



2018 Minerals Yearbook

GERMANIUM [ADVANCE RELEASE]

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By Christine L. Thomas

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

In 2018, 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 facility in Canada for processing. In Tennessee, the Clarksville zinc smelter, owned by Nyrstar NV (Belgium), produced byproduct germanium leach concentrates at the Middle Tennessee mine complex. The U.S. Geological Survey (USGS) estimated that in 2018, 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 130,000 kg, about 5% more than that in 2017 (table 1). The amount of germanium recovered from scrap in 2018 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. Germanium is commercially available as tetrachloride, high-purity oxide, and various forms of metal. The current principal uses of germanium 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 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 used in the manufacture of certain 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 (NDS) in 1984. The Defense Logistics Agency Strategic Materials (DLA Strategic Materials) reported that no germanium metal was sold in 2018. Germanium was last sold in February 2009 at an average price of \$1,331 per kilogram. As of December 31, 2018, the total inventory of germanium held by DLA Strategic Materials was as follows: 14,004 kg of metal; 85,305 wafers; and 2,164 kg of scrap. The Annual Materials Plan (AMP) for fiscal year 2019 (October 1, 2018, through September 30, 2019) allocated 5,000 kg of germanium scrap for potential disposals, and no potential acquisitions of germanium metal were allocated in fiscal year 2019 (Defense Logistics Agency Strategic Materials, 2018a, b).

In May, the U.S. Department of the Interior, in coordination with other executive branch agencies, published a list of 35 critical minerals, including germanium, pursuant to Executive Order 13817, "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals" (Trump, 2017; U.S. Department of the Interior, 2018).

In July, the United States took action under Section 301 of the Trade Act of 1974 and imposed an additional 25% tariff on certain products imported from China that benefited from China's industrial policy and forced technology transfer practices. In response, the Government of China enacted a 25% import tariff on a series of metal products from the United States, including unwrought germanium metal. Following China's response, the United States proposed an additional 10% tariff on a series of additional products imported from China, which included germanium products (Office of the United States Trade Representative, 2018). The United States imposed this additional 10% tariff on September 24, and the additional tariff was likely to increase to 25% in 2019. Unwrought germanium metal was removed from the United States' final tariff list, but other germanium products, such as germanium dioxide, remained (Argus Metals International, 2018c; Office of the United States Trade Representative, 2019).

Production

Teck produced germanium-containing zinc concentrates at its Red Dog zinc-lead open pit mine in Alaska. Approximately 34% of the zinc concentrate produced at Red Dog was sent to Teck's metallurgical complex in Trail, British Columbia,

Canada, for processing. The remainder was sent to several countries in Asia and Europe 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 increased by 8% to 583,000 metric tons (t) in 2018 from 542,000 t in 2017 owing to higher mill throughput, average zinc ore grade, and recovery rates. Teck projected that zinc production at Red Dog would decrease in the next few years, ranging from 535,000 to 555,000 t in 2019 and from 500,000 to 520,000 metric tons per year (t/yr) in 2020 through 2022 (Teck Resources Ltd., 2019a, p. 19; 2019b, p. 24, 49).

Teck also produced germanium-containing zinc concentrates at its Pend Oreille Mine in Washington State. The germanium-containing zinc concentrates produced at the mine were processed at Teck's Trail plant. Zinc-in-concentrate production at Pend Oreille decreased by 10% to 29,700 t in 2018 from 33,100 t in 2017. Teck projected that zinc production for the first 9 months of 2019 would range from approximately 20,000 to 30,000 t. Production rates beyond the third quarter of 2019 were uncertain (Teck Resources Ltd., 2019b, p. 25, 49).

Nyrstar's Clarksville zinc smelter in Tennessee produced byproduct germanium concentrate in 2018. Byproduct germanium concentrate was produced from the Middle Tennessee mines zinc concentrate feedstock. Refined zinc production at the Clarksville smelter in 2018 decreased by 14% from that of 2017 to 101,000 t, owing to a combination of planned and unplanned maintenance outages (Nyrstar NV, 2019).

Secondary processors recovered secondary germanium metal from end-of-life products, such as decommissioned military vehicles and thermal weapon sights. Major secondary producers include Umicore S.A. (Belgium) and 5N Plus Semiconductors LLC (St. George, UT), a wholly owned subsidiary of 5N Plus Inc. (Canada). Umicore's facility in Quapaw, OK, produced germanium tetrachloride and other materials for thermal imaging. 5N Plus Semiconductors LLC produced germanium wafers (5N Plus Inc., 2019).

