USGS
science for a changing world

2009 Minerals Yearbook

GRAPHITE [ADVANCE RELEASE]

U.S. Department of the Interior
U.S. Geological Survey

March 2011

Graphite

By Donald W. Olson

Domestic survey data and tables were prepared by Danielle L. Militello, statistical assistant, and the world production table was prepared by Lisa D. Miller, international data coordinator.

In 2009, there was no reported production of natural graphite, but U.S. production of synthetic graphite was estimated to be 118,000 metric tons (t) valued at about $998 million. U.S. imports and exports of natural graphite were estimated to be 33,100 t and 11,400 t, respectively, while U.S. imports and exports of synthetic graphite were estimated to be 29,400 t and 35,000 t, respectively. U.S. apparent consumption of natural and synthetic graphite was estimated to be 21,700 t and 112,000 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. 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 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 11 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 2009, but 118,000 t of synthetic graphite with an estimated value of $998 million was produced and shipped (table 3).

Consumption

The USGS obtained the data in this report through a survey of natural graphite companies in the United States. The survey of natural graphite companies collected data from 55 of 90 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 decreased by 20% to 40,000 t in 2009 from 49,800 t in 2008 (table 2), owing to decreases of 11%, 58%, 18%, and 17% from the previous year in the amounts of natural graphite used in brake linings, foundries, lubricants, and steelmaking, respectively. 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 decreased in 2009 by 16% to 16,900 t from 20,200 t in 2008. Consumption of amorphous grade decreased by 22% to 23,100 t in 2009 from 29,600 t in 2008. Brake linings, refractories, and steelmaking were the three industries that dominated U.S. natural graphite use. Brake linings, foundries, lubricants, and steelmaking accounted for 74% of natural graphite consumption. The production of batteries and pencils together made up another 3% of consumption. The refractories industry was the leading consumer of crystalline flake graphite, accounting for almost 48% of crystalline flake graphite used in 2009.

Graphite has properties of both metals and nonmetals, 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 (Hawley, 2001).

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 a particle size of 100 mesh and a purity of 95% to 99% graphite.

Crystalline flake graphite accounted for about 42% 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 appropriate 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 significant portion of the synthetic graphite. Other significant 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 (George C. Hawley, President, George C. Hawley and Associates, written commun., January 16, 2004).

Prices

In January and February of 2009, graphite prices fell owing to decreases in demand from the U.S. automobile and construction industry sectors (Industrial Minerals, 2009a). During March and April, prices were unchanged as the graphite market remained constant, with ongoing weak demand (Industrial Minerals, 2009d). In the end of May and during June, prices started edging up owing to firm freight rates combined with a weakening U.S. dollar (Industrial Minerals, 2009c). Natural graphite prices continued a slow increase during the second half of 2009 for most types (Industrial Minerals, 2009e).

Prices for crystalline and crystalline flake graphite concentrates ranged from $550 to $1,350 per metric ton; prices for amorphous powder averaged $430 per ton (table 4). The average unit value of all U.S. natural graphite exports decreased by slightly to $1,900 per ton in 2009 from $1,960 per ton in 2008. Ash and carbon content, crystal and flake size, and size distribution affect the price of graphite. The European port price of synthetic graphite in 2009 ranged from $6,200 to $19,000 per ton. The average unit value of synthetic graphite exports increased slightly to $3,100 per ton in 2009 from $3,040 per ton in 2008 (table 5).

Foreign Trade

Total graphite exports decreased by 26% in tonnage to 46,400 t valued at $130 million in 2009 from 62,800 t valued at $182 million in 2008 owing to a 43% increase and a 36% decrease in natural and synthetic graphite exports, respectively. Total graphite export tonnage was 25% natural graphite and 75% synthetic graphite (table 5). Total natural graphite imports decreased by 43% in tonnage to 33,100 t in 2009 from 58,300 t in 2008, and the value decreased by 38% to $29.7 million in 2009 from $48.1 million in 2008 (table 6). 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 90% of the value of total imports. Mexico provided all the amorphous graphite, and Sri Lanka provided all the lump and chippy dust variety. China and Canada were, in descending order of tonnage, the major 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 decreased slightly in 2009 to an estimated 1.09 million metric tons (Mt) compared with 1.12 Mt in 2008. China maintained its position as the world's leading graphite producer, with 800,000 t. India was the second ranked graphite producer, with 130,000 t, followed by Brazil, North Korea, and Canada, in decreasing order of tonnage produced. These five countries accounted for 97% of world production, and China alone accounted for about 73% (table 8).

