



# 2019 Minerals Yearbook

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## GERMANIUM [ADVANCE RELEASE]

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# GERMANIUM

By Amy C. Tolcin

Tables were prepared by Joshua A. Braunstein, statistical assistant.

In 2019, 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 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 131,000 kilograms (kg), essentially unchanged from that in 2018 (table 1). The amount of germanium recovered from scrap in 2019 was estimated to be about 30% of world production of germanium metal.

Germanium is a hard, brittle semimetal first used about 60 years ago as a semiconductor material in radar units and as the primary material in the first transistors. Germanium is commercially available as tetrachloride, high-purity oxide, and various forms of metal. The principal uses of germanium included lenses or windows in infrared night-vision devices; 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 was used primarily 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 reported that no

germanium metal was sold in 2019. Germanium was last sold from the NDS in February 2009. The Annual Materials Plan for fiscal year 2020 (October 1, 2019, through September 30, 2020) allocated 3,000 kg of germanium scrap for potential disposal and no potential acquisitions (Defense Logistics Agency Strategic Materials, 2019a, b).

## Production

Teck 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. The remainder was sent to several countries in Asia and Europe for processing. Reported production of zinc in concentrate at the Red Dog Mine was 552,400 metric tons (t) in 2019, a decrease from 583,200 t in 2018. Residues from zinc concentrates were treated in roasters or pressure-leach facilities and purified at Teck's Trail facility to produce germanium dioxide and other byproduct metals. Teck projected that zinc production at the Red Dog Mine would decrease in 2020 from that in 2019, ranging from 500,000 to 535,000 t, and would remain stable in 2021 through 2023, ranging from 500,000 to 540,000 metric tons per year (Teck Resources Ltd., 2020, p. 43–44).

Teck also produced germanium-containing zinc concentrates at its Pend Oreille Mine in Washington State. All concentrates were sold to Teck's Trail operations. Zinc-in-concentrate production at Pend Oreille was 19,400 t in 2019, compared with 29,700 t in 2018. Teck placed the Pend Oreille Mine on care-and-maintenance status in July 2019 owing to the exhaustion of current reserves (Teck Resources Ltd., 2020, p. 18, 45).

Nyrstar's Clarksville zinc smelter in Tennessee produced byproduct germanium concentrate, which was sourced from the Middle Tennessee mines zinc concentrate feedstock (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 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. 5N Plus's facility in St. George, UT, produced germanium wafers (5N Plus Inc., 2019; Umicore S.A., undated).

## Consumption

The U.S. Geological Survey (USGS) estimated that domestic consumption of germanium metal (including metal content of compounds) totaled 30,000 kg in 2019, unchanged from that in 2018 (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 was 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. Corning Inc. (Corning, NY) and Prysmian S.p.A. (Italy) were major producers of fiber-optic cable in the United States.

**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. Germanium-containing infrared optics were primarily for military use, although the commercial and personal markets for thermal-imaging devices using germanium lenses has grown. FLIR Systems, Inc. (Wilsonville, OR) was a leading domestic producer of infrared surveillance devices.

**Polymerization Catalysts.**—Consumption of germanium for PET outside the United States was thought to have declined since 2011 owing to germanium price increases leading 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. 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 produced germanium metal from germanium dioxide at its facility in Utah and recovered germanium from industry-generated new scrap at other facilities (5N Plus Inc., 2019).

## Prices

Germanium was 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 \$1,320 per kilogram, increased through March to \$1,350 per kilogram, and then decreased to \$1,050 per kilogram at yearend. Germanium metal prices averaged \$1,236 per kilogram for 2019, a 20% decrease compared with \$1,543 per kilogram in 2018 (tables 1, 3). Germanium dioxide (minimum 99.99% germanium dioxide, approximately 69% germanium content, in-warehouse, Rotterdam) prices began the year at \$1,010 per kilogram and from then decreased to \$770 per kilogram at yearend. Germanium dioxide prices averaged \$913 per kilogram for 2019, a 16% decrease compared with \$1,084 per kilogram in 2018 (tables 1, 3).

