



2017 Minerals Yearbook

GERMANIUM [ADVANCE RELEASE]

GERMANIUM

By Christine L. Thomas

Tables were prepared by Molly L. Reid, statistical assistant.

In 2017, three domestic zinc operations produced recoverable byproduct germanium. In Alaska, the Red Dog Mine, owned by Teck Resources Ltd. (Canada), produced zinc concentrates that were exported to Teck's facilities in Canada for processing and to processors in Asia and Europe. Teck also operated the underground Pend Oreille zinc and lead mine in northeast Washington State. All concentrates were shipped to Teck's facilities in Canada for processing. In Tennessee, the Clarksville zinc smelter, owned by Nyrstar NV (Belgium), produced byproduct germanium leach concentrates for a few months of the year after the Middle Tennessee mine complex commenced production in May 2017 (Nyrstar NV, 2017b). The U.S. Geological Survey (USGS) estimated that in 2017, the combined U.S. refinery production of germanium metal recovered from end-of-life products, such as decommissioned military vehicles and thermal weapons sights, industry-generated scrap, and imported germanium dioxide, was between 5,000 and 15,000 kilograms (kg). The total world production (excluding the United States) of germanium in metal and compounds, including germanium recovered from zinc concentrates, coal fly ash, and recycled material, was estimated to be about 106,000 kg, 16% less than that in 2016. The amount of germanium recovered from scrap in 2017 was estimated to be about 30% of world production of germanium metal.

Germanium is a hard, brittle semimetal that first was used about 60 years ago as a semiconductor material in radar units and as the material for the first transistors. It is commercially available as tetrachloride, high-purity oxide, and various forms of metal. Its current principal uses include lenses or windows in infrared night-vision devices; a component of glass in telecommunications fiber-optic cable; polymerization catalysts for polyethylene terephthalate (PET), a commercially important plastic; and semiconductors and substrates in electronic circuitry and solar cells.

The germanium production process yields various germanium compounds and metal for use in specific applications. Germanium is initially recovered through the leaching of zinc-refining residues or coal ash, followed by precipitation of a germanium concentrate from the leachate. The concentrate, regardless of its source, is chlorinated, distilled, and purified to form the first usable product, germanium tetrachloride, a colorless liquid that is primarily used in fiber-optic cable production. Germanium tetrachloride can be hydrolyzed and dried to produce germanium dioxide, a white powder that is used in the manufacture of certain types of optical lenses, and as a catalyst in the production of PET resin. Germanium metal powder is produced through the reduction of germanium dioxide with hydrogen, and first-reduction bars are cast from melted powder. The germanium bars are zone refined (a process that involves melting and cooling to isolate and remove impurities) to produce high-purity electronic-grade germanium metal. Zone-

refined germanium metal is grown into crystals that are sliced for use as semiconductors or recast into forms suitable for lenses or window blanks for infrared optical devices.

Legislation and Government Programs

As a strategic and critical material, germanium was added to the National Defense Stockpile in 1984. The Defense Logistics Agency Strategic Materials (DLA Strategic Materials) reported that no germanium metal was sold in 2017. Germanium was last sold in February 2009 at an average price of \$1,331 per kilogram. As of December 31, 2017, the total inventory of germanium metal held by DLA Strategic Materials was 13,364 kg. The Annual Materials Plan for fiscal year 2018 (October 1, 2017, through September 30, 2018) allocated 5,000 kg of germanium scrap for potential upgrades or disposals, and DLA Strategic Materials could potentially acquire up to 1,000 kg of germanium metal in fiscal year 2018. In fiscal year 2012, DLA Strategic Materials awarded two contracts to convert 3,000 kg of the germanium ingots held in the stockpile to epitaxial wafers for use as substrates required by the National Security Space Strategy photovoltaic solar cell applications. As of yearend 2017, 101,939 wafers were held in the stockpile, unchanged from the quantity held at yearend 2016 (Defense Logistics Agency Strategic Materials, 2017a, b).

