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# 2008 Minerals Yearbook

## SELENIUM AND TELLURIUM

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# Selenium and Tellurium

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In 2008, the price for tellurium increased as consumption of the metal increased, and the price of selenium decreased slightly as consumption declined. One copper refinery in Texas reported domestic production of primary refined selenium and tellurium. Domestic production of selenium and tellurium increased in 2008 as did estimates of global production.

Selenium and tellurium, rare elements widely distributed within the Earth's crust, do not occur in concentrations high enough to justify mining solely for their content. They were recovered as byproducts of nonferrous metal mining, mostly from the anode slimes associated with electrolytic refining of copper. Selenium and tellurium were also recovered as byproducts from gold, lead, nickel, platinum, and zinc mining.

In a 2006 survey of 56 worldwide electrolytic copper refiners, 52 and 45 plants, respectively, reported selenium and tellurium in their anode slimes. The selenium-containing slimes averaged 7% selenium by weight, with a few containing as much as 25% selenium. Tellurium concentrations were generally lower and averaged 2% (Moats and others, 2007, p. 202–241).

Selenium and tellurium can also be recovered economically from industrial scrap and chemical process residues. Obsolete and damaged photoreceptor drums from plain paper copy machines were shipped by manufacturers to refineries for recovery of selenium and tellurium metal. The supply of old drums, however, has declined in recent years and now appears to be nearly exhausted.

## Production

Asarco LLC's (Tucson, AZ) copper refinery in Amarillo, TX, was the only U.S. producer of refined selenium and tellurium. One copper refinery produced and exported semirefined material containing 90% selenium plus tellurium for toll-refining in Asia. Two other refineries generated selenium- and tellurium-containing slimes that were exported for processing. Most of the selenium and tellurium contained in domestic anodes and slimes came from copper ores in Arizona and Utah. One refinery processed anodes imported from Canada. Domestic production of selenium and tellurium increased in 2008 compared with that of 2007.

Asarco has operated under bankruptcy protection since August 2005. Grupo Mexico S.A.B. de C.V. (parent company of Asarco) lost control of the Asarco refinery to an independent board that was established during bankruptcy proceedings. On October 22, 2008, Asarco terminated a purchase contract with Sterlite Industries (India) Ltd. (Mumbai, India), which had agreed to purchase Asarco's operating assets for $2.6 billion (Asarco LLC, 2008).

With the increase in price and projected increases in consumption of tellurium, exploration for new sources for tellurium increased. The new projects, which were in early stages of exploration, were gold-telluride deposits in Western States.

## Consumption

***Selenium.***—In 2008, world consumption of selenium was estimated to be lower than that in 2007 owing to decreases in consumption by the electrolytic manganese metal, chemical, and agriculture industries in China. The estimated global consumption of selenium by application was glass manufacturing, 40%; metallurgy, 25%; agriculture, 15%; chemicals and pigments, 10%; and electronics, 10%.

The global glass manufacturing industry was the leading consumer of selenium in 2008; however, the level of consumption remained relatively unchanged. Selenium was used to decolorize the green tint caused by iron impurities in glass containers and other soda-lime silica glass. It was also used as a colorant in art and other glass, such as that used in traffic lights, and in architectural plate glass to reduce solar heat transmission through the glass.

In 2008, demand for selenium by electrolytic manganese metal producers in China decreased compared with that in 2007 owing to the decreased consumption in aluminum alloy and stainless steel producers for which electrolytic manganese metal was used. In China, selenium dioxide ($SeO_2$) was substituted for sulfur dioxide to increase yields in the electrolytic production of electrolytic manganese metal. By using $SeO_2$ instead of sulfur dioxide, plants can reduce the power required to operate electrolytic cells. This method requires about 2 kilograms (kg) of $SeO_2$ per metric ton of electrolytic manganese metal produced (Selenium-Tellurium Development Association, 2002; TEX Report, The, 2009).

Metallurgical-grade selenium was used as an additive to cast iron, copper, lead, and steel alloys to improve machinability and casting and forming properties. Selenium was used as an alloy with bismuth to substitute for lead in plumbing fixtures in response to requirements of the Safe Drinking Water Act Amendments of 1996 (Public Law 104–182) to reduce lead in potable water supplies. With increased attention on the dangers of lead exposure, more restrictive legislation has been introduced. The addition of a small amount, about 0.02% by weight, of selenium to low-antimony lead alloys used in the support grid of lead-acid batteries improves the casting and mechanical properties of the alloy.

