2011 Minerals Yearbook

GRAPHITE

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

December 2013

Graphite

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In 2011, there was no reported domestic production of natural graphite, but U.S. production of synthetic graphite was estimated to be 148,000 metric tons (t) valued at about $1.05 billion. U.S. exports and imports of natural graphite were estimated to be 6,280 t and 71,800 t, respectively. U.S. exports and imports of synthetic graphite were estimated to be 53,900 t and 79,700 t, respectively. U.S. apparent consumption of natural and synthetic graphite was estimated to be 65,500 t and 173,000 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 used to produce graphene. Graphene is extremely light and strong (Topf, 2012). 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 17 canvassed producers. Data were estimated for the producers that did not respond to the survey based on responses received in previous years, industry production trends, reports from other industry sources, and discussions with consultants within the graphite industry.

No natural graphite was reported mined in the United States in 2011, but 148,000 t of synthetic graphite with an estimated value of $1.05 billion was produced and shipped (tables 1, 3).

The first process to produce synthetic graphite was invented in the mid-1890s by Edward Goodrich Acheson. He discovered that by heating carborundum to high temperatures, at about 4,150 °C (7,500 °F), the silicon vaporizes, leaving behind almost pure graphitic carbon. Synthetic graphite electrodes that carry the electricity that melts scrap iron and steel or direct-reduced iron in electric arc furnaces are made from petroleum coke mixed with coal tar pitch. The mixture is extruded and shaped, then baked to carbonize the pitch, and finally graphitized by heating it to temperatures approaching 3,000 °C, to convert the carbon to graphite. Synthetic graphite powder is made by heating powdered petroleum coke above the temperature of graphitization (3,000 °C), sometimes with minor modifications (Kopeliovich, 2012).

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 50 of 94 canvassed companies and plants. Data were estimated for the companies that did not respond to the survey based on responses received in previous years, industry consumption trends, reports from other industry sources, and discussions with consultants within the graphite industry. This end-use survey represented most of the graphite industry in the United States.

U.S. consumption of natural graphite reported by end use increased by 29% to 66,100 t in 2011 from 51,200 t in 2010 (table 2), owing to increases of 64% and 15% from the previous year in the amounts of natural graphite used in refractories and the "Other" end-use category, respectively. The "Other" end-use category includes antiknock gasoline additives and other chemical compounds, batteries, crucibles, drilling mud, electrical/electronic devices, industrial diamonds, magnetic tape, mechanical products, nozzles, paints and polishes, pencils, retorts, sleeves, small packages, soldering/welding, steelmaking, stoppers, 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 consumption data reported by end use may include company stocks from previous years. Consequently, the table 2 reported consumption numbers are different from the computed apparent consumption numbers given in table 1. Consumption of crystalline graphite increased in 2011 by 40% to 35,700 t from 25,600 t in 2010. Consumption of amorphous graphite increased by 18% to 30,400 t in 2011 from 25,700 t in 2010. Brake linings, refractories, and steelmaking were the three industries that dominated U.S. natural graphite use. Brake linings and refractories combined accounted for 47% of natural graphite consumption. Foundries and lubricants accounted for another 4% of natural graphite consumption. The refractories industry was the leading consumer of crystalline flake graphite used in 2011.

Graphite has metallic and nonmetallic properties, which make 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 54% 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 use 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 major 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. High purity natural and synthetic graphite are 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.

High purity natural and synthetic graphite have 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 doubling the current graphite supply when fully implemented (O'Driscoll, 2010).

Graphene has been referred to as "the world's next wonder material." This is because this material composed of a tightly packed single layer of carbon atoms that can be used to make inexpensive solar panels, very powerful transistors, and wafer-thin tablets that could be the next-generation tablet computers (Topf, 2012).

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). In 2011, graphite prices continued increasing for all forms of natural graphite, with median yearend prices increasing between 42% and 84% (table 4).

Prices for crystalline and crystalline flake graphite concentrates ranged from $1,400 to $3,000 per metric ton; prices for amorphous powder ranged from $600 to $800 per ton (table 4). The average unit value of all U.S. natural graphite exports decreased by 13% to $2,360 per ton in 2011 from $2,720 per ton in 2010. Ash and carbon content, crystal and flake size, and size distribution affect the price of graphite. The European port price of synthetic graphite in 2011 ranged from $7,000 to $20,000 per ton. The average unit value of synthetic graphite exports decreased by 4% to $3,270 per ton in 2011 from $3,410 per ton in 2010 (table 5).

