2020 Minerals Yearbook

GRAPHITE [ADVANCE RELEASE]

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

September 2024

Graphite

By Donald W. Olson

Domestic survey data and tables were prepared by Annie Hwang, statistical assistant.

In 2020, no domestic production of natural graphite was reported, but U.S. production of synthetic graphite was 236,000 metric tons (t) valued at $1.22 billion. U.S. exports and imports of natural graphite equaled 5,930 t and 36,000 t, respectively. U.S. exports and imports of synthetic graphite totaled 26,900 t and 62,600 t, respectively. U.S. apparent consumption of natural and synthetic graphite equaled 30,000 t and 272,000 t, respectively. World production of natural graphite totaled 966,000 t (tables 1, 9).

Graphite is one of four forms of crystalline carbon; the other forms 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. Graphite is gray to black in color, opaque, and usually has a metallic luster, although it sometimes 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 degrees Celsius (°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 of these properties combined make both natural and synthetic graphite desirable for many industrial applications.

Natural graphite is classified into three types—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. The term “amorphous” is used for lower value graphite products and is the lowest priced graphite. Large amorphous graphite deposits are found in Europe, China, Mexico, and the United States. The 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 graphite. Flake graphite occurs as separate flakes that crystallized in metamorphic rock, and high-quality flake graphite can be four times the price of amorphous graphite. Good quality flakes can be processed into expandable graphite for many uses, such as flame retardants. The foremost deposits of flake graphite are found in Austria, Brazil, Canada, China, Germany, Madagascar, Mozambique, Tanzania, and in Alabama, Alaska, and New York in the United States. 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.

Natural graphite is mined from open pit and underground mines. Production from open pit operations is preferred because it is less expensive where the overburden can be removed economically. Mines in China, Madagascar, and Mozambique are mostly of this type. In the Republic of Korea, Mexico, and Sri Lanka, where the deposits are deep, underground mining techniques are required.

Beneficiation processes for graphite ores may vary from complex four-stage flotation at mills in Europe and North America to simple hand sorting and screening of high-grade ore at operations in Sri Lanka. In the typical beneficiation process used in Europe and North America, the 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 and is then screened to produce a variety of products marketed as flake graphite that contain 85% to 90% carbon. Certain soft graphite ores, such as those found in Madagascar, need no primary crushing and grinding. Such ores usually contain the highest proportion of coarse flakes.

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 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 graphite’s 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. 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 flat parallel sheets of carbon atoms in a hexagonal arrangement. It is possible to insert other atoms between the sheets, a process called intercalation. The insertion of other atoms dramatically changes the properties of graphite. 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 had applications in high-temperature corrosive environments, such as iron blast furnaces, ladles, and steel furnaces. Carbon-alumina linings were used principally in continuous casting steel operations. Alumina- and magnesite-carbon brick requires graphite with a particle size of 100 mesh and a purity of 95% to 99% 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. Data were estimated for nonrespondents 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 mined in the United States in 2020, but 236,000 t of synthetic graphite, valued at $1.22 billion, was produced and shipped (tables 1, 3). This was a 17% decrease in quantity produced and a slight decrease in value compared with that in the previous year. This decrease in quantity was due to large decreases in the production of electric motor brushes and machined graphite shapes, high modulus fibers, and unmachined graphite shapes owing to the negative economic effects of the global coronavirus disease 2019 (COVID-19) pandemic.

Synthetic graphite electrodes used to conduct electricity to melt scrap iron and steel or direct-reduced iron in electric arc furnaces were made from petroleum coke mixed with coal tar pitch. The mixture was 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, 2020).

Exploration and Development

During 2020, two companies were developing and evaluating graphite deposit projects in the United States. Westwater Resources, Inc. (Centennial, CO) was developing the Coosa Graphite project and the Bama Mine project in Alabama, and Graphite One Inc. (Vancouver, British Columbia, Canada) was developing the Graphite Creek project in Alaska (Graphite One Inc., 2021a; Westwater Resources, Inc., 2021a, b).

During 2020, Westwater Resources continued exploring, evaluating, and developing the Bama Mine project and the Coosa Graphite project. The Bama Mine project and the Coosa Graphite project were within the geologic trend of high-quality graphite deposits called the Alabama Graphite Belt from which significant quantities of graphite were produced from the late 1800s through the 1950s. The Bama Mine project encompassed more than 520 hectares (ha) (1,300 acres) in Chilton County, AL, which included the Bama Mine. The Bama Mine, the southernmost mine in the Alabama Graphite Belt, previously produced larger quantities and higher quality flake graphite than any other graphite mine in Alabama. The Bama Mine stopped production in the 1930s because a fire destroyed the mill. In the area of the Bama Mine, widespread weathered graphitic schist occurs at the surface. The Bama Mine project site had access to power and water, existing road and rail infrastructure included within the site, and it is located about 14 kilometers (km) [9 miles (mi)] from an interstate highway and less than 1.5 km (1 mi) from a major railroad (Westwater Resources, Inc., 2021a). During 2020, Westwater Resources also continued exploring and developing its 100%-owned Coosa Graphite project. The Coosa Graphite project consisted of 17,000 ha (42,000 acres) in an area in Coosa County, AL, that was a significant producer of high-grade crystal flake graphite in the past. Alabama Graphite evaluated the deposit and reported an indicated resource of 71.2 million metric tons (Mt) grading 2.39% graphite and an inferred resource of 72.1 Mt grading 2.56% graphite (Westwater Resources, Inc., 2021b). In 2020, Westwater Resources was considering the construction of a graphite-processing facility that would supply material at 99.95% carbon that included coated spherical graphite (CSG), expanded graphite, and purified micronized graphite (PMG). In late 2019, Westwater Resources purchased graphite for testing their pilot process (Roskill Information Services Ltd., 2020).

Following a 2018 field program, Graphite One increased and updated the project's resource estimates in March 2019 from those of the preliminary environmental assessment (PEA). With a cutoff grade of 5.0% graphitic carbon (Cg), inferred resources were estimated to be 91.89 Mt of 8.0% Cg for 7,342,883 t of graphite content, indicated resources were estimated to be 9.26 Mt of 7.7% Cg for 715,363 t of graphite content, and measured resources were estimated to be 1.69 Mt of 8.0% Cg for 135,171 t of graphite content. Full production level would be reached in year 6 of operation. The manufacturing plant was expected to convert 60,000 metric tons per year (t/yr) of concentrate into 41,850 t/yr of CSG and 13,500 t/yr of PMG. Graphite One assumed a selling price of $6,200 per metric ton for CSG and $1,500 per metric ton for PMG, which was expected to generate estimated annual sales of $280 million and annual post-tax earnings of $118 million or $2,132 per metric ton (Graphite One Inc., 2021b, d).