Consumption

The USGS estimated that domestic consumption of germanium metal (including metal content of compounds) was about 30,000 kg in 2018, essentially unchanged from that in 2017 (table 1). The major global end uses were electronics, fiber-optic systems, infrared optics, polymerization catalysts, solar applications, and other uses (such as chemotherapy, phosphors, and metallurgy).

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 2018, Corning Inc. (Corning, NY) reported that sales of its optical communications products increased by 18% from those in 2017, owing to increased enterprise and carrier network sales, increased sales of fiber-optic cable and hardware for fiber-to-the-home installations in North America, and the acquisition of 3M Company's (Maplewood, MN) Communication Markets Division (Corning Inc., 2019, p. 2, 4). 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 million kilometers (12.4 million miles) of fiber-optic cable each year through 2020 (Lightwave, 2017b). In 2018, Corning enhanced its fiber manufacturing facilities to meet ongoing demands after a surge of sales in fourth quarter 2017 (Buckley, 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 multi-mode fibers.

In 2017, Prysmian Group (Italy) announced plans to invest throughout North America, owing in part to a supply contract of fiber-optic cables for Verizon's fiber-platform rollout. Prysmian also announced that 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 the internal Prysmian supply of germanium tetrachloride in the United States (Lightwave, 2017a, c). In June 2018, Prysmian finalized the acquisition of General Cable Corp. (Highland Heights, KY). The addition of General Cable increased Prysmian's North American presence; North America accounted for approximately one-third of Prysmian's sales (Lightwave, 2018).

Infrared Optics.—Germanium was used in lenses and windows for infrared optical systems owing to its transparency to part of the infrared spectrum and its high refractive index. FLIR Systems, Inc. (Wilsonville, OR), a leading domestic producer of infrared surveillance devices, reported a slight decrease in sales revenue in 2018 compared with that in 2017. Decreased revenue was attributed to the divestiture of one of its commercial business units (FLIR Systems, Inc., 2019, p. 39).

Umicore reported that demand for the germanium tetrachloride used in infrared optics remained stable in 2018 compared with that in 2017 (Umicore S.A., 2019, 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 have grown over the past few years.

Polymerization Catalysts.—Estimates indicated that the consumption of germanium for PET outside the United States has declined since 2011, owing to germanium price increases that led to increased use of germanium substitutes. Producers 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 brilliance 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 of substrates for solar cells in space-based applications decreased in 2018 from those in 2017 (Umicore S.A., 2019, p. 9).

5N Plus Semiconductors LLC primarily produced germanium substrates, including 4-inch and 6-inch germanium wafers, for solar cells used in satellites. The company could produce germanium metal from germanium dioxide at its facility in Utah and recover germanium from industry-generated new

scrap at other facilities (5N Plus Inc., 2019). In 2017, 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 (Argus Metals International, 2017a). In April 2018, 5N Plus announced that it would expand its upstream production capacity across Asia and Europe, with production expected in 2019. The company expected the move to increase its specialty metal production capacity by more than 2,000 t/yr and allow it to process additional types of secondary materials (5N Plus Inc., 2018; Argus Metals International, 2018a).

Prices

Germanium is generally traded through long-term supply contracts among consumers, producers, and traders. The prices in Europe reported by Argus Metals International were compiled through interviews with market participants and based on estimates of representative prices in trades carried out on a particular day. Reported germanium metal (minimum 99.999% germanium; cost, insurance, and freight; Europe) prices began the year at about \$1,350 per kilogram, increased through May to about \$1,750 per kilogram, and then decreased to about \$1,320 per kilogram at yearend. Germanium metal prices averaged about \$1,543 per kilogram for 2018, compared with \$1,082 per kilogram in 2017 (fig. 1, table 3). Germanium dioxide (minimum 99.99% germanium dioxide, approximately 69% germanium content, in-warehouse, Rotterdam) prices began the year at about \$800 per kilogram, increased through July to about \$1,175 per kilogram, and then decreased to about \$1,008 per kilogram at yearend. Germanium dioxide prices averaged about \$1,084 per kilogram for 2018, compared with \$731 per kilogram in 2017. Annual average germanium prices from 2009 to 2018 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) increased by 6% to 11,800 kg in 2018 compared with 11,100 kg in 2017 (tables 1, 2). Unwrought germanium metal imports increased by 22% to 8,750 kg in 2018 compared with 7,180 kg in 2017 (table 2) and were mostly sourced from China (63%) and Belgium (26%). China (45%), Russia (31%), and Germany (24%) supplied the majority of imports of wrought germanium, which decreased by 13% to 1,750 kg in 2018 compared with 2,020 kg in 2017. Germany (49%) and Belgium (36%) supplied the majority of imports of germanium powder, which decreased by 35% to 1,260 kg in 2018 compared with 1,930 kg in 2017. In 2018, China, Belgium, Germany, and Russia, in descending order of quantity, accounted for 97% of all types of germanium metal imported into the United States. The estimated germanium content of the germanium dioxide imported in 2018 was about 12,400 kg, a 3% increase compared with 12,000 kg in 2017 (table 1).

