



# 2022 Minerals Yearbook

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## GERMANIUM [ADVANCE RELEASE]

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# GERMANIUM

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In 2022, two domestic zinc operations produced recoverable byproduct germanium. In Alaska, the Red Dog Mine, owned by Teck Resources Ltd. (Canada), produced germanium-containing zinc concentrates that were exported to Teck's metallurgical facility in Trail, British Columbia, Canada, and to processors in Asia, Europe, and Australia. In Tennessee, the Clarksville zinc smelter, owned by Nyrstar NV (Belgium), produced byproduct germanium leach concentrates. There was no primary production of germanium metal or compounds in the United States, and data on secondary production from the processing of scrap were not available.

Germanium is a hard, brittle semimetal that first was used 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 recovered initially 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 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.

## Government Actions and Legislation

As a strategic and critical material, germanium was added to the National Defense Stockpile (NDS) in 1984. The Annual Materials Plan for fiscal year 2023 (October 1, 2022, through September 30, 2023) allocated 5,000 kilograms (kg) of germanium for potential disposals and no potential acquisitions (Defense Logistics Agency Strategic Materials, 2022a, b). At yearend 2022, the NDS held 14,000 kg of uncommitted germanium metal, unchanged from stocks at yearend 2021 (table 1).

In November 2021, the Infrastructure Investment and Jobs Act was signed into law, which included \$65 billion for investment in broadband infrastructure to increase the availability and affordability of reliable high-speed internet across the United States. Most of the funds were expected to be distributed under the Broadband Equity, Access, and Deployment Program, administered by the National Telecommunications and Information Administration (NTIA), with funding prioritized for areas of the United States that lacked access to high-speed internet. In 2022, the NTIA awarded \$2.3 billion in funding, most of which was allocated to the Tribal Broadband Connectivity Program (Davidson, 2022; National Telecommunications and Information Administration, 2022).

## Production

Teck produced germanium-containing zinc concentrate at its Red Dog zinc-lead open pit mine in Alaska. A portion of the zinc concentrate produced at Red Dog was sent to Teck's metallurgical complex in Trail, British Columbia, Canada, for processing. Residues from the processing of zinc concentrate were purified to produce a range of germanium products including germanium dioxide, germanium tetrachloride, and a germanium-based PET catalyst solution. The remainder of the concentrate was sent to Asia, Europe, and Australia for processing (Teck Resources Ltd., 2023a, p. 35; 2023b). Nyrstar's Clarksville zinc smelter in Tennessee produced byproduct germanium concentrate processed from the Middle Tennessee mines zinc concentrate feedstock (Nyrstar NV, 2020a, b).

Secondary processors recovered secondary germanium metal from end-of-life products, such as decommissioned military vehicles and thermal weapon sights. Major secondary producers in the United States included 5N Plus Semiconductors LLC (St. George, UT) and Umicore Optical Materials USA (Quapaw, OK). Umicore's facility in Quapaw, OK, produced germanium tetrachloride, germanium wafers, and other germanium materials. 5N Plus's facility in St. George, UT, produced semiconductor materials, including germanium wafers (5N Plus Inc., 2023, p. 12; Umicore S.A., undated c).

## Consumption

Domestic consumption data of germanium metal (including metal content of compounds) were not available. 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), a major producer of optical fiber and cable in the

United States, announced that it planned to build a new cable manufacturing facility in Gilbert, AZ. The plant was expected to open in 2024 and serve markets in the western United States and Canada. The new facility was part of a series of investments made by Corning totaling more than \$500 million since 2020 to supply the U.S. cable market. In 2022, Corning reported a 15% increase in net sales in its optical communication business segment compared with that in 2021 owing to strong growth in fifth generation (5G) and broadband networks and cloud computing (Corning Inc., 2022; 2023, p. 28).