Selenium, an essential micronutrient for animal and human health, was added to fertilizer used to grow crops for animal and human consumption. This practice was more common outside the United States, especially in countries with selenium-poor soils, such as Australia and China.

Chemical and pigment uses of selenium include industrial and pharmaceutical applications. Selenium's principal pharmaceutical use was in shampoo to control dandruff and dermatitis and as an antifungal agent. Cadmium sulfoselenide compounds were used as pigments in ceramics, glazes, paints, and plastics, but because of the relatively high cost and the toxicity of cadmium-based pigments, their use was generally restricted to applications where they are uniquely suited. Additionally, selenium was used in catalysts to enhance selective oxidation in plating solutions to improve appearance and durability, in blasting caps and gun bluing, in coating digital x-ray detectors, and in zinc selenide for infrared windows in carbon dioxide lasers.

Conventional silicon-based cells were the dominant photovoltaic (PV) technology, accounting for 86% of the global total PV market. Although thin-film PV cells made up less than 14% of the PV market, production continued to increase in 2008. There were three major types of thin-film PV cells—amorphous silicon and thin-silicon, cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS). Amorphous silicon and thin silicon accounted for 53% of current thin film PV cells with estimated annual production of 494 megawatts (MW); CdTe accounted for 26% with annual estimated production of 358 MW; and CIGS accounted for 16% with annual production of 159 MW. Although they are more efficient, conventional silicon-based solar cells were more costly to produce and can only be constructed in a sterile and vacuum-sealed room. Several companies announced plans to expand production of nonsilicon-based solar cells within the next several years. It was estimated the CIGS production will reach almost 1 gigawatt (GW) by 2010 and 2.5 GW by 2012. Recent advancements in CIGS thin films have reduced production costs and improved performance as well as having reduced the environmental impact of production. In 2008, there were more than 40 companies involved in the development of CIGS products; many have delayed production owing to manufacturing issues because the materials do not chemically interact well with each other. In testing, CIGS solar cells have reached efficiencies of 19.9% and used 0.01% of the material contained in crystalline silicon-based solar cells. It was estimated the composition of CIGS were 10% copper, 28% indium, 10% gallium, and 52% selenium. In 2008, the CIGS industry consumed 9 metric tons (t) of selenium to produce 159 MW of CIGS solar cells (Kanellos, 2008; Kho, 2008; Ullal, 2008; Metal Bulletin, 2009; Metal-Pages Ltd., 2009c, d).

***Tellurium.***—World demand for tellurium was estimated to have increased in 2008. The leading use for tellurium was as a metallurgical alloying element. Tellurium was used in steel as a free-machining additive, in copper to improve machinability while not reducing conductivity, in lead to improve resistance to vibration and fatigue, in cast iron to help control the depth of chill, and in malleable iron as a carbide stabilizer. Owing to record-high prices, many steel and nonferrous metals producers have reduced consumption and found substitutes for tellurium.

Consumption in chemical, catalysts, and other uses, the next largest end-use category, declined owing to the increase in price. Tellurium was used as a vulcanizing agent and as an accelerator in the processing of rubber and in catalysts for synthetic fiber production. Other applications include the use of tellurium in blasting caps and as a pigment to produce blue and brown colors in ceramics and glass.

High-purity tellurium is used in electronics applications, such as thermal imaging, thermoelectric, phase change memory, and photoelectric devices. Consumption of tellurium in these applications was estimated to have increased more than the combined reductions in other end uses in 2008.

Mercury-cadmium-telluride is used in thermal imaging devices to convert the raw image into a crisp picture on the screen, for infrared sensors, and for heat-seeking missiles.

Semiconducting bismuth telluride is used in thermoelectric cooling devices employed in electronics and consumer products. These devices consist of a series of couples of semiconducting materials which, when connected to a direct current, cause one side of the thermo element to cool while the other side heats. Thermoelectric coolers were most commonly used in electronics and military applications, such as the cooling of infrared detectors, integrated circuits, laser diodes, and medical instrumentation. Their application in consumer products, such as portable food-and-beverage coolers or automobile car seat cooling systems, continued to increase early in 2008. However, with the global economic downturn in late 2008, tellurium consumption in thermoelectric consumer goods decreased.

