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2020 Minerals Yearbook

SELENIUM AND TELLURIUM [ADVANCE RELEASE]

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Selenium and Tellurium

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In 2020, selenium and tellurium were not refined in the United States. Two copper refineries produced either semirefined selenium and tellurium or selenium- and tellurium-containing copper anode slimes, and all production was exported for further processing. U.S. imports of selenium and tellurium decreased in 2020 compared with those in 2019, and exports of selenium decreased whereas exports of tellurium increased in 2020 compared with those in 2019. The average (in warehouse, Rotterdam) price for 99.5%-pure selenium, as reported by Argus Metals International, decreased in 2020 by 28% to $14.71 per kilogram from $20.44 per kilogram in 2019. The average price for 99.99%-pure tellurium (in warehouse, Rotterdam), as reported by Argus Metals International, decreased by 7% in 2020 to $56.05 per kilogram from $60.45 per kilogram in 2019 (table 1).

Except for two mines in China that began mining tellurium as a principal product in 2010 and one mine in Sweden that recovered tellurium from gold-telluride ores, selenium and tellurium were recovered as byproducts of nonferrous metal mining in 2020, principally from anode slimes produced during the electrolytic refining of copper. Selenium and tellurium also can be recovered as byproducts of gold, lead, nickel, platinum-group metals, and zinc.

Legislation and Government Programs

In 2011, the U.S. Department of Energy (DOE) Critical Materials Strategy Report was released, and tellurium was found to be important for the use of photovoltaic (PV) cells. To address the challenge of ensuring a reliable supply chain for critical minerals and rare-earth elements (REEs), the DOE Office of Fossil Energy and the National Energy Technology Laboratory (NETL) conducted an initial assessment to determine the potential recovery of REEs from coal and coal byproducts. In 2020, the U.S. Small Business Administration's Small Business Innovation Research program announced grant applications for the production of critical minerals, including tellurium, from coal-based resources using the NETL's technical feasibility of recovering REEs and other critical minerals from coal-based resources, such as run-of-mine coal, coal refuse, clay, overburden or underburden materials, ash, and aqueous effluents (U.S. Department of Energy, 2020; U.S. Small Business Administration, 2020).

Production

Two primary electrolytic copper refineries produced selenium- and tellurium-containing intermediate products in the United States in 2020. Rio Tinto Kennecott's [a subsidiary of Rio Tinto plc (United Kingdom)] copper refinery in Garfield, UT, and Freeport-McMoRan Inc.'s copper refinery in Miami, AZ, generated selenium- and tellurium-containing anode slimes. ASARCO LLC's (Tucson, AZ) copper refinery in Amarillo, TX, had a strike in late 2019 that ended in July 2020; however, the electrolytic copper line was not operational for 2020. Domestic production data for selenium and tellurium were withheld to avoid disclosing company proprietary data.

Consumption

Selenium.—The main metallurgical end use for selenium in 2020 was estimated to be for the production of electrolytic manganese in China, where selenium dioxide (SeO_2) was substituted for sulfur dioxide to reduce the power required to operate electrolytic cells. Consumption of SeO_2 in China in 2020 was estimated to be 970 metric tons (t), unchanged from estimated consumption in 2019. In other metallurgical applications, selenium was used with bismuth to substitute for lead as a free-machining agent in brass plumbing fixtures. Metallurgical-grade selenium also was used as an additive to cast copper, iron, lead, and steel alloys (Xu, 2019, p. 11).

In the glass industry, selenium was used to decolorize the green tint caused by iron impurities in container glass and other soda-lime silica glass. It also was used in art and other glass to produce a ruby red color and in architectural plate glass to reduce solar heat transmission through the glass.

Selenium is a micronutrient essential to human and animal health. In areas with selenium-poor soils, selenium was added to fertilizer and applied to acreage used to grow animal feed to increase selenium in the diet of animals and, in turn, the diet of humans. This practice was more common outside the United States.