Prysmian Group (Italy), another major producer of optical fiber and cable in the United States, announced that it planned to invest \$30 million to expand capacity and production capability at its Jackson, TN, cable manufacturing plant. The investment was additional to an \$85 million investment the company announced in 2021 to increase its cable manufacturing capacity in North America (Prysmian Group, 2022).

**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 used in commercial, industrial, and government and military markets. Teledyne FLIR, a subsidiary of Teledyne Technologies Inc. (Thousand Oaks, CA), was a leading manufacturer of thermal imaging infrared cameras in the United States (Teledyne Technologies Inc., 2021).

**Solar Cells.**—The National Renewable Energy Laboratory (Golden, CO) and the Colorado School of Mines (Golden, CO) recently developed a more rapid process for removing III-V solar cells from their substrate during the solar cell production process. III-V solar cells were among the highest in solar efficiency (the conversion rate of solar energy to electricity), but their comparatively high cost restricted their use in many terrestrial applications. The purpose of the research was to investigate a process that could potentially decrease costs by accelerating the production process and reusing the substrate, which is typically gallium arsenide or germanium. Under the existing cell production process, separating a 6-inch cell from the substrate took between 6 and 8 hours. The new process, called spalling, took seconds without repolishing the substrate before reuse. The research used single-junction gallium arsenide solar cells grown on germanium substrates (Hicks, 2022).

**Other.**—In February, Intel Corp. (Santa Clara, CA) announced that it had signed a definitive agreement to acquire Tower Semiconductor Ltd. (Israel) for \$5.4 billion. The transaction was expected to close in 12 months. Tower Semiconductor manufactured integrated circuits in Israel, Italy, Japan, and the United States. The company specialized in advanced analog semiconductors, including those based on silicon germanium technology, for a variety of markets, including aerospace, automotive, defense, infrastructure, medical, and mobile. The acquisition would increase Intel's foundry capacity to meet the increased demand for semiconductor manufacturing capacity (Intel Corp., 2022).

## Prices

Germanium was generally sold through long-term supply contracts among consumers, producers, and traders. Argus Metals International prices were compiled through

interviews with market participants and based on estimates of representative prices in trades carried out on a particular day. On an annual average basis, the germanium metal price (minimum 99.999% germanium; cost, insurance, and freight; Europe) increased by 9% to \$1,294 per kilogram in 2022 from \$1,187 per kilogram in 2021, and the germanium dioxide price (minimum 99.999% germanium dioxide; approximately 69% germanium content; cost, insurance, and freight; Europe) increased by 8% to \$828 per kilogram in 2022 from \$770 per kilogram in 2021 (tables 1, 3). During 2022, prices for germanium dioxide and metal increased during the first 5 months of the year, reaching an annual high in mid-April. The prices remained level through mid-May and then decreased through October to the lowest point of the year. By yearend, prices recovered, but at a lower level compared with that at the start of the year.

## Foreign Trade

Based on trade data from the U.S. Census Bureau that were adjusted by the USGS to exclude low unit-value shipments, U.S. imports for consumption of germanium metal (unwrought, wrought, and powder) increased to an estimated 16,000 kg in 2022 from 13,000 kg in 2021 (tables 1, 2). Unwrought metal imports (Harmonized Tariff Schedule [HTS] code 8112.92.6000), which accounted for 91% of total germanium metal imports, increased to an estimated 15,000 kg in 2022 compared with 9,100 kg in 2021 (table 2). Belgium and China have been the main suppliers of unwrought germanium metal to the United States in recent years, accounting for more than 90% of unwrought imports annually between 2018 and 2022. Germanium powder imports (HTS code 8112.92.6500) were estimated to be 340 kg in 2022, a decrease from an estimated 1,200 kg imported in 2021. China and Germany supplied about one-half of the germanium metal powder imports in 2022. Wrought germanium metal imports (HTS code 8112.99.1000) decreased to an estimated 1,100 kg in 2022 from a revised 2,700 kg in 2021. More than 90% of these imports were sourced from China and Germany, in descending order by import quantity in 2022. Russia was previously a leading supplier of wrought germanium metal, and its share of the wrought imports total increased from about 30% in 2018 to about 50% in 2021. However, Russia only accounted for 2% and less than 0.5% of imports of wrought germanium metal and all germanium metal products, respectively, in 2022. In 2022, China, Belgium, and Germany, in descending order of quantity, accounted for 96% of all types of germanium metal imported into the United States. Germanium metal waste and scrap was imported under HTS code 8112.92.0700 (other base-metal waste and scrap not elsewhere specified or included) and could not be quantified.

