



2010 Minerals Yearbook

GRAPHITE

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In 2010, there was no reported domestic production of natural graphite, but U.S. production of synthetic graphite was estimated to be 134,000 metric tons (t) valued at about \$1.07 billion. U.S. imports and exports of natural graphite were estimated to be 65,400 t and 5,600 t, respectively. U.S. imports and exports of synthetic graphite were estimated to be 41,300 t and 40,000 t, respectively. U.S. apparent consumption of natural and synthetic graphite was estimated to be 59,800 t and 135,000 t, respectively.

This report includes information on U.S. trade and use of natural graphite and U.S. production, trade, and use of synthetic graphite. Trade data in this report are from the U.S. Census Bureau. All percentages in the report were computed using the unrounded data.

Graphite is one of four forms of crystalline carbon; the others are carbon nanotubes, diamonds, and fullerenes. In graphite, the carbon atoms are densely arranged in parallel-stacked, planar honeycomb-lattice sheets. When the graphite structure is only a one-atom-thick planar sheet, it is called graphene. Graphite is gray to black in color, opaque, and usually has a metallic luster; sometimes it exhibits a dull earthy luster. Graphite occurs naturally in metamorphic rocks. It is a soft mineral with a Mohs hardness of 1 to 2, and it exhibits perfect basal (one-plane) cleavage. Graphite is flexible but not elastic, has a melting point of 3,927 °C, and is highly refractory. It has a low specific gravity. Graphite is the most electrically and thermally conductive of the nonmetals and is chemically inert. All these properties combined make graphite desirable for many industrial applications, and both natural and synthetic graphite have industrial uses.

There are three types of natural graphite—amorphous, flake or crystalline flake, and vein or lump. Amorphous graphite is the lowest quality and most abundant. Amorphous refers to its very small crystal size and not to a lack of crystal structure. Amorphous is used for lower value graphite products and is the lowest priced graphite. Large amorphous graphite deposits are found in China, Europe, Mexico, and the United States. Flake or crystalline form of graphite consists of many graphene sheets stacked together. Flake or crystalline flake graphite is less common and higher quality than amorphous. Flake graphite occurs as separate flakes that crystallized in metamorphic rock. Flake graphite can be four times the price of amorphous. Good quality flakes can be processed into expandable graphite for many uses, such as flame retardants. The foremost deposits are found in Austria, Brazil, Canada, China, Germany, and Madagascar. Vein or lump graphite is the rarest, most valuable, and highest quality type of natural graphite. It occurs in veins along intrusive contacts in solid lumps, and it is only commercially mined in Sri Lanka (Moores, 2007).

Natural graphite is mined from open pit and underground mine operations. Production from open pit operations is less expensive and is preferred where the overburden can be removed

economically. Mines in Madagascar are mostly of this type. In Mexico, the Republic of Korea, and Sri Lanka, where the deposits are deep, underground mining techniques are required.

Beneficiation processes for graphite may vary from a complex four-stage flotation at European and United States mills to simple hand sorting and screening of high-grade ore at Sri Lankan operations. Certain soft graphite ores, such as those found in Madagascar, need no primary crushing and grinding. Typically, such ores contain the highest proportion of coarse flakes. Ore is sluiced to the field washing plant, where it undergoes desliming to remove the clay fraction and is subjected to a rough flotation to produce a concentrate with 60% to 70% carbon. This concentrate is transported to the refining mill for further grinding and flotation to reach 85% carbon. It is then screened to produce a variety of products marketed as flake graphite that contain 75% to 90% carbon.

Production

The U.S. Geological Survey (USGS) obtained the production data in this report through a voluntary survey of U.S. synthetic graphite producers. The survey of U.S. synthetic graphite producers collected data from 10 of 16 canvassed producers. Data were estimated for the producers that did not respond to the survey based on responses received in previous years and on industry trends.

No natural graphite was reported mined in the United States in 2010, but 134,000 t of synthetic graphite with an estimated value of \$1.07 billion was produced and shipped (table 3).