Cadmium sulfoselenide compounds were used as pigments in ceramics, glazes, paints, and plastics. Selenium pigments have good heat stability, dissolve well into solution, and are resistant to ultraviolet or chemical exposure. These pigments produce a wide range of red, orange, and maroon colors but, because of the relatively high cost and the toxicity of cadmium-based pigments, their use was limited to applications where cost was not the prevailing factor and human contact was limited, such as art pieces.

Tellurium.—In 2020, three major types of thin-film PV solar cells were in global commercial production. They were, in descending order of gigawatts (GW) produced in 2020, cadmium telluride (CdTe) (6.1 GW), copper indium gallium diselenide (CIGS) (1.5 GW), and amorphous silicon (0.2 GW). CdTe cell production increased by 7% in 2020, CIGS cell production decreased by 6%, and amorphous silicon production remained the same compared with that in 2019. Thin-film solar cells continued to account for only 5% of all solar cells produced in 2020; the majority of PV solar cell production continued to be dominated by the conventional crystalline silicon technology. Global PV solar cell and module production in 2020 equaled 151.6 GW, an 11% increase from that in 2019

(136.8 GW). Asia produced about 92% of the global solar cells and modules in 2020. Worldwide cumulative installations were led by China with 256 GW (36%), North America with 85 GW (12%), Japan with 64 GW (9%), Germany with 57 GW (8%), India with 42 GW (6%), and the rest of the world with 205 GW (29%), totaling 708 GW peak installed at the end of 2020 (Fraunhofer-Institut für Solare Energiesysteme ISE, 2021, p. 16, 21–24).

Within the United States, First Solar, Inc. (Tempe, AZ) shipped 5.5 GW of CdTe cells in 2020, a slight increase from that in 2019. The Perrysburg, OH, facility completed a capacity expansion, and across all First Solar global facilities, the total production capacity was 6.3 GW at the end of 2020. Tellurium consumption for CdTe-based solar panels was estimated to be 91 metric tons per gigawatt, based on information from 2010 (Zweibel, 2010; First Solar, Inc., 2021, p. 4, 22).

Other uses for tellurium included thermal imaging and thermoelectric cooling. In thermal-imaging devices for infrared sensors and heat-seeking missiles, mercury-cadmium-telluride is built up on a base of cadmium-zinc-telluride and is used to convert the raw image into a crisp screen picture in a cryo-cooled environment. Semiconducting bismuth telluride was used in thermoelectric cooling devices. These devices consist of a series of semiconducting material couples that, when connected to a direct current, cause one side of the thermoelement to cool and the other side to heat. Thermoelectric coolers were used in electronics and military applications, such as the cooling of infrared detectors, integrated circuits, laser diodes, and medical instrumentation, as well as in high-end automobiles to cool cup holders and seats. In China, these devices were used in refrigerators, water dispensers, and other home appliances.

In metallurgy, tellurium was used in steel as a free-machining additive, in copper to improve machinability without 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.

Tellurium was used as a vulcanizing agent and as an accelerator in the processing of rubber. It also was used as a catalysts for synthetic fiber production. Other applications included the use of tellurium as a pigment to produce blue and brown colors in ceramics and glass.

Prices

The average annual price for 99.95%-pure selenium (in warehouse, Rotterdam), as reported by Argus Metals International, was $14.71 per kilogram in 2020, 28% less than the annual average price of $20.44 per kilogram in 2019 (table 1). In 2020, the average monthly price of selenium in January was $14.83 per kilogram, increased slightly to a monthly average of $15.33 per kilogram in June, and decreased to a monthly average of $13.56 per kilogram at the end of the year.

The average annual price for 99.99%-pure tellurium (in warehouse, Rotterdam), as reported by Argus Metals International, decreased by 7% in 2020 to $56.05 per kilogram from $60.45 per kilogram in 2019 (table 1). The average monthly tellurium price was $50.00 per kilogram in January 2020, and the average monthly price began to rise in the second quarter of the year, increasing to an average monthly price of $61.21 per kilogram in November, and decreasing slightly in December to an average monthly price of $59.50 per kilogram.