The estimated germanium content of the germanium dioxide imports (HTS code 2825.60.0000, germanium oxides and zirconium dioxide) decreased to 15,000 kg in 2022 from 17,000 kg in 2021 (table 1). Belgium and Canada were estimated to account for most of the imports in 2022. Germanium tetrachloride was imported under HTS code 2827.39.9000 (other chlorides not elsewhere specified or included) and could not be quantified.

Domestic exports of germanium metal (including unwrought, powder, and wrought) and the germanium content of germanium dioxide were estimated to be 6,700 kg in 2022, based on trade data from the U.S. Census Bureau that were adjusted by the USGS, an increase from the 5,900 kg exported in 2021 (table 1).

## World Review

In 2022, sufficient data on the world production of germanium recovered from zinc concentrates, coal fly ash, and recycled material were not available to make reliable estimates (table 1). 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. Scrap was an important source 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 windows from decommissioned military vehicles or fiber-optic cables, has increased during the past decade.

The supply of germanium, a byproduct metal, was 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. The germanium concentration in zinc deposits is variable, and not all zinc mines contain germanium in high enough concentrations to make its recovery economically feasible.

**Belgium.**—In addition to its plant in Quapaw, OK, Umicore also produced germanium metal and other germanium products at its refinery and recycling plant in Olen. Umicore reported strong demand for germanium optical lenses for infrared applications but decreased demand for germanium substrates in 2022. The company also noted that germanium sourcing was subject to the risk of an increasing trend of germanium suppliers moving into downstream markets (Umicore S.A., 2023, p. 46, 141; undated c).

**Canada.**—Germanium dioxide and other germanium products, including germanium tetrachloride and a germanium-based PET catalyst solution, were produced as byproducts at a lead-zinc metallurgical complex operated by Teck in Trail, British Columbia, which included specialty metal plants that produced byproduct metals. Germanium was recovered from germanium-containing zinc concentrates produced at Teck's Red Dog zinc-lead open pit mine in Alaska. Teck reported that it had completed major planned maintenance at Trail in the fourth quarter of 2022. During the maintenance activities, Teck placed large sections of Trail's operations offline between September and December, which resulted in lower production across Trail's products in the second half of 2022. During the year, Teck also announced that it had initiated a pilot program with DLT Labs (Canada) to use blockchain technology to trace its germanium supply chain, beginning with initial production at the Red Dog Mine, through transport and refining at the Trail operations, to Teck's customer, a manufacturer of fiber-optic cable. The blockchain technology would be used to store information on the environmental, governance, and social practices along the supply chain, including greenhouse gas emissions, product certifications, and responsible production assessments (Teck Resources Ltd., 2022; 2023a, p. 37; 2023b).

**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. The two significant germanium-containing coal deposits in China were the Lincang lignite deposit in Yunnan Province and the Wulantuga lignite deposit in Inner Mongolia Autonomous Region. China's exports of germanium metal (including export codes 8112.92.10 and 8112.99.10) increased to 43,700 kg in 2022 from 42,300 kg in 2021. Exports were 29,000 kg in 2020 and 22,900 kg in 2019. In 2022, 95% of China's germanium exports were sent to Hong Kong (31%), Germany (22%), Russia (14%), Japan (11%), the United States (10%), and Belgium (8%) (Liu and others, 2021; Zen Innovations AG, 2023).