Consumption

The USGS obtained the consumption data in this report through a survey of natural graphite companies in the United States. The survey of natural graphite companies collected data from 70 of 91 canvassed companies and plants. Data were estimated for the companies that did not respond to the survey. This survey represented most of the graphite industry in the United States. Graphite uses have changed dramatically in the past 20 years. U.S. reported consumption of natural graphite increased by 28% to 51,200 t in 2010 from 40,000 t in 2009 (table 2), owing to increases of 21%, 37%, and 77% from the previous year in the amounts of natural graphite used in batteries, refractories, and the “Other” end-use category, respectively. The “Other” end-use category includes antiknock gasoline additives and other chemical compounds, drilling mud, electrical/electronic devices, industrial diamonds, magnetic tape, mechanical products, paints and polishes, soldering/welding, and other end uses. The natural graphite consumption data in table 2 include mixtures of natural and synthetic graphite in the amorphous graphite category, and this reported consumption data may include company stocks from

previous years. Consequently, the table 2 consumption numbers are different from the computed apparent consumption numbers given in table 1. Consumption of crystalline grade increased in 2010 by 51% to 25,600 t from 16,900 t in 2009. Consumption of amorphous grade increased by 11% to 25,700 t in 2010 from 23,100 t in 2009. Brake linings, refractories, and steelmaking were the three industries that dominated U.S. natural graphite use, accounting for 61% of natural graphite consumption. Batteries, foundries, and lubricants accounted for another 8% of natural graphite consumption. The refractories industry was the leading consumer of crystalline flake graphite, accounting for almost 49% of crystalline flake graphite used in 2010.

Graphite has metallic and nonmetallic properties, which makes it suitable for many industrial applications. The metallic properties include electrical and thermal conductivity. The nonmetallic properties include high-thermal resistance, inertness, and lubricity. The combination of conductivity and high-thermal stability allows graphite to be used in many applications, such as in batteries, fuel cells, and refractories. Graphite's lubricity and thermal conductivity make it an excellent material for high-temperature applications because it provides effective lubrication at a friction interface while furnishing a thermally conductive matrix to remove heat from the same interface. Electrical conductivity and lubricity allow its use as the primary material in the manufacture of brushes for electric motors. A graphite brush effectively transfers electric current to a rotating armature while the natural lubricity of the brush minimizes frictional wear. Today's advanced technology products, such as friction materials and battery and fuel cells, require high-purity graphite. Natural graphite is purified to 99.9% carbon content for use in battery applications.

Graphite is made up of parallel sheets of carbon atoms in a hexagonal arrangement. It is possible to insert other atoms between the sheets, a process that is called intercalation. The insertion of other atoms makes dramatic changes in the properties of graphite. Lithium ions can be inserted to create graphite anodes for lithium ion batteries. Graphite can be intercalated with sulfuric and nitric acids to produce expanded graphite from which foils are formed that are used in seals, gaskets, and fuel cells.

Refractory applications of graphite included carbon-bonded brick, castable ramming, and gunning mixtures. Carbon-magnesite brick has applications in high-temperature corrosive environments, such as iron blast furnaces, ladles, and steel furnaces. Carbon-alumina linings are principally used in continuous steel-casting operations. Alumina- and magnesite-carbon brick requires graphite with a particle size of 100 mesh and a purity of 95% to 99%.

Crystalline flake graphite accounted for about 50% of natural graphite usage in the United States. It was consumed mainly in batteries and refractories. Amorphous graphite was mainly used in brake linings, foundries, refractories, steelmaking, and other applications where additions of graphite improve the process or the end product. Lump graphite finds uses in a number of areas, such as steelmaking, depending on purity and particle size.

Synthetic graphite is used in more applications in North America than natural graphite and accounts for a significant share of the graphite market. The main market for high-purity synthetic graphite is as a carbon raiser additive in iron and steel.

This market consumes a substantial portion of the synthetic graphite. Other important uses of all types of graphite are in the manufacture of catalyst supports; low-current, long-life batteries; porosity-enhancing inert fillers; powder metallurgy; rubber; solid carbon shapes; static and dynamic seals; steel; and valve and stem packing. The use of graphite in low-current batteries is gradually giving way to carbon black, which is more economical. Graphite is used to manufacture antistatic plastics, conductive plastics and rubbers, electromagnetic interference shielding, electrostatic paint and powder coatings, high-voltage power cable conductive shields, membrane switches and resistors, semiconductive cable compounds, and electrostatic paint and powder coatings.