During 2020, Graphite One was delineating, evaluating, and developing a massive, near-surface deposit at its Graphite Creek project, which included 176 mineral claims in a known graphite mineralization region of 9,583 ha on the Seward Peninsula in western Alaska, about 55 km (37 mi) north of Nome. The Graphite Creek deposit consisted of large-flake, high-grade graphite. Graphite One also completed a prefeasibility study in 2020 (Roskill Information Services Ltd., 2020; Graphite One Inc., 2021d).

The PEAs of Graphite One and Westwater Resources both included product manufacturing plants that were expected to produce CSG and PMG. CSG was used in lithium-ion batteries. PMG was used as a conductivity enhancement material for a variety of battery applications. Westwater Resources tested their process, which produced PMG material suitable for use in battery manufacturing (Westwater Resources, Inc., 2018, 2019; Graphite One Inc., 2021b, c).

Consumption

The USGS obtained the consumption data in this report through a survey of companies that imported and used natural graphite in the United States. Data were estimated for nonrespondents 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 decreased by 6% to 50,600 t in 2020 from that in 2019 (table 2).

The reported natural graphite consumption data in table 2 include a small amount of mixed natural and synthetic graphite in the amorphous graphite category. Apparent consumption in table 1 does not include unreported changes in company stocks and therefore differs from reported consumption in table 2. Reported consumption of crystalline graphite decreased by 7% in 2020 to 21,600 t from 23,300 t in 2019. Consumption of amorphous graphite decreased by 5% in 2020 to 29,100 t from 30,800 t in 2019. The main uses of graphite during 2020 were batteries; brake linings; carbon products (such as bearings and brushes), crucibles, moderator rods in nuclear reactors, nozzles, retorts, stoppers, and sleeves; chemically resistant materials; drilling-mud additives; electrical conductors; foundries; fuel cells; graphene; high-strength composites; lubricants; pencils; powdered metals; refractories; rubber; and steelmaking. The leading applications for graphite were as electrodes used in steel production and as refractories. Automobile manufacturing and construction influenced steelmaking activity, which in turn influenced electrode and refractories demand. The steel industry is the largest domestic graphite consumer (Whiteside and Finn-Foley, 2019).

The batteries end-use category for graphite was predicted to have the largest rate of growth, owing to increased demand for electric and hybrid vehicles and portable electronic devices, such as mobile telephones, smartphones, and tablet-sized computers. During 2020, graphite consumption in battery applications increased by 5% from that in 2019. Graphite was an essential component of many types of batteries, where graphite was used as the predominant anode (negative electrode) material. Battery industry estimates suggest that about 95% to 99% of the raw material used to make battery anodes was graphite, both natural and synthetic, with anode manufacturers mixing natural material into synthetic bases to reduce costs. This made graphite the largest component in any electric vehicle (EV) battery, making up some 25% of a battery's total volume (Kool, 2023). Consumption of crystalline flake graphite for processing into spherical graphite to be used as battery anode material in lithium-ion batteries continued to be the leading growth market for natural graphite in 2020. There are forecasts of rapid growth for graphite in the battery sector, where global consumption is expected to grow to nearly 1 Mt by 2030 (Whiteside and Finn-Foley, 2019). Natural graphite continued to compete with synthetic graphite for battery market share and use in other applications such as flame retardants. It was estimated that the current market split of natural to synthetic graphite was 50–50, although demand for synthetic graphite was reported to be increasing more quickly than demand for natural material (Industrial Minerals, 2019). Synthetic graphite was the higher cost option for anode material, but its higher purity made it preferred for use in premium batteries. Most battery anode producers used a blend of synthetic and natural graphite, balancing cost and performance (Whiteside and Finn-Foley, 2019).

Tesla Motors, Inc. continued investment into its large plant called Gigafactory 1, in Sparks, NV, to manufacture lithium-ion EV battery packs; the factory was operating during 2020. Tesla partnered with battery maker Panasonic Corp. so that both companies operated parts of the factory. Panasonic manufactured battery cells, which Tesla assembled into battery packs (Valdes-Dapena, 2016). The battery packs were then installed into the vehicles at Tesla's assembly plant in Freemont, CA. When complete, the plant was expected to use 35,000 t/yr of spherical graphite, produced from 95,000 t/yr of flake graphite, as anode material for lithium-ion batteries. The factory started limited production of battery packs in the first quarter of 2016 and reached initial capacity of battery cells in January 2017 (Randall, 2017). At the end of July 2018, Gigafactory 1 had reached a battery production rate of about 20 gigawatthours per year (GWh/yr). By the end of the first quarter of 2019, Gigafactory 1 battery production reached a production rate of about 23 GWh/yr, which made it the world's leading battery plant by a substantial margin. Tesla reported production of more batteries in terms of kilowatthours than the combined production of all other carmakers. Tesla planned to add three battery cell production lines, which would result in a production rate of 35 GWh/yr, which was the originally announced production rate (Lambert, 2018, 2019a, b). In August 2020, Panasonic announced that it would be investing another $100 million in Gigafactory 1 to further boost battery production capacity by 10% to 39 GWh/yr (Duprey, 2020). In July 2020, Tesla confirmed that it was building Gigafactory 5 in Austin, TX. The production facility was expected to have an initial completion date of May 2021 (Doll, 2021).

Crystalline flake graphite accounted for 59% of natural graphite use in the United States in 2020 (table 2). It was consumed mainly in batteries, brake linings, lubricants, powdered metals, refractories, and rubber. Amorphous graphite accounted for 40% of natural graphite use and was used mainly in brake linings, foundries, lubricants, powdered metals, refractories, steelmaking, and other applications where additions of graphite improve the process or the end product. Lump graphite was used in several areas, such as steelmaking, depending on purity and particle size.

U.S. apparent consumption of natural graphite decreased by 32% to 30,000 t in 2020 from 44,200 t in 2019, and U.S. apparent consumption of synthetic graphite decreased by 20% to 272,000 t in 2020 from 339,000 t (revised) in 2019. Total U.S. graphite consumption, combined natural and synthetic, decreased by 21% to 302,000 t in 2020 from the revised 383,000 t in 2019 (table 1).

Synthetic graphite was used in more applications in the United States than natural graphite and accounted for a 90% share by quantity and a 98% share by value of the graphite consumption in 2020 (table 1). The leading market for high-purity synthetic graphite was as an additive to increase the carbon content in iron and steel. This market consumed a substantial portion of synthetic graphite. Other important uses of all types of graphite were 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 was being replaced by carbon black, which was cheaper. High-purity natural and synthetic graphite were 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 also played an important role in emerging nonhydrocarbon energy applications. In energy production, graphite was used as pebbles for modular nuclear reactors and in high-strength composites for wind, tide, and wave turbines. In energy storage applications, graphite was used in bipolar plates for fuel cells and flow batteries, anodes for lithium-ion batteries, electrodes for supercapacitors, high-strength composites for fly wheels, phase change heat storage, and solar boilers. In energy management applications, graphite was used in high-performance polystyrene thermal insulation and for silicon chip heat dissipation. These energy applications used value-added graphite products such as high-carbon purity, small particle size, potato shapes called spherical graphite; expanded graphite; and graphene (O'Driscoll, 2010).