Yunnan Chihong Zinc and Germanium Co. Ltd., China's leading producer of germanium, reported that it produced 55,900 kg of germanium in germanium products in 2022, 20% more than production in 2021, and had the capacity to produce 60,000 kilograms per year (kg/yr) of germanium contained in germanium products. The company owned polymetallic mines that contained recoverable amounts of germanium, including the Huize and Yiliang lead-zinc-silver mines in Yunnan Province, and produced several germanium products, including germanium lenses, germanium tetrachloride, and monocrystalline germanium wafers, through several subsidiaries. In June, Yunnan Chihong reported that it began producing optical-fiber-grade germanium tetrachloride; annual output was projected to be 30,000 kg. The company announced that it planned to continue to focus on its expansion into producing downstream germanium products for the infrared and fiber-optics markets (Yunnan Chihong Zinc and Germanium Co. Ltd., 2023, p. 8, 15, 17). Yunnan Lincang Xinyuan Germanium Industry Co. Ltd. was another major producer of germanium in China. In 2022, the company reported a production capacity of 47,600 kg/yr of germanium ingot and production of 31,200 kg of germanium products. The company also produced germanium lenses, germanium tetrachloride, and monocrystalline germanium wafers (Yunnan Lincang Xinyuan Germanium Industry Co. Ltd., 2023, p. 11, 14).

**Congo (Kinshasa).**—In February, Ivanhoe Mines Ltd. (Canada) announced that Kipushi Holding Ltd. (a wholly owned subsidiary of Ivanhoe Mines) and state-owned La Générale des Carrières et des Mines SARL (Gécamines) signed a new agreement to reopen the Kipushi zinc-copper mine in Haut-Katanga Province. The mine, which had been on care-and-maintenance status since 1993, was a past producer of byproduct germanium. Ivanhoe Mines held a 68% share in the Kipushi project, and Gécamines owned the remaining 32% share. The company also announced the results of a feasibility study on Kipushi that evaluated the mine's existing underground infrastructure and the construction of a new mill capable of processing 800,000 metric tons per year (t/yr) of ore to produce about 240,000 t/yr of zinc in concentrate. Mine life was projected to be 14 years, based on current resource estimates, and preproduction capital costs were estimated to be \$382 million. The company began construction of the processing plant in September 2022 with production targeted to begin in the third quarter of 2024 (Ivanhoe Mines Ltd., 2023, p. 8, 16, 67, 75, 83).



**Russia.**—Germanium and Applications Ltd. recovered germanium from coal fly ash produced at the Spetsugli Mine within 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 kg/yr of germanium, and its facilities in Moscow and Novomoskovsk could produce germanium blanks for optical use, germanium oxide and metal, 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 compounds, finished products, and metal. 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 Germanium exported more than 80% of the germanium that it produced (JSC Germanium, 2016).

## 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. 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 growth. However, an increase in the substitution of specialty glass for pure germanium lenses in infrared applications will continue to be attractive to commercial and industrial markets. LightPath Technologies Inc. (Orlando, FL) was a domestic commercial producer of germanium-free chalcogenide glass, which could be used as the optical lens material in thermal imaging devices (LightPath Technologies Inc., 2022, p. 8). An emerging use for germanium is in the production of vertical-cavity surface-emitting lasers (VCSELs). VCSELs are a component in three-dimensional sensors used in a variety of applications, including autonomous vehicles, facial recognition systems, and Light Detection and Ranging (LiDAR). Although most VCSELs are currently grown on gallium arsenide substrates, germanium substrates may be more suitable for higher volume production of VCSELs as it has certain beneficial mechanical properties compared with gallium arsenide (Umicore S.A., undated a, b).

On the supply side, 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.