Graphite has played an important role in the emerging noncarbon energy sector and has been used in several new energy applications. In energy production applications, graphite is used in pebbles for modular nuclear reactors and in high-strength composites for wind, tide, and wave turbines. In energy storage applications, graphite is used in bipolar plates for fuel cells and flow batteries, in anodes for lithium-ion batteries, in electrodes for supercapacitors, in high-strength composites for fly wheels, in phase change heat storage, and in solar boilers. In energy management applications, graphite is used in high-performance polystyrene thermal insulation and in silicon chip heat dissipation. These new energy applications use value-added graphite products, such as high purity, small particle size, potato shape, expanded graphite, and graphene. Current graphite capacity may not be adequate for the increasing demands of these new energy applications, which may require double the current graphite supply when fully implemented (O'Driscoll, 2010).

Prices

Natural graphite prices slowly increased during the second half of 2009 for most types (Industrial Minerals, 2009a). In 2010, graphite prices increased more rapidly especially for crystalline flake graphite, owing to increased demand for graphite used in friction material applications such as brake linings, as a high-quality refractory, as lubricants, and in the manufacturing of graphite foils and long-life alkaline batteries (Industrial Minerals, 2010b).

Prices for crystalline and amorphous graphite concentrates ranged from \$950 to \$2,000 per metric ton; prices for amorphous powder ranged from \$430 to \$450 per ton (table 4). The average unit value of all U.S. natural graphite exports increased by 43% to \$2,720 per ton in 2010 from \$1,900 per ton in 2009. Ash and carbon content, crystal and flake size, and size distribution affect the price of graphite. The European port price of synthetic graphite in 2010 ranged from \$7,000 to \$20,000 per ton. The average unit value of synthetic graphite exports increased by 10% to \$3,410 per ton in 2010 from \$3,100 per ton in 2009 (table 5).

Foreign Trade

Total graphite exports decreased slightly in tonnage to 45,600 t valued at \$152 million in 2010 from 46,400 t valued at \$130 million in 2009. Total graphite export tonnage was 12% natural graphite and 88% synthetic graphite (table 5). Total natural graphite imports increased by 98% in tonnage to

65,400 t in 2010 from 33,100 t in 2009, and the value increased by 76% to \$52.1 million in 2010 from \$29.7 million in 2009 (table 6). This large increase was a result of the graphite industry starting to recover during 2010 from the drastic effects of the global recession on end-use markets, adverse weather in major graphite production areas, and unfavorable regulatory measures in China. Principal import sources of natural graphite were, in descending order of tonnage, China, Mexico, Canada, Brazil, and Madagascar, which combined, accounted for 98% of the tonnage and 91% of the value of total imports. Mexico provided all the amorphous graphite, and Sri Lanka provided all the lump and chippy dust variety. China, Canada, Brazil, Madagascar, and Belgium were, in descending order of tonnage, the suppliers of crystalline flake and flake dust graphite. A number of other producing nations supplied several other natural types and grades of graphite to the United States; among the most notable were Brazil and Canada.

World Review

World production of natural graphite increased by 21% in 2010 to an estimated 925,000 t compared with 762,000 t in 2009. China maintained its position as the world's leading graphite producer, with 600,000 t or 65% of the total. India was the second ranked graphite producer, with 140,000 t, followed by Brazil, North Korea, and Canada, in decreasing order of tonnage produced. These five countries accounted for 94% of world production (table 8).

South Africa became a new graphite producer with the startup of the Jonkel Mine. Jonkel Group produced graphite through its subsidiary, Jonkelkoza Minerals and Resources (Pty) Ltd, and became South Africa's sole graphite producer since Germany's Graphit Kropfmühl AG closed its operations several years ago (Feytis, 2010b).

Outlook

Worldwide demand for graphite is expected to continue increasing as global economic conditions improve. Demand is also expected to continue increasing as more noncarbon energy applications that use graphite are developed.

The trend towards collaboration between Far Eastern and Western graphite producers is expected to continue. These collaborations have been combining superior management, processing, and packaging techniques of Western companies with China's production capabilities located in and adjacent to the largest markets. China offers the optimum cost-location balance. China has made progress in eliminating logistics challenges, such as freight issues, shipping problems, and rising container rates; and the Chinese graphite industry is expected to continue to expand (Moores, 2007; Feytis, 2010a).