Graphene consists of a single atomic layer of carbon atoms arranged in a flat honeycomb-like pattern. Within a 1-millimeter-thick graphite flake, there are approximately 3 million stacked sheets of graphene. Crystalline flake graphite can be processed into graphene, which has unique properties. Graphene is the world's thinnest, strongest, and most conductive material, of both electricity and heat. These properties give graphene the potential to transform entire industries, in such fields as batteries, electrical conductivity, electricity, energy generation, energy storage, heat conductivity, sensors, thermal applications, and more. Graphene can be used to enhance the strength of other materials. Adding even a trace amount of graphene to plastics, metals, or other materials can make these materials much stronger mechanically and lighter. It is then possible to use a smaller amount of material to attain the same strength. Graphene-enhanced composite materials may be used in aerospace, building materials, mobile devices, and many other applications. Since graphene is a very efficient heat conductor, lightweight, and strong, it is a good material for making heat dissipation films and heat sinks. This is useful in microelectronics (for example, to make light-emitting-diode [LED] lights more efficient and longer lasting) and in other applications like thermal foils for mobile devices (for example, smartphones, tablets, and other computers). Since graphene is an ultra-thin material with an extremely high surface-area-to-volume ratio, it is promising for use in batteries and supercapacitors. Graphene may make it possible for batteries, supercapacitors, and fuel cells to store more energy and charge faster. Graphene also was used for additional applications, such as anti-corrosion coatings and paints, accurate and efficient sensors, electronics, flexible displays, solar panels, DNA sequencing, and drug delivery. Because of its properties, it appears that many industries could benefit from using graphene (Graphene-info.com, 2020).

Prices

During 2020, there were no available prices for any mesh sizes of 90%-carbon natural crystalline flake graphite, but prices were available for the higher quality 94%-carbon natural crystalline flake graphite. Of the 94%-carbon flake, the median yearend prices for fine mesh size increased by 6%, median yearend prices for medium mesh size increased by 32%, and median yearend prices for large mesh size increased by 24% from those in 2019; the average median yearend price for all crystalline sizes combined increasing by 22%. Prices for natural amorphous powder graphite increased by 15% compared with those in 2019. Prices for synthetic graphite could not be compared because data were not available (table 4).

Prices for crystalline and crystalline flake graphite concentrates ranged from $520 to $1,010 per metric ton; prices for amorphous powder ranged from $375 to $460 per metric ton (table 4). The average unit value of all U.S. natural graphite exports increased by 7% to $3,450 per metric ton in 2020 from $3,210 per metric ton in 2019 (tables 1, 5). The average unit value of all U.S. natural graphite imports increased by 11% to $1,240 per metric ton in 2020 from $1,120 per metric ton in 2019 (tables 1, 6). Ash and carbon content, crystal and flake size, and size distribution affect the price of graphite. The average unit value of U.S. synthetic graphite production increased by 19% to $5,150 per metric ton in 2020 from $4,340 per metric ton in 2019 (tables 1, 3). The average unit value of U.S. synthetic graphite exports increased by 5% to $5,920 per metric ton in 2020 from $5,640 per metric ton in 2019 (tables 1, 5). The average unit value of all U.S. synthetic graphite imports decreased by 13% to $5,030 per metric ton in 2020 from $5,760 per metric ton in 2019 (tables 1, 8).

Foreign Trade

Total U.S. graphite exports decreased by 30% in tonnage to 32,900 t valued at $180 million in 2020 from 46,600 t valued at $248 million in 2019 (table 5). Total graphite export tonnage was 18% natural graphite and 82% synthetic graphite. Total U.S. natural graphite imports decreased by 28% in tonnage to 36,000 t in 2020 from 50,100 t in 2019, and the value decreased by 21% to $44.6 million in 2020 from $56.1 million in 2019 (tables 1, 6). The decrease in natural graphite imports resulted from substantial decreases in quantity and in value of both the crystalline flake and the amorphous graphite categories during 2020 (table 6). Principal import sources of natural graphite were, in descending order of tonnage, China (including Hong Kong), Mexico, Canada, Madagascar, Mozambique, and Brazil, which combined accounted for 93% of both tonnage and value of total natural graphite imports. Mexico, China, and Madagascar were, in descending order of tonnage, the leading suppliers of amorphous graphite. Sri Lanka provided all the lump and chippy dust. China was the leading supplier of high-purity, expandable graphite varieties. Canada, Mozambique, China, Brazil, and Madagascar were, in descending order of tonnage, the leading suppliers of crystalline flake and flake dust graphite (table 6).

Total synthetic graphite imports decreased by 33% in tonnage to 62,600 t in 2020 from 93,400 t in 2019, and the value decreased by 41% to $315 million in 2020 from the revised $537 million in 2019. Principal import sources of synthetic graphite were, in descending order of tonnage, China (including Hong Kong), Mexico, Japan, Spain, France, and Switzerland, which combined accounted for 88% of the tonnage and 89% of the value of total synthetic graphite imports (table 8).

World Review

World production of natural graphite decreased by 38% in 2020 to an estimated 966,000 t from 1.57 Mt (revised) in 2019. Of this 966,000 t of natural graphite production, an estimated 20.8% was amorphous, 78.8% was crystalline flake, and 0.4% was vein or lump graphite. China maintained its position as the world's leading graphite producer, with an estimated 762,000 t, or 79% of total global production. Brazil ranked second with 63,600 t, or 7% of the total, followed by Mozambique, Russia, Madagascar, Ukraine, Norway, North Korea, Canada, and India, in descending order of tonnage. These 10 countries accounted for 98% of world production (table 9).

Brazil.—In 2020, Brazil had estimated production of 63,600 t of marketable natural graphite. Nacional de Grafite Ltda. was the leading producer of natural flake graphite in Brazil from mines and plants at three sites in the State of Minas Gerais. Extrativa Metalquímica (also known as Grafite do Brasil) also produced natural flake graphite from its mine and plant located in Bahia. JMN Mineração, also located in Minas Gerais, did not produce graphite from its mine, but continued to process ore at its plant from stocks. High-grade crystalline flake graphite projects were being developed in Brazil with five companies conducting or considering graphite exploration and development (Roskill Information Services Ltd., 2020).

Canada.—In 2020, Canada had two active open pit mines with combined production of about 8,000 t of natural flake graphite. Most production came from the Lac des Iles flake graphite mine in Quebec, operated by Imerys Graphite & Carbon. The Black Crystal flake graphite quarry in British Columbia, owned by Eagle Graphite Corp., also produced natural flake graphite.

