic circuit boards, relays, and switches may contain arsenic, no arsenic was recovered from them during recycling 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 (2011–14): Arsenic: China, 89%; Japan, 9%; and other, 2%. Arsenic trioxide: Morocco, 58%; China (including Hong Kong), 32%; Belgium, 10%; and other, less than 1%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–15**
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.

Events, Trends, and Issues: China and Morocco continued to be the leading global producers of arsenic trioxide, accounting for more than 90% of estimated world production, and supplied about 99% of U.S. imports of arsenic trioxide in 2015. China was the leading world producer of arsenic metal and supplied about 98% of U.S. arsenic imports in 2015.

Human health and environmental concerns continued to limit the demand for arsenic compounds. A voluntary ban on the use of CCA wood preservatives in most residential applications, effective yearend 2003, significantly reduced demand in wood preservative applications. Owing to the residential ban, imports of arsenic trioxide declined to an average of 5,700 tons per year gross weight during 2010 to 2014, from an average of almost 28,000 tons per year during 1999 to 2003. Concern over the adverse effects of arsenic from natural and anthropogenic sources has led to numerous studies of arsenic in food and water. Information on the U.S. Environmental Protection Agency standards for arsenic in drinking water may be accessed at http://water.epa.gov/lawsregs/rulesregs/sdwa/arsenic/index.cfm, and information on the U.S. Food and Drug Administration arsenic-related food studies and recommendations may be accessed at http://www.fda.gov/Food/ FoodborneIllnessContaminants/ Metals/ucm280202.htm.

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ARSENIC

The U.S. Geological Survey (USGS) has been studying the natural occurrence of arsenic in groundwater as part of its National Water Quality Assessment Program. Arsenic in groundwater is largely the result of minerals dissolving from weathered rocks and soils. Information on USGS maps and related studies on arsenic in groundwater may be accessed at http://water.usgs.gov/nawqa/trace/arsenic/index.html.

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 compounds, alloys, and residues containing arsenic. Therefore, the estimated consumption reported under salient U.S. statistics reflects only imports of arsenic products.

High-purity (99.9999%) arsenic metal was used to produce gallium-arsenide (GaAs), indium-arsenide, and indium gallium-arsenide semiconductors that were used in biomedical, communications, computer, electronics, and photovoltaic applications. In 2015, global GaAs device demand increased by about 6% to $7 billion, primarily owing to a growing wireless infrastructure in Asia, and increased use of feature-rich, application-intensive, third- and fourth-generation “smartphones,” which employ up to 10 times the amount of GaAs as standard cellular handsets. Based on the reported consumption of gallium, an estimated 24 metric tons of arsenic was consumed domestically to produce GaAs integrated circuits and optoelectronic devices in 2015. See the Gallium chapter for additional details.

World Production and Reserves:

	Production[5] (arsenic trioxide)		Reserves[6]
	2014	2015[e]	
United States	—	—	World reserves data are unavailable but are thought to be more than 20 times world production.
Belgium	1,000	1,000	
Bolivia	52	50	
China	25,000	25,000	
Japan	45	45	
Morocco	8,800	8,500	
Russia	1,500	1,500	
World total (rounded)	36,400	36,000	

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 realgar and orpiment 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. Global resources of copper and lead contain approximately 11 million tons of arsenic.

Substitutes: Substitutes for CCA in wood treatment include alkaline copper quaternary, ammoniacal copper quaternary, ammoniacal copper zinc arsenate, copper azole, and copper citrate. Treated wood substitutes include concrete, plastic composite material, plasticized wood scrap, or steel.

[e]Estimated. — Zero.
[1]Most of the materials reported to the U.S. Census Bureau as arsenic exports are probably arsenic-containing compounds or residues.
[2]Estimated to be the same as imports.
[3]Calculated from U.S. Census Bureau import data.
[4]Defined as imports.
[5]Chile, Mexico, and Peru were significant producers of commercial-grade arsenic trioxide, but have reported no production in recent years.
[6]See Appendix C for resource/reserve definitions and information concerning data sources.

ASBESTOS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Domestic mining of asbestos ceased in 2002 owing to the decline in U.S. asbestos markets associated with health and liability issues; the United States is wholly dependent on imports to meet manufacturing needs. In 2015, asbestos consumption in the United States was estimated to be about 360 tons. The chloralkali industry accounted for an estimated 90% of U.S. consumption, with the remainder used in coatings and compounds, plastics, roofing products, and other unknown applications. The chloralkali industry 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.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Imports for consumption	1,180	1,610	772	406	358
Exports[1]	169	47	27	279	38
Consumption, estimated[2]	1,180	1,020	772	406	358
Price, average value, dollars per ton[3]	931	1,570	1,510	1,830	1,610
Net import reliance[4] as a percentage of estimated consumption	100	100	100	100	100

Recycling: None.

Import Sources (2011–14): Brazil, 77%; Canada, 22%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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.

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ASBESTOS

Events, Trends, and Issues: Estimated domestic asbestos consumption declined 12% in 2015, continuing the downward trend from the record high of 803,000 tons in 1973. This decline has occurred because asbestos substitutes, alternative materials, and new technology have displaced asbestos from traditional domestic markets. The chloralkali industry, currently the leading consumer of asbestos in the United States, gained a greater share of the U.S. asbestos market as other end uses fell. Use of asbestos by the chloralkali industry may decline, however, as companies make greater use of nonasbestos diaphragms and membrane cell technology that does not require asbestos. Globally, asbestos-cement products are expected to be the leading market for asbestos. World production is likely to remain steady at approximately 2.0 million metric tons for the near future owing to continued demand for asbestos products in many regions of the world.

In 2015, at least 95% of the asbestos imported and used in the United States was chrysotile originating in Brazil. Although Canada was a major source of imports during the time period from 2011 to 2014, the United States has not imported asbestos fiber from Canada since 2011.

World Mine Production and Reserves:

	Mine production		Reserves[5]
	2014	2015[e]	
United States	—	—	Small
Brazil	284,000	311,000	10,000,000
China[e]	400,000	400,000	Large
Kazakhstan	240,000	215,000	Large
Russia[e]	1,100,000	1,100,000	Large
Other countries[e]	370	350	Moderate
World total (rounded)	2,020,000	2,000,000	Large

World Resources: The world has 200 million tons of identified asbestos resources. U.S.resources are large, but 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.

[1]Comprises nonasbestos materials and (or) reexports. The United States no longer produces asbestos.

[2]Assumed to equal imports, except in 2012, when an estimated 590 tons of asbestos were put into company stocks for future use.

[3]Average Customs unit value of U.S. imports.

[4]Defined as imports – exports.

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

BARITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2015, about 700,000 tons of crude barite valued at an estimated $91 million was sold or used for grinding. Most of the production came from four mines in Nevada; a significantly smaller sales volume came from 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 eight States. More than 97% 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. The barite imported to Louisiana and Texas mostly went to offshore drilling operations in the Gulf of Mexico and to onshore drilling operations in Louisiana, Oklahoma, and Texas.

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 consumed as liquid is used as a contrast medium in medical x-ray examinations.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Sold or used, mine	710	666	723	663	700
Ground and crushed[1]	2,910	3,310	3,550	3,410	2,400
Imports for consumption	2,320	2,920	2,250	2,700	1,800
Exports	98	151	199	153	140
Consumption, apparent[2] (crude and ground)	2,930	3,430	2,770	3,210	2,360
Estimated price, ground, average value, dollars per ton, f.o.b. mill	168	187	180	191	190
Employment, mine and mill, number	461	554	624	614	458
Net import reliance[3] as a percentage of apparent consumption	76	81	74	79	70

Recycling: None.

Import Sources (2011–14): China, 73%; India, 14%; Morocco, 6%; Mexico, 6%; and other, 1%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–15**
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.

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BARITE

Events, Trends, and Issues: Oil and gas drilling, the leading end use for barite, has undergone changes that have had a significant impact on barite consumption. In recent years, petroleum production in the United States increased dramatically owing to advances in the application of horizontal drilling and hydraulic fracturing in shale and other tight resources. However, global petroleum supply began to exceed demand, prices began to fall, and U.S. producers reduced production. The count of operating drill rigs exploring for oil and gas traditionally has been a good barometer of barite consumption or industry stockpiling. Between January and October 2015, the number of drill rigs operating in the United States fell from 1,811 to 787. The decrease in drilling activity is estimated to have reduced domestic barite consumption by approximately 25% to 30%.

As the world's leading barite consumer, changes in U.S. consumption significantly affect global barite production and trade. In recent years, India, Mexico, and Morocco significantly increased barite production, with a corresponding increase in exports to the United States. In 2015, these same countries greatly reduced their barite production, partly in response to lower U.S. consumption.

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

	Mine production		Reserves[4]
	2014	2015[e]	
United States	663	700	15,000
China	3,000	3,000	100,000
India	1,140	900	32,000
Iran	300	300	24,000
Kazakhstan	300	300	85,000
Mexico	420	220	7,000
Morocco	1,200	900	10,000
Pakistan	132	120	1,000
Peru	106	100	NA
Thailand	135	130	NA
Turkey	270	200	35,000
Vietnam	100	90	NA
Other countries	483	500	66,000
World total (rounded)	8,250	7,460	380,000

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 is identified resources.

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]Defined as sold or used by domestic mines + imports – exports.
[3]Defined as imports – exports.
[4]See Appendix C for resource/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 2015, bauxite consumption was estimated to be 9.0 million tons, nearly all of which was imported, with an estimated value of $252 million. More than 95% of the bauxite was converted to alumina, and the remainder went to nonmetallurgical products, such as abrasives, chemicals, proppants, and refractories. Four domestic Bayer-process refineries had a combined alumina production capacity of 5.6 million tons per year. About 90% 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:	2011	2012	2013	2014	2015[e]
Bauxite:					
Production, mine	NA	NA	NA	NA	NA
Imports for consumption[2]	10,200	11,000	10,800	11,800	9,000
Exports[2]	76	42	21	15	20
Stocks, industry, yearend[2]	1,350	2,770	3,400	5,400	5,380
Consumption, apparent[3]	8,820	9,560	10,200	9,780	9,000
Price, average value, U.S. imports (f.a.s.), dollars per ton	30	28	27	27	28
Net import reliance,[4] as a percentage of apparent consumption	100	100	100	100	100
Alumina:					
Production, refinery	3,790	4,370	4,400	4,390	4,000
Imports for consumption[5]	2,160	1,900	2,050	1,630	1,700
Exports[5]	1,660	1,720	2,250	2,130	2,100
Stocks, industry, yearend[5]	961	363	280	277	300
Consumption, apparent[3]	3,710	5,170	4,280	3,900	3,580
Price, average value U.S. imports (f.a.s.) dollars per ton	413	374	368	394	410
Net import reliance,[4] as a percentage of apparent consumption	E	15	E	E	E

Recycling: None.

Import Sources (2011–14):[6] Bauxite: Jamaica, 44%; Guinea, 24%; Brazil, 23%; Guyana, 4%; and other, 5%. Alumina: Suriname, 35%; Australia, 34%; Brazil, 12%; Jamaica, 8%; and other, 11%. Total: Jamaica, 29%; Brazil, 19%; Guinea, 18%; Australia, 11%; and other, 23%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Bauxite, calcined (refractory grade)	2606.00.0030	Free.
Bauxite, calcined (other)	2606.00.0060	Free.
Bauxite, crude dry (metallurgical grade)	2606.00.0090	Free.
Alumina	2818.20.0000	Free.
Aluminum hydroxide	2818.30.0000	Free.

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

Government Stockpile: None

Events, Trends, and Issues: Global alumina and bauxite production increased by 9% and 12%, respectively, compared with that of 2014. Production of alumina in China, which accounted for nearly one-half of global production, increased by 19% as capacity increased to 66 million metric tons per year. However, several refineries in China announced shutdowns during the last quarter of the year, citing low prices for alumina. Following Indonesia's ban on the export of bauxite in January 2014, bauxite production in China increased, imports from countries other than Indonesia increased, and stocks of bauxite were drawn down. In 2015, Australia supplied 20 million tons of bauxite to China, 28% more than in 2014. Bauxite production in Malaysia increased to 21.2 million tons in 2015 from 3.26 million tons in 2014, and nearly all was exported to China in both years. In response to Indonesia's export ban on bauxite, one alumina refinery in Indonesia started production in 2014, and a second one was expected to be completed in 2016. Low alumina prices, China's ability to secure alternate sources of bauxite, and China's growth in alumina capacity could limit global demand for Indonesian alumina and discourage further refinery construction in Indonesia.

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BAUXITE AND ALUMINA

At a 1,600,000-ton-per-year alumina refinery in Corpus Christi, TX, a shutdown of one potline, ahead of an employee lockout beginning in October 2014, reduced production by 25% during the first half of 2015. The owner of a 2.3-million-ton-per-year alumina refinery in Point Comfort, TX, announced that it would temporarily shut down 1.2 million tons per year of its alumina capacity starting in the fourth quarter of 2015, citing low prices for alumina and aluminum.

The estimated annual average price free alongside ship (f.a.s.) for U.S. imports for consumption of metallurgical-grade alumina was $410 per ton, ranging between $376 per ton and $528 per ton during the first 9 months of 2015. According to production data from the International Aluminium Institute, world alumina production through September 2015 increased by about 6% compared with that of the same period in 2014. For the first 9 months of 2015, the estimated average price (f.a.s.) for U.S. imports for consumption of crude-dry bauxite was $28 per ton, unchanged from that of the same period in 2014. A significant portion of bauxite consumed at alumina refineries in the United States came from mines owned by the same companies that owned the refineries.

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

	Alumina		Bauxite		Reserves[7]
	2014	2015[e]	2014	2015[e]	
United States	4,390	4,000	NA	NA	20,000
Austraila	20,500	20,200	78,600	80,000	6,200,000
Brazil	10,600	10,300	34,800	35,000	2,600,000
China	47,800	57,000	55,000	60,000	830,000
Greece	800	800	1,900	1,900	250,000
Guinea	—	—	17,300	17,700	7,400,000
Guyana	—	—	1,600	1,700	850,000
India	5,060	5,470	16,500	19,200	590,000
Indonesia	240	300	2,550	1,000	1,000,000
Jamaica	1,850	1,950	9,680	10,700	2,000,000
Kazakhstan	1,600	1,600	5,200	5,200	160,000
Malaysia	—	—	3,260	21,200	40,000
Russia	2,570	2,580	5,590	6,600	200,000
Suriname	1,300	970	3,000	2,200	580,000
Venezuela	650	650	1,500	1,500	320,000
Vietnam	485	500	1,090	1,100	2,100,000
Other countries	10,600	11,400	7,200	8,500	2,400,000
World total (rounded)	108,000	118,000	245,000	274,000	28,000,000

World Resources: Bauxite resources are estimated to be 55 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 U.S. and global resources of clay are technically feasible sources of alumina. Other domestic raw materials, such as alunite, anorthosite, coal wastes, and oil shales, offer additional potential alumina sources. Some refineries in China recover alumina from coal ash, and processes for recovering alumina from clay were being tested in Australia and Canada to determine if they would be economically competitive. Synthetic mullite, produced from kaolin, bauxitic kaolin, kyanite, and sillimanite, substitutes for bauxite-based refractories. Although more costly, silicon carbide and alumina-zirconia can substitute for bauxite-based abrasives.

[e]Estimated. E Net exporter. NA Not available. — 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]The sum of U.S. production and net import reliance.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]Calcined equivalent weights.
[6]Based on aluminum equivalents.
[7]See Appendix C for resource/reserve definitions and information concerning data sources.

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—some of which was sold. Estimated beryllium consumption of 310 tons was valued at about $158 million, based on the estimated unit value for beryllium in imported beryllium-copper master alloy. Based on value-added sales revenues, approximately 20% of beryllium products were used in industrial components, 18% in consumer electronics, 16% in automotive electronics, 8% each in energy applications and telecommunications infrastructure, 6% in defense applications, 2% in medical applications, and 22% 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 beryllium metal and beryllium composite products were used in defense and scientific applications.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production, mine shipments	235	225	235	270	275
Imports for consumption[1]	92	100	57	68	73
Exports[2]	21	55	35	26	33
Government stockpile releases[3]	22	([4])	10	1	([4])
Consumption:					
Reported, ore	250	220	250	280	285
Apparent[5]	333	265	262	318	310
Unit value, annual average, beryllium-copper master alloy, dollars per pound contained beryllium[6]	203	204	208	215	231
Stocks, ore, consumer, yearend	10	15	20	15	20
Net import reliance[7] as a percentage of apparent consumption	29	15	10	15	11

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 its 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 (2011–14):[1] Kazakhstan, 56%; China, 8%; Nigeria, 6%; United Kingdom, 6%; and other, 24%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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:		
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).

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

Stockpile Status—9–30–15[8]

Material	Inventory	Disposal Plan FY 2015	Disposals FY 2015
Beryl ore	1	—	—
Metal	77	16	—
Structured powder	2	—	—

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BERYLLIUM

Events, Trends, and Issues: Apparent consumption of beryllium-based products decreased slightly in 2015 from that of 2014, but was still 17% more than that of 2013 and 18% more than that of 2012. During the first 6 months of 2015, the leading U.S. beryllium producer reported net sales of its beryllium alloy strip/bulk products and beryllium metal/composite products to be slightly higher than those during the first 6 months of 2014. Sales of beryllium products to the industrial components and defense industries increased owing to stronger demand from foundries and plastics manufacturers and Government spending on delayed defense programs. Sales of beryllium products to the energy market decreased owing to a significant decline of activity in the oil and gas sector.

In 2014, the only U.S. beryllium producer increased beryllium hydroxide production capacity at its operation in Delta, UT. The company anticipated that global demand for beryllium would exceed production during the next 3 years and global inventories would be drawn down.

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

World Mine Production and Reserves:

	Mine production[e]		Reserves[9]
	2014	2015	
United States	270	275	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 bertrandite reserves in Utah total about 15,000 tons of contained beryllium. World beryllium reserves are not available.
China	20	20	
Mozambique	2	2	
Other countries	1	1	
World total (rounded)	290	300	

World Resources: World identified resources of beryllium have been estimated to be more than 80,000 tons. About 65% of these resources are in nonpegmatite deposits in the United States; the Gold Hill and Spor Mountain areas in Utah and the Seward Peninsula in Alaska 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, and beryllium-copper master alloy.
[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]Less than ½ unit.
[5]The sum of U.S. mine shipments and net import reliance.
[6]Calculated from gross weight and customs value of imports; beryllium content estimated to be 4%.
[7]Defined as imports – exports + adjustments for Government and industry stock changes.
[8]See Appendix B for definitions.
[9]See Appendix C for resource/reserve definitions and information concerning data sources.

BISMUTH

(Data in metric tons of bismuth content 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. Some domestic firms recycle small quantities of bismuth. Bismuth is contained in some lead ores mined domestically, but the last domestic primary lead smelter closed at yearend 2013, and all lead concentrates now are exported for smelting. In 2014, the value of reported consumption of bismuth was approximately $23 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 also is used in the manufacture of ceramic glazes, crystal ware, and pearlescent pigments. Bismuth has a wide variety of metallurgical applications, including use as a nontoxic replacement for lead in brass, free-machining steels, and solders, and as an additive to enhance metallurgical quality in the foundry industry. 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, and bismuth-tellurium oxide alloy film paste is used in the manufacture of semiconductor devices.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Refinery	—	—	—	—	—
Secondary (old scrap)[e]	80	80	80	80	80
Imports for consumption, metal	1,750	1,700	1,710	2,270	2,200
Exports, metal, alloys, and scrap	628	764	816	567	600
Consumption:					
Reported[e]	696	647	774	727	900
Apparent	1,120	940	978	1,504	1,610
Price, average, domestic dealer, dollars per pound	11.47	10.10	8.71	11.14	7.50
Stocks, yearend, consumer	138	134	50	329	400
Net import reliance[1] as a percentage of apparent consumption	93	93	92	95	95

Recycling: Bismuth-containing new and old alloy scrap was recycled and thought to compose less than 10% of U.S. bismuth consumption, or about 80 tons.

Import Sources (2011–14): China, 64%; Belgium, 26%; Peru, 3%; United Kingdom, 2%; and other, 5%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
Bismuth and articles thereof, including waste and scrap	8106.00.0000	Free.

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

Government Stockpile: None.

Events, Trends, and Issues: In China, the Fanya Metal Exchange Co. Ltd., which began trading bismuth in March 2013, froze accounts in June, halting bismuth deliveries in or out of the exchange. Additionally, the Ri Jin Bao, an investment product that guaranteed annual returns of at least 13%, had its payments suspended in July. Investors were unable to buy or sell contracts, and the price of bismuth fell dramatically. In August, Fanya entered into a debt-restructuring plan, and Fanya's investors reportedly met with the China Securities Regulatory Commission (China's stock market regulator) and Provincial-level authorities to protest Fanya's actions. At the time deliveries were frozen, Fanya warehouses held 19,000 tons of bismuth.

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BISMUTH

The U.S. domestic dealer price of bismuth, which had trended upward in 2014, started 2015 at $10.90 per pound, decreased steadily throughout the year, and ended October between $5.80 and $6.20 per pound. In 2015, the estimated average price of bismuth was about 27% lower than that in 2014. Industry analysts attributed the sharp decrease in price to the events of the Fanya Metal Exchange.

The Nui Phao bismuth-copper-fluorspar-tungsten mine in Vietnam, commissioned late in 2013, reportedly produced 4,950 tons of contained bismuth during 2014, making it one of the leading bismuth producers in the world. In Canada, the NICO gold-cobalt-bismuth-copper mine and concentrator in the Northwest Territories is still under development. In Peru, the administrator of idle La Oroya Metallurgical complex, a past producer of bismuth, was attempting to sell the facility. Although the sale was anticipated in May, it was not completed owing to the environmental operating standards and remediation requirements that were a condition of the purchase.

New bismuth applications under development in 2015 include wearable technology and a new anode for sodium-ion batteries. For wearable devices, bismuth ferrite nanoparticles are added to a polymer alcohol solution, and when dried, the films can be stretched and bent with no loss in magnetic or electrical properties. This new film could be used for bendable or foldable computer screens. Bismuth nanoparticles have also been wrapped with graphene to create a new anode for sodium-ion batteries having superior electrochemical performance and recharging properties.

World Mine Production and Reserves: Production and reserves figures for Vietnam were revised based on new data from the Masan Group.

	Mine production		Reserves[2]
	2014	2015[e]	
United States	—	—	—
Bolivia	10	10	10,000
Canada	3	3	5,000
China	7,600	7,500	240,000
Mexico	948	700	10,000
Russia	40	40	NA
Vietnam	4,950	5,000	53,000
Other countries	—	—	50,000
World total (rounded)	13,600	13,600	370,000

World Resources: Bismuth, at an estimated 8 parts per billion by weight, ranks 69th in elemental abundance in the Earth's crust and is about twice as abundant as gold. World reserves of bismuth are usually based on 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 that produced bismuth from bismuth ore.

Substitutes: Bismuth can be replaced in pharmaceutical applications by alumina, antibiotics, and magnesia. Titanium dioxide-coated mica flakes and fish-scale extracts are substitutes in pigment uses. Indium can 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 imports – exports + adjustments for industry stock changes.

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

BORON

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

Domestic Production and Use: Two companies in southern California produced borates in 2015, 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 containing kernite, tincal, and ulexite by open pit methods and operated associated compound plants. The kernite was used for boric acid production, tincal was used as a feedstock for sodium borate production, and ulexite was used as a primary ingredient in the manufacture of a variety of specialty glasses and ceramics. A second company produced borates from brines extracted through solution mining techniques. Boron minerals and chemicals were principally consumed in the North Central and the Eastern United States. In 2015, 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:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production	W	W	W	W	W
Imports for consumption:					
Refined borax	69	86	127	152	164
Boric acid	56	55	53	57	60
Colemanite	—	24	38	45	42
Ulexite	—	1	—	34	74
Exports:					
Boric acid	235	190	232	225	161
Refined borax	492	457	489	584	532
Consumption, apparent	W	W	W	W	W
Price, average value of mineral imports at port of exportation, dollars per ton	553	510	433	372	400
Employment, number	1,180	1,180	1,180	1,180	1,180
Net import reliance[1] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2011–14): Borates: Turkey, 80%; Bolivia, 8%; China, 3%; Argentina, 3%; and other, 6%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
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.

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BORON

Events, Trends, and Issues: Elemental boron is a metalloid with limited commercial applications. Although the term "boron" is commonly referenced, it does not occur in nature in an elemental state. Boron combines with oxygen and other elements to form boric acid, or inorganic salts called borates. Boron compounds, chiefly borates, are commercially important; therefore, boron products are priced and sold based on their boric oxide content (B_2O_3), varying by ore and compound and by the absence or presence of calcium and sodium. The four borate minerals—colemanite, kernite, tincal, and ulexite—make up 90% of the borate minerals used by industry worldwide. Although borates were used in more than 300 applications, more than three-quarters of the world's supply is consumed in ceramics, detergents, fertilizers, and glass. Imports of refined borax increased each year between 2011 through 2015, including an 8% estimated increase between 2014 and 2015.

Consumption of borates is expected to increase in the foreseeable future, spurred by demand in the agricultural, ceramic, and glass markets in Asia and South America. Demand for borates was expected to shift slightly away from detergents and soaps toward glass and ceramics.

Canada, China, the Republic of Korea, Malaysia, and the Netherlands are the countries that imported the largest quantities of mined borates from the United States in 2015. 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 increase 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. 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: The reserves estimate for Turkey was revised based on data from Government reports.

	Production—All forms[2]		Reserves[3]
	2014	2015[e]	
United States	W	W	40,000
Argentina	500	500	NA
Bolivia	15	15	NA
Chile	580	580	35,000
China	160	160	32,000
Kazakhstan	30	30	NA
Peru	225	225	4,000
Russia	250	250	40,000
Turkey	4,100	4,200	230,000
World total (rounded)	[4]5,860	[4]5,960	380,000

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. Small deposits are being mined in South America. 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. — Zero.
[1]Defined as imports – exports.
[2]Gross weight of ore in thousand metric tons.
[3]See Appendix C for resource/reserve definitions and information concerning data sources.
[4]Excludes U.S. production.

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 accounted for about one-third of world production capacity.

Primary uses of bromine compounds are in flame retardants, drilling fluids, and water treatment, in descending order by quantity. Bromine also is used in the manufacture of dyes, perfumes, pesticides, pharmaceuticals, and photographic chemicals. Other bromine compounds are used in a variety of applications, including chemical synthesis, control of mercury emissions from coal-fired powerplants, and paper manufacturing.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production	W	W	W	W	W
Imports for consumption, elemental bromine and compounds[1]	47,500	53,600	36,700	59,800	62,200
Exports, elemental bromine and compounds	6,800	6,400	7,860	7,400	9,300
Consumption, apparent	W	W	W	W	W
Employment, number[e]	1,050	1,050	1,050	1,050	1,050
Net import reliance[2] as a percentage of apparent consumption	<50	<50	<50	<50	<50

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 is recycled with virgin bromine brines and is a source of bromine production. Plastics containing bromine flame retardants can be incinerated as solid organic waste, and the bromine can be recovered. This recycled bromine is not included in the virgin bromine production reported to the U.S. Geological Survey by companies but may be included in data collected by the U.S. Census Bureau.

Import Sources (2011–14): Israel, 88%; China, 6%; Germany, 3%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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.

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

Government Stockpile: None.

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BROMINE

Events, Trends, and Issues: The United States maintained its position as one of the leading bromine producers in the world. U.S. imports of bromine and bromine compounds increased in 2015 in response to increased domestic demand. China, Israel, and Jordan also are major producers of elemental bromine.

U.S. companies did not announce prices for bromine and bromine compounds in 2015. Trade publications, however, reported that U.S. bromine prices ranged from about $3,400 to $5,400 per ton during the year. Prices were relatively stable during the first half of the year and began to rise midyear 2015. One domestic producer increased its global prices for elemental bromine and bromine derivatives, with the exception of clear brine fluids, by 30% in March. Global price increases were attributed to reduced production by some leading producers. Additionally, the bromine company in Israel experienced a 3-month labor strike at its bromine compounds plant in early 2015, which decreased its bromine sales compared with sales from the same period in 2014.

The leading use of bromine is in flame retardants; however, in response to environmental and toxicological concerns regarding some bromine-based compounds, such as hexabromocyclododecane and decabromodiphenyl ether, some products were being phased out of production. Alternative products have been introduced into the market, allowing for the continued use of bromine in the manufacture of flame retardants.

The use of bromine to mitigate mercury emissions at powerplants continued to increase. Bromine compounds bond with mercury in flue gases from coal-fired powerplants creating mercuric bromide, a substance that is more easily captured in flue-gas scrubbers than the mercuric chloride that is produced at many facilities. Other growth markets included oilfield chemicals, which use bromine brines in offshore deep-water drilling applications.

World Production and Reserves

	Production		Reserves[3]
	2014	2015[e]	
United States	W	W	11,000,000
Azerbaijan	3,500	—	300,000
China	110,000	100,000	NA
Germany	1,500	1,500	NA
India	2,100	2,100	NA
Israel	190,000	150,000	NA
Japan	30,000	30,000	NA
Jordan	100,000	100,000	NA
Turkmenistan	500	500	700,000
Ukraine	3,500	3,500	NA
World total (rounded)	[4]440,000	[4]390,000	Large

World Resources: Bromine is found principally in seawater, evaporitic (salt) lakes, and underground brines associated with petroleum deposits. In the Middle East, the Dead Sea 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 and gas well completion and packer applications. Because plastics have a low ignition temperature, alumina, 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]Defined as imports – exports.
[3]See Appendix C for resource/reserve definitions and information concerning data sources.
[4]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 2015. 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 and other cadmium-bearing scrap. Domestic production and consumption of cadmium from 2011 to 2015 were withheld to avoid disclosing company proprietary data. Cadmium metal and compounds are mainly consumed for alloys, coatings, NiCd batteries, pigments, and plastic stabilizers.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production, refined[1]	W	W	W	W	W
Imports for consumption:					
Unwrought cadmium and powders	201	170	284	133	270
Wrought cadmium and other articles (gross weight)	9	21	104	6	20
Cadmium waste and scrap (gross weight)	([2])	1	([2])	—	80
Exports:					
Unwrought cadmium and powders	63	253	131	198	290
Wrought cadmium and other articles (gross weight)	204	378	266	72	120
Cadmium waste and scrap (gross weight)	5	—	20	—	—
Consumption of metal, apparent[3]	W	W	W	W	W
Price, metal, annual average,[4] dollars per kilogram	2.76	2.03	1.92	1.94	1.05
Stocks, yearend, producer and distributor	W	W	W	W	W
Net import reliance[5] as a percentage of apparent consumption	<25%	E	<25%	E	E

Recycling: Secondary cadmium is mainly recovered from spent consumer and industrial NiCd batteries. Other waste and scrap from which cadmium can be recovered includes copper-cadmium alloy scrap, some complex nonferrous alloy scrap, and cadmium-containing dust from electric arc furnaces (EAF). The amount of cadmium recovered from secondary sources in 2015 was withheld to avoid disclosing company proprietary data.

Import Sources (2011–14):[6] Canada, 40%; Australia, 17%; China, 11%; Mexico, 10%; and other, 22%.

Tariff: Item	Number	Normal Trade Relations[7] 12–31–15
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.

Events, Trends, and Issues: Most of the world's primary cadmium metal was produced in Asia, The leading global producers were China, the Republic of Korea, and Japan. Secondary production accounted for about 20% of global production. Cadmium was consumed primarily in Belgium, China, India, and Japan. NiCd battery production accounted for more than 80% of global cadmium consumption, and the remainder was used, in order of descending consumption, in pigments, coatings and plating, stabilizers for plastics, nonferrous alloys, and other specialized uses.

The average annual cadmium price declined for the fourth consecutive year, decreasing by 46% in 2015 from that of 2014 to about $1.05 per kilogram. The price began the year averaging $1.76 per kilogram in January and fell to an average of $0.79 per kilogram by September. Decreasing prices were attributed to an oversupply of cadmium in the market, reduced demand in India, and a decline in nickel-cadmium battery production in China because an increase in domestic environmental regulations resulted in several facility closures.

In mid-June, a U.S.-based solar cell manufacturer announced that it had improved the energy conversion efficiency of

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CADMIUM

its cadmium telluride (CdTe) photovoltaic modules to 18.6%, surpassing the efficiency of multicrystalline silicon modules and potentially increasing the market competitiveness of CdTe solar technology.

In October 2013, the European Parliament amended the European Union (EU) Battery Directive (2006/66/EC) to prohibit the inclusion of NiCd batteries in cordless power tools beginning December 31, 2016, after which nickel-cadmium batteries could only be used in emergency systems and medical equipment in the EU. In late 2014, cadmium fluoride and cadmium sulfate were added to the European Chemical Agency's (ECHA) candidate list of Substances of Very High Concern, requiring ECHA and the European Commission to determine whether the use of these chemicals would require special authorization under the EU's Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) legislation. In May, the European Parliament voted against extending an exemption on cadmium-containing quantum dots under the Restriction of Hazardous Substances directive. Cadmium-containing quantum dots are used in light-emitting diodes for display technologies. Despite these restrictions, cadmium-containing residues will continue to be produced as a byproduct from zinc smelting. If the applications and markets for cadmium continue to decline, excess byproduct cadmium may need to be permanently stockpiled and managed.

World Refinery Production and Reserves:

	Refinery production 2014	Refinery production 2015[e]	Reserves[8]
United States	W	W	Quantitative estimates of reserves are not available. The cadmium content of typical zinc ores averages about 0.03%. See the Zinc chapter for zinc reserves.
Australia	350	380	
Bulgaria	350	340	
Canada	1,310	1,480	
China	7,000	8,090	
India	380	460	
Japan	1,830	1,970	
Kazakhstan	1,200	1,190	
Korea, Republic of	4,010	4,250	
Mexico	1,410	1,460	
Netherlands	640	640	
Peru	769	750	
Poland	628	640	
Russia	1,200	1,170	
Other countries	1,350	1,330	
World total (rounded)	[9]22,400	[9]24,200	

World Resources: Cadmium is generally recovered from zinc ores and concentrates. Sphalerite, the most economically significant zinc 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 are replacing NiCd batteries in some applications. However, the higher cost of these alternatives restricts their use in less-expensive products. Except where the surface characteristics of a coating are critical (for example, fasteners for aircraft), coatings of zinc or vapor-deposited aluminum 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 polyvinylchloride applications.

[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]Defined as domestic refined production + imports of unwrought metal and metal powders – exports of unwrought metal and metal powders + adjustments for industry stock changes.
[4]Average New York dealer price for 99.95% purity in 5-short-ton lots. Source: Platts Metals Week (2011–2014), Metal Bulletin (2015).
[5]Defined as imports of unwrought metal and metal powders – exports of unwrought metal and metal powders + adjustments for industry stock changes.
[6]Imports for consumption of unwrought metal and metal powders (Tariff no. 8107.20.0000).
[7]No tariff for Australia, Canada, Mexico, and Peru for items shown.
[8]See Appendix C for resource/reserve definitions and information concerning data sources.
[9]Does not include production in Algeria and the United States.

CEMENT

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2015, domestic production of cement increased slightly to about 80.4 million tons of portland cement and 2.4 million tons of masonry cement; output was from 99 plants in 34 States. Cement also was produced at two plants in Puerto Rico. Production continued to be well below the record level of 99 million tons in 2005, and reflected continued full-time idle status at a few plants, underutilized capacity at many others, and plant closures in recent years. Cement sales increased significantly in 2015, with much of the increase accounted for by imports; overall, sales were still nearly 35 million tons lower than the record volume in 2005. The overall value of sales was about $9.8 billion. Most of the sales of cement were to make concrete, worth at least $50 billion. As in recent years, about 70% of cement sales went to ready-mixed concrete producers, 11% to concrete product manufacturers, 8% to contractors (mainly road paving), 4% each to oil and gas well drillers and to building materials dealers, and 3% to others. Texas, California, Missouri, Florida, and Alabama were, in descending order, the five leading cement-producing States and accounted for nearly 50% of U.S. production.

Salient Statistics—United States:[1]	**2011**	**2012**	**2013**	**2014**	**2015**[e]
Production:					
Portland and masonry cement[2]	67,895	74,151	76,804	[e]82,600	82,800
Clinker	61,241	67,173	69,420	[e]74,400	75,800
Shipments to final customers, includes exports	73,402	79,951	83,187	90,047	92,700
Imports of hydraulic cement for consumption	5,812	6,107	6,289	7,584	10,000
Imports of clinker for consumption	606	786	806	720	900
Exports of hydraulic cement and clinker	1,414	1,749	1,670	1,397	1,300
Consumption, apparent[3]	72,200	77,900	81,700	[e]89,200	93,000
Price, average mill value, dollars per ton	89.50	89.50	95.00	[e]100.50	105.50
Stocks, cement, yearend	6,270	6,900	6,570	[e]6,150	4,800
Employment, mine and mill, number[e]	11,500	10,500	10,300	10,000	10,000
Net import reliance[4] as a percentage of apparent consumption	7	7	7	8	10

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 (2011–14):[5] Canada, 50%; Republic of Korea, 18%; China, 8%; Greece, 7%; and other, 17%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–15**
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: Cement sales continued to increase in 2015 but at a more moderate rate than had originally been expected. Although construction spending levels were generally higher during the year, low oil and gas prices led to a significant drop in exploration and production drilling, as well as reduced demand for general use and oil well cements used for such drilling; this, in turn, significantly reduced overall cement sales in Texas and in a number of other States that had recently been experiencing a boom in drilling. Production of cement remained well below capacity, with some multikiln plants continuing to rely primarily on a single kiln during the year. Much of the growth in cement sales in 2015 was of imported rather than domestic material; this may have reflected technical, economic, and environmental difficulties in restarting long-idle kilns at some plants. Imports resumed at several terminals that had been idle or substantially inactive during the recession, and cement imports came from more countries than in the recent past.

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CEMENT

The merger, announced in 2014, of two of the world's largest cement companies, was completed in 2015. In the United States, both partners were required to sell certain distribution terminals and concrete subsidiaries. In addition, the merger resulted in the sale by one partner of a cement plant in Montana and slag-grinding plants in Indiana and New Jersey, and the other partner sold a cement plant in Iowa. In 2015, a major international company announced its intention to purchase a smaller international company. Both companies operated in the United States, and were it to be approved, the takeover was expected to result in the sale of a cement plant in Indiana, where both companies had facilities, and of a plant in either Maryland or West Virginia, where the two companies had dominant market share. Both companies also owned cement plants in Pennsylvania, but the market there was sufficiently diverse to possibly not require a divestiture. In 2014, a former U.S. cement producer returned to cement making through its purchase of a U.S. cement company. The purchase involved two cement plants in California and two in Texas, and was followed by the sale in 2015 of the larger plant in California to another California producer and the closure of the smaller facility. Production resumed in 2015 at a small plant in Illinois that had been idle since early 2009. No new plants opened in 2015, but upgrades were underway at several plants, including in Maryland, New York, and Texas.

The 2010 National Emissions Standards for Hazardous Air Pollutants (NESHAP) protocol for cement plants went into effect in September 2015; it greatly reduces the acceptable emissions levels of mercury and certain other pollutants. Many plants installed emissions reduction technologies to comply with the NESHAP, but it was unclear if such modifications would be economic at all plants, or for all kilns (some being of older technology) at multikiln plants.

World Production and Capacity:

	Cement production[e]		Clinker capacity[e]	
	2014	2015	2014	2015
United States (includes Puerto Rico)	83,200	83,400	105,600	106,000
Brazil	72,000	72,000	60,000	60,000
China	2,480,000	2,350,000	2,000,000	2,000,000
Egypt	50,000	55,000	46,000	46,000
Germany	32,000	32,000	31,000	31,000
India	260,000	270,000	280,000	280,000
Indonesia	65,000	65,000	59,000	59,000
Iran	65,000	65,000	78,600	79,000
Italy	22,000	23,000	46,000	46,000
Japan	53,800	55,000	55,000	55,000
Korea, Republic of	63,200	63,000	50,000	50,000
Mexico	35,000	35,000	42,000	42,000
Pakistan	32,000	32,000	44,000	44,000
Russia	68,400	69,000	80,000	80,000
Saudi Arabia	55,000	55,000	55,000	55,000
Thailand	35,000	35,000	50,000	50,000
Turkey	75,000	77,000	69,000	69,000
Vietnam	60,500	61,000	80,000	80,000
Other countries (rounded)	573,000	603,000	369,000	368,000
World total (rounded)	4,180,000	4,100,000	3,600,000	3,600,000

World Resources: Although individual plant reserves 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 in making concrete or mortars and competes in the construction sector with concrete substitutes, such as aluminum, asphalt, clay brick, fiberglass, glass, steel, stone, and wood. A number of materials, especially fly ash and ground granulated blast furnace slag, develop good hydraulic cementitious properties by reacting with the lime 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.

[2]Includes cement made from imported clinker.

[3]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.

CESIUM

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

Domestic Production and Use: In 2015, there was no domestic mine production of cesium and the United States was 100% import reliant for cesium minerals. The United States sources the majority of its pollucite, the principal cesium mineral, from the largest known North American deposit at Bernic Lake, Manitoba, Canada.

Cesium, in the form of chemical compounds, is the principal end use of cesium ore. By gross weight, formate brines used for high-pressure, high-temperature well drilling for oil and gas production and exploration, are the primary applications for cesium. 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 repellents 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 global positioning satellites, Internet and cellular telephone transmissions, and aircraft guidance systems. 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 a 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.

Fission byproducts cesium-131 and cesium-137 are used primarily to treat cancer. A company in Richland, WA, produced a range of cesium-131 medical products for treatment of various cancers. Cesium-137 also 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 is 100% import dependent for its cesium needs. In 2015, one company offered 1-gram ampoules of 99.8% (metal basis) cesium for $59.70 and 99.98% (metal basis) cesium for $73.40, the same as those in 2014, and an increase of 3.9% and 4.1%, respectively, from those in 2013. The prices that the company offered for 50 grams of 99.9% (metal basis) cesium acetate, cesium bromide, cesium carbonate, cesium chloride, and cesium nitrate were $111.40, $67.70, $95.80, $96.60, and $173.00, respectively. The price for a cesium-plasma standard solution (10,000 micrograms per milliliter) was $81.40 for 50 milliliters and $124.00 for 100 milliliters.

Recycling: Cesium formate brines are typically rented by oil and gas exploration clients. After completion of the well, the used cesium formate brine is returned and reprocessed for subsequent drilling operations. Cesium formate production from Canada was estimated to be 5,630 tons per year, including 3,890 tons of cesium from 17,300 tons of pollucite ore. The formate brines are recycled with a recovery rate of 85%, which can be retrieved for further use.

Import Sources (2011–14): Canada is the chief source of pollucite concentrate imported by the United States.

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CESIUM

Tariff:

Item	Number	Normal Trade Relations 12–31–15
Ores and concentrates, other	2617.90.0060	Free
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 early 2013, the underground mining operation at Bernic Lake, Manitoba, Canada, experienced a partial collapse in the area of the mine's crowning pillar. A similar event had taken place in 2010. In 2015, mining continued while work to stabilize the area progressed. The mining rate was set to not exceed 1,000 tons per day of material. At operations in Argentina and Canada, site sampling and development continued with the goal of establishing cesium and rubidium mines.

World Mine Production and Reserves: Pollucite, mainly formed 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). Data on cesium resources, other than those listed, are either limited or not available. The main pollucite zone at Bernic Lake in Canada contains approximately 120,000 tons of contained cesium oxide in pollucite ore, with premining average ore grades of 23.3% Cs_2O. Sites near Lake Ontario have identified cesium resources; exploration of those deposits began in the last quarter of 2013. Zimbabwe and Namibia produced cesium in small quantities as a byproduct of lithium mining operations.

	Reserves[1]
Canada	120,000
Namibia	30,000
Zimbabwe	60,000
Other countries	NA
World total (rounded)	210,000

World Resources: World resources of cesium have not been estimated. Cesium is associated with lithium-bearing pegmatites worldwide, and cesium resources have been identified in the United States, Canada, Namibia, and Zimbabwe. In the United States, pollucite occurs in pegmatites in Alaska, Maine, and South Dakota. Lower concentrations are also known in brines in Chile and China and in geothermal systems in Germany, India, and Tibet. China was believed to have cesium-rich deposits of pollucite, lepidolite, and geyserite, with concentrations highest in Yichun, Jiangxi, 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/reserve definitions and information concerning data sources.

CHROMIUM

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

Domestic Production and Use: In 2015, the United States was expected to consume about 5% of world chromite ore production in various forms of imported materials, such as chromite ore, chromium chemicals, chromium ferroalloys, chromium metal, and stainless steel. One U.S. company mined chromite ore in Oregon from which it produced foundry sand. 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 2014 was $971 million as measured by the value of net imports, excluding stainless steel, and was expected to be about $1 billion in 2015.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production:					
Mine	—	NA	NA	NA	NA
Recycling[1]	147	146	150	157	162
Imports for consumption	531	554	475	637	676
Exports	232	234	235	250	381
Government stockpile releases	4	4	10	15	15
Consumption:					
Reported (includes recycling)	400	401	402	418	418
Apparent[2] (includes recycling)	450	471	400	558	471
Unit value, average annual import (dollars per ton):					
Chromite ore (gross quantity)	355	392	310	243	214
Ferrochromium (chromium content)	2,603	2,362	2,156	2,209	1,035
Chromium metal (gross quantity)	14,090	13,333	11,147	11,006	10,866
Stocks, yearend, held by U.S. consumers	8	8	8	8	8
Net import reliance[3] as a percentage of apparent consumption	67	69	63	72	66

Recycling: In 2015, recycled chromium (contained in reported stainless steel scrap receipts) accounted for 34% of apparent consumption.

Import Sources (2011–14): Chromite (mineral): South Africa, 98%; and other, 2%. Chromium-containing scrap: Canada, 50%; Mexico, 42%; and other, 8%. Chromium (primary metal): South Africa, 33%; Kazakhstan, 18%; Russia, 10%; and other, 39%. Total imports: South Africa, 37%; Kazakhstan, 16%; Russia, 8%; and other, 39%.

Tariff:[4] Item	Number	Normal Trade Relations 12–31–15
Chromium ores and concentrates:		
Not more than 40% Cr_2O_3	2610.00.0020	Free.
Cr_2O_3 more than 40% and less than 46%	2610.00.0040	Free.
Cr_2O_3 not less than 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.
Sulfates of chromium	2833.29.4000	3.7% ad val.
Sodium dichromate	2841.30.0000	1.5% 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.
Other:		
Carbon more than 0.5%	7202.49.5010	3.1% ad val.
Other	7202.49.5090	3.1% ad val.
Ferrochromium silicon	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.

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CHROMIUM

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

Government Stockpile: For FY 2016, the Defense Logistics Agency (DLA) Strategic Materials announced maximum disposal limits for chromium materials of about 21,300 tons of ferrochromium and 181 tons of chromium metal. No acquisitions were planned.

Stockpile Status—9–30–15[5]

Material[6]	Inventory	Disposal Plan FY 2015	Disposals FY 2015
Ferrochromium:			
High-carbon	63.0	[7]21.0	11.8
Low-carbon	32.9	—	4.04
Chromium metal	3.96	0.136	—

Events, Trends, and Issues: Chromium is consumed in the form of ferrochromium to produce stainless steel. China was the leading chromium-consuming and ferrochromium-producing country and the leading stainless steel producer. South Africa was the leading chromite ore and a leading ferrochromium producer upon which world stainless steel producers depend directly or indirectly for chromium supply. Ferrochromium production is electrical energy intensive, so constrained electrical power supply results in constrained ferrochromium production. South Africa was the leading ferrochromium producer for many years before 2012, the first year that China's ferrochromium producers, motivated by China's stainless steel industry demand, matched South African ferrochromium production. China produced more ferrochromium, much of it derived from South African chromite ore, than South Africa in 2013 and 2014. However, the startup of a new smelter in 2014, as well as the restarting of other ferrochromium production capacity, which was shut down in 2012 and 2013 under electrical power buy-back contracts, permitted ferrochromium production in South Africa to rebound strongly in 2015. The leading ferrochromium producer in 2015 will likely be determined by the amount of electrical power reduction required in South Africa during its winter months and the amount of hydropower available in China during its rainy season.

DLA Strategic Materials planned to continue selling ferrochromium in fiscal year 2016 until it reaches its limit; however, DLA Strategic Materials would need congressional authority to continue sales into fiscal year 2017.