During the last half of 2008, global demand for graphite started weakening as the global economy slipped into a recession. Graphite demand continued to weaken until a bottom was reached in June 2009. Since June, market conditions improved somewhat and were not expected to get worse, but at yearend 2009, graphite demand was still slow. These market conditions were because of the recession's effects in the refractory and metallurgical sectors, in which graphite is widely used (Industrial Minerals, 2009b).

Outlook

Worldwide demand for graphite is expected to increase slowly as the world's economy comes out of recession.

An increasing trend of collaboration between Far Eastern and Western graphite producers is taking place in the graphite industry. These collaborations combine superior management, processing, and packaging techniques of Western companies with China's production power located in and adjacent to the largest markets. China offers the optimum cost-location balance. China has serious logistics challenges, though, such as freight issues and shipping problems, rising container rates, Chinese-Government-prioritized internal transportation, possible renewal of export taxes, and licensing law issues. Despite these challenges, the Chinese graphite industry was thriving and is expected to continue increasing (Moores, 2007).

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 furnace. 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 (Hand, l997). 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 utilizes a furnace lining of thermally conductive graphite and carbon to lower the temperature and remove the 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" is caused to freeze 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, 2009f). 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 amounts of natural graphite compared with 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 a 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, 2009g; 2010). 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).

Global demand for graphite used in batteries is expected to continue increasing and will be spread 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 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 growing, 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 U.S. company based in California 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, 2009h).

References Cited

Hand, G.P., 1997, Outlook for graphite and graphite technology: Mining Engineering, v. 49, no. 2, February, p. 34–36.
Hawley, G.C., 2001, New uses for graphite: Canadian Conference on Markets for Industrial Minerals, 13th, Toronto, Ontario, Canada, October 17, 2001, Presentation, 13 p.
Industrial Minerals, 2009a, Downturn softens graphite prices: Industrial Minerals, February 19. (Accessed July 13, 2010, via http://www.indmin.com/.)
Industrial Minerals, 2009b, Graphite demand still slow: Industrial Minerals, November 5. (Accessed November 20, 2009, via http://www.indmin.com/.)
Industrial Minerals, 2009c, Graphite prices edge up: Industrial Minerals, June 9. (Accessed July 13, 2010, via http://www.indmin.com/.)
Industrial Minerals, 2009d, Graphite prices in gridlock: Industrial Minerals, April 14. (Accessed July 13, 2010, via http://www.indmin.com/.)
Industrial Minerals, 2009e, Graphite prices on the rise: Industrial Minerals, October 8. (Accessed July 13, 2010, via http://www.indmin.com/.)
Industrial Minerals, 2009f, Graphite refractory for ilmenite: Industrial Minerals, April 7. (Accessed July 13, 2010, via http://www.indmin.com/.)
Industrial Minerals, 2009g, Li-ion graphite 'woefully short': Industrial Minerals, December 29. (Accessed July 13, 2010, via http://www.indmin.com/.)
Industrial Minerals, 2009h, Synthetic graphite from CO_2 gas: Industrial Minerals, June 17. (Accessed July 13, 2010, via http://www.indmin.com/.)
Industrial Minerals, 2010, Concern over battery grade graphite supplies: Industrial Minerals, January 24. (Accessed July 13, 2010, via http://www.indmin.com/.)
Moores, Simon, 2007, China draws in the West: Industrial Minerals, no. 481, October, p. 38–51.
Taylor, H.A., 2006, Graphite, *in* Kogel, J.E., Trivedi, N.C., Barker, J.M., and Krukowski, S.T., eds., Industrial minerals and rocks (7th ed.): Littleton, CO, Society for Mining, Metallurgy, and Exploration Inc., p. 507–518.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Graphite. Ch. in Mineral Commodity Summaries, annual.
Graphite. Ch. in United States Mineral Resources, Professional Paper 820, 1973.
Natural Graphite. International Strategic Minerals Inventory Summary Report, Circular 930–H, 1988.

TABLE 1
SALIENT NATURAL GRAPHITE STATISTICS[1]

		2005	2006	2007	2008	2009
United States:						
Apparent consumption[2]	metric tons	42,400	30,400	42,900	50,300	21,700
Exports:						
Quantity	do.	22,100	22,200	15,700	7,950	11,400
Value	thousands	$15,900	$16,000	$19,100	$15,600	$21,600
Imports for consumption:						
Quantity	metric tons	64,500	52,600	58,600	58,300	33,100
Value	thousands	$34,700	$29,100	$37,300	$48,100	$29,700
World, production	metric tons	1,030,000	1,020,000	1,110,000 r	1,120,000	1,090,000 e

[e]Estimated. [r]Revised. do. Ditto.
[1]Data are rounded to no more than three significant digits.
[2]Domestic production plus imports minus exports.