In recent years, many potential graphite producers were exploring and developing flake graphite projects in Canada. Exploration was focused primarily on properties in Ontario and Quebec, but other graphite exploration projects were underway in British Columbia (Roskill Information Services Ltd., 2020).

China.—In 2020, China was the world's leading producer, exporter, and consumer of natural and synthetic graphite. China also may have the largest natural graphite resources in the world (Robinson and others, 2017, table J4, p. J18). Production in China was estimated to be 762,000 t of natural graphite, of which an estimated 580,000 t was flake graphite and the remaining 182,000 t was amorphous graphite; this was about 79% of the total global production. More than 60% of China's flake graphite was produced in Heilongjiang Province, and most of the country's amorphous graphite was produced in Hunan Province. The iron and steel industry was the leading consuming market of natural and synthetic graphite in China (Roskill Information Services Ltd., 2020).

During 2020, China was the leading global exporter of natural crystalline flake graphite, accounting for 58% of natural graphite exports or an estimated 258,000 t (IndexBox, Inc., 2022). China imported an estimated 21,000 t of natural crystalline flake graphite. China also exported an estimated 57,000 t of amorphous graphite, and there were no amorphous graphite imports. China's synthetic graphite production was estimated to be 1.02 Mt. In 2020, China's synthetic graphite exports were estimated to be 825,000 t, and synthetic graphite imports were estimated to be 63,000 t (Roskill Information Services Ltd., 2020).

Continuing growth in China's natural flake and synthetic graphite production was being driven by the global lithium-ion battery industry, which was centered in China for almost all parts of the supply chain. China was the leading producer of battery-grade graphite (which included nearly all the world's spherical graphite processed from natural flake), anode materials, and the anodes and batteries themselves. Demand for synthetic graphite also was increasing owing to increasing levels of electric arc furnace steel production in China, resulting in rising consumption of synthetic graphite electrodes. China's consumption of natural amorphous graphite declined during 2020. China accounted for an increased share of global synthetic graphite production in the form of electrode and spherical graphite. Electrode manufacturers added about 0.6 t/yr of new capacity since 2017 and increased electrode capacity for all types of electrodes, not just synthetic graphite. In 2020, China continued dominating global production of spherical graphite, but its estimated exports of spherical graphite decreased slightly to 54,300 t from 55,800 t in 2019 (Roskill Information Services Ltd., 2020).

Madagascar.—In 2020, Madagascar had estimated production of 20,900 t of natural flake graphite (table 9). Flake graphite production increased significantly in 2018 and 2019 from new investment in the existing mines of Établissements Gallois, from Chinese investment in the mines of Madagascar Graphite Ltd., from redevelopment of the Graphmada operation by Australian investment, and from redevelopment of the Sahamamy Mine by Indian investment. Then, in 2020, production decreased by 61%, most likely owing to the impact of the COVID-19 pandemic.

During 2020, Malagasy exports decreased by 61% to 20,900 t from 53,400 t in 2019. Some of these exports may have been crude graphite for processing in China (Roskill Information Services Ltd., 2020).

Mexico.—In 2020, Mexico had estimated production of 3,300 t of natural amorphous graphite, a decrease of 61% from 8,500 t in 2019 (table 9). All of the production was amorphous graphite from the State of Sonora, most of which was mined underground. Mexico produced both natural and synthetic graphite. The United States had had a long tradition of investing in the Mexico's graphite industry. United States companies owned shares in natural graphite mines and operated synthetic production facilities in Mexico. Almost all production of natural graphite was exported to the United States. In 2020, Mexico imported 3,430 t natural graphite and exported 6,730 t of natural graphite (Roskill Information Services Ltd., 2020).

Mozambique.—In 2020, Mozambique had estimated production of 28,000 t of natural flake graphite (table 9). Mozambique became a leading producer in the global graphite market during 2018 and 2019. The largest known graphite deposit in the world was the Balama deposit owned by Syrah Resources Ltd. (Australia), located in the Cabo Delgado Province. Flake graphite production at the Balama Mine started at the end of 2017 and ramped up quickly throughout the following year. The Balama Mine experienced problems during 2018. Issues with ramping up the mine and processing facility kept production behind forecasts, although the company continued increasing its production. Balama reached full production in December 2018 and declared first commercial production on January 1, 2019. Full production was at a rate of 15,000 metric tons per month (t/mo), but Balama production was scaled back significantly during the fourth quarter of 2019 to a rate of 5,000 t/mo. This production cut was made to reduce surplus graphite supplies and help raise graphite prices. Then, owing to the impacts of the COVID-19 pandemic, production was suspended in March 2020, and operations were restarted in February 2021 (Miningdataonline.com, 2022). While production was reduced at Balama throughout most of 2020, the company's sales were ongoing during the year from available finished product inventories. Resources at Balama were estimated to be 1.1 billion metric tons, which was more natural graphite than that contained in all other known global deposits combined. Production of natural flake graphite began in Mozambique because of foreign investment. The initial success of the Balama Mine and its proximity to China's growing battery market attracted additional investment, with Mozambique becoming a focus for graphite development projects in recent years, most located close to existing producers in the Cabo Delgado Province. Most of the graphite from the Balama Mine was exported to China for processing into spherical graphite. Purchasers included Shenzhen BTR New Energy Materials, which was one of the world's leading producers of lithium-ion anode materials.

Syrah Resources also was developing its own 20,000-t/yr spherical graphite plant in the U.S. State of Louisiana, which it hoped to supply with material from the Balama Mine. The Louisiana spherical graphite plant produced its first purified spherical graphite in November 2019 which was sent to potential customers for testing. Syrah Resources also had agreements in place to supply large-size flake graphite to China for use in expandable graphite.

The Ancuabe operation in Cabo Delgado Province was operated by Triton Minerals Ltd. (Australia). Work at the Ancuabe project began in June 2017. According to Triton Minerals, Ancuabe had the potential to become a major high-grade graphite project. Ancuabe was located near the Balama deposit. Triton Minerals completed a definitive feasibility study on the Ancuabe graphite project in December 2017, and a mining concession was granted in May 2019. The project was planned with 60,000 t/yr of capacity from a mill feed of 0.9 to 1.1 million metric tons per year and could produce graphite concentrate at 96% to 98% total graphitic carbon for use in expanded graphite and lithium-ion batteries. The mine life was expected to be 27 years. In March 2019, Triton Minerals signed a nonbinding memorandum of understanding with Qingdao Jinhui Graphite which could invest in 10% of the Ancuabe project, receiving up to 15,000 t/yr of concentrate as offtake. Triton Minerals had been testing its graphite for use in downstream products such as foil, refractory, and flame-retardant markets with another Chinese company, Xincheng Graphite. Several other graphite projects were under development in Cabo Delgado. Graphite mining in the Balama District of Mozambique was projected to be relatively low cost because ores were easily accessible by open pit mining, of high quality, and 240 km (149 mi) from the deepwater port of Pemba (Roskill Information Services Ltd., 2017, p. 199; 2018, p. 223–225; 2020; Industrial Minerals, 2019; Syrah Resources Ltd., undated).

