



2015 Minerals Yearbook

BERYLLIUM [ADVANCE RELEASE]

BERYLLIUM

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On the basis of estimated beryllium content, U.S. mine shipments of beryllium ore in 2015 decreased by 24% to 205 metric tons (t) from 270 t in 2014, and reported consumption of ore for the production of beryllium hydroxide decreased by 21% (table 1). From 2005 through 2015, U.S. mine shipments of beryllium ore increased at a compound annual growth rate of 6%, whereas reported ore consumption increased at a compound annual growth rate of about 3% (fig. 1). On the basis of estimated beryllium content, imports of beryllium materials decreased by about 3% and exports increased by about 10% in 2015 from those of 2014 (table 3).

In 2015, estimated world beryllium ore production decreased by 24% compared with that of 2014 (table 4). The United States accounted for about 90% of estimated world production. China is thought to be a significant producer but does not report its beryl production. Beryl, a principal mineral of beryllium mined outside of the United States, is commonly stockpiled for later processing, and sales or exports may not accurately reflect current production. As a result, world production and the U.S. share of world production have a high degree of uncertainty.

Beryllium is gray in color and one of the lightest metals. Its physical and mechanical properties—outstanding stiffness-to-weight and strength-to-weight ratios, high melting point relative to other light metals, high specific heat, excellent thermal conductivity, outstanding dimensional stability over a wide range of temperatures, high reflectivity, lowest neutron absorption cross section of any metal and high neutron-scattering cross section, and transparency to x rays—make it useful for many applications. Beryllium is used primarily in beryllium-copper alloys, beryllium oxide ceramics, and as beryllium metal in a wide variety of products, such as bearings and bushings, computer chip heat sinks, contacts and connectors, disc brakes, highly conductive and high-strength wire, mirrors, protective housings, switches and relays, and x-ray windows. Industries that use beryllium products include aerospace, automotive, computer, defense, electronics, energy, marine, medical, nuclear, and telecommunications.

The leading use for beryllium, accounting for about 75% of total world consumption, was in copper-base alloys containing from 0.2% to 2.0% beryllium. Beryllium enhances the strength, stiffness, and hardness of copper alloys while retaining relatively good ductility, machinability, and electrical and thermal conductivity. Beryllium-copper alloys are predominantly formed into strip products used as electrical connectors, contacts, relays, shielding, and switches, and as bulk products in the form of bars, plates, rods, and tubes. The second leading use of beryllium, consuming 20% of total world production, was as 99.5% pure or greater beryllium metal and beryllium-base alloys containing greater than 60% beryllium (primarily alloyed with aluminum). Beryllium

metal and alloys are typically used to produce components for high-technology equipment where low weight, low thermal distortion, and good machinability are critical factors. Beryllium oxide ceramics, which accounted for the remaining 5% of beryllium consumption, were used where electrical insulation and heat extraction are essential, such as automotive electrical systems and heat sinks for radar and radio-frequency equipment (Trueman and Sabey, 2014, p. 101–103).

Only two beryllium minerals are of commercial importance for the production of beryllium. Bertrandite, which can contain about 15% beryllium, is the principal beryllium mineral mined in the United States; however, bertrandite ore mined in the United States contains significantly less than 0.5% beryllium by weight. Beryl, which can contain up to 5% beryllium, is the principal beryllium mineral mined in the rest of the world from ores typically grading 4% beryllium or less. Commercial beryl contains approximately 12% beryllium oxide, 19% aluminum oxide, 67% silicon dioxide, and 2% other oxides. Artisanal mining of the gemstone varieties of beryl, most notably aquamarine and emerald, is a primary source of byproduct beryl for beryllium extraction. More information on gem-quality beryl and chrysoberyl can be found in the Gemstones chapter of the U.S. Geological Survey (USGS) Minerals Yearbook, volume I, Metals and Minerals.

Legislation and Government Programs

Because beryllium is toxic, various international, national, and State guidelines and regulations have been established to determine and monitor allowable beryllium content in air, water, and other media. Industry regulations require control of the quantity of beryllium dust, fumes, and mists in the workplace and effluent discharges.