Production

Teck Resources Ltd. produced germanium-containing zinc concentrates at its Red Dog zinc-lead open pit mine in Alaska. Approximately 30% of the zinc concentrate produced at Red Dog was sent to Teck's metallurgical complex in Trail, British Columbia, Canada, for processing. Residues from zinc concentrates were treated in roasters or pressure-leach facilities and purified to produce germanium dioxide and other byproduct metals. Teck reported that zinc-in-concentrate production at Red Dog decreased by 7% to 542,000 metric tons (t) in 2017 from 583,000 t in 2016 owing to lower mill throughput and average zinc ore grade. Teck projected that zinc production at Red Dog would decrease in the next few years, ranging from 525,000 to 545,000 t in 2018 and from 475,000 to 525,000 metric tons per year in 2019 through 2021 (Teck Resources Ltd., 2018, p. 21, 41).

Teck also produced germanium-containing zinc concentrates at its Pend Oreille Mine in Washington State. The concentrates were processed at Teck's Trail plant. Zinc-in-concentrate production at Pend Oreille decreased by 3% to 33,100 t in 2017 from 34,100 t in 2016. Teck projected that zinc production in 2018 would increase to approximately 35,000 t. Production rates beyond 2018 were uncertain, but there was potential to extend the mine life for several more years (Teck Resources Ltd., 2018, p. 22, 41).

Nyrstar's Clarksville zinc smelter in Tennessee produced byproduct germanium concentrate for a few months in

2017. After being placed on care-and-maintenance status in December 2015, the Middle Tennessee mine complex restarted mill production ahead of schedule in May 2017 (Nyrstar NV, 2017a, p. 9; 2017b). Byproduct germanium concentrate was produced from the Middle Tennessee mines' zinc-concentrate feedstock. Refined zinc production at the Clarksville smelter in 2017 increased by 4% from that of 2016 to 117,000 t owing to the restart of the Middle Tennessee mines, which was partially offset by planned maintenance in the third quarter of 2017 (Nyrstar NV, 2018, p. 7, 10).

Secondary germanium metal was recovered by secondary processors from end-of-life products, such as decommissioned military vehicles and thermal weapons sights. Major secondary producers included Umicore s.a. (Belgium) and 5N Plus Semiconductors LLC (St. George, UT). Umicore's facility in Quapaw, OK, produced germanium tetrachloride and other materials for thermal imaging. The 5N Plus facility in St. George, UT, produced germanium wafers (5N Plus Inc., undated).

Consumption

The USGS estimated that domestic consumption of germanium metal (including metal content of compounds) was about 30,000 kg in 2017, essentially unchanged from that in 2016 (table 1). The major global end uses were fiber-optic systems, infrared optics, electronics and solar applications, polymerization catalysts, and other uses (such as phosphors, metallurgy, and chemotherapy).

Fiber-Optic Systems.—Germanium dioxide is used as a dopant (a substance added in small amounts) in the pure silica glass core of optical fibers to increase the refractive index, preventing signal loss while not absorbing light.

In 2017, Corning Inc. (Corning, NY) reported that sales of its optical communications products increased by 18% from those in 2016 owing to increased enterprise and carrier network sales, two significant acquisitions, and increased sales of fiber-optic cable and hardware for fiber-to-the-home installations in North America. In 2017, Verizon Communications Inc. (New York, NY) signed a purchase agreement with Corning for the supply of fiber-optic cable and associated hardware to support its wireless broadband network. Starting in 2018, Verizon would buy up to 20.0 million kilometers of fiber-optic cable each year through 2020 (Lightwave, 2017b). In 2018, Corning's optical communications sales were expected to increase by about 10% (Corning Inc., 2018). Corning's fiber-optic manufacturing facilities were in Midland and Wilmington, NC. The plant in Midland, NC, produced single-mode fibers, and the plant in Wilmington, NC, produced multimode fibers.

In September, Furukawa Electric Co., Ltd. (Japan) announced plans to expand the optical fiber production capacity of its wholly owned subsidiary OFS Fitel, LLC (Norcross, GA) to meet global demand. OFS Fitel's U.S. fiber optic manufacturing facilities were in Norcross, GA (single-mode fibers), and Sturbridge, MA (multimode fibers). Furukawa Electric previously increased its global fiber production capacity by 20% between 2014 and 2016 and planned to achieve another 20% capacity increase by 2018 (OFS Fitel, LLC, 2017).