Outlook

Worldwide demand for natural and synthetic graphite is expected to continue increasing as more battery and other nonhydrocarbon energy applications that use graphite are developed. Steel production and other types of metallurgical activity, which are important consumers of graphite, are expected to increase as well. Global graphite consumption is expected to increase owing to new technologically advanced applications, such as aerospace applications, fuel cells, graphene, lithium-ion batteries, pebble-bed nuclear reactors, and solar power. Most notable for graphite among these applications are fuel cells, lithium-ion batteries, and pebble-bed nuclear reactors. Battery production is predicted to increase and become the leading graphite market by 2030, surpassing the traditional leading graphite markets of electrodes and refractories (Barrera, 2021). Consumption for electrodes and refractories are expected to decline whenever steelmaking declines (Roskill Information Services Ltd., 2020).

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 graphite with improved properties in electronics, foils, friction materials, and lubrication applications. Products available through advanced refining technology could increase profitability in the U.S. graphite industry in the next few years.

References Cited

Barrera, Priscila, 2021, Graphite outlook 2021—Demand from battery segment to grow: Investing News Network, January 11. (Accessed August 19, 2021, at https://investingnews.com/daily/resource-investing/battery-metals-investing/graphite-investing/graphite-outlook/.)

Doll, Scooter, 2021, Tesla factory locations—Where they are and could soon be: Electrek.co, July 14. (Accessed August 19, 2021, at https://electrek.co/2021/07/14/tesla-factory-locations-where-they-are-and-could-soon-be/.)

Duprey, Rich, 2020, Tesla Gigafactory 1 to boost battery production capacity 10% after new $100 million Panasonic investment: The Motley Fool, August 19. (Accessed April 19, 2021, at https://www.fool.com/investing/2020/08/19/tesla-gigafactory-1-to-boost-battery-production-ca/.)

Graphene-info.com, 2020, Graphene applications—What is graphene used for?: Graphene-info.com, July 12. (Accessed August 15, 2022, at https://www.graphene-info.com/graphene-applications#:~:text=Coatings%20%2Csensors%2C%20electronics%20and%20more,%2C%20drug%20delivery%2C%20and%20more.)

Graphite One Inc., 2021a, Graphite Creek: Vancouver, British Columbia, Canada, Graphite One Inc. (Accessed January 28, 2021, via http://www.graphiteoneresources.com/projects/projects-overview/.)

Graphite One Inc., 2021b, Graphite One project—Overview: Vancouver, British Columbia, Canada, Graphite One Inc. (Accessed January 28, 2021, at http://www.graphiteoneresources.com/projects/graphite-one-project-pea/overview/.)

Graphite One Inc., 2021c, Graphite One project—Product manufacturing plant: Vancouver, British Columbia, Canada, Graphite One Inc. (Accessed January 28, 2021, at http://www.graphiteoneresources.com/projects/graphite-one-project-pea/product-manufacturing-plant/.)

Graphite One Inc., 2021d, Graphite resource estimates: Vancouver, British Columbia, Canada, Graphite One Inc. (Accessed January 28, 2021, at http://www.graphiteoneresources.com/projects/graphite-creek/resource-estimates/.)

IndexBox, Inc., 2022, Global graphite market—China's share reaches 82%-IndexBox: Los Angeles, CA, Global Newswire news release, March 1. (Accessed June 15, 2022, at https://www.globenewswire.com/news-release/2022/03/01/2394028/0/en/Global-Graphite-Market-China-s-Share-Reaches-82-IndexBox.html#:~:text=In%202020%2C%20the%20average%20graphite,tonne)%20was%20amongst%20the%20lowest.)

Industrial Minerals, 2019, Year in review—Graphite: London, United Kingdom, Industrial Minerals, January 2. (Accessed October 28, 2019, via http://www.indmin.com.)
Kool, Tom, 2023, Graphite wars—The trillion dollar battery race has a big problem: London, United Kingdom, OilPrice.com, August 22. (Accessed February 16, 2024, at https://oilprice.com/Energy/Energy-General/Graphite-Wars-The-Trillion-Dollar-Battery-Race-Has-A-Big-Problem.html.)
Kopeliovich, Dmitri, 2020, Graphite manufacturing process: SubsTech Forum, June 13. (Accessed March 15, 2021, at http://www.substech.com/dokuwiki/doku.php?id=graphite_manufacturing_process.)
Lambert, Fred, 2018, Tesla confirms Gigafactory 1 battery production at '~20 GWh'—More than all other carmakers combined: Electrek.co, August 2. (Accessed June 19, 2020, at https://electrek.co/2018/08/02/tesla-gigafactory-1-battery-production-20-gwh/.)
Lambert, Fred, 2019a, Tesla Gigafactory 1 battery cell production is still limited to about 23 GWh, says Elon Musk: Electrek.co, April 14. (Accessed June 17, 2021, at https://electrek.co/2019/04/14/tesla-gigafactory-1-battery-cell-production-issues-elon-musk/#more-89637.)
Lambert, Fred, 2019b, Tesla Gigafactory 1—Panasonic ready to ramp up battery production to 54 GWh: Electrek.co, December 30. (Accessed June 17, 2021, at https://electrek.co/2019/12/30/tesla-gigafactory-1-panasonic-ready-ramp-up-battery-cell-production/.)
Miningdataonline.com, 2022, Balama Mine fact sheet: Miningdataonline.com mining data solutions. (Accessed August 12, 2022, at https://miningdataonline.com/property/1033/Balama-Mine.aspx.)
O'Driscoll, Mike, 2010, Minerals meet in Miami heat: Industrial Minerals, no. 510, March, p. 67–75.
Randall, Tom, 2017, Tesla flips the switch on the gigafactory: Bloomberg.com, January 4. (Accessed March 26, 2021, at https://www.bloomberg.com/news/articles/2017-01-04/tesla-flips-the-switch-on-the-gigafactory.)
Robinson, G.R., Jr., Hammarstrom, J.M., and Olson, D.W., 2017, Graphite, chap. J *of* Schulz, K.J., DeYoung, J.H., Jr., Seal, R.R., II, and Bradley, D.C., eds., Critical mineral resources of the United States—Economic and environmental geology and prospects for future supply: U.S. Geological Survey Professional Paper 1802, p. J1–J24. (Accessed March 26, 2021, at https://doi.org/10.3133/pp1802J.)
Roskill Information Services Ltd., 2017, Natural and synthetic graphite—Global industry, markets and outlook to 2026 (10th ed.): Roskill Information Services Ltd., London, 475 p.
Roskill Information Services Ltd., 2018, Natural and synthetic graphite—Global industry, markets and outlook to 2027 (11th ed.): Roskill Information Services Ltd., London, 504 p.
Roskill Information Services Ltd., 2020, Natural and synthetic—Outlook to 2030 (13th ed.): Roskill Information Services Ltd., London, October 14, 586 p. (Accessed March 11, 2021, via https://www.roskillinteractive.com/reportaction/NGR13/Toc.)
Syrah Resources Ltd., [undated], Overview: Melbourne, Victoria, Australia, Syrah Resources Ltd. (Accessed June 23, 2021, at http://www.syrahresources.com.au/overview.)
Valdes-Dapena, Peter, 2016, Inside Tesla's ginormous gigafactory: CNN Business, July 27. (Accessed August 3, 2021, at https://money.cnn.com/2016/07/26/technology/tesla-gigafactory/index.html.)
Westwater Resources, Inc., 2018, Westwater successfully produces battery ready graphite: Centennial, CO, Westwater Resources, Inc. news release, September 6. (Accessed January 28, 2021, at https://www.globenewswire.com/en/news-release/2018/09/06/1566354/0/en/Westwater-Successfully-Produces-Battery-Ready-Graphite.html.)
Westwater Resources, Inc., 2019, Westwater Resources reports 2018 results & energy minerals business update: Centennial, CO, Westwater Resources, Inc. news release, February 19. (Accessed January 28, 2021, at https://www.bloomberg.com/press-releases/2019-02-19/westwater-resources-reports-2018-results-energy-minerals-business-update.)
Westwater Resources, Inc., 2021a, Bama Mine project: Centennial, CO, Westwater Resources, Inc. (Accessed January 28, 2021, at http://www.westwaterresources.net/projects/graphite/bama-mine-project.)
Westwater Resources, Inc., 2021b, Coosa Graphite project: Centennial, CO, Westwater Resources, Inc. (Accessed January 28, 2021, at http://www.westwaterresources.net/projects/graphite/coosa-graphite-project.)
Whiteside, James, and Finn-Foley, Dan, 2019, Supply chain looms as serious threat to batteries' green reputation: Edinburgh, United Kingdom, Wood Mackenzie, Ltd., November 25. (Accessed June 15, 2021, at https://www.greentechmedia.com/articles/read/graphite-the-biggest-threat-to-batteries-green-reputation.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Graphite (Natural). Ch. in Mineral Commodity Summaries, annual.
Graphite. Ch. in Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply, Professional Paper 1802, 2017.
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.