Defense Production Act.—To ensure current and future availability of high-quality domestic beryllium to meet critical defense needs, in 2008, the U.S. Department of Defense (DOD), under the Defense Production Act Title III Program, invested in a public-private partnership with Materion Corp. (Mayfield Heights, OH) to build a primary beryllium facility in Elmore, OH. The facility was designed to produce high-purity beryllium metal from beryllium hydroxide sourced from Materion's Delta, UT, operation. Approximately two-thirds of the facility's output was to be allocated for defense and Government-related end uses; the remaining output was to go to the private sector. Plant production capacity was designed to be 73 metric tons per year (t/yr) of beryllium metal. The plant was placed in service in 2012 (Materion Corp., 2016a, p. 58).

National Defense Stockpile.—The Defense Logistics Agency Strategic Materials, DOD, offered and sold selected beryllium materials from the National Defense Stockpile (NDS). At yearend 2015, the stockpile contained 79 t of beryllium metal,

an excess to the NDS beryllium metal stockpile goal of 47 t. The Annual Materials Plan for fiscal year 2015, which represented the maximum quantities of beryllium metal that could be sold from October 1, 2014, through September 30, 2015, was 16 t, the same as that in fiscal year 2014. In calendar year 2015, the NDS sold approximately 1 t of beryllium metal. The NDS also upgraded beryllium hot pressed metal powder into hot isostatic pressing structured metal powder to meet product specification for many modern DOD applications. NDS calendar yearend inventories of beryllium materials are listed in table 2 (U.S. Department of Defense, 2016, p. 8–11).

Production

Domestic production and consumption data for beryllium-containing ores (tables 1, 4) were collected by the USGS from two voluntary surveys of U.S. operations. In 2015, 100% of the canvassed respondents replied to the survey. A small number of unidentified producers may have shipped minimal quantities of byproduct beryl, but these have not been included. In 2015, the only domestic beryllium mine shipped approximately 205 t of contained beryllium, 24% less than that of 2014.

The United States is one of only three countries known to process beryllium ores and concentrates into beryllium products. Materion converted bertrandite from open pit mines in the Topaz-Spor Mountain region of Juab County, UT, into beryllium hydroxide at its operations near Delta. Most of the beryllium hydroxide was shipped to Elmore, where Materion converted it into beryllium-copper master alloy (BCMA), metal, or oxide, and some was sold to NGK Insulators, Ltd. of Japan. In 2015, 94% of Materion's beryllium hydroxide was produced from bertrandite, and 6% was produced from imported beryl (Materion Corp., 2016a, p. 32). Very-high-purity beryllium is made exclusively from beryl, as beryl typically has fewer impurities than bertrandite (for example, fluorine and uranium). Beryl-sourced high-purity beryllium is used in nuclear applications, where the absence of uranium in the beryllium allows for safe and timely disposal of nuclear waste containing beryllium, and in foil for use as x-ray windows for medical applications (Keith Smith, Vice President, Technology and Government Business Development, Materion Corp., oral commun., April 4, 2016).

In 2015, based on the expectation that worldwide stockpiles of beryllium concentrate were being depleted, Materion invested \$23 million to further develop its bertrandite pits in the Topaz-Spor Mountain region. In 2013, the company increased its capacity to produce beryllium hydroxide at its Delta plant. In 2015, the capacity utilization of the Delta plant was 55%, a decrease of 18% from that of 2014 (Materion Corp., 2014, p. 37; 2016a, p. 2, 32).

Consumption

In 2015, U.S. reported consumption of bertrandite ore and beryl for the production of beryllium hydroxide was approximately 220 t of contained beryllium, a 21% decrease from that of 2014. U.S. apparent consumption of all beryllium materials in 2015, as calculated from mine shipments, net trade, and changes in Government and industry stocks, was estimated

to be about 233 t of contained beryllium, a decrease of 27% from that of 2014. Beryllium mine shipments and net imports decreased in 2015.

Materion produced beryllium hydroxide, beryllium products (including metal, metal-matrix composites, and ceramics), and beryllium strip and bulk products in the Performance Metals unit of its Performance Alloys and Composites segment. Materion produced two types of metal-matrix composites—one made from aluminum and beryllium, and the other made from beryllium and beryllium oxide (BeO or beryllia). Foil, rod, sheet, tube, and a variety of customized shapes were produced at plants in Elmore and in Fremont, CA. Beryllia ceramic products for aerospace, defense, electronics, medical, semiconductor, telecommunications, and wireless applications were produced at its plant in Tucson, AZ, and copper- and nickel-base alloy products, the majority of which contained beryllium, were produced at plants in Elmore and in Shoemakersville, PA. These included alloy strip products (which were used as connectors, contacts, relays, shielding, and switches) and alloy bulk products (including bar, plate, rod, tube, and customized forms).