In 2008, the CdTe thin film PV cell industry increased investments and capacity. First Solar Inc. (Phoenix, AZ), the global leader in CdTe production with plants in Germany and Ohio, planned to commission a new plant in Malaysia in phases beginning in 2009. In 2008, estimated annual global production was 358 MW of which First Solar had 308 MW. 5N Plus (Saint-Laurent, Quebec, Canada), the primary supplier of cadmium and tellurium to First Solar, consumed 100 t of tellurium in 2008 to create cadmium telluride material, about 78% of which was sold to First Solar. Other manufacturers that were starting to produce were AVA Solar, Inc. (Fort Collins, CO), Calyxo GmbH (Bitterfeld-Wolfen, Germany), and PrimeStar Solar Inc. (Arvada, CO) (Kho, 2008; Ullal, 2008; Metal-Pages Ltd., 2009a).

## Prices

The Platts Metals Week average New York dealer price for selenium was $32.29 per pound in 2008 and was slightly lower than the annual average price in 2007. The price rose sharply during the first 2 months of the year, reached a high in late March, and averaged more than $40 per pound in the last 2 weeks of March and the first week of April. Though volatile on average, the price trended downward for the rest of 2008 to an annual low of $23 per pound by yearend. The price volatility and decline was attributed to fluctuating but overall lower demand from electrolytic manganese metal producers in China.

The United Kingdom price for lump and powder, 99.95% tellurium, as published in Mining Journal, started 2008 at $115 to $135 per kilogram. The price increased to an alltime high of $240 to $290 per kilogram in late April and early May, based on speculation that the increased investment and investigations in CdTe cell technologies would create a tellurium shortage. The price trended downward, dropping to a range of $240 to $275 per kilogram in late May, $200 to $230 per kilogram in

September, and \$160 to \$190 per kilogram in October, where it remained until yearend.

### Foreign Trade

Exports of selenium materials in 2008 decreased by 3% compared with those of 2007. In descending order, Australia, China, Germany, the Republic of Korea, Hong Kong, Sweden, the Netherlands, and Chile accounted for 88% of selenium exports in 2008 (table 2).

In 2008, imports of selenium ($SeO_2$ and selenium unwrought and waste and scrap) decreased by 5% to 519 t, compared with 2007 imports (table 3). Belgium, Germany, Canada, the United Kingdom, the Philippines, Mexico, and Japan, in descending order, accounted for 95% of the imports of selenium metal and $SeO_2$ into the United States in 2008.

Imports of unwrought tellurium and tellurium waste and scrap increased by 133% in 2008 compared with those in 2007. The leading suppliers, in descending order, China, Canada, Belgium, Russia, and Peru accounted for more than 95% of the total imports of tellurium metal into the United States (table 5). In 2008, tellurium exports rose to 50 t, a 230% increase from 15 t in 2007. The main destinations, in descending order, were China, Canada, India, Malaysia, and Hong Kong; theses accounted for 92% of total tellurium exports (table 4).

### World Review

Global selenium and tellurium output cannot be easily determined because not all companies report production and because trade in scrap and semirefined products may be included in selenium trade data.

In 2008, refinery production of selenium from a select few countries decreased slightly to 1,510 t (table 6). Total world production of selenium and tellurium has been estimated to be 3,000 to 3,500 metric tons per year (t/yr) and 450 to 500 t/yr, respectively. Based on global copper refinery data (Moats and others, 2007, p. 202–241), the U.S. Geological Survey estimated that copper anode slimes will probably generate 4,600 t/yr and 1,200 t/yr of selenium and tellurium, respectively.

***Canada.***—In 2008, the Government of Canada estimated selenium production to be 156 t, up 8% compared with that of 2007. Tellurium production in Canada was 19 t, up 36% from that of 2007 (Natural Resources Canada, 2009).

***China.***—In 2008, China was the leading consumer and a major producer of selenium. Although a major producer, China still depended on imports for most of its selenium needs and imported 1,360 t of a wide range of selenium products in 2008, a 23% decrease compared with 2007 imports. The major import sources were, in descending order, Japan (19%), the Republic of Korea (16%), Belgium (11%), Kazakhstan (10%), and Australia (7%). The decrease was because of a decline in production of electrolytic manganese metal. After the electrolytic manganese metal industry, the leading uses of selenium in China were, in descending order, glassmaking, pigments, ceramics, and chemicals (Metal-Pages Ltd., 2009b).