TABLE 2
U.S. CONSUMPTION OF NATURAL GRAPHITE, BY END USE[1]

End use	Crystalline Quantity (metric tons)	Crystalline Value (thousands)	Amorphous[2] Quantity (metric tons)	Amorphous[2] Value (thousands)	Total Quantity (metric tons)	Total Value (thousands)
2008:						
Batteries	W	W	--	--	W	W
Brake linings	515	$2,260	3,070	W	3,590	W
Carbon products[3]	266	693	W	W	W	W
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	W	W
Foundries[4]	W	W	3,600	$13,100	W	W
Lubricants[5]	844	2,910	W	W	W	W
Pencils	W	W	W	W	W	W
Powdered metals	561	1,770	4	8	565	$1,780
Refractories	7,210	6,280	W	W	W	W
Rubber	24	W	W	W	W	W
Steelmaking	W	W	W	W	W	W
Other[6]	8,830	12,900	3,670	21,600	12,500	34,500
Total	20,200	30,900	29,600	125,000	49,800	156,000
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

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

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

[2]Includes mixtures of natural and manufactured graphite.

[3]Includes bearings and carbon brushes.

[4]Includes foundries (other) and foundry facings.

[5]Includes ammunition and packings.

[6]Includes 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 USE[1]

End use	Quantity (metric tons)	Value (thousands)
2008:		
Anodes	W	W
Cloth and fibers (low modulus)	W	$211,000
Crucibles and vessels, refractories	W	W
Electric motor brushes and machined shapes	W	W
Electrodes	134,000	W
High-modulus fibers	5,720	168,000
Unmachined graphite shapes	10,800	118,000
Synthetic graphite powder and scrap[2]	W	W
Other	W	W
Total	196,000	1,050,000
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

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

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

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

TABLE 4

REPRESENTATIVE YEAREND GRAPHITE PRICES[1]

(Dollars per metric ton)

Type	2008	2009
Crystalline large, 94% to 97% carbon, +80 mesh	900–1,000	1,100–1,350
Crystalline large, 90% carbon, +80 mesh	100–800	700–800
Crystalline medium, 94% to 97% carbon, +100-80 mesh	800–900	880–1,150
Crystalline medium, 90% carbon, +100-80 mesh	680–780	650–750
Crystalline medium, 85% to 87% carbon, +100-80 mesh	670–770	650–750
Crystalline fine, 94% to 97% carbon, +100 mesh	600–700	620–1,000
Crystalline fine, 90% carbon, -100 mesh	550–650	550–600
Amorphous powder, 80% to 85% carbon	460	430
Synthetic 99.95% carbon[2]	5,550–17,900	6,200–19,000

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

[2]Swiss border for 2008 and European port for 2009.

Sources: Industrial Minerals, no. 495, December 2008, p. 88; no. 507, December 2009, p. 68, 69.

TABLE 5

U.S. EXPORTS OF NATURAL AND ARTIFICIAL GRAPHITE, BY COUNTRY[1, 2]

	Natural[3]		Artificial[4]		Total	
Country	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)
2008:						
Canada	1,500	$1,130	8,330	$13,500	9,830	$14,600
China	259	323	6,100	22,500	6,360	22,700
France	20	189	5,130	31,900	5,150	32,100
Germany	125	441	2,010	5,030	2,140	5,470
Hong Kong	3	13	156	486	159	498
Italy	269	447	1,220	4,770	1,490	5,220
Japan	727	1,360	3,290	16,100	4,020	17,500
Korea, Republic of	149	1,330	2,830	10,500	2,980	11,800
Mexico	1,120	1,130	6,040	6,630	7,160	7,760
Netherlands	47	72	596	2,180	642	2,250
Taiwan	305	478	2,170	6,280	2,470	6,760
United Kingdom	379	2,100	1,480	3,410	1,860	5,510
Other	3,060	6,570	15,500	43,100	18,600	49,900
Total	7,950	15,600	54,900	166,000	62,800	182,000
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

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

[2]Numerous countries for which data were reported have been combined in “Other.”

[3]Amorphous, 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.

[4]Includes data from the applicable HTS nomenclatures “Artificial graphite” and “Colloidal or semicolloidal graphite,” codes 3801.10.0000 and 3801.20.0000.