In 2015, sales from the Performance Alloys and Composites segment decreased by 9% from that of 2014 owing mostly to a combination of lower sales volumes and strengthening of the U.S. dollar against the euro and yen. Lower sales to the energy, medical, and consumer electronics markets were the main drivers of the decrease. Sales to the energy market decreased by 60% owing to a significant decline in oil and gas exploration. Sales to the consumer electronics market were lower owing to weaker customer demand, primarily in Asia. The decrease in sales to these markets was partially offset by a significant increase in demand for defense applications, mostly owing to the timing of government spending programs. Sales to the industrial components market also increased, mostly owing to stronger sales of specialty metal alloys and products for plastics production. In 2015, industrial components accounted for 21% of the Performance Alloys and Composites value-added sales, and consumer electronics applications accounted for 18%. The remaining sales were distributed as follows: automotive electronics, 15%; defense, 9%; telecommunications infrastructure, 8%; energy, 7%; medical, 2%; and other, 20% (Materion Corp., 2015, p. 20; 2016a, p. 2, 24; 2016b, p. A–9).

IBC Advanced Alloys Corp. (Vancouver, British Columbia, Canada) manufactured beryllium-aluminum and beryllium-copper alloys and its proprietary Beralcast® alloys, which were castable beryllium-aluminum products, at plants located in Franklin, IN, New Madrid, MO, Royersford, PA, and Wilmington, MA. IBC had multiyear agreements to purchase beryllium metal and BCMA from the Ulba Metallurgical Plant (UMP) in Kazakhstan. In 2014, IBC entered into a contract with Lockheed Martin Corp. to provide critical cast components for Lockheed Martin's F-35 Lightning II Electro-Optical Targeting System. In July 2015, IBC delivered the first component to Lockheed—an azimuth gimbal housing manufactured using IBC's Beralcast® beryllium-aluminum casting alloy. In 2015, IBC received a second purchase order from Lockheed to produce critical cast components for the F-35 Lightning II Electro-Optical Targeting System, two new orders from an Asian precision manufacturing customer, and an order from

United Technologies Corp. Aerospace Systems to supply Beralcast® components for critical imaging systems used on a variety of U.S. and foreign military aircraft (Equities, 2016; IBC Advanced Alloys Corp., 2016, p. 1–4).

Other domestic producers of beryllium alloy products included NGK Metals Corp. (a subsidiary of NGK Insulators, Ltd.) in Sweetwater, TN, and GBC Metals, LLC (doing business as Olin Brass) in East Alton, IL. American Beryllia Inc. produced beryllium oxide ceramic products at its plant in Haskell, NJ.

Recycling

Beryllium was recycled from new scrap generated during the manufacture of beryllium-containing components, as well as from old scrap collected from end users. Detailed data on the quantities of recycled beryllium are not available but may have represented as much as 20% to 25% of U.S. consumption. Beryllium products manufactured by Materion from recycled metal require only 20% of the full-cycle (mine through manufacture) energy as that of beryllium products manufactured from primary material. Materion established a comprehensive recycling program for its beryllium products and indicated a 40% beryllium recovery rate from processed new and old beryllium scrap (Stephen Freeman, President, International Business Development, Materion Corp., oral commun., August 2, 2012).

Foreign Trade

U.S. foreign trade in beryllium materials, as reported by the U.S. Census Bureau, is summarized in table 3. On the basis of estimated beryllium content, total beryllium imports decreased by 3% compared with those of 2014, primarily owing to reduced imports of unwrought beryllium metal from Kazakhstan and the United Kingdom. The leading suppliers of beryllium materials to the United States were, by beryllium content, Kazakhstan, Japan, and the United Kingdom.

On the basis of estimated contained beryllium, beryllium exports increased by 10% compared with those of 2014, mostly from a 228% increase in exports of unwrought beryllium metal, most of which went to China. Canada was the major recipient of total exported beryllium metal. The U.S. Census Bureau, however, only identifies exported beryllium metal; exported BCMA and beryllium oxide and hydroxide are not identified. According to Materion, BCMA typically accounts for about 85% of domestic beryllium exports, whereas beryllium metal typically accounts for less than 15% of exports (Stephen Freeman, President, International Business Development, Materion Corp., oral commun., January 10, 2013).