Apollo Solar Energy, Inc. (Chengdu, Sichuan Province) completed the first phase of construction of its solar PV industry park. Apollo Solar also owned the Dashuigou and Majiagou Mines, the only primary tellurium projects in the world (Apollo Solar Energy, Inc., 2009, p. 1–5).

***Japan.***—The major producers of selenium and tellurium were Mitsubishi Materials Corp.; Mitsui Metal Mining and Smelting Co., Ltd.; Nikko Metals Co., Ltd.; Nippon Rare Metals, Inc.; Shinko Kagaku Kogyo Co., Ltd.; and Sumitomo Metal Mining Co., Ltd. In 2008, selenium production was estimated to be 754 t, a decrease of 6% compared with that of 2007. Japanese primary production of tellurium was as a byproduct of copper refining, and the majority was consumed in the Japanese steel industry. In 2007, tellurium production was 41 t of which 40 t was consumed as a substitute for lead in free-cutting steel following the implementation of the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2008 (RoHS). Secondary tellurium production, which had been exclusively from the recycling of photocopier drums, ceased, and stocks of tellurium scrap were depleted. In 2008, stocks of selenium increased by 33% compared with the level in 2007 to 160 t (Roskill's Letters from Japan, 2008; 2009).

***Mexico.***—In 2008, Southern Copper Corp. (Phoenix, AZ) produced 47,300 kg of selenium, 39% more than that in 2007, at the La Caridad precious metal plant in the State of Sonora (Southern Copper Corp., 2009).

Mexivada Mining Corp. (Vancouver, British Columbia, Canada) staked two exploration concessions near Moctezuma, Sonora. The La Viuda and La Vidua 1 were adjacent to the La Bambolla tellurium-gold mine, which was under construction by a European mining company. The area has abandoned mines that had high grades of tellurium, and mine dumps also contain visible native tellurium (Mexivada Mining Corp., 2008).

***Peru.***—Southern Copper produced selenium at its Ilo refinery in the southern part of Peru. In 2008, selenium production was 44,200 kg, up 25% compared with that of 2007 (Southern Copper Corp., 2009).

***Poland.***—Copper producer KGHM Polska Miedź S.A. (Lubin) reported producing 82 t of selenium in 2008, a 4% decrease from that of 2007. Selenium was produced at its precious metal plant at the Glogów smelter from anode slimes generated at its Glogów and Legnica copper refineries (KGHM Polska Miedź S.A., 2009).

***Sweden.***—Gold-Ore Resources Ltd. (Vancouver, British Columbia, Canada) announced positive metallurgical test results for recovery of bismuth and tellurium from gold concentrates from its Bjorkdal gold mine 750 kilometers north of Stockholm. The gold mine produced gold concentrates with high levels of bismuth and tellurium and has had to pay penalties to the refiners for exceeding acceptable impurity levels. SGS Minerals Services (Lakefield, Ontario, Canada) developed an acid leach process that recovered 70% of the bismuth and tellurium. Gold-Ore Resources hoped that further research would lead to improved recoveries and marketable bismuth and tellurium byproducts (Gold-Ore Resources Ltd., 2009).

### Outlook

The supply of selenium and tellurium are directly affected by the production of the principal product from which it is derived, copper, and to a lesser extent, by the production of gold, lead, nickel, or zinc produced from sulfide ores. Since global production of selenium- and tellurium-bearing copper ore was expected to increase in 2009, global selenium and tellurium production from copper refiners will probably also increase. Increased recovery rates at copper refiners, investments in gold-tellurium deposits, and other sources of tellurium could lead to a further growth in supply. Although increased environmental regulation and prices have encouraged the recycling of electronic scrap, recycling has been declining during the past several years owing to the reduction in available scrap selenium- and tellurium-based copier drums. The main primary source is still anode slimes from copper refining. Since selenium and tellurium prices do not influence copper production, an increase in selenium or tellurium demand is not likely to result in a significant increase in the production of copper and its byproducts. However, many companies that are currently producing slimes or other process streams that contain selenium, tellurium, and other metals and are not fully recovering selenium and tellurium are expected to invest in byproduct recovery. There have been investigations into recovering more tellurium from gold-telluride deposits.

Demand from China for selenium is expected to increase owing to increased demand for agriculture and from the electrolytic manganese metal industry. Global demand for selenium from glass and solar cell manufacturers will probably increase as there are few substitutes in glass manufacturing, and the expansion of solar cell production is expected to continue.