Refractory use trends for graphite closely follow events in the steel industry because graphite is used to manufacture refractory brick for lining iron and steel furnaces. The ability to refine and modify graphite is expected to be the key to future growth in the graphite industry. Refining techniques have enabled the use of improved graphite in electronics, foils, friction materials, and lubrication applications. Graphite "freeze" refractories are being developed and tested as an alternative to magnesia refractories

for ilmenite smelting by U.S.-based GrafTech International Holdings Inc. This technology uses a furnace lining of thermally conductive graphite and carbon to lower the temperature and remove heat from the furnace lining. Once the temperature drops below the melting point of the molten material in the furnace, a protective slag layer called a "skull" freezes onto the hot face of the refractory lining. Once the slag skull has formed, it extends the life of the lining by insulating the refractories from chemical attacks and thermal shocks (Industrial Minerals, 2009b). Graphite-based refractories also are used as continuous casting ware, usually in the form of nozzles to guide molten steel from ladle to mold. Brake linings and other friction materials are expected to steadily use more natural graphite as new automobile production continues to increase and more replacement parts are required for the increasing number of vehicles. Natural graphite (amorphous and fine flake) is used as a substitute for asbestos in brake linings for vehicles heavier than cars and light trucks. Flexible graphite products, such as grafoil (a thin graphite cloth), are expected to be the fastest growing market but are expected to use small quantities of natural graphite compared to major end-use markets, such as brake linings and refractories. Products produced by advanced refining technology in the next few years, despite a weak refractory market and competitive pricing from Chinese material, could increase profitability in the U.S. graphite industry.

There is also need to double the world's present flake graphite production to satisfy the forecast increased lithium-ion battery demand, particularly in automobiles. Synthetic graphite may offer the most promise for filling that demand (Industrial Minerals, 2009c; 2010a). The expected increase in manufacture and sales of hybrid and electric vehicles is likely to increase demand for high-purity graphite in fuel-cell and battery applications. Fuel cells are a potential high-growth, large-volume graphite (natural and synthetic) end use but are currently a very small part of consumption. High volumes of graphite are not expected to be consumed in this end use for many years but may be used in the longer term (Taylor, 2006, p. 517). In general, the forecasted need to double present graphite supplies to produce value-added graphite products for new energy applications has triggered reopening of shutdown graphite mines and development of graphite resources globally (O'Driscoll, 2010).

Increased global demand for graphite used in batteries will be divided between two main consuming sectors—alkaline batteries and lithium-ion batteries. Synthetic and natural graphite are used in these batteries. In alkaline batteries, graphite is the conductive material in the cathode. Until recently, synthetic graphite was predominantly used in these batteries. With the advent of new purification techniques and more efficient processing methods, it has become possible to improve the conductivity of most natural graphite to the point where it can be used in batteries. The decision of whether to use synthetic or natural graphite will be based on performance and price. The growth of the lithium-ion battery market could have a more dramatic effect on the graphite market as the demand for mobile energy storage systems rises.

There is a common industry trend toward higher purity and consistency in specifications for some specialized and high-tech applications. The trend to produce higher purity graphite using

thermal processing and acid leaching techniques continues. High-purity graphite has applications in advanced carbon graphite composites.

The markets for graphite used in rubber and plastics (including Styrofoam coatings) are increasing, and continued growth is expected. The U.S. market for graphite in pencils has almost disappeared; pencil “leads” now are imported directly from China (Taylor, 2006, p. 517). These markets, however, use little graphite and are not expected to have a significant impact on future consumption.

A California-based company was developing a technology that turns carbon dioxide emissions into high-purity synthetic graphite. With the world’s industrialized nations pledging to reduce their carbon dioxide emissions by 50% by 2050, this technology could become a promising new synthetic graphite source while helping industrialized nations reach their target goal (Industrial Minerals, 2009d).

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TABLE 1
 SALIENT NATURAL GRAPHITE STATISTICS¹

		2006	2007	2008	2009	2010
United States:						
Apparent consumption ²	metric tons	30,400	42,900	50,300	21,700	59,800
Exports:						
Quantity	do.	22,200	15,700	7,950	11,400	5,600
Value	thousands	\$16,000	\$19,100	\$15,600	\$21,600	\$15,200
Imports for consumption:						
Quantity	metric tons	52,600	58,600	58,300	33,100	65,400
Value	thousands	\$29,100	\$37,300	\$48,100	\$29,700	\$52,100
World, production ^e	metric tons	1,020,000	1,110,000	962,000 ^r	762,000 ^r	925,000

^eEstimated. ^rRevised. do. Ditto.

¹Data are rounded to no more than three significant digits.

²Domestic production plus imports minus exports.