Foreign Trade

Total graphite exports increased by 32% in tonnage to 60,200 t valued at $191 million in 2011 from 45,600 t valued at $152 million in 2010. Total graphite export tonnage was 10% natural graphite and 90% synthetic graphite (table 5). Total natural graphite imports increased by 10% in tonnage to 71,800 t in 2011 from 65,400 t in 2010, and the value increased by 56% to $81.3 million in 2011 from $52.1 million in 2010 (table 6). This large increase in value was owing to an increase of $19.8 million in the value of the "other natural crude" graphite category during 2011. Principal import sources of natural graphite were, in descending order of tonnage, China, Mexico, Canada, Brazil, Madagascar, and Sri Lanka, which combined, accounted for 99% of the tonnage and 93% 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, and Madagascar were, in descending order of tonnage, the leading 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 China.

World Review

World production of natural graphite increased slightly in 2011 to an estimated 1.15 million metric tons (Mt) compared with 1.13 Mt in 2010. China maintained its position as the world's leading graphite producer, with 800,000 t or 70% of the total. India was the second ranked graphite producer, with 150,000 t, followed by Brazil, North Korea, Canada, and Romania, in decreasing order of tonnage produced. These six countries accounted for 95% of world production (table 8).

Eight companies were exploring for graphite in Canada. This exploration was focused on properties in Ontario and Quebec (Topf, 2012).

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 of 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 had made progress in eliminating logistics challenges, such as freight issues, shipping problems, and rising container rates (Moores, 2007; Feytis, 2010). In 2011, the Chinese Government ordered the majority of graphite mines it controls in the Hunan Province to be closed for environmental and resource protection. This action is expected to cause future production decreases for the world's leading graphite producer. Amorphous graphite availability will most likely decline, while flake graphite production will probably remain stable (Moores, 2011). The Chinese Government also began restricting graphite exports in order to protect its own domestic industries (Topf, 2012). These restrictions also are expected to cause future decreases in graphite marketplace supplies.

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 also is 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. 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. 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).

References Cited

Feytis, Alex, 2010, Graphite supply situation report—Graphite set to move up a gear: Industrial Minerals, no. 510, March, p. 29–31.

Industrial Minerals, 2009a, Graphite prices on the rise: Industrial Minerals, October 8. (Accessed July 13, 2010, via http://www.indmin.com/.)

Industrial Minerals, 2009b, Graphite refractory for ilmenite: Industrial Minerals, April 7. (Accessed July 13, 2010, via http://www.indmin.com/.)

Industrial Minerals, 2009c, Li-ion graphite 'woefully short': Industrial Minerals, December 29. (Accessed July 13, 2010, via http://www.indmin.com/.)

Industrial Minerals, 2009d, Synthetic graphite from CO_2 gas: Industrial Minerals, June 17. (Accessed July 13, 2010, via http://www.indmin.com/.)

Industrial Minerals, 2010a, Concern over battery grade graphite supplies: Industrial Minerals, January 24. (Accessed July 13, 2010, via http://www.indmin.com/.)

Industrial Minerals, 2010b, Graphite prices rising daily: Industrial Minerals, June 29. (Accessed July 4, 2010, via http://www.indmin.com/.)

Kopeliovich, Dmitri, 2012, Graphite manufacturing process: SubsTech Forum, August 25. (Accessed September 25, 2012, at http://www.substech.com/dokuwiki/doku.php?id=graphite_manufacturing_process.)

Moores, Simon, 2007, China draws in the West: Industrial Minerals, no. 481, October, p. 38–51.

Moores, Simon, 2011, Top ten—Graphite production 2011: Industrial Minerals, November 3. (Accessed August 22, 2012, via http://www.indmin.com/.)

O'Driscoll, Mike, 2010, Minerals meet in Miami heat: Industrial Minerals, no. 510, March, p. 67–75.

Topf, Andrew, 2012, Riding the graphite bull: Mining.com, March 27. (Accessed August 22, 2012, via http://www.mining.com/.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Graphite (Natural). Ch. in Mineral Commodity Summaries, annual.

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

Historical Statistics for Mineral and Material Commodities in the United States, Data Series 140.

Natural Graphite. International Strategic Minerals Inventory Summary Report, Circular 930–H, 1988.