## Foreign Trade

According to the U.S. Census Bureau, imports for consumption of germanium metal (wrought, unwrought, and

powder) increased by 19% to 14,100 kg in 2019 compared with 11,900 kg in 2018 (tables 1, 2). Unwrought germanium metal imports increased by 23% to 10,900 kg in 2019 compared with 8,850 kg (revised) in 2018 (table 2) and were mostly sourced from China (70%) and Belgium (26%). China (50%), Russia (33%), and Germany (16%) supplied the majority of imports of wrought germanium, which decreased by 17% to 1,450 kg in 2019 compared with 1,750 kg in 2018. Germany (64%) and Belgium (29%) supplied the majority of imports of germanium powder, which increased by 35% to 1,700 kg in 2019 compared with 1,260 kg in 2018. In 2019, China, Belgium, Germany, and Russia, in descending order of quantity, accounted for 99% of all types of germanium metal imported into the United States. The estimated germanium content of the germanium dioxide imported in 2019 was about 21,000 kg, nearly double compared with the 12,200 kg (revised) in 2018 (table 1).

Domestic exports of germanium metal and dioxide were estimated to be 4,600 kg in 2019, based on trade data from the U.S. Census Bureau that were adjusted by the USGS to remove low-value exports, and were 6% less compared with estimated exports in 2018 (table 1).

## World Review

In 2019, world production of germanium recovered from zinc concentrates, coal fly ash, and recycled material was estimated to be 131,000 kg (table 1). About 30% of the world's total production of germanium was estimated to be from scrap. 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, 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.

Because germanium is a byproduct metal, its supply 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.

**Belgium.**—Umicore produced germanium metal, germanium tetrachloride for fiber optics, germanium substrates, and germanium optical products at its refinery and recycling plant in Olen.

**Canada.**—The metallurgical complex operated by Teck in Trail, British Columbia, included two specialty metal plants that produced byproduct metals, including germanium dioxide.

**China.**—China continued to be the leading global producer and exporter of germanium metal, which was recovered from germanium-bearing coal ash and zinc ore. In 2019, an estimated 85,700 kg of germanium metal was reportedly produced in China, a 10% decrease from that in 2018 (table 1). China's exports of germanium metal increased by 12% to 22,800 kg in 2019 from 20,300 kg in 2018. Germanium was exported mainly to Belgium (30%), Japan (22%), Russia (21%), and the United States (21%) (IHS Markit Ltd., 2020).

Before the Fanya Metal Exchange collapsed in late 2015, the Exchange reported that it held approximately 92,000 kg of germanium in its warehouses (Roskill's Letter from Japan, 2016, 2017). In October, 92,310 kg of germanium were purchased through an auction by Kunming Rongke New Material for \$84 million<sup>1</sup> (Argus Metals International, 2019). Kunming Rongke was established in early September by Vital Materials Co. Ltd. (China), although Vital's ownership of Kunming Rongke was not announced until January 2020. Vital Materials made several purchases of Fanya's minor metals stocks, including a quantity of indium equivalent to 5 years of global production (Daly, 2020). In recent years, Vital focused on acquiring advanced and specialty materials companies outside of China. In 2017, Vital purchased Umicore's indium-tin-oxide (ITO) sputtering target business and subsequently closed Umicore's ITO plant in Rhode Island and moved the manufacturing process to China (Umicore S.A., 2017).

**Russia.**—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, Siberia, 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.

<sup>1</sup>Value has been converted from Chinese yuan renminbi (CNY) to U.S. dollars (US\$) at the rate of CNY6.62=US\$1.00 for 2018.