In May, Prysmian Group (Italy) announced plans to invest throughout North America, owing in part to a supply contract for

fiber-optic cables for Verizon's fiber platform rollout (Lightwave, 2017a, c). In November, Prysmian Group announced it would invest \$54 million to expand production capacity by 60% at its Claremont, NC, facility, which produced core rods and fiber optics. The expansions and investments were made at this facility to increase the use of internal Prysmian supply of germanium tetrachloride in the United States (Lightwave, 2017a).

Infrared Optics.—Germanium was used in lenses and windows for infrared optical systems owing to its transparency to part of the infrared spectrum and to its high refractive index. FLIR Systems, Inc. (Wilsonville, OR), a leading domestic producer of infrared surveillance devices, reported an 8.3% increase in sales revenue in 2017 compared with that in 2016. This increase in revenue was primarily a result of the company's acquisition of Armasight, Inc. (San Francisco, CA), Point Grey Research Inc. (Canada), and Prox Dynamics AS (Norway) (FLIR Systems, Inc., 2018, p. 38).

Umicore reported that demand for germanium tetrachloride used for infrared optics remained stable in 2017 (Umicore s.a., 2018, p. 9). Germanium-containing infrared optics were primarily for military use, and the commercial and personal markets for thermal-imaging devices that use germanium lenses has grown over the past few years.

Polymerization Catalysts.—Estimates indicated that consumption of germanium for PET outside the United States has been declining since 2011 owing to germanium price increases that led to substitutions for germanium. Producers have substituted lower cost antimony- and titanium-based products for germanium dioxide catalysts. The majority of germanium consumed for PET resin production took place in Japan, where the high brilliancy of the polymer is preferred for bottle applications.

Solar Cells.—Germanium-based solar cells were used in space-based applications and terrestrial installations. Umicore, a leading germanium substrate producer, reported that revenues from substrates for solar cells in space-based applications increased in 2017 from those in 2016 (Umicore s.a., 2018, p. 9).

5N Plus Semiconductors, a wholly owned subsidiary of 5N Plus Inc. (Canada), primarily produced germanium substrates, including 4-inch and 6-inch germanium wafers, for solar cells used in satellites. The company had the capability to produce germanium metal from germanium dioxide at its facility in Utah and recover germanium from industry-generated new scrap at other facilities. In May, the company commented that demand for specialized substrate materials from semiconductor manufacturers was likely to be a significant driver of its business in the near term (Metal-Pages, 2017).

Prices

Germanium is generally traded through long-term supply contracts among consumers, producers, and traders. Prices from Argus Media group – Argus Metals International are compiled through interviews with individual traders and are based on estimates of representative prices in trades carried out on a particular day. Reported germanium metal (minimum 99.999% germanium) prices began the year at about \$900 per kilogram and increased during the year to about \$1,350 per kilogram at yearend. Germanium metal prices averaged at about \$1,082 per

kilogram for 2017, compared with \$1,087 per kilogram in 2016 (fig. 1, table 3). Germanium dioxide prices began the year at about \$625 per kilogram, trended upward, and ended the year at \$800 per kilogram. Germanium dioxide prices averaged at about \$731 per kilogram for 2017, compared with \$830 per kilogram in 2016. Annual average germanium prices from 2008 to 2017 are shown in figure 1 and table 3.

Foreign Trade

According to the U.S. Census Bureau, imports for consumption of germanium metal (wrought, unwrought, and powder) were 11,000 kg in 2017, essentially unchanged compared with those in 2016 (tables 1, 2). Unwrought germanium metal imports were 6,660 kg in 2017, unchanged from those in 2016 (table 2), and were mostly (78%) sourced from China. China also supplied the majority (60%) of imports of wrought germanium, which decreased slightly to 2,050 kg in 2017 compared with 2,120 kg in 2016. Imports of germanium powder increased by 4% to 2,330 kg in 2017 compared with 2,240 kg in 2016. Decreased imports from Belgium and China were offset by an increase in imports from Russia, Switzerland, and the United Kingdom. In 2017, China, Belgium, Russia, and Germany, in descending order of quantity, accounted for 95% of all types of germanium metal imported into the United States. The estimated germanium content of the germanium dioxide imported in 2017 was about 12,000 kg, a 21% decrease compared with 15,200 kg in 2016 (table 1).