In 2009, tellurium consumption is expected to increase, chiefly from increased electronics and solar cell production. As the technologies for these uses, especially solar cells and thermoelectronics, continue to advance, manufacturers likely will find ways to reduce consumption through efficiency, recycling, and thrifting. Consumption for metallurgical alloying and chemicals was expected to decrease as the cost of tellurium continues to rise; producers of low-value products will find substitutes.

### References Cited


Apollo Solar Energy, Inc., 2009, Form 10–K—2008: Securities and Exchange Commission, 140 p.

Asarco LLC, 2008, Asarco terminates purchase contract with Sterlite: Tucson, AZ, ASARCO LLC news release, October 22, 1 p.

Gold-Ore Resources Ltd., 2009, Gold-Ore announces positive tellurium metallurgical studies: Vancouver, British Columbia, Canada, Gold-Ore Resources Ltd. news release, January 7, 2 p.

Kanellos, Michael, 2008, How the CIGS explosion will play out: Greentech Media, September 3. (Accessed September 10, 2008, at http://www.greentechmedia.com/articles/how-the-cigs-explosion-will-play-out-1351.html.)

Kho, Jennifer, 2008, Thin-film solar has bright future: Greentech Media, May 29. (Accessed June 2, 2008, at http://www.greentechmedia.com/articles/thin-film-solar-has-bright-future-946.html.)

KGHM Polska Miedź S.A., 2009, Smelter zone: Lubin, Poland, KGHM Polska Miedź S.A. (Accessed June 9, 2009, via http://www.kghm.pl/.)

Metal Bulletin, 2009, Indium demand from Cigs sector could hit 100 tonnes in 2010, says Recaptures: Metal Bulletin, no. 9096, May 4, p. 8.

Metal-Pages Ltd., 2009a, Canada's 5N Plus builds inventories of cadmium, tellurium products: Metal-Pages Ltd., April 8. (Accessed April 9, 2009, via http://www.metal-pages.com/.)

Metal-Pages Ltd., 2009b, Chinese selenium imports slump in 2008: Metal-Pages Ltd., March 20. (Accessed March 20, 2009, via http://www.metal-pages.com/.)

Metal-Pages Ltd., 2009c, Solar cells to increase indium, gallium and selenium demand: Metal-Pages Ltd., April 29. (Accessed June 9, 2009, via http://www.metal-pages.com/.)

Metal-Pages Ltd., 2009d, The current state of thin-film photovoltaics globally: Metal-Pages Ltd., February 25. (Accessed March 20, 2009, via http://www.metal-pages.com/.)

Mexivada Mining Corp., 2008, Mexivada stakes new gold-tellurium property in Mexico: Vancouver, British Columbia, Canada, Mexivada Mining Corp. news release, June 12, 2 p.

Moats, Michael, Davenport, William, Demetrio, Sergio, Robinson, Tim, and Karcas, George, 2007, Electrolytic copper refining—2007 world tankhouse operating data: Toronto, Ontario, Canada, Electrorefining and Electrowinning, v. V, p. 195–241.

Natural Resources Canada, 2009, Mineral production annual statistics: Natural Resources Canada, Mineral and Metals Sector. (Accessed June 2, 2009, via http://mmsd.mms.nrcan.gc.ca/stat-stat/prod-prod/ann-ann-eng.aspx.)

Roskill's Letters from Japan, 2008, Selenium and tellurium—By-product metals production fails to match demand: Roskill's Letters from Japan, no. 384, August, p. 2–3.

Roskill's Letters from Japan, 2009, Non-ferrous metals—Japanese production in 2008: Roskill's Letters from Japan, no. 392, April, p. 1–6.

Selenium-Tellurium Development Association, Inc., 2002, Applications for selenium: Cavite, Philippines, Selenium-Tellurium Development Association, Inc. (Accessed September 24, 2002, via http://www.stda.com/.)

Southern Copper Corp., 2009, Other products: Phoenix, AZ, Southern Copper Corp. (Accessed May 26, 2009, via http://www.southernperu.com/.)

TEX Report, The, 2009, Cost situation to produce electrolytic manganese metal in China: TEX Report, v. 41, no. 9655, January 26, p. 3.

Ullal, Harin, 2008, Overview and challenges of thin film solar electric technologies: National Renewable Energy Laboratory Conference Paper NREL/CP–520–43355, Glasgow, Scotland, July 19–25, 2008, World Renewable Energy Congress X and Exhibition 2008, 4 p.