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## GENERAL SOURCES OF INFORMATION

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### Other

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TABLE 1  
SALIENT GERMANIUM STATISTICS<sup>1</sup>

(Kilograms unless otherwise specified)

	2015	2016	2017	2018	2019
United States:					
Refinery production	W	W	W	W	W
Imports for consumption:					
Germanium metal <sup>2</sup>	20,100	11,000	11,100	11,900 <sup>r</sup>	14,100
Germanium dioxide <sup>3</sup>	14,300	15,200	12,000	12,200 <sup>r</sup>	21,000
Exports, germanium metal and dioxide <sup>4</sup>	5,000	4,780	3,670	4,880	4,600
Consumption, germanium metal <sup>5</sup>	34,000	30,000	30,000	30,000	30,000
Price, average:					
Germanium metal <sup>6</sup> dollars per kilogram	1,785 <sup>r</sup>	1,087	1,082	1,543	1,236
Germanium dioxide <sup>7</sup> do.	1,207 <sup>r</sup>	830	731	1,084	913
Stocks, December 31, U.S. Government <sup>8</sup>	13,400	13,400	13,400	14,000	14,000
World, refinery production: <sup>c</sup>					
China	100,000	82,000 <sup>r</sup>	79,100	94,900	85,700
Russia	6,000	5,000	5,000	5,000	5,000
Other <sup>9</sup>	40,000	40,000	40,000	30,000	40,000
Total	146,000	127,000 <sup>r</sup>	124,000	130,000	131,000

<sup>c</sup>Estimated. <sup>r</sup>Revised. do. Ditto. W Withheld to avoid disclosing company proprietary data; not included in "World, refinery production."

<sup>1</sup>Table includes data available through July 14, 2020. Data are rounded to no more than three significant digits, except prices; may not add to totals shown.

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

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

<sup>4</sup>Includes Schedule B 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.

<sup>5</sup>Estimated consumption of germanium contained in metal and germanium dioxide.

<sup>6</sup>Cost, insurance, and freight value; Europe; minimum 100-kilogram (kg) lots. For 2015, prices are for minimum 99.99% purity. For 2016–19, prices are for minimum 99.999% purity. Source: Argus Media group – Argus Metals International.

<sup>7</sup>In-warehouse, Rotterdam; minimum 100-kg lots. For 2015, prices are for minimum 99.99% purity. For 2016–19, prices are for minimum 99.999% purity. Source: Argus Media group – Argus Metals International.

<sup>8</sup>Defense Logistics Agency Strategic Materials. Data are uncommitted germanium metal only.

<sup>9</sup>Includes Belgium, Canada, Germany, and other countries or localities.

TABLE 2  
U.S. IMPORTS FOR CONSUMPTION OF GERMANIUM METAL, BY COUNTRY OR LOCALITY<sup>1</sup>

(Kilograms unless otherwise specified)