[5]Values 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)
2008:										
Brazil	2,800	$3,600	--	--	26	$46	--	--	2,820	$3,640
Canada	10,900	8,890	--	--	1,770	7,570	--	--	12,700	16,500
China	27,900	18,800	--	--	--	--	--	--	27,900	18,800
Germany	--	--	--	--	127	1,000	--	--	127	1,000
Guyana	--	--	--	--	--	--	1,380	$92	1,380	92
Japan	--	--	--	--	140	1,500	--	--	140	1,500
Madagascar	799	653	--	--	--	--	--	--	799	653
Mexico	--	--	--	--	--	--	11,500	2,510	11,500	2,510
Sri Lanka	--	--	523	$1,330	--	--	--	--	523	1,330
United Kingdom	--	--	--	--	211	914	--	--	211	914
Other[4]	18	17	--	--	107	1,110	43	8	168	1,140
Total	42,500	32,000	523	1,330	2,380	12,100	12,900	2,610	58,300	48,100
2009:										
Brazil	989	1,170	--	--	1,860	3,030	--	--	2,850	4,200
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
Guyana	--	--	--	--	--	--	--	--	--	--
Japan	--	--	--	--	105	1,250	--	--	105	1,250
Madagascar	899	839	--	--	--	--	--	--	899	839
Mexico	--	--	--	--	--	--	7,310	1,820	7,310	1,820
Sri Lanka	--	--	134	189	--	--	--	--	134	189
United Kingdom	--	--	--	--	173	872	--	--	173	872
Other[4]	--	--	--	--	75	470	--	--	75	470
Total	19,200	13,300	134	189	6,460	14,400	7,310	1,820	33,100	29,700

-- Zero.

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

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

[3]Customs values.

[4]Includes Austria (2008), Belgium (2008), Czech Republic (2008), France (2009), India (2008), Italy, Japan (2009), Korea, Republic of, Netherlands (2008), Russia (2008), Singapore (2009), Sweden (2008), Switzerland, Taiwan (2009), and Ukraine (2008).

Source: U.S. Census Bureau, 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)
2008:		
Canada	9,640	$45,100
China	29,000	61,200
Germany	2,020	13,600
India	1,010	2,870
Italy	129	265
Japan	18,100	87,200
Mexico	23,800	62,400
Poland	4,410	10,900
Russia	7,350	12,400
Ukraine	961	2,570
Other[4]	1,650	4,630
Total	98,100	303,000
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
Ukraine	482	1,420
United Kingdom	851	4,930
Other[4]	784	2,500
Total	50,600	190,000

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

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

[3]Customs values.

[4]Includes data for countries that ship less than 1,000 metric tons per year to the United States.

Source: U.S. Census Bureau.

TABLE 8

GRAPHITE: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country	2005	2006	2007	2008	2009[e]
Brazil, marketable	77,494 [r, 3]	76,194 [3]	77,163 [3]	76,200 [r, 3]	76,200
Canada	28,000	28,000	28,000	27,000	25,000
China	720,000	720,000	800,000	810,000	800,000
Czech Republic	3,000	5,000	3,000	3,000	--
Germany, marketable	2,638 [3]	--	--	--	--
India, run-of-mine[4]	130,000	120,000	130,000	140,000	130,000
Korea, North	32,000	30,000	30,000	30,000	30,000
Korea, Republic of	39 [3]	68 [3]	52 [3]	73 [r, 3]	70
Madagascar	6,400 [3]	4,857 [3]	5,000	5,000 [e]	5,000
Mexico, amorphous	12,357 [3]	12,500	12,500	7,229 [r, 3]	5,011 [p, 3]
Norway	2,300	2,300	2,000	2,000	2,000
Romania	500	--	--	--	--
Sri Lanka	3,000	5,756 [r, 3]	9,593 [r, 3]	10,000 [r]	11,000
Sweden	800	800	800	800	800
Turkey, run-of-mine[5]	100	300	400	400	400
Ukraine	10,400 [r]	5,800 [r]	5,800 [r]	5,800 [r]	5,800
Uzbekistan	60	60	60	60	60
Zimbabwe	4,298 [3]	6,588 [3]	6,000 [r]	5,000 [r]	2,500
Total	1,030,000	1,020,000	1,110,000 [r]	1,120,000	1,090,000

[e]Estimated. [p]Preliminary. [r]Revised. -- Zero.

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

[2]Table includes data available through May 5, 2010.

[3]Reported figure.

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

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