Foreign Trade

Selenium.—Exports of selenium in 2020 decreased by 59% to 147 t from 361 t in 2019. In descending order of quantity, Egypt, Hong Kong, the Republic of Korea, Mexico, and South Africa were the leading destinations for selenium exports in 2020 and collectively accounted for 82% of the export tonnage. Exports to Canada, the leading destination for selenium exports in 2019, decreased to 2 t in 2020 from 99 t in 2019. Exports also decreased to Hong Kong (by 49 t), Mexico (36 t), Indonesia (22 t), and Egypt (14 t), but these decreases were partially offset by increases in exports to the Republic of Korea (by 15 t) and South Africa (5 t). Based on unrounded data, the annual average unit value of exports in 2020 was $11.80 per kilogram ($5.35 per pound), 34% less than the 2019 annual average of $18.00 per kilogram ($8.16 per pound) (table 2).

In 2020, imports for consumption of selenium, including the selenium content of SeO_2, decreased by 23% to 384 t from 501 t. Based on unrounded data, the annual average unit value of all imported selenium materials, by selenium content, in 2020 was $23.45 per kilogram ($10.64 per pound), 23% less than that in 2019 (table 3).

In 2020, imports of selenium metal decreased by 26% to 366 t from 496 t in 2019. The Philippines, Mexico, Germany, Canada, and Japan, in descending order of quantity, collectively accounted for 72% of the imports of selenium metal into the United States in 2020. Imports decreased from China (58 t), the Philippines (33 t), Germany (29 t), Chile (27 t), and Mexico (19 t), which was slightly offset by increased imports from Pakistan (30 t), Poland (17 t), and Canada (12 t). Based on unrounded data, the annual average unit value of all imported selenium metal in 2020 was $22.86 per kilogram ($10.37 per pound), 25% less than that in 2019 (table 3).

In 2020, imports for consumption of SeO_2, by selenium content, increased by 286% to 18 t from the revised quantity of 4.6 t in 2019. Three countries—the Republic of Korea, China, and Germany, in decreasing order of quantity—collectively supplied the United States with 92% of SeO_2 imports in 2020. Based on unrounded data, the annual average unit value of SeO_2 imports, with respect to selenium content, was $35.49 per kilogram ($16.10 per pound), a 3% decrease compared with that in 2019 (table 3).

Tellurium.—In 2020, tellurium exports equaled 12 t, by tellurium content, almost 15 times greater than exports in 2019. The main destination was Hong Kong, which accounted for 98% of total tellurium exports. Based on unrounded data, the annual average unit value of tellurium exports was $33.52 per kilogram ($15.20 per pound), a 92% decrease compared with that in 2019. The export values appear to be inaccurate owing to exports to Hong Kong. Excluding Hong Kong, tellurium exports were 197 kg, a 76% decrease compared with exports in 2019. Excluding Hong Kong, the annual average unit value of tellurium exports was $556 per kilogram ($252 per pound), a 31% increase compared with that in 2019 (table 4).

Imports for consumption of tellurium metal in 2020 decreased by 80% compared with imports in 2019. The leading suppliers

were, in descending order of quantity, the Philippines, Canada, China, and Japan, which collectively accounted for 92% of the total imports of tellurium into the United States. Imports from Germany, Canada, and Hong Kong decreased by 45.6 t, 1.75 t and 1.3 t, respectively, while imports from China increased by 1.49 t. Based on unrounded data, the annual average unit value of tellurium imports in 2020 was $155 per kilogram ($70.20 per pound), a 50% increase compared with that in 2019 (table 5).