Other

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

TABLE 1
SALIENT NATURAL AND SYNTHETIC GRAPHITE STATISTICS[1]

		2016	2017	2018	2019	2020
United States:						
Natural:						
Exports:						
Quantity	metric tons	14,300	13,900	9,950	5,890 r	5,930
Value	thousands	$21,100	$24,800	$23,600	$18,900	$20,500
Imports for consumption:						
Quantity	metric tons	38,900	51,900	70,700	50,100 r	36,000
Value	thousands	$47,600	$58,500	$64,500	$56,100	$44,600
Apparent consumption:[2]						
Quantity	metric tons	24,700	38,000	60,700	44,200 r	30,000
Value	thousands	$26,500	$33,700	$40,900	$37,200 r	$24,100
Synthetic:						
Production:						
Quantity	metric tons	207,000	226,000	219,000	286,000 r	236,000
Value	thousands	$658,000	$726,000	$1,170,000	$1,240,000 r	$1,220,000
Exports:						
Quantity	metric tons	30,100	40,600	50,500	40,700 r	26,900
Value	thousands	$145,000	$233,000	$279,000	$230,000	$159,000
Imports for consumption:						
Quantity	metric tons	75,000	111,000	129,000	93,400	62,600
Value	thousands	$127,000	$183,000	$428,000	$537,000 r	$315,000
Apparent consumption:[2]						
Quantity	metric tons	252,000	296,000	298,000	339,000 r	272,000
Value	thousands	$640,000	$676,000	$1,320,000	$1,550,000 r	$1,370,000
World production, natural[3]	metric tons	917,000 r	1,280,000 r	1,510,000 r	1,570,000 r	966,000

[r]Revised.
[1]Table includes data available through May 18, 2021. Data are rounded to no more than three significant digits.
[2]Domestic production plus imports minus exports.
[3]May include estimated data.

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)
2019:				
Brake lining	1,010	$2,820	2,930	$5,350
Carbon products[3]	238	1,260	W	680
Foundries[4]	W	W	3,090 r	3,420 r
Lubricants[5]	W	W	W	W
Powdered metals	W	W	W	W
Refractories	W	W	W	W
Rubber	W	W	765	2,080
Other[6]	22,000 r	98,300 r	24,000 r	54,100 r
Total	23,300 r	102,000	30,800 r	65,600 r
2020:				
Brake lining	1,050	3,220	2,080	1,800
Carbon products[3]	210	1,160	W	W
Foundries[4]	W	W	1,930	2,090
Lubricants[5]	W	W	W	W
Powdered metals	W	W	W	W
Refractories	W	W	W	W
Rubber	W	W	W	W
Other[6]	20,300	70,000	25,100	59,600
Total	21,600	74,400	29,100	63,400

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Other."

[1]Table includes data available through May 18, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Includes 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 and electronic devices, industrial diamonds, magnetic tape, mechanical products, nozzles, paints and polishes, pencils, retorts, sleeves, small packages,

TABLE 3
SHIPMENTS OF SYNTHETIC GRAPHITE BY U.S. COMPANIES, BY END USE[1]

End use	Quantity (metric tons)	Value (thousands)
2019:		
Cloth and fibers (low modulus)	W	W
Electrodes	93,100	W
Unmachined graphite shapes	9,000	W
Other[2]	184,000 r	$1,240,000 r
Total	286,000 r	1,240,000 r
2020:		
Cloth and fibers (low modulus)	W	W
Electrodes	93,100	W
Unmachined graphite shapes	7,630	W
Other[2]	135,000	1,220,000
Total	236,000	1,220,000

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Other."
[1]Table includes data available through May 18, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Includes anodes, crucibles and vessels, electric motor brushes and machined shapes, graphite articles, high-modulus fibers, lubricants (solid or semisolid), refractories, steelmaking, carbon raisers, additives in metallurgy, and other powder data.

TABLE 4
REPRESENTATIVE YEAREND GRAPHITE PRICES[1]

(Dollars per metric ton)

Type	2019	2020
Crystalline fine, 94% to 97% carbon, -100 mesh	470–540	520–550
Crystalline medium, 94% to 97% carbon, +100-80 mesh	640–690	860–890
Crystalline large, 94% to 97% carbon, +80 mesh	795–820	1,000–1,010
Amorphous powder, 80% to 85% carbon	330–395	375–460

[1]Prices are cost, insurance, and freight China to main European port, unless otherwise specified.