Net import reliance as a percentage of apparent consumption is one measure of the adequacy of current domestic beryllium production to meet U.S. demand. Net import reliance is defined as imports minus exports plus adjustments for Government and industry stock changes. Included among stock changes are acquisitions or shipments from the NDS, regardless of whether the materials were imported or produced in the United States. For 2015, net import reliance as a percentage of apparent consumption was 12%, a decrease from 15% in 2014. Net

import reliance as a percentage of apparent consumption has decreased since its peak of 61% in 2010 owing, on average, to increased U.S. bertrandite production and downstream beryllium metal production and a commensurate decrease in beryllium imports and Government stockpile shipments.

World Review

China.—Two facilities in China were thought to be capable of processing beryllium ores and concentrates into beryllium products—Hunan Shuikoushan Nonferrous Metals Group Co., Ltd. in Xinjiang Province, and Fuyun Hengsheng Beryllium Industry Co., Ltd. in Guangdong Province. In 2012, the last year with supplied information, China produced an estimated 65 t of beryllium contained in beryllium-copper alloys, beryllium oxide ceramics, and beryllium metal. In 2015, China was thought to have produced a similar amount of contained beryllium. Approximately 20 t of the contained beryllium was sourced from domestic ore and 45 t was obtained from foreign sources. According to Materion, China imported most of its contained beryllium from Kazakhstan's UMP and was thought to be UMP's leading customer (Stephen Freeman, President, International Business Development, Materion Corp., oral commun., January 10, 2013).

Kazakhstan.—It was estimated that UMP produced about 90 t of beryllium contained in beryllium-copper alloys, beryllium oxide ceramics, and beryllium metal in 2015, a decrease from the 95 t thought to have been produced in 2014 (based on 2013 data—the last year with supplied information). Production was reportedly from stockpiled beryllium concentrate imported mainly from Russia, which had accumulated prior to the breakup of the Soviet Union (Kazatomprom JSC, 2014, p. 33). Anecdotal reports have indicated that the stockpile was nearing depletion and may only have several years of supply remaining. In 2015, Kazakhstan's investment ministry announced that it would auction off a mining license for the Nura-Taldy beryllium deposit in the Karaganda district (Sparks, 2015).

Russia.—MBC Corp. (a subsidiary of Metropal Investment Group), Russia's state-owned Rusnano Corp., and technology specialists from a number of research institutions continued work on resuming mining and construction of a processing plant at the Ermakovskoe bertrandite deposit in the Siberian Republic of Buryatiya. It was reported that the project could begin commercial operation by 2020 (Siberian Times, The, 2015). Financing of the project was to be shared by Metropal and Rusnano. Ermakovskoe was thought to be the largest identified beryllium deposit in Russia with remaining reported reserves of 1,394,000 t of fluorine-beryllium ore. Metropal projected an annual mining and processing capacity of 25,000 t/yr of ore and a beryllium hydroxide production capacity of 130 t/yr. The mining was to be carried out in two stages: open pit mining of 764,000 t of reserves followed by underground mining of the remaining 630,000 t of reserves (MBC Corp., 2009, 2011; Rusnano Corp., 2012).

In an effort to augment the beryllium metal imported by Russia, Russia's Industry and Trade Ministry financed research on beryllium metal production. In January 2015, Tomsk Polytechnic University and the Siberian Chemical Plant

jointly produced Russia's first 100-gram sample of beryllium metal. By December, a total of 1 kilogram had been produced. Scientists expected to initially source raw materials from Russia's Federal State Reserve Agency, and eventually source raw materials from the Ermakovskoe deposit. The Priargunsky Industrial Mining and Chemical Union in Krasnokamensk, Trans-Baikal Territory, near the Ermakovskoe deposit was being considered for a concentrator, and the Siberian Chemical Combine in Seversk, Tomsk Region was being considered for the beryllium hydrometallurgical plant. Commercial production of beryllium metal was expected to begin in 2020, with a planned production capacity of 30 t/yr of beryllium (Dragomanovich, 2015; Tass, 2015).

Outlook

The United States is expected to remain self-sufficient with respect to most of its beryllium requirements. At yearend 2015, Materion reported proven reserves in Juab County, UT, of 5.50 million dry metric tons of bertrandite having an average grade of 0.259% beryllium and containing about 14,200 t of beryllium. Materion owned approximately 90% of its proven mineral reserves and leased the remainder from the State (Materion Corp., 2016a, p. 32).