Domestic exports of germanium metal and articles thereof were estimated to be about 4,780 kg in 2018, based on trade data from the U.S. Census Bureau that were adjusted by the USGS to exclude low-value scrap. Belgium, France, Germany, Japan,

the Republic of Korea, and Russia accounted for the majority of germanium exported from the United States in 2018. The estimated germanium content of germanium dioxide exported from the United States in 2018 was about 100 kg.

World Review

In 2018, world production of germanium recovered from zinc concentrates, coal fly ash, and recycled material was estimated to be about 130,000 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 and zinc residues 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 capable of extracting and producing germanium (Mikolajczak, 2013, p. 9).

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 2018, the company reported decreased sales of substrates for solar cells used in satellites and stable revenues for germanium tetrachloride for use in fiber optics (Umicore S.A., 2019, 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 containing about 28,000 kg of germanium (Teck Cominco Ltd., 2008).

In January 2018, Teck declared a partial force majeure on metal sales from its Trail smelting and refining complex after an explosion at its No. 2 Slag Fuming Furnace (Ashreena, 2018). This incident led to a global germanium shortage and contributed to higher prices during the first half of the year. In July, Teck announced that it would remove the partial force majeure on its germanium output after restarting the fuming furnace in the fourth quarter of 2018 (Hotter, 2018). In 2018, it was estimated that Canada exported about 10,000 kg of germanium contained in germanium dioxide (Global Trade Information Services Inc., 2019).

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 2018, an estimated 94,900 kg of germanium metal was produced in China, a 20% increase from that of 2017 (Minor Metals Monthly, 2019). This increase was attributed to production resuming in 2018 at Xilingol Tongli Germanium Industry Co., Ltd. and Xilingol Mengdong Germanium Technology Co., Ltd., as well as expanded capacity at Henyang Henrong High Purity Semiconductor Materials Co., Ltd. (Minor Metals Monthly, 2018a, 2019). These companies restarted production after complying with stricter environmental protection requirements in China, which had limited domestic raw material sources available to germanium producers in recent years (Argus Metals International, 2018b; Minor Metals Monthly, 2018a).

During the first 3 months of 2018, germanium prices in China increased by approximately 19%. This increase was attributed to a supply decrease in China (Minor Metals Monthly, 2018b). Prices remained stable from April to June and then declined through to November. The decline during the second half of the year was attributed to a supply surplus and a decrease in exports (Minor Metals Monthly, 2018a). Prices increased from November to the end of the year. This increase was attributed to the implementation of an export duty reimbursement policy and an increase in demand (Minor Metals Monthly, 2018c, 2019).

It was estimated that China's consumption of germanium increased by about 26% to 75,100 kg in 2018 from 59,700 kg in 2017. This increase in consumption was mainly attributed to the commissioning of Kunming Yunzhe High-Tech Co., Ltd.'s new production capacity for optical fiber germanium tetrachloride. Increased consumption in China was the result of the increase in fiber-optic, infrared optic, and solar cell demand (Minor Metals Monthly, 2019).

China's exports of germanium metal decreased by about 4% to 20,300 kg in 2018 from 21,200 kg in 2017. China's exports of germanium dioxide (germanium content) increased by an estimated 17% to 1,400 kg in 2018 from 1,200 kg in 2017. Total exports of germanium metal and germanium dioxide decreased by about 3% to 21,700 kg in 2018 from 22,300 kg in 2017. The overall decrease in 2018 exports was attributed to the increase in domestic consumption (Minor Metals Monthly, 2019).