## References Cited

- 5N Plus Inc., 2023, Annual information form for the fiscal year ended December 31, 2022: Montreal, Quebec, Canada, 5N Plus Inc., February 21, 24 p. (Accessed May 17, 2023, at [https://www.5nplus.com/files/15/5N%20Plus%20Inc.%20-%20AIF%20-%20FY2022\\_2023-02-21-18-01.pdf](https://www.5nplus.com/files/15/5N%20Plus%20Inc.%20-%20AIF%20-%20FY2022_2023-02-21-18-01.pdf).)
- Corning Inc., 2022, Corning announces new cable manufacturing facility in Gilbert: Corning, NY, Corning Inc. news release, August 30. (Accessed August 30, 2022, at <https://www.azcommerce.com/news-events/news/2022/8/corning-announces-new-cable-manufacturing-facility-in-gilbert/#:~:text=Corning%20will%20build%20a%20new%20cable%20manufacturing%20facility,growing%20demand%20in%20the%20western%20U.S.%20and%20Canada.>)
- Corning Inc., 2023, Form 10-K—2022: Washington, DC, U.S. Securities and Exchange Commission, 106 p. (Accessed February 13, 2022, via <https://investor.corning.com/investor-relations/financials/sec-filings/default.aspx>.)
- Davidson, Alan, 2022, 2022—A year of big moves for NTIA: Washington, DC, National Telecommunications and Information Administration, December 23. (Accessed May 17, 2023, at <https://www.internetforall.gov/blog/2022-year-big-moves-ntia>.)
- Defense Logistics Agency Strategic Materials, 2022a Annual Materials Plan for FY 2023 (potential acquisitions): Fort Belvoir, VA, Defense Logistics Agency Strategic Materials announcement DLA-SM-23-3220, October 4, 1 p. (Accessed October 4, 2022, via <http://www.dla.mil/HQ/Acquisition/StrategicMaterials/Announcements.aspx>.)
- Defense Logistics Agency Strategic Materials, 2022b, Annual Materials Plan for FY 2023 (potential disposals\*): Fort Belvoir, VA, Defense Logistics Agency Strategic Materials announcement DLA-SM-23-3219, October 4, 1 p. (Accessed October 4, 2022, via <http://www.dla.mil/HQ/Acquisition/StrategicMaterials/Announcements.aspx>.)
- Germanium and Applications Ltd., 2018, Company profile: Moscow, Russia, Germanium and Applications Ltd. (Accessed December 12, 2018, at <http://www.geapplic.ru/en/company/profile/>.)
- Hicks, Wayne, 2022, NREL, Mines researchers show advances in development of III-V solar cells for use on earth: Golden, CO, National Renewable Energy Laboratory news release, October 27. (Accessed October 27, 2022, at <https://www.nrel.gov/news/program/2022/nrel-mines-researchers-show-advances-in-development-of-iii-v-solar-cells-for-use-on-earth.html>.)
- Intel Corp., 2022, Intel to acquire Tower Semiconductor for \$5.4 billion: Santa Clara, CA, Intel Corp. news release, February 15. (Accessed February 15, 2022, at <https://www.intel.com/content/www/us/en/newsroom/news/feb-2022-corporate-news.html>.)
- Ivanhoe Mines Ltd., 2023, Annual information form for the year ended December 31, 2022: Vancouver, British Columbia, Canada, Ivanhoe Mines Ltd., March 23, 157 p. (Accessed March 31, 2023, at [https://ivanhoemines.com/site/assets/files/5780/2023-03\\_-\\_ivn\\_aif\\_2022\\_v10\\_final.pdf](https://ivanhoemines.com/site/assets/files/5780/2023-03_-_ivn_aif_2022_v10_final.pdf).)
- JSC Germanium, 2016, About enterprise: Krasnoyarsk, Russia, JSC Germanium website. (Accessed December 12, 2018, at <http://eng.krasgermanium.com/about-company/about-enterprise>.)
- LightPath Technologies Inc., 2022, Form 10-K—For the fiscal year ended June 30, 2022: Washington, DC, U.S. Securities and Exchange Commission, 43 p. (Accessed April 28, 2023, at <https://app.quotemedia.com/data/downloadFiling?webmasterId=102691&ref=116949148&type=PDF&symbol=LPTH&companyName=LightPath+Technologies+Inc.&formType=10-K&formDescription=Annual+report+pursuant+to+Section+13+or+15%28d%29&dateFiled=2022-09-15>.)
- Liu, Jingjing, Spiro, B.F., Dai, Shifeng, French, David, Graham, I.T., Wang, Xibo, Zhao, Lei, Zhao, Jingtao, and Zeng, Rognshu, 2021, Strontium isotopes in high- and low-Ge coals from the Shengli Coalfield, Inner Mongolia, northern China—New indicators for Ge source: International Journal of Coal Geology, v. 233, January 1, 11 p.