TABLE 1

SALIENT NATURAL AND SYNTHETIC GRAPHITE STATISTICS[1]

		2007	2008	2009	2010	2011
United States:						
Natural:						
Exports:						
Quantity	metric tons	15,700	7,950	11,400	5,600	6,280
Value	thousands	$19,100	$15,600	$21,600	$15,200	$14,800
Imports for consumption:						
Quantity	metric tons	58,600	58,300	33,100	65,400	71,800
Value	thousands	$37,300	$48,100	$29,700	$52,100	$81,300
Apparent Consumption:[2]						
Quantity	metric tons	42,900	50,300	21,700	59,800	65,500
Value	thousands	$18,100	$32,500	$8,050	$36,900	$66,500
World production, Natural[e]	metric tons	1,120,000 [r]	975,000 [r]	744,000 [r]	1,130,000 [r]	1,150,000
Synthetic:						
Production:						
Quantity	metric tons	198,000	196,000	118,000	134,000	148,000
Value	thousands	$1,180,000	$1,050,000	$998,000	$1,070,000	$1,050,000
Exports:						
Quantity	metric tons	44,100	54,900	35,000	40,000	53,900
Value	thousands	$128,000	$166,000	$109,000	$136,000	$177,000
Imports for consumption:						
Quantity	metric tons	51,500	66,600	33,800	44,000	79,700
Value	thousands	$128,000	$131,000	$79,400	$119,000	$176,000
Apparent Consumption:[2]						
Quantity	metric tons	205,000	208,000	116,000	138,000	173,000
Value	thousands	$1,180,000	$1,010,000	$969,000	$1,050,000	$1,050,000

[e]Estimated. [r]Revised.

[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)
2010:						
Brake lining	332	W	3,040	W	3,380	W
Carbon products[3]	306	W	232	W	538	$2,280
Foundries[4]	W	W	W	W	1,760	W
Lubricants[5]	683 r	W	355	W	1,040	4,070
Powdered metals	370	1,480	--	--	370	1,480
Refractories	W	W	W	W	16,800	16,600
Rubber	W	W	W	W	372	W
Other[6]	11,200 r	W	15,800	W	27,000 r	104,000 r
Total	25,500 r	37,000 r	25,700	W	51,200 r	149,000 r
2011:						
Brake lining	442	W	2,970	W	3,420	W
Carbon products[3]	W	W	W	W	622	2,750
Foundries[4]	W	W	W	W	1,680	W
Lubricants[5]	W	W	W	W	1,090	4,490
Powdered metals	309	1,300	--	--	309	1,300
Refractories	W	W	W	W	27,500	34,500
Rubber	W	W	W	W	396	W
Other[6]	11,200	W	19,900	W	31,100	131,000
Total	35,700	52,600	30,400	142,000	66,100	195,000

rRevised. W Withheld to avoid disclosing company proprietary data; included in “Total.” -- Zero.
[1]Data are rounded to no more than three significant digits.
[2]Includedes mixtures of natural and manufactured graphite.
[3]Includes bearings and carbon brushes.
[4]Includes foundries (other) and foundry facings.
[5]Includes ammunition packings.
[6]Includes antiknock gasoline additives and other compounds, batteries, crucibles, drilling mud, electrical/electronic devices, industrial diamonds, magnetic tape, mechanical products, nozzles, paints and polishes, pencils, retorts, sleeves, small packages, soldering/welding, steelmaking, stoppers, 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)
2010:		
Cloth and fibers (low modulus)	W	$195,000
Electrodes	92,100	W
Unmachined graphite shapes	7,430	96,900
Other[2]	W	W
Total	134,000	1,070,000
2011:		
Cloth and fibers (low modulus)	W	W
Electrodes	93,300	532,000
Unmachined graphite shapes	8,860	122,000
Other[2]	45,600	395,000
Total	148,000	1,050,000

W Withheld to avoid disclosing company proprietary data; included in “Total.”
[1]Data are rounded to no more than three significant digits.
[2]Includes anodes, crucibles and vessels, electric motor brushes and machined shapes, high-modulus fibers, lubricants (alone/in greases), refractories, steelmaking carbon raisers, additives in metallurgy, and other powder data.

TABLE 4
REPRESENTATIVE YEAREND GRAPHITE PRICES[1]

(Dollars per metric ton)

Type	2010	2011
Crystalline large, 94% to 97% carbon, +80 mesh	1,450–2,000	2,500–3,000
Crystalline large, 90% carbon, +80 mesh	1,100–1,350	2,000–2,500
Crystalline medium, 94% to 97% carbon, +100-80 mesh	1,350–1,900	2,200–2,500
Crystalline medium, 90% carbon, +100-80 mesh	1,050–1,300	1,500–2,000
Crystalline medium, 85% to 87% carbon, +100-80 mesh	1,000–1,400	1,500–1,900
Crystalline fine, 94% to 97% carbon, +100 mesh	1,250–1,700	2,000–2,400
Crystalline fine, 90% carbon, -100 mesh	950–1,300	1,400–1,800
Amorphous powder, 80% to 85% carbon	430–450	600–800
Synthetic 99.95% carbon[2]	7,000–20,000	7,000–20,000

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

Source: Industrial Minerals, no. 519, December 2010, p. 70; no. 531, December 2011, p. 62.