Sources: Fastmarkets IM, December 2019 Price Movements; Fastmarkets IM, December 2020 Price Movements.

TABLE 5

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

	Natural[3]		Synthetic[4]		Total	
Country or locality	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)	Quantity (metric tons)	Value[5] (thousands)
2019:						
Belgium	248	$861	433	$4,340	681	$5,200
Brazil	315	741	1,180	6,040	1,490	6,780
Canada	1,190 r	924 r	6,650	21,500	7,830	22,400
China	325	1,050	3,270	37,600	3,600	38,700
Colombia	253	406	295 r	809 r	549 r	1,220 r
France	17	48	1,320	6,110	1,330	6,160
Germany	432	1,130	1,800	15,600	2,230	16,700
India	334	1,100	789 r	2,410 r	1,120	3,510 r
Italy	52	131	1,220	10,700	1,270	10,800
Japan	602	2,310	2,870	22,800	3,470	25,200
Korea, Republic of	1,000	5,640	1,390	16,200	2,390	21,800
Mexico	479	939	12,100	24,700	12,600	25,600
Poland	17	65	634	3,920	651	3,980
Saudi Arabia	1	11	1,280	6,480	1,280	6,490
United Arab Emirates	--	--	554	1,090	554	1,090
United Kingdom	47	179	1,350	2,860	1,390	3,040
Other	573 r	3,340	3,610 r	46,500 r	4,180 r	49,900
Total	5,880	18,900	40,700 r	230,000	46,600 r	248,000 r
2020:						
Brazil	91	236	587	3,120	677	3,360
Canada	1,190	980	4,020	16,100	5,210	17,100
China	279	1,010	1,420	21,900	1,700	23,000
France	129	595	1,040	7,140	1,170	7,730
Germany	338	858	319	10,200	657	11,000
India	526	1,450	553	2,020	1,080	3,470
Italy	35	130	807	9,380	841	9,510
Japan	371	1,740	1,070	9,080	1,440	10,800
Korea, Republic of	1,170	6,820	1,470	17,200	2,640	24,100
Mexico	483	673	6,780	15,900	7,260	16,600
Poland	43	98	752	3,110	795	3,210
Saudi Arabia	685	2,620	3,560	10,100	4,250	12,800
Taiwan	32	80	474	6,130	506	6,210
United Arab Emirates	--	--	715	1,480	715	1,480
United Kingdom	53	225	845	1,460	897	1,690
Other	502	2,950	2,500	24,800	3,000	27,800
Total	5,930	20,500	26,900	159,000	32,900	180,000

[r]Revised. -- Zero.

[1]Table includes data available through May 10, 2021. 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," "Colloidal or semicolloidal graphite," "Preparations based on graphite," and "Graphite products containing greater than 50% graphite by weight," codes 3801.10.0000, 3801.10.5000, 3801.20.0000, 3801.90.0000, and 6903.10.0000.

[5]Values are free alongside ship.

Source: U.S. Census Bureau.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF NATURAL GRAPHITE, BY COUNTRY OR LOCALITY[1]

	Crystalline flake and flake dust		Lump and chippy dust		Other natural crude, high-purity, expandable		Amorphous		Total	
Country or locality	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)	Quantity (metric tons)	Value[2] (thousands)
2019:										
Austria	14[r]	$12[r]	--	--	--	--	156[r]	$100[r]	169	$113
Belgium	63	101	--	--	--	--	--	--	63	101
Brazil	2,420[r]	4,360[r]	--	--	217[r]	$648[r]	--[r]	--[r]	2,640	5,010
Canada	10,500[r]	13,900[r]	--	--	29[r]	306[r]	--	--	10,600	14,200
China	8,290[r]	11,600[r]	--	--	2,100[r]	6,850[r]	6,960[r]	4,110[r]	17,400	22,500
Germany	62[r]	131[r]	--	--	70[r]	928[r]	--	--	132	1,060
Japan	161[r]	296[r]	--	--	138[r]	1,690[r]	--	--	299[r]	1,980[r]
Madagascar	2,080[r]	2,090[r]	--	--	--	--	3,410[r]	1,910[r]	5,480	4,000
Mexico	19[r]	27[r]	--	--	39[r]	108[r]	11,200	4,940[r]	11,200	5,080
Mozambique	1,150[r]	765	--	--	--	--	--	--	1,150[r]	765
Netherlands	--	--	--	--	(3)	7	127	88	127	95
Norway	25[r]	36[r]	--	--	--	--	--[r]	--[r]	25	36
Sri Lanka	--	--	252	$601	--	--	--	--	252	601
Turkey	20[r]	28[r]	--	--	1[r]	6[r]	--[r]	--[r]	20	34
United Kingdom	12[r]	19[r]	--	--	4[r]	50[r]	527[r]	296[r]	543	364
Vietnam	--	--	--	--	--	--	39	20	39	20
Other	--[r]	--[r]	--	--	8[r]	100[r]	--	--	8	100[r]
Total	24,800[r]	33,400[r]	252	601	2,610[r]	10,700[r]	22,400[r]	11,500[r]	50,100[r]	56,100
2020:										
Austria	--	--	--	--	(3)	8	488	305	488	313
Belgium	95	151	--	--	--	--	--	--	95	151
Brazil	2,590	4,900	--	--	182	560	--	--	2,770	5,460
Canada	5,740	8,410	--	--	10	272	--	--	5,750	8,680
China	3,600	6,040	--	--	2,410	8,650	4,460	2,490	10,500	1,720
Germany	22	41	--	--	50	1,130	--	--	72	1,170
Hong Kong	--	--	--	--	--	--	407	290	407	290
India	8	12	--	--	--	--	--	--	8	12
Japan	60	140	--	--	36	322	--	--	96	462
Madagascar	2,540	2,680	--	--	20	95	1,850	1,020	4,410	3,800
Mexico	11	15	--	--	1	18	5,800	3,380	5,810	3,410
Mozambique	3,940	2,590	--	--	--	--	--	--	3,940	2,590
Netherlands	20	25	--	--	--	--	--	--	20	25
Norway	20	25	--	--	--	--	--	--	20	25
Russia	17	36	--	--	--	--	--	--	17	36
Sri Lanka	--	--	31	91	--	--	--	--	31	91
United Kingdom	--	--	--	--	3	30	1,560	772	1,560	802
Other	--	--	--	--	2	68	--	--	2	26
Total	18,700	25,100	31	91	2,710	11,100	14,600	8,260	36,000	44,600

[r]Revised. -- Zero.
[1]Table includes data available through May 10, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Customs values.
[3]Less than ½ unit.