TABLE 2
U.S. CONSUMPTION OF NATURAL GRAPHITE, BY END USE¹

End use	Crystalline		Amorphous ²		Total	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
2009:						
Batteries	W	W	--	--	W	W
Brake linings	376	\$1,560	2,810	W	3,190	W
Carbon products ³	257	644	W	W	W	W
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	W	W
Foundries ⁴	W	W	1,420	\$6,490	W	W
Lubricants ⁵	684	2,120	W	W	W	W
Pencils	W	W	W	W	W	W
Powdered metals	420	1,270	2	5	423	\$1,280
Refractories	8,060	6,230	W	W	W	W
Rubber	29	W	W	W	W	W
Steelmaking	W	W	W	W	W	W
Other ⁶	5,590	7,950	2,210	13,200	7,800	21,100
Total	16,900	23,300	23,100	95,300	40,000	119,000
2010:						
Batteries	W	W	--	--	W	W
Brake linings	332	1,250	3,040	W	3,380	W
Carbon products ³	306	929	W	W	W	W
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	W	W
Foundries ⁴	W	W	1,610	8,090	W	W
Lubricants ⁵	688	2,150	W	W	W	W
Pencils	W	W	W	W	W	W
Powdered metals	370	1,480	--	--	370	1,480
Refractories	12,500	11,600	W	W	W	W
Rubber	59	W	W	W	W	W
Steelmaking	W	W	W	W	W	W
Other ⁶	9,450	16,000	4,320	26,400	13,800	42,500
Total	25,600	37,100	25,700	112,000	51,200	149,000

W Withheld to avoid disclosing company proprietary data; included in "Total." -- Zero.

¹Data are rounded to no more than three significant digits.

²Includes mixtures of natural and manufactured graphite.

³Includes bearings and carbon brushes.

⁴Includes foundries (other) and foundry facings.

⁵Includes ammunition and packings.

⁶Includes antiknock and other compounds, drilling mud, electrical/electronic devices, industrial diamonds, magnetic tape, mechanical products, paints and polishes, small packages, soldering/welding, and other end-use categories.

TABLE 3
SHIPMENTS OF SYNTHETIC GRAPHITE BY U.S. COMPANIES, BY END USE¹

End use	Quantity (metric tons)	Value (thousands)
2009:		
Anodes	W	W
Cloth and fibers (low modulus)	W	\$165,000
Crucibles and vessels, refractories	W	W
Electric motor brushes and machined shapes	W	W
Electrodes	80,900	W
High-modulus fibers	W	W
Unmachined graphite shapes	8,680	91,300
Synthetic graphite powder and scrap ²	W	W
Other	W	W
Total	118,000	998,000
2010:		
Anodes	W	W
Cloth and fibers (low modulus)	W	195,000
Crucibles and vessels, refractories	W	W
Electric motor brushes and machined shapes	W	W
Electrodes	92,100	W
High-modulus fibers	W	W
Unmachined graphite shapes	7,430	96,900
Synthetic graphite powder and scrap ²	W	W
Other	W	W
Total	134,000	1,070,000

W Withheld to avoid disclosing company proprietary data; included in "Total."

¹Data are rounded to no more than three significant digits.

²Includes lubricants (alone/in greases), steelmaking carbon raisers, additives in metallurgy, and other powder data.

TABLE 4
REPRESENTATIVE YEAREND GRAPHITE PRICES¹

(Dollars per metric ton)

Type	2009	2010
Crystalline large, 94% to 97% carbon, +80 mesh	1,100–1,350	1,450–2,000
Crystalline large, 90% carbon, +80 mesh	700–800	1,100–1,350
Crystalline medium, 94% to 97% carbon, +100-80 mesh	880–1,150	1,350–1,900
Crystalline medium, 90% carbon, +100-80 mesh	650–750	1,050–1,300
Crystalline medium, 85% to 87% carbon, +100-80 mesh	650–750	1,000–1,400
Crystalline fine, 94% to 97% carbon, +100 mesh	620–1,000	1,250–1,700
Crystalline fine, 90% carbon, -100 mesh	550–600	950–1,300
Amorphous powder, 80% to 85% carbon	430	430–450
Synthetic 99.95% carbon ²	6,200–19,000	7,000–20,000

¹Prices are normally cost, insurance, and freight main European port.

²European port for 2009 and Swiss border for 2010.

Sources: Industrial Minerals, no. 507, December 2009, p. 68–69; no. 519, December 2010, p. 70.