## GENERAL SOURCES OF INFORMATION

### U.S. Geological Survey Publications

Mineral Commodity Profiles—Selenium. Open-File Report 03–018, 2004.

Selenium. Ch. in Metal Prices in the United States Through 1998, 1999.

Selenium. Ch. in Mineral Commodity Summaries, annual.

Selenium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

Tellurium. Ch. in Metal Prices in the United States Through 1998, 1999.

Tellurium. Ch. in Mineral Commodity Summaries, annual.

Tellurium. Ch. in United States Mineral Resources, Professional Paper 820, 1973.

### Other

American Metal Market.

Metal Bulletin.

Selenium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

Tellurium. Ch. in Mineral Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.

TABLE 1

SALIENT SELENIUM AND TELLURIUM STATISTICS[1]

(Kilograms, contained metal, unless otherwise specified)

| | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|
| Selenium: | | | | | |
| United States: | | | | | |
| Production, primary refined | W | W | W | W | W |
| Exports | 160,000 | 254,000 | 191,000 | 562,000 | 545,000 |
| Imports for consumption | 412,000 | 589,000 | 409,000 | 544,000 | 519,000 |
| Dealers' price, average, commercial grade,[2] dollars per pound | 24.89 | 51.43 | 24.57 | 33.08 r | 32.29 |
| World, refinery production | 1,440,000 | 1,340,000 | 1,440,000 | 1,540,000 r | 1,510,000 |
| Tellurium, United States: | | | | | |
| Production, primary refined | W | W | W | W | W |
| Exports | 6,160 | 51,000 | 3,550 | 15,100 | 50,000 |
| Imports for consumption | 62,800 | 42,200 | 31,100 | 43,700 | 102,000 |
| Price at yearend, commercial grade,[3] dollars per kilogram | 22.50 | 110.00 | 60.00 | 110.00 | 175.00 |

[r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Source: Platts Metals Week.

[3]Average yearend price published by Mining Journal for United Kingdom lump and powder, 99.95% tellurium.

TABLE 2
U.S. EXPORTS OF SELENIUM[1]

| | 2007 | | 2008 | |
|---|---|---|---|---|
| Country | Quantity (kilograms, contained Se) | Value | Quantity (kilograms, contained Se) | Value |
| Australia | 50,100 | $923,000 | 115,000 | $1,790,000 |
| Belgium | 103,000 | 1,870,000 | -- | -- |
| Canada | 24,300 | 693,000 | 5,590 | 171,000 |
| Chile | -- | -- | 23,000 | 356,000 |
| China | 48,200 | 736,000 | 90,200 | 1,400,000 |
| Colombia | 50 | 4,730 | 3,480 | 61,000 |
| Dominican Republic | -- | -- | 6,580 | 83,200 |
| El Salvador | 7,840 | 95,100 | -- | -- |
| France | 5,160 | 80,000 | -- | -- |
| Germany | 80,600 | 1,370,000 | 75,300 | 1,320,000 |
| Hong Kong | 73,600 | 1,280,000 | 49,500 | 1,050,000 |
| India | 301 | 2,800 | 12,300 | 191,000 |
| Italy | 658 | 10,200 | 479 | 7,430 |
| Japan | 35,300 | 546,000 | 2,500 | 38,800 |
| Jordan | -- | -- | 1,440 | 22,400 |
| Korea, Republic of | 26,600 | 237,000 | 58,600 | 886,000 |
| Malaysia | -- | -- | 3,120 | 48,300 |
| Mexico | 24,900 | 386,000 | 8,250 | 124,000 |
| Netherlands | 24,300 | 365,000 | 26,100 | 404,000 |
| Panama | -- | -- | 2,350 | 36,400 |
| Philippines | 20,400 | 321,000 | 4,600 | 90,500 |
| Singapore | 2,950 | 25,500 | 3,360 | 29,700 |
| South Africa | 5,470 | 84,700 | 4,500 | 69,700 |
| Sweden | -- | -- | 39,700 | 615,000 |
| Taiwan | 14,900 | 230,000 | 612 | 3,760 |
| Thailand | 4,820 | 101,000 | 31 | 2,830 |
| United Kingdom | 749 | 14,400 | 5,810 | 90,000 |
| Venezuela | 6,180 | 95,900 | -- | -- |
| Vietnam | 1,600 | 24,800 | 2,030 | 32,200 |
| Total | 562,000 | 9,500,000 | 545,000 | 8,920,000 |

-- Zero.