World Mine Production and Reserves:

	Mine production[8] 2014	2015[e]	Reserves[9] (shipping grade)[10]
United States	NA	NA	620
India	3,540	3,500	54,000
Kazakhstan	3,700	3,800	230,000
South Africa	12,000	15,000	200,000
Turkey	2,600	3,600	NA
Other countries	4,590	4,600	NA
World total (rounded)	26,400	27,000	>480,000

World Resources: World resources are greater than 12 billion tons of shipping-grade chromite, sufficient to meet conceivable demand for centuries. About 95% of the world's chromium resources is geographically concentrated in Kazakhstan and southern Africa; U.S. 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 stainless steel scrap receipts.
[2]Defined as production (from mines and recycling) + imports – exports + adjustments for Government and industry stock changes.
[3]Defined as imports – exports + adjustments for Government and industry stock changes.
[4]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.
[5]See Appendix B for definitions.
[6]Units are metric tons of material gross quantity.
[7]High-carbon and low-carbon ferrochromium, combined.
[8]Mine production units are thousand tons, gross weight, of marketable chromite ore.
[9]See Appendix C for resource/reserve definitions and information concerning data sources.
[10]Reserves units are thousand tons of shipping-grade chromite ore, which is deposit quantity and grade normalized to 45% Cr_2O_3.

CLAYS

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: The U.S. production of clays (sold or used) was estimated to be 25.5 million tons valued at $1.48 billion in 2015, with about 150 companies operating clay and shale mines in 40 States. The leading 20 firms produced approximately 60% of the domestic tonnage and 84% of the value for all types of clay. The United States accounted for 15% to 25% of the global production of refined clays, excluding common clay and shale. Principal uses for specific clays were estimated to be as follows: ball clay—41% floor and wall tile and 18% sanitaryware; bentonite—32% drilling mud, 29% pet waste absorbents, and 10% each for foundry sand and iron ore pelletizing; common clay—42% brick, 28% cement, and 20% lightweight aggregate; fire clay—51% refractory products and miscellaneous uses and 49% heavy clay products (for example, brick and cement); fuller's earth—69% pet waste absorbents; and kaolin—45% paper coating and filling. Lightweight ceramic proppants for use in hydraulic fracturing have also become a significant market for kaolin, but available data are insufficient for a reliable estimate of the market size.

In 2015, the United States exported an estimated 922,000 tons of bentonite, or 21% of the estimated domestic bentonite production. Canada and Japan were the leading destinations for U.S. bentonite and accounted for 55% of bentonite exports. About 2.4 million tons of kaolin (39% of production) was exported primarily to Japan, Mexico, and China, which combined received 45% of U.S. international kaolin shipments. Based on the ports from which fire clay was exported, up to 75% of listed fire clay exports were thought to be misclassified refractory-grade kaolin.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production (sold or used):					
Ball clay	886	973	1,000	1,030	1,070
Bentonite	4,990	4,980	4,350	4,800	4,320
Common clay	11,700	11,900	11,100	11,600	11,700
Fire clay	215	183	151	217	235
Fuller's earth[1]	1,950	1,980	1,990	1,990	1,970
Kaolin	5,950	5,900	6,140	6,310	6,160
Total[1, 2]	25,700	25,900	24,700	25,900	25,500
Imports for consumption:					
Artificially activated clay and earth	31	31	24	26	23
Kaolin	549	472	467	518	513
Other	13	21	27	33	37
Total[2]	593	524	518	576	574
Exports:					
Ball clay	49	77	52	33	54
Bentonite	1,020	1,030	890	901	922
Clays, not elsewhere classified	209	315	304	282	274
Fire clay[3]	371	289	268	237	206
Fuller's earth	102	107	86	92	77
Kaolin	2,490	2,450	2,540	2,640	2,420
Total[2]	4,240	4,270	4,140	4,190	3,950
Consumption, apparent[4]	22,100	22,200	21,100	22,300	22,100
Price, average, dollars per ton:					
Ball clay	46	46	43	44	44
Bentonite	61	62	65	67	60
Common clay	12	12	11	10	10
Fire clay	30	27	23	18	18
Fuller's earth[1]	100	92	90	86	86
Kaolin	143	149	146	143	143
Employment, number:					
Mine (may not include contract workers)	810	900	820	860	850
Mill	4,200	4,350	4,350	4,330	4,290
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2011–14): Brazil, 88%; Mexico, 4%; China, 2%; United Kingdom, 2%; and other, 4%.

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CLAYS

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
Kaolin and other kaolinitic 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 earths	2508.40.0120	Free.
Other clays	2508.40.0150	Free.
Chamotte or dina's 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 estimated domestic sales of clay fell slightly in 2015. Increases in construction spending and housing starts led to a slight growth in sales of common clay and ball clay, but bentonite sales declined, likely driven by decreased domestic oil drilling activity. Lower kaolin production was likely a result of declining sales to paper markets and reduced 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[e]					
	Bentonite		Fuller's earth		Kaolin	
	2014	2015	2014	2015	2014	2015
United States (sales)	[7]4,800	4,320	[1, 7]1,990	[1]1,970	[7]6,310	6,160
Brazil (beneficiated)	440	440	—	—	[7]1,710	1,700
China	3,500	3,500	—	—	3,300	3,300
Czech Republic	230	310	—	—	[8]3,100	[8]3,300
Germany (sales)	360	360	—	—	4,300	4,300
Greece	[7, 8]1,010	[8]1,300	—	—	—	—
India	1,080	1,080	6	6	[8]4,480	[8]4,480
Iran	430	430	—	—	1,500	1,500
Mexico	600	600	110	110	165	170
Senegal	—	—	235	235	—	—
Spain	115	115	647	645	[8]330	[8]330
Turkey	650	700	10	10	1,200	1,300
Ukraine	220	220	—	—	1,000	1,400
United Kingdom (sales)	—	—	—	—	1,100	1,100
Other countries	2,660	2,600	265	265	4,980	5,000
World total (rounded)[2]	16,100	16,000	[1]3,260	[1]3,240	33,500	34,000

World Resources: Resources of all clays are extremely large.

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

[e]Estimated. E Net exporter. — Zero.
[1]Excludes 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/reserve definitions and information concerning data sources.
[7]Reported figure.
[8]Includes production of crude kaolin ore.

COBALT

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

Domestic Production and Use: In 2015, a nickel-copper mine in Michigan ramped up production of cobalt-bearing nickel concentrate. A Pennsylvania producer of extra-fine cobalt metal powder ceased producing the powder in 2015. 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; 9% in cemented carbides for cutting and wear-resistant applications; 18% in various other metallic applications; and 27% in a variety of chemical applications. The total estimated value of cobalt consumed in 2015 was $280 million.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production:					
Mine[e]	—	—	—	120	700
Secondary	2,210	2,160	2,160	2,200	2,500
Imports for consumption	10,600	11,100	10,500	11,400	11,500
Exports	3,390	3,760	3,850	4,500	3,900
Shipments from Government stockpile excesses[1]	—	—	—	—	—
Consumption:					
Reported (includes secondary)	9,180	8,660	8,090	8,560	9,000
Apparent[2] (includes secondary)	9,230	9,510	8,670	8,920	10,000
Price, average, dollars per pound:					
U.S. spot, cathode[3]	17.99	14.07	12.89	14.48	13.50
London Metal Exchange (LME), cash	16.01	13.06	12.26	14.00	13.10
Stocks, yearend:					
Industry	1,040	980	1,080	1,240	1,190
LME, U.S. warehouse	43	51	41	9	120
Net import reliance[4] as a percentage of apparent consumption	76	77	75	75	75

Recycling: In 2015, cobalt contained in purchased scrap represented an estimated 28% of cobalt reported consumption.

Import Sources (2011–14): Cobalt contained in metal, oxide, and salts: China, 19%; Norway, 13%; Finland and Russia, 9% each; and other, 50%.

Tariff: Item	Number	Normal Trade Relations[5] 12–31–15
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: In FY 2015, the Defense Logistics Agency acquired 450 kilograms of lithium nickel cobalt aluminum oxide and 91 kilograms of lithium cobalt oxide.

Stockpile Status—9–30–15[6]

Material	Inventory	Disposal Plan FY 2015	Disposals FY 2015
Cobalt metal	301	—	—

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COBALT

Events, Trends, and Issues: Congo (Kinshasa) continued to be the world's leading source of mined cobalt, supplying more than one-half of world cobalt mine production. Growth in world cobalt supply, mainly from increased production from new projects and expansions to existing operations, and growth in world cobalt consumption, driven mainly by the battery and aerospace industries, are thought to be in balance. During the first 6 months of 2015, world availability of refined cobalt (as measured by production) was 11% higher than that of the same period in 2014, mainly owing to increased production in China. China was the world's leading producer of refined cobalt and the leading supplier of cobalt imports to the United States. Much of China's production was from ore and partially refined cobalt imported from Congo (Kinshasa); stocks of cobalt materials also contributed to China's supply. China was the world's leading consumer of cobalt, with nearly 75% of its consumption being used by the battery industry.

World Mine Production and Reserves: Reserves for Brazil, Canada, the Philippines, South Africa, the United States, and "Other countries" were revised based on company or Government reports.

	Mine production		Reserves[7]
	2014	2015[e]	
United States	[e]120	700	23,000
Australia	5,980	6,000	[8]1,100,000
Brazil	2,600	2,600	78,000
Canada	6,570	6,300	240,000
China	7,200	7,200	80,000
Congo (Kinshasa)	63,000	63,000	3,400,000
Cuba	3,700	4,200	500,000
Madagascar	3,100	3,600	130,000
New Caledonia[9]	4,040	3,300	200,000
Philippines	4,600	4,600	250,000
Russia	6,300	6,300	250,000
South Africa	3,000	2,800	31,000
Zambia	5,500	5,500	270,000
Other countries	7,080	7,700	610,000
World total (rounded)	123,000	124,000	7,100,000

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: In some applications, substitution for cobalt would result in a loss in product performance. Potential substitutes 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; iron-phosphorous, manganese, nickel-cobalt-aluminum, or nickel-cobalt-manganese in lithium-ion batteries; nickel-based alloys or ceramics in jet engines; nickel in petroleum catalysts; and rhodium in hydroformylation catalysts.

[e]Estimated. — Zero.
[1]Cobalt metal. In 2014–15, the Defense Logistics Agency acquired cobalt-bearing battery precursor materials.
[2]The sum of U.S. net import reliance and secondary production, as estimated from consumption of purchased scrap.
[3]As reported by Platts Metals Week.
[4]Defined as imports – exports + adjustments for Government and industry stock changes for refined cobalt.
[5]Tariffs for certain countries and items may be eliminated under special trade agreements.
[6]See Appendix B for definitions.
[7]See Appendix C for resource/reserve definitions and information concerning data sources.
[8]For Australia, Joint Ore Reserves Committee-compliant reserves were about 390,000 tons.
[9]Overseas territory of France.

COPPER

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

Domestic Production and Use: U.S. mine production of copper in 2015 decreased by 8% to about 1.25 million tons, and was valued at about $7.6 billion. Arizona, New Mexico, Utah, Nevada, Montana, and Michigan—in descending order of production—accounted for more than 99% of domestic mine production; copper also was recovered in Idaho and Missouri. Twenty-six mines recovered copper, 18 of which accounted for about 99% of production. Three primary smelters, 3 electrolytic and 4 fire refineries, and 15 electrowinning facilities operated during 2015. Refined copper and scrap were used at about 30 brass mills, 14 rod mills, and 500 foundries and miscellaneous consumers. Copper and copper alloys products were used in building construction, 43%; electric and electronic products, 19%; transportation equipment, 19%; consumer and general products, 12%; and industrial machinery and equipment, 7%.[1]

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production:					
Mine, recoverable	1,110	1,170	1,250	1,360	1,250
Refinery:					
Primary	992	962	993	1,050	1,000
Secondary	37	39	47	46	50
Copper from old scrap	153	164	166	171	160
Imports for consumption:					
Ores and concentrates	15	6	3	([2])	([2])
Refined	670	630	734	620	770
General imports, refined	649	628	730	614	700
Exports:					
Ores and concentrates	252	301	348	410	380
Refined	40	169	111	127	120
Consumption:					
Reported, refined	1,760	1,760	1,830	1,750	1,800
Apparent, unmanufactured[3]	1,730	1,760	1,760	1,780	1,780
Price, average, cents per pound:					
Domestic producer, cathode	405.9	367.3	339.9	318.1	277.0
London Metal Exchange, high-grade	399.8	360.6	332.3	311.1	270.0
Stocks, yearend, refined, held by U.S. producers, consumers, and metal exchanges	409	236	258	193	180
Employment, mine and mill, thousands	10.6	11.5	12.1	12.1	11.4
Net import reliance[4] as a percentage of apparent consumption (refined copper)	34	36	34	31	36

Recycling: Old scrap, converted to refined metal and alloys, provided 160,000 tons of copper, equivalent to 9% of apparent consumption. Purchased new scrap, derived from fabricating operations, yielded 670,000 tons of contained copper. Of the total copper recovered from scrap (including aluminum- and nickel-base scrap), brass mills recovered 79%; copper smelters, refiners, and ingot makers, 15%; and miscellaneous manufacturers, foundries, and chemical plants, 6%. Copper in all scrap contributed about 32% of the U.S. copper supply.

Import Sources (2011–14): Unmanufactured (ore and concentrates, blister and anodes, refined, and so forth): Chile, 51%; Canada, 26%; Mexico, 16%; and other, 7%. Refined copper accounted for 87% of unmanufactured copper imports.

Tariff: Item	Number	Normal Trade Relations[5] 12–31–15
Copper ores and concentrates	2603.00.0000	1.7¢/kg on lead content.
Unrefined copper anode	7402.00.0000	Free.
Refined and alloys; unwrought	7403.00.0000	1.0% ad val.
Copper wire (rod)	7408.11.6000	3.0% ad val.

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

Government Stockpile: None.

Events, Trends, and Issues: In 2015, the COMEX spot copper monthly average price increased to $2.89 per pound of copper in May from $2.65 per pound in January. In August, however, it fell to $2.33 per pound, the lowest monthly average since June 2009. The decrease in the copper price was in large part owing to reduced demand growth from

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COPPER

slower economic growth in China. At the end of August, domestic stocks of refined copper were 12% lower than those at yearend 2014. The International Copper Study Group (ICSG) projected that in 2015, global refined copper production would exceed consumption by about 40,000 tons. Global production of refined copper was projected to increase by 1.0% and consumption was projected to decrease by 1.2%.[6]

U.S. mine production decreased by about 8% in 2015, mainly owing to decreases in production in Arizona and Utah. Copper production at the Bingham Canyon Mine in Utah decreased by an estimated 100,000 tons owing to lower mill throughput during repair work on the east wall of the mine. The two leading domestic producers announced production decreases at mines in Arizona during the second half of the year owing to low copper prices. Decreases in production were partly offset by increased production at the Morenci Mine in Arizona and at several smaller mines. Total U.S. refined production decreased by about 5% mainly owing to a smelter maintenance shutdown and a concentrate shortfall at Bingham Canyon's integrated smelter.

In 2016, domestic mine and refined production of copper were expected to increase moderately, and according to ICSG projections, global refined copper consumption was expected to exceed output owing to consumption growth of 3.0%, outpacing a 2.3% growth in global refined production. Mine and refined production were expected to lag behind earlier projections owing to mine cutbacks and reduced scrap availability attributable to lower prices.

World Mine Production and Reserves: Reserves for Australia and Peru were revised based on new information from the Governments of those countries. Reserves for Mexico and the United States were revised based on reported company data.

	Mine production		Reserves[7]
	2014	2015[e]	
United States	1,360	1,250	33,000
Australia	970	960	[8]88,000
Canada	696	695	11,000
Chile	5,750	5,700	210,000
China	1,760	1,750	30,000
Congo (Kinshasa)	1,030	990	20,000
Mexico	515	550	46,000
Peru	1,380	1,600	82,000
Russia	742	740	30,000
Zambia	708	600	20,000
Other countries	3,600	3,900	150,000
World total (rounded)	18,500	18,700	720,000

World Resources: A 1998 USGS assessment estimated that 550 million tons of copper was contained in identified and undiscovered resources in the United States.[9] A 2014 USGS global assessment of copper deposits indicated that identified resources contain 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.[10] (For a listing of USGS regional copper resource assessments, go to http://minerals.usgs.gov/global.)

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

[e]Estimated.
[1]Some electrical components are included in each end use. Distribution for 2014 by the Copper Development Association, Inc., 2015.
[2]Less than ½ unit.
[3]Defined as primary refined production + copper from old scrap converted to refined metal and alloys + refined imports – refined exports ± changes in refined stocks. General imports were used to calculate apparent consumption.
[4]Defined as imports – exports + adjustments for industry stock changes for refined copper.
[5]No tariff for Canada, Chile, Mexico, and Peru for items shown. Tariffs for other countries may be eliminated under special trade agreements.
[6]International Copper Study Group, 2015, Forecast 2015–2016: Lisbon, Portugal, International Copper Study Group press release, October 6, 2 p.
[7]See Appendix C for resource/reserve definitions and information concerning data sources.
[8] For Australia, Joint Ore Reserves Committee-compliant reserves were about 26 million 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.
[10]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)

(Data in million carats unless otherwise noted)

Domestic Production and Use: In 2015, total domestic production of industrial diamond was estimated to be 111 million carats with a value of $109 million. The United States was one of the world's leading markets. Domestic output was synthetic grit, powder, and stone. One firm in Ohio 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 was estimated to be 38.3 million carats with a value of $28.8 million. The following industry sectors were the major consumers of industrial diamond: computer chip production, construction, machinery manufacturing, mining services (drilling for mineral, natural gas, and oil exploration), stone cutting and polishing, and transportation systems (infrastructure and vehicles). Stone cutting and highway building, milling, and repair consumed most of the industrial diamond stone. About 95% of the U.S. industrial diamond market now uses synthetic industrial diamond because its quality can be controlled and its properties can be customized to fit specific requirements.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Bort, grit, and dust and powder; natural and synthetic:					
Production:					
Manufactured diamond[e]	41.5	43.7	45.7	52.6	39.1
Secondary	34.7	36.5	38.1	43.7	37.8
Imports for consumption	726	595	728	682	550
Exports	148	155	149	163	143
Consumption, apparent	654	520	663	615	484
Price, value of imports, dollars per carat	0.13	0.13	0.11	0.11	0.13
Net import reliance[1] as a percentage of apparent consumption	88	85	87	84	84
Stones, natural and synthetic:					
Production:					
Manufactured diamond[e]	56.7	59.7	62.5	95.0	72.0
Secondary	0.31	0.33	0.34	0.52	0.48
Imports for consumption[2]	2.46	2.33	1.94	2.16	1.35
Exports	—	—	—	—	—
Sales from Government stockpile excesses	—	—	—	—	—
Consumption, apparent	59.4	62.3	64.8	97.7	73.8
Price, value of imports, dollars per carat	19.67	15.30	15.50	14.40	15.50
Net import reliance[1] as a percentage of apparent consumption	4	4	3	2	2

Recycling: In 2015, the amount of diamond bort, grit, and dust and powder recycled was estimated to be 37.8 million carats with an estimated value of $27.4 million. It was estimated that 477,000 carats of diamond stone was recycled with an estimated value of $1.36 million.

Import Sources (2011–14): Bort, grit, and dust and powder; natural and synthetic: China, 79%; Ireland, 8%; Romania, 4%; Republic of Korea, 4%; and other, 5%. Stones, primarily natural: Botswana, 24%; India, 22%; South Africa, 22%; Ghana, 10%; and other, 22%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–15**
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.
Industrial diamonds, other	7102.29.0000	Free.
Grit or dust and powder of natural or synthetic diamonds	7105.10.0000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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DIAMOND (INDUSTRIAL)

Events, Trends, and Issues: In 2015, China was the world's leading producer of synthetic industrial diamond, with annual production exceeding 4 billion carats. The United States is likely to continue to be one of the world's leading markets for industrial diamond into the next decade and likely will 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 cement in highway construction and repair work.

Demand for synthetic diamond grit and powder is expected to remain greater than that for natural diamond material. Constant-dollar prices of synthetic diamond products probably will continue to decline as production technology becomes more cost effective; the decline is even more likely if competition from low-cost producers in China and Russia continues to increase.

World Mine Production and Reserves:[3] Reserves for Australia were revised based on new Government information.

	Mine production		Reserves[4]
	2014	2015[e]	
United States	—	—	NA
Australia	9	10	220
Botswana	7	7	130
Congo (Kinshasa)	13	13	150
Russia	17	16	40
South Africa	1	1	70
Zimbabwe	4	4	NA
Other countries	2	3	90
World total (rounded)	53	54	700

World Resources: Natural diamond resources 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]Defined as imports – exports + adjustments for industry stock changes.
[2]May include synthetic miners' diamond.
[3]Natural industrial diamond only. Note that synthetic diamond production far exceeds natural industrial diamond output. Worldwide production of manufactured industrial diamond totaled at least 4.4 billion carats in 2015; the leading producers included Belarus, China, Ireland, Japan, Russia, South Africa, Sweden, and the United States.
[4]See Appendix C for resource/reserve definitions and information concerning data sources.

DIATOMITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2015, production of diatomite was estimated to be 925,000 tons with an estimated processed value of $287 million, f.o.b. plant. Six companies produced diatomite at 11 mining areas and nine processing facilities in California, Nevada, Oregon, and Washington. Diatomite is used in filter aids, 55%; cement, 21%; fillers, 14%, absorbents, 9%; and other applications, 1%, including specialized pharmaceutical and biomedical uses. The unit value of diatomite varied widely in 2015, from approximately $10 per ton when used as a lightweight aggregate in portland cement concrete to more than $400 per ton for limited specialty markets, including art supplies, cosmetics, and DNA extraction.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production[1]	813	735	782	901	925
Imports for consumption	2	3	1	4	7
Exports	106	96	92	82	79
Consumption, apparent	709	642	691	823	853
Price, average value, dollars per ton, f.o.b. plant	269	286	293	298	310
Stocks, producer, yearend[e]	40	40	40	40	40
Employment, mine and plant, number[e]	660	660	660	660	660
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: None.

Import Sources (2011–14): Mexico, 30%; Canada, 26%; France, 24%; and other, 20%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
Siliceous fossil meals, including diatomite	2512.00.0000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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DIATOMITE

Events, Trends, and Issues: The amount of domestically produced diatomite sold or used by producers in 2015 increased by 3% compared with that of 2014. Apparent domestic consumption increased by 4% in 2015 to an alltime estimated high of 853,000 tons; exports decreased by 9%. Filtration (including the purification of beer, liquors, and wine and the cleansing of greases and oils) continued to be the largest end use for diatomite, also known as diatomaceous earth. Domestically, diatomite used in the production of cement was the next largest use. 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.

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

	Mine production		Reserves[3]
	2014	2015[e]	
United States[1]	901	925	250,000
Argentina	100	55	NA
China	420	420	110,000
Czech Republic	49	50	NA
Denmark[4] (processed)	95	95	NA
France	75	75	NA
Japan	90	100	NA
Mexico	88	80	NA
Peru	125	125	NA
Russia	70	70	NA
Spain	36	36	NA
Turkey	85	90	44,000
Other countries	122	170	NA
World total (rounded)	2,260	2,290	Large

World Resources: 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 continuing 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 and used by producers.
[2]Defined as imports – exports + adjustments for industry stock changes.
[3]See Appendix C for resource/reserve definitions and information concerning data sources.
[4]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 2015 had an estimated value of $32 million. The three leading producers mined and processed about 80% of production, with four other companies supplying the remainder. Producing States were North Carolina, Idaho, California, Virginia, Oklahoma, and South Dakota, in descending order of estimated tonnage. Feldspar processors reported coproduct recovery of mica and silica sand. The only nepheline syenite produced in the United States was used in construction applications and is not included in production.

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 2015 end-use distribution of domestic feldspar and nepheline syenite was glass, 60%, and ceramic tile, pottery, and other uses, 40%.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production, marketable[1]	580	560	550	530	510
Imports for consumption:					
Feldspar	2	2	4	8	90
Nepheline syenite	394	386	491	503	460
Exports, feldspar	17	13	18	16	18
Consumption, apparent:[1]					
Feldspar only	570	550	540	520	580
Feldspar and nepheline syenite	960	930	1,000	1,000	1,000
Price, average value, feldspar, marketable production, dollars per ton	78	66	73	66	63
Employment, mine, preparation plant, and office, number[e]	400	380	380	370	360
Net import reliance[2] as a percentage of apparent consumption:					
Feldspar	E	E	E	E	12
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 (2011–14): Feldspar: Turkey, 57%; Mexico, 27%; Germany, 7%; India, 5%; and other, 4%. Nepheline syenite: Canada, 99%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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 2015, domestic production and sales of feldspar decreased slightly from those of 2014. In Europe, consumption declined, mostly owing to continued sluggishness in the region’s construction industry; moderate to strong growth in consumption continued in Asia.

Glass, including beverage containers, plate glass, and fiberglass insulation for housing and building construction, continued to be the leading end use of feldspar in the United States. Most feldspar consumed by the glass industry is for the manufacture of container glass. The glass container industry was moderately stable, although the trend in recent years to import less-expensive containers from China continued to present a challenge to the industry. Additionally, the use of cullet, especially from ongoing growth in post-consumer recycling programs, continued to compete as a substitute for primary raw materials such as feldspar, and decreased the demand for them in the manufacture of glass containers.

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FELDSPAR AND NEPHELINE SYENITE

Domestically, residential construction, in which feldspar is a raw material used in the production of glass and ceramic tiles, insulation, and plate glass, increased in 2015. Housing starts and completions rose by about 12% and 10%, respectively, during the first 9 months of 2015 compared with those in the same period in 2014, and increases were expected to continue in 2016. Domestic spending on nonresidential construction, which accounted for about 63% of construction expenditures, and on residential construction increased by about 10% and 12%, respectively, during the first 9 months of 2015 compared with that in the same period in 2014, and was expected to continue to increase in 2016. Consumption of flat glass for residential and commercial construction and window replacement in existing buildings, and fiberglass for thermal insulation continued to increase in 2015 and was expected to continue to increase in line with housing and commercial building construction in the United States through 2016.

Domestic feldspar consumption has been gradually shifting toward glass markets from that of ceramics. A growing segment in the glass industry was solar glass, used in the production of solar panels.

Imports of nepheline syenite, which may be substituted for feldspar in some glass and more commonly in ceramics manufacture applications, decreased by about 8.5% in 2015; virtually all nepheline syenite imports came from Canada.

A company based in Canada proceeded with development of its White Mountain high-purity calcium feldspar (anorthosite) deposit in southwestern Greenland. Results from laboratory testing confirmed alumina recovery to be greater than 90% for possible use in nonmetallurgical applications that require higher purity feldspar, including refractories and ceramics.

World Mine Production and Reserves:[3] Reserves for Egypt and Iran were revised based on new Government information.

	Mine production		Reserves[4]
	2014	2015[e]	
United States[1]	530	510	NA
Argentina	220	220	NA
Brazil	300	330	320,000
China	2,500	2,500	NA
Czech Republic	420	430	25,000
Egypt	200	300	1,000,000
Germany	200	200	NA
India	1,410	1,500	45,000
Iran	550	600	630,000
Italy	4,700	4,700	NA
Korea, Republic of	340	340	NA
Malaysia	320	320	NA
Poland	400	400	14,000
Spain	600	600	NA
Thailand	1,100	1,500	NA
Turkey	4,600	5,000	240,000
Other countries	1,640	1,700	NA
World total (rounded)	20,000	21,200	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 also 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. Defined as production + imports – exports.
[2]Defined as imports – exports.
[3]Feldspar only.
[4]See Appendix C for resource/reserve definitions and information concerning data sources.

FLUORSPAR

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2015, 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, and uranium processing, but no data were collected from any of these operations.

U.S. fluorspar consumption was supplied by imports and small amounts of byproduct synthetic fluorspar. Domestically, production of hydrofluoric acid (HF) in Louisiana and Texas was by far the leading use for acid-grade fluorspar. HF 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.

An estimated 70,000 tons of fluorosilicic acid (equivalent to about 114,000 tons of fluorspar grading 100%) was recovered from five phosphoric acid plants processing phosphate rock. Fluorosilicic acid was used primarily in water fluoridation.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Finished, all grades	NA	NA	NA	NA	NA
Fluorspar equivalent from phosphate rock	114	120	121	114	114
Imports for consumption:					
Acid grade	560	464	512	291	330
Metallurgical grade	167	156	130	123	60
Total fluorspar imports	727	620	643	414	390
Hydrofluoric acid	132	133	119	125	131
Aluminum fluoride	41	50	43	38	38
Cryolite	10	8	19	16	20
Exports	24	24	16	13	15
Consumption:					
Reported	456	416	441	W	W
Apparent[1]	672	525	548	518	440
Price,[2] acid grade, yearend, dollars per ton:					
Filtercake	400–450	400–450	350	290–330	290–330
Arsenic <5 parts per million	540–550	540–550	540–550	370–420	370–420
Stocks, yearend, consumer and dealer[3]	162	234	313	196	130
Employment, mine, number[e]	11	5	6	6	5
Net import reliance[4] as a percentage of apparent consumption	100	100	100	100	100

Recycling: A few thousand tons per year of synthetic fluorspar are recovered—primarily from uranium enrichment, but also from petroleum alkylation and stainless steel pickling. Primary aluminum producers recycle HF and fluorides from smelting operations. HF is recycled in the petroleum alkylation process.

Import Sources (2011–14): Mexico, 76%; China, 11%; South Africa, 8%; Mongolia, 3%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
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.

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FLUORSPAR

Events, Trends, and Issues: The weak fluorspar market that began in 2011 and was attributed to oversupply in fluorspar and excess downstream fluorochemical production saw little improvement in 2015. Prices, particularly for acid-grade fluorspar from China, remained low. Prolonged adverse market conditions have affected numerous mining projects. In the past several years, mines in India, Namibia, Russia, and South Africa have been put on care-and-maintenance status or permanently closed. Exploration and development projects have been abandoned or experienced significant delays. However, one new mine, a polymetallic project in Vietnam that began producing fluorspar in 2014, continued to ramp up production in 2015.

Another factor creating uncertainty in the fluorspar market is increased regulation of fluorinated gases, such as refrigerants, aerosols, and foam-blowing agents, particularly in Europe and North America. Earlier generations of these substances, which include chlorofluorocarbons and hydrochlorofluorocarbons, had been targeted for either reduction in use or complete phaseout under the Montreal Protocol on Substances that Deplete the Ozone Layer because of their ozone-depleting potential. In 2014 and 2015, however, the European Union and the United States introduced new measures to decrease reliance on many hydrofluorocarbons (HFCs) as well. Although HFCs do not deplete the ozone, environmental concerns are now focused on their global-warming potential.

World Mine Production and Reserves: Production estimates for individual countries were made using country or company-specific data whenever available; other estimates were made based on general knowledge of end-use markets.

	Mine production		Reserves[5, 6]
	2014	2015[e]	
United States	NA	NA	4,000
China	3,800	3,800	24,000
Germany	60	60	NA
Iran	90	90	3,400
Kazakhstan	110	110	NA
Kenya	70	63	5,000
Mexico	1,110	1,100	32,000
Mongolia	375	375	22,000
Morocco	75	75	580
Namibia	65	—	NA
South Africa	285	200	41,000
Spain	98	95	6,000
United Kingdom	77	70	NA
Other countries	177	210	110,000
World total (rounded)	6,390	6,250	250,000

World Resources: Identified world fluorspar resources were approximately 500 million tons of contained fluorspar. Additionally, enormous quantities of fluorine are present in phosphate rock. Current U.S. reserves of phosphate rock are estimated to be 1.1 billion tons, containing about 79 million tons of 100% fluorspar equivalent. World reserves of phosphate rock are estimated to be 69 billion tons, equivalent to about 4.8 billion tons of 100% fluorspar equivalent.

Substitutes: Fluorosilicic acid has been used as a substitute in aluminum fluoride production and also has the potential to be used as a substitute in HF production. However, these practices have not been adopted in the United States. 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. — Zero.
[1]Excludes fluorspar production, withheld for proprietary reasons, and fluorspar equivalent of fluorosilicic acid, HF, and cryolite.
[2]Free on board, Tampico, Mexico. Source: Industrial Minerals.
[3]Industry stocks for leading consumers and fluorspar distributors.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]See Appendix C for resource/reserve definitions and information concerning data sources.
[6]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 were valued at about $9 million. Gallium arsenide (GaAs) and gallium nitride (GaN) wafers used in integrated circuits (ICs) and optoelectronic devices accounted for approximately 75% of domestic gallium consumption. Production of trimethyl gallium and triethyl gallium, metalorganic sources of gallium used in the epitaxial layering process for the production of light-emitting diodes (LEDs), accounted for most of the remainder. About 57% of the gallium consumed was used in ICs. Optoelectronic devices, which include laser diodes, LEDs, photodetectors, and solar cells, accounted for nearly all of the remaining gallium consumption. 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:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, primary	—	—	—	—	—
Imports for consumption	85,700	58,200	35,400	53,900	32,000
Exports	NA	NA	NA	NA	NA
Consumption, reported	35,300	34,400	37,800	35,800	36,000
Price, yearend, dollars per kilogram[1]	688	529	502	363	295
Stocks, consumer, yearend	6,850	6,220	5,470	3,980	3,000
Net import reliance[2] 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 (2011–14): Germany, 35%; China, 26%; United Kingdom, 22%; Ukraine, 9%; and other, 8%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
Gallium arsenide wafers, undoped	2853.00.0010	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: Imports of gallium metal and GaAs wafers continued to account for all U.S. consumption of gallium. Gallium prices decreased throughout 2015, continuing the more than 3-year decline, as significant increases in China's low-grade (99.99%-pure) primary gallium production continued to exceed increases in worldwide consumption. In January, the price for low-grade gallium in Asia averaged $195 per kilogram. By October, the price had decreased to $140 per kilogram. China's low-grade primary gallium production capacity has expanded tremendously to approximately 600 metric tons per year in 2015 from 140 metric tons per year in 2010 on the expectations of increases in LED-based backlighting and general lighting demand. China accounted for 83% of worldwide low-grade gallium capacity.

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GALLIUM

Owing to their large power-handling capabilities, high-switching frequencies, and higher-voltage capabilities, GaN-based products, which historically have been used in defense and military applications, have begun to gain acceptance in cable television transmission, commercial wireless infrastructure, power electronics, and satellite markets. In 2015, the GaN radio frequency device market was valued at about $250 million, a 22% increase from that of 2014, and was forecast to increase at an average annual rate of 22% to reach $560 million in 2019.

Global demand for GaAs- and GaN-based products increased in 2015. GaAs device consumption increased by about 6% to $7 billion owing to a growing wireless infrastructure in Asia; growth of feature-rich, application-intensive, third- and fourth-generation “smartphones,” which employ up to 10 times the amount of GaAs as standard cellular handsets; and robust use in military radar and communications applications. In 2015, approximately 1.5 billion smartphones were sold worldwide, a 16% increase from that of 2014. Smartphones were estimated to account for 75% of all worldwide cellular telephone sales.

During the last several years, significant expansion of LED manufacturing capacity in Asia took place, much of it owing to China’s Government-instituted incentives to increase LED production, and LED production costs and prices have declined. Owing to overproduction, only 22% of the LED chips produced in 2015 were consumed. General lighting became the largest sector among LED applications, surpassing television backlighting in 2014, and was expected to be the major driver of the LED market for the rest of the decade. The LED market, valued at $15.6 billion in 2014, was forecast to increase at an average annual rate of 7% to reach $22 billion in 2019.

World Production and Reserves:[3] In 2015, world low-grade primary gallium production was estimated to be 435 metric tons—about the same as production in 2014. Some low-grade primary gallium producers most likely restricted output owing to a large surplus of primary gallium. China, Germany, Japan, and Ukraine were the leading producers; countries with lesser output were Hungary, the Republic of Korea, and Russia. Kazakhstan, which had been a leading producer in 2012, did not produce any low-grade primary gallium in 2013, and most likely did not produce any in 2014 and 2015. Refined high-purity gallium production (from low-grade primary sources only, not recycled) in 2015 was estimated to be about 160 metric tons. China, Japan, the United Kingdom, the United States, and possibly Slovakia were the principal producers of high-purity refined gallium. Gallium was recycled from new scrap in Canada, Germany, Japan, the United Kingdom, and the United States. World low-grade primary gallium production capacity in 2015 was estimated to be 730 metric tons per year; high-purity refinery capacity, 230 metric tons per year; and secondary capacity, 200 metric tons per year.

Gallium occurs in very small concentrations in ores of other metals. Most gallium is produced as a byproduct of treating bauxite, and the remainder is produced from zinc-processing residues. Only part of the gallium present in bauxite and zinc ores is recoverable, and the factors controlling the recovery are proprietary. Therefore, an estimate of reserves is not practicable.

World Resources: The average gallium content of bauxite is 50 parts per million (ppm). U.S. bauxite deposits consist mainly of subeconomic resources that are not generally suitable for alumina production owing to their high silica content. Recovery of gallium from these deposits is therefore unlikely. Some domestic zinc ores contain as much as 50 ppm gallium and could be a significant resource, although no gallium is currently recovered from domestic ore. Gallium contained in world resources of bauxite is estimated to exceed 1 million metric tons, and a considerable quantity could be contained in world zinc resources. However, only a small percentage 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 challenged 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]The United States has not produced gallium since 1987 and recovers no gallium from old scrap. All domestic consumption is assumed to originate from imported gallium.
[3]See Appendix C for resource/reserve definitions and information concerning data sources.

GARNET (INDUSTRIAL)[1]

(Data in metric tons of garnet unless otherwise noted)

Domestic Production and Use: Garnet for industrial use was mined in 2015 by four firms—one in Idaho, one in Montana, and two in New York. The estimated value of crude garnet production was about $5.79 million, and refined material sold or used had an estimated value of $9.33 million. Major end uses for garnet were: waterjet cutting, 35%; abrasive blasting media, 30%; water filtration, 20%; abrasive powders, 10%; and other end uses, 5%. 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:	2011	2012	2013	2014	2015[e]
Production (crude)	56,400	46,900	33,900	32,200	34,000
Production (refined, sold or used)	33,700	25,800	32,600	30,900	32,700
Imports for consumption[e]	154,000	222,000	197,000	213,000	266,000
Exports[e]	14,500	14,600	14,400	15,500	15,200
Consumption, apparent[e, 2]	196,000	254,000	216,000	230,000	285,000
Employment, mine and mill, number[e]	160	160	160	150	150
Net import reliance[3] as a percentage of apparent consumption	71	82	84	86	88

Recycling: Small quantities of garnet reportedly are recycled.

Import Sources (2011–14):[e] Australia, 46%; India, 38%; China, 8%; and other, 8%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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.
Natural abrasives on woven textile	6805.10.0000	Free.
Natural abrasives on paper or paperboard	6805.20.0000	Free.
Natural abrasives sheets, strips, disks, belts, sleeves, or similar form	6805.30.1000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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GARNET (INDUSTRIAL)

Events, Trends, and Issues: During 2015, estimated domestic U.S. production of crude garnet concentrates increased by 6% compared with production of 2014. U.S. garnet production was 2% of total global garnet production. U.S. garnet consumption increased by 24% compared with that of 2014. The United States consumed about 17% of global garnet production. In 2015, imports were estimated to have increased by 25% compared with those of 2014, and exports were estimated to have decreased slightly from those of 2014. The 2015 estimated domestic sales or use of refined garnet increased by 6% compared with sales in 2014. In 2015, the United States remained a net importer. Garnet imports have supplemented U.S. production in the domestic market; Australia, Canada, China, and India were major garnet suppliers.

Garnet prices during 2015 varied over a wide range per metric ton, depending on the amount of processing and refining, degree of fracturing, garnet mineral type, quality, and quantity purchased. Most crude garnet concentrate is priced from $75 to $210 per ton, and most refined material is $200 to $335 per ton. The average value of garnet imports was $213 per ton, which was a slight increase compared to the average value in 2014.

The garnet market is very competitive. To increase profitability and remain competitive with foreign 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: The reserves data for India were revised based on information reported by the Government of India.

	Mine production		Reserves[4]
	2014	2015[e]	
United States	32,200	34,000	5,000,000
Australia	260,000	260,000	Moderate to Large
China	520,000	520,000	Moderate to Large
India	800,000	800,000	19,000,000
Other countries	50,000	50,000	6,500,000
World total (rounded)	1,660,000	1,660,000	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, and India, 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, the Czech Republic, Pakistan, South Africa, 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.
[1]Excludes gem and synthetic garnet.
[2]Defined as crude production – exports + imports.
[3]Defined as imports – exports.
[4]See Appendix C for resource/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 2015 increased slightly compared with that of 2014. Domestic gemstone production included agate, beryl, coral, garnet, jade, jasper, opal, pearl, quartz, sapphire, shell, topaz, tourmaline, turquoise, and many other gem materials. In decreasing order of production value, Arizona, California, Oregon, Utah, Montana, Tennessee, Colorado, Arkansas, Idaho, Maine, and North Carolina produced 90% of U.S. natural gemstones. Laboratory-created gemstones were manufactured by five firms in North Carolina, Florida, New York, 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:	2011	2012	2013	2014	2015[e]
Production:[2]					
Natural[3]	11.0	11.3	9.6	9.5	9.6
Laboratory-created (synthetic)	31.9	31.2	56.9	51.0	52.4
Imports for consumption	23,500	21,500	24,700	26,400	25,700
Exports, including reexports[4]	18,200	16,900	19,400	21,300	19,000
Consumption, apparent	5,360	4,570	5,400	5,120	6,770
Price	Variable, depending on size, type, and quality				
Employment, mine, number[e]	1,100	1,100	1,100	1,100	1,100
Net import reliance[5] as a percentage of apparent consumption	99	99	99	99	99

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

Import Sources (2011–14 by value): Israel, 38%; India, 27%; Belgium, 19%; South Africa, 4%; and other, 12%. Diamond imports accounted for 93% of the total value of gem imports.

Tariff:

Item	Number	Normal Trade Relations 12–31–15
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, natural, graded, temporarily strung	7101.10.3000	Free.
Pearls, natural, not elsewhere specified or included	7101.10.6000	Free.
Pearls, cultured	7101.21.0000	Free.
Diamond, unworked or sawn	7102.31.0000	Free.
Diamond, ½ carat or less	7102.39.0010	Free.
Diamond, cut, more than ½ carat	7102.39.0050	Free.
Jadeite, unworked	7103.10.2020	Free.
Other gemstones, unworked	7103.10.2080	Free.
Rubies, cut	7103.91.0010	Free.
Sapphires, cut	7103.91.0020	Free.
Emeralds, cut	7103.91.0030	Free.
Jadeite, cut but not set	7103.99.1020	Free.
Other gemstones, cut but not set	7103.99.1080	Free.
Jadeite, otherwise worked	7103.99.5020	10.5% ad val.
Other gemstones, otherwise worked	7103.99.5080	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.

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GEMSTONES

Events, Trends, and Issues: In 2015, the U.S. market for gem-quality diamonds was estimated to be about $23.8 billion compared with $24.6 billion in 2014. This accounted for more than 35% of world demand. The domestic market for natural, nondiamond gemstones was estimated to be about $1.89 billion compared with $1.78 billion in 2014. The United States is expected to continue to dominate global gemstone consumption.

World Gem Diamond Mine Production and Reserves:

	Mine production[6]		Reserves[7]
	2014	2015[e]	
Angola	7,100	7,100	World reserves of diamond-bearing deposits are substantial. No reserve data are available for other gemstones.
Australia	186	190	
Botswana	17,300	17,300	
Brazil	57	60	
Canada	12,000	12,000	
Congo (Brazzaville)	53	55	
Congo (Kinshasa)	3,130	3,150	
Ghana	242	240	
Guinea	131	130	
Guyana	100	100	
Lesotho	346	350	
Namibia	1,920	1,920	
Russia	21,500	21,500	
Sierra Leone	496	500	
South Africa	5,950	6,000	
Tanzania	190	200	
Zimbabwe	477	500	
Other countries	44	45	
World total (rounded)	71,200	71,300	

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: Plastics, glass, 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 garnet. See Diamond (Industrial) and Garnet (Industrial).
[2]Estimated minimum production.
[3]Includes production of freshwater shell.
[4]Reexports account for between 67% and 90% of the totals.
[5]Defined as imports – exports and reexports.
[6]Data in thousands of carats of gem diamond.
[7]See Appendix C for resource/reserve definitions and information concerning data sources.

GERMANIUM

(Data in kilograms of germanium content unless otherwise noted)

Domestic Production and Use: Germanium production in the United States comes from either the processing of imported germanium compounds or the recycling of domestic industry-generated scrap. Germanium for domestic consumption also was obtained from imported germanium chemicals that were directly consumed or consumed in the production of other germanium compounds. Germanium was recovered from zinc concentrates produced at mines in Alaska and Washington and exported to Canada for processing. A zinc smelter in Clarksville, TN, produced and exported germanium leach concentrates recovered from processing zinc concentrates from its mines in Tennessee. A germanium processor in Utica, NY, produced germanium tetrachloride for optical-fiber production. A refinery in Quapaw, OK, processed scrap and imported chemicals into refined germanium and compounds for the production of fiber optics, infrared optical devices, and substrates for electronic devices. The domestic end-use distribution was estimated to be: fiber optics, 40%; infrared optics, 30%; electronics and solar applications, 20%; and other uses, 10%. Germanium was not used in polymerization catalysts in the United States. The worldwide end-use pattern for germanium was estimated to be: fiber optics, 30%; infrared optics, 20%; polymerization catalysts, 20%; electronics and solar applications, 15%; and other uses (such as phosphors, metallurgy, and chemotherapy), 15%. In 2015, estimated domestic consumption of germanium declined from that in 2014 by about 6%. Consumption for fiber optics and substrates for space-based applications increased from that in 2014, but use in infrared optics declined. Germanium-containing infrared optics are primarily for military use, and defense-related spending has declined during the past few years. Growth in the commercial and personal markets for thermal-imaging devices that use lenses containing germanium partially offset the decline in defense consumption. The estimated value of germanium metal consumed in 2015, based on the annual average producer price, was about $56 million, 16% less than that in 2014.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, refinery[e]	3,000	W	W	W	W
Total imports[1]	38,500	48,500	45,700	36,200	37,000
Total exports[1]	5,900	15,300	12,500	12,000	12,000
Shipments from Government stockpile excesses	—	—	—	—	—
Consumption, estimated	36,000	38,000	38,000	32,000	30,000
Price, producer, yearend, dollars per kilogram:					
Zone refined	1,450	1,640	1,900	1,900	1,760
Dioxide, electronic grade	1,250	1,360	1,230	1,300	1,170
Stocks, producer, yearend	NA	NA	NA	NA	NA
Net import reliance[2] as a percentage of estimated consumption	90	85	85	85	85

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 window blanks in decommissioned tanks and other military vehicles.

Import Sources (2011–14):[3] China, 63%; Belgium, 20%; Russia, 9%; Canada, 4%; and other, 4%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
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: The Defense Logistics Agency (DLA) Strategic Materials did not allocate any germanium for sale in the fiscal year 2016 Annual Materials Plan, and it was possible that the DLA could acquire up to 1,600 kilograms of germanium metal. As of October 2015, there were 101,899 germanium epitaxial wafers (upgraded from germanium metal from the stockpile in 2014) held for the stockpile at private warehouses.

Stockpile Status—9–30–15[4]

Material	**Inventory**	**Disposal Plan FY 2016**	**Disposals FY 2016**
Germanium	13,364	—	—

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GERMANIUM

Events, Trends, and Issues: Germanium dioxide prices were relatively stable during the first half of 2015, remaining close to 2014 levels, and were nearly double those in 2010. Prices began to decline in the second half of the year and reached $1,170 per kilogram in October. The decline was partially attributed to China's elimination of a 5% export tax on germanium dioxide in May in an effort to help domestic producers lower prices and become more competitive in the international market. The germanium metal price began the year at about $1,900 per kilogram, remained there until June, and then steadily declined to $1,760 per kilogram by early October. The price declines were partially attributed to the cessation of a buildup of germanium in Fanya Metal Exchange warehouses and to the end of purchases by the State Reserve Bureau in China. Stockpiling activities contributed to global price increases from 2012 through 2014 by limiting the amount of germanium that was available to consumers.

In 2015, China remained the leading global producer of germanium. The four leading suppliers produced an estimated 90 metric tons in 2015. China consumed about 26 tons of germanium in 2015, a slight increase from that in 2014. A significant quantity of germanium stocks were held in China: the State Reserve Bureau held 30 tons, the Fanya Metal Exchange warehouses reportedly held more than 91 tons at the end of September, and producers held an estimated 20 to 40 tons. Germanium producers in China continued to integrate downstream operations in order to sell more value-added products, and exports of germanium metal have steadily declined since 2012. Germanium use in fiber optics increased substantially in China from 2012 to 2015 and was its leading germanium consumption growth area. In May, China's Ministry of Commerce issued a preliminary antidumping ruling against imports of fiber-optic preforms (rods used to make fibers) from Japan and the United States. It was thought that antidumping measures would reduce imports and increase domestic production.