- National Telecommunications and Information Administration, 2022, Grants: Washington, DC, National Telecommunications and Information Administration. (Accessed July 1, 2022, at <https://ntia.gov/category/grants/>.)
- Nyrstar NV, 2020a, Clarksville smelter: Balen, Belgium, Nyrstar NV, December, 2 p. (Accessed July 20, 2021, at <https://www.nyrstar.com/cdn/96ce453c-621f-42b4-b0fb-15f6eb3ee52a/2020-fact-sheet-clarksville.pdf>.)
- Nyrstar NV, 2020b, Middle Tennessee mines: Balen, Belgium, Nyrstar NV, December, 2 p. (Accessed September 13, 2021, at <https://www.nyrstar.com/cdn/ffe9e139-5aab-4193-afe0-71ab97dd66c2/2020-fact-sheet-middle-tennessee.pdf>.)
- Prysmian Group, 2022, New investments adding optical cable capacity and capability in Jackson, TN cable plant: Milan, Italy, Prysmian Group news release, May 16. (Accessed May 16, 2022, at <https://www.prysmiangroup.com/en/media/press-releases/new-investments-adding-optical-cable-capacity-and-capability-in-jackson-tn-cable-plant>.)
- Teck Resources Ltd., 2022, Teck and DLT partner to pilot traceability for critical minerals with blockchain: Vancouver, British Columbia, Canada, Teck Resources Ltd. news release, January 20, 2 p. (Accessed January 20, 2022, at <https://www.teck.com/media/22-4-TR.pdf>.)
- Teck Resources Ltd., 2023a, 2022 annual information form: Vancouver, British Columbia, Canada, Teck Resources Ltd., February 21, 106 p. (Accessed February 23, 2023, at <https://www.teck.com/media/2023-AIF.pdf>.)
- Teck Resources Ltd., 2023b, Specialty metals—Germanium: Vancouver, British Columbia, Canada, Teck Resources Ltd. (Accessed June 23, 2023, at <https://www.teck.com/products/other-metals/germanium>.)
- Teledyne Technologies Inc., 2021, Teledyne completes acquisition of FLIR: Thousand Oaks, CA, Teledyne Technologies Inc. news release, May 14. (Accessed May 14, 2021, at <https://www.teledyne.com/en-us/news/Pages/teledyne-completes-acquisition-of-flir.aspx>.)
- Umicore S.A., 2023, Integrated annual report 2022: Brussels, Belgium, Umicore S.A., 288 p. (Accessed April 27, 2023, at <https://annualreport.umicore.com/en/2022>.)
- Umicore S.A., [undated]a, Germanium for VCSEL applications: Brussels, Belgium, Umicore S.A. (Accessed June 30, 2023, at <https://eom.umicore.com/en/germanium-solutions/markets/vcsels/>.)
- Umicore S.A., [undated]b, Germanium has a role in the exciting future of VCSEL-based 3D sensing applications: Brussels, Belgium, Umicore S.A. (Accessed June 30, 2023, at <https://eom.umicore.com/en/media/news/germanium-has-a-role-in-the-exciting-future-of-vcsel-based-3d-sensing-applications/>.)
- Umicore S.A., [undated]c, Germanium products: Brussels, Belgium, Umicore S.A. (Accessed September 1, 2021, at <https://eom.umicore.com/en/germanium-solutions/products>.)
- Yunnan Chihong Zinc and Germanium Co. Ltd., 2023, 2022 annual report: Qujing, Yunnan Province, China, Yunnan Chihong Zinc and Germanium Co. Ltd., 218 p. (Accessed June 30, 2023, via <https://www.capitaliq.spglobal.com/>.)
- Yunnan Lincang Xinyuan Germanium Industry Co. Ltd., 2023, 2022 annual report: Kunming, Yunnan Province, China, Yunnan Lincang Xinyuan Germanium Industry Co. Ltd., 190 p. (Accessed August 14, 2023, via <https://www.capitaliq.spglobal.com/>.)
- Zen Innovations AG, 2023, Global trade tracker: Bern-Kehrsatz, Switzerland, Zen Innovations AG database. (Accessed April 27, 2023, via <https://www.globaltradetracker.com>.)