Country or locality	2015		2016		2017		2018		2019	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
<b>Unwrought:<sup>2</sup></b>										
Belgium	5,220	\$8,280,000	1,560	\$2,070,000	1,450	\$1,680,000	2,280	\$3,830,000	2,890	\$4,970,000
China	10,700	16,000,000	4,930	4,590,000	5,220	5,070,000	5,610 <sup>r</sup>	6,480,000 <sup>r</sup>	7,660	8,000,000
Germany	309	427,000	31	25,700	123	148,000	463	211,000	253	136,000
Japan	--	--	140	112,000	--	--	--	--	--	--
Korea, Republic of	--	--	--	--	--	--	8	19,300	36	84,800
Russia	32	19,400	--	--	200	111,000	159	86,500	50	50,000
United Kingdom	--	--	--	--	189	113,000	322	23,700	35	7,790
Other	4 <sup>r</sup>	12,500 <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	6 <sup>r</sup>	38,500 <sup>r</sup>	2	2,520
<b>Total</b>	<b>16,200</b>	<b>24,700,000</b>	<b>6,660</b>	<b>6,800,000</b>	<b>7,180</b>	<b>7,120,000</b>	<b>8,850<sup>r</sup></b>	<b>10,700,000<sup>r</sup></b>	<b>10,900</b>	<b>13,200,000</b>
<b>Powder:<sup>3</sup></b>										
Belgium	77	513,000	712	860,000	29	165,000	453	1,120,000	494	901,000
China	57	53,100	618	620,000	391 <sup>r</sup>	427,000	173	153,000	94	96,800
Germany	480	822,000	639	868,000	611	753,000	611	1,020,000	1,080	1,790,000
Russia	217	283,000	263	282,000	591	572,000	21	32,500	22	29,600
Switzerland	--	--	--	--	257	275,000	--	--	--	--
United Kingdom	65	80,700	3	4,370	49	5,850	--	--	3	2,120
Other	3	3,980	--	--	-- <sup>r</sup>	-- <sup>r</sup>	--	--	1	3,000
<b>Total</b>	<b>899</b>	<b>1,760,000</b>	<b>2,240</b>	<b>2,630,000</b>	<b>1,930</b>	<b>2,200,000</b>	<b>1,260</b>	<b>2,320,000</b>	<b>1,700</b>	<b>2,820,000</b>
<b>Wrought:<sup>4</sup></b>										
Belgium	300	461,000	66	105,000	17	73,200	2	12,800	5	55,100
China	1,480	2,400,000	682	872,000	1,190	1,470,000	780	1,170,000	719	987,000
Germany	512	1,060,000	225	325,000	304	438,000	416	806,000	229	419,000
Israel	35	83,400	--	--	--	--	--	--	--	--
Romania	153	292,000	277	615,000	--	--	--	--	--	--
Russia	343	500,000	838	1,270,000	452	481,000	543	748,000	474	517,000
South Africa	26	19,200	--	--	23	19,700	--	--	23	25,300
United Kingdom	108	33,600	20	35,200	1	13,100	3	9,070	--	--
Other	3 <sup>r</sup>	6,070 <sup>r</sup>	9	10,500	27 <sup>r</sup>	12,800 <sup>r</sup>	8 <sup>r</sup>	6,620 <sup>r</sup>	2	2,840
<b>Total</b>	<b>2,960</b>	<b>4,850,000</b>	<b>2,120</b>	<b>3,230,000</b>	<b>2,020</b>	<b>2,500,000</b>	<b>1,750</b>	<b>2,750,000</b>	<b>1,450</b>	<b>2,010,000</b>

<sup>r</sup>Revised. -- Zero.

<sup>1</sup>Table includes data available through July 14, 2020. Data are rounded to no more than three significant digits; may not add to totals shown.

<sup>2</sup>Includes Harmonized Tariff Schedule of the United States (HTS) code 8112.92.6000.

<sup>3</sup>Includes HTS code 8112.92.6500.

<sup>4</sup>Includes HTS code 8112.99.1000.

Source: U.S. Census Bureau.

TABLE 3  
ANNUAL AVERAGE PRICES<sup>1</sup>

(Dollars per kilogram)

Year	Germanium metal <sup>2</sup>	Germanium dioxide <sup>3</sup>
2010	926 <sup>r</sup>	575
2011	1,539	1,218
2012	1,464	1,179
2013	1,771 <sup>r</sup>	1,309 <sup>r</sup>
2014	1,917 <sup>r</sup>	1,291
2015	1,785 <sup>r</sup>	1,207 <sup>r</sup>
2016	1,087	830
2017	1,082	731
2018	1,543	1,084
2019	1,236	913

<sup>r</sup>Revised.

<sup>1</sup>Table includes data available through July 14, 2020.

<sup>2</sup>Cost, insurance, and freight value; Europe; minimum 100-kilogram (kg) lots. For 2010–15, prices are for minimum 99.99% purity. For 2016–19, prices are for minimum 99.999% purity.

<sup>3</sup>In-warehouse, Rotterdam; minimum 100-kg lots. For 2010–15, prices are for minimum 99.99% purity. For 2016–19, prices are for minimum 99.999% purity.

Source: Argus Media group – Argus Metals International.