The operator of a leading zinc smelter in Australia was upgrading capacity and adding a facility that would be able to separate base metals from minor metals and produce indium and germanium.

In early 2015, scientists from a major university in the United States and a partner company developed a multijunction solar cell that used germanium quantum dots on a standard silicon wafer and was capable of capturing energy across a wider light spectrum than competing solar-cell technology, making it a potentially more efficient option for solar-cell installations.

World Refinery Production and Reserves:

	Refinery production[e] 2014	Refinery production[e] 2015	Reserves[5]
United States	W	W	Data on the recoverable content of zinc ores are not available.
China	120,000	120,000	
Russia	5,000	5,000	
Other countries[6]	40,000	40,000	
World total	[7]165,000	[7]165,000	

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 and Tennessee. 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. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]In addition to the gross weight of wrought and unwrought germanium and waste and scrap that comprise these figures, this series includes estimated germanium content of germanium dioxide.
[2]Defined as imports – exports + adjustments for Government stock changes; rounded to the nearest 5%.
[3]Import sources are based on the gross weight of wrought and unwrought germanium.
[4]See Appendix B for definitions.
[5]See Appendix C for resource/reserve definitions and information concerning data sources.
[6]Includes Belgium, Canada, Germany, and others.
[7]Excludes U.S. production.

GOLD

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

Domestic Production and Use: In 2015, domestic gold mine production was estimated to be about 200 tons, 5% less than that in 2014, and the value was estimated to be about $7.6 billion. Gold was produced at fewer than 45 lode mines, at several large placer mines in Alaska, and numerous smaller placer mines (mostly in Alaska and in the Western States). About 7% of domestic gold was recovered as a byproduct of processing domestic base-metal ores, chiefly copper. The top 29 operations yielded more than 99% of the mined gold produced in the United States. Commercial-grade gold was produced at about 25 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 were jewelry; 43%; electrical and electronics, 37%; official coins, 15%; and other, 5%.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production:					
Mine	234	235	230	210	200
Refinery:					
Primary	220	222	223	203	200
Secondary (new and old scrap)	263	215	210	161	140
Imports for consumption[2]	550	326	315	308	265
Exports[2]	664	695	691	500	500
Consumption, reported	168	147	160	150	150
Stocks, yearend, Treasury[3]	8,140	8,140	8,140	8,140	8,140
Price, dollars per troy ounce[4]	1,572	1,673	1,415	1,269	1,170
Employment, mine and mill, number[5]	11,100	12,700	13,000	11,800	11,000
Net import reliance[6] as a percentage of apparent consumption	([7])	([7])	([7])	([7])	([7])

Recycling: In 2015, 140 tons of new and old scrap was recycled, slightly less than the reported consumption. Following the decline in price, the domestic and global supply of gold from recycling continued to decline from the high level in 2011.

Import Sources (2011–14):[2] Mexico, 41%; Canada, 19%; Colombia, 13%; Peru, 8%; and other, 19%.

Tariff: Most imports of unwrought gold, including bullion and doré, enter the United States duty 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 2015 was 8% less than the price in 2014 and was down by 30% from the record-high annual price in 2012. The Engelhard daily price of gold in 2015 fluctuated through several cycles. The gold price began the year at $1,174.24 per troy ounce and increased to $1,304.66 per troy ounce on January 22, the highest level of the year. The price trended downward to $1,084.49 per troy ounce on July 24, the lowest daily price since February 5, 2010, and ended October at $1,146.59 per troy ounce. Many attributed the decrease of the average gold price to the uncertainty over the timing of anticipated interest rate increases by the U.S. Federal Reserve System.

The decrease in domestic mine production was attributed to lower ore grades at the two leading gold mines, Cortez and Goldstrike, and closure of some smaller scale mines in Nevada as a result of lower gold prices. Gold production from the Bingham Canyon Mine in Utah declined owing to lower mill throughput during continued cleanup of the east pit wall landslide that took place in 2013.

In 2015, worldwide gold production was slightly more than that in 2014, principally owing to increased production in China and Australia, the leading and second-ranked gold-producing countries, respectively.

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GOLD

In 2015, domestic consumption of gold used in the production of coins, bars, and jewelry increased because of greater demand owing to the lower price of gold and improved economic environment. The global consumption of gold, however, decreased with China's stock market decline in the first half of 2015, which reportedly discouraged investment in gold bars, coins, and jewelry. Gold stored by physical exchange-traded funds also decreased during the last 3 years, although central banks, taking advantage of lower prices, increased their purchase of gold bullion.

Artisanal and small-scale gold mining has been identified as a potential source of funding for armed groups engaged in civil unrest in Congo (Kinshasa) and surrounding countries. The United States, through the enactment of Section 1502 of the Dodd-Frank Wall Street Reform and Consumer Protection Act (Dodd-Frank Act) in 2010, made it a statutory obligation for all companies registered with the U.S. Securities and Exchange Commission (SEC) to perform due diligence to determine whether the products they manufacture, or the components of the products they manufacture, contain tantalum, tin, tungsten, and (or) gold (3TG) minerals and, if so, to determine whether these minerals were sourced from Congo (Kinshasa)and (or) its bordering countries. Under rules issued by the SEC, publicly traded companies were required to report the sources of 3TG materials used by May 2014. The Federal courts issued a decision that the SEC must have the final resource extraction rule ready for congressional decision by June 27, 2016.

World Mine Production and Reserves: Reserves for Australia, Chile, Ghana, Peru, and Russia were revised based on information from the respective country Governments or corporate reports.

	Mine production		Reserves[8]
	2014	2015[e]	
United States	210	200	3,000
Australia	274	300	9,100
Brazil	80	80	2,400
Canada	152	150	2,000
China	450	490	1,900
Ghana	91	85	1,200
Indonesia	69	75	3,000
Mexico	118	120	1,400
Papua New Guinea	53	50	1,200
Peru	140	150	2,800
Russia	247	242	8,000
South Africa	152	140	6,000
Uzbekistan	100	103	1,700
Other countries	858	855	13,000
World total (rounded)	2,990	3,000	56,000

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.
[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.
[2]Refined bullion, doré, 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 2014, the price was estimated by the U.S. Geological Survey based on monthly data from January through October.
[5]Data from Mine Safety and Health Administration.
[6]Defined as imports – exports + adjustments for Government and industry stock changes.
[7]In recent years, the United States has been a net exporter; however, large unreported investor stock changes preclude calculation of a meaningful net import reliance.
[8]See Appendix C for resource/reserve definitions and information concerning data sources.
[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 thousand metric tons unless otherwise noted)

Domestic Production and Use: Although natural graphite was not produced in the United States in 2015, approximately 90 U.S. firms, primarily in the Northeastern and Great Lakes regions, consumed 54,400 tons valued at \$50.7 million. The major uses of natural graphite in 2015 were brake linings, foundry operations, lubricants, refractory applications, and steelmaking. During 2015, U.S. natural graphite imports were 65,900 tons, which were 65% flake and high-purity, 34% amorphous graphite, and 1% lump and chip.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, mine	—	—	—	—	—
Imports for consumption	72	57	61	64	66
Exports	6	6	9	12	12
Consumption, apparent[1]	65	50	52	53	54
Price, imports (average dollars per ton at foreign ports):					
Flake	1,180	1,370	1,330	1,270	1,240
Lump and chip (Sri Lankan)	1,820	1,960	1,720	1,870	1,890
Amorphous	301	339	375	360	370
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 were the leading sources of recycled graphite products. The market for recycled refractory graphite material is growing, with material being reused in products such as brake linings and thermal insulation.

Recovering high-quality flake graphite from steelmaking kish, a mixture of graphite, desulfurization slag, and iron, is technically feasible, but not practiced at the present time because it is not economical. 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 (2011–14): China, 38%; Mexico, 32%; Canada, 18%; Brazil, 6%; and other, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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.

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GRAPHITE (NATURAL)

Events, Trends, and Issues: Worldwide demand for graphite has increased steadily since 2012 and into 2015. This increase resulted from the improvement of global economic conditions and its impact on industries that use graphite. Principal import sources of natural graphite were, in descending order of tonnage, China, Mexico, Canada, Brazil, and Madagascar, which combined, accounted for 97% of the tonnage and 91% of the value of total imports. Mexico provided all of the amorphous graphite, and Sri Lanka provided all of the lump and chippy dust variety. China, Canada, and Madagascar were, in descending order of tonnage, the major suppliers of crystalline flake and flake dust graphite.

During 2015, China produced 66% of the world's graphite and consumed 35%. North America produced 5% of the world's graphite supply, with production only in Canada and Mexico. Although no production of natural graphite was reported in the United States, two companies were exploring for and developing graphite projects in the United States. Alabama Graphite Corp. was developing the Coosa Graphite Project in Alabama, and Graphite One Resources Inc. was developing the Graphite Creek Project in Alaska.

One U.S. automaker was building a large plant to manufacture lithium-ion electric vehicle batteries. The plant's completion was expected by 2020, and it would require 93,000 tons of flake graphite for use as anode material. Advances in thermal technology and acid-leaching techniques that enable the production of higher purity graphite powders are likely to lead to development of new applications for graphite in high-technology fields. Such innovative refining techniques have enabled the use of improved graphite in carbon-graphite composites, electronics, foils, friction materials, and special lubricant applications. Flexible graphite product lines, such as graphoil (a thin graphite cloth), are likely to be the fastest growing market. Large-scale fuel-cell applications are being developed that could consume as much graphite as all other uses combined.

World Mine Production and Reserves: The reserves data for Brazil and Turkey were revised based on new information reported by those countries' Governments.

	Mine production		Reserves[2]
	2014	2015[e]	
United States	—	—	—
Brazil	80	80	72,000
Canada	30	30	([3])
China	780	780	55,000
India	170	170	8,000
Korea, North	30	30	([3])
Madagascar	5	5	940
Mexico	22	22	3,100
Norway	8	8	([3])
Russia	15	15	([3])
Sri Lanka	4	4	([3])
Turkey	29	32	90,000
Ukraine	5	5	([3])
Zimbabwe	7	7	([3])
Other countries	1	1	([3])
World total (rounded)	1,190	1,190	230,000

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/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 2015, domestic production of crude gypsum was estimated to be 11.5 million tons with a value of about $98 million. The leading crude gypsum-producing States were, in descending order, Oklahoma, Texas, Nevada, Kansas, Iowa, and Arkansas, which together accounted for 70% of total output. Overall, 47 companies produced or processed gypsum in the United States at 50 mines in 16 States. Approximately 90% of domestic consumption, which totaled approximately 26.8 million tons, was accounted for by manufacturers of wallboard and plaster products. Approximately 4.2 million tons of gypsum was used in cement production and in agricultural applications and small quantities of high-purity gypsum, used in a wide range of industrial processes, accounted for the remaining tonnage. At the beginning of 2015, the production capacity of operating wallboard plants in the United States was about 33 billion square feet[1] per year.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Crude	9,770	14,800	12,900	11,000	11,500
Synthetic[2]	11,800	12,100	10,800	11,000	11,500
Calcined[3]	11,900	12,800	14,600	14,700	15,000
Wallboard products sold (million square feet[1])	17,200	18,900	21,800	21,500	22,000
Imports, crude, including anhydrite	3,330	3,250	3,290	3,720	3,900
Exports, crude, not ground or calcined	316	408	142	67	60
Consumption, apparent[4]	24,600	29,700	26,800	25,700	26,800
Price:					
Average crude, f.o.b. mine, dollars per metric ton	8.20	7.70	9.00	8.90	9.00
Average calcined, f.o.b. plant, dollars per metric ton	28.70	28.70	27.60	29.80	30.00
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	12	10	11	14	14

Recycling: Some of the more than 4 million tons of gypsum scrap that was generated by wallboard manufacturing, wallboard installation, and building demolition was recycled. The 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 (2011–14): Mexico, 42%; Canada, 35%; Spain, 22%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Gypsum; anhydrite	2520.10.0000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. gypsum production increased by 5% compared with that of 2014. Apparent consumption also increased by 4% compared with that of 2014. The world's leading gypsum producer, China, produced more than 10 times the amount produced in the United States. Iran, ranked second in world production, supplied much of the gypsum needed for construction in the Middle East. Spain, the leading European producer, ranked sixth in the world and supplied crude gypsum and gypsum products to much of Western Europe. An 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.

Demand for gypsum depends principally on the strength of the construction industry, particularly in the United States where about 95% 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 increase of future FGD units and, therefore, the production of synthetic gypsum. Gypsum imports increased by 5% compared with those of 2014. Exports, although very low compared with imports and often subject to wide fluctuations, decreased by 10%.

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GYPSUM

World Mine Production and Reserves: Reserves for Brazil, India, and Iran were updated with new data from Government and industry sources.

	Mine production 2014	Mine production 2015[e]	Reserves[6]
United States	11,000	11,500	700,000
Algeria	2,130	2,200	NA
Argentina	1,440	1,400	NA
Australia	3,500	3,500	NA
Brazil	3,750	3,300	290,000
Canada	2,650	2,700	450,000
China	129,000	132,000	NA
France	2,300	3,300	NA
Germany	1,950	1,800	NA
India	3,540	3,500	39,000
Iran	15,000	22,000	1,600
Italy	4,100	4,100	NA
Japan	4,670	5,000	NA
Mexico	5,090	5,300	NA
Oman	2,790	3,500	NA
Pakistan	1,320	1,300	NA
Russia	5,100	4,500	NA
Saudi Arabia	2,400	2,400	NA
Spain	6,400	6,400	NA
Thailand	6,300	12,500	NA
Turkey	13,800	10,000	NA
United Kingdom	1,700	1,200	NA
Other countries	14,300	15,000	NA
World total (rounded)	244,000	258,000	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; 79 countries produced gypsum in 2015.

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 tonnage order). In 2015, synthetic gypsum accounted for approximately 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.
[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/reserve definitions and information concerning data sources.

HELIUM

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

Domestic Production and Use: The estimated value of Grade-A helium (99.997% or better) extracted domestically during 2015 by private industry was about $900 million. Nine plants (four in Kansas, four in Texas, and one in Wyoming) extracted helium from natural gas and produced only a crude helium product that varied from 50% to 99% helium. Two plants (one in Colorado and one in Wyoming) extracted helium from natural gas and produced a Grade-A helium product. Four plants (three in Kansas and one in Oklahoma) accepted a crude helium product from other producers and the Bureau of Land Management (BLM) pipeline and purified it to a Grade-A helium product. Estimated 2015 domestic consumption of helium is 43 million cubic meters (1.5 billion cubic feet) and was used for cryogenic applications, 32%; for pressurizing and purging, 18%; for controlled atmospheres, 18%; for welding cover gas, 13%; leak detection, 4%; breathing mixtures, 2%; and other, 13%.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Helium extracted from natural gas[2]	71	73	69	75	76
Withdrawn from storage[3]	59	60	49	27	24
Grade-A helium sales	130	133	118	102	100
Imports for consumption	—	—	2	7	10
Exports[4]	82	85	81	67	67
Consumption, apparent[4]	48	48	39	42	43
Net import reliance[5] as a percentage of apparent consumption	E	E	E	E	E

Price: In fiscal year (FY) 2015, the price for crude helium to Government users was $3.06 per cubic meter ($85.00 per thousand cubic feet) and to non-Government users was $3.75 per cubic meter ($104.00 per thousand cubic feet). The price for the Government-owned helium is mandated by the Helium Stewardship Act of 2013 (Public Law 113–46) and determined through public auctions and industry surveys. The estimated price for private industry's Grade-A helium was about $7.21 per cubic meter ($200 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 (2011–14): Qatar, 100%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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 Public Law 113–46, 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 Helium Stewardship Act of 2013 mandated that the BLM sell Federal Conservation helium stored in Bush Dome at the Cliffside Field annually at sale or auction. The amounts sold are approximately equal to the amount that the Federal helium system can produce each year. The Federal Government will dispose of all helium-related assets when the remaining Conservation helium falls below 83 million cubic meters or not later than 2021.

In FY 2015, privately owned companies purchased about 4.5 million cubic meters (162 million cubic feet) of in-kind crude helium. Privately owned companies also purchased 27 million cubic meters (1.0 billion cubic feet) of open market sales helium. During FY 2015, the BLM's Amarillo Field Office, Helium Operations, accepted about 9.8 million cubic meters (354 million cubic feet) of private helium for storage and redelivered nearly 32.1 million cubic meters (1.16 billion cubic feet). As of September 30, 2015, about 62.4 million cubic meters (2.25 billion cubic feet) of privately owned helium remained in storage at Cliffside Field.

Stockpile Status—9–30–15[6]

Material	**Uncommitted inventory**	**Authorized for disposal**	**Disposal plan FY 2015**	**Disposals FY 2015**
Helium	227.2	227.2	27.0	24.0

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HELIUM

Events, Trends, and Issues: In 2015, the BLM continued implementation of the Helium Stewardship Act of 2013 by conducting its second auction of helium from Federal helium storage at the Cliffside Field near Amarillo. The average price of helium sold to private buyers as a result of this process was $3.75 per cubic meter ($104.00 per thousand cubic feet). By the end of the decade, international helium extraction facilities are likely to become the main source of supply for world helium users. Seven international helium plants are in operation and more are planned during the next 3 to 5 years. Expansions to facilities have been completed in Algeria and Qatar. In 2015, demand for helium both domestically and worldwide increased. Additionally in 2015, a new helium recovery facility began operation in southwest Colorado. As a result, demand for helium stored in the U.S. Government's helium facilities has decreased by more than 50% during the past 2 years.

World Production and Reserves:

	Production		Reserves[8]
	2014	2015[e]	
United States (extracted from natural gas)	75	76	3,900
United States (from Cliffside Field)	26	24	([9])
Algeria	16	16	1,800
Australia	5	5	NA
Canada	NA	NA	NA
China	NA	NA	NA
Poland	3	3	25
Qatar	35	40	NA
Russia	4	4	1,700
Other countries	NA	NA	NA
World total (rounded)	164	168	NA

World Resources: Section 16 of Public Law 113-40 requires the U.S. Geological Survey (USGS) to complete a national helium gas assessment along with a global helium gas assessment. Over the past 2 years, the USGS and the BLM have been coordinating efforts to complete this assessment. However, it may be several years before a project of this magnitude will be completed. 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 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 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. Cliffside Field, Hugoton (Kansas, Oklahoma, and Texas), Panhandle West, Panoma, and Riley Ridge in Wyoming 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, 2010, the BLM had analyzed about 22,000 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. — Zero.
[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.
[5]Defined as imports – exports + adjustments for Government and industry stock changes.
[6]See Appendix B for definitions.
[7]Team Leader, Resources and Evaluation Group, Bureau of Land Management, Amarillo Field Office, Helium Operations, Amarillo, TX.
[8]See Appendix C for resource/reserve definitions and information concerning data sources.
[9]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 2015. 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 124 tons in 2015. The estimated value of refined indium consumed domestically in 2015, based on the average New York dealer price, was about $67 million.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, refinery	—	—	—	—	—
Imports for consumption	146	109	97	123	145
Exports	NA	NA	NA	NA	NA
Price, annual average, dollars per kilogram:					
New York dealer[1]	685	540	570	705	540
Free market[2]	NA	NA	NA	NA	460
U.S. producer[3]	720	650	615	735	NA
99.99% c.i.f. Japan[4]	680	510	575	700	NA
Net import reliance[5] as a percentage of estimated consumption	100	100	100	100	100

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

Import Sources (2011–14): Canada, 21%; China, 16%; Belgium, 15%; Republic of Korea, 10%; and other, 38%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Unwrought indium, including powders	8112.92.3000	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The 2015 estimated average free market price of indium was $460 per kilogram. Free market prices for indium declined significantly during the year, having an average range of about $545 per kilogram to $625 per kilogram in the first quarter, $450 per kilogram to $510 per kilogram in the second quarter, and $295 per kilogram to $365 per kilogram in the third quarter. Decreasing prices were attributed to an absence of investor demand in China coincident with the Fanya Metal Exchange halting indium deliveries in or out of exchange warehouses in June and the reported freezing of funds invested in the Ri Jin Bao—Fanya's main investment product that guaranteed annual returns of more than 13%—in July. In August, Fanya entered into a debt-restructuring plan, and investors reportedly met with the China Securities Regulatory Commission (China's stock market regulator) and provincial-level authorities to protest Fanya's actions. At the time Fanya halted delivery of indium into its warehouses, exchange warehouses held 3,600 tons of indium, equivalent to about 4.5 years of primary production, and the listed price of indium on the exchange was $1,190 per kilogram, significantly more than prevailing domestic market prices.

According to market reports, indium production in China declined by 15% to 30% in the first half of 2015 compared with that during the same period of the previous year. Decreasing prices resulted in large state-owned zinc smelters reducing their indium production by at least 10%, small-scale zinc smelters suspending their indium production, and stand-alone indium producers reducing output by 30% to 40%.

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INDIUM

China returned to being a net exporter of indium in 2015, owing mostly to a lack of domestic investor demand, as well as to higher international prices compared with domestic market prices in the second half of the year and an elimination of the domestic export tariff on indium.

China's ITO production capacity has increased notably in the past few years, along with the country's expanding flat-screen display industry. Within the past year, a China-based company commissioned an ITO production plant in Henan Province, and a Belgium-based ITO producer, in a joint venture with a China-based materials company, constructed a 200-metric-ton-per-year ITO plant in Guangdong, China, which could be commissioned by the end of 2015, at the earliest.

World Refinery Production and Reserves:

	Refinery production[e]		Reserves[6]
	2014	2015	
United States	—	—	Quantitative estimates of reserves are not available.
Belgium	25	25	
Canada	65	65	
China	460	370	
France	43	38	
Germany	10	10	
Japan	72	72	
Korea, Republic of	150	150	
Peru	14	15	
Russia	5	10	
World total (rounded)	844	755	

World Resources: 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 metals are subeconomic for indium.

Substitutes: Antimony tin oxide coatings have been developed as an alternative to ITO coatings in LCDs and have been successfully annealed to LCD glass; carbon nanotube coatings have been developed as an alternative to ITO coatings in flexible displays, solar cells, and touch screens; PEDOT [poly(3,4-ethylene dioxythiophene)] has also been developed as a substitute for ITO in flexible displays and organic light-emitting diodes; and 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. Gallium arsenide can substitute for indium phosphide in solar cells and in many semiconductor applications. Hafnium can replace indium in nuclear reactor control rod alloys.

[e]Estimated. NA Not available. — Zero.
[1]Price is based on 99.99%-minimum-purity indium at warehouse (Rotterdam); cost, insurance, and freight (in minimum lots of 50 kilograms). Source: Platts Metals Week.
[2]Price is based on 99.99%-minimum-purity indium at warehouse (Rotterdam). Source: Metal Bulletin.
[3]Indium Corp.'s price for 99.97%-purity metal, free on board. Price discontinued in 2015. Source: Platts Metals Week, Metal Bulletin.
[4]Price is based on 99.99%-purity indium, primary or secondary, shipped to Japan. Price discontinued in 2015. Source: Platts Metals Week.
[5]Defined as imports – exports.
[6]See Appendix C for resource/reserve definitions and information concerning data sources.

IODINE

(Data in metric tons elemental iodine unless otherwise noted)

Domestic Production and Use: Iodine was produced from brines in 2015 by two companies operating in Oklahoma, and one company with operations in Oklahoma and Texas. Production in 2015 was estimated to have increased from that of 2014. U.S. iodine production in 2015 was withheld to avoid disclosing company proprietary data. The average cost, insurance, and freight value of iodine imports in 2015 was estimated to be $28.00 per kilogram.

Because domestic and imported iodine were used by downstream manufacturers to produce many intermediate iodine compounds, it was difficult to establish an accurate end-use pattern. Of the consumers that participated in an annual U.S. Geological Survey canvass, 13 plants reported consumption of iodine in 2014. Iodine and iodine compounds reported were ethyl and methyl iodide, 51%; potassium iodide, 15%; ethylenediamine dihydroiodide, 6%; crude iodine, 4%; hydriodic acid, 3%; resublimed iodine, sodium iodide, and miscellaneous iodate and iodines, 2% each; potassium iodate, 1%; and other inorganic compounds, 14%. Iodine and its compounds are primarily used in x-ray contrast media, pharmaceuticals, liquid-crystal-display (LCD) screens, and iodophors, in descending order.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production	W	W	W	W	W
Imports for consumption, crude content	6,620	5,960	5,960	5,360	6,300
Exports	902	1,040	1,150	1,240	1,300
Consumption:					
Reported	4,780	4,930	4,070	3,900	4,100
Apparent	W	W	W	W	W
Price, average c.i.f. value, dollars per kilogram, crude	38.35	42.28	42.77	37.04	28.00
Employment, number[e]	60	60	60	60	60
Net import reliance[1] as a percentage of reported consumption	>50	>50	>50	>50	>50

Recycling: Small amounts of iodine were recycled, but no data were reported.

Import Sources (2011–14): Chile, 88%; Japan, 11%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Iodine, crude	2801.20.0000	Free.
Iodide, potassium	2827.60.2000	2.8% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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IODINE

Events, Trends, and Issues: The 2015 iodine price continued to decline from the historically high levels of 2012 and early 2013. Iodine prices steadily declined throughout 2015. Spot prices of iodine crystal averaged about $33 per kilogram at the beginning of 2015 and decreased to an average of about $30 per kilogram in August 2015, according to trade publications. Although global demand for iodine and its derivative compounds was steady in 2015, prices continued to decline owing to a surplus of iodine in the market. Additionally, a competitive market where customers had multiple sourcing options, and a decline in industrial iodine consumption in China contributed to the continuation of low iodine prices. Major producers in the United States and Chile responded to low iodine prices by working to reduce their production costs.

As in recent years, Chile was the world's leading producer of iodine, followed by Japan and the United States. Chile accounted for about 65% of world production in 2015, having two of the leading iodine producers in the world.

World Mine Production and Reserves:

	Mine production		Reserves[2]
	2014	2015[e]	
United States	W	W	250,000
Azerbaijan	221	230	170,000
Chile	20,000	20,000	1,800,000
China	NA	NA	4,000
Indonesia	50	50	100,000
Japan	9,500	9,500	5,000,000
Russia	—	—	120,000
Turkmenistan	500	500	70,000
World total (rounded)	[3]30,300	[3]30,300	7,500,000

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

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

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

IRON AND STEEL[1]

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

Domestic Production and Use: The iron and steel industry and ferrous foundries produced goods in 2015 with an estimated value of about $103 billion. Pig iron was produced by four companies operating integrated steel mills in 11 locations. About 58 companies produce raw steel at about 110 minimills. Combined production capability was about 110 million tons. Indiana accounted for 27% of total raw steel production, followed by Ohio, 13%; Michigan, 6%; and Pennsylvania, 5%, with no other States having more than 5% of total domestic raw steel production. The distribution of steel shipments was estimated to be warehouses and steel service centers, 26%; construction, 17%; transportation (predominantly automotive), 19%; cans and containers, 2%; and other, 36%.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Pig iron production[2]	30.2	30.1	30.3	29.4	26
Steel production	86.4	88.7	86.9	88.2	81
Basic oxygen furnaces, percent	39.7	40.9	39.4	37.4	37
Electric arc furnaces, percent	60.3	59.1	60.6	62.6	63
Continuously cast steel, percent	98.0	98.6	98.8	98.5	99
Shipments:					
Steel mill products	83.3	87.0	86.6	89.1	89
Steel castings[e, 3]	0.4	0.4	0.4	0.4	0.4
Iron castings[e, 3]	4.0	4.0	4.0	4.0	4.0
Imports of steel mill products	25.9	30.4	29.2	40.2	39
Exports of steel mill products	12.2	12.5	11.5	10.9	11
Apparent steel consumption[4]	90	98	100	107	110
Producer price index for steel mill products (1982=100)[5]	216.2	208.0	195.0	200.2	200
Steel mill product stocks at service centers, yearend[6]	7.6	7.8	7.6	9.0	9.0
Total employment, average, number:					
Blast furnaces and steel mills[3]	142,021	148,688	147,418	149,000[e]	149,000
Iron and steel foundries[3]	68,456	70,506	67,566	69,000[e]	69,000
Net import reliance[7] as a percentage of apparent consumption	7	11	12	26	25

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

Import Sources (2011–14): Canada, 14%; the Republic of Korea, 12%; Brazil, 11%; Russia, 11%; and other, 52%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Carbon steel:		
Semifinished	7207.00.0000	Free.
Sheets, hot-rolled	7208.10.0000	Free.
Hot-rolled, pickled	7208.10.1500	Free.
Cold-rolled	7209.00.0000	Free.
Galvanized	7210.00.0000	Free.
Bars, hot-rolled	7213.00.0000	Free.
Structural shapes	7216.00.0000	Free.
Stainless steel:		
Semifinished	7218.00.0000	Free.
Cold-rolled sheets	7219.31.0000	Free.
Bars, cold-finished	7222.20.0000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: The expansion or contraction of gross domestic product (GDP) may be considered a predictor of the health of the steelmaking and steel manufacturing industries, worldwide and domestically. The World Bank's forecast of global GDP growth for 2015, 2016, and 2017 was 2.8%, 3.3%, and 3.2%, respectively. The U.S. Federal Reserve's projections, as of November 2015, for the U.S. 2016, 2017, and 2018 GDP growth rates were 2.3%, 2.2%, and 2.0%, respectively.

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IRON AND STEEL

Globally, China's slowing GDP growth and continued high production rates of crude steel contributed to a global glut of seaborne steel supply. In 2013, China was estimated to have 35% to 40% more steelmaking capacity than it needed for domestic consumption. In 2015, Chinese surplus steel sales continued to expand into other industrialized countries with steelmaking capability, such as the United States, reducing the consumption of U.S. domestic crude steel production. Declines in the consumption of tubular goods in the U.S. domestic energy sector, especially in the development of new oil and natural gas projects, also contributed to reduced demand. Domestic manufacturing growth in the U.S., as measured by the Institute of Supply Management's Purchasing Managers Index, has expanded continually for over 2 years and the overall economy has continued to grow for over 6 consecutive years, although at its lowest rate since May 2013.

The rise in imports from 2013 to 2014 was sustained through 2015, creating a difficult competitive market for domestic iron and steel products. Imported steel adversely affected domestic production in 2015, resulting in idled or permanently closed iron and steel operations, including a blast furnace in Alabama, a coke plant in Illinois, an electric arc furnace and bar mill in Indiana, and a tubular plant in Texas. One company continued construction on a new electric arc furnace in Alabama on the site of the recently closed blast furnace. This company also planned to shift approximately 15,000 tons per month of production from its operations in Canada to steel mills in the United States.

In June, the Trade Promotion Authority and the Trade Preferences Extension Act, which included Trade Adjustment Assistance, was signed into law. Representatives of the iron and steel industry described these laws as tools to assist U.S. companies and workers that were disproportionately affected by alleged dumping of iron and steel products and unfair trade practices. In July, the U.S. Department of Commerce imposed duties, ranging from 10% to 118%, on steel imports from nine countries, including India, the Republic of Korea, Taiwan, Turkey, and Vietnam. In November, the U.S. Department of Commerce released a preliminary ruling that established duties on corrosion-resistant steel from China of up to 236% for 5 years. This ruling went into effect immediately; however, the final ruling was scheduled to be made in January 2016.

World Production:

	Pig iron		Raw steel	
	2014	**2015[e]**	**2014**	**2015[e]**
United States	29	26	88	81
Brazil	27	30	34	34
China	712	710	823	822
France	11	11	16	17
Germany	27	28	43	44
India	55	54	87	83
Japan	84	84	111	111
Korea, Republic of	47	47	71	72
Russia	51	51	71	71
Ukraine	25	25	27	27
United Kingdom	10	9	12	12
Other countries	95	101	273	258
World total (rounded)	1,170	1,180	1,650	1,640

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 Ore and Iron and Steel Scrap.
[2]More than 95% of iron made is transported in molten form to steelmaking furnaces located at the same site.
[3]U.S. Census Bureau.
[4]Defined as steel shipments + imports – exports + adjustments for industry stock changes – semifinished steel product imports.
[5]U.S. Department of Labor, Bureau of Labor Statistics.
[6]Metals Service Center Institute.
[7]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 2015, the total value of domestic purchases (receipts of ferrous scrap by all domestic consumers from brokers, dealers, and other outside sources) and exports was estimated to be $18.3 billion, approximately 30% less than that of 2014. U.S. apparent steel consumption, an indicator of economic growth, decreased to about 102 million tons in 2015. Manufacturers of pig iron, raw steel, and steel castings accounted for about 91% 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 9% 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 2015, raw steel production was about 81 million tons, down by 8% from 88 million tons in 2014; annual steel mill capability utilization was about 71% compared with 78% for 2014. Net shipments of steel mill products were about 89 million tons, about the same as those in 2014.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Home scrap	10	10	8.5	7.3	7
Purchased scrap[2]	72	70	77	62	67
Imports for consumption[3]	4.0	3.7	3.9	4.3	3.9
Exports[3]	24	21	18	15	13
Consumption, reported	63	63	59	59	49
Consumption, apparent	61	63	71	59	63
Price, average, dollars per metric ton delivered, No. 1 Heavy Melting composite price, Iron Age Average, Pittsburgh, Philadelphia, Chicago	392	360	341	352	228
Stocks, consumer, yearend	4.0	4.2	4.2	4.4	5.8
Employment, dealers, brokers, processors, number[4]	30,000	30,000	30,000	30,000	30,000
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.

In the United States, the primary source of old steel scrap was the automobile. The recycling rate for automobiles in 2013, the latest year for which statistics were available, was about 85%. In 2013, the automotive recycling industry recycled more than 14 million tons of steel from end-of-life vehicles through more than 300 car shredders, the equivalent of nearly 12 million automobiles. More than 7,000 vehicle dismantlers throughout North America resell parts.

The recycling rates for appliances and steel cans in 2013 were 82% and 70%, respectively; this was the latest year for which statistics were available. Recycling rates for construction materials in 2013 were, as in 2012, about 98% for plates and beams and 72% for rebar and other materials. The recycling rates for appliance, can, and construction steel are expected to increase not only in the United States, but also 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.

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 59% post-consumer (old, obsolete) scrap, 23% prompt scrap (produced in steel-product manufacturing plants), and 18% home scrap (recirculating scrap from current operations).

Import Sources (2011–14): Canada, 79%; Mexico, 8%; Sweden, 5%; Netherlands, 3%; and other, 5%.

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IRON AND STEEL SCRAP

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
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: The producer price index for steel mill products increased to 222 in May 2011 from 153 in May 2009 and was 202 in August 2014. In 2015, the producer price index began the year at 196 in January and steadily declined to around 170 in the fourth quarter. Steel mill production capacity utilization peaked at 80.9% in April 2012 from 40.8% in April 2009, decreased to 68% in October 2012, and then rose to 79.6% in July 2014. During 2015, production capacity utilization fluctuated from a high of 76.4% in January, falling to 67.7% in March. It rose again to 74.4% in June before slowly declining throughout the second half of the year.

Scrap prices fluctuated during the first 9 months of 2015, between about $316 and $210 per ton. 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 $241 per ton during the first 9 months of 2014. Exports of ferrous scrap decreased in 2015 to an estimated 13 million tons from 15 million tons during 2014, primarily to Turkey, Taiwan, and the Republic of Korea, in descending order of export tonnage. The value of exported scrap decreased from $6.2 billion in 2014 to an estimated $4.2 billion in 2015.

During 2015, the U.S. ferrous scrap industry was adversely affected by the ongoing decreased global consumption of ferrous products and oversupply of steelmaking raw materials and crude steel. World steel consumption was expected to increase by 0.5% to 1.54 billion tons in 2015 and by 1.4% to 1.57 billion tons in 2015.

Demand for iron and steel scrap closely mirrors the demand of crude steel products, which are primarily driven by the automotive and construction industries. An anticipated increase in demand for tubular goods throughout the oil-producing areas of the Midwest, specifically in areas around the Bakken Shale, failed to materialize during the year, lowering expectations for total steel scrap consumption. Steady increases in automotive production were expected to increase steel production, specifically higher-end ferroalloys and specialty steel. In China, a rapid increase in automotive scrap availability was expected to continue lowering global prices for scrap as supply exceeds demand. The United States likely will continue exporting valuable ferrous scrap for at least another decade, and the Republic of Korea and Turkey likely will remain large importers of scrap through 2020. The Asia-Pacific region represents the largest and fastest growing market in steel consumption and production, led by a high rate of urbanization and industrialization in developing countries and China.

World Mine Production and Reserves: Not applicable.

World Resources: Not applicable.

Substitutes: About 4.4 million tons of direct-reduced iron was used in the United States in 2015 as a substitute for iron and steel scrap, down from 4.8 million tons in 2014.

[e]Estimated. E Net exporter.
[1]See also Iron and Steel and Iron Ore.
[2]Receipts – shipments by consumers + exports – imports.
[3]Includes used rails for rerolling and other uses, and ships, boats, and other vessels for scrapping.
[4]Estimated, based on 2002 Census of Wholesale Trade for 2010 through 2014.
[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: Ferrous slags are coproducts of the making of iron and steel and, after cooling and processing, are sold primarily to the construction industry. Data are unavailable on actual U.S. slag production, but it is estimated to have been in the range of 16 to 22 million tons in 2015. Domestic slag sales[1] in 2015 amounted to an estimated 17 million tons, valued at about $330 million (ex-plant). Iron (blast furnace) slag accounted for about 47% of the tonnage sold and had a value of about $260 million; nearly 90% of this value was from sales of granulated slag. Steel slag produced from basic oxygen and electric arc furnaces accounted for 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 in 32 States; included in this tally are a number of facilities that grind and sell ground granulated blast furnace slag (GGBFS) based on imported unground feed.

The prices listed in the table below are weighted, but rounded, averages for iron and steel slags sold for a variety of applications. Actual prices per ton ranged widely in 2015, from a few cents for some steel slags at a few locations to about $110 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; 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, including from overseas.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, marketed[1, 3]	15.4	16.0	15.5	16.6	17.0
Imports for consumption[4]	1.6	1.2	1.7	1.8	1.9
Exports	([5])	([5])	([5])	0.1	0.1
Consumption, apparent[4, 6]	15.4	16.0	15.5	16.5	16.9
Price average value, dollars per ton, f.o.b. plant[7]	17.00	17.00	17.50	19.00	19.50
Employment, number[e]	2,000	1,800	1,700	1,700	1,700
Net import reliance[8] as a percentage of apparent consumption	9	7	11	10	11

Recycling: Slag, after metal removal, 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, but data on metal returns are unavailable.

Import Sources (2011–14): The dominant imported ferrous slag type is granulated blast furnace slag (mostly unground), but official import data in some years include significant tonnages of nonslag materials (such as cenospheres, fly ash, and silica fume) and slags or other residues of various metallurgical industries (such as copper slag) whose unit values are outside the range expected for granulated slag. The official data appear to have underreported the granulated slag imports in some recent years, but likely not in 2011–12. Based on official data, the principal country sources for 2011–14 were Canada, 35%; Japan, 32%; Spain, 12%; Italy, 5%, and other, 16%; however, much of the tonnage from Spain in 2013–14 may in fact be from Italy.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Granulated slag	2618.00.0000	Free.
Slag, dross, scale, from manufacture of iron and steel	2619.00.3000	Free.

Depletion Allowance: Not applicable.

Government Stockpile: None.

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IRON AND STEEL SLAG

Events, Trends, and Issues: The supply of blast furnace slag overall is becoming problematic in the United States because of the closure and (or) continued idling of a number of active U.S. blast furnaces in recent years, including one in 2015, the lack of construction of new furnaces, and the depletion of old slag piles. Likewise, only a limited quantity of locally produced granulated blast furnace slag was available. At yearend 2015, granulation cooling was available at only two active U.S. blast furnaces, down from three in 2014. Other blast furnaces were being evaluated for the installation of granulators, but it was unclear if this would be economic. Pelletized blast furnace slag was in very limited supply (one site only), and it was uncertain if any additional pelletizing capacity was being planned. Basic oxygen furnace steel slag from domestic furnaces has become less available recently because of the closure of several integrated iron and steel complexes; thus, the long-term supply of steel slag will be increasingly reliant on electric arc furnaces. Where slag availability has not been a problem, slag (as aggregate) sales to the construction sector have sometimes been less volatile than those of natural aggregates. Domestic- and import-supply constraints appear to have limited the domestic demand for GGBFS in recent years, and sales have failed to match the relative volume and price 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 the plant closures or switchover at many powerplants to lower-cost 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. This has the potential to increase future demand for GGBFS, but the availability of material to satisfy this demand will increasingly depend on imports, either of ground or unground material. Imports may be constrained because of increasing international demand for the same material and because not all granulated slag produced overseas is of high quality. New restrictions on mercury emissions by cement plants 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 it is estimated that global iron slag output in 2015 was on the order of 300 to 360 million tons, and steel slag about 170 to 250 million tons, based on typical ratios of slag to crude iron and steel output.

World Resources: Not applicable.

Substitutes: In the construction sector, ferrous slags compete with crushed stone and sand and gravel as aggregates, 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, and to a lesser degree with silica fume. In this respect, GGBFS also competes with portland cement itself. Slags (especially steel slag) can be used as a partial substitute for limestone and some other natural raw materials for clinker (cement) manufacture. Some other metallurgical slags, such as copper slag, can compete with ferrous slags in some specialty markets, but they are generally in much more restricted supply than ferrous slags.

[e]Estimated.

[1]Data are from an annual survey of slag processors and pertain to the quantities of processed slag sold rather than that processed or produced during the year. The data exclude any entrained metal that may be recovered during slag processing and returned to iron and, especially, steel furnaces, and 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 2011–15.

[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). Overall, actual production of blast furnace slag 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.

[4]Based on official (U.S. Census Bureau) data. In some years, the official data appear to have understated the true imports; the apparent discrepancy was small for 2011–12, but may have been nearly 0.4 million tons in 2013 and 2014, depending on whether imports from Italy were mischaracterized as being from Spain or not. The U.S. Geological Survey canvass captures only part of the imported slag.

[5]Less than 0.05 million tons.

[6]Although definable as total sales of slag (including those from imported feed) – exports, apparent consumption of slag does not significantly differ from total sales owing to the very small export tonnages.

[7]Rounded to the nearest $1.00 per metric ton; component data include a large proportion of estimates.

[8]Defined as total imports of slag – exports of slag.

IRON ORE[1]

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

Domestic Production and Use: In 2015, mines in Michigan and Minnesota shipped 98% of the usable iron ore products in the United States—the remaining 2% of domestic iron ore was produced for nonsteel end uses—with an estimated value of $3.8 billion. Twelve iron ore mines (nine open pits and three reclamation operations) and three iron metallic plants, including direct-reduced iron (DRI) and iron nugget producers, operated during the year to supply steelmaking raw materials. Each open pit mine site included a concentration plant and pelletizing plant. A stand-alone pelletizing plant in Indiana used iron ore fines from reclamation plants in Minnesota. The United States was estimated to have produced and consumed 2.5% of the world's iron ore output.

Salient Statistics[2]—United States:	2011	2012	2013	2014	2015[e]
Production					
Iron ore	54.7	54.0	52.0	55.9	42.5
Iron metallics	0.4	0.4	0.5	1.9	2.5
Shipments	55.6	52.9	52.7	55.9	44.9
Imports for consumption	5.3	5.2	3.2	5.1	4.2
Exports	11.1	11.2	11.0	12.1	8.1
Consumption:					
Reported (ore and total agglomerate)	46.3	48.8	51.7	48.9	37.9
Apparent[3]	49.1	48.1	45.0	45.9	39.4
Value, U.S. dollars per metric ton	99.45	98.16	96.88	92.78	84.00
Stocks, mine, dock, and consuming plant, yearend, excluding byproduct ore	3.26	3.11	2.29	5.34	4.50
Employment, mine, concentrating and pelletizing plant, number	5,270	5,420	5,644	6,273	4,850
Net import reliance[4] as a percentage of apparent consumption (iron in ore)	E	E	E	E	E

Recycling: None. (See Iron and Steel Scrap.)

Import Sources (2011–14): Canada, 56%; Brazil, 35%; Sweden, 3%; Argentina, 2%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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 decreased in 2015 owing to an approximate 30% increase in steel imports in 2014 that persisted through 2015. This increase in low-cost steel imports led to reduced demand for domestic steel, reducing iron ore consumption from domestic iron ore mines. Major declines in seaborne iron ore prices in the current and preceding years coincided with the rising rate of low-cost steel imports in the United States.

During the year, six iron ore mines in the United States had either been idled, reduced production, or closed permanently. As of November, three operations remained idled indefinitely and an open pit mine and its associated iron nugget facility were to be idled through the first half of 2017. A DRI facility in Louisiana increased its production rate early in 2015 after equipment failures in 2014. Construction resumed on a 7-million-ton-per-year iron ore operation in Minnesota; production was scheduled to begin in the second half of 2016. Construction continued on a 2-million-ton-per-year hot-briquetted iron facility in Texas; production was scheduled to begin in the first quarter of 2016. One iron ore operation was scheduled to be idled at the end of 2016. One company planned to use the current idling of an iron ore facility to reconfigure equipment to produce an alternate flux pellet to meet contract requirements.

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IRON ORE

The industry continued efforts to reduce costs and improve efficiencies, including working with labor unions to reduce labor costs. Some producers decreased operational costs because utility companies reduced electricity rates for mines in Minnesota, where the State reduced royalty payments for some mines on a temporary basis. In addition, a new trade agreement with countries in Asia and import duties implemented for 11 countries on steel products in 2015 were considered by industry leaders to be beneficial to the domestic iron ore companies. In October, one company announced that it would shift production of steel products from its subsidiary in Canada to facilities in the United States as part of a restructuring effort, increasing potential domestic iron ore consumption.

Globally, price reductions continued for seaborne iron ore in 2015 as steel production in China decreased and projects to increase iron ore production capacity continued, primarily in Australia and Brazil. Production, by gross weight, in Australia and Brazil increased by 112 million tons in 2013 and by 116 million tons in 2014, and was estimated to increase by 67 million tons in 2015. Global steel demand was forecast to decrease by 1.7% in 2015, following an increase of 0.7% in 2014.

The monthly mean price of iron ore fines at 62% iron content at Tianjin Port, cost and freight, fell from the 5-year high of $187.18 in February 2011 to $56.43 in September 2015, the most recent date for which prices were available. As a result of lower prices, an estimated 200 million tons of iron ore capacity was idled between 2014 and 2015, most notably in Australia, Brazil, Canada, China, Sweden, the United States, and western Africa. Additional capacity was expected to be brought online during the next 5 years, with the largest capacity increases among the top four miners to reach 40 million tons in 2016 and 60 million tons in 2017.

World Mine Production and Reserves:

	Mine production		Reserves[5]	
	2014	2015[e]	Crude ore	Iron content
United States	56	43	11,500	3,500
Australia	774	824	54,000	24,000
Brazil	411	428	23,000	12,000
Canada	44	39	6,300	2,300
China[6]	1,510	1,380	23,000	7,200
India	129	129	8,100	5,200
Iran	33	33	2,700	1,500
Kazakhstan	25	25	2,500	900
Russia	102	112	25,000	14,000
South Africa	81	80	1,000	650
Sweden	37	37	3,500	2,200
Ukraine	68	68	[7]6,500	[7]2,300
Other countries	153	125	18,000	9,500
World total (rounded)	*3,420	*3,320	190,000	85,000

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. At some blast furnace operations, ferrous scrap may constitute as much as 7% of the blast furnace feedstock. DRI, iron nuggets, and scrap are extensively used for steelmaking in electric arc furnaces and in iron and steel foundries, but scrap availability can be limited. Technological advancements have been made, which allow hematite to be recovered from tailings basins and pelletized.

[e]Estimated. E Net exporter.
[1]Data is for iron ore used as a raw material in steelmaking unless otherwise noted. See also Iron and Steel and Iron and Steel Scrap.
[2]Salient statistics are for all forms of iron ore used in steelmaking, except iron metallics, which include direct-reduced iron, hot-briquetted iron, and iron nuggets. Iron metallics production is listed separately and based on nondomestic iron ore consumption.
[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/reserve definitions and information concerning data sources.
[6]Production for China is reported in crude ore, rather than usable ore.
[7]For Ukraine, reserves consist of the A+B categories of the former Soviet Union's reserves classification system.