World Review

Global selenium and tellurium output cannot be determined with certainty because some companies and countries did not report production and trade in scrap and semirefined products may have been included with refined metal trade data. World production of selenium, excluding output from Australia, Iran, Kazakhstan, Mexico, the Philippines, Uzbekistan, and the United States, was estimated to have increased by 3% to 3,120 t in 2020 compared with 3,040 t (revised) in 2019 (table 6). World production of tellurium, excluding Australia, Belgium, Chile, Colombia, Germany, Kazakhstan, Mexico, the Philippines, Poland, and the United States, was estimated to have increased slightly to 562 t from the revised total of 551 t in 2019 (table 7).

China.—China was the leading global producer of selenium and tellurium and accounted for an estimated 38% and 59% of world production, respectively. China produced an estimated 1,200 t of selenium in 2020, a 9% increase from that in 2019. Estimated production of tellurium in China was 330 t, a slight increase from the estimated production in 2019 (tables 6, 7).

On January 20, Ziangtang Jurong Technology, an SeO_2 producer, announced the halt of selenium production owing to the global coronavirus disease 2019 (COVID-19) pandemic. Jurong later announced the restart of production on February 24. The company had produced between 40 and 50 t of SeO_2 per month prior to the shutdown (Argus Metals International, 2020).

Based on data from the China Nonferrous Industry Association, estimated selenium consumption in China remained steady at 2,100 t in 2020, unchanged from the previous year. The electrolytic manganese industry remained the leading consumer of selenium in China, followed by glass production, agriculture, electronics, and pigments. Selenium consumption was estimated to be less than supply. Estimated consumption of tellurium in China remained steady at 170 t in 2020. Consumption of tellurium in China was in the following areas: thermal coolers (50%), metallurgy (25%), photovoltaics (10%), petroleum chemicals (5%), and other (10%). Tellurium consumption in China was estimated to be less than production in 2020 (Mai and Xiaohui, 2019, p. 10–11, 15; Xu, 2019, p. 10–11).

Sweden.—Tellurium production at Boliden AB's Kankberg gold-tellurium mine increased slightly in 2020 to 41,742 kg from 40,953 kg in 2019. Boliden reopened the Kankberg Mine in 2012, and it is now part of the Boliden Area, which includes the Kristineberg, Petiknas N, Renstrom, Kankberg, and Algtrask Mines (Boliden AB, 2021, p. 111).

Outlook

The supply of selenium and tellurium is 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, platinum-group metals, and zinc produced from sulfide ores. Recovery rates of selenium and tellurium from copper slimes are not expected to increase if selenium and (or) tellurium prices remain at or near those at yearend 2020. Production of CdTe solar cells is expected to increase over the next 5 years (First Solar, Inc., 2021, p. 53; Mai and Xiaohui, 2019, p. 15; Xu, 2019, p. 10–11).

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TABLE 1
SALIENT SELENIUM AND TELLURIUM STATISTICS[1]

(Kilograms, metal content, unless otherwise specified)

	2016	2017	2018	2019	2020
Selenium:					
United States:					
Production, primary refined	W	W	W	W	W
Exports	150,000	242,000	158,000	361,000	147,000
Imports for consumption[2]	433,000	469,000	458,000	501,000	384,000
Price, average, commercial grade, dollars per pound[3]	23.69	10.78	18.97	20.00	NA
Price, average, dollars per kilogram[4]	NA	36.23	38.98	20.44	14.71
World, refinery production[5]	2,670,000	2,790,000	3,060,000 r	3,040,000 r	3,120,000
Tellurium:					
United States:					
Production, primary refined	W	W	W	W	W
Exports	2,620	2,310	4,150	827	12,400
Imports for consumption	72,700	163,000	192,000	59,300	11,900
Price, average, dollars per kilogram[6]	31.45 r	37.63	73.67 r	60.45	56.05
World, refinery production[5]	423,000	467,000	527,000 r	551,000 r	562,000

rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through June 22, 2021. Data are rounded to no more than three significant digits, except prices.
[2]Includes selenium metal and the selenium content of selenium dioxide.
[3]Annual average New York dealer price for 99.5% selenium. Source: S&P Global Platts Metals Week.
[4]Annual average price published by the Argus Media group, Argus Metals International for duties unpaid in warehouse, Rotterdam, 99.5% selenium.
[5]May include estimated data.
[6]Annual average price published by the Argus Media group, Argus Metals International for duties unpaid in warehouse, Rotterdam, 99.99% tellurium.