Before the Fanya Metal Exchange (FME) collapsed in late 2015, the exchange claimed it held 92 t of germanium in its warehouses (Roskill's Letter from Japan, 2016, 2017). In 2017, news reports indicated that the FME metal stocks could be actioned off in 2018 after the legal case against Fanya officials was likely to end (Argus Metals International, 2017b). No auctions took place in 2018, but an auction of Fanya indium stocks took place in January 2019. As of January 2019, there were no reports of an auction of Fanya germanium stocks (Argus Metals International, 2019).

Russia.—During the past few years, Russia's germanium production was estimated to have remained stable. 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 could 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

The global demand for fiber-optic cable is expected to continue to increase during the next several years. Germanium-based optical blanks and windows incorporated into infrared devices are expected to continue to experience heavy use by military and law enforcement agencies. Strong demand from the defense industry for thermal imaging applications is expected to increase the use of germanium in coming years. 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, an increase in the substitution of specialty glass for pure germanium in infrared applications will continue to be attractive to commercial and industrial markets.

Germanium production relies 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 their product lines to include downstream germanium products for export. Overall, the germanium market is expected to remain stable 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)

	2014	2015	2016	2017	2018
United States:					
Refinery production	W	W	W	W	W
Imports for consumption:					
Germanium metal ²	23,700	20,100	11,000	11,100 ^r	11,800
Germanium dioxide ^{e,3}	12,500	14,300	15,200	12,000	12,400
Exports, germanium metal ^{e,4}	12,000	5,000	4,780	3,670	4,880
Consumption, germanium metal ^{e,5}	32,000	34,000	30,000	30,000	30,000
Price, average:					
Germanium metal ⁶ dollars per kilogram	1,918	1,792	1,087	1,082	1,543
Germanium dioxide ⁷ do.	1,291	1,211	830	731	1,084
Stocks, December 31, U.S. Government ⁸	13,400	13,400	13,400	13,400	14,000
World, refinery production: ^e					
China	98,000	100,000	80,000	79,100 ^r	94,900
Russia	6,000	6,000	5,000 ^r	5,000 ^r	5,000
Other ⁹	40,000	40,000	40,000	40,000	30,000
Total	144,000	146,000	125,000 ^r	124,000 ^r	130,000

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

¹Table includes data available through June 19, 2019. 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. Dioxide data were multiplied by 69% to account for germanium content.

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

⁶Minimum 99.99% germanium; cost, insurance, and freight; Europe. Source: Argus Media group – Argus Metals International.

⁷Minimum 99.99% germanium dioxide, approximately 69% metal content, in-warehouse, Rotterdam. 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	2014		2015		2016		2017		2018	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Unwrought:²										
Belgium	7,010	\$13,100,000	5,220	\$8,280,000	1,560	\$2,070,000	1,450 ^r	\$1,680,000 ^r	2,280	\$3,830,000
Canada	503	62,000	3	8,040	--	--	--	--	--	--
China	11,200	18,400,000	10,700	16,000,000	4,930	4,590,000	5,220	5,070,000	5,510	6,390,000
Germany	346	515,000	309	427,000	31	25,700	123	148,000	463	211,000
Hong Kong	--	--	--	--	--	--	--	--	--	--
Russia	271	151,000	32	19,400	--	--	200	111,000	159	86,500
Other	3	5,330	1	4,500	140	112,000	189	113,000	336	81,400
Total	19,300	32,200,000	16,200	24,700,000	6,660	6,800,000	7,180 ^r	7,120,000 ^r	8,750	10,600,000
Powder:³										
Belgium	55	291,000	77	513,000	712	860,000	29	165,000	453	1,120,000
Canada	4	2,600	--	--	--	--	--	--	--	--
China	8	32,000	57	53,100	618	620,000	392	427,000	173	153,000
Germany	471	951,000	480	822,000	639	868,000	611	753,000	611	1,020,000
Russia	305	458,000	217	283,000	263	282,000	591	572,000	21	32,500
United Kingdom	5	3,430	65	80,700	3	4,370	49	5,850	--	--
Other	1	5,000	3	3,980	--	--	257 ^r	275,000 ^r	--	--
Total	849	1,740,000	899	1,760,000	2,240	2,630,000	1,930 ^r	2,200,000 ^r	1,260	2,320,000
Wrought:⁴										
Belgium	549	948,000	300	461,000	66	105,000	17	73,200	2	12,800
Canada	3	36,300	--	--	--	--	--	--	7	4,150
China	1,910	3,380,000	1,480	2,400,000	682	872,000	1,190 ^r	1,470,000 ^r	780	1,170,000
Germany	364	802,000	512	1,060,000	225	325,000	304	438,000	416	806,000
Romania	--	--	153	292,000	277	615,000	--	--	--	--
Russia	705	1,110,000	343	500,000	838	1,270,000	452	481,000	543	748,000
United Kingdom	1	4,000	108	33,600	20	35,200	1	13,100	3	9,070
Other	9	42,400	64	109,000	9	10,500	50	32,500	1	2,470
Total	3,540	6,330,000	2,960	4,850,000	2,120	3,230,000	2,020 ^r	2,500,000 ^r	1,750	2,750,000

^rRevised. -- Zero.