IRON OXIDE PIGMENTS

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Iron oxide pigments (IOPs) were mined by three companies in three States in the United States. Production, which was withheld by the U.S. Geological Survey to avoid disclosing company proprietary data, increased slightly in 2015 from that of 2014. Six companies, including the three producers of natural IOPs, processed and sold about 45,000 tons of finished natural and synthetic IOPs at an estimated value of $72 million, significantly below the sales peak of 88,100 tons in 2007. About 50% of natural and synthetic finished IOPs were used in concrete and other construction materials, 35% in coatings and paints, 3% each in animal food and foundry uses, 2% each in industrial chemicals and fertilizer, and 5% in other uses.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, mine	W	W	W	W	W
Production, finished natural and synthetic IOP	48,000	48,400	47,200	45,300	45,000
Imports for consumption	158,000	151,000	165,000	175,000	180,000
Exports, pigment grade	8,660	8,950	8,170	8,790	8,200
Consumption, apparent[1]	197,000	190,000	204,000	212,000	217,000
Price, average value, dollars per kilogram[2]	1.54	1.61	1.60	1.60	1.65
Employment, mine and mill	58	55	60	65	70
Net import reliance[3] as a percentage of apparent consumption	>50%	>50%	>50%	>70%	>70%

Recycling: None.

Import Sources (2011–14): Natural: Cyprus, 63%; France, 15%; Austria, 9%; and other, 13%. Synthetic: China, 50%; Germany, 25%; Canada, 8%; Brazil, 6%; and other, 11%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
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 2015, domestic production and sales of crude natural IOPs increased slightly. In Europe, consumption of IOPs declined, mostly owing to continued sluggishness in the region's construction industry. In Asia, moderate to strong growth continued and consumption of IOPs increased. 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 in the first half of 2015. Housing starts and completions rose by about 11% and 10%, respectively, compared with those of the same period in 2014.

Spending on residential construction increased by more than 12% during the first 9 months of 2015 compared with the same period in 2014. Spending on nonresidential construction, which accounted for about 63% of construction expenditures, increased by about 10% in the first 9 months of 2015 compared with the same period in 2014. Increases were expected to continue through 2016. Increased residential and nonresidential construction could lead to an increase in IOP consumption in this sector.

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IRON OXIDE PIGMENTS

Exports of pigment-grade IOPs decreased by about 7% during 2015 compared with those of 2014; about 80% went to Mexico, China, and Belgium, in descending order of quantity. Exports of other grades of iron oxides and hydroxides, about seven times that of pigment-grade, decreased by about 6% during 2015 compared with those in 2014, mostly owing to a significant decrease in exports to Spain. About 85% of exports of other grades of iron oxides and hydroxides went to China, Spain, and Canada, in descending order. Total imports of natural and synthetic IOPs increased slightly during 2015 compared with those in 2014.

A company in Utah that began production of a high-purity “advanced natural” iron oxide in 2014, mostly composed of goethite and hematite, promoted its transparent iron oxide products to the woodstain market and other natural IOP products to the paints and coatings industries. The company also marketed iron oxide products to the energy and biogas industries as a desulfurization catalyst, 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 leading Texas-based specialty chemical company neared completion of its synthetic IOP production plant in Augusta, GA—the first new IOP production plant built in the United States in about 35 years. Operations were expected to begin in early 2016.

Globally, two other leading producers of finished natural and synthetic IOPs continued construction of synthetic IOP production plants in China. The plants—one in Tongling, Anhui Province, owned by a Hong Kong-based company, and the other in Ningbo, Zhejiang Province, owned by a German chemical company—are expected to begin production 2016. Both plants will employ an advanced process that uses enhanced water and waste gas treatment. In India, one company began production of yellow IOPs at its Sahupuram, Tamil Nadu, facility, by separating out IOPs from leach liquor, a waste from ilmenite production.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2014	2015[e]	
United States	W	W	Moderate
Austria (micaceous IOP)	3,500	4,000	NA
Cyprus (umber)	4,000	4,000	Moderate
France	1,000	1,000	NA
Germany[5]	200,000	200,000	Moderate
India (ochre)	1,600,000	1,600,000	55,000,000
Pakistan (ocher)	33,000	35,000	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 cost 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 several 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 production of finished natural and synthetic IOPs + imports – exports.
[2]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/reserve definitions and information concerning data sources.
[5]Includes natural and synthetic iron oxide pigment.
[6]A significant number of other countries, including Azerbaijan, China, Honduras, Kazakhstan, Russia, Turkey, and Ukraine, are thought to produce IOPs, but output is not reported and no basis is available to formulate estimates of output levels.

KYANITE AND RELATED MINERALS

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: One firm in Virginia with integrated mining and processing operations produced kyanite from two hard-rock open pit mines and mullite by calcining kyanite. Two other companies produced synthetic mullite, one in Alabama and another in Georgia from materials mined from four sites. Each company sourced materials from one site in Alabama and one site in Georgia; these data are withheld to avoid disclosing company proprietary data. Commercially produced synthetic mullite is made by sintering or fusing such feedstock materials as kyanite 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 usage was consumed by the iron and steel industries, and the remainder was used by industries that manufacture chemicals, glass, nonferrous metals, and other materials. Andalusite was commercially mined from a pyrophyllite-andalusite deposit in North Carolina for use in a variety of refractory mineral products for the foundry and ceramics industries.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Mine	[1]98	[1]99	[e]100	[e]110	110
Synthetic mullite	W	W	W	W	W
Imports for consumption (andalusite)	5	3	4	4	8
Exports	38	36	42	40	40
Consumption, apparent	W	W	W	W	W
Price, average, dollars per metric ton:[2]					
U.S. kyanite, raw concentrate	335	340	300	270	290
U.S. kyanite, calcined	503	513	448	410	440
Andalusite, Transvaal, South Africa	300	300	348	370	380
Employment, kyanite mine, office, and plant, number[3, e]	120	125	135	150	150
Employment, mullite plant, office, and plant, number[3, e]	180	185	190	200	200
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Insignificant.

Import Sources (2011–14): South Africa, 82%; France, 8%; Peru, 6%; and other, 4%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Andalusite, kyanite, and sillimanite	2508.50.0000	Free.
Mullite	2508.60.0000	Free.

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

Government Stockpile: None.

Events, Trends, and Issues: Crude steel production in the United States, which ranked fourth in the world, decreased by 8.5% in the first 8 months of 2015 compared with that of the same period in 2014, indicating a potential decrease in consumption of kyanite-mullite refractories if this trend continues. Total world steel production decreased by 2.3% during the first 8 months of 2015 compared with a 3.7% increase in the same period in 2014, mostly as the result of decreases in steel production in China, Japan, the Republic of Korea, and the United States. Of the total world refractories market, which was estimated to be approximately 40 million metric tons, crude steel manufacturing consumed more than 70% of refractories production.

The decrease in world steel production during the first 8 months of 2015 was, in part, the result of a deceleration in growth in China, a continued sluggish economy in Western Europe, slower-than-expected economic growth in Eastern Europe, and lower steel demand in the United States. Although steel production and consumption was expected to be lower than previously forecast for 2015, gradual improvements were expected in 2016. Andalusite and mullite could receive increasing consideration as alternative aluminosilicate refractory minerals to refractory bauxite; a lack of readily available, inexpensive refractory-grade bauxite from China, which accounted for about three-quarters of market share worldwide, has continued.

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KYANITE AND RELATED MINERALS

Although experiencing an economic slowdown, China is expected to continue to have growth rates of 6% to 7% and to be the largest market for refractories, comprising the majority of global demand. Slowing, but still above-average, growth is expected in India and portions of Asia. Eastern Europe, North America, and Western Europe are expected to have sluggish but continuing refractory demand because of their large industrial bases. The economies of North America and Western Europe are expected to increase in 2016 with recovery in manufacturing and steel production, but may lag behind the worldwide average in the longer term with steel production increasing in India and shifting to less-developed countries, such as Egypt, Indonesia, and Vietnam. Demand for refractories in iron and steel production is expected to have greater increases in countries with higher rates of growth in steel production. Increased demand also is anticipated for refractories used to produce other metals and in the industrial mineral market because of increasing production of cement, ceramics, glass, and other mineral products.

Andalusite projects in Peru continued to progress. One facility increased production capacity by 50% and planned to increase by about 25% more in 2016. Exploration continued at another deposit in Peru and development of a processing operation was planned with production to begin in 2016. Large resources of kyanite were discovered in Murmansk in the Kola Penisula region of Russia.

World Mine Production and Reserves:

	Mine production		Reserves[5]
	2014	2015[e]	
United States[e] (kyanite)	110	110	Large
India (kyanite and sillimanite)	62	65	1,600
Peru (andalusite)	30	35	NA
South Africa (andalusite)	200	200	NA
Other countries	1	10	NA
World total (rounded)	[6]403	[6]420	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 economical to mine at present. The characteristics of kyanite resources in the rest of the world are thought to be similar to those in the United States. Significant resources of andalusite are known to exist in China, France, Peru, and South Africa; kyanite, in Brazil, Russia, and India; and sillimanite, 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]Sources: Virginia Department of Mines, Minerals and Energy.
[2]Source: Average of prices reported in Industrial Minerals.
[3]Includes mine, mill, and office employment. Source: Mine Safety and Health Administration.
[4]Defined as imports – exports.
[5]See Appendix C for resource/reserve definitions and information concerning data sources.
[6]In addition to the countries listed, France continued production of andalusite and Brazil 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: Six lead mines in Missouri, plus five mines in Alaska, Idaho, and Washington that produced lead as a coproduct, accounted for all domestic lead mine production. The value of the lead in concentrates mined in 2015, based on the average North American Market price for refined lead, was about $790 million. The 11 secondary lead refineries in 10 States that had capacities of at least 30,000 tons per year of refined lead accounted for more than 95% of secondary lead production in 2015. Lead was consumed at more than 70 manufacturing plants. The lead-acid battery industry accounted for about 90% of reported U.S. lead consumption during 2015. Lead-acid batteries were primarily used as starting-lighting-ignition (SLI) batteries for automobiles and trucks, as industrial-type batteries for standby power for computer and telecommunications networks, and for motive power for forklifts. During the first 9 months of 2015, 94.1 million lead-acid automotive batteries were shipped by North American producers, a slight increase from those shipped in the same period of 2014.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Mine, lead in concentrates	342	345	340	379	385
Primary refinery	118	111	114	—	—
Secondary refinery, old scrap	1,130	1,110	1,150	1,130	1,120
Imports for consumption:					
Lead in concentrates	([1])	([1])	([1])	([1])	([1])
Refined metal, wrought and unwrought	316	351	487	596	550
Exports:					
Lead in concentrates	223	214	210	356	350
Refined metal, wrought and unwrought	47	53	48	60	50
Consumption:					
Reported	1,410	1,350	1,390	1,510	1,470
Apparent[2]	1,540	1,500	1,700	1,670	1,620
Price, average, cents per pound:					
North American Producer	122	114	115	NA	NA
North American Market	NA	NA	110	106	93
London Metal Exchange	109	93.5	97.2	95.0	83.0
Stocks, metal, producers, consumers, yearend	48	72	67	64	60
Employment:					
Mine and mill (average), number[3]	1,700	1,660	1,690	1,730	1,730
Primary smelter, refineries	290	290	290	—	—
Secondary smelters, refineries	2,000	2,000	2,000	1,800	1,800
Net import reliance[4] as a percentage of apparent consumption, refined lead	19	18	26	32	31

Recycling: In 2015, about 1.12 million tons of secondary lead was produced, an amount equivalent to 69% of apparent domestic consumption. Nearly all secondary lead was recovered from old (post-consumer) scrap.

Import Sources (2011–14): Metal, wrought and unwrought: Canada, 57%; Mexico, 20%; Peru, 5%; Australia and Kazakhstan, 4% each; and other, 10%.

Tariff: Item	**Number**	**Normal Trade Relations[5] 12–31–15**
Lead ores and concentrates	2607.00.0020	1.1¢/kg on lead content.
Refined lead	7801.10.0000	2.5% ad val.
Antimonial lead	7801.91.0000	2.5% ad val.
Alloys of lead	7801.99.9030	2.5% ad val.

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

Government Stockpile: None.

Events, Trends, and Issues: The average London Metal Exchange (LME) cash lead price declined by about 13% in 2015 from that in 2014. The LME price averaged $0.83 per pound ton in January, peaked at $0.91 in May, and declined to $0.78 per pound in October. The price decline took place despite global LME warehouse stocks decreasing to 147,225 tons at the end of October from 221,975 tons at yearend 2014, and an anticipated decrease in global refined production. Essentially all of the remaining lead stocks were held in warehouses in Asia and Europe.

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LEAD

Domestic mine production in 2015 increased from that in the previous year owing to increases in all of the lead-producing States. The Pend Oreille Mine in Washington reopened in late 2014 and began producing lead in 2015. Total domestic secondary lead production was slightly lower than that in 2014. Increased production at several secondary smelters was expected to be offset by the closure of one smelter. In early 2014, a producer temporarily shut down operations of a lead smelter in Vernon, CA, owing to environmental concerns from State regulators. The company had intended to restart operations in 2015 but closed the plant instead. In March, one secondary producer announced plans to build a new secondary lead refinery in Nevada capable of producing high-purity lead for use in advanced lead-acid batteries. The plant would use an electrochemical battery recycling technology and be built in 2016. The United States has become more reliant on imported refined lead during the past few years owing to the closure of the last primary lead smelter in 2013, and increased exports of spent SLI lead-acid batteries have reduced the amount of scrap available to secondary smelters. During the first 8 months of the year, 19.3 million spent SLI lead-acid batteries, containing an estimated 167,000 tons of lead, were exported.

Global mine production of lead was expected to decline to about 4.70 million tons in 2015. The International Lead and Zinc Study Group (ILZSG) forecast global refined lead production to be 10.8 million tons, a slight decrease from that in 2014, primarily driven by decreases in China and Peru. ILZSG projected global lead consumption to be 10.8 million tons in 2015, a slight decline from that in 2014, partially owing to a decrease in China's consumption. In 2015, global refined lead production was expected to be essentially the same as consumption.[6]

World Mine Production and Reserves: Reserve estimates for India, Peru, and Turkey were revised based on information from Government and industry sources.

	Mine production[e]		Reserves[7]
	2014	2015	
United States	379	385	5,000
Australia	728	633	35,000
Bolivia	94	82	1,600
China	2,400	2,300	15,800
India	106	130	2,200
Ireland	41	33	600
Kazakhstan	38	38	NA
Korea, North	45	45	NA
Mexico	250	240	5,600
Peru	278	300	6,700
Poland	38	40	1,700
Russia	90	90	9,200
South Africa	29	40	300
Sweden	71	76	1,100
Turkey	65	54	860
Other countries	214	225	3,000
World total (rounded)	4,870	4,710	89,000

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 of 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 + refined imports – refined exports + adjustments for industry stock changes.
[3]Includes lead and zinc-lead mines for which lead was either a principal product or significant byproduct.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]No tariff for Canada, Mexico, and Peru for items shown.
[6]International Lead and Zinc Study Group, 2015, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group news release, October 9, 5 p. (Accessed November 10, 2015, via http://www.ilzsg.org/).
[7]See Appendix C for resource/reserve definitions and information concerning data sources.

LIME[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2015, an estimated 19 million tons (21 million short tons) of quicklime and hydrate was produced (excluding commercial hydrators), valued at about $2.2 billion. At yearend, 31 companies were producing lime, which included 20 companies with commercial sales and 11 companies that produced lime strictly for internal use (for example, sugar companies). These companies had 77 primary lime plants (plants operating lime kilns) in 29 States and Puerto Rico. The four leading U.S. lime companies produced quicklime or hydrate in 24 States and accounted for 73% of U.S. lime production. Principal producing States were, in descending order of production, Missouri, Alabama, Kentucky, Ohio, and Texas. Major markets for lime were, in descending order of consumption, steelmaking, flue gas desulfurization, construction, water treatment, mining, paper and pulp, and precipitated calcium carbonate.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production[2]	19,100	18,800	19,200	19,500	19,000
Imports for consumption	512	468	394	414	350
Exports	231	212	270	319	300
Consumption, apparent[3]	19,400	19,100	19,300	19,500	19,000
Quicklime average value, dollars per ton at plant	107.90	115.40	117.80	119.10	116.00
Hydrate average value, dollars per ton at plant	130.90	136.90	140.60	142.20	140.00
Employment, mine and plant, number	5,100	5,100	5,100	5,100	5,100
Net import reliance[4] 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 (2011–14): Canada, 94%; Mexico, 4%; and other, 2%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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 2015, domestic lime production was expected to decrease slightly, owing to decreased consumption by the U.S. nonferrous metallurgical industries (primarily copper) and steel industries. Domestic copper production and crude steel production were each forecast to decrease by 8% in 2015 compared to that in 2014. As a result, national lime prices decreased slightly compared with those in 2014.

One existing lime plant in Alabaster, AL, reopened at yearend 2014. Companies continued with construction projects in Pennsylvania and Virginia, which involved installation of new natural-gas-fired vertical-shaft kilns. Low interest rates and low energy prices have provided opportunities for lime companies to add new capacity or replace existing old capacity with natural-gas-fired kilns. One sugar cooperative announced plans to close its sugar beet processing facility in Torrington, WY, and shift production to existing plants in Colorado and Nebraska in 2016. In sugar refining, milk-of-lime is used to raise the pH of the product stream to precipitate out colloidal impurities. The lime itself is then removed by reaction with carbon dioxide to precipitate calcium carbonate.

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LIME

World Lime Production and Limestone Reserves:

	Production 2014	Production 2015[e]	Reserves[5]
United States	19,500	19,000	Adequate for all countries listed.
Australia	2,000	2,000	
Belgium	1,400	1,400	
Brazil	8,300	8,300	
Bulgaria	1,500	1,500	
Canada	1,950	1,900	
Chile	900	910	
China	230,000	230,000	
Czech Republic	1,000	1,000	
France	3,900	3,800	
Germany	6,900	6,900	
India	16,000	16,000	
Iran	2,800	2,800	
Italy[6]	3,600	3,500	
Japan (quicklime only)	7,910	7,800	
Kazakhstan	870	870	
Korea, Republic of	5,100	5,000	
Malaysia (sales)	1,400	1,400	
Poland	1,700	1,800	
Romania	1,700	1,700	
Russia	11,000	11,000	
Slovakia	820	830	
South Africa (sales)	1,200	1,200	
Spain (sales)	1,900	1,900	
Turkey (sales)	4,400	4,300	
Ukraine	3,700	3,500	
United Kingdom	1,500	1,500	
Vietnam	850	800	
Other countries	11,000	9,600	
World total (rounded)[7]	360,000	350,000	

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.
[1]Data are for quicklime, hydrated lime, and refractory dead-burned dolomite. Includes Puerto Rico.
[2]Sold or used by producers.
[3]Includes some double counting based on nominal, undifferentiated reporting of company export sales as U.S. production.
[4]Defined as imports – exports.
[5]See Appendix C for resource/reserve definitions and information concerning data sources.
[6]Includes hydraulic lime.
[7]World production data are rounded to no more than two significant digits when estimated. Data reported by countries such as Canada, Japan, and the United States are rounded to three significant digits. Data may not add to totals shown.

LITHIUM

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

Domestic Production and Use: The only lithium mine operating in the United States was a brine operation in Nevada. Two companies produced a large array of downstream lithium compounds in the United States from domestic or imported lithium carbonate, lithium chloride, and lithium hydroxide. Domestic production was not published to protect proprietary data.

Although lithium markets vary by location, global end-use markets are estimated as follows: batteries, 35%; ceramics and glass, 32%; lubricating greases, 9%; air treatment and continuous casting mold flux powders, 5% each; polymer production, 4%; primary aluminum production, 1%; and other uses, 9%. 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 worldwide.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production	W	W	[1]870	W	W
Imports for consumption	2,850	2,760	2,210	2,120	2,980
Exports	1,310	1,300	1,230	1,420	1,770
Consumption:					
Apparent	W	W	1,800	W	W
Estimated	[2]2,000	[2]2,000	1,800	[2]2,000	[2]2,000
Price, annual average, battery-grade lithium carbonate, dollars per metric ton[3]	5,180	6,060	6,800	6,690	6,400
Employment, mine and mill, number	70	70	70	70	70
Net import reliance[4] as a percentage of apparent consumption	>80%	>60%	>50%	>50%	>60%

Recycling: Historically, lithium recycling has been insignificant but has increased steadily owing to the growth in consumption of lithium batteries. One U.S. company has recycled lithium metal and lithium-ion batteries since 1992 at its facility in British Columbia, Canada. In 2009, the U.S. Department of Energy awarded the company $9.5 million to construct the first U.S. recycling facility for lithium-ion vehicle batteries. Construction neared completion in 2015.

Import Sources (2011–14): Chile, 58%; Argentina, 38%; China, 3%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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.P. grade	2836.91.0010	3.7% ad val.
Other	2836.91.0050	3.7% ad val.

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

Government Stockpile: The Defense Logistics Agency Strategic Materials planned to acquire 150 kilograms of lithium cobalt oxide and 540 kilograms of lithium nickel cobalt aluminum oxide in FY 2015.

Stockpile Status—9–30–15[5]

Material	Inventory	Disposal Plan FY 2015	Disposals FY 2015
Lithium cobalt oxide (kilograms, gross weight)	91	—	—
Lithium nickel cobalt aluminum oxide (kilograms, gross weight)	450	—	—

Events, Trends, and Issues: Worldwide lithium production increased slightly in 2015 in response to increased lithium demand for battery applications. Production in Argentina increased by about 17% and production in Australia and Chile increased slightly. Major lithium producers expected worldwide consumption of lithium in 2015 to be approximately 32,500 tons, an increase of 5% from 31,000 tons in 2014. Owing to increased worldwide demand, spot lithium carbonate prices increased approximately 10% to 15% from those of 2014. For large fixed contracts, however, Industrial Minerals reported a 4% decrease in average U.S. lithium carbonate prices.

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LITHIUM

In the late 1990s, subsurface brines became the dominant raw material for lithium carbonate production worldwide because of lower production costs compared with the mining and processing of hard-rock ores. Owing to growing lithium demand from China in the past several years, however, mineral-sourced lithium regained market share and was estimated to account for one-half of the world's lithium supply in 2015. Two brine operations in Chile and a spodumene operation in Australia accounted for the majority of world production. Argentina produced lithium carbonate and lithium chloride from brines. China produced lithium carbonate, lithium chloride, and lithium hydroxide, mostly from imported spodumene, but also from domestic brines and minerals. A new brine operation in Argentina began commercial production in 2015.

Lithium supply security has become a top priority for technology companies in the United States and Asia. Strategic alliances and joint ventures between technology companies and exploration companies have been, and are continuing 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, and the United States; spodumene mining operations were under development in Australia, Canada, China, and Finland; a jadarite mining operation was under development in Serbia; and a lithium clay-mining operation was under development in Mexico. Additional exploration for lithium continued, with numerous claims having been leased or staked worldwide.

Rechargeable batteries were the largest potential growth area for lithium compounds. Demand for rechargeable lithium batteries exceeds that of other rechargeable batteries. Automobile companies were developing lithium batteries for electric and hybrid electric vehicles. A leading electric car manufacturer was constructing a lithium-ion battery plant in Nevada capable of producing up to 500,000 lithium-ion vehicle batteries per year. The plant was expected to be vertically integrated, capable of producing finished battery packs directly from raw materials by 2020.

World Mine Production and Reserves: The reserves estimates for Argentina, Australia, and China have been revised based on new information from Government and industry sources.

	Mine production		Reserves[6]
	2014	2015[e]	
United States	W	W	38,000
Argentina	3,200	3,800	2,000,000
Australia	13,300	13,400	1,500,000
Brazil	160	160	48,000
Chile	11,500	11,700	7,500,000
China	2,300	2,200	3,200,000
Portugal	300	300	60,000
Zimbabwe	900	900	23,000
World total (rounded)	[7]31,700	[7]32,500	14,000,000

World Resources: Identified lithium resources in the United States have been revised to 6.7 million tons and total approximately 34 million tons in other countries. Identified lithium resources in Bolivia and Chile are 9 million tons and more than 7.5 million tons, respectively. Identified lithium resources in major producing countries are: Argentina, 6.5 million tons; Australia, 1.7 million tons; and China, 5.1 million tons. In addition, Canada, Congo (Kinshasa), Russia, and Serbia have resources of approximately 1 million tons each. Identified lithium resources in Brazil and Mexico are180,000 tons each, and Austria has 130,000 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. Substitutes for aluminum-lithium alloys in structural materials are composite materials consisting of boron, glass, or polymer fibers in resins.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Source: Rockwood Holdings, Inc., 2014, 2013 annual report: Princeton, NJ, Rockwood Holdings, Inc., p. 16.
[2]Rounded to one significant figure to avoid disclosing company proprietary data.
[3]Source: Industrial Minerals, IM prices: Lithium carbonate, large contracts, delivered continental United States, annual average.
[4]Defined as imports – exports + adjustments for Government and industry stock changes.
[5]See Appendix B for definitions.
[6]See Appendix C for resource/reserve definitions and information concerning data sources.
[7]Excludes U.S. production.

MAGNESIUM COMPOUNDS[1]

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

Domestic Production and Use: Seawater and natural brines accounted for about 63% of U.S. magnesium compounds production in 2015. The value of production of magnesium compounds, excluding dead-burned magnesia, was $137 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 stockpiled olivine that was previously mined. About 54% 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 46% was used for refractories in the form of dead-burned magnesia, fused magnesia, and olivine.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production	306	244	297	288	295
Imports for consumption	316	260	230	258	265
Exports	20	19	21	23	30
Consumption, apparent	602	485	506	523	520
Employment, plant, number[e]	300	275	250	250	260
Net import reliance[2] as a percentage of apparent consumption	49	50	41	45	43

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

Import Sources (2011–14): China, 54%; Brazil, 14%; Canada, 9%; Australia, 6%; and other, 17%.

Tariff:[3] Item	**Number**	**Normal Trade Relations 12–31–15**
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: Global consumption of dead-burned and fused magnesia declined slightly during the first 8 months of 2015 compared with that in the same period of 2014, owing to a 7% decline in China's steel production and an overall slight decrease in global steel production during the same comparative periods. The reduced consumption and an increase in capacity in China resulted in an increase in the amount of magnesia in China available for export. The resulting lower prices for magnesia products from China put pressure on other producers to also lower prices. As a result, prices for magnesia declined throughout the first half of 2015; caustic-calcined magnesia prices did not decrease as much as those of dead-burned magnesia and fused magnesia.

In recent years, fused magnesia has replaced dead-burned magnesia in some steel furnaces, and this trend is expected to continue as more fused magnesia capacity comes on line. Fused magnesia has superior properties to dead-burned magnesia in some refractory applications, owing to higher magnesia content, higher density, and larger crystal size.

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MAGNESIUM COMPOUNDS

Although fused magnesia costs more than dead-burned magnesia, its longer campaign life reduces downtime, lowering the overall cost of production. The steel industry in China was expected to continue to become more efficient in its use of refractories, which would result in less magnesia consumed per unit of steel produced.

Domestic consumption of dead-burned magnesia decreased as the use of higher quality fused-magnesia refractories increased and crude steel production in the United States decreased by 9% in 2015. 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 flue gas treatment and wastewater treatment, also accounted for increasing consumption of magnesium compounds, including caustic-calcined magnesia and magnesium hydroxide. Deicing and dust control have increased consumption of magnesium chloride in recent years.

New capacity in China was expected to be limited because concerns about overcapacity deter further investment in the magnesia industry. New capacity in other countries, such as Russia and Turkey, was expected to be completed as planned, but further expansions were less likely, especially for dead-burned magnesia.

World Magnesite Mine Production and Reserves:

	Mine production		Reserves[4]
	2014	2015[e]	
United States	W	W	10,000
Australia	145	120	95,000
Austria	215	220	15,000
Brazil	175	175	86,000
China	5,910	5,770	500,000
Greece	105	115	80,000
India	65	70	26,000
Korea, North	70	70	450,000
Russia	375	375	650,000
Slovakia	200	200	35,000
Spain	185	200	10,000
Turkey	780	800	111,000
Other countries	190	180	390,000
World total (rounded)	[5]8,420	[5]8,300	2,400,000

In addition to magnesite, vast reserves exist of well and lake brines and seawater from which magnesium compounds can be recovered.

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.

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

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]See also Magnesium Metal.
[2]Defined as imports – exports + adjustments.
[3]Tariffs are based on gross weight.
[4]See Appendix C for resource/reserve definitions and information concerning data sources.
[5]Excludes U.S. production.

MAGNESIUM METAL[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2015, primary magnesium was produced by one company in Utah at an electrolytic process plant that recovered magnesium from brines from the Great Salt Lake. Production in 2015 was estimated to have increased from that of 2014. Statistical information regarding U.S. magnesium metal production in 2015 was withheld to avoid disclosing company proprietary data. The leading use for primary magnesium metal, which accounted for 34% of apparent consumption, was in aluminum-base alloys that were used for packaging, transportation, and other applications. Use as a reducing agent for the production of titanium and other metals accounted for 30% of primary magnesium metal consumption. Structural uses of magnesium (castings and wrought products) accounted for 18% of primary metal consumption, desulfurization of iron and steel, 12%, and other uses, 6%. Secondary production accounted for about two-thirds of apparent consumption.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production:					
Primary	W	W	W	W	W
Secondary (new and old scrap)	67	77	79	79	80
Imports for consumption	48	51	46	52	47
Exports	12	18	16	17	16
Consumption:					
Reported, primary	81	72	69	66	70
Apparent[2]	110	110	120	120	120
Price, yearend:					
U.S. spot Western, dollars per pound, average	2.13	2.20	2.13	2.15	2.15
China free market, dollars per metric ton, average	3,025	3,170	2,615	2,325	2,060
Stocks, producer and consumer, yearend	W	W	W	W	W
Employment, number[e]	400	420	420	420	420
Net import reliance[3] as a percentage of apparent consumption	33	29	27	29	26

Recycling: In 2015, about 25,000 tons of secondary magnesium was recovered from old scrap and 55,000 tons were recovered from new scrap. Aluminum-base alloys accounted for 77% of the secondary magnesium recovered. Magnesium chloride produced as a waste product of titanium sponge production at a plant in Utah is returned to the primary magnesium supplier where it is reduced to produce metallic magnesium; however, this metal is not included in the secondary magnesium statistics.

Import Sources (2011–14): Israel, 32%; Canada, 22%; China, 10%; Mexico, 6%; and others, 30%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Unwrought metal	8104.11.0000	8.0% ad val.
Unwrought alloys	8104.19.0000	6.5% 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 use of magnesium in automobile parts continued to increase as automobile manufacturers seek to decrease vehicle weight in order to comply with fuel-efficiency standards. A plant in Mexico, MO, which manufactures die-cast magnesium parts for the automotive industry, was expanded by about 30% and rampup was expected to be completed in early 2016.

Because many magnesium consumers were concerned about diversity of supply, several projects were under development to increase primary magnesium metal capacity. The sole U.S. primary magnesium producer was expanding capacity by 20%, and the expansion is scheduled to be completed in 2017, with incremental capacity to be ramped up in 2016. Another company was seeking financing for a proposed plant to produce magnesium from dolomite in Nevada. A preliminary economic assessment of the dolomite deposit was completed in 2012, but permits

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MAGNESIUM METAL

had not been issued for the project. Two companies proposed producing magnesium from asbestos tailings in Quebec, Canada. One of the companies was building a pilot plant to test its process and, if the process proves economically feasible, proposed to build a 50,000-ton-per-year plant. The other company was in the planning stage of its project. A company in Australia was conducting a feasibility study for a 5,000-ton-per-year plant to recover magnesium from coal fly ash.

In China, production during the first half of the year decreased owing to the shutdown of older, smaller producers that had higher costs. More magnesium capacity is expected to be shut down in China as the Government enforces environmental regulations on energy-intensive industries. However, new capacity for producing magnesium from lake brines and from dolomite in locations with lower energy costs, such as Shaanxi Province, was expected to result in an increase in China's magnesium production.

Consumption of magnesium in the production of titanium metal by the Kroll process was expected to increase with increased use of titanium in aerospace applications. The aerospace industry was also expected to directly consume more magnesium as regulators have approved the use of magnesium for seat frames. The substitution of steel by aluminum in automobiles was also expected to increase consumption of magnesium in aluminum alloys used in automobile sheet.

Development of alloys that are resistant to ignition was expected to increase magnesium consumption as a substitute for other metals. Magnesium alloyed with calcium, gadolinium, neodymium, or yttrium has been shown to have higher ignition temperatures, making it suitable for new applications. Magnesium has been prohibited from structural components in commercial aircraft because of its low ignition point. Protective coatings to prevent corrosion of magnesium, especially when in contact with other metals, were also being developed to enable substitution for other materials in several applications.

World Primary Production and Reserves:

	Primary production		Reserves[4]
	2014	**2015[e]**	
United States	W	W	Magnesium metal is derived from seawater, natural brines, dolomite, and other minerals. The reserves for this metal are sufficient to supply current and future requirements.
Brazil	16	16	
China	874	800	
Israel	26	25	
Kazakhstan	20	20	
Korea, Republic of	10	10	
Malaysia	—	—	
Russia	18	30	
Serbia	2	2	
Ukraine	7	9	
World total[5] (rounded)	970	910	

World Resources: Resources from which magnesium may be recovered range from large to virtually unlimited and are globally widespread. Resources of dolomite 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. For iron and steel desulfurization, calcium carbide may be used instead of magnesium. The relatively light weight of magnesium is an advantage over aluminum and zinc in castings and wrought products; however, its high cost is a disadvantage relative to these substitutes. Magnesium is preferred to calcium carbide for desulfurization of iron and steel because calcium carbide produces acetylene in the presence of water.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]See also Magnesium Compounds.
[2]Rounded to two significant digits to protect proprietary data.
[3]Defined as imports – exports.
[4]See Appendix C for resource/reserve definitions and information concerning data sources.
[5]Excludes U.S. production.

MANGANESE

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

Domestic Production and Use: Manganese ore containing 20% or more manganese has not been produced domestically since 1970. Manganese ore was consumed mainly by 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 plant fertilizers and animal feed, and as a brick colorant. Manganese ferroalloys were produced at two smelters. Construction, machinery, and transportation end uses accounted for about 33%, 13%, and 10%, respectively, of manganese consumption. Most of the rest went to a variety of other iron and steel applications. In 2015, the value of domestic consumption, estimated from foreign trade data, was about $950 million.

Salient Statistics—United States:[1]	2011	2012	2013	2014	2015[e]
Production, mine[2]	—	—	—	—	—
Imports for consumption:					
Manganese ore	552	506	549	396	430
Ferromanganese	348	401	331	364	330
Silicomanganese[3]	348	348	329	444	340
Exports:					
Manganese ore	1	2	1	1	1
Ferromanganese	5	5	2	2	3
Silicomanganese	8	6	6	3	1
Shipments from Government stockpile excesses:[4]					
Manganese ore	-75	—	—	—	—
Ferromanganese	10	6	1	18	36
Consumption, reported:[5]					
Manganese ore[6]	532	538	523	551	530
Ferromanganese	303	382	368	360	330
Silicomanganese	106	150	152	146	130
Consumption, apparent, manganese[7]	699	843	794	852	750
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]	6.67	4.97	4.61	4.49	3.79
C.i.f, China, CRU Ryan's Notes	5.72	4.84	5.29	4.72	[8]3.65
Stocks, producer and consumer, yearend:					
Manganese ore[6]	250	203	217	158	200
Ferromanganese	25	31	27	23	21
Silicomanganese	22	19	6	10	9
Net import reliance[9] 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 (2011–14): Manganese ore: Gabon, 67%; Australia, 14%; South Africa, 12%; Mexico, 2%; and other, 5%. Ferromanganese: South Africa, 61%; Norway, 9%; Australia, 9%; Republic of Korea, 8%; and other, 13%. Manganese contained in principal manganese imports:[10] South Africa, 34%; Gabon, 21%; Australia, 11%; Georgia, 10%; and other, 24%.

Tariff:

Item	Number	Normal Trade Relations 12–31–15
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.
Silicomanganese	7202.30.0000	3.9% ad val.
Metal, unwrought	8111.00.4700/4990	14% ad val.

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

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MANGANESE

Government Stockpile:

Stockpile Status—9–30–15[11]

Material	Inventory	Authorized for disposal	Disposals FY 2015
Manganese ore[12]	292	91	—
Ferromanganese, high-carbon	286	45	47

Events, Trends, and Issues: U.S. manganese apparent consumption was projected to decrease by 12% to 750,000 tons in 2015 compared to that in 2014. This was primarily a result of the significant decrease in silicomanganese imports and, to a lesser extent, a decrease in ferromanganese imports in response to the 8% decrease in domestic steel production. The annual average domestic manganese ore contract price followed the 22% decrease in the average Chinese spot market price for metallurgical-grade ore in 2015.

World Mine Production and Reserves (metal content): Reserves for Australia, Brazil, and Gabon have been revised downward and those for South Africa revised upward, based on reported data by the Governments of Australia and Brazil and the major manganese producers in Gabon and South Africa. Reserves for Ghana have been added based on reported data by the sole manganese ore producer in the country.

	Mine production		Reserves[13]
	2014	2015[e]	
United States	—	—	—
Australia	3,050	2,900	91,000
Brazil	1,040	1,000	50,000
Burma	98	100	NA
China	3,000	3,000	44,000
Gabon	1,860	1,800	22,000
Ghana	418	390	13,000
India	945	950	52,000
Kazakhstan	385	390	5,000
Malaysia	378	400	NA
Mexico	236	240	5,000
South Africa	5,200	6,200	200,000
Ukraine	422	390	140,000
Other countries	740	740	Small
World total (rounded)	17,800	18,000	620,000

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 75% 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]Excludes insignificant quantities of low-grade manganiferous ore.
[3]Imports more nearly represent amount consumed than does reported consumption.
[4]Net quantity, in manganese content, defined as stockpile shipments – receipts. If receipts, a negative quantity is shown.
[5]Manganese consumption cannot be estimated as the sum of manganese ore and ferromanganese consumption because so doing would count manganese in ore used to produce ferromanganese twice.
[6]Consumers only, exclusive of ore consumed and stocks at iron and steel plants.
[7]Thousand tons, manganese content; based on estimated average content for all components, except imports, for which content is reported.
[8]Average weekly price through September 2015.
[9]Defined as imports – exports + adjustments for Government and industry stock changes.
[10]Includes imports of ferromanganese, manganese ore, silicomanganese, synthetic manganese dioxide, and unwrought manganese metal.
[11]See Appendix B for definitions.
[12]Metallurgical grade.
[13]See Appendix C for resource/reserve definitions and information concerning data sources.

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 2015, 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 50 metric tons per year of mercury was consumed domestically. The leading domestic end users of mercury were the chlorine-caustic soda (chloralkali), electronics, and fluorescent-lighting manufacturing industries. Only two mercury cell chloralkali plants operated in the United States in 2015. 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.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Mine (byproduct)	NA	NA	NA	NA	NA
Secondary	NA	NA	NA	NA	NA
Imports for consumption (gross weight), metal	110	249	38	49	15
Exports (gross weight), metal	133	103	([1])	—	—
Price, average value, dollars per flask, free market[2, 3]	1,850	1,850	1,850	1,850	1,850
Net import reliance[4] as a percentage of apparent consumption	E	E	NA	NA	NA

Recycling: In 2015, six companies in the United States accounted for the majority of secondary mercury production. Mercury-containing automobile convenience switches, barometers, compact and traditional fluorescent lamps, computers, dental amalgam, medical devices, thermostats, and some mercury-containing toys were collected by as many as 50 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. The increased use of mercury substitutes has resulted in a shrinking reservoir of mercury-containing products for recycling. Minimizing the use of mercury in products that still require mercury has further reduced the amount of secondary mercury available for recovery.

Import Sources (2011–14): Chile, 32%; Argentina, 29%; Canada, 19%; Germany, 13%; and other, 7%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–15**
Mercury	2805.40.0000	1.7% ad val.

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

Government Stockpile: An inventory of 4,436 tons of mercury was held in storage at the Hawthorne Army Depot, Hawthorne, NV. About 1,200 tons of mercury also was held by the U.S. Department of Energy, Oak Ridge, TN. Sales of mercury from the National Defense Stockpile remained suspended.

Stockpile Status—9–30–15[5]

Material	**Inventory**	**Disposal Plan FY 2015**	**Disposals FY 2015**
Mercury	4,436	—	—

Events, Trends, and Issues: The average annual and monthly prices of one flask of domestic or free market mercury remained at $1,850 per flask. Imports decreased and were significantly below the average annual imports for the past 10 years.

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, and incineration of mercury-containing medical devices. In 2010, the total anthropogenic emission of

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mercury to the atmosphere was estimated at 1,960 t. Mercury is no longer used in 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. Global consumption of mercury was estimated to be less than 2,000 tons per year, and approximately 50% of this consumption was as mercury compounds used as catalysts in the coal-based manufacture of vinyl chloride monomer in China. 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.

Globally, the number of operating primary mercury mines was uncertain; however, most were located in China, Kyrgyzstan, or Russia. 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. The quantity of byproduct mercury entering the global supply from foreign gold-silver processing may fluctuate dramatically from year to year because mercury is frequently stockpiled in producing countries until sufficient material is available for export. Domestic mercury consumption will continue to decline because increasing use of compact fluorescent bulbs, which use a small amount of mercury, will be more than offset by reduced use of conventional fluorescent tubes; increased use of light-emitting-diode (LED) lighting; and continued substitution of nonmercury-containing products, such as digital thermometers, in measuring, control, and dental applications.

World Mine Production and Reserves: Data on reserves of mercury are out of date, not available, or not disclosed owing to the hazardous nature of the mineral. Chile is included with "Other countries".

	Mine production 2014	Mine production 2015[e]	Reserves[6]
United States	NA	NA	Quantitative estimates of reserves are not available. China, Kyrgyzstan, and Peru are thought to contain the largest reserves.
China	1,600	1,600	
Kyrgyzstan	75	70	
Mexico (exports)	500	500	
Peru (exports)	40	40	
Russia	50	50	
Tajikistan	30	30	
Other countries	73	70	
World Total (rounded)	2,350	2,340	

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 Peru, mercury production from the Santa Barbara Mine (Huancavelica) stopped in the 1990s; however, Peru continues to be an important source of byproduct mercury imported into the United States. 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 another century or more of use.

Substitutes: For aesthetic or human health concerns, natural-appearing 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. E Net exporter. 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 34.5 kilograms, or 0.035 ton.
[3]Platts Metals Week average mercury price quotation for the year. Actual prices may vary significantly from quoted prices.
[4]Defined as imports – exports + adjustments for Government stock changes.
[5]See Appendix B for definitions.
[6]See Appendix C for resource/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 41,500 tons valued at $4.5 million. Mica was mined in Georgia, North Carolina, South Dakota, and Virginia. Scrap mica was recovered principally from mica and sericite schist and as a byproduct from feldspar, industrial sand beneficiation, and kaolin. Seven companies produced 67,800 tons of ground mica valued at about $21 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 the Spruce Pine area of North Carolina. The domestic consuming industry was dependent upon imports to meet demand for sheet mica. Most sheet mica was fabricated into parts for electrical and electronic equipment.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Scrap and flake:					
Production:[1, 2]					
Mine	52,000	47,500	48,100	46,000	41,500
Ground	80,400	78,500	79,200	73,800	67,800
Imports, mica powder and mica waste	27,500	27,200	30,900	32,800	35,200
Exports, mica powder and mica waste	5,870	5,900	6,380	8,080	8,340
Consumption, apparent[3]	73,600	68,800	72,600	70,700	68,400
Price, average, dollars per metric ton, reported:					
Scrap and flake	133	128	124	120	109
Ground:					
Dry	281	281	279	285	280
Wet	360	360	360	369	370
Employment, mine, number	NA	NA	NA	NA	NA
Net import reliance[4] as a percentage of apparent consumption	29	31	34	35	39
Sheet:					
Production, mine[e]	([5])	([5])	([5])	([5])	([5])
Imports, plates, sheets, strips; worked mica; split block; splittings; other >$1.00/kg	2,190	2,380	1,910	2,470	2,510
Exports, plates, sheets, strips; worked mica; crude and rifted into sheet or splittings >$1.00/kg	1,040	1,660	1,150	1,030	1,070
Consumption, apparent	1,160	716	757	1,400	1,440
Price, average value, dollars per kilogram, muscovite and phlogopite mica, reported:					
Block	152	145	129	148	150
Splittings	1.63	1.72	1.72	1.70	1.70
Stocks, fabricator and trader, yearend	NA	NA	NA	NA	NA
Net import reliance[4] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2011–14): Scrap and flake: Canada, 49%; China, 34%; Finland, 7%; India, 4%; and other, 6%. Sheet: India, 54%; Brazil, 17%; China, 15%; Belgium, 5%; and other, 9%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
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.

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MICA (NATURAL)

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

Government Stockpile: None.

Events, Trends, and Issues: Domestic production and consumption of scrap and flake mica were estimated to have decreased in 2015. Apparent consumption of scrap and flake mica decreased slightly because the 10% decrease in production was offset by the estimated 7% increase in imports. Apparent consumption of sheet mica increased slightly in 2015. No environmental concerns are associated with the manufacture and use of mica products.

Future supplies of mica for U.S. consumption were expected to come increasingly from imports, primarily from Brazil, Canada, China, and India.

World Mine Production and Reserves:

	Scrap and flake			Sheet		
	Mine production[e]		Reserves[6]	Mine production[e]		Reserves[6]
	2014	2015		2014	2015	
All types:						
United States[1]	46,000	41,500	Large	([5])	([5])	Very small
Argentina	7,500	7,500	Large	—	—	NA
Brazil	11,500	12,000	Large	NA	NA	NA
Canada	22,000	22,000	Large	NA	NA	NA
China	780,000	780,000	Large	NA	NA	NA
Finland	54,000	54,000	Large	NA	NA	NA
France	20,000	20,000	Large	NA	NA	NA
India	18,500	19,000	Large	1,260	1,300	Very large
Korea, Republic of	30,000	30,000	Large	—	—	NA
Madagascar	9,600	9,600	Large	—	—	NA
Russia	100,000	100,000	Large	1,500	1,500	Moderate
Taiwan	9,000	9,000	Large	—	—	NA
Other countries	18,600	18,600	Large	200	200	Moderate
World total (rounded)	1,130,000	1,120,000	Large	2,960	3,000	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 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, vinyl-PVC, 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. — Zero.
[1]Sold or used by producing companies.
[2]Excludes low-quality sericite used primarily for brick manufacturing.
[3]Based on scrap and flake mica mine production.
[4]Defined as imports – exports.
[5]Less than ½ unit.
[6]See Appendix C for resource/reserve definitions and information concerning data sources.

MOLYBDENUM

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

Domestic Production and Use: In 2015, 56,300 metric tons of molybdenum, valued at about $1.0 billion (based on an average oxide price), was produced at 10 mines. Molybdenum ore was produced as a primary product at two mines—both in Colorado—whereas eight copper mines (five in Arizona, 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. Iron and steel and superalloy producers accounted for about 74% of the molybdenum consumed.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production, mine	63,700	61,500	61,000	68,200	56,300
Imports for consumption	21,100	19,800	20,200	25,300	22,200
Exports	56,700	48,900	53,100	65,100	63,400
Consumption:					
Reported[1]	19,100	19,400	18,600	19,500	19,000
Apparent[2]	26,100	33,100	29,800	27,900	15,600
Price, average value, dollars per kilogram[3]	34.34	28.09	22.85	25.84	17.80
Stocks, consumer materials	1,810	1,770	1,820	2,010	1,750
Employment, mine and plant, number	940	940	960	1,000	950
Net import reliance[4] as a percentage of apparent consumption	E	E	E	E	E

Recycling: Molybdenum is recycled as a component of catalysts, ferrous scrap, and superalloy scrap. Ferrous scrap 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 of the alloys in which molybdenum is found, such as iron, nickel, and chromium.

Import Sources (2011–14): Ferromolybdenum: Chile, 83%; Canada, 9%; United Kingdom, 4%; and other, 4%. Molybdenum ores and concentrates: Mexico, 31%; Canada, 28%; Peru, 23%; Chile, 17%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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.

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MOLYBDENUM

Events, Trends, and Issues: U.S. estimated mine output of molybdenum in concentrate in 2015 decreased by 17% from that of 2014. U.S. imports for consumption decreased by 12% from those of 2014, and U.S. exports decreased slightly from those of 2014. Reported U.S. consumption of primary molybdenum products decreased slightly from that of 2014. Apparent consumption decreased by 44% from that of 2014.

The average molybdenum price for 2015 was lower than that of 2014. Primary molybdenum production continued at the Climax Mine in Lake County and Summit County, CO, but primary production at the Ashdown Mine in Humboldt County, NV, and at the Questa Mine in Taos County, NM, continued to be suspended. The Thompson Creek Mine in Custer County, ID, and the Mineral Park Mine in Mohave County, AZ, were put on care and maintenance at yearend 2014 and did not reopen in 2015. The decline in U.S. molybdenum production was attributed mainly to the closure of the Thompson Creek Mine. The Chino Mine, a copper mine in Grant County, NM, did not produce molybdenum in 2015. Both the Mission Mine in Pima County, AZ, and the Pinto Valley Mine in Gila County, AZ, produced molybdenum in 2015.