## GENERAL SOURCES OF INFORMATION

### U.S. Geological Survey Publications

- Germanium. Ch. in Mineral Commodity Summaries, annual.
- Germanium and Indium. Ch. in Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply, Professional Paper 1802, 2017.
- Germanium (Ge). Ch. in Metal Prices in the United States Through 2010, Scientific Investigations Report 2012–5188, 2013.
- Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.
- Mineral Commodity Profiles—Germanium. Open-File Report 2004–1218, 2004.

### Other

- Defense Logistics Agency Strategic Materials.
- Germanium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

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

(Kilograms, unless otherwise specified)

	2018	2019	2020	2021	2022
United States:					
Refinery production	NA	NA	NA	NA	NA
Imports for consumption: <sup>e</sup>					
Germanium metal <sup>2</sup>	10,000	14,000	14,000	13,000	16,000
Germanium dioxide, Ge content <sup>3</sup>	12,000	21,000	11,000 <sup>r</sup>	17,000	15,000
Exports, germanium metal and dioxide, Ge content <sup>e,4</sup>	3,600	4,500	4,800	5,900 <sup>r</sup>	6,700
Consumption, Ge content <sup>e,5</sup>	30,000	30,000	30,000	30,000	NA
Price, average: <sup>6</sup>					
Germanium metal dollars per kilogram	1,543	1,236	1,046	1,187	1,294
Germanium dioxide do.	1,084	913	724	770	828
Stocks, December 31, U.S. Government <sup>7</sup>	14,000	14,000	14,000	14,000	14,000
World, refinery production: <sup>e</sup>					
China	94,900	85,700	95,000	NA	NA
Russia	5,000	5,000	5,000	NA	NA
Other <sup>8</sup>	30,000	40,000	40,000	NA	NA
Total	130,000	131,000	140,000	NA	NA

<sup>e</sup>Estimated. <sup>r</sup>Revised. do. Ditto. NA Not available.

<sup>1</sup>Table includes data available through April 18, 2023. Data are rounded to no more than two 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. Data have been adjusted to exclude low-value shipments.

<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 content of metal and germanium dioxide.

<sup>6</sup>Source: Argus Media group – Argus Metals International. Prices are for minimum 99.999% purity, Europe.

<sup>7</sup>Source: Defense Logistics Agency Strategic Materials. Data are uncommitted germanium metal only.

<sup>8</sup>Includes Belgium, Canada, Germany, and other countries or localities. Excludes U.S. production.