TABLE 5
U.S. EXPORTS OF NATURAL AND SYNTHETIC GRAPHITE, BY COUNTRY[1, 2]

	Natural[3]		Synthetic[4]		Total	
Country	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)
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
2011:						
Canada	1,590	1,980	6,170	15,200	7,760	17,100
China	277	565	5,120	25,500	5,390	26,100
France	24	92	3,460	26,300	3,480	26,400
Germany	425	831	2,740	7,800	3,170	8,630
Hong Kong	11	62	262	818	273	879
Italy	253	450	1,230	6,770	1,480	7,220
Japan	722	1,930	2,070	10,500	2,790	12,500
Korea, Republic of	62	287	3,390	14,300	3,450	14,600
Mexico	1,360	1,620	7,720	9,730	9,080	11,300
Netherlands	123	138	162	672	285	810
Taiwan	91	463	3,950	6,280	4,040	6,740
United Kingdom	227	3,430	981	2,540	1,210	5,970
Other	1,110	3,000	16,700	50,100	17,800	53,100
Total	6,280	14,800	53,900	177,000	60,200	191,000

[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 applicable HTS nomenclatures “Artificial graphite” and “Colloidal or semicollidal 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)
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
2011:										
Austria	--	--	--	--	15	27	--	--	15	27
Brazil	--	--	--	--	3,940	7,290	--	--	3,940	7,290
Canada	12,300	16,600	--	--	--	--	--	--	12,300	16,600
China	20,700	22,600	--	--	13,900	21,800	--	--	34,500	44,400
Germany	--	--	--	--	167	702	--	--	167	702
India	--	--	--	--	26	118	--	--	26	118
Japan	--	--	--	--	186	3,760	--	--	186	3,760
Madagascar	831	873	--	--	--	--	--	--	831	873
Mexico	--	--	--	--	--	--	19,000	5,700	19,000	5,700
Sri Lanka	--	--	616	1,120	--	--	--	--	616	1,120
United Kingdom	--	--	--	--	114	584	--	--	114	584
Other	24	27	--	--	27	163	--	--	52	163
Total	33,900	40,100	616	1,120	18,300	34,400	19,000	5,700	71,800	81,300

-- 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 U.S. Harmonized Tariff Schedule base data.

[3]Customs 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)
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
2011:		
Canada	11,700	59,900
China	26,200	52,500
Germany	3,010	21,400
India	16,300	37,800
Japan	19,800	99,800
Mexico	16,100	46,800
Poland	1,120	4,930
Russia	10,000	27,900
South Africa	2,050	8,410
Ukraine	1,890	5,200
United Kingdom	242	1,070
Other	1,230	6,150
Total	110,000	372,000

[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.

Source: U.S. Census Bureau.

TABLE 8

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

(Metric tons)

Country	2007	2008	2009	2010	2011
Austria	--	--	750	420 r	800
Brazil, marketable	77,163 3	74,831 r, 3	59,425 r, 3	72,623 r, 3	73,000 p
Canada	28,000	27,000	15,000 r	20,000 r	25,000
China	800,000	650,000	450,000 r	800,000 r	800,000
Czech Republic	3,000	3,000	--	--	--
India, run-of-mine[4]	130,000	140,000	130,000	140,000	150,000
Korea, North	30,000	30,000	30,000	30,000	30,000
Korea, Republic of	52 3	73 3	48	34 r	50
Madagascar	5,351 r, 3	4,967 r, 3	3,437 r, 3	3,783 r, 3	3,800
Mexico, amorphous	12,500	7,229 3	5,011 3	6,759 3	6,700
Norway	2,000	2,000	2,000	2,000	1,500
Romania	--	--	20,000	20,000	20,000
Russia	14,000	14,000	14,000	14,000	14,000
Sri Lanka	9,593 3	6,615 3	3,171 r, 3	3,437 r, 3	3,500
Sweden	800	800	800	700	700
Turkey, run-of-mine[5]	400	3,236 3	2,400 3	3,000	10,000
Ukraine	5,800	5,800	5,500	5,800	5,800
Uzbekistan	60	60	60	60	60
Zimbabwe	5,418 3	5,134 3	2,463 3	5,000 r	5,000
Total	1,120,000 r	975,000 r	744,000 r	1,130,000 r	1,150,000

pPreliminary. rRevised. -- 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 11, 2012.

[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.