World Mine Production and Reserves: Reserves for Iran were updated from Iran Mines and Mining Industries Summit data.

	Mine production		Reserves[5]
	2014	2015[e]	(thousand metric tons)
United States	68,200	56,300	2,700
Armenia	7,100	7,300	150
Australia	—	—	190
Canada	9,700	9,300	260
Chile	48,800	49,000	1,800
China	103,000	101,000	4,300
Iran	4,000	4,000	43
Kazakhstan	—	—	130
Kyrgyzstan	NA	NA	100
Mexico	14,400	13,000	130
Mongolia	2,000	2,000	160
Peru	17,000	18,100	450
Russia[e]	4,800	4,800	250
Turkey	1,300	1,400	100
Uzbekistan[e]	530	520	60
World total (rounded)	281,000	267,000	11,000

World Resources: Identified resources of molybdenum in the United States are about 5.4 million tons and, in the rest of the world, about 14 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 as an alloying element 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 the alloying properties of the metal. Potential substitutes for molybdenum include boron, chromium, niobium (columbium), and vanadium in alloy steels; tungsten in tool steels; graphite, tantalum, and tungsten for refractory materials in high-temperature electric furnaces; and cadmium-red, chrome-orange, and organic-orange pigments for molybdenum orange.

[e]Estimated. E Net exporter. NA Not available. — Zero.
[1]Reported consumption of primary molybdenum products.
[2]Apparent consumption of molybdenum concentrates roasted to make molybdenum oxide.
[3]Time-weighted average price per kilogram of molybdenum contained in technical-grade molybdic oxide, as reported by Ryan's Notes.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]See Appendix C for resource/reserve definitions and information concerning data sources.

NICKEL

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

Domestic Production and Use: The United States had only one active nickel mine—the underground Eagle Mine in Michigan. The new mine has been producing separate concentrates of chalcopyrite and pentlandite for export to Canadian and overseas smelters since April 2014. Three mining projects were in varying stages of development in northeastern Minnesota. The principal nickel-consuming State was Pennsylvania, followed by Kentucky, Illinois, New York, and North Carolina. Approximately 45% of the primary nickel consumed went into stainless and alloy steel production, 43% into nonferrous alloys and superalloys, 7% into electroplating, and 5% into other uses. End uses were as follows: transportation and defense, 34%; fabricated metal products, 20%; electrical equipment, 13%; chemical and petroleum industries, 7% each; construction, household appliances, and industrial machinery, 5% each; and other, 4%. The estimated value of apparent primary consumption was $1.57 billion.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production:					
Mine	—	—	—	4,300	26,500
Refinery, byproduct	W	W	W	W	W
Shipments of purchased scrap[1]	132,000	130,000	125,000	114,000	142,000
Imports:					
Primary	138,000	133,000	126,000	156,000	134,000
Secondary	21,300	22,300	26,300	38,900	28,700
Exports:					
Primary	12,400	9,100	10,600	10,400	9,770
Secondary	64,800	59,800	61,200	56,400	51,500
Consumption:					
Reported, primary metal	110,000	114,000	114,000	141,000	148,000
Reported, secondary	88,800	92,400	89,600	93,800	102,000
Apparent, primary metal	125,000	125,000	110,000	146,000	124,000
Total[2]	213,000	218,000	200,000	239,000	226,000
Price, average annual, London Metal Exchange:					
Cash, dollars per metric ton	22,890	17,533	15,018	16,865	12,635
Cash, dollars per pound	10.383	7.953	6.812	7.650	5.731
Stocks:					
Consumer, yearend	18,100	16,600	18,600	17,800	17,700
Producer, yearend[3]	6,650	6,550	9,730	9,290	9,260
Net import reliance[4] as a percentage of apparent consumption	48	49	46	56	37

Recycling: In 2015,101,900 tons of nickel was recovered from purchased scrap in 2015. This represented about 45% of reported secondary plus apparent primary consumption for the year.

Import Sources (2011–14): Canada, 40%; Australia, 10%; Russia, 10%; Norway, 8%; and other, 32%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Nickel ores and concentrates	2604.00.0040	Free.
Nickel oxides, chemical grade	2825.40.0000	Free.
Ferronickel	7202.60.0000	Free.
Unwrought nickel, not alloyed	7502.10.0000	Free.

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

Government Stockpile: The U.S. Government sold the last of the nickel in the National Defense Stockpile in 1999. The U.S. Department of Energy is holding 8,800 tons of nickel ingot contaminated by low-level radioactivity at Paducah, KY, plus 5,080 tons of contaminated shredded nickel scrap at Oak Ridge, TN. Ongoing decommissioning activities at former nuclear defense sites are expected to generate an additional 20,000 tons of nickel in scrap.

Events, Trends, and Issues: The U.S. steel industry produced 1.81 million tons of austenitic (nickel-bearing) stainless steel in 2015—up by 8% from 2014, and 53% greater than the output of 1.18 million tons in 2009, the last year of the recession. Stainless steel has traditionally accounted for two-thirds of primary nickel use worldwide, with more than one-half of the steel going into the construction, food processing, and transportation sectors.

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NICKEL

Nickel prices declined during 2015. In January, the London Metal Exchange (LME) cash mean for 99.8%-pure nickel was $14,767 per metric ton. By September, the price had fallen to $9,895. Decreased prices were attributed to declining growth rates for global production of austenitic stainless steel, as well as the commissioning of nickel refineries in Madagascar and Canada and the rampup of production at new ferronickel smelters in Brazil and New Caledonia. Despite weak prices and an oversupply of nickel, companies continue to bring on new mining and processing projects in anticipation of a turnaround in the global economy. Stocks in LME warehouses were at record high levels of more than 423,000 tons of nickel metal at the end of October.

In January 2014, the Government of Indonesia banned the export of direct shipping ores (DSO) of nickel. The ban was designed to encourage construction of additional ferronickel and nickel pig iron (NPI) plants in the archipelago, and also to bolster the country's foreign revenues. The ban had three immediate effects. First, several companies from China filed plans to construct NPI plants on Halmahera, Java, and Sulawesi. Second, the NPI industry in China increased its imports of DSO from the Philippines. In 2015, the Philippines was the largest exporter of DSO in the world. Third, companies from Australia, China, and Japan began showing renewed interest in the Solomon Islands after the High Court of the Islands approved a long-stalled request to develop the Isabel saprolitic deposit.

Production of austenitic stainless steel was at an alltime high in 2015, although growth rates declined; China produced a record-high 17.6 million tons, accounting for more than one-half of global output. Demand for nickel-base superalloys has been especially strong in the aerospace and power-generation sectors. Engineers are working to produce a microlattice of nickel metal that could be 100 times lighter than Styrofoam. The interwoven network of struts, which consists of 99.99% air, might be used for thermal insulation, battery electrodes, and impact protection.

World Mine Production and Reserves: Reserves data for Brazil, Guatemala, and New Caledonia were revised based on new information from company or Government reports.

	Mine production		Reserves[5]
	2014	2015[e]	
United States	4,300	26,500	160,000
Australia	245,000	234,000	[6]19,000,000
Brazil	102,000	110,000	10,000,000
Canada	235,000	240,000	2,900,000
China	100,000	102,000	3,000,000
Colombia	81,000	73,000	1,100,000
Cuba	50,400	57,000	5,500,000
Guatemala	38,400	50,000	1,800,000
Indonesia	177,000	170,000	4,500,000
Madagascar	40,300	49,000	1,600,000
New Caledonia	178,000	190,000	8,400,000
Philippines	523,000	530,000	3,100,000
Russia	239,000	240,000	7,900,000
South Africa	55,000	53,000	3,700,000
Other countries	377,000	410,000	6,500,000
World total (rounded)	2,450,000	2,530,000	79,000,000

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 instead of nickel-metal hydride may be used in certain applications.

[e]Estimated. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Scrap receipts – shipments by consumers + exports – imports + adjustments for consumer stock changes.
[2]Apparent primary consumption + reported secondary consumption.
[3]Stocks of producers, agents, and dealers held only in the United States.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]See Appendix C for resource/reserve definitions and information concerning data sources.
[6]For Australia, Joint Ore Reserves Committee-compliant reserves were about 7.0 million tons.

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 80%; and superalloys, about 20%. In 2015, the estimated value of niobium consumption was $400 million, as measured by the value of imports.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production, mine	—	—	—	—	—
Imports for consumption[e, 1]	9,520	10,100	8,580	11,100	8,900
Exports[e, 1]	363	385	435	1,110	1,300
Government stockpile releases[e, 2]	—	—	—	—	—
Consumption:[e]					
Reported[3]	9,060	7,460	7,500	8,210	7,700
Apparent	9,160	9,730	8,140	10,000	7,600
Unit value, ferroniobium, dollars per metric ton[4]	41,825	43,658	43,415	42,000	42,000
Net import reliance[5] 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 (2011–14): Niobium ore and concentrate: Brazil, 39%; Rwanda, 16%; Canada, 10%; Australia, 10%; and other, 25%. Niobium metal and oxide: Brazil, 83%; Canada, 12%; and other, 5%. Total imports: Brazil, 82%; Canada, 13%; and other, 5%. Of the U.S. niobium material imports, 99% (by gross quantity) was ferroniobium and niobium metal and oxide.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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	5.0% ad val.
Other	7202.93.8000	5.0% ad val.
Niobium:		
Waste and scrap[6]	8112.92.0600	Free.
Unwrought, powders	8112.92.4000	4.9% ad val.
Niobium, other[6]	8112.99.9000	4.0% ad val.

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

Government Stockpile: In the annual materials plan for FY 2016, the Defense Logistics Agency (DLA) Strategic Materials announced the 2016 maximum acquisition limit of 104.5 tons for ferroniobium.

Stockpile Status—9–30–15[7]

Material	Inventory	Disposal Plan FY 2015	Disposals FY 2015
Niobium metal	10	—	—

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NIOBIUM (COLUMBIUM)

Events, Trends, and Issues: Niobium principally was imported in the form of ferroniobium and niobium unwrought metal, alloy, and powder. Based on data for part of 2015, U.S. niobium apparent consumption (measured in contained niobium) was estimated to be 7,600 metric tons, 24% less than that of 2014.

Brazil was the world's leading niobium producer with 90% of global production, followed by Canada with 9%. Brazil exported about 5,000 to 7,000 tons of ferroniobium per month, distributed among China, Europe, and the United States. The increase in electrical power cost in Brazil that caused suspended production at 13 ferroalloy operations did not affect two Brazilian ferroniobium producers. Both companies operated vertically integrated mine-to-plant supply chains. One company announced plans to take cost-savings measures. The other company planned to upgrade or order a new ferroniobium submerged-arc furnace, rated at 15 megavolt-amperes, for completion in 2016 or 2017.

One domestic company planned to exploit the only primary niobium deposit in the United States at its Elk Creek project in Nebraska, where it planned to begin production in 2017. One domestic company concluded an offtake agreement for ferroniobium with a second company. Under the 10-year agreement, the first company would purchase 3,750 tons of ferroniobium per year, which equated to about one-half of the second company's planned production.

The DLA Strategic Materials planned to acquire ferroniobium to address a U.S. stockpile shortfall.

World Mine Production and Reserves:

	Mine production		Reserves[8]
	2014	2015[e]	
United States	—	—	—
Brazil	50,000	50,000	4,100,000
Canada	5,480	5,000	200,000
Other countries	420	1,000	NA
World total (rounded)	55,900	56,000	>4,300,000

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 150,000 tons of niobium-identified resources, all of which were considered uneconomic at 2015 prices for niobium.

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

[e]Estimated. NA Not available. — Zero.
[1]Imports and exports include the estimated niobium content of niobium and tantalum ores and concentrates, niobium oxide, ferroniobium, niobium unwrought alloys, metal, and powder.
[2]Government stockpile inventory reported by DLA Strategic Materials is the basis for estimating Government stockpile releases.
[3]Includes ferroniobium and nickel niobium.
[4]Unit value is mass-weighted average U.S. import value of ferroniobium assuming 65% niobium content. To convert dollars per metric ton to dollars per pound, divide by 2,205.
[5]Defined as imports – exports + adjustments for Government and industry stock changes.
[6]This category includes materials other than niobium-containing material.
[7]See Appendix B for definitions.
[8]See Appendix C for resource/reserve definitions and information concerning data sources.

NITROGEN (FIXED)—AMMONIA

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

Domestic Production and Use: Ammonia was produced by 13 companies at 29 plants in 15 States in the United States during 2015; 2 additional plants were idle for the entire year. About 60% 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 2015, U.S. producers operated at about 80% 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 plastics, synthetic fibers and resins, explosives, and numerous other chemical compounds.

Salient Statistics—United States:[1]	**2011**	**2012**	**2013**	**2014**	**2015**[e]
Production	[2]9,350	[3]8,730	[3]9,170	[3]9,330	9,400
Imports for consumption	5,600	5,170	4,960	4,150	4,530
Exports	26	31	196	111	640
Consumption, apparent	14,900	13,900	13,900	13,300	13,300
Stocks, producer, yearend	178	180	[4]240	280	300
Price, dollars per short ton, average, f.o.b. Gulf Coast[4]	531	579	541	530	470
Employment, plant, number[e]	1,050	1,100	1,200	1,200	1,200
Net import reliance[5] as a percentage of apparent consumption	37	37	34	30	29

Recycling: None.

Import Sources (2011–14): Trinidad and Tobago, 59%; Canada, 18%; Russia, 7%; Ukraine, 6%; and other, 10%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–15**
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 about $2.30 and $3.30 per million British thermal units for most of the year, with an average of about $2.80 per million British thermal units. Natural gas prices in 2015 were relatively stable; slightly higher prices were a result of increased demand for natural gas owing to unseasonably cold and high temperatures and associated increased demand for power generation. The weekly average Gulf Coast ammonia price was $565 per short ton at the beginning of 2015 and decreased to $345 per short ton in October. The average ammonia price for 2015 was estimated to be about $470 per short ton. The U.S. Department of Energy, Energy Information Administration, projected that Henry Hub natural gas spot prices would average $3.05 per million British thermal units in 2016.

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. During the next 4 years, it is expected that about 5.0 million tons per year of production capacity will be added in the United States. The additional capacity will reduce but likely not eliminate ammonia imports.

Global ammonia capacity is expected to increase by 15% during the next 4 years. Capacity additions are expected in Africa, Asia, Eastern Europe, and Latin America. The largest growth is expected in China and Russia.

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NITROGEN (FIXED)—AMMONIA

Large corn plantings increase the demand for nitrogen fertilizers. According to the U.S. Department of Agriculture, U.S. corn growers planted 36 million hectares of corn in the 2015 crop year (July 1, 2014, through June 30, 2015), which is 2% less than the area planted in 2014. Corn acreage decreased in most of the Corn Belt States in the 2015 crop year because of anticipated lower net returns from corn compared to other commodities. Overall corn acreage in the United States was expected to increase owing to continued U.S. ethanol production and U.S. corn exports in response to a strong global demand for feed grains.

Nitrogen fertilizers continue to be an environmental concern. Overfertilization and the subsequent runoff of excess fertilizer may contribute to nitrogen accumulation in watersheds. Nitrogen in excess fertilizer runoff was suspected to be a cause of the hypoxic zone that arises in the Gulf of Mexico during the summer. A hypoxic zone happens where water near the bottom of a large body of water, such as the Gulf of Mexico, contains less than 2 parts per million of dissolved oxygen. This may cause stress or death in bottom-dwelling organisms that cannot move out of the hypoxic zone. Scientists continued to study the effects of fertilization on the Nation’s environmental health.

World Ammonia Production and Reserves:

	Plant production		Reserves[6]
	2014	2015[e]	
United States	9,330	9,400	Available atmospheric nitrogen and sources of natural gas for production of ammonia are considered adequate for all listed countries.
Australia	1,250	1,300	
Belarus	1,060	1,100	
Canada	3,940	3,900	
China	47,300	48,000	
Egypt	2,660	2,600	
Estonia	3,000	3,000	
France	2,600	2,600	
Germany	2,800	2,800	
India	11,000	11,000	
Indonesia	5,000	5,000	
Iran	2,500	2,500	
Malaysia	1,000	1,000	
Netherlands	1,800	1,800	
Oman	1,100	1,100	
Pakistan	2,700	2,700	
Poland	2,100	2,100	
Qatar	2,990	3,000	
Russia	11,800	12,000	
Saudi Arabia	3,200	3,200	
Trinidad and Tobago	4,730	4,700	
Ukraine	4,240	4,200	
United Kingdom	1,100	1,100	
Uzbekistan	1,350	1,300	
Venezuela	1,200	1,200	
Other countries	13,300	13,000	
World total (rounded)	145,000	146,000	

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 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]U.S. Department of Commerce data unless otherwise noted.
[2]Source: U.S. Census Bureau and The Fertilizer Institute; data adjusted by the U.S. Geological Survey.
[3]Source: The Fertilizer Institute; data adjusted by the U.S. Geological Survey.
[4]Source: Green Markets.
[5]Defined as imports – exports + adjustments for industry stock changes.
[6]See Appendix C for resource/reserve definitions and information concerning data sources.

PEAT

(Data in thousand metric tons unless otherwise noted)[1]

Domestic Production and Use: The estimated f.o.b. plant value of marketable peat production in the conterminous United States was $11.5 million in 2015. Peat was harvested and processed by about 31 companies in 12 of the conterminous States. The Alaska Department of Natural Resources, which conducted its own canvass of producers, estimated 93,000 cubic meters of peat was produced in 2013; output was reported only by volume.[2] Production estimates were unavailable for Alaska for 2014 and 2015. Florida and Minnesota were the leading producing States, in order of quantity harvested. Reed-sedge peat accounted for approximately 87% of the total volume produced, followed by sphagnum moss with 11%. About 91% of domestic peat was sold for horticultural use, including general soil improvement, nurseries, and potting soils. Other applications included earthworm culture medium, golf course construction, mixed fertilizers, mushroom culture, 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:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production	568	488	465	468	460
Commercial sales	595	484	453	479	480
Imports for consumption	982	909	915	984	1,020
Exports	49	75	41	29	32
Consumption, apparent[3]	1,470	1,240	1,380	1,380	1,470
Price, average value, f.o.b. mine, dollars per ton	22.73	24.44	25.37	24.97	25.00
Stocks, producer, yearend	133	218	174	222	200
Employment, mine and plant, number[e]	600	580	560	550	550
Net import reliance[4] as a percentage of apparent consumption	61	61	66	66	69

Recycling: None.

Import Sources (2011–14): Canada, 97%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
Peat	2703.00.0000	Free.

Depletion Allowance: 5% (Domestic and foreign).

Government Stockpile: None.

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PEAT

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 to account for more than 60% of domestic consumption.

The 2015 peat harvest season was adequate across most of Canada's production regions. Eastern Canada, the largest producing region, had good weather throughout the peat harvest season and was expected to reach its production goal. The Prairie Provinces experienced good weather early in the season, which was later followed by poor weather conditions. Good weather early in the season allowed for this region to achieve its projected peat harvest. Poor weather conditions in Quebec's North Shore and South Shore areas caused a delay to the start of the harvest season, which, along with continued heavy rain throughout the balance of peat harvest season resulted in a below-average peat harvest.

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

	Mine production		Reserves[5]
	2014	2015[e]	
United States	468	460	150,000
Belarus	1,600	1,800	2,600,000
Canada	1,150	1,200	720,000
Estonia	1,000	1,000	60,000
Finland	6,470	6,500	6,000,000
Germany	3,000	3,000	([6])
Ireland	4,100	4,100	([6])
Latvia	1,000	1,000	190,000
Lithuania	519	500	190,000
Moldova	475	480	([6])
Norway	500	500	([6])
Poland	500	500	([6])
Russia	1,500	1,500	1,000,000
Sweden	3,660	3,700	([6])
Ukraine	600	600	([6])
Other countries	750	750	1,400,000
World total (rounded)	27,300	27,600	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. peatlands are located in undisturbed areas of Alaska. Total world resources of peat were estimated to be between 5 trillion and 6 trillion tons, covering about 400 million hectares.[7]

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.

[e]Estimated.
[1]See Appendix A for conversion to short tons.
[2]Harbo, L.A., Mineral Specialist, Alaska Office of Economic Development, oral commun., August 12, 2014.
[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/reserve definitions and information concerning data sources.
[6]Included with "Other countries."
[7]Lappalainen, Eino, 1996, Global peat resources: Jyvaskyla, Finland, International Peat Society, p. 55.

PERLITE

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2015, domestic production of processed crude perlite was estimated to be 483,000 tons with a value of $28.5 million. Crude ore production was from seven mines operated by six companies in five Western States. New Mexico continued to be the leading producing State. Processed crude perlite was expanded at 59 plants in 28 States. Domestic consumption was 613,000 tons. The applications for expanded perlite were building construction products, 51%; horticultural aggregate, 19%; fillers, 15%; and filter aid, 10%. The remaining 5% included specialty insulation and miscellaneous uses.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, processed crude perlite	420	393	419	451	483
Imports for consumption[e]	193	150	187	166	170
Exports[e]	36	38	51	46	40
Consumption, apparent	577	505	555	576	613
Price, average value, dollars per ton, f.o.b. mine	56	52	55	57	59
Employment, mine and mill	95	95	117	119	122
Net import reliance[1] as a percentage of apparent consumption	27	22	25	24	21

Recycling: Not available.

Import Sources (2011–14): Greece, 96%; Turkey, 2%; and other, 2%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–15**
Vermiculite, perlite and chlorites, unexpanded	2530.10.0000	Free.

Depletion Allowance: 10% (Domestic and foreign).

Government Stockpile: None.

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PERLITE

<u>Events, Trends, and Issues</u>: Perlite is a siliceous volcanic rock that expands up to 20 times its original volume when quickly heated. Expanded perlite is used to provide moisture retention and aeration when added to soil. Construction applications for expanded perlite are numerous because it is lightweight, fire resistant, and an excellent insulator. The amount of processed crude perlite sold or used from U.S. mines increased for the third consecutive year—to the highest level since 2005. Increased demand for perlite-based construction products, fillers, and filter aids during 2014 and 2015 was met by increased domestic production and net import reliance, as a percent of apparent consumption reached it lowest level since 2009. Horticultural applications also increased, owing to increased popularity of and demand for perlite in hydroponic growing medium. Novel and small markets for perlite have increased during the last 10 years; one of the more notable applications is using perlite as a filter aid to assist with controlling road runoff.

According to estimated data, the world's leading producers were, in descending order of production, Turkey, Greece, and the United States with 41%, 26%, and 18% of the world production, respectively. Although China was the source country for nearly 15% of the world's processed crude perlite exports, insufficient production data for China and several other countries are unavailable to make reliable estimates of their production.

Domestic perlite mining generally takes place in remote areas, and its environmental impact is modest. 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 there is practically no runoff to contribute to water pollution.

<u>World Processed Perlite Production and Reserves</u>: The reserves estimates for Hungary and Turkey were revised based on new information from official Government sources.

	Production		Reserves[2]
	2014	2015[e]	
United States	451	483	50,000
Greece	680	700	50,000
Hungary	65	70	28,000
Italy	60	60	NA
Japan	200	200	NA
Turkey	1,000	1,100	57,000
Other countries	70	70	NA
World total (rounded)	2,530	2,680	NA

<u>World Resources</u>: Insufficient information is available to make reliable estimates of resources in perlite-producing countries.

<u>Substitutes</u>: In construction applications, diatomite, expanded clay and shale, pumice, and slag can be substituted for perlite. For horticultural uses, vermiculite, coco coir, and pumice are alternative soil additives and are sometimes used in conjunction with perlite.

[e]Estimated. NA Not available.
[1]Defined as imports − exports.
[2]See Appendix C for resource/reserve definitions and information concerning data sources.

PHOSPHATE ROCK

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Phosphate rock ore was mined by five firms at 10 mines in four States and processed into an estimated 27.6 million tons of marketable product valued at $2.2 billion, f.o.b. mine. Florida and North Carolina accounted for about 80% 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 45% of the wet-process phosphoric acid produced was exported in the form of upgraded granular diammonium and monoammonium phosphate 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 a variety of industrial applications.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production, marketable	28,100	30,100	31,200	25,300	27,600
Used by producers	28,600	27,300	28,800	26,700	26,500
Imports for consumption	3,750	3,570	3,170	2,390	1,900
Consumption, apparent[1]	32,000	30,400	31,300	29,100	28,300
Price, average value, dollars per ton, f.o.b. mine[2]	96.64	102.54	91.11	78.59	80.00
Stocks, producer, yearend	4,580	6,700	9,000	5,880	6,500
Employment, mine and beneficiation plant, number[e]	2,260	2,230	2,170	2,100	2,050
Net import reliance[3] as a percentage of apparent consumption	15	5	3	18	4

Recycling: None.

Import Sources (2011–14): Morocco, 64%; and Peru, 36%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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: U.S. production of phosphate rock was estimated to have increased in 2015 over that of 2014; however, consumption of phosphate rock was estimated to have decreased owing to lower phosphoric acid production. World production of phosphate rock increased in 2015, with most of the increases taking place in the Middle East and South America. U.S. imports of phosphate rock were lower because of the closure of a phosphoric acid plant in Mississippi that used phosphate rock from Morocco. Two phosphoric acid plants in the United States have closed permanently since late 2014; the plant in Mississippi was shut down after the owner declared bankruptcy and the other in northern Florida was closed because of company consolidation. The closures reduced U.S. annual phosphoric acid production capacity by 0.8 million tons, to 8.5 million tons.

Domestic phosphate rock production capacity remained at 32.7 million tons. A company based in Canada that was developing a new underground mine in southeastern Idaho curtailed permitting activities from January to September 2015 because of financial constraints. The company expected to complete the permitting process in 2016, with production of about 0.9 million tons per year commencing after 2017. No other increases in production capacities were expected, because all new mines planned in the United States would be replacements for existing mines.

World phosphate rock production was expected to increase incrementally from 223 million tons in 2015 to 255 million tons in 2019. The leading areas of growth were planned in Africa and the Middle East. In Morocco, mine production capacity was expected to double owing to expansion of existing mines and development of a new mining complex. Phosphate-processing plants are planned to triple in capacity by 2018 through construction of new facilities. In Saudi Arabia, a new 5.3-million-ton phosphate mining and processing complex was under construction with completion expected by late 2016.

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PHOSPHATE ROCK

Other phosphate rock projects that were planned to begin operating by 2019 were in Algeria, Australia, Brazil, China, Egypt, Jordan, Kazakhstan, Peru, Russia, and Tunisia. Offshore mining projects in Namibia have been delayed until after 2019, owing to a moratorium on offshore mining from October 2013 through March 2015 to study the possible effects to the fishing industry. After the moratorium expired, no significant progress had been made in resolving the issue. An environmental assessment had not been completed and the Namibian Government has not issued any mining licenses. About 10 other projects throughout Africa were in various stages of development in 2015, but none were expected to begin production until after 2020.

World consumption of P_2O_5 contained in fertilizers and industrial uses was projected to increase gradually from 43.7 million tons in 2015 to 48.2 million tons in 2019.

World Mine Production and Reserves: Reserves in Brazil, Egypt, and India were revised based on information from official Government sources. Reserves for Canada were moved to "Other countries" because no phosphate rock was produced in Canada in 2014 and 2015.

	Mine production		Reserves[4]
	2014	2015[e]	
United States	25,300	27,600	1,100,000
Algeria	1,500	1,200	2,200,000
Australia	2,600	2,600	1,000,000
Brazil	6,040	6,700	320,000
China[5]	100,000	100,000	3,700,000
Egypt	5,500	5,500	1,200,000
India	1,110	1,100	65,000
Iraq	200	200	430,000
Israel	3,360	3,300	130,000
Jordan	7,140	7,500	1,300,000
Kazakhstan	1,600	1,600	260,000
Mexico	1,700	1,700	30,000
Morocco and Western Sahara	30,000	30,000	50,000,000
Peru	3,800	4,000	820,000
Russia	11,000	12,500	1,300,000
Saudi Arabia	3,000	3,300	960,000
Senegal	900	1,000	50,000
South Africa	2,160	2,200	1,500,000
Syria	1,230	750	1,800,000
Togo	1,200	1,000	30,000
Tunisia	3,780	4,000	100,000
Vietnam	2,700	2,700	30,000
Other countries	2,370	2,600	380,000
World total (rounded)	218,000	223,000	69,000,000

World Resources: Some world reserves were reported only in terms of ore 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.

Substitutes: There are no substitutes for phosphorus in agriculture.

[e]Estimated.
[1]Defined as phosphate rock sold or used + imports.
[2]Marketable phosphate rock, weighted value, all grades.
[3]Defined as imports – exports + adjustments for industry stock changes.
[4]See Appendix C for resource/reserve definitions and information concerning data sources.
[5]Production data for large mines only.

PLATINUM-GROUP METALS

(Platinum, palladium, rhodium, ruthenium, iridium, osmium)
(Data in kilograms unless otherwise noted)

Domestic Production and Use: In 2015, one domestic mining company produced platinum-group metals (PGMs) with an estimated value of nearly $532 million from its two mines in south-central Montana. Small quantities of PGMs were also recovered as byproducts of copper refining. The leading use for PGMs continued to be in catalytic converters to decrease harmful emissions from automobiles. PGMs are also used in catalysts for bulk-chemical production and petroleum refining; in electronic applications, such as in computer hard disks to increase storage capacity, in multilayer ceramic capacitors, and in hybridized integrated circuits; in glass manufacturing; jewelry; and in laboratory equipment. Platinum is used in the medical sector; platinum and palladium, along with gold-silver-copper-zinc alloys, are used as dental restorative materials. Platinum, palladium, and rhodium are used as investments in the form of exchange-traded products, as well as through the individual holding of physical bars and coins.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Mine production:[1]					
Platinum	3,700	3,670	3,720	3,660	3,700
Palladium	12,400	12,300	12,600	12,400	12,500
Imports for consumption:					
Platinum	129,000	172,000	116,000	141,000	139,000
Palladium	98,900	80,100	83,100	92,400	89,000
Rhodium	13,100	12,800	11,100	11,100	11,000
Ruthenium	13,300	10,200	15,300	11,100	9,000
Iridium	2,790	1,230	1,720	1,990	730
Osmium	48	130	77	322	40
Exports:					
Platinum	11,300	8,630	11,200	14,800	11,000
Palladium	32,000	32,200	25,900	22,500	27,000
Rhodium	1,370	1,040	1,220	428	600
Other PGMs	1,150	1,640	1,320	901	800
Price,[2] dollars per troy ounce:					
Platinum	1,724.51	1,555.39	1,489.57	1,387.89	1,080.00
Palladium	738.51	649.27	729.58	809.98	690.00
Rhodium	2,204.35	1,274.98	1,069.10	1,174.23	970.00
Ruthenium	165.85	112.26	75.63	65.13	48.00
Iridium	1,035.87	1,066.23	826.45	556.19	530.00
Employment, mine, number[1]	1,570	1,670	1,780	1,620	1,600
Net import reliance[3] as a percentage of apparent consumption:					
Platinum	89	90	84	89	90
Palladium	64	57	60	65	58

Recycling: An estimated 125,000 kilograms of platinum, palladium, and rhodium was recovered globally from new and old scrap in 2015, including about 55,000 kilograms recovered from automobile catalytic converters in the United States.

Import Sources (2011–14): Platinum: South Africa, 18%; Germany, 16%; United Kingdom, 13%; Canada, 11%; and other, 42%. Palladium: Russia, 24%; South Africa, 24%; United Kingdom, 21%; Switzerland, 6%; and other, 25%.

Tariff: All unwrought and semimanufactured forms of PGMs are imported duty free.

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

Government Stockpile: Sales of iridium and platinum from the National Defense Stockpile remained suspended through FY 2015.

Stockpile Status—9–30–15[4]

Material	Inventory	Disposal Plan FY 2015	Disposals FY 2015
Platinum	261	—	—
Iridium	15	—	—

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PLATINUM-GROUP METALS

Events, Trends, and Issues: Platinum mining companies in South Africa continued to recover from the effects of the 5-month-long workers' strike that took place in 2014. Although rampup in production was completed during 2015 by the three major mining companies affected by the strike, total South African production was lower than prestrike levels. Low metal prices continued to adversely affect the mining industry. Some companies placed mines on care-and-maintenance status, one mining company sold unprofitable mines, and some mining companies implemented work force reductions. The mining sector in South Africa also continued to be affected by insufficient electric power generation capacity and increased power costs, labor unrest, and safety-related stoppages.

Production by the sole U.S. PGM-mining company increased slightly. However, owing to low metal prices, the company adjusted its mine plan to focus on the most profitable areas of one of its mines, planned to continue to maximize production at its other mine, and planned a reorganization that included reducing the number of workers.

Global economic conditions, including slower growth of China's economy and reduced PGM demand, resulted in lower PGM prices. Monthly average prices of platinum and rhodium generally decreased from January through August; palladium monthly average prices remained unchanged through May and then decreased through August. The average monthly prices for platinum, palladium, and rhodium in August were at their lowest levels in 6 years, 3 years, and 11 years, respectively. Daily platinum prices, which generally track the trend of gold prices, were below those of gold from February through September. The monthly average prices for iridium and ruthenium fell from June through August owing to weak industrial demand.

Introduction in some countries of more stringent emission standards for automobiles was expected to result in increased demand for palladium, platinum, and rhodium for use in catalytic converters. Automobile production levels were expected to increase, particularly in developing countries, and this was also expected to increase demand for platinum-group metals in 2015 and beyond.

World Mine Production and Reserves:

	Mine production				PGMs
	Platinum		Palladium		Reserves[5]
	2014	2015[e]	2014	2015[e]	
United States	3,660	3,700	12,400	12,500	900,000
Canada	8,500	9,000	20,000	24,000	310,000
Russia	23,000	23,000	83,000	80,000	1,100,000
South Africa	94,000	125,000	58,400	73,000	63,000,000
Zimbabwe	12,500	12,500	10,100	10,000	([6])
Other countries	5,800	4,800	9,000	8,000	800,000
World total (rounded)	147,000	178,000	193,000	208,000	66,000,000

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: Less-expensive palladium has been substituted for platinum in most gasoline-engine catalytic converters. About 25% 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. — Zero.
[1]Estimates from published sources.
[2]Engelhard Corp. unfabricated metal.
[3] Defined as imports – exports + adjustments for industry stock changes.
[4] See Appendix B for definitions.
[5]See Appendix C for resource/reserve definitions and information concerning data sources.
[6]Included with "Other countries."

POTASH

(Data in thousand metric tons of K_2O equivalent unless otherwise noted)

Domestic Production and Use: In 2015, the production value of marketable potash, f.o.b. mine, was about $680 million. Potash was produced in New Mexico and Utah. Most of the production was from southeastern New Mexico, where two companies operated four mines. Sylvinite and langbeinite ores in New Mexico were beneficiated by flotation, dissolution-recrystallization, heavy-media separation, solar evaporation, or combinations of these processes, and provided more than 75% of total U.S. producer sales. In Utah, two companies operated three mines. 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 potassium chloride (muriate of potash or MOP) from byproduct sodium chloride. The firm also processed subsurface brines by solar evaporation and flotation to produce MOP at its other facility. Another company processed brine from the Great Salt Lake by solar evaporation to produce potassium sulfate (sulfate of potash or SOP) and byproducts.

The fertilizer industry used about 85% of U.S. potash sales, and the chemical industry used the remainder. About 60% of the potash produced was MOP. Potassium magnesium sulfate (sulfate of potash-magnesia or SOPM) and SOP, which are required by certain crops and soils, accounted for the remaining 40% of production.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, marketable[1]	1,000	900	960	850	770
Sales by producers, marketable[1]	990	980	880	930	760
Imports for consumption	4,980	4,240	4,650	4,970	4,000
Exports	202	234	289	118	30
Consumption, apparent[1, 2]	5,800	5,000	5,200	5,800	4,700
Price, dollars per ton of K_2O, average, muriate, f.o.b. mine[3]	730	710	640	580	635
Employment, number:					
Mine	660	750	760	670	600
Mill	620	740	770	660	620
Net import reliance[4] as a percentage of apparent consumption	83	82	82	85	84

Recycling: None.

Import Sources (2011–14): Canada, 84%; Russia, 9%; Israel, 3%; Chile, 2%; and other, 2%.

Tariff:

Item	Number	Normal Trade Relations 12–31–15
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.
Potassium-sodium nitrate mixtures	3105.90.0010	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: U.S. consumption, imports, production, and sales of potash were estimated to be lower in 2015 compared with those in 2014. Production decreased, owing in part to one company in New Mexico producing only SOPM after it ceased production of MOP at the mine at the end of 2014. In addition, the leading U.S. potash producer closed one mine in New Mexico for 15 days for maintenance issues. Consumption and imports were lower because many farmers postponed buying potash because of high inventories and anticipation of lower prices in the fourth quarter. The price of potash increased primarily because of higher prices in the first half of 2015. U.S. imports of potash account for more than 80% of consumption. Most of the imports are from Canada, which has the world's largest reserves and production capacity and lower production costs than in the United States.

The leading potash producer announced in late 2015 that it would stop production of MOP and only recover SOPM at one of its three mines in New Mexico. The company would use MOP from its lower cost solar solution mine, which began operating at normal levels in 2015, to replace MOP from the old mine.

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POTASH

A Canadian company continued development of a new underground potash mine in southeastern New Mexico that would produce SOP only. The company planned to begin production in 2017 or 2018, with an annual production capacity of 714,000 tons of SOP.

Annual production capacity was projected to increase globally from 52 million tons in 2015 to 61 million tons in 2019. More than one-half of the new capacity would be from expansions of existing facilities in Belarus, Canada, China, and Russia. The remainder would be from new mines in Belarus, Canada, Russia, Turkmenistan, the United States, and Uzbekistan. In 2015, Belarus, Canada, China, and Russia accounted for 75% of world production and capacity and by 2019 could account for 80% of world production capacity. Other significant potash projects were under development in Australia, Brazil, Canada, Congo (Brazzaville), Eritrea, Ethiopia, Kazakhstan, Laos, Peru, Thailand, and the United Kingdom. None of these projects, however, were expected to be completed until after 2020.

In 2015, world consumption was estimated to have increased slightly over that of 2014, owing to higher fertilizer consumption in India and South America, which offset level consumption in the rest of the world. World consumption for all uses of potash was projected to increase gradually from 35.5 million tons K_2O in 2015 to 39.5 million tons K_2O in 2019. Asia and South America would account for most of the growth in consumption.

World Mine Production and Reserves: U.S. reserves were revised to reflect the closure of one mine in late 2013 and another ceasing production of MOP in 2014. Reserves for Brazil (K_2O) were revised with official Government data. Reserves for Canada were reduced owing to one company revising its resource evaluation after completion of a new pilot plant study. Reserves for Israel and Jordan were revised to reflect the potassium content of the Dead Sea and the potential amount of potash that could be recovered.

	Mine production		Reserves[5]	
	2014	2015[e]	Recoverable ore	K_2O equivalent
United States[1]	850	770	1,500,000	120,000
Belarus	6,290	6,500	3,300,000	750,000
Brazil	311	311	300,000	13,000
Canada	11,000	11,000	4,200,000	1,000,000
Chile	1,200	1,200	NA	150,000
China	4,400	4,200	NA	210,000
Germany	3,000	3,000	NA	150,000
Israel	1,770	1,800	NA	[6]270,000
Jordan	1,260	1,250	NA	[6]270,000
Russia	7,380	7,400	2,800,000	600,000
Spain	715	700	NA	20,000
United Kingdom	610	610	NA	70,000
Other countries	50	50	250,000	90,000
World total (rounded)	38,800	38,800	NA	3,700,000

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 the 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]Average prices based on actual sales; excludes soluble and chemical muriates.
[4]Defined as imports – exports.
[5]See Appendix C for resource/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 2015, 11 operations in six States produced pumice and pumicite. Estimated production[1] was 280,000 tons with an estimated processed value of about $9.0 million, f.o.b. plant. Pumice and pumicite were mined in Oregon, Idaho, California, New Mexico, Kansas, and Oklahoma, in descending order of production. About 47% of mined pumice was used in the production of construction building block and 23% was used for horticultural purposes. The remainder was consumed in abrasives, concrete admixtures and aggregates, and other uses, including absorbent, filtration, laundry stone washing, and road use.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, mine[1]	343	338	269	278	280
Imports for consumption	23	67	72	60	85
Exports[e]	14	12	13	14	11
Consumption, apparent	352	393	328	324	354
Price, average value, dollars per ton, f.o.b. mine or mill	30.63	31.88	34.64	32.41	32
Employment, mine and mill, number	140	140	140	140	140
Net import reliance[2] as a percentage of apparent consumption	3	14	18	14	21

Recycling: Not available.

Import Sources (2011–14): Greece, 93%; Iceland, 4%; Mexico, 2%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
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.

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PUMICE AND PUMICITE

Events, Trends, and Issues: The amount of domestically produced pumice and pumicite sold or used in 2015 was essentially unchanged from that in 2014. Imports increased and exports decreased compared with those of 2014. Almost all imported pumice originated from Greece in 2015, 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.

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.

All known domestic pumice and pumicite mining in 2015 was accomplished through open pit methods, generally in remote areas where land-use conflicts were not significant obstacles. Although the generation and disposal of reject fines in mining and milling resulted in local dust issues at some operations, the environmental impact was restricted to a relatively small geographic area.

World Mine Production and Reserves:

	Mine production		Reserves[3]
	2014	2015[e]	
United States[1]	278	280	Large in the United States. Quantitative estimates of reserves for most countries are not available.
Algeria[4]	315	350	
Cameroon[4]	600	650	
Chile[4]	830	830	
Ecuador[4]	1,050	1,100	
Ethiopia	420	420	
France[4]	276	280	
Greece[4]	1,230	1,200	
Guadeloupe	200	200	
Italy[4]	4,030	4,030	
Saudi Arabia[4]	1,000	1,000	
Spain	195	195	
Syria[4]	324	315	
Turkey	5,200	5,500	
Other countries[4]	850	850	
World total (rounded)	16,800	17,200	

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 imports – exports.
[3]See Appendix C for resource/reserve definitions and information concerning data sources.
[4]Includes pozzolan and (or) volcanic tuff.

QUARTZ CRYSTAL (INDUSTRIAL)

(Data in kilograms unless otherwise noted)

Domestic Production and Use: Cultured quartz crystal is produced by two companies in the United States, but production statistics were not available. One of these companies uses cultured quartz crystal that has been rejected owing to crystallographic imperfections 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. Lascas[1] mining and processing in Arkansas ended in 1997.

Virtually all quartz crystal used for electronics was cultured, rather than natural, crystal. Electronic-grade quartz crystal is essential for making 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: The U.S. Census Bureau, which is the primary Government source of U.S. trade data, does not provide specific import or export statistics on lascas. The U.S. Census Bureau collects import and export statistics on electronic and optical-grade quartz crystal; however, the quartz crystal import and export quantities and values reported were predominantly fused mullite and fused zirconia that was inadvertently reported to be quartz crystal, not including mounted piezoelectric crystals. The price of as-grown cultured quartz was estimated to be $280 per kilogram in 2015. Lumbered quartz, which is as-grown cultured quartz that has been processed by sawing and grinding, was estimated to range from $20 per kilogram to more than $1,000 per kilogram in 2015, depending on the application. Other salient statistics were not available.

Recycling: An unspecified amount of rejected cultured quartz crystal was used as feed material for the production of cultured quartz crystal.

Import Sources (2011–14): Although no definitive data exist listing import sources for cultured quartz crystal, imported material is thought to be mostly from China, Japan, Romania, and the United Kingdom.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Quartz (including lascas)	2506.10.0050	Free.
Piezoelectric quartz	7104.10.0000	3% ad val.

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

Government Stockpile: As of September 30, 2015, 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 2015. Previously, only individual crystals in the stockpile that weighed 10 kilograms or more and could be used as seed material were sold.

Stockpile Status—9–30–15[2]

Material	Inventory	Disposal Plan FY 2015	Disposals FY 2015
Quartz crystal	7,148	—	—

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QUARTZ CRYSTAL (INDUSTRIAL)

Events, Trends, and Issues: Demand for 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 automotive stability control applications. Future capacity increases to grow quartz crystal may be negatively affected by this development. 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 quartz crystal.

World Mine Production and Reserves:[3] 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 growth nutrient could mean a decreased dependence on lascas for growing cultured quartz.

Substitutes: Quartz crystal is the best material for frequency-control oscillators and frequency filters 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.

— Zero.
[1]Lascas is a nonelectronic-grade quartz used as a feedstock for growing cultured quartz crystal and for production of fused quartz.
[2]See Appendix B for definitions.
[3]See Appendix C for resource/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 for part of the year by one company in 2015. Bastnäsite, a fluorocarbonate mineral, was mined and processed into concentrates and rare-earth compounds at Mountain Pass, CA. The United States continued to be a net importer of rare-earth products in 2015. The estimated value of rare-earth compounds and metals imported by the United States in 2015 was $150 million, a decrease from $191 million imported in 2014. The estimated distribution of rare earths by end use was as follows, in decreasing order: catalysts, 60%; metallurgical applications and alloys, 10%; ceramics and glass, 10%; glass polishing, 10%; and other, 10%.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production, bastnäsite concentrates	—	3,000	5,500	5,400	4,100
Imports:[2]					
Compounds:					
Cerium compounds	1,120	1,390	1,110	1,440	1,400
Other rare-earth compounds	6,020	3,400	7,330	9,400	9,700
Metals:					
Ferrocerium, alloys	186	276	313	371	360
Rare-earth metals, scandium, and yttrium	468	240	393	348	460
Exports:[2]					
Compounds:					
Cerium compounds	1,640	996	734	608	600
Other rare-earth compounds	3,620	1,830	5,570	3,800	6,000
Metals:					
Ferrocerium, alloys	2,010	960	1,420	1,640	1,200
Rare-earth metals, scandium, and yttrium	3,030	2,080	1,050	140	60
Consumption, estimated	11,000	15,000	15,000	17,000	17,000
Price, dollars per kilogram, yearend:[3]					
Cerium oxide, 99.5% minimum	40–45	10–12	5–6	4–5	2
Dysprosium oxide, 99.5% minimum	1,400–1,420	600–630	440–490	320–360	215–240
Europium oxide, 99.9% minimum	3,780–3,800	1,500–1,600	950–1,000	680–730	130–175
Lanthanum oxide, 99.5% minimum	50–52	9–11	6	5	2
Mischmetal, 65% cerium, 35% lanthanum	47–49	14–16	9–10	9–10	5–6
Neodymium oxide, 99.5% minimum	190–200	75–80	65–70	56–60	37–42
Terbium oxide, 99.99% minimum	2,800–2,820	1,200–1,300	800–850	590–640	410–490
Employment, mine and mill, annual average	146	275	380	391	351
Net import reliance[4] as a percentage of estimated consumption	100	80	63	68	76

Recycling: Limited quantities, from batteries, permanent magnets, and fluorescent lamps.

Import Sources (2011–14): Rare-earth compounds and metals: China, 71%; Estonia, 7%; France, 6%; Japan, 6%; and other, 10%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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).

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RARE EARTHS

Government Stockpile: None.

Events, Trends, and Issues: In 2015, excess supply caused prices for rare-earth compounds and metals to decline significantly, and China continued to dominate the global supply of rare earths. According to China's Rare Earth Industry Association, consumption of rare-earth oxides in China was forecast to increase from 98,000 tons in 2015 to 149,000 tons in 2020. In 2015, China's consumption was led by magnets (35%), abrasives (18%), and catalysts (15%). Illegal production was cited as a major factor in declining prices. According to sources in China, despite Government efforts, illegal production of rare-earth materials was ongoing. China's rare-earths industry was in the process of being consolidated into six major industrial entities. The rare-earth mining production quota for 2015 was set at 105,000 tons, unchanged from 2014. China ended its rare-earth export quotas, removed export tariffs, and began to impose resource taxes on rare earths based on sales value instead of production quantity. Through October 2015, China had exported 26,800 tons of rare-earth materials, a 20% increase compared with exports for the same period in 2014. Production of rare-earth oxide equivalent in Malaysia, derived from Australian mine production, was 7,750 tons through September 2015, a 55% increase compared with the same period in 2014. U.S. domestic consumption of rare-earth compounds and metals was estimated to be nearly unchanged compared with that of 2014. In October, the Mountain Pass mining and separation operations were idled indefinitely. Price declines were cited as a key factor in the suspension of operations. The suspension resulted in a decline in mine production and exports of rare-earth compounds.