TABLE 5
U.S. EXPORTS OF NATURAL AND SYNTHETIC GRAPHITE, BY COUNTRY^{1,2}

Country	Natural ³		Synthetic ⁴		Total	
	Quantity (metric tons)	Value ⁵ (thousands)	Quantity (metric tons)	Value ⁵ (thousands)	Quantity (metric tons)	Value ⁵ (thousands)
2009:						
Canada	1,070	\$961	3,230	\$7,820	4,300	\$8,780
China	1,790	3,210	2,460	8,860	4,250	12,100
France	11	17	3,630	19,000	3,640	19,000
Germany	65	170	1,300	3,360	1,370	3,530
Hong Kong	25	97	125	362	150	460
Italy	100	164	1,080	5,400	1,180	5,570
Japan	473	1,070	1,700	9,970	2,170	11,000
Korea, Republic of	4,490	7,250	1,970	6,400	6,460	13,600
Mexico	1,080	1,290	4,820	6,670	5,910	7,960
Netherlands	28	101	74	151	102	252
Taiwan	85	281	1,590	6,030	1,670	6,310
United Kingdom	265	2,850	657	1,830	922	4,680
Other	1,900	4,160	12,400	32,800	14,300	36,900
Total	11,400	21,600	35,000	109,000	46,400	130,000
2010:						
Canada	1,510	1,470	4,360	13,200	5,870	14,600
China	253	1,250	3,870	16,900	4,130	18,200
France	31	57	2,830	22,200	2,860	22,300
Germany	285	598	1,910	5,220	2,200	5,820
Hong Kong	12	79	74	200	86	279
Italy	198	265	1,190	5,390	1,380	5,660
Japan	728	1,480	1,040	5,280	1,760	6,770
Korea, Republic of	69	610	2,300	9,890	2,370	10,500
Mexico	934	1,080	5,350	7,840	6,290	8,920
Netherlands	16	193	483	911	499	1,100
Taiwan	111	346	2,010	7,820	2,120	8,160
United Kingdom	338	4,240	724	2,550	1,060	6,800
Other	1,110	3,520	13,900	39,100	15,000	42,700
Total	5,600	15,200	40,000	136,000	45,600	152,000

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

²Numerous countries for which data were reported have been combined in "Other."

³Amorphous, crystalline flake, lump and chip, and natural, not elsewhere classified. The applicable Harmonized Tariff Schedule of the United States (HTS) nomenclatures are "Natural graphite in powder or in flakes" and "Other," codes 2504.10.0000 and 2504.90.0000.

⁴Includes data from the applicable HTS nomenclatures "Artificial graphite" and "Colloidal or semicolloidal graphite," codes 3801.10.0000 and 3801.20.0000.

⁵Values are free alongside ship.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY^{1,2}

Country	Crystalline flake and flake dust		Lump and chippy dust		Other natural crude; high-purity; expandable		Amorphous		Total	
	Quantity (metric tons)	Value ³ (thousands)	Quantity (metric tons)	Value ³ (thousands)	Quantity (metric tons)	Value ³ (thousands)	Quantity (metric tons)	Value ³ (thousands)	Quantity (metric tons)	Value ³ (thousands)
2009:										
Austria	--	--	--	--	4	\$6	--	--	4	\$6
Brazil	989	\$1,170	--	--	1,860	3,030	--	--	2,850	4,190
Canada	2,150	1,860	--	--	4,180	8,540	--	--	6,330	10,400
China	15,100	9,430	--	--	--	--	--	--	15,100	9,430
Germany	--	--	--	--	72	205	--	--	72	205
Japan	--	--	--	--	105	1,250	--	--	105	1,250
Madagascar	899	839	--	--	--	--	--	--	899	839
Mexico	--	--	--	--	--	--	7,310	\$1,820	7,310	1,820
Singapore	--	--	--	--	3	21	--	--	3	21
Switzerland	--	--	--	--	63	350	--	--	63	350
Sri Lanka	--	--	134	\$189	--	--	--	--	134	189
United Kingdom	--	--	--	--	173	872	--	--	173	872
Other	--	--	--	--	5	95	--	--	5	95
Total	19,200	13,300	134	189	6,460	14,400	7,310	1,820	33,100	29,700
2010:										
Austria	--	--	--	--	14	25	--	--	14	25
Belgium	16	13	--	--	--	--	--	--	16	13
Brazil	2,420	2,960	--	--	1,520	2,740	--	--	3,940	5,700
Canada	3,150	3,830	--	--	4,960	8,580	--	--	8,110	12,400
China	39,900	25,900	--	--	--	--	--	--	39,900	25,900
Germany	--	--	--	--	208	510	--	--	208	510
India	--	--	--	--	3	11	--	--	3	11
Japan	--	--	--	--	90	2,210	--	--	90	2,210
Madagascar	858	738	--	--	--	--	--	--	858	738
Mexico	--	--	--	--	3	11	11,500	2,950	11,500	2,960
Sri Lanka	--	--	682	1,160	--	--	--	--	682	1,160
Switzerland	--	--	--	--	4	41	--	--	4	41
United Kingdom	--	--	--	--	95	491	--	--	95	491
Other	--	--	--	--	2	28	--	--	2	28
Total	46,400	33,400	682	1,160	6,910	14,600	11,500	2,950	65,400	52,100
-- Zero.										