Domestic exports of germanium metal and articles thereof were estimated to be about 3,670 kg in 2017 on the basis of trade data from the U.S. Census Bureau that were adjusted by the USGS to exclude low-value scrap. Belgium, China, Germany, Japan, and Russia accounted for the majority of germanium exported from the United States in 2017. The estimated germanium content of germanium dioxide exported from the United States in 2017 was less than 100 kg.

World Review

In 2017, world production of germanium recovered from zinc concentrates, coal fly ash, and recycled material was estimated to be about 106,000 kg (table 1). Scrap was estimated to have supplied about 30% of the world's total production of germanium. Owing to the high value of refined germanium, new scrap generated during the manufacture of fiber-optic cables, infrared optics, and substrates was typically reclaimed and fed back into the production process. Recycling of germanium from old scrap, such as fiber-optic windows from decommissioned military vehicles or fiber-optic cables, has increased during the past decade. China accounted for the majority of global germanium production. Primary germanium was recovered from zinc residues in Belgium and Canada (concentrates shipped from the United States), coal ash and zinc residues in China (multiple sources), and coal ash in Russia.

As a byproduct metal, the supply of germanium was heavily reliant on zinc mine production. Although an important factor, global changes in zinc mine production may not be an indicator of a corresponding change in the supply of germanium. It has been estimated that less than 5% of the germanium contained in zinc concentrates reaches refineries that are capable of extracting and producing germanium (Mikolajczak, 2013, p. 9).

Australia.—In 2015, Nyrstar NV announced plans to upgrade production capacity at its zinc smelter in Hobart, Tasmania. The upgrades included construction of a side-leach plant that would enable the smelter to split base metals from minor metals and produce germanium and indium. The development phase of the project progressed in 2017 and is projected to be completed by yearend 2018 (Nyrstar NV, 2015, 2016, 2018, p. 6).

Belgium.—Umicore produced germanium metal, germanium tetrachloride for fiber optics, germanium substrates, and germanium optical products at its refinery and recycling plant in Olen. In 2017, the company reported increased sales of substrates for solar cells used in satellites and stable revenues for germanium tetrachloride for use in fiber optics (Umicore s.a., 2018, p. 9).

Canada.—The metallurgical complex operated by Teck in Trail, British Columbia, included two specialty metal plants that produced byproduct metals, including germanium dioxide. Historically, Teck has been one of the leading germanium producers in the world. The last year for which the company released production data was 2007, when Teck produced about 40,000 kg of germanium dioxide. In 2017, it was estimated that Canada exported about 15,000 kg of germanium contained in germanium dioxide (Teck Cominco Ltd., 2008, p. 44; Global Trade Information Services Inc., 2018a).

China.—China continued to be the leading global producer of germanium metal and germanium compounds, which were recovered from germanium-bearing coal ash and zinc ore. In 2017, an estimated 60,000 kg of germanium metal was produced in China, 25% less than that in 2016 (Argus Metals International, 2017a); stricter environmental protection requirements in China limited domestic raw material sources available to germanium producers (Minor Metals Monthly, 2018). Reduced output in 2017 was also in response to sustained price declines in 2016 and resulted in the germanium price in China rebounding in October 2017 to its highest level since April 2016 (Argus Metals International, 2017a, c). By yearend 2017, germanium prices in China increased by 30% compared with those at yearend 2016 (Minor Metals Monthly, 2018).

It was estimated that China's consumption of germanium increased by 14% in 2017 compared with that in 2016. Consumption and demand increased within the fiber-optic sector after Yunnan Lincang Xinyuan Germanium Industrial Co., Ltd. (Yunnan Germanium) completed an expansion project in 2017 that increased its germanium tetrachloride production capacity. Consumption and demand also increased in the photovoltaic market. The infrared devices market was stable (Minor Metals Monthly, 2018).