Exploration efforts to develop rare-earth projects continued in 2015. Exploration and development assessments in the United States included Bear Lodge, WY; Bokan Mountain, AK; Diamond Creek, ID; Elk Creek, NE; La Paz, AZ; Lemhi Pass, ID-MT; Pea Ridge, MO; Round Top, TX; and Thor, NV. Additional projects were underway in Australia, Brazil, Canada, China, Finland, Greenland, India, Kyrgyzstan, Madagascar, Malawi, Mozambique, Namibia, South Africa, Sweden, Tanzania, Turkey, and Vietnam.

World Mine Production and Reserves:

	Mine production[e]		Reserves[5]
	2014	2015	
United States	5,400	4,100	1,800,000
Australia	8,000	10,000	[6]3,200,000
Brazil	—	—	22,000,000
China[7]	105,000	105,000	55,000,000
India	NA[8]	NA[8]	3,100,000
Malaysia	240	200	30,000
Russia	2,500	2,500	([9])
Thailand[10]	2,100	2,000	NA
Other countries	NA	NA	41,000,000
World total (rounded)	123,000	124,000	130,000,000

World Resources: Rare earths are relatively abundant in the Earth's crust, but discovered minable concentrations are less common than for most other ores. U.S. and world resources are contained primarily in bastnäsite and monazite. Bastnäsite deposits in China and the United States constitute the largest percentage of the world's rare-earth economic resources, and monazite deposits constitute the second largest segment.

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

[e]Estimated. 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]Price range from Metal-Pages Ltd.
[4]Defined as estimated consumption – production. Insufficient data were available to determine stock changes and unattributed imports and exports of rare-earth materials.
[5]See Appendix C for resource/reserve definitions and information concerning data sources.
[6]For Australia, Joint Ore Reserves Committee-compliant reserves were about 2.2 million tons.
[7]Production quota does not include undocumented production.
[8]Significant quantities are contained in stockpiled monazite tailings, but quantitative data are not available.
[9]Included with "Other countries."
[10]Based on imports to China.

RHENIUM

(Data in kilograms of rhenium content unless otherwise noted)

Domestic Production and Use: During 2015, ores containing 8,500 kilograms of rhenium were mined at nine operations (six in Arizona, and one each in Montana, New Mexico, 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 70% and 20%, 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-based 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 estimated value of rhenium consumed in 2015 was about $80 million.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production[1]	8,610	7,910	7,100	8,500	8,500
Imports for consumption	33,500	40,800	27,600	24,800	32,600
Exports	NA	NA	NA	NA	NA
Consumption, apparent	42,100	48,700	34,700	33,300	41,000
Price,[2] average value, dollars per kilogram, gross weight:					
Metal pellets, 99.99% pure	4,670	4,040	3,160	3,000	2,900
Ammonium perrhenate	4,360	3,990	3,400	3,100	2,800
Employment, number	Small	Small	Small	Small	Small
Net import reliance[3] as a percentage of apparent consumption	80	84	80	74	79

Recycling: Nickel-based 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 a growing number of companies, mainly in the United States, Canada, Estonia, Germany, and Russia. Rhenium-containing catalysts were also recycled.

Import Sources (2011–14): Rhenium metal powder: Chile, 87%; Poland, 8%; Germany, 2%; and other, 3%. Ammonium perrhenate: Kazakhstan, 43%; Republic of Korea, 36%; Canada, 8%; Germany, 5%; and other, 8%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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 (and other metals), 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.

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RHENIUM

Events, Trends, and Issues: During 2015, the United States continued to rely on imports for much of its supply of rhenium. Chile, Germany, Kazakhstan, Poland, and the Republic of Korea supplied most of the imported rhenium. Rhenium imports for consumption increased by 31% from those of 2014. Primary rhenium production in the United States stayed the same as that of 2014. Operations at the Zhezkazgan smelter and refinery in Kazakhstan were temporarily suspended in mid-2013. The facility was being upgraded to process copper-molybdenum ore from the newly developed Bozshakol mining and concentrating complex also in Kazakhstan. Operations were expected to reopen by 2017. Therefore, during 2014 and 2015, Kazakhstan only produced a small amount of APR.

In 2015, both rhenium metal and catalytic-grade APR prices declined from those in 2014. In 2015, catalytic-grade APR prices averaged $2,800 per kilogram and rhenium metal pellet price averaged $2,900 per kilogram.

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 rhenium used in engine blades as currently designed, as well as testing rhenium-free alloys for other engine components. New technology continued to be developed to allow recycling of nickel-base superalloy scrap more efficiently. The processing of scrapped engine parts to generate engine revert increased worldwide and this increase in engine revert supply was expected to continue to have a significant impact on the rhenium market.

World Mine Production and Reserves:

	Mine production[4]		Reserves[5]
	2014	2015[e]	
United States	8,500	8,500	390,000
Armenia	351	350	95,000
Canada	—	—	32,000
Chile[6]	25,000	26,000	1,300,000
China	NA	NA	NA
Kazakhstan	300	200	190,000
Peru	—	—	45,000
Poland	7,600	7,800	NA
Russia	NA	NA	310,000
Uzbekistan	900	1,000	NA
Other countries	2,000	2,000	91,000
World total (rounded)	44,700	46,000	2,500,000

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 not included.
[2]Average price per kilogram of rhenium in pellets or catalytic-grade ammonium perrhenate, from Metal Bulletin.
[3]Defined as imports – exports + adjustments for industry stock changes.
[4]Estimated amount of rhenium recovered in association with copper and molybdenum production. Secondary rhenium production not included.
[5]See Appendix C for resource/reserve definitions and information concerning data sources.
[6]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: Rubidium is not actively 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 sources the majority of pollucite from the largest known North American deposit at Bernic Lake, Manitoba, Canada.

Applications for rubidium and its compounds include biomedical research, electronics, specialty glass, and pyrotechnics. Specialty glasses are the leading market for rubidium; rubidium carbonate is used to reduce electrical conductivity, which improves stability and durability in fiber optic telecommunications networks. Biomedical applications include rubidium salts used in antishock agents, and the treatment of epilepsy and thyroid disorder; rubidium-82, a radioactive isotope, used as a blood-flow tracer in positron emission tomographic imaging; and rubidium chloride, used as an antidepressant. Rubidium atoms are used in academic research, including the development of quantum mechanics-based computing devices, a future application with potential for relatively high consumption of rubidium. Quantum computing research uses ultracold rubidium atoms in a variety of applications. Quantum computers, which have the ability to perform more complex computational tasks than traditional computers by calculating in two quantum states simultaneously, were expected to be in prototype phase within a decade.

Rubidium's photo-emissive 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 and produce violet hues. The U.S. military frequency standard, the United States Naval Observatory (USNO) Time Scale, 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, which was sourced primarily from Canada, was exported to the United States for further processing. Industry information during the last decade suggests an annual domestic consumption rate of approximately 2,000 kilograms.

In 2015, one company offered 1-gram ampoules of 99.75%-grade rubidium (metal basis) for $80.30 and 100 grams ampoules of the same material for $1,472.00, the same as in 2014 and a 4% increase from that of 2013. The price for 10-gram ampoules of 99.8% rubidium formate hydrate (metal basis) was $56.20, the same as in 2014, and a 4% increase from that of 2013. The prices for 10 grams of 99.8% (metals basis) rubidium acetate, rubidium bromide, rubidium carbonate, rubidium chloride, and rubidium nitrate were $47.00, $62.00, $59.30, $55.10, and $45.90, respectively. The price for a rubidium-plasma standard solution (10,000 µg/ml) was $56.50 for 50 ml and $84.20 for 100 ml.

Recycling: None.

Import Sources (2011–14): The United States is 100% import reliant on byproduct rubidium-concentrate imports, most of which were thought to be imported from Canada.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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.

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RUBIDIUM

Events, Trends, and Issues: Domestic rubidium occurrences will remain uneconomic unless market conditions change, such as the discovery of new end uses or increased consumption for existing end uses, which in turn would lead to increased prices. No known human health issues are associated with naturally occurring rubidium, and its use has minimal environmental impact.

An underground mining operation at Bernic Lake, Manitoba, Canada, experienced a partial collapse in early 2013, in the area of the mine's crowning pillar, following a similar event in 2010. In 2015, work continued to stabilize the area during mine production. The mining rate was not expected to exceed 1,000 tons per day of pollucite. Operations in Argentina and Canada continued site sampling and development with the goal of establishing mines.

The National Institute of Standards and Technology created the world's first "photonic molecules," structures made of light, by firing two photons into a cloud of supercooled rubidium atoms. The development of this technology has potential applications in communications, fiber optics, and micrography. An extreme ultralow noise rubidium clock, or synchronized rubidium oscillator, was developed for potential defense applications, including airborne and radio communications, and radar.

World Mine Production and Reserves: One mine in Canada produced rubidium ore as a byproduct, which was processed as concentrate; however, production data for that mine are not available. 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 reserves are found in zoned pegmatites, which are exceptionally coarse-grained plutonic rocks that formed late in the crystallization of a silicic magma. Mineral resources exist globally, but extraction and concentration are cost prohibitive. Production is known to take place periodically in Canada, Namibia, and Zimbabwe, but production data are not available. Rubidium is also mined in China, but information regarding reserves and production is unavailable.

	Reserves[1]
Canada	12,000
Namibia	50,000
Zimbabwe	10,000
Other countries	8,000
World total	80,000

World Resources: In addition to several significant rubidium-bearing zoned pegmatites in Canada, similar pegmatite occurrences have been identified in Afghanistan, China, Denmark, Germany, Japan, Kazakhstan, Namibia, Peru, Russia, the United Kingdom, the United States, and Zambia. Minor amounts of rubidium are reported in brines in northern Chile and China and in evaporites in France, Germany, and the United States (New Mexico and Utah).

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/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 6% in 2015 to 48 million tons. The total value of salt sold or used was estimated to be about $2.3 billion. Twenty-nine companies operated 64 plants in 16 States. The top producing States, in alphabetical order, were Kansas, Louisiana, Michigan, New York, Ohio, Texas, and Utah. These seven States produced about 95% of the salt in the United States in 2015. The estimated percentage of salt sold or used was, by type, rock salt, 44%; salt in brine, 38%; solar salt, 9%; and vacuum pan salt, 9%.

Highway deicing accounted for about 46% of total salt consumed. The chemical industry accounted for about 36% of total salt sales, with salt in brine accounting for 88% 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%; food processing, 4%; agricultural, 3%; general industrial, 2%; primary water treatment, 1%; and other uses combined with exports, 1%.

Salient Statistics—United States:[1]	2011	2012	2013	2014	2015[e]
Production	45,000	37,200	39,900	45,300	48,000
Sold or used by producers	45,500	34,900	43,100	46,000	47,200
Imports for consumption	13,800	9,880	11,900	20,100	23,200
Exports	846	809	525	940	846
Consumption:					
Reported	48,000	36,900	47,600	56,500	57,000
Apparent[2]	58,500	44,000	54,500	65,200	69,500
Price, average value of bulk, pellets and packaged salt, dollars per ton, f.o.b. mine and plant:					
Vacuum and open pan salt	174.00	169.93	172.09	180.61	182.00
Solar salt	51.19	71.87	78.04	83.90	89.00
Rock salt	38.29	36.89	47.22	48.11	50.00
Salt in brine	8.14	8.44	8.49	9.08	9.15
Employment, mine and plant, number[e]	4,100	4,100	4,100	4,200	4,200
Net import reliance[3] as a percentage of apparent consumption	24	22	22	29	32

Recycling: None.

Import Sources (2011–14): Chile, 37%; Canada, 36%; Mexico, 12%; The Bahamas, 5%; and other, 10%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Salt (sodium chloride)	2501.00.0000	Free.

Depletion Allowance: 10% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: The 2014–15 winter was colder than average for the second year in a row, and the amount of frozen precipitation and the number of winter weather events were above average in many parts of the United States, requiring more salt for highway deicing. Rock salt production and imports in 2015 increased from the levels in 2014 because of increased demand from many local and State transportation departments that reported low levels of rock salt inventories at the end of the 2014–15 winter season. The majority of local and State governments in cold regions reportedly had rebuilt their stockpiles and had large supplies of rock salt available for the winter of 2015–16.

Owing to the greatly increased demand for deicing salt during severe winter weather periods, many buyers were experiencing double-digit percentage increases in spot rock salt prices for emergency salt purchases. Many contracts between salt suppliers and consumers require the customer to take delivery of at least 80 percent of its order with some options to purchase more at the agreed to unit price. But salt purchasers without contracts are subject to substantial spikes in pricing if they require an unplanned salt allocation.

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SALT

The National Oceanic and Atmospheric Administration predicted a milder winter for the traditional snowbelt in the northern tier of the United States, with average or below-average winter precipitation and average to warmer temperatures. The southern part of the United States was expected to be cooler and wetter than average. However, since the southern area traditionally uses much less salt, the overall impact may be that less salt is consumed nationwide. It was anticipated that the salt industry would be able to provide adequate salt supplies from domestic and foreign sources for emergency use in the event of harsher than anticipated winter weather.

World Production and Reserves:

	Production		Reserves[4]
	2014	2015[e]	
United States[1]	45,300	48,000	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	11,000	
Brazil	7,400	7,500	
Canada	13,000	12,500	
Chile	8,500	9,000	
China	68,000	70,000	
France	6,000	6,000	
Germany	12,200	12,500	
India	16,000	17,000	
Mexico	10,700	10,500	
Poland	4,300	4,200	
Spain	4,380	4,300	
Turkey	5,400	5,500	
Ukraine	6,100	6,100	
United Kingdom	6,700	6,700	
Other countries	41,000	42,000	
World total (rounded)	266,000	273,000	

World Resources: World continental resources of salt are vast, and the salt content in the oceans is virtually inexhaustible. 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/reserve definitions and information concerning data sources.

SAND AND GRAVEL (CONSTRUCTION)[1]

(Data in million metric tons unless otherwise noted)[2]

Domestic Production and Use: Construction sand and gravel valued at $7.2 billion was produced by an estimated 4,100 companies and government agencies from about 6,300 operations in 50 States. Leading producing States were, in order of decreasing tonnage, Texas, California, Minnesota, Washington, Michigan, Colorado, Arizona, North Dakota, Wisconsin, and Ohio, which together accounted for about 55% of total output. It is estimated that about 45% of construction sand and gravel was used as concrete aggregates; 25% for road base and coverings and road stabilization; 13% as asphaltic concrete aggregates and other bituminous mixtures; 12% as construction fill; 1% each for concrete products, such as blocks, bricks, and pipes; plaster and gunite sands; and snow and ice control; and the remaining 2% for filtration, golf courses, railroad ballast, roofing granules, and other miscellaneous uses.

The estimated output of construction sand and gravel in the 48 continuous States, 702 million tons shipped for consumption in the first 9 months of 2015, was 5% higher than the 672 million tons estimated for the same period in 2014. 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:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production	809	816	850	[e]904	931
Imports for consumption	3	4	4	5	4
Exports	([3])	([3])	([3])	([3])	([3])
Consumption, apparent	812	820	854	908	935
Price, average value, dollars per ton	7.49	7.66	7.61	7.68	7.72
Employment, mines, mills, and shops, number	29,800	30,600	30,000	28,600	28,100
Net import reliance[4] as a percentage of apparent consumption	([3])	([3])	([3])	([3])	([3])

Recycling: Recycling of asphalt road surface layers, cement concrete surface layers, and concrete structures was increasing, although it was still a small percentage of aggregates consumption.

Import Sources (2011–14): Canada, 89%; Mexico, 7%; Norway, 1%; and other, 3%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
Sand, silica and quartz, less than 95% silica	2505.10.5000	Free.
Sand, other	2505.90.0000	Free.
Pebbles and gravel	2517.10.0015	Free.

Depletion Allowance: Common varieties, 5% (Domestic and foreign).

Government Stockpile: None.

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SAND AND GRAVEL (CONSTRUCTION)

Events, Trends, and Issues: With U.S. economic activity gradually improving, construction sand and gravel output for 2015 increased by about 3% compared with that of 2014. According to the U.S. Census Bureau of the Department of Commerce, construction spending in the United States for the first 10 months of 2015 increased by about 4% compared to the same period in 2014. These numbers are also reflected in the quarterly reports with a steady increase over the last five quarters in sand and gravel sales. However, production remains significantly lower than that of 2006 when sand and gravel reached an alltime high of 1.34 billion tons, before the recession began in 2008.

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, driven by regulations and local sentiment. Resultant regional shortages of construction sand and gravel could thus result in higher-than-average price increases in industrialized and urban areas. Owing to the strengthening demand for sand in other parts of the world, there is an increasing trend in illegal sand mining and dredging. This is fueled largely by the demand for concrete, which uses large quantities of sand.

World Mine Production and Reserves:

	Mine production[e]		Reserves[5]
	2014	2015	
United States	904	931	Reserves are controlled largely by land use and (or) environmental concerns.
Other countries[6]	NA	NA	
World total	NA	NA	

World Resources: Sand and gravel resources of the world are plentiful. However, because of environmental restrictions, geographic distribution, and quality requirements for some uses, sand and gravel extraction is uneconomic in some locations. 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 small in 2015.

[e]Estimated. NA Not available.
[1]See also Sand and Gravel (Industrial) and Stone (Crushed).
[2]See Appendix A for conversion to short tons.
[3]Less than ½ unit.
[4]Defined as imports – exports.
[5]See Appendix C for resource/reserve definitions and information concerning data sources.
[6]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 country chapters of the USGS Minerals Yearbook.

SAND AND GRAVEL (INDUSTRIAL)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2015, industrial sand and gravel valued at about $8.3 billion was produced by 230 companies from 335 operations in 35 States. The value of production of industrial sand and gravel in 2015 remained unchanged over the previous year. Leading States were, in order of tonnage produced, Wisconsin, Texas, Illinois, Minnesota, Missouri, Oklahoma, Arkansas, Ohio, North Carolina, and Louisiana. Combined production from these States accounted for 83% of the domestic total. About 71% of the U.S. tonnage was used as hydraulic-fracturing sand and well-packing and cementing sand; 8% as other whole-grain silica; 7% as glassmaking sand; 6% as foundry sand; 2%, each, as whole-grain fillers and building products, and other ground silica; 1% as ground and unground sand for chemicals; and 3% for other uses.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production	43,800	50,600	62,100	110,000	94,900
Imports for consumption	316	306	160	244	300
Exports	4,330	4,360	2,960	4,450	4,500
Consumption, apparent	39,800	46,600	59,300	106,000	90,700
Price, average value, dollars per ton	45.74	52.80	55.80	74.80	86.93
Employment, quarry and mill, number[e]	3,000	3,500	3,800	4,000	3,800
Net import reliance[2] 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 (2011–14): Canada, 83%; Mexico, 11%; and other, 6%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
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 90.7 million tons in 2015, a 14% decrease from that of the previous year. Mine output was sufficient to accommodate many uses, which included ceramics, chemicals, container, fillers (ground and whole grain), filtration, flat and specialty glass, foundry, hydraulic fracturing, and recreational uses. Decreased demand for hydraulic-fracturing sand to support production of natural gas and petroleum from shale deposits has led to slackened production beginning at yearend 2014 and continuing into 2015. New and more efficient hydraulic-fracturing techniques, which require more silica sand use per well (mostly for secondary recovery at mature wells) could stabilize demand for hydraulic-fracturing sand. Although the United States remains a net exporter of industrial sand and gravel, imports in 2015 increased to about 300,000 tons from 244,000 tons in 2014. 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). Exports of industrial sand and gravel increased slightly in 2015 compared with those of 2014.

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SAND AND GRAVEL (INDUSTRIAL)

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.

The industrial sand and gravel industry continued to be concerned with safety and health regulations and environmental restrictions in 2015, especially those concerning crystalline silica exposure. The Occupational Safety and Health Administration was formulating new regulations to further restrict exposure to crystalline silica at mine sites, with final implementation scheduled for January 2017. Local shortages of industrial sand and gravel were expected to continue to increase owing to local zoning regulations and land development alternatives, 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 situations are expected to cause future sand and gravel operations to be located farther from high-population centers.

World Mine Production and Reserves:

	Mine production[e]		Reserves[3]
	2014	**2015**	
United States	110,000	94,900	
Australia	5,500	5,500	Large. Industrial sand and gravel deposits are widespread.
Canada	1,690	1,700	
Chile	1,360	1,350	
Czech Republic	1,270	1,270	
Finland	2,400	2,400	
France	8,750	8,750	
Germany	7,500	7,500	
India	3,430	3,400	
Italy	13,900	13,900	
Japan	3,000	3,000	
Malaysia	1,240	1,250	
Mexico	3,590	3,600	
Moldova	3,500	3,800	
Norway	1,000	1,000	
Poland	2,300	2,300	
Saudi Arabia	1,400	1,400	
South Africa	2,110	2,100	
Spain	3,400	3,400	
Turkey	7,970	8,000	
United Kingdom	4,000	4,000	
Other countries	6,030	6,000	
World total (rounded)	196,000	181,000	

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 more costly 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 imports – exports.
[3]See Appendix C for resource/reserve definitions and information concerning data sources.

SCANDIUM[1]

(Data in metric tons of scandium oxide content unless otherwise noted)

Domestic Production and Use: Domestically, scandium-bearing minerals were neither mined nor recovered from mine tailings in 2015. Scandium that was previously produced domestically was primarily from the scandium-yttrium silicate mineral thortveitite and from byproduct leach solutions from uranium operations. Domestic capacity to produce ingot and distilled scandium metal was at three facilities, in Ames, IA; Phoenix, AZ; and Urbana, IL. The principal source for scandium metal and scandium compounds was imports from China.

The principal uses for scandium in 2015 were in solid oxide fuel cells (SOFCs) and aluminum-scandium alloys. Other uses for scandium included ceramics, electronics, lasers, lighting, and radioactive isotopes. In SFOCs, electricity is generated directly from oxidizing a fuel. Scandium is added to a zirconia-base electrolyte to improve the power density and lower the reaction temperature of the cell. For metal applications, scandium metal is typically produced by reducing scandium fluoride with calcium metal. Scandium-aluminum alloys are produced for sporting goods, aerospace, and other high-performance applications. Scandium is used in small quantities in a number of electronic applications. Some lasers that contain scandium are used in defense applications and in dental treatments. In lighting, scandium iodide is used in mercury-vapor high-intensity lights to simulate natural light. Scandium isotopes are used as a tracing agent in oil refining.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Price, yearend, dollars:					
Compounds, per gram:					
Acetate, 99.9% purity, 5-gram sample size[2]	48.40	50.10	51.90	43.00	43.00
Chloride, 99.9% purity, 5-gram sample size[2]	138.00	143.00	148.00	123.00	123.00
Fluoride, 99.9% purity, 5-gram sample size[2]	235.80	244.00	253.00	263.00	263.00
Iodide, 99.999% purity, 5-gram sample size[2]	213.00	220.00	228.00	187.00	187.00
Oxide, 99.99% purity, 5-kilogram lot size[3]	4.70	4.70	5.00	5.40	5.10
Metal:					
Scandium, distilled dendritic, per gram, 2-gram sample size[2]	199.00	206.00	213.00	221.00	221.00
Scandium, ingot, per gram, 5-gram sample size[2]	163.00	169.00	175.00	134.00	134.00
Scandium-aluminum alloy, per kilogram, metric-ton lot size[2]	220.00	220.00	155.00	386.00	220.00
Net import reliance[4] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2010–14): Although no definitive data exist listing import sources, imported material is mostly from China.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–15**
Rare-earth metals, scandium and yttrium, whether or not intermixed or interalloyed	2805.30.0000	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 rare earth oxides, including scandium	2846.90.2040	Free.
Mixtures of rare-earth carbonates, other, including scandium	2846.90.8075	3.7% ad val.
Other rare-earth compounds, including scandium	2846.90.8090	3.7% ad val.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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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 increasing. Prices for small samples of scandium metal and scandium compounds varied significantly, but generally were unchanged compared with those in 2014. The global scandium market remained small relative to most other metals. In the United States, developers of multimetallic deposits, including the Round Top project in Texas and the Elk Creek project in Nebraska, were examining the incorporation of scandium recovery into project plans.

In New South Wales, Australia, definitive feasibility and economic assessment studies of the Nyngan scandium project neared completion. Using a 100-parts-per-million scandium cutoff grade, measured and indicated resources were 12 million tons containing about 3,100 tons of scandium. The developer expected to complete project financing and begin construction in 2016. The project was expected to produce as much as 36 tons per year of scandium oxide. Also in New South Wales, developers of the Syerston project were conducting demonstration plant studies, a drilling program, and expected to complete a feasibility study in 2016. Using a 600-parts-per-million scandium cutoff grade, the measured and indicated resource of the Syerston project was reported to be 1.2 million tons containing about 1,200 tons of scandium oxide. In northern Queensland, Australia, the developers of the SCONI project were seeking joint- venture partners. The measured and indicated resources of the SCONI project were about 11 million tons containing 2,700 tons of scandium oxide using a 100-parts-per-million scandium cutoff grade. The project's prefeasibility studies were based on an operation producing up to 50 tons per year of scandium oxide.

In Quebec, Canada, one company was developing technology to recover scandium and high-purity alumina from red mud (a residue generated during the production of alumina), fly ash, and mine tailings. In 2015, the company was commissioning a high-purity alumina plant and planned to add a scandium extraction unit in 2016. Feedstock for the plant was from the Grande-Vallée clay deposit in Quebec.

In Japan, efforts were underway to recover scandium and other metals from a titanium dioxide pigment production facility using ion-exchange extraction processes. If a pilot-plant study is successful, the proprietary technology could be scaled up and used at other titanium dioxide pigment production facilities.

In the Philippines, a 10-kilogram-per-month pilot plant was recovering scandium oxide following the leaching of nickel laterite for nickel-cobalt sulfide. At yearend, a decision to construct a commercial-scale plant had not been reached.

In Russia, an aluminum producer was conducting a pilot-plant study to produce scandium concentrate from red mud. The plant was reported to be capable of producing 2.5 tons per year of concentrate. Additional plans called for an additional 500-kilogram-per-year pilot plant to process the scandium concentrate into scandium oxide. In Lermontov, Kurgan region, a pilot study was underway to recover as much as 1.5 tons of scandium as a byproduct of uranium production. Scandium recovery projects were also being considered in Japan, Kazakhstan, and Ukraine.

World Mine Production and Reserves:[5] 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 (titanium and rare earths), Kazakhstan (uranium), Russia (apatite), and Ukraine (uranium). Foreign mine production data in 2015 were not available.

World Resources: Resources of scandium are abundant in relation to demand. Scandium is rarely concentrated in nature because of its lack of affinity for the common ore-forming anions. It is widely dispersed in the lithosphere and forms solid solutions in more than 100 minerals. There are identified scandium resources in Australia, Canada, China, Kazakhstan, Madagascar, Norway, the Philippines, Russia, and Ukraine.

Substitutes: Titanium and aluminum high-strength alloys, as well as carbon-fiber materials, may substitute in high-performance scandium-alloy applications. Light-emitting diodes, also known as LEDs, displace halide and fluorescent lighting in 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.
[2]Prices from Alfa Aesar, a Johnson Matthey company.
[3]Prices from Stanford Materials Corp.
[4]Defined as imports – exports + adjustments for stock changes.
[5]See Appendix C for resource/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 three electrolytic copper refineries operating in the United States, one in Texas reported production of primary selenium, one exported semirefined selenium for toll refining in Asia, and one generated selenium-containing slimes that were exported for processing.

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 plastics, ceramics, and glass to produce a ruby-red color. Selenium is used in catalysts to enhance selective oxidation; in plating solutions, where it improves appearance and durability; in blasting caps; in gun bluing to improve cosmetic appearance and provide corrosion resistance; in rubber compounding chemicals to act as a vulcanizing agent; in the electrolytic production of manganese to increase yields; and in copper, lead, and steel alloys to improve machinability. It is used in thin-film photovoltaic copper-indium-gallium-diselenide (CIGS) solar cells.

Selenium is used as a human dietary supplement and in antidandruff shampoos. The leading agricultural uses are as a dietary supplement for livestock and as a fertilizer additive to enrich selenium-poor soils.

Estimates for world consumption are as follows: metallurgy, 40%; glass manufacturing, 25%; agriculture, 10%; chemicals and pigments, 10%; electronics, 10%; and other uses, 5%.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production, refinery	W	W	W	W	W
Imports for consumption, metal and dioxide	601	460	439	441	480
Exports, metal, waste and scrap	1,350	952	648	521	735
Consumption, apparent	W	W	W	W	W
Price, dealers, average, dollars per pound, 100-pound lots, refined	66.35	54.47	36.17	26.78	22.80
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[1] 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 (2011–14): Japan, 21%; China, 16%; Belgium, 14%; Germany, 12%; and other, 37%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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. In the first 3 months of 2015, the price of selenium remained relatively stagnant, ranging from $22.00 per pound to $25.00 per pound. During the second and third quarters of the year, the price of selenium decreased to $8.00 per pound, a 90% decrease from its alltime high value of $80.00 per pound in 2011. The average price of selenium has decreased by a factor of 3 over the past 5 years.

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SELENIUM

In China, the Fanya Metal Exchange Co. Ltd., which began trading minor metals in 2011, froze accounts in June, halting selenium deliveries in or out of the exchange. Additionally, the Ri Jin Bao, an investment product that guaranteed annual returns of at least 13%, had its payments suspended in July. Investors were unable to buy or sell contracts, and the price of selenium fell dramatically. In August, Fanya entered into a debt-restructuring plan, and Fanya's investors reportedly met with the China Securities Regulatory Commission (China's stock market regulator) and Provincial-level authorities to protest Fanya's actions. At the time deliveries were frozen, Fanya warehouses reportedly held 338 tons of selenium as compared with 205 tons in October 2014, although the reliability of this data was uncertain.

The global use of selenium in glass remained unchanged owing to stable manganese and glass production. The use of selenium in fertilizers as a supplement in the plant-animal food chain and as a human vitamin supplement also was unchanged. Selenium consumption in CIGS solar cells also remained unchanged in 2015, despite technological advances which increased the efficiency of CIGS solar cells to above that for silicon-based solar cells.

World Refinery Production and Reserves: Selenium reserves in China were estimated based on selenium content of Chinese copper reserves; however, production estimates for China were not available.

	Refinery production[2]		Reserves[3]
	2014	2015[e]	
United States	W	W	10,000
Belgium	200	200	—
Canada	159	160	6,000
Chile	41	50	25,000
China	NA	NA	26,000
Finland	94	100	—
Germany	700	700	—
Japan	782	790	—
Peru	49	50	13,000
Poland	90	90	3,000
Russia	145	150	20,000
Other countries	[4]50	[4]50	21,000
World total (rounded)	[5]NA	[5]NA	120,000

World Resources: Reserves for selenium are based on identified copper deposits and average selenium contents. Coal generally contains between 0.5 and 12 parts per million of selenium, or about 80 to 90 times the average for porphyry copper deposits. The recovery of selenium from coal fly ash, although technically feasible, appears unlikely to be economical in the foreseeable future.

Substitutes: Silicon is the major substitute for selenium in low- and medium-voltage rectifiers and solar photovoltaic cells. 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 power cells.

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

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

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

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

[4]Includes India, Serbia, and Sweden.

[5]Australia, China, Iran, Kazakhstan, Mexico, the Philippines, and Uzbekistan are known to produce refined selenium, but output is not reported, and information is inadequate for formulation of reliable production estimates. Total world production is not shown because of the lack of data from China and other major world producers.

SILICON

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

Domestic Production and Use: Estimated value of silicon alloys and metal produced in the United States in 2015 was $1.14 billion. Four companies produced silicon materials in seven plants, all east of the Mississippi River. Ferrosilicon and metallurgical-grade silicon metal were produced in four and five plants, respectively. Two companies produced both products at two plants. 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 and 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:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Silicon alloys and metal	326	383	365	373	410
Imports for consumption:					
Ferrosilicon, all grades[1]	156	173	159	186	153
Silicon metal	187	136	118	139	150
Exports:					
Ferrosilicon, all grades[1]	20	12	10	9	10
Silicon metal	79	75	38	45	39
Consumption, apparent:					
Ferrosilicon, all grades[1]	W	W	W	W	W
Silicon metal[2]	W	W	W	W	W
Total	564	601	602	642	660
Price,[3] average, cents per pound Si:					
Ferrosilicon, 50% Si	111	100	103	108	104
Ferrosilicon, 75% Si	102	92	94	98	92
Silicon metal[2]	158	127	122	140	136
Stocks, producer, yearend:					
Silicon alloys and metal	30	34	25	27	34
Net import reliance[4] 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	36	39	42	38

Recycling: Insignificant.

Import Sources (2011–14): Ferrosilicon: Russia, 42%; China, 26%; Canada, 11%; Venezuela, 10%; and other, 11%. Silicon metal: Brazil, 32%; South Africa, 24%; Canada, 14%; Australia, 11%; and other, 19%. Total: Russia, 23%; Brazil, 16%; China, 14%; Canada, 12%; and other, 35%.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–15**
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.

Depletion Allowance: Quartzite, 14% (Domestic and foreign); gravel, 5% (Domestic and foreign).

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SILICON

Government Stockpile: None.

Events, Trends, and Issues: Combined domestic ferrosilicon and silicon metal production in 2015, expressed in terms of contained silicon, was expected to increase from that of 2014. By August 2015, annual average U.S. ferrosilicon spot market prices had decreased by 4% and 6%, for 50%-grade and 75%-grade ferrosilicon, respectively, and the annual average silicon metal spot market price had decreased by 3% compared with the same period in 2014.

Despite a slight reduction in global steel demand in 2015, production of silicon materials was expected to remain about the same in 2015 as in 2014. Although U.S. domestic production was estimated to have increased in 2015, Brazil experienced its worst recession in 25 years, with foundry production decreasing by about 8% in the first half of 2015. In Ukraine, ferrosilicon production significantly decreased in 2015 owing to the idling of its main ferrosilicon producer in August 2014.

A new 36,000-metric-ton-per-year silicon metal processing facility in Burnsville, MS, began operations in September. It was the first new silicon metal production facility built in the United States during the past 40 years.

World Production and Reserves:

	Production[e, 5]		Reserves[6]
	2014	2015	
United States	373	410	The reserves in most major producing countries are ample in relation to demand. Quantitative estimates are not available.
Bhutan[7]	72	72	
Brazil	154	150	
Canada	52	52	
China	5,500	5,500	
France	130	130	
Iceland	75	75	
India[7]	86	86	
Norway	332	330	
Russia	700	680	
South Africa	84	84	
Spain	81	81	
Ukraine[7]	92	70	
Other countries	379	380	
World total (rounded)	8,110	8,100	

Excluding the United States, ferrosilicon accounts for about 64% 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, Norway, and the United States, and, for silicon metal, the leading producers were China, the United States, Norway, and France. China contributed approximately 68% to the global estimated production in 2015.

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]Based on U.S. dealer import price.
[4]Defined as imports – exports + adjustments for industry stock changes.
[5]Production quantities are combined totals of estimated silicon content for ferrosilicon and silicon metal, as applicable, except as noted.
[6]See Appendix C for resource/reserve definitions and information concerning data sources.
[7]Ferrosilicon only.

SILVER

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

Domestic Production and Use: In 2015, U.S. mines produced approximately 1,100 tons of silver with an estimated value of $560 million. Silver was produced at 3 silver mines and as a byproduct or coproduct from 37 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 2,000 tons from domestic and foreign ores and concentrates and from old and new scrap. The physical properties of silver include high ductility, electrical conductivity, malleability, and reflectivity. In 2015, the estimated domestic uses for silver were electrical and electronics, 29%; coins and medals, 25%; photography, 8%; jewelry and silverware, 7%; 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:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Mine	1,120	1,060	1,040	1,180	1,100
Refinery:					
Primary	790	796	800	800	800
Secondary (new and old scrap)	1,710	1,660	1,700	1,400	1,200
Imports for consumption[2]	6,410	5,070	5,080	4,960	6,700
Exports[2]	904	946	409	383	900
Consumption, apparent[3]	8,310	6,890	7,410	7,150	8,100
Price, average, dollars per troy ounce[4]	35.28	31.22	23.87	19.37	16.00
Stocks, yearend:					
Industry	150	109	110	120	130
Treasury Department[5]	498	498	498	498	498
COMEX	3,650	4,610	5,350	5,610	5,000
Employment, mine and mill,[6] number	632	709	819	792	750
Net import reliance[7] as a percentage of apparent consumption	66	60	63	64	72

Recycling: In 2015, approximately 1,200 tons of silver was recovered from new and old scrap, about 15% of apparent consumption.

Import Sources (2011–14):[2] Mexico, 54%; Canada, 26%; Poland, 4%; Peru, 3%; and other, 13%.

Tariff: No duties are imposed on imports of unrefined silver or refined bullion.

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 2015 was 17% lower than the average price in 2014. The Engelhard daily price of silver in 2015 fluctuated through several cycles. The price began the year at $15.61 per troy ounce and increased to $18.40 per troy ounce on January 21, the highest level of the year, before cycling downward to $14.20 on August 27, the lowest price since August 2009. At the end of October, the price was $15.60 per troy ounce. The price decrease was attributed to weak global silver demand for coins, industrial uses, and jewelry manufacture. In October, however, these trends appeared to reverse and demand and prices started to increase.

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SILVER

In 2015, lower silver prices resulted in a 5% increase in global consumption of silver for jewelry. Global industrial silver consumption increased slightly owing to increased demand from crystalline silicon photovoltaic cell and ethylene oxide producers, which more than offset the reduced demand from the photography and computer industries. During the first half of 2015, investment demand for silver was strong, with exchange-traded funds increasing silver holdings and annual coin sales increasing to the fifth highest level on record. The U.S. Mint temporarily suspended sales of silver coins after exhausting its inventory on July 7; however, sales resumed on July 27 on an allocated basis.

World silver mine production increased slightly in 2015 to 27,300 tons, principally as a result of increased production from mines in Mexico and Russia. Domestic silver mine production decreased by 7%. The Lucky Friday Mine in Idaho (the fourth-ranked domestic silver-producing mine) produced less silver in 2015 because of lower millhead ore grade and throughput, and the Bingham Canyon Mine in Utah (the fifth-ranked producer) produced less silver, owing to lower mill throughput during continued cleanup and redevelopment of the east pit wall following a landslide in 2013.

World Mine Production and Reserves: Reserves for Peru and Russia were revised based on new information from Government sources.

	Mine production		Reserves[8]
	2014	2015[e]	
United States	1,180	1,100	25,000
Australia	1,720	1,700	85,000
Bolivia	1,340	1,300	22,000
Canada	493	500	7,000
Chile	1,570	1,600	77,000
China	4,060	4,100	43,000
Mexico	5,000	5,400	37,000
Peru	3,780	3,800	120,000
Poland	1,260	1,300	85,000
Russia	1,330	1,500	20,000
Other countries	5,040	5,000	50,000
World total (rounded)	26,800	27,300	570,000

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 future reserves and resources.

Substitutes: Digital imaging, film with reduced silver content, silverless black-and-white film, and xerography substitute for traditional photographic applications, which used silver. Surgical pins and plates may be made with stainless steel, tantalum, and titanium in place of silver. Stainless steel may be substituted for silver flatware. Nonsilver batteries may replace silver batteries in some applications. Aluminum and rhodium may be used to replace silver that was traditionally used in mirrors and other reflecting surfaces. Silver may be used to replace more costly metals in catalytic converters for off-road vehicles.

[e]Estimated.
[1]One metric ton (1,000 kilograms) = 32,150.7 troy ounces.
[2]Ores and concentrates, refined bullion, and doré; excludes coinage, and waste and scrap material.
[3]Defined as mine production + secondary production + imports – exports + adjustments for Government and industry stock changes.
[4]Engelhard quotations.
[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; Greens Creek Mine is included under zinc.
[7]Defined as imports – exports + adjustments for Government and industry stock changes.
[8]See Appendix C for resource/reserve definitions and information concerning data sources.

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 2015 was estimated to be about $1.7 billion.[1] U.S. production of 11.7 million tons was about equal to that in 2014 but about 1 million tons higher than production in 2011. The U.S. soda ash industry comprised four companies in Wyoming operating five plants, one company in California with one plant, and one company (which owned one of the Wyoming plants) with one mothballed plant in Colorado,. The five producing companies have a combined annual nameplate capacity of 13.9 million metric 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 the Colorado operation using soda ash feedstock shipped from the company's Wyoming facility.

Based on 2015 quarterly reports, the estimated 2015 distribution of soda ash by end use was glass, 47%; chemicals, 30%; soap and detergents, 7%; distributors, 6%; flue gas desulfurization and miscellaneous uses, 4% each; pulp and paper; and water treatment, 1% each.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production[2]	10,700	11,100	11,500	11,700	11,700
Imports for consumption	27	13	13	39	44
Exports	5,470	6,110	6,470	6,670	6,700
Consumption:					
Reported	5,150	5,060	5,120	5,170	4,950
Apparent	5,220	4,980	4,990	5,110	5,070
Price:					
Quoted, yearend, soda ash, dense, bulk:					
F.o.b. Green River, WY, dollars per short ton	260.00	275.00	275.00	290.00	302.00
Average sales value (natural source),					
f.o.b. mine or plant, dollars per short ton	133.57	141.90	133.18	135.68	142.00
Stocks, producer, yearend	282	338	348	271	300
Employment, mine and plant, number	2,400	2,400	2,500	2,500	2,500
Net import reliance[3] as a percentage of apparent consumption	E	E	E	E	E

Recycling: No soda ash was recycled by producers; however, glass container producers are using cullet glass, thereby reducing soda ash consumption.

Import Sources (2011–14): Germany, 30%; Canada, 21%; Italy, 21%; Mexico, 8%; and other, 20%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Disodium carbonate	2836.20.0000	1.2% ad val.

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

Government Stockpile: None.

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 natural soda ash. 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. Cessation of production has been reported in recent years in Australia, Brazil, China, Japan, the Republic of Korea, and the United Kingdom. Some production in Kenya was curtailed owing to high production costs, especially fuel costs.

Two of the five domestic producers had ownership changes in 2015. Tronox Ltd. completed its acquisition of FMC Corp.'s soda ash facilities in April.[4] In October, Ciner Group purchased a 73% share of a limited partnership in OCI Resources LP from OCI Enterprises, Inc.[5]

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SODA ASH

During 2015, identical legislation was introduced in the U.S. House of Representatives and the U.S. Senate that aims to maintain a competitive 2% royalty rate on sodium compounds produced on Federal land for 5 years. The bills had not been passed by yearend.

In June, one of the major Wyoming soda ash producers announced soda ash price increases effective September 1, 2015, or as contracts permitted. Other producers followed with similar announcements. The companies stated that the increases were necessary to recover production cost increases and assist in continued investments in the operations.

Three groups dominate production and have become the world's leading suppliers of soda ash—American National Soda Ash Corp. (ANSAC), which represented three of the five domestic producers in 2015; 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. Although total production in the United States was likely to be flat during 2015, producers are expecting to see modest growth in production and exports through 2020.

World Production and Reserves:

	Mine production		Reserves[6, 7]
Natural:	**2014**	**2015[e]**	
United States	11,700	11,700	[8]23,000,000
Botswana	250	225	400,000
Kenya	475	450	7,000
Mexico	290	290	200,000
Turkey	1,700	2,000	200,000
Uganda	NA	NA	20,000
Other countries	—	—	260,000
World total, natural (rounded)	14,400	14,700	24,000,000
World total, synthetic (rounded)	36,900	37,000	XX
World total (rounded)	51,300	51,700	XX

World Resources: 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 more costly 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. — Zero.
[1]Does not include values for soda liquors and mine waters.
[2]Natural only.
[3]Defined as imports – exports + adjustments for industry stock changes.
[4]Tronox Ltd., 2015, Tronox announces closing of alkali chemicals acquisition: Stamford, CT, Tronox Ltd. press release, April 1.
[5]Sweetwater Now, 2015, OCI sold to Ciner Group: Sweetwater Now, October 26.
[6]The reported quantities are sodium carbonate only. About 1.8 tons of trona yields 1 ton of sodium carbonate.
[7]See Appendix C for resource/reserve definitions and information concerning data sources.
[8]From trona, nahcolite, and dawsonite sources.

STONE (CRUSHED)[1]

(Data in million metric tons unless otherwise noted)[2]

Domestic Production and Use: In 2015, 1.32 billion metric tons of crushed stone valued at more than $13.8 billion was produced by 1,430 companies operating 3,700 quarries, 82 underground mines, and 187 sales/distribution yards in 50 States. Leading States were, in descending order of production, Texas, Pennsylvania, Missouri, Florida, Ohio, Illinois, Kentucky, Indiana, North Carolina, and Virginia, which together accounted for more than one-half of the total crushed stone output. Of the total domestic crushed stone produced in 2015, about 70% was limestone and dolomite; 13%, 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 1.39 billion tons of crushed stone consumed in the United States in 2015, 76% was used as construction material, mostly for road construction and maintenance; 11% for cement manufacturing; 7% for lime manufacturing; 4% for other chemical, special, and miscellaneous uses and products; and 2% for agricultural uses.

The estimated output of crushed stone in the 48 conterminous States shipped for consumption in the first 9 months of 2015 was 991 million tons, an increase of 6% compared with that of the same period of 2014. Third quarter shipments for consumption increased by 7% compared with those of the same period of 2014. 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 Construction Sand and Gravel.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production	1,160	1,180	1,180	1,250	1,320
Recycled material	27	31	41	42	42
Imports for consumption	15	15	18	20	22
Exports	1	1	([3])	([3])	([3])
Consumption, apparent	1,200	1,220	1,240	1,310	1,390
Price, average value, dollars per metric ton	9.60	9.73	9.89	10.15	10.46
Employment, quarry and mill, number[4]	67,000	66,200	65,900	65,600	65,500
Net import reliance[5] as a percentage of apparent consumption	1	1	1	2	2

Recycling: Road surfaces made of asphalt and crushed stone and portland cement concrete surface layers and structures were recycled on a limited but increasing basis in most States. Asphalt road surfaces and concrete were recycled in all 50 States. The amount of material reported to be recycled increased by 3% in 2015 compared with that of the previous year.

Import Sources (2011–2014): Mexico, 71%; The Bahamas, 16%; Canada, 7%; Honduras, 5%; and other, 1%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Crushed stone	2517.10.0000	Free.

Depletion Allowance: (Domestic) 14% for some special uses; 5%, if used as ballast, concrete aggregate, riprap, road material, and similar purposes.

Government Stockpile: None.

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STONE (CRUSHED)

Events, Trends, and Issues: Crushed stone production was about 1.32 billion tons in 2015, an increase of 6% compared with that of 2014. Apparent consumption also increased, to about 1.39 billion tons. Demand for crushed stone was higher in 2015 because of increased demand during every quarter since the second quarter of 2013, which offset the slowdown in activity that some of the principal construction markets had experienced during the previous years. With significantly stronger construction activity across the country in 2015 and recovery in the private sector and residential construction experiencing a level of growth not seen since late 2005, consumption of construction aggregates is likely to continue to increase. It is expected that the increased consumption in 2015 from that in 2014 will reach or exceed the historical annual average of the past 50 years, which was a 2% to 4% increase per year. The underlying factors that would support a rise in prices of crushed stone are expected to be present in 2016, especially in and near metropolitan areas.

World Mine Production and Reserves:

	Mine production		Reserves[6]
	2014	2015[e]	
United States	1,250	1,320	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 of the world are very large. 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.

[e]Estimated. NA Not available.
[1]See also Stone (Dimension).
[2]See Appendix A for conversion to short tons.
[3]Less than ½ unit.
[4]Including office staff. Source: Mine Safety and Health Administration.
[5]Defined as imports – exports.
[6]See Appendix C for resource/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 country chapters of the USGS Minerals Yearbook.

STONE (DIMENSION)[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: Approximately 2.51 million tons of dimension stone, valued at $474 million, was sold or used by U.S. producers in 2015. Dimension stone was produced by 216 companies, operating 293 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 66% of the production and contributed about 63% of the value of domestic production. Approximately 42%, by tonnage, of dimension stone sold or used was limestone, followed by granite (21%), sandstone (17%), miscellaneous stone (16%), and marble and slate (2% each). By value, the leading sales or uses were for limestone (38%), followed by granite (25%), miscellaneous stone (18%), sandstone (11%), and marble and slate (4% each). Rough stone represented 59% of the tonnage and 49% 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 (58%), and in irregular-shaped stone (27%). Dressed stone mainly was sold for ashlars and partially squared pieces (44%), curbing (20%), and flagging (11%), by tonnage.