In the first half of 2016, value-added sales for Materion's beryllium-rich Performance Alloys and Composites segment decreased by about 8% from that in the first half of 2015 owing to continued weak sales to energy customers and to a lack of raw material beryllium hydroxide customers (Materion Corp., 2016c, p. 20).

In 2013, Materion forecast worldwide beryllium consumption to increase between 3% and 6% per year and anticipated BCMA consumption growth to be higher, at approximately 10% per year. The physical size of many beryllium-containing components, however, has decreased over time owing to improved technology. Therefore, growth in beryllium consumption may lag behind the expected continued growth in applications (Stephen Freeman, President, International Business Development, Materion Corp., oral commun., January 10, 2013).

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TABLE 1
SALIENT BERYLLIUM MINERAL STATISTICS

(Metric tons of contained beryllium)

	2011	2012	2013	2014	2015
United States, beryllium-containing ores:					
Mine shipments ¹	235	225	235	270	205
Imports for consumption, beryl ²	6	12	8	9	18
Consumption, reported ³	250	220	250	280	220
Stocks, December 31:					
Industry ¹	10	15	20	15	25
U.S. Government, beryl ^{2, 4}	(5)	(5)	(5)	(5)	(5)
World, production ^{e, 2}	262	265 ^r	264 ^r	302 ^r	230

^eEstimated. ^rRevised.

¹Data are rounded to the nearest 5 metric tons.

²Based on a beryllium content of 4%.

³Data are rounded to the nearest 10 metric tons.

⁴Data from Defense Logistics Agency Strategic Materials.

⁵Less than ½ unit.

TABLE 2
U.S. GOVERNMENT NATIONAL DEFENSE STOCKPILE
BERYLLIUM STATISTICS IN 2015¹

(Metric tons of contained beryllium)

Material	Stockpile goal ²	Annual Materials Plan ³	Inventory, December 31
Beryl ore	--	--	(4)
Beryllium metal:			
Hot-pressed powder	(5)	(5)	68
Rods	--	--	(4)
Structured powder	--	--	4
Vacuum-cast	(5)	(5)	6
Total	47	16	79
Grand total	47	16	79

-- Zero.

¹Data were converted from gross weights reported in short tons; may not add to totals shown.

²2013 Biennial Report on Stockpile Requirements. Goal is for beryllium metal, excluding beryllium structured powder.

³Maximum quantity of material that can be disposed during 12-month period ending September 30, 2015.

⁴Less than ½ unit.

⁵Stockpile goal and Annual Materials Plan for beryllium metal included under "Total."

Source: Defense Logistics Agency Strategic Materials.

TABLE 3
U.S. FOREIGN TRADE OF BERYLLIUM MATERIALS, BY TYPE¹

Type and material	2014			2015			Principal destinations or sources, 2015 ³
	Gross weight (kilograms)	Content ² (kilograms)	Value (thousands)	Gross weight (kilograms)	Content ² (kilograms)	Value (thousands)	
Exports:							
Beryllium, unwrought ⁴	2,200	2,200	\$95	7,210	7,210	\$300	China, 65%; Japan, 10%; Taiwan, 6%; Germany, 4%; Republic of Korea, 4%; Switzerland, 4%.
Beryllium waste and scrap	401	401	64	37	37	10	China, 95%; United Kingdom, 5%.
Beryllium, other ⁵	23,800	23,800	20,800	21,700	21,700	15,000	Canada, 62%; Germany, 8%; Japan, 8%; France, 4%; United Kingdom, 4%.
Total	26,400	26,400	21,000	28,900	28,900	15,300	Canada, 47%; China, 17%; Japan, 8%; Germany, 7%.
Imports for consumption:							
Beryllium ores and concentrates	217,000	8,670	563	452,000	18,100	1,270	United Kingdom, 36%; Nigeria, 26%; Brazil, 22%; Rwanda, 16%.
Beryllium oxide and hydroxide	19,800	7,120	122	20,700	7,450	129	Republic of Korea, 56%; China, 39%; Mexico, 5%.
Beryllium, unwrought ⁴	22,700	22,700	5,730	8,660	8,660	1,720	United Kingdom, 51%; Kazakhstan, 49%.
Beryllium waste and scrap	2,060	2,060	9	406	406	133	United Kingdom, 100%.
Beryllium, other ⁵	13,700	13,700	1,160	13,800	13,800	1,160	Kazakhstan, 90%; Canada, 9%.
Beryllium-copper master alloy	159,000	6,360	3,010	151,000	6,030	2,920	Kazakhstan, 87%; Japan, 7%; Germany, 6%.
Beryllium-copper plates, sheets, and strip	520,000	7,810	8,200	782,000	11,700	11,900	Japan, 98%.
Total	954,000	68,500	18,800	1,430,000	66,200	19,300	Japan, 55%; United Kingdom, 12%; Kazakhstan, 10%; Nigeria, 8%; Brazil, 7%; Rwanda, 5%.