On a year-on-year basis, China's export volumes for germanium metal in the first three quarters of 2017 almost doubled to 18 t owing to increased demand for germanium from the infrared, photovoltaic, and fiber-optic industries outside of China in 2017 (Xu, 2017). China exported 21,120 kg of unwrought and wrought germanium metal in 2017, a 31% increase from 16,075 kg in 2016, and imported 3,674 kg of wrought and unwrought metal in 2017, an 11% increase compared with 3,298 kg in 2016 (Minor Metals Monthly, 2017, p. 17–19; 2018, p. 25–26).

China's germanium market has become highly integrated in recent years, with Yunnan Germanium and Xilingol Tongli

Germanium Co. Ltd. accounting for most of the country's production (Argus Metals International, 2017a). Price declines in 2015 and 2016 resulted in producers reducing output or moving into the production of downstream materials such as blanks, germanium compounds, or wafers (Argus Metals International, 2017c). Two other large-scale germanium suppliers, China Germanium Co. Ltd. and Chihong Zinc and Germanium Co. Ltd., focused on producing highly refined products, such as monocrystalline germanium and other semiconductor materials for the infrared and solar cell industries. These two companies sold only small volumes of germanium to external buyers (Argus Metals International, 2017a).

In recent years, the Government of China was thought to have supported the germanium market through its national stockpiling program and various environmental inspection programs (Roskill's Letter from Japan, 2017). In 2017, China's State Reserve Bureau, which maintained the country's national stockpile of strategic materials, was not thought to have purchased germanium, compared with the 9,517 kg of germanium purchased in the first half of 2016 (Metal Bulletin, 2017).

Before the Fanya Metal Exchange (FME) collapsed in late 2015, the FME claimed it held 92 t of germanium in its warehouses. As of October 2017, the FME inventories remained at 92 t (Metal Bulletin, 2017; Roskill's Letter from Japan, 2016, 2017). In December 2017, news reports indicated that the FME metal stocks could be actioned off in 2018 after the legal case against FME officials was likely to end (Argus Metals International, 2017b).

Finland.—From 2010 to 2016, Finland produced refined germanium products from zinc residues at a chemical plant in Kokkola owned by Freeport Cobalt Oy. In 2017, the Geological Survey of Finland reported that germanium production by Freeport Cobalt Oy ceased in 2016 (Lauri, 2016, p. 6; Geological Survey of Finland, 2017).

Russia.—During the past few years, Russia's germanium production was estimated to have remained stable. Exports in 2017 decreased compared with those of 2016 (Global Trade Information Services Inc., 2018b). Germanium and Applications Ltd. recovered germanium from fly ash from coal mined at the massive Pavlovskoye coal deposit in the Russian Far East. The company reported that coal production from the open pit mine could yield as much as 21,000 kilograms per year (kg/yr) of germanium, and its facilities in Moscow and Novomoskovsk had the capability to produce germanium oxide and metal, germanium blanks for optical use, and substrates for electronics (Germanium and Applications Ltd., 2018).

JSC Germanium operated an integrated refinery in Krasnoyarsk that processed concentrates, fly ash, and waste to produce germanium metal, compounds, and finished products. The company reported that it could produce germanium at a rate of about 20,000 kg/yr, but it did not specify if that included the germanium content of finished products, such as germanium lenses. JSC exported more than 80% of the germanium that it produced (JSC Germanium, 2018).

Outlook

Global demand for fiber-optic cable is likely to continue to increase during the next several years. Germanium-based optical

blanks and windows that are incorporated in infrared devices are expected to continue to be heavily used by military and law enforcement agencies. New applications for infrared products that use germanium lenses in commercial and industrial markets are expected to become more prevalent and represent a significant potential for consumption growth. However, increased substitution of specialty glass for pure germanium in infrared applications will likely continue to be attractive to commercial and industrial markets.

Germanium production will continue to be reliant on the zinc market. The availability of recycled germanium recovered from end-of-life products, such as fiber optics, military vehicles, and solar cells, is expected to increase during the next two decades as aging products are taken out of service. In China, germanium producers are expected to continue to expand to downstream products and manufacture finished products for export. Overall, the germanium market is expected to remain relatively balanced during the next several years owing to limited sources of supply and modest increases in global consumption.