Salient Statistics—United States:[2]	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Sold or used by producers:[3]					
Tonnage	1,850	2,150	2,280	2,470	2,510
Value, million dollars	395	452	459	470	474
Imports for consumption, value, million dollars	1,590	1,740	2,100	2,230	2,370
Exports, value, million dollars	66	65	61	70	80
Consumption, apparent, value, million dollars	1,910	2,130	2,500	2,630	2,760
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	3,600	3,200	4,000	4,000	4,000
Net import reliance[5] as a percentage of apparent consumption (based on value)	80	79	82	82	83
Granite only:					
Production	462	499	496	519	530
Imports, value, million dollars	1,010	1,080	1,290	1,320	1,340
Exports (rough and finished)	80	77	85	88	88
Price	Variable, depending on type of product				
Employment, quarry and mill, number[4]	1,300	700	880	880	880

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

Import Sources (2011–14 by value): All dimension stone: China, 30%; Brazil, 25%; Italy, 23%; Turkey, 14%; and other, 8%. Granite only: Brazil, 45%; China, 23%; India, 14%; Italy, 12%; and other, 6%.

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 2015. Most crude or rough-trimmed stone was imported at 3.0% 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.

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STONE (DIMENSION)

<u>Events, Trends, and Issues</u>: The United States is one of the world's leading markets for dimension stone. Total imports of dimension stone increased in value to about $2.37 billion compared with $2.23 billion in 2014. Slow growth in the U.S. economy in 2015, coupled with flat to slow growth in new residential construction, resulted in domestic production of dimension stone that was essentially level with the previous year. Dimension stone for construction and refurbishment was used in commercial and residential markets; in 2015, refurbishment and remodeling activity of existing homes remained steady compared with those of 2014. These factors contributed to a steady rise in dimension stone imports. Dimension stone exports increased to about $80 million. Apparent consumption, by value, was estimated to be $2.76 billion in 2015—a 5% increase from that of 2014.

According to Italy's Internazionale Marmi e Macchine Carrara S.p.A., world dimension granite and marble production, including the United States, was estimated to be approximately 142 Mt in 2013, the last year for which data were available. Although some small-scale production was likely in many nations, dimension granite and marble was produced and officially reported in 29 countries. The top five producing countries in 2013 were, in descending order by tonnage, China, Turkey, India, Iran, and Italy, and these countries accounted for about 72% of the world's dimension granite and marble production. Global production of dimension granite and marble increased by 14% in 2013 compared with that of 2012. The United States ranked 18th in world production of dimension granite and marble in 2013.

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

	Mine production		Reserves[6]
	2014	2015[e]	
United States	2,470	2,510	Adequate except for certain
Other countries	NA	NA	special types and local
World total	NA	NA	shortages.

<u>World Resources</u>: 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.

<u>Substitutes</u>: 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 Puerto Rico.
[3]Includes granite and other types of dimension stone.
[4]Excluding office staff.
[5]Defined as imports – exports.
[6]See Appendix C for resource/reserve definitions and information concerning data sources.

STRONTIUM

(Data in metric tons of strontium content[1] 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. A few domestic companies produce small quantities of downstream strontium chemicals from imported strontium carbonate. The estimated end-use distribution for strontium compounds in the United States was pyrotechnics and signals, 30%; ceramic ferrite magnets, 30%; master alloys, 10%; pigments and fillers, 10%; electrolytic production of zinc, 10%; and other applications, including glass, 10%.

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.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production	—	—	—	—	—
Imports for consumption:					
Celestite	7,320	8,660	21,900	24,200	21,900
Strontium compounds	10,000	8,150	7,190	7,600	7,800
Exports, compounds	18	71	37	104	110
Consumption, apparent:					
Celestite	7,320	8,660	21,900	24,200	21,900
Compounds	9,980	8,080	7,150	7,500	7,690
Total	17,300	16,700	29,000	31,700	29,600
Price, average value of celestite imports at port of exportation, dollars per ton	46	50	50	50	50
Net import reliance[2] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2011–14): Celestite: Mexico, 100%. Strontium compounds: Mexico, 57%; Germany, 32%; China, 10%; and other, 1%. Total imports: Mexico, 85%; Germany, 11%; China, 3%; and other, 1%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
Celestite	2530.90.8010	Free.
Strontium metal	2805.19.1000	3.7% ad val.
Compounds:		
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.

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STRONTIUM

Events, Trends, and Issues: After increasing for 5 consecutive years, imports of celestite, the most commonly used strontium mineral, decreased by about 10% in 2015. The decrease was likely the result of decreased natural gas and oil drilling activity. All of the material came from Mexico 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 carbonate is sintered with iron oxide to produce permanent ceramic ferrite magnets. Strontium nitrate contributes a brilliant red color to fireworks and signal flares. Approximately equal quantities of strontium compounds were thought to be used in these end uses. Smaller quantities of strontium compounds were consumed in several other applications, including glass production, electrolytic production of zinc, master alloys, and pigments and fillers. Strontium may be ingested by humans as a dietary supplement, as an active ingredient in toothpastes, and as a pain reliever for some types of cancer. Although specific information is not available, these uses likely consume very small quantities of strontium compounds, but the compounds must be extremely pure, and thus are of high unit value.

With improvements to global economic conditions, consumption of strontium compounds, and thus celestite, would be expected to increase. Little information is available about the potential for celestite consumption in drilling fluids, but if oil and gas drilling increases, celestite consumption in that end use may increase as well.

In descending order of production, China, Spain, and Mexico are the world's leading producers of celestite. China also is a major importer of celestite.

World Mine Production and Reserves:[3]

	Mine production		Reserves[4]
	2014	2015[e]	
United States	—	—	—
Argentina	10,000	10,000	All other:
China	170,000	150,000	6,800,000
Mexico	70,000	70,000	
Morocco	2,500	2,500	
Spain	90,000	90,000	
World total (rounded)	343,000	320,000	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%; this factor was used to convert units of celestite to strontium content.
[2]Defined as imports – exports.
[3]Gross weight of celestite in metric tons.
[4]See Appendix C for resource/reserve definitions and information concerning data sources.

SULFUR

(Data in thousand metric tons of sulfur unless otherwise noted)

Domestic Production and Use: In 2015, recovered elemental sulfur and byproduct sulfuric acid were produced at 103 operations in 27 States. Total shipments were valued at about $933 million. Elemental sulfur production was 8.7 million tons; Louisiana and Texas accounted for about 52% of domestic production. Elemental sulfur was recovered, in descending order of tonnage, at petroleum refineries, natural-gas-processing plants, and coking plants by 39 companies at 96 plants in 26 States. Byproduct sulfuric acid, representing about 6% of production of sulfur in all forms, was recovered at seven nonferrous smelters in five States by five companies. Domestic elemental sulfur provided 64% of domestic consumption, and byproduct acid accounted for about 5%. The remaining 31% 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:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production					
Recovered elemental	8,230	8,410	8,600	9,040	8,720
Other forms	720	586	616	587	575
Total (rounded)	8,950	9,000	9,210	9,630	9,300
Shipments, all forms	8,930	9,030	9,200	9,670	9,330
Imports for consumption:					
Recovered, elemental[e]	3,270	2,930	2,990	2,370	2,200
Sulfuric acid, sulfur content	871	933	972	1,060	1,200
Exports:					
Recovered, elemental	1,310	1,860	1,770	2,000	1,600
Sulfuric acid, sulfur content	108	53	54	52	60
Consumption, apparent, all forms	11,700	11,000	11,300	11,000	11,000
Price, reported average value, dollars per ton of elemental sulfur, f.o.b., mine and (or) plant	159.88	123.54	68.71	80.07	100.00
Stocks, producer, yearend	175	132	161	142	140
Employment, mine and/or plant, number	2,600	2,600	2,600	2,600	2,600
Net import reliance[1] as a percentage of apparent consumption	23	18	19	13	16

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 (2011–14): Elemental: Canada, 82%; Mexico, 12%; Venezuela, 4%; and other, 2%. Sulfuric acid: Canada, 67%; Mexico, 18%; and other, 15%. Total sulfur imports: Canada, 78%; Mexico, 14%; Venezuela, 3%; and other, 5%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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 decreased by about 3% and shipments decreased by about 4% compared with those of 2014. Domestic production of elemental sulfur from petroleum refineries and recovery from natural gas operations decreased by 4%. 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.

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SULFUR

World sulfur production increased slightly and is likely to steadily increase for the foreseeable future. Significantly increased production is expected from sulfur recovery at liquefied natural gas operations in the Middle East and a moderate increase in recovered sulfur from petroleum and natural gas operations in Africa, East and South Asia, and Latin America, unless a downturn in the world economy limits investments in those areas. In addition, sulfur production may decrease as global demand for oil or natural gas declines.

The contract sulfur prices in Tampa, FL, began 2015 at around $129 per ton. The price increased to $147 per ton at the beginning of February and remained at that level through mid-April when prices decreased to $132 per ton. 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. The price decrease seen in 2015 is a reflection of China’s decreased demand for sulfur.

Domestic phosphate rock consumption was lower in 2015 than in 2014, which resulted in decreased demand for sulfur to process the phosphate rock into phosphate fertilizers. Decreased consumption of sulfur can also be attributed to decreased use of sulfuric acid resulting from the decline in copper-ore leaching.

World Production and Reserves:

	Production—All forms		Reserves[2]
	2014	2015[e]	
United States	9,630	9,300	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.
Australia	830	900	
Brazil	540	540	
Canada	5,910	6,000	
Chile	1,700	1,700	
China	10,500	11,000	
Finland	740	740	
Germany	3,800	3,800	
India	2,830	2,800	
Iran	2,100	2,100	
Italy	740	740	
Japan	3,250	3,300	
Kazakhstan	2,740	2,700	
Korea, Republic of	1,400	1,400	
Kuwait	800	800	
Mexico	1,840	1,800	
Netherlands	515	510	
Poland	1,070	1,100	
Qatar	820	820	
Russia	7,300	7,300	
Saudi Arabia	3,300	3,300	
United Arab Emirates	1,900	1,900	
Uzbekistan	540	540	
Venezuela	800	800	
Other countries	4,210	4,210	
World total (rounded)	70,000	70,100	

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.

[e]Estimated.

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

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

TALC AND PYROPHYLLITE[1]

(Data in thousand metric tons unless otherwise noted)

Domestic Production and Use: In 2015, domestic talc production was estimated to have increased by about 4% to 633,000 tons valued at $25 million. Four companies operated six talc-producing mines in four States. Montana was the leading producer State, followed by Texas, Vermont, and Virginia, and one company in California shipped from stocks. The top three companies accounted for more than 99% of the U.S. talc production. Domestic sales of talc were estimated to be 559,000 tons valued at $104 million, slightly higher than in 2014. Talc produced and sold in the United States was used in ceramics (27%), paper (18%), paint (17%), unclassified end uses (14%), plastics (12%), roofing (6%), cosmetics (3%), and rubber (3%). Of the approximately 310,000 tons of talc that was imported in 2015, it is estimated that more than 75% was used in cosmetics, paint, and plastics applications. Including imported talc, the domestic end-use rankings were, in decreasing order by tonnage, plastics, ceramics, paint, paper, roofing, cosmetics, rubber, and other.

One company in North Carolina mined pyrophyllite in 2015. Domestic production was withheld in order to protect company proprietary data and was estimated to have remained about the same as that of 2014. Pyrophyllite was used in refractory products, paint, and ceramics.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production, mine	616	515	542	610	633
Sold by producers	567	575	560	553	559
Imports for consumption	285	350	275	327	308
Exports	223	270	196	186	210
Consumption, apparent[2]	678	595	621	751	731
Price, average, milled, dollars per metric ton[3]	155	152	163	183	185
Employment, mine and mill, talc	290	310	280	260	260
Employment, mine and mill, pyrophyllite	31	30	30	33	36
Net import reliance[4] as a percentage of apparent consumption	9	13	13	19	13

Recycling: Insignificant.

Import Sources (2011–14): Pakistan, 32%; Canada, 26%; China, 23%; Japan, 5%; and other, 14%. Large quantities of crude talc are mined in Afghanistan before being milled in Pakistan.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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. The Defense Logistics Agency Strategic Materials landfilled the final 865 metric tons of block and lump talc and 621 metric tons of ground talc remaining in the National Defense Stockpile during September and October of 2014.

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TALC AND PYROPHYLLITE

Events, Trends, and Issues: Talc production increased for the third consecutive year in 2015, but production and apparent consumption were still approximately 40% and 28% lower, respectively, than in 1995. Several domestic talc markets have declined over this 20-year period. The largest decreases took place in the ceramics (talc usage fell by an estimated 50%), paint (42%), paper (37%), and cosmetics (35%) 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. Many domestic ceramic tile manufacturing plants also closed as ceramic tile imports increased, leading a major domestic producer to stop mining talc in 2008. 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 decreased 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, domestic talc consumption in plastics rose by an estimated 82% from 1995 to 2015, primarily the result of increased use in automotive plastic components. However, a significant share of the increase in demand appears to have been met through the use of imported talc. The paper industry has traditionally been the largest consumer of talc worldwide, but plastics are expected to overtake paper as the predominant end use within the next several years as Asian papermakers make greater use of talc substitutes.

The Board of Governors of the Federal Reserve System reported a 1.2% rise in the manufacture of durable goods, with 9.4% growth in automobile and truck manufacture and 3.5% growth in plastics and rubber components, from September 2014 to September 2015. The U.S. Census Bureau reported that housing starts also increased by nearly 18% over the same time period. These trends could lead to increased consumption of talc, if they are sustained, because talc is used in manufacturing catalytic converter bodies (ceramics), automotive and truck body and underhood components (plastics), paint, coatings, and rubber. Talc is also used to manufacture such construction products as adhesives, caulk, joint compounds, and roofing products.

In 2015, Pakistan (32% of imports) and Canada (28%) continued to be the primary sources for imported talc, as they have been in every year since 2012. The percentage of imports originating from China increased to 21% after falling to 12% in 2014. Similar to the prior 2 years, Canada and Mexico collectively received nearly 70% of U.S. talc exports in 2015.

World Mine Production and Reserves:

	Mine production[e]		Reserves[5]
	2014	2015	
United States	[6]610	633	140,000
Brazil (crude)[7]	700	740	44,000
China (unspecified minerals)	2,200	2,200	Large
Finland	[6]381	385	Large
France (crude)	450	450	Large
India[7]	1,160	1,170	4,300,000
Japan[7]	365	370	100,000
Korea, Republic of[7]	503	505	11,000
Other countries (includes crude)[7]	865	870	Large
World total (rounded)	7,230	7,320	Large

World Resources: The United States is self-sufficient in most grades of talc and related minerals. 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]Excludes pyrophyllite unless otherwise noted.
[2]Defined as mine production + imports – exports.
[3]Average unit value of milled talc sold by U.S. producers, based on data reported by companies.
[4]Defined as imports – exports.
[5]See Appendix C for resource/reserve definitions and information concerning data sources.
[6]Reported figure.
[7]Includes pyrophyllite.

TANTALUM

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

Domestic Production and Use: No significant U.S. tantalum mine production has 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, compounds, and metal from imported tantalum-containing materials, and metal and alloys were recovered from foreign and domestic scrap. Tantalum domestic consumption is not reported. Major end uses for tantalum capacitors include automotive electronics, mobile phones, and personal computers. Tantalum oxide is used in glass lenses to get lighter weight lenses that produce a brighter image. Tantalum carbide is used in cutting tools. The value of tantalum consumed in 2015 was expected to exceed $290 million as measured by the value of imports.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Mine	—	—	—	—	—
Secondary	NA	NA	NA	NA	NA
Imports for consumption[e, 1]	1,850	1,010	1,100	1,230	1,250
Exports[e, 1]	648	577	844	754	600
Government stockpile releases[e, 2]	—	—	—	—	—
Consumption, apparent	1,210	437	260	479	650
Price, tantalite, dollars per pound of Ta_2O_5 content[3]	125	108	118	100	88
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.

Import Sources (2011–14): Tantalum minerals: Brazil, 40%; Rwanda, 17%; Canada, 11%; Australia, 10%; and other, 22%. Tantalum metal: China, 29%; Kazakhstan, 28%; Germany, 15%; Thailand, 11%; and other, 17%. Tantalum waste and scrap: Estonia, 21%; Indonesia, 17%; China, 14%; and other 48%. Tantalum contained in niobium (columbium) and tantalum ore and concentrate; tantalum metal; and tantalum waste and scrap: China, 18%; Germany, 12%; Indonesia, 9%; Kazakhstan, 9%; and other, 52%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
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:

Stockpile Status—9–30–15[6]

Material	**Inventory**	**Disposal Plan FY 2015**	**Disposals FY 2015**
Tantalum carbide powder	1.71	—	—
Tantalum metal scrap	0.09	—	—

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TANTALUM

Events, Trends, and Issues: U.S. tantalum apparent consumption in 2015 was estimated to have increased by 36% from that of 2014. Tantalum waste and scrap was the leading imported tantalum material, accounting for about 51% of tantalum imports. In 2015, the average monthly price of tantalum ore remained at about $88 per pound of Ta_2O_5 content from January through August. This was 20% lower than the average price of $110 in 2014. Rwanda accounts for about 50% of global tantalum production and Congo (Kinshasa) accounts for about 17%. The Dodd-Frank Wall Street Reform and Consumer Protection Act (Dodd-Frank Act) included provisions that required companies to disclose the source of conflict minerals [defined to be tantalum, tin, tungsten, and gold (3TG)] used in their production processes.

The United States, through the enactment of Section 1502 of the Dodd-Frank Act in 2010, made it a statutory obligation for all companies registered with the U.S. Securities and Exchange Commission (SEC) to perform due diligence to determine whether the products they manufacture, or the components of the products they manufacture, contain tantalum, tin, tungsten, and (or) gold minerals and, if so, to determine whether these minerals were sourced from Congo (Kinshasa) and (or) its bordering countries. Under rules issued by the SEC, publicly traded companies were required to report the sources of 3TG materials used by May 2014. The Federal courts issued a decision that the SEC must have the final resource extraction rule ready for congressional decision by June 27, 2016.

Canada, China, and the European Union considered legislation similar to the Dodd-Frank Act mineral information identification to promote responsible sourcing of mineral resources from Congo (Kinshasa) or its adjoining countries.

World Mine Production and Reserves:

	Mine production		Reserves[7]
	2014	2015[e]	
United States	—	—	—
Australia	50	50	[8]67,000
Brazil	150	150	36,000
China	60	60	NA
Congo (Kinshasa)	200	200	NA
Rwanda	600	600	NA
Other	140	140	NA
World total (rounded)	1,200	1,200	>100,000

World Resources: Identified resources of tantalum, most of which are in Australia, Brazil, and Canada, are considered adequate to meet projected needs. The United States has about 1,500 tons of tantalum resources in identified deposits, all of which are considered uneconomic at 2015 prices.

Substitutes: The following materials can be substituted for tantalum, but usually with less effectiveness: niobium in carbides; aluminum and ceramics in electronic capacitors; glass, niobium, platinum, 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.
[2]Government stockpile inventory reported by DLA Strategic Materials is the basis for estimating Government stockpile releases.
[3]Price is annual average price reported in Ryan's Notes.
[4]Defined as imports – exports + adjustments for Government and industry stock changes.
[5]This category includes other than tantalum-containing material.
[6]See Appendix B for definitions.
[7]See Appendix C for resource/reserve definitions and information concerning data sources.
[8]For Australia, Joint Ore Reserves Committee-compliant reserves were 30,000 tons.

TELLURIUM

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

Domestic Production and Use: In 2015, one firm in Texas produced commercial-grade tellurium as a byproduct from domestic copper anode slimes and lead refinery skimmings. The primary producer and intermediate 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 2015 was withheld.

Tellurium was used in the production of cadmium-telluride (CdTe) solar cells, which was the major end use for tellurium in the United States. 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 devices and as a pigment to produce various colors in glass and ceramics.

Global consumption estimates for the end use of tellurium are as follows: solar, 40%; thermoelectric power generation, 30%; metallurgy, 15%; rubber applications, 5%; and other, 10%.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, refinery	W	W	W	W	W
Imports for consumption	71	36	64	111	102
Exports	39	47	42	28	55
Consumption, apparent	W	W	W	W	W
Price, dollars per kilogram, 99.95% minimum[1]	349	150	112	119	89
Stocks, producer, refined, yearend	W	W	W	W	W
Net import reliance[2] as a percentage of apparent consumption	>60%	<50%	>60%	>80%	>80%

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 CdTe solar cells were relatively new and had not reached the end of their useful life.

Import Sources (2011–14): Canada, 59%; China, 21%; Philippines, 9%; Belgium, 9%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
Tellurium	2804.50.0020	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

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TELLURIUM

Events, Trends, and Issues: In 2015, estimated domestic tellurium production was less than production in 2014. The sole domestic producer shipped at least a portion of its anode slimes to Mexico for treatment and refining. World production of tellurium in 2015 is estimated at 400 tons. The price of tellurium in 2015 decreased sharply from its peak at the beginning of the year of $127 per pound to $50 per pound in October, the lowest price since 2008.

In China, the Fanya Metal Exchange Co. Ltd., which began trading tellurium in 2014, froze accounts in June, halting tellurium deliveries in or out of the exchange. Additionally, the Ri Jin Bao, an investment product that guaranteed annual returns of at least 13%, had its payments suspended in July. Investors were unable to buy or sell contracts, and the price of tellurium fell dramatically. By October 2015, Fanya reported that 170 metric tons (t) of tellurium were held in its approved warehouses; however, industry has questioned the accuracy of tellurium and other minor metal stock levels reported by Fanya.

Canada remained the leading source of domestic imports of tellurium, increasing its exports to the United States by over 400 percent and accounting for quadruple the imports from China, the next leading supplier. Sweden’s new mine operations started to produce tellurium concentrate in 2012, increasing production from 7 tons to 31 tons in 2014.

CdTe solar cells continue to improve with respect to efficiency when compared with silicon-based solar cells. In February, researchers reported achieving an energy conversion efficiency of 21.5% for individual CdTe cells and a module efficiency record of 17.5%.

World Refinery Production and Reserves: The figures shown for reserves include only tellurium contained in copper reserves. These estimates are based on the assumption that more than one-half of the tellurium contained in unrefined copper anodes is recoverable. Reserves for Sweden were based on reported company data.

	Refinery production		Reserves[3]
	2014	2015[e]	
United States	W	W	3,500
Canada	9	10	800
Japan	32	35	—
Peru	—	—	3,600
Russia	32	35	NA
Sweden	31	40	700
Other countries[4]	NA	NA	16,000
World total (rounded)	NA	NA	25,000

World Resources: Data on tellurium resources, other than reserves, 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. Other potential sources of tellurium include bismuth telluride and gold telluride ores.

Substitutes: Several materials can replace tellurium in most of its uses, but usually with losses in efficiency or product characteristics. 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 elements.

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 to CdTe in thin-film photovoltaic solar cells.

[e]Estimated. NA Not available. W Withheld to avoid disclosing company proprietary data. — Zero.
[1]Average price published by Metal-Pages for 99.95% tellurium.
[2]Defined as imports – exports + adjustments industry stock changes.
[3]See Appendix C for resource/reserve definitions and information concerning data sources.
[4]In addition to the countries listed, Australia, Belgium, Chile, China, Colombia, Germany, India, Kazakhstan, Mexico, the Philippines, and Poland produce refined tellurium, but output was not reported, and available information was inadequate for formulation of reliable production and detailed reserve estimates.

THALLIUM

(Data in kilograms of thallium content 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 $2.1 million. 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 (HTS) 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:	2011	2012	2013	2014	2015[e]
Production, refinery	—	—	—	—	—
Imports for consumption:[1]					
Unwrought and powders	1,300	—	—	44	—
Other	200	685	209	53	330
Total	1,500	685	209	97	330
Exports:[1]					
Unwrought and powders	34	21	3	51	50
Waste and scrap	42	26	11	103	250
Other	469	31	8	—	—
Total	545	78	22	154	300
Consumption	997	633	198	46	280
Price, metal, dollars per kilogram[2]	6,000	6,800	6,990	7,200	7,400
Net import reliance[3] as a percentage of estimated consumption	100	100	100	100	100

Recycling: None.

Import Sources (2011–14): Germany, 53%; Russia, 45%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
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 2015, the price for thallium metal increased for the sixth consecutive year, reportedly owing to the limited availability of thallium produced in China and the constraint it placed on global supply. In 2015, 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 July 2010, China canceled a 5% value-added-tax rebate on exports of many minor metals, including fabricated thallium products. In addition, higher internal demand for many metals has prompted China to import more thallium.

Demand for thallium for use in cardiovascular-imaging applications has declined owing to price increases and 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.

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THALLIUM

In late 2011, a Brazilian minerals exploration company discovered a substantial thallium deposit in northwest Bahia, Brazil. According to the company, the deposit was unique because it was the only known occurrence in the world in which thallium had been found with cobalt and manganese. Exploration of the site concluded by yearend 2015 and the company finished testing a hydrometallurgical process that could be used to extract thallium from the ore. Construction of a plant to produce thallium was dependent on obtaining licenses for operation and finding investment partners. No further development plans were released for 2016.

Two of the leading global markets for thallium were glass lenses, prisms, and windows for the fiber optics industry and optics for digital cameras. The majority of producers of these products were in China, Japan, and the Republic of Korea.

In 2015, researchers at the Oak Ridge National Laboratory in Tennessee experimented with the semiconductor compound thallium sulfide iodide as a candidate for use in room-temperature radiation detection equipment. Radiation detectors are used increasingly for astronomy, medical imaging, national security, and petroleum well logging. Most conventional semiconductor radiation detectors use germanium and silicon and require low temperatures to operate, limiting their applications outside of laboratories.

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 electronics, drugs, 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 for thallium at 2 parts per billion in drinking water.

World Refinery Production and Reserves: Thallium is produced commercially in only a few countries as a byproduct in the roasting of copper, lead, and zinc ores or is recovered from flue dust. Because most producers withhold thallium production data, global production data are not complete. In 2015, global production of thallium was estimated to be less than 10,000 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 parts 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 forms. 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 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. — Zero.
[1]Thallium content was estimated by the U.S. Geological Survey.
[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.

THORIUM

(Data in metric tons of thorium oxide (ThO_2) equivalent unless otherwise noted)

Domestic Production and Use: The world's primary source of thorium is the rare-earth and thorium phosphate mineral monazite. In 2015, monazite was not recovered domestically as a salable product. Past production had been as a byproduct during processing for titanium and zirconium minerals; monazite was recovered for its rare-earth content. 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 2015 was $32,000, a significant decrease compared with $761,000 in 2014.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, mine and refinery[1]	—	—	—	—	—
Imports for consumption:					
Thorium ore and concentrates (monazite), gross weight	30	43	—	—	—
Thorium compounds (oxide, nitrate, etc.), gross weight	5.71	4.40	2.83	11.01	0.20
Thorium compounds (oxide, nitrate, etc.), ThO_2 content[e]	2.68	2.07	1.33	5.18	0.10
Exports:					
Thorium ore and concentrates (monazite), gross weight	—	—	—	—	—
Thorium compounds (oxide, nitrate, etc.), gross weight	4.28	3.16	1.01	14.80	2.40
Thorium compounds (oxide, nitrate, etc.), ThO_2 content[e]	3.17	2.34	0.74	10.90	1.80
Consumption, apparent[2]	1.61	2.73	0.59	([2])	([2])
Price, thorium compounds, gross weight, dollars per kilogram:[3]					
France	158	153	NA	NA	NA
India	58	60	65	65	NA
Net import reliance[4] as a percentage of apparent consumption	100	100	100	100	100

Recycling: None.

Import Sources (2011–14): Monazite: United Kingdom, 100%. Thorium compounds: India, 96%; and France, 4%. U.S. imports of monazite from the United Kingdom were from previously stockpiled imports.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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.

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THORIUM

Events, Trends, and Issues: Domestic demand for thorium alloys, compounds, and metals was limited and believed to be largely for research purposes. Imports and existing stocks supplied essentially all thorium consumed in the United States in 2015. Globally, thorium's commercial uses included catalysts, high-temperature ceramics, and welding electrodes.

On the basis of data through September 2015, the average value of imported thorium compounds increased to $176 per kilogram from the 2014 average of $69 per kilogram (gross weight). The increase was caused by a cessation of lower unit value imports from India. The United Kingdom was the primary source of imported thorium compounds in 2015. The average value of exported thorium compounds increased to $345 per kilogram based on data through September 2015, compared with $129 per kilogram for all of 2014. The change was attributed to variations in the type and purity of compounds exported in each year.

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 Thailand was the leading exporter.

Interest in thorium as an energy source continued worldwide, as various countries, including China, France, India, Japan, Norway, Russia, and the United States, continued research and development of thorium-fueled nuclear power. The Chinese Academy of Sciences continued a research initiative to develop thorium molten-salt reactor technologies and planned to build demonstration reactors by 2020 and commercial reactors by 2030. India continued research and development of thorium-related reactor technologies. According to India's Atomic Energy Commission, the process of selection of a site for construction of an advanced heavy-water reactor (AHWR) is in an advanced stage. The AHWR is a nuclear reactor that burns thorium in its fuel core. In Norway, a testing program backed by an international consortium of utilities, industry, and research organizations was planning to demonstrate that thorium-mixed oxide fuel could operate safely in a commercial reactor.

In 2015, exploration and development of rare-earth projects containing associated thorium were underway in Australia, Brazil, Canada, Greenland, India, Kazakhstan, Kenya, Madagascar, Malawi, Mozambique, Namibia, Sweden, Russia, South Africa, Tanzania, Turkey, the United States, and Vietnam.

World Refinery Production and Reserves:[5] 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 demand conditions.

World Resources: The world's leading thorium resources are found in placer, carbonatite, and vein-type deposits. According to a 2014 report by the Organisation for Economic Co-operation and Development's Nuclear Energy Agency and the International Atomic Energy Agency, worldwide thorium resources from major deposits are 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 12 million tons of monazite were contained in heavy-mineral sands. India's monazite was reported to have an average thorium oxide content of 9% to 10%. Geoscience Australia estimated its inferred resources of thorium at 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.

[e]Estimated. NA Not available. — Zero.
[1]All domestically consumed thorium was derived from imported materials.
[2]Excludes ores and concentrates. Owing to sporadic shipments and unknown variations in the oxide content of exports, the apparent consumption calculation yields a negative value in 2014 and 2015.
[3]Based on U.S. Census Bureau customs value.
[4]Defined as imports – exports; however, all exports were derived from imports, and net import reliance is assumed to be 100%.
[5]See Appendix C for resource/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 2015. The major uses for tin in the United States were cans and containers, 22%; chemicals, 20%; solder, 18%; alloys, 14%; and other, 26%. Based on the average Platts Metals Week New York Dealer price for tin, the estimated value of imported refined tin was $800 million, and the estimated value of old scrap recovered domestically was $240 million.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production, secondary:					
Old scrap[e]	11,000	11,200	10,600	10,600	10,600
New scrap	2,530	2,440	2,150	2,060	2,000
Imports for consumption, refined tin	34,200	36,900	34,900	35,600	37,300
Exports, refined tin and tin alloys	5,450	5,560	5,870	5,700	5,800
Shipments from Government stockpile	—	—	—	—	—
Consumption, reported:					
Primary	25,200	24,500	25,700	24,200	23,300
Secondary	3,280	3,240	4,730	3,250	2,800
Consumption, apparent[1]	39,900	41,900	40,000	40,000	42,200
Price, average, cents per pound:[2]					
New York dealer	1,216	990	1,041	1,023	720
Metals Week composite	1,575	1,283	1,352	NA	NA
London Metal Exchange, cash	1,184	957	1,012	994	700
Kuala Lumpur	1,188	958	1,012	993	NA
Stocks, consumer and dealer, yearend	6,280	6,910	6,520	7,010	6,900
Net import reliance[3] as a percentage of apparent consumption	72	73	74	74	75

Recycling: About 12,600 tons of tin from old and new scrap was recycled in 2015 accounting for about 30% of apparent consumption. Of this, about 10,600 tons was recovered from old scrap at 2 detinning plants and about 75 secondary nonferrous metal-processing plants.

Import Sources (2011–14): Peru, 35%; Indonesia, 18%; Bolivia, 15%; Malaysia, 13%; and other, 19%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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:

Stockpile Status—9–30–15[4]

Material	Inventory	Disposal Plan FY 2015	Disposals FY 2015
Tin	4,041	—	—

Events, Trends, and Issues: Apparent consumption of tin in the United States increased by 6% in 2015 compared with consumption in 2014. Peru remained the primary supplier of tin to the United States, and recycling rates of tin remained unchanged from those in 2014. Tin prices decreased significantly during 2015. The New York dealer price averaged 912 cents per pound in January and continued to decrease through September, when it stabilized at 731 cents per pound. The London Metal Exchange (LME) price averaged 880 cents per pound in January, and continued to decrease until August, when it stabilized at about 700 cents per pound.

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TIN

The price declines are attributed to increased tin production in Burma, where investments in tin mines by companies from China have resulted in a near doubling of production since 2013, and to reduced demand in China for imported tin metal. In China, the world's leading consumer of tin, imports of tin ores from Burma supplanted imports of tin metal from Indonesia. In Indonesia, tin producers responded to the lower tin prices by restricting sales of tin when the price of tin fell below a specific price threshold, with the result that one-half of tin producers in Indonesia stopped refined tin production in April. This attempt to raise tin prices had little effect owing to Burma's increased mine output, high tin stock levels in China, and a strong U.S. dollar.

Artisanal and small-scale tin mining has been identified as a potential source of funding for armed groups engaged in civil unrest in the Congo (Kinshasa) and surrounding countries. The United States, through the enactment of Section 1502 of the Dodd-Frank Act in 2010, made it a statutory obligation for all companies registered with the U.S. Securities and Exchange Commission (SEC) to perform due diligence to determine whether the products they manufacture, or the components of the products they manufacture, contain tantalum, tin, tungsten, and (or) gold (3TG) minerals and, if so, to determine whether these minerals were sourced from the Congo and (or) its bordering countries. Under rules issued by the SEC, publicly traded companies were required to report the sources of 3TG materials used by May 2014. The Federal courts issued a decision that the SEC must have the final resource extraction rule ready for congressional decision by June 27, 2016.

World Mine Production and Reserves: Reserves figures for Peru were revised based on data from the Ministerio de Energia y Minas del Peru.

	Mine production		Reserves[5]
	2014	2015[e]	
United States	—	—	—
Australia	7,210	7,000	370,000
Bolivia	19,900	20,000	400,000
Brazil	14,700	17,000	700,000
Burma	25,000	30,000	NA
China	96,000	100,000	1,500,000
Congo (Kinshasa)	6,400	6,400	NA
Indonesia	76,000	50,000	800,000
Laos	800	900	NA
Malaysia	3,780	3,800	250,000
Nigeria	2,800	2,800	NA
Peru	23,100	22,500	130,000
Russia	240	100	350,000
Rwanda	4,200	3,700	NA
Thailand	200	200	170,000
Vietnam	5,400	5,400	NA
Other countries	100	100	180,000
World total (rounded)	286,000	294,000	4,800,000

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, China, Indonesia, and Russia, are extensive and, if developed, could sustain recent annual production rates well into the future.

Substitutes: Aluminum, glass, paper, plastic, or tin-free steel substitute for tin in cans and containers. Other materials that substitute for tin are epoxy resins for solder; aluminum alloys, 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 old scrap + imports – exports + adjustments for Government and industry stock changes.

[2]Source: Platts Metals Week

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

[4]See Appendix B for definitions.

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

TITANIUM AND TITANIUM DIOXIDE[1]

(Data in metric tons unless otherwise noted)

Domestic Production and Use: Titanium sponge metal was produced by 3 operations in Nevada and Utah, and titanium ingot was produced by 10 operations in 8 States. Domestic and imported ingot was consumed by numerous firms to produce wrought products and castings. In 2015, an estimated 77% of titanium metal was used in aerospace applications. The remaining 23% was used in armor, chemical processing, marine hardware applications, medical implants, power generation, sporting goods, and other applications. Assuming an average purchase price of $9.86 per kilogram, the value of sponge metal consumed was about $302 million.

In 2015, titanium dioxide (TiO_2) pigment, which was produced by four companies at six facilities in five States, was valued at about $3.0 billion. The estimated end-use distribution of TiO_2 pigment consumption was paint (includes lacquers and varnishes), 60%; plastic, 20%; paper, 12%; and other, 8%. Other uses of TiO_2 included catalysts, ceramics, coated fabrics and textiles, floor coverings, printing ink, and roofing granules.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Titanium sponge metal:					
Production	W	W	W	W	W
Imports for consumption	33,800	33,600	19,900	17,700	22,600
Exports	256	1,420	1,860	2,220	1,640
Consumption, reported	48,400	35,100	24,600	26,400	30,600
Price, dollars per kilogram, yearend	10.35	11.78	11.57	11.00	9.93
Stocks, industry yearend[e]	10,800	18,100	25,200	22,900	26,800
Employment, number[e]	300	300	300	300	300
Net import reliance[2] as a percentage of reported consumption	69	71	44	58	68
Titanium dioxide pigment:					
Production	1,290,000	1,140,000	1,280,000	1,260,000	1,160,000
Imports for consumption	200,000	203,000	213,000	224,000	242,000
Exports	790,000	625,000	671,000	685,000	655,000
Consumption, apparent[3]	706,000	722,000	826,000	802,000	747,000
Producer price index, yearend	268	268	236	224	190
Employment, number[e]	3,400	3,400	3,400	3,400	3,100
Net import reliance[2] as a percentage of apparent consumption	E	E	E	E	E

Recycling: About 51,000 tons of scrap metal was recycled by the titanium industry in 2015. Estimated use of titanium scrap by the steel industry was about 10,200 tons; by the superalloy industry, 500 tons; and by other industries, 1,200 tons.

Import Sources (2011–14): Sponge metal: Japan, 59%; Kazakhstan, 17%; China; 13%; and other, 11%. Titanium dioxide pigment: Canada, 37%; China, 22%; Germany, 10%; and other, 31%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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	8108.20.0000	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.

Depletion Allowance: Not applicable.

Government Stockpile: None.

Events, Trends, and Issues: Based on increased imports, domestic consumption of titanium sponge in 2015 was estimated to have increased by 15% from that in 2014, owing to increased demand from the aerospace industry as production begins on next generation titanium-intensive aircraft. The operator of the titanium sponge plant in Rowley, UT, completed necessary certifications for using titanium sponge produced in its plant for use in rotating jet engine

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TITANIUM AND TITANIUM DIOXIDE

parts. A titanium producer in Kazakhstan and its joint-venture partner, a titanium forging company in France, entered into a project with a regional bank and a Government agency in France to build a plant to recycle aviation-grade titanium in Saint-Georges-de-Mons, France. The joint venture would provide the European manufacturing industry with a new supply chain for aerospace-grade titanium independent of sources in the United States and Russia. In July, a major titanium producer in Russia signed an agreement to provide semifinished titanium products to a British jet engine manufacturer and, in August, announced an agreement with a company in China to provide titanium mill products for use in civilian aircraft. In November, a titanium producer in Ukraine began a program to certify its titanium sponge for the aerospace market.

Domestic production of TiO_2 pigment in 2015 was estimated to be about 1.16 million tons, an 8% decrease from that of 2014, owing to closure of a pigment plant in Delaware and closure of two production lines—one at a plant in Mississippi and one at a plant in Tennessee. Similar closures took place in other countries owing to global overcapacity, excess inventories, and stagnant demand. In China, multiple pigment plants representing at least 280,000 tons per year of capacity were closed owing to overcapacity and (or) environmental issues. Two companies in China announced a merger that would make the combined company the world's fourth largest producer with a capacity of 540,000 tons per year of TiO_2 pigment. In Mexico, upgrades to a chloride-route pigment plant were expected to be completed in 2016, which would increase the capacity of the plant to 200,000 tons per year.

World Sponge Metal Production and Sponge and Pigment Capacity:

	Sponge production		Capacity 2015[4]	
	2014	2015[e]	Sponge	Pigment
United States	W	W	24,500	1,090,000
Australia	—	—	—	260,000
Belgium	—	—	—	85,000
Canada	—	—	—	105,000
China[e]	110,000	80,000	140,000	3,000,000
Finland	—	—	—	130,000
France	—	—	—	125,000
Germany	—	—	—	456,000
Italy	—	—	—	80,000
Japan[e]	25,000	30,000	64,500	310,000
Kazakhstan[e]	9,000	9,000	26,000	1,000
Mexico	—	—	—	130,000
Russia[e]	42,000	42,000	46,500	20,000
Spain	—	—	—	80,000
Ukraine[e]	7,200	9,000	12,000	120,000
United Kingdom	—	—	—	300,000
Other countries	500	500	500	887,000
World total (rounded)	[5]194,000	[5]171,000	316,000	7,200,000

World Resources:[6] The commercial feedstocks for titanium are ilmenite, leucoxene, rutile, slag, and synthetic rutile. For information on resources and reserves of titanium minerals, see Titanium Mineral Concentrates.

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]Yearend operating capacity.
[5]Excludes U.S. production.
[6]See Appendix C for resource/reserve definitions and information concerning data sources.

TITANIUM MINERAL CONCENTRATES[1]

(Data in thousand metric tons of contained TiO_2 unless otherwise noted)

Domestic Production and Use: Three firms produced ilmenite and rutile concentrates from surface-mining operations in Florida, Georgia, and Virginia. Based on reported data through October 2015, the estimated value of titanium mineral concentrates consumed in the United States in 2015 was $670 million. Zircon was a coproduct of mining from ilmenite and rutile deposits. About 95% of titanium mineral concentrates were consumed by domestic titanium dioxide (TiO_2) pigment producers. The remaining 5% was used in welding-rod coatings and for manufacturing carbides, chemicals, and metal.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production[2] (rounded)	300	300	200	100	100
Imports for consumption	1,010	1,110	1,190	1,110	1,000
Exports,[e] all forms	16	26	7	1	1
Consumption, estimated	1,300	1,390	1,390	1,190	1,100
Price, dollars per metric ton:					
Ilmenite, bulk, minimum 54% TiO_2, f.o.b. Australia[3]	195	300	265	155	110
Rutile, bulk, minimum 95% TiO_2, f.o.b. Australia[3]	1,350	2,200	1,250	950	840
Slag, 80%–95% TiO_2[4]	463–489	694–839	538–777	720–762	742–755
Employment, mine and mill, number[e]	195	195	195	144	190
Net import reliance[5] as a percentage of apparent consumption	77	78	86	92	91

Recycling: None.

Import Sources (2011–14): South Africa, 35%; Australia, 31%; Canada, 17%; Mozambique, 11%; and other, 6%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
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 consumption of titanium mineral concentrates was estimated be unchanged in 2015 from that of 2014.

Domestic mining of titanium ores and production of concentrates took place at one mine near Starke, FL; one mine near Nahunta, GA; and two mines near Stony Creek, VA. Prices for titanium mineral concentrates decreased slightly throughout the year. U.S. imports of ores and concentrates decreased by about 10% and exports were virtually unchanged. The operator of the Virginia mines expected to extract the remaining ore from both mines and complete operations by yearend 2015. The operator of the mine in Georgia was developing a second mine in Brantley County and had completed construction of a mineral sand plant near Offerman to process heavy-mineral concentrates from these mines. A fourth company was planning to process tailings from mineral sand mines in New Jersey to produce zircon and titanium concentrates. Construction of a mineral-sands concentrator in New Jersey was expected to be completed by the second quarter of 2016.

Global production of titanium concentrates (excluding the United States) was estimated to have decreased slightly in 2015 compared with that of 2014. One of the major producers of titanium slag produced less titanium slag, reportedly in response to low prices and weak demand. The startup of a new titanium slag project in Jazan, Saudi Arabia, was delayed until the second half of 2016 owing to technical issues. Heavy-mineral exploration and mining projects were underway in Australia, Madagascar, Mozambique, Tanzania, and Sri Lanka.

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TITANIUM MINERAL CONCENTRATES

World Mine Production and Reserves: Reserves for Australia were revised based on a Geoscience Australia publication. Reserves for Kenya were based on company reports.

	Mine production 2014	Mine production 2015[e]	Reserves[6]
Ilmenite:			
United States[2, 7]	100	100	2,000
Australia	720	720	140,000
Brazil	100	100	43,000
Canada[8]	480	360	31,000
China	960	900	200,000
India	190	210	85,000
Kenya	100	430	54,000
Madagascar	300	240	40,000
Mozambique	510	450	14,000
Norway	440	420	37,000
Russia	110	100	NA
Senegal	60	230	NA
South Africa[8]	600	480	63,000
Ukraine	250	240	5,900
Vietnam	560	540	1,600
Other countries	90	90	26,000
World total (ilmenite, rounded)	5,570	5,610	740,000
Rutile:			
United States	([9])	([9])	([9])
Australia	190	144	22,000
India	17	18	7,400
Kenya	22	65	13,000
Madagascar	9	9	NA
Sierra Leone	100	110	NA
South Africa	53	55	8,300
Ukraine	63	63	2,500
Other countries	17	19	400
World total (rutile, rounded)	[9]470	[9]480	54,000
World total (ilmenite and rutile, rounded)	6,040	6,090	790,000

World Resources: Ilmenite accounts for about 92% 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 one significant digit to avoid disclosing company proprietary data.
[3]Source: Industrial Minerals; yearend average of high-low price.
[4]Landed duty-paid value based on U.S. imports for consumption. Data series revised to reflect annual average price range of significant importing countries.
[5]Defined as imports – exports.
[6]See Appendix C for resource/reserve definitions and information concerning data sources.
[7]Includes rutile.
[8]Mine production is primarily used to produce titaniferous slag.
[9]U.S. rutile production and reserves data are included with ilmenite.

TUNGSTEN

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

Domestic Production and Use: A tungsten mine northeast of Los Angeles, California, produced concentrates in 2015. Approximately seven 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 consumed in the United States was used in cemented carbide parts for cutting and wear-resistant materials, primarily in the construction, metalworking, mining, and oil- and gas-drilling industries. The remaining tungsten was consumed to make tungsten heavy alloys for applications requiring high density; electrodes, filaments, wires, and other components for electrical, electronic, heating, lighting, and welding applications; steels, superalloys, and wear-resistant alloys; and chemicals for various applications. The estimated value of apparent consumption in 2015 was approximately $700 million.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production:					
Mine	NA	NA	NA	NA	NA
Secondary	11,000	9,180	8,610	8,520	7,100
Imports for consumption:					
Concentrate	3,640	3,650	3,690	4,080	3,900
Other forms	9,600	8,060	8,480	8,730	6,600
Exports:					
Concentrate	169	203	1,060	1,230	300
Other forms	6,960	6,530	6,670	5,420	3,600
Government stockpile shipments:					
Concentrate	1,180	1,780	2,100	282	—
Other forms	46	([1])	—	([1])	—
Consumption:					
Reported, concentrate	W	W	W	W	W
Apparent,[2, 3] all forms	18,100	15,000	14,700	15,000	14,000
Price, concentrate, dollars per mtu WO_3,[4] average, U.S. spot market, Platts Metals Week	248	358	358	348	320
Stocks, industry, yearend:					
Concentrate	W	W	W	W	W
Other forms	W	W	W	W	W
Net import reliance[5] as a percentage of apparent consumption	40	39	41	43	49

Recycling: In 2015, the estimated tungsten contained in scrap consumed by processors and end users represented 59% of apparent consumption of tungsten in all forms.

Import Sources (2011–14): Tungsten contained in ores and concentrates, intermediate and primary products, wrought and unwrought tungsten, and waste and scrap: China, 40%; Bolivia and Canada, 8% each; Germany, 6%; and other, 38%.

Tariff: Item	**Number**	**Normal Trade Relations[6] 12–31–15**
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.

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

Government Stockpile:

Stockpile Status—9–30–15[7]

Material	**Inventory**	**Disposal Plan FY 2015**	**Disposals FY 2015**
Metal powder	125	35	—
Ores and concentrates	11,600	1,360	—

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TUNGSTEN

Events, Trends, and Issues: World tungsten supply was dominated by production in China and exports from China. China was also the world's leading tungsten consumer. China's Government has regulated its tungsten industry by limiting the number of exploration, mining, and export licenses; limiting or forbidding foreign investment; imposing constraints on mining and processing; imposing quotas on production and exports; adjusting export quotas to favor value-added downstream materials and products; and imposing export duties on tungsten materials. As a result of a 2014 World Trade Organization (WTO) ruling that China's export restraints were inconsistent with its WTO obligations, China discontinued its tungsten export quota system and its tungsten export duties in 2015, but maintained export qualifications and changed its resource tax basis from quantity produced to sales value.

The tungsten market was in oversupply, owing to an economic slowdown in China and weak economic conditions elsewhere, which ultimately led to mine production exceeding consumption. Global tungsten prices trended downward during 2014 and 2015. As a result of these and other factors, in late 2015, the sole tungsten mine in Canada suspended operations and was placed on care-and-maintenance status, eight large producers in China announced plans to reduce their output of tungsten concentrates, and China's state reserve bureau reportedly planned to buy tungsten concentrates. In spite of oversupply and low prices, new production entered the market. In 2015, tungsten mines in the United Kingdom and Zimbabwe began production, a large new mine in Vietnam ramped up production and its processing plant started producing ammonium paratungstate and tungsten oxides, and new ferrotungsten plants in Russia and the Republic of Korea began production.