¹Table includes data available through June 19, 2019. 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 (minimum 99.99% purity)	Germanium dioxide (minimum 99.99% purity)
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
2017	1,082	731
2018	1,543	1,084
Average	1,424	1,005

¹Table includes data available through June 19, 2019.

Source: Argus Media group – Argus Metals International.

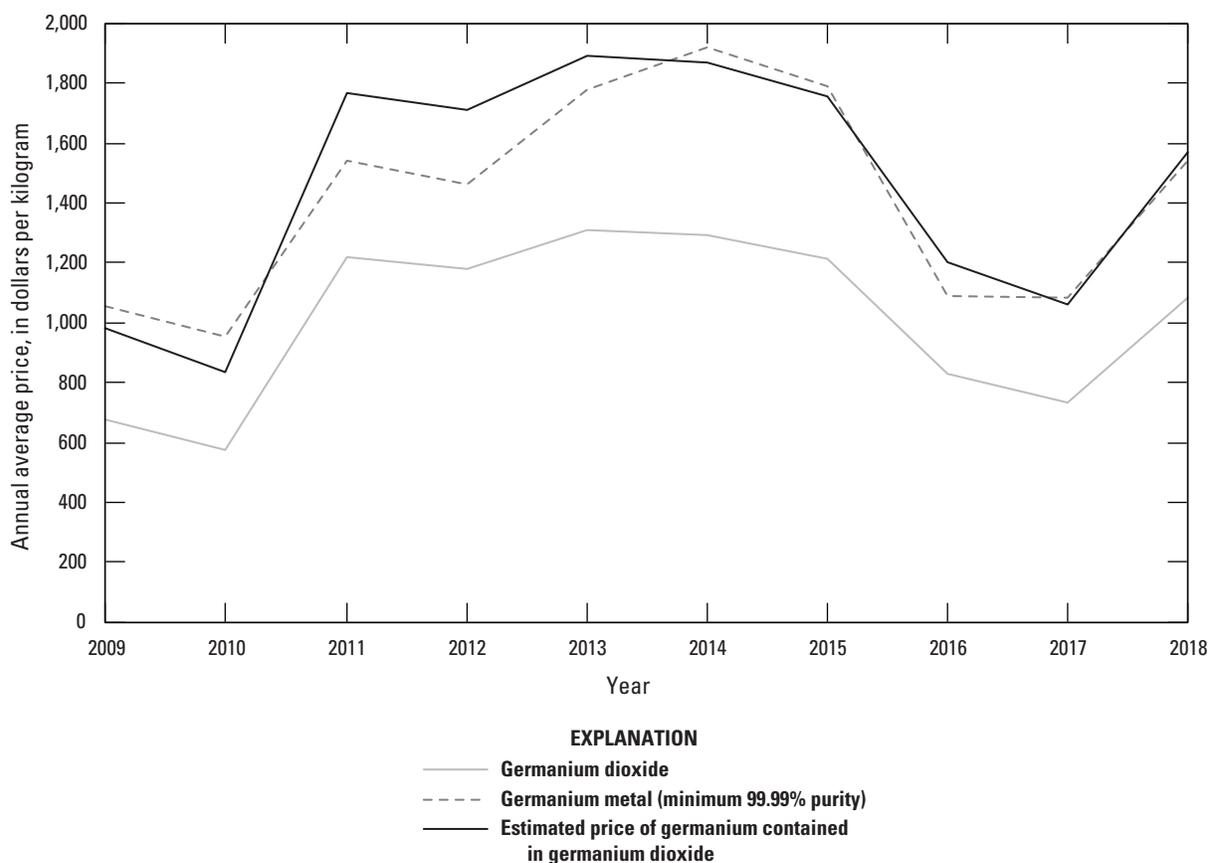


Figure 1. Average annual prices for germanium metal and germanium dioxide from 2008 through 2018. Source: Argus Media group – Argus Metals International.