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TABLE 1
SALIENT GERMANIUM STATISTICS¹

(Kilograms, unless otherwise specified)

	2013	2014	2015	2016	2017
United States:					
Refinery production	W	W	W	W	W
Imports for consumption:					
Germanium metal ²	34,200	23,700	20,100	11,000	11,000
Germanium dioxide ^{2, 3}	11,400	12,500	14,300	15,200	12,000
Exports, germanium metal ⁴	12,500	12,000	5,000	4,780	3,670
Consumption, germanium metal ⁵	38,000	32,000	34,000	30,000	30,000
Price, average:					
Germanium metal ⁶ dollars per kilogram	1,778	1,918	1,792	1,087	1,082
Germanium dioxide ⁷ do.	1,307	1,291	1,211	830 ^r	731
Stocks, December 31, U.S. Government ⁸	16,400	13,400	13,400	13,400	13,400
World, refinery production: ^c					
China	110,000	98,000	100,000	80,000	60,000
Russia	5,000	6,000	6,000	6,000	6,000
Other ⁹	40,000	40,000	40,000	40,000	40,000
Total	155,000	144,000	146,000	126,000	106,000

^cEstimated. ^rRevised. do. Ditto. W Withheld to avoid disclosing company proprietary data; not included in "World, refinery production."

¹Table includes data available through May 10, 2018. Data are rounded to no more than three significant digits, except prices; may not add to totals shown.

²Includes Harmonized Tariff Schedule of the United States (HTS) codes 8112.92.6000, 8112.92.6500, and 8112.99.1000.

³Includes HTS code 2825.60.000. Data have been adjusted to exclude low-value shipments, then multiplied by 69% to account for germanium content.

⁴Includes HTS codes 8112.92.6100, 8112.99.1000, and 2825.60.0000. Data have been adjusted to exclude low-value shipments. Oxide data were multiplied by 69% to account for germanium content.

⁵Estimated consumption of germanium contained in metal and germanium dioxide.

⁶Minimum 99.99% germanium. Source: Argus Media group – Argus Metals International.

⁷Minimum 99.99% germanium dioxide, approximately 69% metal content. Source: Argus Media group – Argus Metals International.

⁸Defense Logistics Agency Strategic Materials. Data are uncommitted germanium metal only.

⁹Includes Belgium, Canada, Germany, and other countries or localities.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF GERMANIUM METAL, BY COUNTRY OR LOCALITY¹

(Kilograms, unless otherwise specified)

Country or locality	2013		2014		2015		2016		2017	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Unwrought:²										
Belgium	2,250	\$3,720,000	7,010	\$13,100,000	5,220	\$8,280,000	1,560	\$2,070,000	923	\$1,150,000
Canada	2,360	1,020,000	503	62,000	3	8,040	--	--	--	--
China	20,800	33,000,000	11,200	18,400,000	10,700	16,000,000	4,930	4,590,000	5,220	5,070,000
Germany	71	143,000	346	515,000	309	427,000	31	25,700	123	148,000
Hong Kong	193	368,000	--	--	--	--	--	--	--	--
Russia	267	211,000	271	151,000	32	19,400	--	--	200	111,000
Other	200	354,000	3	5,330	1	4,500	140	112,000	189	113,000
Total	26,100	38,800,000	19,300	32,200,000	16,200	24,700,000	6,660	6,800,000	6,660	6,590,000
Powder:³										
Belgium	37	83,400	55	291,000	77	513,000	712	860,000	376	507,000
Canada	--	--	4	2,600	--	--	--	--	--	--
China	3	3,000	8	32,000	57	53,100	618	620,000	392	427,000
Germany	114	222,000	471	951,000	480	822,000	639	868,000	611	753,000
Russia	406	661,000	305	458,000	217	283,000	263	282,000	591	572,000
United Kingdom	--	--	5	3,430	65	80,700	3	4,370	49	5,850
Other	10	8,910	1	5,000	3	3,980	--	--	312	315,000
Total	570	978,000	849	1,740,000	899	1,760,000	2,240	2,630,000	2,330	2,580,000
Wrought:⁴										
Belgium	3,250	2,990,000	549	948,000	300	461,000	66	105,000	17	73,200
Canada	85	117,000	3	36,300	--	--	--	--	--	--
China	2,360	3,920,000	1,910	3,380,000	1,480	2,400,000	682 ^r	872,000 ^r	1,230	1,510,000
Germany	156	471,000	364	802,000	512	1,060,000	225 ^r	325,000 ^r	304	438,000
Romania	--	--	--	--	153	292,000	277	615,000	--	--
Russia	1,650	2,210,000	705	1,110,000	343	500,000	838 ^r	1,270,000 ^r	452	481,000
United Kingdom	--	--	1	4,000	108	33,600	20	35,200	1	13,100
Other	1	18,200	9	42,400	64	109,000	9	10,500	50	32,500
Total	7,500	9,730,000	3,540	6,330,000	2,960	4,850,000	2,120 ^r	3,230,000 ^r	2,050	2,550,000