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

Source: U.S. Census Bureau.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF SELENIUM[1]

| Class and country | 2007 Quantity (kilograms, contained Se) | 2007 Value | 2008 Quantity (kilograms, contained Se) | 2008 Value |
|---|---|---|---|---|
| Selenium: | | | | |
| Australia | 998 | $5,500 | 2,000 | $10,700 |
| Belgium | 260,000 | 10,600,000 | 234,000 | 9,960,000 |
| Canada | 49,900 | 2,720,000 | 68,600 | 3,960,000 |
| China | 24,900 | 1,090,000 | 15,100 | 1,300,000 |
| Germany | 78,900 | 5,620,000 | 82,000 | 5,540,000 |
| India | -- | -- | 5 | 9,500 |
| Japan | 54,200 | 3,180,000 | 22,600 | 1,270,000 |
| Korea, Republic of | 8,190 | 83,800 | 1,000 | 81,600 |
| Mexico | 4,030 | 209,000 | 23,800 | 1,450,000 |
| Netherlands | 8,750 | 268,000 | 4,670 | 140,000 |
| Peru | -- | -- | 24,100 | 1,050,000 |
| Philippines | 30,800 | 1,370,000 | 60 | 5,100 |
| United Kingdom | 15,400 | 886,000 | 30,100 | 1,620,000 |
| Total | 536,000 | 26,000,000 | 508,000 | 26,400,000 |
| Selenium dioxide:[2] | | | | |
| China | -- | -- | 4,970 | 432,000 |
| Germany | 7,450 r | 594,000 | 5,360 | 463,000 |
| Japan | 708 r | 62,000 | 708 | 63,200 |
| Liechtenstein | 12 | 2,500 | -- | -- |
| Total | 8,170 r | 658,000 | 11,000 | 958,000 |
| Grand total | 544,000 | 26,600,000 | 519,000 | 27,400,000 |

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Selenium content calculated as 71% of gross weight of material.

Source: U.S. Census Bureau.

TABLE 4
U.S. EXPORTS OF TELLURIUM[1]

| Country | 2007 Quantity (kilograms, contained Te) | 2007 Value | 2008 Quantity (kilograms, contained Te) | 2008 Value |
|---|---|---|---|---|
| Argentina | 5 | $4,920 | -- | -- |
| Belgium | 429 | 37,200 | 722 | $72,200 |
| Brazil | 284 | 22,800 | -- | -- |
| Canada | -- | -- | 9,610 | 447,000 |
| China | 9,300 | 596,000 | 19,800 | 491,000 |
| France | 160 | 117,000 | 138 | 105,000 |
| Germany | 108 | 163,000 | 109 | 187,000 |
| Hong Kong | -- | -- | 4,610 | 374,000 |
| India | 545 | 47,900 | 7,000 | 175,000 |
| Japan | 262 | 19,700 | -- | -- |
| Korea, Republic of | 65 | 6,750 | 126 | 46,400 |
| Malaysia | -- | -- | 5,080 | 533,000 |
| Mexico | 45 | 4,510 | 38 | 5,110 |
| Spain | 500 | 118,000 | 900 | 410,000 |
| Sweden | 87 | 13,000 | -- | -- |
| Taiwan | 315 | 17,900 | 28 | 4,260 |
| United Kingdom | 3,020 | 364,000 | 1,810 | 175,000 |
| Total | 15,100 | 1,530,000 | 50,000 | 3,030,000 |

-- Zero.

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

Source: U.S. Census Bureau.

TABLE 5
U.S. IMPORTS FOR CONSUMPTION OF TELLURIUM[1]

| Country | 2007 Quantity (kilograms, contained Te) | 2007 Value | 2008 Quantity (kilograms, contained Te) | 2008 Value |
|---|---|---|---|---|
| Belgium | 4,610 | $394,000 | 6,570 | $1,020,000 |
| Canada | 9,320 | 1,670,000 | 10,100 | 2,430,000 |
| China | 15,000 | 1,720,000 | 70,100 | 11,500,000 |
| Germany | 50 | 24,300 | 1,230 | 139,000 |
| Japan | 53 | 18,300 | 73 | 54,700 |
| Korea, Republic of | -- | -- | 600 | 162,000 |
| Netherlands | -- | -- | 1,040 | 252,000 |
| Peru | 2,070 | 254,000 | 4,200 | 660,000 |
| Phillippines | 10,700 | 653,000 | 2,000 | 132,000 |
| Russia | -- | -- | 5,550 | 1,380,000 |
| Ukraine | 882 | 87,000 | 247 | 11,400 |
| United Kingdom | 1,050 | 154,000 | 51 | 10,800 |
| Total | 43,700 | 4,980,000 | 102,000 | 17,700,000 |

-- Zero.