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

²The information framework from which data for this material were derived originated from U.S. Harmonized Tariff Schedule base data.

³Customs values.

Source: U.S. Census Bureau; data adjusted by the U.S. Geological Survey.

TABLE 7
U.S. IMPORTS FOR CONSUMPTION
OF GRAPHITE ELECTRODES, BY COUNTRY^{1,2}

Country	Quantity (metric tons)	Value ³ (thousands)
2009:		
Canada	5,160	\$30,700
China	12,500	34,100
Germany	1,120	6,750
India	7,410	21,600
Japan	5,980	40,900
Mexico	8,980	24,000
Poland	1,810	7,910
Russia	5,560	15,300
South Africa	418	784
Ukraine	482	1,420
United Kingdom	851	4,930
Other	366 ^r	1,720 ^r
Total	50,600	190,000
2010:		
Canada	10,600	56,400
China	15,700	43,400
Germany	2,090	15,400
India	5,280	15,100
Japan	18,000	102,000
Mexico	20,000	58,400
Poland	1,290	5,530
Russia	11,600	31,000
South Africa	1,010	4,070
Ukraine	779	2,160
United Kingdom	1,260	5,590
Other	587	3,090
Total	88,200	342,000

^rRevised.

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

²The applicable Harmonized Tariff Schedule of the United States (HTS) nomenclature is "Electric furnace electrodes," code 8545.11.0000.

³Customs values.

Source: U.S. Census Bureau.

TABLE 8
 GRAPHITE: ESTIMATED WORLD PRODUCTION, BY COUNTRY ^{1,2}

(Metric tons)

Country	2006	2007	2008	2009	2010
Austria	--	--	250	750	1,000
Brazil, marketable	76,194 ³	77,163 ³	76,200 ^{r,3}	76,200	76,000 ^p
Canada	28,000	28,000	27,000	25,000	25,000
China	720,000	800,000	650,000 ^r	450,000 ^r	600,000
Czech Republic	5,000	3,000	3,000	--	--
India, run-of-mine ⁴	120,000	130,000	140,000	130,000	140,000
Korea, North	30,000	30,000	30,000	30,000	30,000
Korea, Republic of	68 ³	52 ³	73 ^{r,3}	48 ^r	50
Madagascar	4,857 ³	5,421 ^r	5,000 ^e	5,000	5,000
Mexico, amorphous	12,500	12,500	7,229 ^{r,3}	5,011 ³	6,759
Norway	2,300	2,000	2,000	2,000	2,000
Romania	--	--	--	20,000 ^r	20,000
Sri Lanka	5,756 ^{r,3}	9,593	6,615 ^r	7,000 ^r	8,000
Sweden	800	800	800	800	700
Turkey, run-of-mine ⁵	-- ^{r,3}	400	3,236 ^{r,3}	2,400 ^{r,3}	3,000
Ukraine	5,800 ^r	5,800	5,800	5,500 ^r	5,800
Uzbekistan	60	60	60	60	60
Zimbabwe	6,588 ³	5,418 ^{r,3}	5,134 ^{r,3}	2,463 ^{r,3}	2,000
Total	1,020,000	1,110,000	962,000 ^r	762,000 ^r	925,000

^pPreliminary. ^rRevised. -- Zero.

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

²Table includes data available through May 4, 2011.

³Reported figure.

⁴Indian marketable production is 10% to 20% of run-of-mine production.

⁵Turkish marketable production averages approximately 5% of run-of-mine production. Almost all is for domestic consumption.