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

	2019		2020	
Country or locality	Selenium content (kilograms)	Value	Selenium content (kilograms)	Value
Australia	200	$16,400	--	--
Bulgaria	364	15,100	2,580	$39,400
Canada	99,000	2,780,000	2,290	71,500
China	222	3,580	4,610	57,400
Dominican Republic	1,010	29,100	4,730	93,200
Ecuador	470	17,500	--	--
Egypt	68,300	1,060,000	54,600	892,000
France	--	--	279	4,720
Hong Kong	83,800	664,000	34,900	119,000
India	3,680	57,100	--	--
Indonesia	26,600	412,000	4,800	74,400
Italy	--	--	351	8,460
Japan	3,870	60,000	--	--
Korea, Republic of	275	6,000	15,300	51,400
Mexico	45,800	990,000	10,100	143,000
Netherlands	9,000	135,000	428	14,800
Panama	--	--	500	8,650
Peru	6,930	107,000	--	--
Philippines	4,410	37,000	1,020	2,660
South Africa	1,090	16,900	6,520	90,900
Thailand	--	--	3,560	55,200
Venezuela	5,530	85,800	772	12,000
Total	361,000	6,490,000	147,000	1,740,000

-- Zero.

[1]Table includes data available through May 7, 2021. 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 or locality	2019 Selenium content (kilograms)	2019 Value	2020 Selenium content (kilograms)	2020 Value
Selenium metal:				
Australia	--	--	3	$5,500
Belgium	19,300	$392,000	16,800	235,000
Canada	33,800	742,000	46,000	485,000
Chile	33,000	627,000	6,300	84,300
China	59,500	878,000	1,340	32,500
France	--	--	530	15,900
Germany	79,600	2,450,000	51,100	1,140,000
India	200	5,000	225	12,000
Ireland	--	--	1	4,780
Italy	168	8,270	--	--
Japan	53,500	2,910,000	45,000	1,530,000
Korea, Republic of	17,000	301,000	12,000	148,000
Mexico	76,500	1,280,000	57,100	624,000
Netherlands	3	7,780	3	6,210
New Zealand	1,000	7,360	1	7,360
Pakistan	--	--	30,000	368,000
Philippines	96,100	5,130,000	63,300	3,270,000
Poland	14,000	177,000	31,500	358,000
Russia	3,000	72,800	5,190	59,600
Singapore	9,500	204,000	--	--
Total	496,000	15,200,000	366,000	8,380,000
Selenium dioxide:[2]				
Belgium	--	--	18	2,080
China	710	13,000	2,040	46,300
Germany	1,930 r	74,200	959	29,900
Japan	193	12,600	386	19,900
Korea, Republic of	1,780	69,000	13,700	507,000
Philippines	--	--	667	25,900
Total	4,610 r	169,000	17,800	632,000
Grand total	501,000	15,400,000	384,000	9,010,000

rRevised. -- Zero.
[1]Table includes data available through May 7, 2021. 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]

	2019		2020	
Country or locality	Tellurium content (kilograms)	Value	Tellurium content (kilograms)	Value
Canada	429	$253,000	132	$54,900
China	--	--	4	5,700
Hong Kong	--	--	12,200	306,000
Indonesia	3	2,540	1	3,770
Jordan	352	52,800	--	--
Korea, Republic of	43	43,500	39	36,000
Mexico	--	--	3	6,520
Singapore	--	--	18	2,720
Total	827	352,000	12,400	415,000

-- Zero.