World Mine Production and Reserves: Reserves for Spain, the United Kingdom, Vietnam, and "Other countries" were revised based on company or Government reports.

	Mine production		Reserves[8]
	2014	2015[e]	
United States	NA	NA	NA
Austria	870	870	10,000
Bolivia	1,250	1,200	NA
Canada	2,340	1,700	290,000
China	71,000	71,000	1,900,000
Portugal	671	630	4,200
Russia	2,800	2,500	250,000
Rwanda	1,000	1,000	NA
Spain	800	730	32,000
United Kingdom	—	600	51,000
Vietnam	4,000	5,000	100,000
Other countries	2,060	2,100	670,000
World total (rounded)	[3]86,800	[3]87,000	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 and titanium carbide, ceramics, ceramic-metallic composites (cermets), and tool steels. Potential substitutes for other applications are as follows: molybdenum for certain tungsten mill products; molybdenum steels for tungsten steels; 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]The sum of U.S. net import reliance (see footnote 5) and secondary production.
[3]Does not include U.S. mine production.
[4]A metric ton unit (mtu) of tungsten trioxide (WO_3) contains 7.93 kilograms of tungsten.
[5]Defined as imports – exports + adjustments for Government and industry stock changes.
[6]No tariff for Canada. Tariffs for other countries for some items may be eliminated under special trade agreements.
[7]See Appendix B for definitions.
[8]See Appendix C for resource/reserve definitions and information concerning data sources.

VANADIUM

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

Domestic Production and Use: In 2015, six U.S. firms that compose most of the domestic vanadium industry produced ferrovanadium, vanadium pentoxide, vanadium metal, and vanadium-bearing chemicals or specialty alloys by processing materials such as petroleum residues, spent catalysts, utility ash, and vanadium-bearing pig iron slag. In 2009–13, small quantities of vanadium were produced as a coproduct from the mining of uraniferous sandstones on the Colorado Plateau. All coproduct vanadium production was suspended in 2014 and 2015. Metallurgical use, primarily as an alloying agent for iron and steel, accounted for about 93% of the domestic vanadium consumption in 2015. 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:	2011	2012	2013	2014	2015[e]
Production, mine, mill	590	106	591	—	—
Imports for consumption:					
Ferrovanadium	2,220	4,190	3,710	3,230	3,300
Vanadium pentoxide, anhydride	2,800	1,640	2,040	3,410	3,500
Oxides and hydroxides, other	886	905	205	104	35
Aluminum-vanadium master alloys (gross weight)	86	115	169	431	260
Ash and residues	1,510	2,210	4,190	6,160	2,200
Sulfates	42	29	30	19	18
Vanadates	303	280	276	197	64
Vanadium metal, including waste & scrap (gross weight)	44	154	35	161	113
Exports:					
Ferrovanadium	316	337	299	253	120
Vanadium pentoxide, anhydride	89	62	90	201	105
Oxides and hydroxides, other	264	305	427	350	200
Aluminum-vanadium master alloys (gross weight)	318	432	347	443	45
Vanadium metal, including waste & scrap (gross weight)	102	26	58	32	14
Consumption:					
Reported	4,140	3,960	3,980	4,070	3,600
Apparent	7,570	8,530	10,100	12,300	9,100
Price, average, dollars per pound V_2O_5	6.76	6.49	6.04	5.61	4.40
Stocks, consumer, yearend[1]	193	219	220	225	180
Net import reliance[2] as a percentage of apparent consumption	92	99	94	100	100

Recycling: The quantity of vanadium recycled from spent chemical process catalysts was significant and may compose as much as 40% of total vandium catalysts. Some tool steel scrap was recycled primarily for its vanadium content but this only accounted for a small percentage of total vanadium used.

Import Sources (2011–14): Ferrovanadium: Czech Republic, 43%; Canada, 22%; Republic of Korea, 18%; Austria, 14%; and other, 3%. Vanadium pentoxide: South Africa, 40%; Russia, 35%; China, 18%; and other, 7%.

Tariff: Ash, residues, slag, and waste and scrap enter duty-free.

Item	Number	Normal Trade Relations 12–31–15
Vanadium pentoxide anhydride	2825.30.0010	5.5% ad val.
Vanadium oxides and hydroxides, other	2825.30.0050	5.5% ad val.
Vanadates	2841.90.1000	5.5% ad val.
Ferrovanadium	7202.92.0000	4.2% ad val.
Vanadium and articles thereof[3]	8112.99.2000	2.0% ad val.

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

Government Stockpile: None.

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VANADIUM

Events, Trends, and Issues: U.S. reported consumption of vanadium in 2015 was slightly more than that of 2014. Among the major uses for vanadium, production of carbon, full-alloy, and high-strength low-alloy steels accounted for 16%, 43%, and 34%, respectively, of domestic consumption. U.S. imports for consumption of vanadium in 2015 decreased by 31% from those of the previous year. The main decrease was in imports of vanadium-bearing ash and residues (64% decrease from those of 2014). U.S. exports decreased by 55% from those of the previous year. The decrease was seen across all materials being exported, not just one specific material.

In April 2015, a vanadium producer in South Africa announced that it planned to apply for bankruptcy protection. The company had been suffering from ongoing energy supply interruptions as well as rising energy costs that affected ferrovanadium (FeV) production costs. South African FeV export prices have gradually declined since 2009. Any disruption in the supply of feedstock by the company could affect vanadium production in Austria, South Africa, and the United States. Products dependent on the feedstock from South Africa included aluminum-vanadium, FeV, vanadium chemicals, and vanadium oxides.

Vanadium pentoxide (V_2O_5) and FeV prices continued to decrease throughout 2015. In May 2015, V_2O_5 prices were $4.15 per pound. Weak demand for vanadium, triggered by a slowdown of the Chinese economy, was a contributing factor. If prices continue to decrease or remain at 2015 levels, more secondary vanadium producers are expected to temporarily suspend vanadium production.

World Mine Production and Reserves:

	Mine production		Reserves[4]
	2014	2015[e]	(thousand metric tons)
United States	—	—	45
Australia	—	—	1,800
Brazil	1,030	2,800	NA
China	45,000	42,000	5,100
Russia	15,100	15,000	5,000
South Africa	21,000	19,000	3,500
Other countries	580	600	NA
World total (rounded)	82,700	79,400	15,000

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 in aerospace titanium alloys.

[e]Estimated. NA Not available. — Zero.
[1]Does not include vanadium pentoxide.
[2]Defined as imports – exports + adjustments for industry stock changes.
[3]Aluminum-vanadium master alloy consisting of 35% aluminum and 64.5% vanadium.
[4]See Appendix C for resource/reserve definitions and information concerning data sources.

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. Most of the vermiculite concentrate was shipped to 17 exfoliating plants in 11 States. The end uses for exfoliated vermiculite were estimated to be agriculture/horticulture, 50%; lightweight concrete aggregates (including cement premixes, concrete, and plaster), 10%; insulation, 5%; and other, 35%.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production[e, 1]	100	100	100	100	100
Imports for consumption[e, 2]	53	57	36	43	25
Exports[e]	2	2	2	3	2
Consumption, apparent, concentrate[3]	150	160	130	140	120
Consumption, reported, exfoliated	62	59	64	63	65
Price, range of value, concentrate, dollars per ton, ex-plant[4]	115–460	145–525	145–565	140–575	140–580
Employment, number[e]	80	75	70	70	70
Net import reliance[5] as a percentage of apparent consumption	30	35	25	30	20

Recycling: Insignificant.

Import Sources (2011–14): South Africa, 35%; Brazil, 35%; China, 28%; and other, 2%.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
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, U.S. exports were slightly lower in 2015 than those in 2014. U.S. imports, excluding any material from Canada and Mexico, were estimated to be about 25,000 tons in 2015, significantly lower than those of 2014, especially from South Africa. Coarse-grade vermiculite remained in short supply, and prices were unchanged in 2015.

An Australian company transferred full ownership of its East African Namekara vermiculite mine in Uganda to its financial lenders, releasing it from all debt. The mine remained on care-and-maintenance status, mostly as a result of an oversupply of the medium-to-finer grades in the world market; sluggish market conditions in Europe, its largest market; and transportation and related infrastructure-improvement issues. The Namekara deposit has sufficient resources for more than 50 years of production and is a portion of the larger East African vermiculite project, which has about 55 million tons of inferred resources and is considered to be one of the world's largest deposits.

A company in Turkey, in a joint venture, worked to complete development of the country's first vermiculite mine in Sivas in central Turkey. Small quantities of vermiculite from development activities were sold to customers in Spain, with further sales to be processed through the sales network of a France-based major company that purchased one of the joint-venture companies earlier in the year. With the date of full production not yet determined, first year production is expected to be about 5,000 tons from a total reserve of 7 million tons, of which more than one-half were considered high quality.

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VERMICULITE

A company in Russia mined vermiculite in the Murmansk Region of northwest Russia and marketed its vermiculite concentrate and exfoliated vermiculite mostly in Russia, as well as in Eastern Europe and Western Europe.

A company in Brazil continued to expand production capacity at its vermiculite mine in central Brazil and to develop another deposit near Brasilia. The new operation, which is planned to begin production in 2016, will bring the company's total production capacity to 200,000 tons per year.

World Mine Production and Reserves: Reserves for Brazil were revised based on new Government information.

	Mine production		Reserves[6]
	2014	**2015[e]**	
United States[e, 1]	100	100	25,000
Brazil	70	70	6,300
Bulgaria	18	18	NA
India	10	10	1,700
South Africa	143	160	14,000
Zimbabwe	30	40	NA
Other countries	10	10	NA
World total	381	408	NA

World Resources: Marginal reserves of vermiculite in Colorado, Nevada, North Carolina, Texas, and Wyoming are estimated to be 2 million to 3 million tons. Reserves 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 host rock and overburden.

Substitutes: Expanded perlite is a substitute for vermiculite in lightweight concrete and plaster. Other more dense but less costly substitutes in these applications are expanded clay, shale, slag, and slate. Alternate materials for loosefill 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 and used by producers. Data are rounded to one significant digit to avoid disclosing company proprietary data.
[2]Excludes Canada and Mexico.
[3]Rounded to two significant digits to protect proprietary data.
[4]Source: Mining Engineering.
[5]Defined as imports – exports.
[6]See Appendix C for resource/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 in 2015. U.S. production of wollastonite (sold or used) was withheld to protect company proprietary data but was estimated to have increased slightly from that of 2014. Domestic deposits of wollastonite have been identified in Arizona, California, Idaho, Nevada, New Mexico, New York, and Utah, but 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 2015 compared to the previous year. Plastics and rubber markets (thermoplastic and thermoset resins and elastomer compounds) were estimated to have accounted for more than 25% of U.S. usage of wollastonite, followed by ceramics (frits, sanitaryware, and tile), paint (architectural and industrial paints), metallurgical applications (flux and conditioner), friction products (primarily brake linings), and miscellaneous uses (including adhesives, concrete, glass, and sealants). Globally, ceramics were estimated to account for more than 30% of wollastonite sales, followed by polymers and paint. Lesser global uses for wollastonite included miscellaneous construction products, friction materials, and metallurgical applications.

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 its resistance to weathering, reduces gloss, reduces 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 2015. Exports were estimated to be less than 10,000 tons and imports were probably less than 4,000 tons. Comprehensive trade data were not available. Prices for wollastonite were reported in the trade literature to range from $80 to $445 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 110 people were employed at wollastonite mines and mills in 2015.

Recycling: None.

Import Sources (2011–14): Comprehensive trade data were not available, but wollastonite was primarily imported from China, Finland, India, and Mexico.

Tariff:

Item	Number	Normal Trade Relations 12–31–15
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 10% (Domestic and foreign).

Government Stockpile: None.

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WOLLASTONITE

Events, Trends, and Issues: Sales to domestic construction-related markets, such as adhesives, caulks, cement board, ceramic tile, paints, stucco, and wallboard, were likely to have increased in 2015 owing to growth in residential and commercial construction. With increased domestic manufacturing, sales of wollastonite to the manufacturing industries, such as metal casting and processing, paint, plastics, and rubber, probably also increased. In Western Europe and Asia, demand for wollastonite likely remained unchanged or increased just slightly because of the effect of economic uncertainties on construction and manufacturing.

Environmental groups that had been challenging the leading U.S. wollastonite producer's proposed exploratory drilling program within the Adirondack Forest Preserve in New York decided not to pursue any further legal action. The 81-hectare property contains an estimated 1.2 to 1.5 million tons of wollastonite reserves, sufficient to extend the company's mining operations in the area by an additional 10 years.

World Mine Production and Reserves: United States production of wollastonite ranks third globally. Production data were not available for many countries.

	Mine production[e]		Reserves[1]
	2014	2015	
United States	W	W	
China	300,000	300,000	World reserves of wollastonite were estimated to exceed 90 million tons. Many deposits, however, have not been surveyed, precluding accurate reserves estimates.
Finland	10,000	10,000	
India	180,000	180,000	
Mexico	[2]54,600	55,500	
Other countries	6,000	6,000	
World total (rounded)[3, 4]	550,000	550,000	

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/reserve definitions and information concerning data sources.
[2]Reported figure.
[3]Excludes U.S. production.
[4]Refined concentrate production.

YTTRIUM[1]

[Data in metric tons of yttrium oxide (Y_2O_3) equivalent content unless otherwise noted]

Domestic Production and Use: Rare earths were mined in the United States by one company in 2015. Bastnaesite, a rare-earth fluorocarbonate mineral, was mined as a primary product at Mountain Pass, CA. Domestic production of total rare-earth mineral concentrate was estimated to be 4,500 tons of rare-earth oxide equivalent in 2015, down from an estimated 5,400 tons in 2014. Yttrium was estimated to represent about 0.12% of the rare-earth elements in the Mountain Pass bastnaesite ore; however, it was not processed domestically owing to its low concentration.

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:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production, mine[2]	—	NA	NA	NA	NA
Imports for consumption:					
Yttrium, alloys, compounds, and metal[e, 3]	550	160	200	200	200
Exports, in ore and concentrate	NA	NA	NA	NA	NA
Consumption, estimated[4]	550	160	200	200	200
Price,[e] dollars:					
Yttrium oxide, per kilogram, minimum 99.999 purity[5]	136–141	86–91	23–27	15–17	8–9
Yttrium metal, per kilogram, minimum 99.9% purity[5]	162–172	141–151	60–70	55–65	47–54
Net import reliance[e, 2, 6] as a percentage of apparent consumption	100	>95	>95	>95	>95

Recycling: Small quantities, primarily from phosphors.

Import Sources (2011–14): Yttrium compounds:[7] China, 78%; Japan, 9%; Germany, 5%; Austria, 2%; and other, 6%. Nearly all imports of yttrium metal and compounds are derived from mineral concentrates produced in China.

Tariff: Item	**Number**	**Normal Trade Relations 12–31–15**
Rare-earth metals, scandium and yttrium, whether or not intermixed or interalloyed	2805.30.0000	5.0% ad val.
Mixtures of rare-earth oxides or of rare-earth chlorides	2846.90.2000	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: None.

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. Processing was primarily at facilities in Guangdong, Jiangsu, and Jiangxi Provinces.

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YTTRIUM

In 2015, global consumption of yttrium oxide was estimated to be 6,000 tons. Globally, yttrium was mainly consumed in the form of high-purity oxide compounds for phosphors. Lesser amounts were consumed in ceramics, electronic devices, lasers, and metallurgical applications. In October, the Mountain Pass mining and separation operations were idled indefinitely. Price declines were cited as a key factor in the suspension of operations.

Owing to shrinking demand in some markets and excess supply, prices for yttrium metal and oxide continued to decrease in 2015, approaching historic lows. According to industry reports, increasing popularity of light-emitting-diode (LED) lighting over traditional fluorescent lighting has reduced the consumption of yttrium-based phosphors. New designs for LEDs using remote phosphors may reverse this trend in the coming years. Remote phosphors can improve energy efficiency and are applied on to a separate component rather than directly on the LEDs.

According to China's preliminary export statistics, yttrium oxide exports increased in 2015. During the first three quarters of 2015, China exported 1,100 tons of yttrium oxide, primarily to Japan (53%), Italy (16%), and the United States (10%). China's other exports of yttrium included 110 kilograms of yttrium chloride, 1.17 tons of yttrium fluoride, 5.06 tons of unspecified yttrium compounds, and 13 tons of yttrium metal. China continued efforts to manage its rare-earth industry through industry consolidations, crack downs on illegal production, and stockpiling.

In 2015, the Defense Logistics Agency (DLA) Strategic Materials was seeking comments on the potential market impact of the proposed Fiscal Year 2017 National Defense Stockpile Annual Materials Plan. The plan included a maximum acquisition of 10 tons of yttrium oxide as a potential addition to the national stockpile. The DLA awarded a research contract to a domestic firm using a rhyolite feedstock from the Round Top rare-earth deposit in Texas to produce high-purity yttrium oxide.

World Mine Production and Reserves:[8] World production of yttrium was almost entirely from China. In 2015, world production was estimated to be 8,000 to 10,000 tons. Programs to stem the undocumented production of rare earths in China were ongoing. 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, China, India, and the United States.

World Resources: The world's resources of yttrium are probably very large. Yttrium is associated with most rare-earth deposits. It occurs in various minerals in differing concentrations and occurs in a wide variety of geologic environments, including alkaline granites and other intrusives, carbonatites, hydrothermal deposits, laterites, placers, and vein-type deposits. 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. Large resources of yttrium in monazite and xenotime are available worldwide in placer deposits, carbonatites, uranium ores, and weathered clay deposits (ion-adsorption ore). Additional resources of yttrium occur in apatite-magnetite-bearing rocks, deposits of niobium-tantalum minerals, non-placer monazite-bearing deposits, sedimentary phosphate deposits, and uranium ores.

Substitutes: Substitutes for yttrium are available for some applications but generally are much less effective. In most uses, especially in electronics, lasers, and phosphors, yttrium is not subject to 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]Based on data from the U.S. Census Bureau and the Port Import/Export Reporting Service, JOC Group Inc.
[4]Essentially, all yttrium consumed domestically was imported or refined from imported materials.
[5]Free on board China from Metal-Pages Ltd., Teddington, United Kingdom.
[6]Defined as imports – exports. Insufficient data were available to determine exports and were excluded from the calculation.
[7]In 2013 and 2014, import sources were expanded to include chlorides (HTS 2846.90.8060), oxides (HTS 2846.90.8050), and yttrium compounds greater than 19% to less than 85% weight percent yttrium oxide equivalent (HTS 2846.90.4000).
[8]See Appendix C for resource/reserve definitions and information concerning data sources.

ZEOLITES (NATURAL)

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2015, eight companies in the United States operated 10 zeolite mines and produced an estimated 72,400 tons of natural zeolites, a 13% increase from that of 2014. Chabazite was mined in Arizona, and clinoptilolite was mined in California, Idaho, New Mexico, Oregon, and Texas. New Mexico was estimated to be the leading natural zeolite-producing State, followed by Idaho, Texas, California, Oregon, and Arizona. The top three U.S. companies accounted for about 85% of total domestic production.

An estimated 71,100 tons of natural zeolites were consumed in the United States during 2015. Domestic uses for natural zeolites were, in decreasing order by tonnage, animal feed, odor control, water purification, unclassified end uses, pet litter, wastewater treatment, gas absorbents (and air filtration), fertilizer carriers, oil absorbents, desiccants, catalysts, fungicide or pesticide carriers, aquaculture, and cement (primarily downhole cement applications by the drilling industry). Animal feed, odor control, water purification, pet litter, and wastewater treatment accounted for nearly 80% of the domestic sales tonnage.

Salient Statistics—United States:	**2011**	**2012**	**2013**	**2014**	**2015[e]**
Production	65,400	74,000	69,500	64,100	72,400
Sales, mill	65,200	70,500	68,300	62,700	71,300
Imports for consumption[e]	150	5	5	25	25
Exports[e]	1,100	750	200	175	200
Consumption, apparent[e, 1]	64,200	69,800	68,100	62,600	71,100
Price, range of value, dollars per metric ton[2]	40–800	50–800	50–800	110–440	110–440
Employment, mine and mill	95	110	105	95	100
Net import reliance[3] 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 (2011–14): Comprehensive trade data were not available for natural zeolites. Nearly all imports and exports were synthetic zeolites.

Tariff: **Item**	**Number**	**Normal Trade Relations 12–31–15**
Mineral substances not elsewhere specified or included	2530.90.8050	Free.

Depletion Allowance: 14% (Domestic and foreign).

Government Stockpile: None.

Events, Trends, and Issues: During the past 20 years, the animal feed industry has seen the greatest increase in sales of natural zeolites. Sales for cement, odor control, wastewater treatment, and water purification applications have also increased in the past 10 years, although expansion of these markets has not been as great as with animal feed. Sales for pet litter declined during the past 20 years because of competition from other products and shifting of some pet litter sales to other zeolite markets.

The permitting process for expanding the pit at the Bear River Zeolite project in southeastern Idaho was initiated in 2015. The company was targeting applications in the oil and gas industry as end uses for the increased zeolite production. Another U.S. company received a permit to mine all minerals at its operation in southeastern Oregon, allowing for the removal of overburden that was inhibiting access to the zeolite deposit. At full production, the mine, which contained an estimated 45 million tons of zeolite resources, had the potential to be one of the top employers among all domestic zeolite mines.

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ZEOLITES (NATURAL)

World Mine Production and Reserves: Most countries do not report natural zeolite production. Countries mining large tonnages of zeolites typically use them in low-value applications. The ready availability of zeolite-rich rock at low cost and the shortage of competing minerals and rocks are probably the most important factors encouraging its large-scale use. Examples of such usage are dimension stone, lightweight aggregate, pozzolanic cement, and soil conditioners.

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 that contain low to moderate concentrations of zeolites. These typically are used in high-volume construction applications; some deposits should, therefore, be excluded from reserves estimates because it is the rock itself and not its zeolite content that makes the deposit valuable.

	Mine production[e]		Reserves[4]
	2014	**2015**	
United States	[5]64,100	72,400	
China[6]	2,000,000	2,000,000	World reserves are not determined but are estimated to be large.
Cuba	44,000	43,000	
Jordan	13,000	13,000	
Korea, Republic of	230,000	230,000	
Turkey	45,000	70,000	
Other countries[6]	350,000	350,000	
World total (rounded)	2,750,000	2,780,000	

World Resources: World resources have not been estimated for natural zeolites. An estimated 120 million tons of chabazite, clinoptilolite, erionite, mordenite, and phillipsite is present in near-surface deposits in the Basin and Range province in the United States. Resources in the United States may approach 10 trillion tons for zeolite-rich deposits.

Substitutes: For pet litter, natural 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]Estimate based on values reported by U.S. producers and prices published in the trade literature. Bulk shipments typically range from $100 to $230 per ton.
[3]Defined as imports – exports.
[4]See Appendix C for resource/reserve definitions and information concerning data sources.
[5]Reported figure.
[6]Includes materials appropriate for pozzolan applications.

ZINC

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

Domestic Production and Use: The value of zinc mined in 2015, based on zinc contained in concentrate, was about $1.78 billion. Zinc was mined in 5 States at 15 mines operated by 4 companies. Four facilities, one primary and three secondary, operated by three companies, produced commercial-grade zinc metal. Of the total reported zinc consumed, about 80% was used in galvanizing, 6% in brass and bronze, 5% in zinc-base alloys, and 9% in other uses.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production:					
Mine, zinc in concentrate	769	738	784	832	850
Metal production:					
At primary smelters	110	114	106	110	125
At secondary smelters	138	147	127	70	50
Imports for consumption:					
Zinc in ore and concentrate	27	6	3	([1])	([1])
Refined zinc	716	655	713	805	800
Exports:					
Zinc in ore and concentrate	653	591	669	644	740
Refined zinc	18	14	12	20	15
Shipments from Government stockpile	—	—	—	—	—
Consumption, apparent, refined zinc[2]	946	902	935	965	960
Price, average, cents per pound:					
North American[3]	106.2	95.8	95.6	107.1	95.0
London Metal Exchange (LME), cash	99.5	88.3	86.6	98.1	87.0
Reported producer and consumer stocks, refined zinc, yearend	72	74	74	84	85
Employment:					
Mine and mill, number[4]	2,240	2,310	2,560	2,620	2,680
Smelter, primary, number	244	252	257	259	259
Net import reliance[5] as a percentage of apparent consumption (refined zinc)	74	71	75	81	82

Recycling: In 2015, about 37% (65,000 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 (2011–14): Ore and concentrate: Peru, 50%; Canada, 30%; Mexico, 16%; and Turkey, 4%. Refined metal: Canada, 64%; Mexico, 13%; Peru, 8%; Australia, 7%; and other, 8%. Waste and scrap: Canada, 72%; Mexico, 24%; and other, 4%. Combined total: Canada, 64%; Mexico, 14%; Peru, 9%; Australia, 7%; and other, 6%.

Tariff: Item	Number	Normal Trade Relations[6] 12–31–15
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.

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

Government Stockpile:

Stockpile Status—9–30–15[7]

Material	Inventory	Disposal Plan FY 2015	Disposals FY 2015
Zinc	7	—	—

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ZINC

Events, Trends, and Issues: Global zinc mine production in 2015 was 13.4 million tons, essentially unchanged from that of 2014. According to the International Lead and Zinc Study Group,[8] global refined zinc production in 2015 increased by 4% to 14.0 million tons, and metal consumption rose slightly to 13.9 million tons, resulting in a production-to-consumption surplus of about 100,000 tons of refined zinc. Domestic zinc mine production increased slightly in 2015, owing mostly to the reopening of the Pend Oreille Mine in Washington in late 2014. The mine was expected to reach full production by yearend 2015. Refined zinc production decreased slightly; an increase in primary production was more than offset by a decrease in secondary production. Rampup of a new 140,000-metric-ton-per-year zinc recycling facility in Mooresboro, NC, continued to be delayed by technical issues. Apparent zinc consumption remained unchanged. Growth in the domestic galvanizing industry has been limited by the stronger dollar and a significant increase in galvanized steel imports from China. In June, six steel producers with operations in the United States filed antidumping and countervailing duty petitions asserting that imports of galvanized steel from China, India, Italy, the Republic of Korea, and Taiwan during the past 3 years have materially injured the domestic steel industry and that producers in these countries have benefitted significantly from Government-sponsored subsidy programs that allowed them to price products at less than fair value.

North American Special High Grade zinc prices averaged $1.03 per pound in the first quarter of 2015 and $1.08 per pound in the second quarter, reaching an average monthly high of $1.12 per pound in May. Zinc prices then decreased significantly in the second half of the year, in tandem with a general decrease in base metal prices, falling to an average of $0.86 per pound in September. Decreasing metal prices during this time were attributed to weakening global economic conditions with slowing growth in China.

World Mine Production and Reserves: Reserves estimates for Bolivia, Canada, India, Ireland, Kazakhstan, Mexico, and other countries were revised based on company data. The reserves estimates for Australia, China, and Peru were revised based on data from Government reports.

	Mine production[9]		Reserves[10]
	2014	2015[e]	
United States	832	850	11,000
Australia	1,560	1,580	[11]63,000
Bolivia	449	430	4,600
Canada	353	300	6,200
China	4,930	4,900	38,000
India	706	830	10,000
Ireland	283	230	1,100
Kazakhstan	345	340	4,000
Mexico	660	660	15,000
Peru	1,320	1,370	25,000
Other countries	1,860	1,870	26,000
World total (rounded)	13,300	13,400	200,000

World Resources: Identified zinc resources of the world are about 1.9 billion metric tons.

Substitutes: Aluminum and plastics substitute for galvanized sheet in automobiles; and aluminum alloy, cadmium, paint, and plastic coatings replace zinc coatings in other applications. Aluminum- and magnesium-based alloys are major competitors for zinc-based die-casting alloys. Many elements are substitutes for zinc in chemical, electronic, and pigment uses.

[e]Estimated. — Zero.
[1]Less than ½ unit.
[2]Defined as primary refined production + secondary refined production + refined imports – refined exports + adjustments for Government stock changes.
[3]Platts Metals Week price for North American SHG zinc; based on the LME cash price plus premium.
[4]Includes mine and mill employment at all zinc-producing mines. Source: Mine Safety and Health Administration.
[5]Defined as imports – exports + adjustments for Government stock changes.
[6]No tariff for Canada, Mexico, and Peru for items shown.
[7]See Appendix B for definitions.
[8]International Lead and Zinc Study Group, 2015, ILZSG session/forecasts: Lisbon, Portugal, International Lead and Zinc Study Group press release, October 9, 5 p.
[9]Zinc content of concentrate and direct shipping ore.
[10]See Appendix C for resource/reserve definitions and information concerning data sources.
[11]For Australia, Joint Ore Reserves Committee-compliant reserves were about 25 million tons.

ZIRCONIUM AND HAFNIUM

(Data in metric tons unless otherwise noted)

Domestic Production and Use: In 2015, three firms recovered zircon (zirconium silicate) from surface-mining operations in Florida, Georgia, and Virginia as a coproduct from the mining and processing of heavy minerals. Zirconium metal and hafnium metal were produced from zirconium chemical intermediates by one domestic producer in Oregon and one in Utah. Typically, zirconium and hafnium are contained in zircon at a ratio of about 50 to 1. Zirconium chemicals were produced by the metal producer in Oregon and by at least 10 other companies. Ceramics, foundry sand applications, opacifiers, and refractories are the leading end uses for zircon. Other end uses of zircon include abrasives, chemicals (predominantly, zirconium oxychloride octohydrate and zirconium basic sulfate as intermediate chemicals), metal alloys, and welding rod coatings. The leading consumers of zirconium metal and hafnium metal are the nuclear energy and chemical process industries.

Salient Statistics—United States:	2011	2012	2013	2014	2015[e]
Production, zircon (ZrO_2 content)	W	W	W	W	[1]60,000
Imports:					
Zirconium, ores and concentrates (ZrO_2 content)	17,200	16,700	8,050	32,800	20,700
Zirconium, unwrought, powder, and waste and scrap	487	279	395	843	1,400
Zirconium, wrought	390	288	321	257	195
Hafnium, unwrought, powder, and waste and scrap	10	24	10	21	55
Exports:					
Zirconium ores and concentrates (ZrO_2 content)	15,800	13,000	19,000	4,850	2,830
Zirconium, unwrought, powder, and waste and scrap	677	554	600	534	470
Zirconium, wrought	1,330	1,250	1,140	913	1,030
Consumption, apparent, zirconium ores and concentrates, (ZrO_2 content)	W	W	W	W	80,000
Prices:					
Zircon, dollars per metric ton (gross weight):					
Domestic[2]	2,650	2,650	1,050	1,050	1,050
Imported[3]	2,122	2,533	996	1,106	1,052
Zirconium, unwrought, import, France, dollars per kilogram[4]	64	91	75	59	86
Hafnium, unwrought, import, France, dollars per kilogram[4]	544	503	578	561	608
Net import reliance[5] as a percentage of apparent consumption:					
Zirconium	<10%	<10%	E	<50%	<25%
Hafnium	NA	NA	NA	NA	NA

Recycling: Companies in Oregon and Utah recycled zirconium from new scrap generated during metal production and fabrication and/or from post-commercial old scrap. Zircon foundry mold cores and spent or rejected zirconia refractories are often recycled. Hafnium metal recycling was insignificant.

Import Sources (2011–14): Zirconium mineral concentrates: South Africa, 67%; Australia, 28%; and other, 5%. Zirconium, unwrought, including powder: China, 44%; Japan, 30%; Germany, 20%; France, 4%; and other, 2%. Hafnium, unwrought: France, 47%; Germany, 28%; Australia, 17%; United Kingdom, 5%; and other, 3%.

Tariff: Item	Number	Normal Trade Relations 12–31–15
Zirconium ores and concentrates	2615.10.0000	Free.
Germanium oxides and zirconium dioxide	2825.60.0000	3.7% ad val.
Ferrozirconium	7202.99.1000	4.2% ad val.
Zirconium, unwrought and zirconium 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 mining of zirconium ores and production of concentrates took place at two mines near Stony Creek, VA; one near Starke, FL; and one near Nahunta, GA. Prices for zircon concentrates remained constant throughout the year. U.S. imports of ores and concentrates decreased by about 38% and exports decreased by 42% because end users adjusted to the forthcoming idling of operations in Virginia and commencement of mineral processing operations in Georgia. The operator of the two Virginia mines expected to extract the remaining ore from both mines and complete operations by yearend 2015. The operator of the mine in Georgia was developing a second mine in Brantley County and completed construction of a mineral sand plant near Offerman to process heavy-mineral concentrates from these mines. A fourth company was planning to process tailings from mineral sand mines in New Jersey to produce zircon and titanium concentrates. Construction of a mineral sands concentrator was expected to be complete by the second quarter of 2016. Global production of zirconium concentrates (excluding the United States) was estimated to have decreased by 5% compared with that of 2014. According to the leading world producer, global consumption of zirconium concentrates during the first half of 2015 was essentially unchanged from that in the first half of 2014, and modest year-over-year gains in consumption were expected in the second half of 2015. Heavy-mineral exploration and mining projects were underway in Australia, Madagascar, Mozambique, Sri Lanka, and Tanzania.

World Mine Production and Reserves: World primary hafnium production data are not available. Although hafnium occurs with zirconium in the minerals zircon and baddeleyite, quantitative estimates of hafnium reserves are not available.

	Zirconium mine production (thousand metric tons, gross weight)		Zirconium reserves[6] (thousand metric tons, ZrO_2)
	2014	2015[e]	
United States	W	[1]60	500
Australia	551	500	51,000
China	150	140	500
India	40	40	3,400
Indonesia	110	110	NA
Mozambique	51	50	1,100
South Africa	387	380	14,000
Other countries	130	130	7,200
World total (rounded)	[7]1,420	1,410	78,000

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] Rounded to one significant digit to avoid disclosing company proprietary data.
[2] Source: Industrial Minerals, yearend average of high-low price range.
[3] Unit value based on U.S. imports for consumption from Australia and South Africa.
[4] Unit value based on U.S. imports for consumption from France.
[5] Defined as imports – exports.
[6] See Appendix C for resource/reserve definitions and information concerning data sources.
[7] Excludes U.S. production.

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 will be specified in the text accompanying the table.

Authorized for disposal refers to quantities that are in excess of the stockpile goal for a material, and for which 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.

Disposal plan FY 2015 indicates the total amount of a material in the National Defense Stockpile that the U.S. Department of Defense is permitted to sell under the Annual Materials Plan approved by Congress for the fiscal year. FY 2015 (fiscal year 2015 is the period October 1, 2014, through September 30, 2015). For mineral commodities that have a disposal plan greater than the inventory, actual quantity will be limited to 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.

Disposals FY 2015 refers to material sold or traded from the stockpile in FY 2015.

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 extraction feasibility 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' supply 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 metric tons of copper. Since then, almost 500 million metric tons of copper have been produced worldwide, but world copper reserves in 2015 were estimated to be 720 million metric tons of copper, more than double 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. USGS reports provide estimates of undiscovered mineral resources using a three-part assessment methodology (Singer and Menzie, 2010). Mineral-resource assessments have been carried out for small parcels of land being evaluated for land reclassification, for the Nation, and for the world.

Reference Cited

Singer, D.A., and Menzie, W.D., 2010, Quantitative mineral resource assessments—An integrated approach: Oxford, United Kingdom, Oxford University Press, 219 p.

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.

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.

[1]Based on U.S. Geological Survey Circular 831, 1980.

Demonstrated.—A term for the sum of measured plus indicated.

Measured.—Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and(or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurements are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated.—Quantity and grade and(or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and 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:

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*

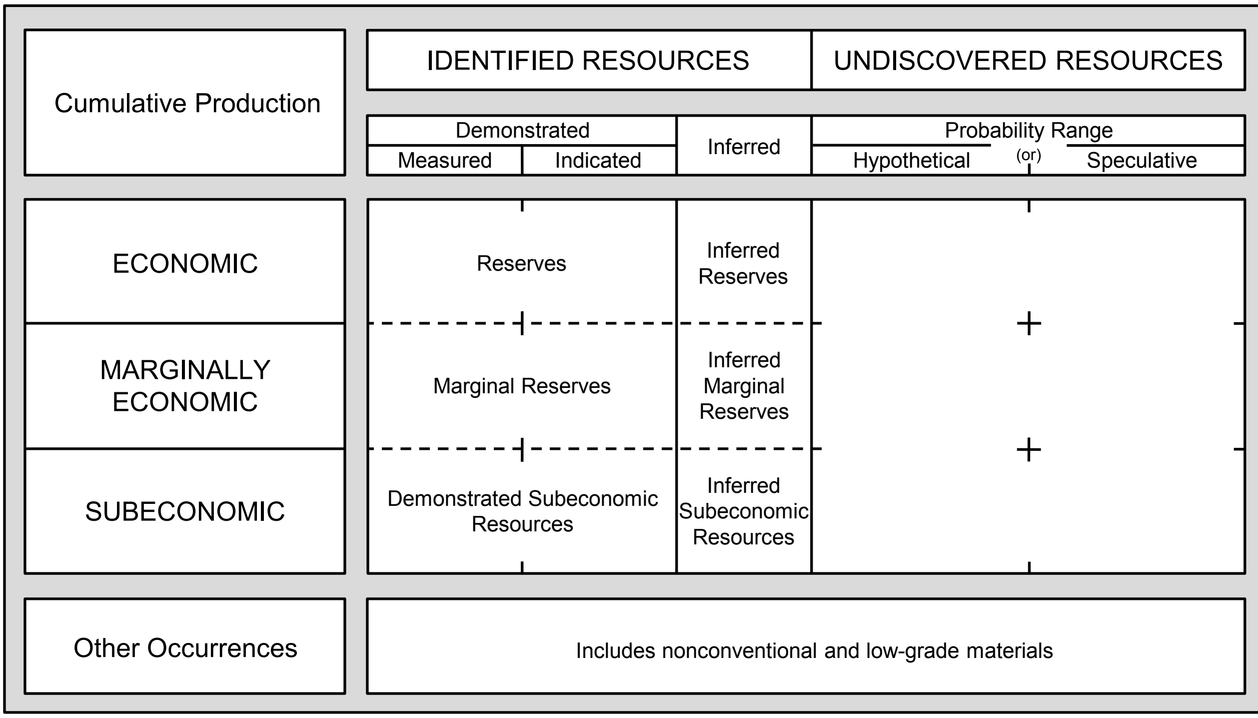
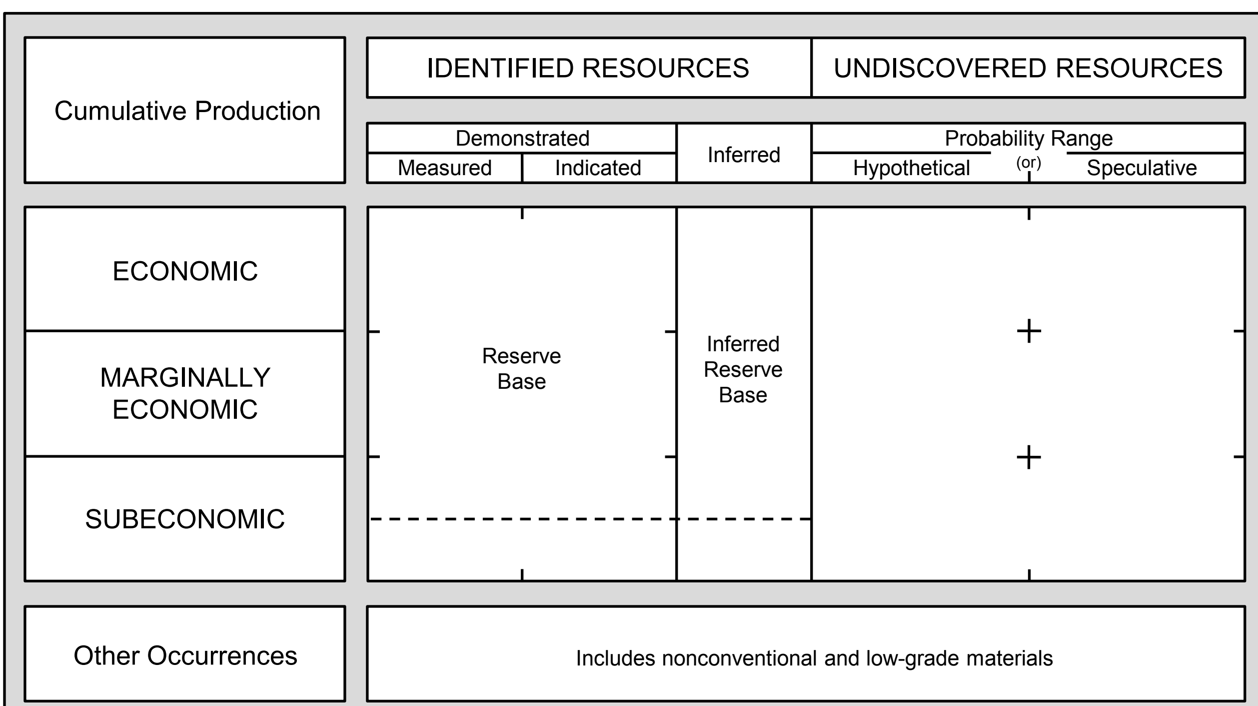


Figure 2.—*Reserve Base* and *Inferred Reserve Base* Classification Categories



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 (http://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 2016 are Accessible EDR. For more information, see Australia's Identified Mineral Resources 2014 (http://www.ga.gov.au/corporate_data/82311/82311_Identified_Minerals.pdf).

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 http://www.cim.org/en/News-and-Events/News/2014/CIM-Definition-Standards-and-Guidance-updated.

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 (MRR)], 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	Omayra Bermúdez-Lugo
Bahrain	Mowafa Taib
Benin	John R. Matzko
Botswana	Thomas R. Yager
Burkina Faso	Omayra Bermúdez-Lugo
Burundi	Thomas R. Yager
Cameroon	John R. Matzko
Cabo Verde	John R. Matzko
Central African Republic	James J. Barry
Chad	Mowafa Taib
Comoros	James J. Barry
Congo (Brazzaville)	James J. Barry
Congo (Kinshasa)	Thomas R. Yager
Côte d'Ivoire	Omayra Bermúdez-Lugo
Djibouti	Mowafa Taib
Egypt	Mowafa Taib
Equatorial Guinea	James J. Barry
Eritrea	Thomas R. Yager
Ethiopia	Thomas R. Yager
Gabon	James J. Barry
The Gambia	James J. Barry
Ghana	Omayra Bermúdez-Lugo
Guinea	Omayra Bermúdez-Lugo
Guinea-Bissau	James J. Barry
Iran	Sinan Hastorun
Iraq	Mowafa Taib
Israel	Thomas R. Yager
Jordan	Mowafa Taib
Kenya	Thomas R. Yager
Kuwait	Mowafa Taib
Lebanon	Mowafa Taib
Lesotho	James J. Barry
Liberia	Omayra Bermúdez-Lugo
Libya	Mowafa Taib
Madagascar	Thomas R. Yager
Malawi	Thomas R. Yager
Mali	Omayra Bermúdez-Lugo
Mauritania	Mowafa Taib
Mauritius	John R. Matzko
Morocco & Western Sahara	Mowafa Taib
Mozambique	Thomas R. Yager
Namibia	Omayra Bermúdez-Lugo
Niger	Omayra Bermúdez-Lugo
Nigeria	Thomas R. Yager
Oman	Mowafa Taib
Qatar	Mowafa Taib
Reunion	James J. Barry
Rwanda	Thomas R. Yager
São Tomé & Principe	James J. Barry
Saudi Arabia	Mowafa Taib
Senegal	Omayra Bermúdez-Lugo
Seychelles	John R. Matzko
Sierra Leone	Omayra Bermúdez-Lugo
Somalia	Mowafa Taib
South Africa	Thomas R. Yager
South Sudan	Mowafa Taib
Sudan	Mowafa Taib
Swaziland	James J. Barry
Syria	Mowafa Taib
Tanzania	Thomas R. Yager
Togo	James J. Barry
Tunisia	Mowafa Taib
Uganda	Thomas R. Yager
United Arab Emirates	Mowafa Taib
Yemen	Mowafa Taib
Zambia	James J. Barry
Zimbabwe	James J. Barry

Asia and the Pacific

Afghanistan	Karine Renaud
Australia	Omayra Bermúdez-Lugo
Bangladesh	Yolanda Fong-Sam
Bhutan	Yolanda Fong-Sam
Brunei	Lin Shi
Burma (Myanmar)	Yolanda Fong-Sam
Cambodia	Yolanda Fong-Sam
China	Sean Xun
East Timor	Lin Shi
Fiji	Sean Xun
India	Karine Renaud
Indonesia	Susan Wacaster
Japan	Susan Wacaster
Korea, North	Susan Wacaster
Korea, Republic of	Susan Wacaster
Laos	Yolanda Fong-Sam
Malaysia	Lin Shi
Mongolia	Lin Shi
Nauru	Lin Shi
Nepal	Yolanda Fong-Sam
New Caledonia	Sean Xun
New Zealand	Lin Shi
Pakistan	Karine Renaud
Papua New Guinea	Sean Xun
Philippines	Yolanda Fong-Sam
Singapore	Lin Shi
Solomon Islands	Karine Renaud
Sri Lanka	Karine Renaud
Taiwan	Lin Shi
Thailand	Yolanda Fong-Sam
Vietnam	Yolanda Fong-Sam

Europe and Central Eurasia

Albania	Sinan Hastorun
Armenia[1]	Elena Safirova
Austria[2]	Sinan Hastorun
Azerbaijan[1]	Elena Safirova
Belarus[1]	Elena Safirova
Belgium[2]	Alberto A. Perez
Bosnia and Herzegovina	Sinan Hastorun

Europe and Central Eurasia—continued

Bulgaria[2]	Elena Safirova
Croatia[2]	Sinan Hastorun
Cyprus[2]	Sinan Hastorun
Czech Republic[2]	Elena Safirova
Denmark, Faroe Islands, and Greenland[2]	Alberto A. Perez
Estonia[2]	Karine Renaud
Finland[2]	Alberto A. Perez
France[2]	Alberto A. Perez
Georgia	Elena Safirova
Germany[2]	Alberto A. Perez
Greece[2]	Sinan Hastorun
Hungary[2]	Sinan Hastorun
Iceland	Alberto A. Perez
Ireland[2]	Alberto A. Perez
Italy[2]	Alberto A. Perez
Kazakhstan[1]	Elena Safirova
Kosovo	Sinan Hastorun
Kyrgyzstan[1]	Karine Renaud
Latvia[2]	Karine Renaud
Lithuania[2]	Lin Shi
Luxembourg[2]	Alberto A. Perez
Macedonia	Karine Renaud
Malta[2]	Sinan Hastorun
Moldova[1]	Elena Safirova
Montenegro	Sinan Hastorun
Netherlands[2]	Alberto A. Perez
Norway	Alberto A. Perez
Poland[2]	Alberto A. Perez
Portugal[2]	Alberto A. Perez
Romania[2]	Alberto A. Perez
Russia[1]	Elena Safirova
Serbia	Karine Renaud
Slovakia[2]	Lin Shi
Slovenia[2]	Lin Shi
Spain[2]	Alberto A. Perez
Sweden[2]	Alberto A. Perez
Switzerland	Sinan Hastorun
Tajikistan[1]	Karine Renaud
Turkey	Sinan Hastorun
Turkmenistan[3]	Karine Renaud
Ukraine[3]	Elena Safirova
United Kingdom[2]	John R. Matzko
Uzbekistan[1]	Elena Safirova

North America, Central America, and the Caribbean

Aruba	Yadira Soto-Viruet
Belize	Susan Wacaster
Bermuda	Yadira Soto-Viruet
Canada	Susan Wacaster
Costa Rica	Susan Wacaster
Cuba	Yadira Soto-Viruet
Dominican Republic	Yadira Soto-Viruet
El Salvador	Susan Wacaster
Guatemala	Susan Wacaster
Haiti	Yadira Soto-Viruet
Honduras	Susan Wacaster
Jamaica	Yadira Soto-Viruet
Mexico	Yadira Soto-Viruet
Nicaragua	Susan Wacaster
Panama	Susan Wacaster
Trinidad and Tobago	Yadira Soto-Viruet

South America

Argentina	Susan Wacaster
Bolivia	Susan Wacaster
Brazil	Yadira Soto-Viruet
Chile	Susan Wacaster
Colombia	Susan Wacaster
Ecuador	Susan Wacaster
French Guiana	Sean Xun
Guyana	Sean Xun
Paraguay	Yadira Soto-Viruet
Peru	Sean Xun
Suriname	Sean Xun
Uruguay	Yadira Soto-Viruet
Venezuela	Sean Xun

[1]Member of Commonwealth of Independent States.
[2]Member of European Union.
[3]Associate of Commonwealth of Independent States.

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