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 OR LOCALITY[1, 2]

Country or locality	Quantity (metric tons)	Value[3] (thousands)
2019:		
Austria	4,650	$54,300
China	10,800 r	44,800 r
France	673	3,060
Germany	2,220	24,400
India	21,200	51,600
Israel	102	1,170
Italy	3,190	31,400
Japan	7,530 r	96,000 r
Malaysia	980	8,590
Mexico	18,800	74,000
Poland	2,370	10,500
Russia	7,570	29,400
Spain	3,500	30,400
Ukraine	2,000	14,600
United Kingdom	784	5,240
Other	72	1,080
Total	86,400 r	481,000 r
2020:		
Austria	1,650	16,000
Canada	89	51
China	11,700	24,900
France	225	488
Germany	264	4,040
India	8,900	22,100
Italy	3,860	18,900
Japan	1,040	13,700
Mexico	15,500	58,400
Poland	1,620	7,730
Russia	5,920	16,600
Spain	58	209
Taiwan	127	622
Ukraine	704	1,610
United Kingdom	1,010	3,610
Other	107	545
Total	52,800	190,000

[r]Revised.
[1]Table includes data available through May 10, 2021. 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 “Graphite electrodes, not exceeding 425 mm in diameter, of a kind used for furnaces,” “Graphite electrodes, exceeding 425 mm in diameter, of a kind used for furnaces,” and “Carbon electrodes of a kind used for furnaces, excluding graphite,” codes 8545.11.0010, 8545.11.0020, and 8545.11.0050.
[3]Customs value.

Source: U.S. Census Bureau.

TABLE 8
U.S. IMPORTS FOR CONSUMPTION OF SYNTHETIC GRAPHITE, BY COUNTRY OR LOCALITY[1, 2]

Country or locality	2019 Quantity (metric tons)	2019 Value[3] (thousands)	2020 Quantity (metric tons)	2020 Value[3] (thousands)
Austria	81	$80	10	$6
Belgium	7	247	28	328
Brazil	498 r	631 r	1,930	1,320
Canada	1,220	4,740	1,510	5,730
China	28,400 r	191,000	20,600	118,000
France	4,640	34,700	3,160	20,500
Germany	1,800	15,500	951	11,500
Hong Kong	4,900	1,690	320	45
India	1,940	6,790	360	2,490
Italy	1,490	2,750	416	2,420
Japan	10,600	99,500	5,560	54,000
Korea, Republic of	695	7,200	1,100	8,070
Malaysia	69	279	30	266
Mexico	20,800	66,100	18,600	49,600
Netherlands	45	401	76	746
Norway	57	64	228	195
Poland	420	1,020	125	675
Russia	172	149	(4)	31
Spain	11,300	89,600	3,990	24,600
Sri Lanka	222	407	129	230
Sweden	58	148	(4)	17
Switzerland	3,350	12,100	3,140	12,000
Taiwan	57	266	16	249
Thailand	--	--	23	158
United Arab Emirates	72	127	--	--
United Kingdom	409	1,690	317	1,110
Other	50 r	312 r	9	269
Total	93,400	537,000 r	62,600	315,000

r Revised. -- Zero.
[1]Table includes data available through May 10, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Synthetic graphite data are for Harmonized Tariff Schedule of the United States codes 3801.10.1000, 3801.10.5000, 3801.20.0000, 3801.90.0000, and 6903.10.0000.
[3]Customs value.
[4]Less than ½ unit.

Source: U.S. Census Bureau and the U.S. International Trade Commission.

TABLE 9
NATURAL GRAPHITE: WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Metric tons)

Country or locality	2016	2017	2018	2019	2020
Austria, amorphous[e]	800	1,000	500 r	500 r	500
Brazil, crystalline flake	61,687	53,332 r	96,800 r	84,700 r	63,600 e
Canada, crystalline flake	NA	14,000	11,000	11,000	8,000 e
China:					
Amorphous	199,800 r	333,400 r, 2	469,600 r, 2	473,600 r, 2	182,400 e
Crystalline flake	539,200 r	748,600 r	694,400 r	711,400 r	580,000 e
Total	739,000 r	1,082,000 r	1,164,000 r	1,185,000 r	762,000 e
Germany, crystalline flake[e]	500	800	200 r	300 r	300
India:[e, 3]					
Amorphous	3,000	3,500	800 r	800 r	600
Crystalline flake	27,000	31,500	7,100 r	7,200 r	5,400
Total	30,000	35,000	7,900 r	8,000 r	6,000
Korea, North:[e]					
Amorphous	1,000	1,000	3,600 r	3,600 r	3,600
Crystalline flake	4,500	4,500	4,500 r	4,500 r	4,500
Total	5,500	5,500	8,100 r	8,100 r	8,100
Madagascar, crystalline flake	9,200	13,300	47,900	53,400 r	20,900 e
Mexico, amorphous[e]	8,500	10,300 r	4,200 r	8,500 r	3,300
Mozambique, crystalline flake	--	1,042	106,773	153,000 r, e	28,000 e
Namibia, crystalline flake	--	2,216	3,456	-- 4	-- 4
Norway, crystalline flake	9,600 r	9,600 r	10,000 r	9,500 r, e	12,000 e
Pakistan, crystalline flake	400 r, e	-- r	-- r	-- r	--
Russia:[e, 5]					
Amorphous	8,000 r	8,000 r	8,000 r	8,000 r	8,000
Crystalline flake	11,400 r	17,200 r	9,800 r	10,000 r	17,000
Total	19,400	25,200	17,800 r	18,000 r	25,000
Sri Lanka, vein	3,908 r	3,769 r	3,800 e	4,000 e	4,000 e
Tanzania, crystalline flake	1,191	128	150 e	150 e	--
Turkey, amorphous[e, 6]	2,000	2,300	2,500 r	2,500 r	2,500
Ukraine, crystalline flake[e]	14,600 r	14,900 r	15,000 r	16,000 r	16,000
Uzbekistan, crystalline flake[e]	100	100	100	100	100
Vietnam, crystalline flake[e]	5,000	5,000	5,000	5,000	5,000
Zimbabwe, crystalline flake	5,622	1,577	--	-- 4	--
Grand total	917,000 r	1,280,000 r	1,510,000 r	1,570,000 r	966,000
Of which:					
Amorphous	223,000 r	360,000 r	489,000 r	498,000 r	201,000
Crystalline flake	690,000 r	918,000 r	1,010,000 r	1,070,000 r	761,000
Vein or lump	3,910 r	3,770 r	3,800	4,000	4,000

[e]Estimated. [r]Revised. NA Not available. -- Zero.

[1]Table includes data available through June 30, 2021. All data are reported unless otherwise noted; totals may include estimated data. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Source: China Nonmetallic Mining Industry Association.

[3]Indian marketable production was estimated to be 10% to 20% of run-of-mine production.

[4]The mine was put on-care-and maintenance status in November 2018.

[5]About 48% amorphous and 52% crystalline flake graphite.

[6]Turkish marketable production averaged approximately 5% of run-of-mine production. Almost all was for domestic consumption.