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

(Kilograms, unless otherwise specified)

Country or locality	2018		2019		2020		2021		2022	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Unwrought: <sup>2</sup>										
Belgium	2,300	\$3,800,000	2,900	\$5,000,000	4,200	\$5,700,000	3,100	\$4,600,000 <sup>r</sup>	4,100	\$7,000,000
Brazil	--	--	--	--	--	--	--	--	63	67,000
Canada	--	--	--	--	10	10,000	4	4,800	24	31,000
China	5,200	6,300,000	7,700	8,000,000	6,400	5,900,000 <sup>r</sup>	5,200	5,400,000	10,000	12,000,000
Germany	63	110,000	37	85,000	6	10,000	4	44,000	110	110,000
Estonia	--	--	--	--	--	--	--	--	330	240,000
Russia	28	41,000	50	50,000	49	45,000	560	600,000	18	20,000
United Kingdom	25	19,000	10	5,300	64	34,000	210	110,000	--	--
Other	14	58,000	38	87,000	27 <sup>r</sup>	19,000 <sup>r</sup>	52 <sup>r</sup>	82,000 <sup>r</sup>	7	25,000
Total	7,600	10,000,000	11,000	13,000,000	11,000	12,000,000	9,100	11,000,000	15,000	20,000,000
Powder: <sup>3</sup>										
Belgium	450	1,100,000	380	840,000	200	1,400,000	260	980,000	29	120,000
Canada	--	--	--	--	--	--	--	--	49	46,000
China	91	130,000	82 <sup>r</sup>	74,000 <sup>r</sup>	70 <sup>r</sup>	110,000 <sup>r</sup>	2	3,500	100	99,000
Germany	520	980,000	1,100	1,800,000	980	1,400,000	870	1,300,000	80	150,000
Russia	21	33,000	22	30,000	37	47,000	16	25,000	--	--
United Kingdom	--	--	3	2,100	78	51,000	--	--	36	50,000
Other	--	--	1 <sup>r</sup>	3,000 <sup>r</sup>	-- <sup>r</sup>	-- <sup>r</sup>	100 <sup>r</sup>	110,000 <sup>r</sup>	46	56,000
Total	1,100	2,300,000	1,600	2,700,000	1,400	3,000,000	1,200 <sup>r</sup>	2,500,000	340	520,000
Wrought: <sup>4</sup>										
Belgium	2	13,000	5	55,000	110	270,000	150	310,000	32	37,000
China	730	1,200,000	630	930,000	850 <sup>r</sup>	1,100,000 <sup>r</sup>	1,000	1,300,000	540	710,000
Germany	420	810,000	230	420,000	330	470,000	220	430,000	430	730,000
Russia	540	750,000	470	520,000	780	750,000	1,300 <sup>r</sup>	1,300,000 <sup>r</sup>	22	37,000
United Kingdom	3	9,100	--	--	5	12,000	--	--	46	150,000
Other	3 <sup>r</sup>	4,500 <sup>r</sup>	25	28,000	2 <sup>r</sup>	4,200 <sup>r</sup>	6	21,000	1	5,500
Total	1,700	2,700,000	1,400	1,900,000	2,100	2,600,000 <sup>r</sup>	2,700 <sup>r</sup>	3,400,000 <sup>r</sup>	1,100	1,700,000

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

<sup>1</sup>Table includes data available through April 18, 2023. Data are rounded to no more than two significant digits; may not add to totals shown. Data have been adjusted to exclude low-value shipments.

<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>
2013	1,770 <sup>r</sup>	1,310 <sup>r</sup>
2014	1,918 <sup>r</sup>	1,291
2015	1,792 <sup>r</sup>	1,211 <sup>r</sup>
2016	1,087	830
2017	1,082	731
2018	1,543	1,084
2019	1,236	913
2020	1,046	724
2021	1,187	770
2022	1,294	828

<sup>1</sup>Revised.

<sup>1</sup>Table includes data available through April 18, 2023.

<sup>2</sup>Cost, insurance, and freight value; Europe; minimum 100-kilogram (kg) lots. For 2013–17, prices are for minimum 99.99% purity. For 2018–22, prices are for minimum 99.999% purity.

<sup>3</sup>In-warehouse, Rotterdam; minimum 100-kg lots. As of September 2021, prices were cost, insurance, and freight value; Europe. For 2013–17, prices are for minimum 99.99% purity. For 2018–22, prices are for minimum 99.999% purity.

Source: Argus Media group – Argus Metals International.