[1]Table includes data available through May 7, 2021. 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 METAL[1]

	2019		2020	
Country or locality	Tellurium content (kilograms)	Value	Tellurium content (kilograms)	Value
Australia	--	--	46	$49,500
Belgium	--	--	132	5,690
Canada	4,000	$744,000	2,250	1,020,000
China	314	74,700	1,800	186,000
Germany	46,300	4,570,000	735	47,300
Hong Kong	1,300	72,000	--	--
Japan	2,370	193,000	1,740	123,000
Netherlands	1	3,160	--	--
Philippines	4,750	442,000	5,230	413,000
Russia	284	14,200	--	--
United Kingdom	--	--	1	2,840
Total	59,300	6,120,000	11,900	1,850,000

-- Zero.

[1]Table includes data available through May 7, 2021. 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 PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Kilograms, selenium content)

Country or locality[2]	2016	2017	2018	2019	2020
Belgium[e]	200,000	200,000	200,000	200,000	200,000
Canada[3]	175,000	72,000	85,000 [r]	57,000	60,000 [e]
China	750,000	930,000	1,050,000	1,100,000 [e]	1,200,000 [e]
Finland	104,420	100,198	108,918	115,236 [r]	84,000 [e]
Germany	300,000	300,000 [e]	300,000 [e]	300,000 [e]	300,000 [e]
India[4]	17,000 [e]	17,000 [e]	17,000 [e]	14,600 [r]	14,000 [e]
Japan	752,173	729,132	749,677	708,812 [r]	740,000 [e]
Peru[e]	45,000	45,000	45,000	40,000	35,000
Poland	81,660	73,900	66,360	75,760 [r]	74,000 [e]
Russia	150,000	150,000 [e]	303,000 [r]	331,000 [r]	340,000 [e]
Serbia	18,300	19,000	29,000	17,000	10,000
South Africa, anode slimes[e]	14,000	12,000	9,300 [r]	8,500 [r]	4,200
Sweden	60,000	89,000	45,000	19,000	10,000
Turkey	--	50,000 [e]	50,000 [e]	50,000 [e]	50,000 [e]
United States	W	W	W	W	W
Total	2,670,000	2,790,000	3,060,000 [r]	3,040,000 [r]	3,120,000

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

[1]Table includes data available through June 14, 2021. All data are reported unless otherwise noted; totals may include estimated data. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]In addition to the countries and (or) localities listed, Australia, Iran, Kazakhstan, Mexico, the Philippines, and Uzbekistan may have produced refined selenium, but available information was inadequate to make reliable estimates of output. 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.

[3]Excludes selenium intermediates exported for refining.

[4]Production is based on fiscal year, with a starting date of April 1 of the year shown.

TABLE 7
TELLURIUM: WORLD REFINERY PRODUCTION, BY COUNTRY OR LOCALITY[1, 2]

(Kilograms, contained tellurium)

Country or locality[3]	2016	2017	2018	2019	2020
Bulgaria	4,479	5,095	3,931	2,944 [r]	3,000 [e]
Canada[4]	18,000	49,000	40,000 [e]	40,000 [e]	44,000 [e]
China	279,000	291,000	307,000 [e]	325,000 [e]	330,000 [e]
Japan	32,911	37,754	57,231	66,664 [r]	70,000 [e]
Russia	42,900	44,000	70,000 [r]	71,400 [r]	71,000 [e]
South Africa[e]	6,700	5,300	4,200 [r]	3,900 [r]	2,000
Sweden	38,680	34,979	44,641	40,953	41,742
United States	W	W	W	W	W
Total	423,000	467,000	527,000 [r]	551,000 [r]	562,000

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

[1]Table includes data available through June 15, 2021. All data are reported unless otherwise noted; totals may include estimated data. Totals and estimated data are 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 tellurium contained in copper ores, copper concentrates, blister copper, or refinery residues but did not recover refined tellurium are excluded to avoid double counting.

[3]In addition to the countries and (or) localities listed, Australia, Belgium, Chile, Colombia, Germany, Kazakhstan, Mexico, the Philippines, and Poland may have produced refined tellurium, but available information was inadequate to make reliable estimates of output.

[4]Excludes tellurium intermediates exported for refining.