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

²Estimated from gross weights.

³Principal destination or source percentages based on beryllium gross weight data.

TABLE 4
BERYL: WORLD PRODUCTION, BY COUNTRY^{1,2}

(Metric tons of gross weight)

Country ³	2011	2012	2013	2014	2015 ^c
China ^e	550	500	500	500	500
Madagascar ^{e,4}	12	16	85 ^r	135 ^r	135
Mozambique	58	532 ^{r,5}	103 ^r	-- ^r	--
United States, mine shipments ⁶	5,920	5,570	5,910	6,900	5,100
Total	6,540	6,610 ^r	6,600 ^r	7,530 ^r	5,740

^eEstimated. ^rRevised. -- Zero.

¹World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

²Includes data available through August 1, 2016. Unless otherwise noted, figures represent beryl ore for the production of beryllium and exclude gem-quality beryl.

³In addition to the countries listed, Brazil, Kazakhstan, Nigeria, Portugal, Russia, Rwanda, and Uganda may also have produced beryl ore, but information is inadequate to make reliable estimates of production. Other nations that produced gemstone beryl ore may also have produced some industrial beryl ore.

⁴Beryl in quartz concentrates.

⁵Mozambique reported significantly higher beryl ore production in 2012. The accuracy of the reported data could not be confirmed.

⁶Includes raw bertrandite ore, calculated as equivalent to beryl containing 11% beryllium oxide.

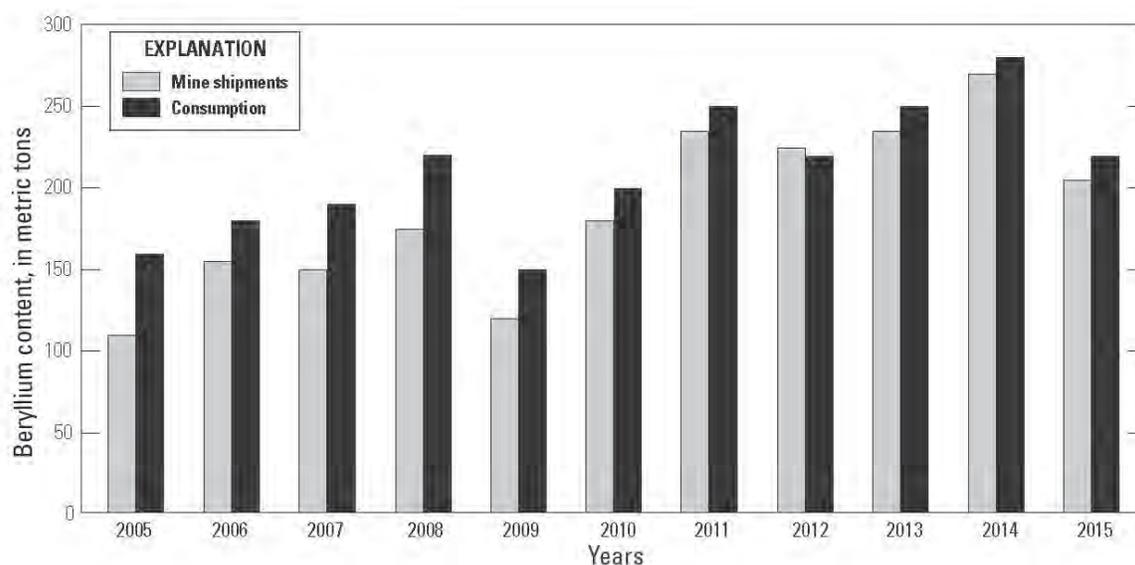


Figure 1. U.S. mine shipments and consumption of beryllium from 2005 through 2015.