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

Source: U.S. Census Bureau.

TABLE 6

SELENIUM: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Kilograms, contained selenium)

| Country[3] | 2004 | 2005 | 2006 | 2007 | 2008[e] |
|---|---|---|---|---|---|
| Belgium[e] | 200,000 | 200,000 | 200,000 | 200,000 | 200,000 |
| Canada[4] | 271,073 | 107,000 | 106,000 | 144,000 [r] | 156,000 [p] |
| Chile[e] | 82,000 | 84,000 | 74,000 | 70,000 [r] | 78,000 |
| Finland | 61,256 | 62,000 | 62,000 [e] | 60,000 [e] | 60,000 |
| Germany[e] | 1,000 | 2,000 | 2,500 | 2,500 | 2,000 |
| India[e, 5] | 12,000 | 13,000 | 13,000 | 14,000 | 14,000 |
| Japan | 599,170 | 624,630 | 730,100 | 805,600 | 754,000 |
| Peru | 51,900 | 48,800 | 49,800 | 45,000 | 45,000 [p] |
| Philippines[e] | 48,000 | 68,000 | 65,000 | 65,000 | 65,000 |
| Russia[e] | 85,000 | 100,000 | 110,000 | 110,000 | 110,000 |
| Serbia[e] | 5,170 [r, 6] | 8,320 [r, 6] | 7,500 [r] | 7,500 [r] | 7,500 |
| Sweden[e] | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 |
| United States | W | W | W | W | W |
| Total | 1,440,000 | 1,340,000 | 1,440,000 | 1,540,000 [r] | 1,510,000 |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data; not included in total.

[1]World totals and estimated data have been rounded to no more than three significant digits; may not add to totals shown.

[2]Insofar as possible, data relate to refinery output only; thus, countries that produced selenium contained in copper ores, copper concentrates, blister copper, and/or refinery residues but did not recover refined selenium from these materials indigenously were excluded to avoid double counting. Table includes data available through May 24, 2009.

[3]In addition to the countries listed, Australia, China, Iran, Kazakhstan, Mexico, Poland, and Uzbekistan produced refined selenium, but output is not reported, and available information is inadequate for formulation of reliable estimates output levels. Australia is known to produce selenium in intermediate metallurgical products and has facilities to produce elemental selenium. In addition to having facilities for processing imported anode slimes for the recovery of selenium and precious metals, the United States has facilities for processing selenium scrap.

[4]Excludes selenium intermediates exported for refining.

[5]Data are for Indian fiscal year beginning April 1 of year stated.

[6]Montenegro and Serbia formally declared independence in June 2006 from each other and dissolved their union.

TABLE 7

TELLURIUM: WORLD REFINERY PRODUCTION, BY COUNTRY[1, 2]

(Kilograms, contained tellurium)

| Country[3] | 2004 | 2005 | 2006 | 2007 | 2008[e] |
|---|---|---|---|---|---|
| Canada[4] | 55,000 | 11,000 | 10,000 [r] | 14,000 [r] | 19,000 [p] |
| Japan | 33,000 [r] | 34,000 [r] | 35,000 [r] | 41,000 [r] | 40,000 |
| Peru | 22,000 | 32,880 | 33,000 | 33,000 | 30,000 |
| United States | W | W | W | W | W |

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Estimated data are rounded to no more than three significant digits.

[2]Insofar as possible, data relate to refinery output only; thus, countries that produced tellurium contained in copper ores, copper concentrates, blister copper, and/or refinery residues but did not recover refined tellurium are excluded to avoid double counting. Table is not totaled because of exclusion of data from major world producers.

[3]Australia, Belgium, Chile, China, Colombia, Germany, Mexico, the Philippines, Poland, and some countries of the Commonwealth of Independent States, including Kazakhstan and Russia, are known to produce refined tellurium, but output is not reported; available information is inadequate for formulation of reliable estimates of output levels.

[4]Excludes tellurium intermediates exported for refining.