^rRevised. -- Zero.

¹Table includes data available through May 10, 2018. Data are rounded to no more than three significant digits; may not add to totals shown.

²Includes Harmonized Tariff Schedule of the United States (HTS) code 8112.92.6000.

³Includes HTS code 8112.92.6500.

⁴Includes HTS code 8112.99.1000.

Source: U.S. Census Bureau.

TABLE 3
ANNUAL AVERAGE PRICES¹

(Dollars per kilogram)

	Germanium metal (min. 99.99% purity)	Germanium dioxide (min. 99.99% purity)
2008	1,456	948
2009	1,054	677
2010	953	575
2011	1,539	1,218
2012	1,464	1,179
2013	1,778	1,307
2014	1,918	1,291
2015	1,792	1,211
2016	1,087	830 ^r
2017	1,082	731

^rRevised.

¹Table includes data available through May 10, 2018.

Source: Argus Media group – Argus Metals International.

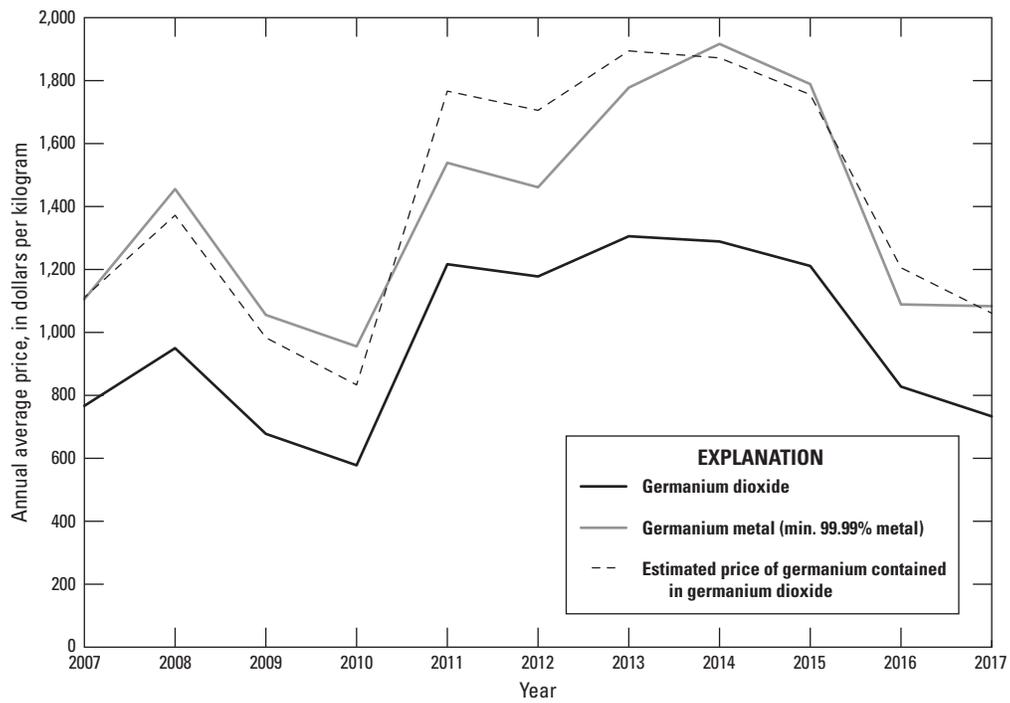


Figure 1. Average annual prices for germanium metal and germanium dioxide from 2007 through 2017. Source: Argus Media group – Argus Metals International.