Office of Industries
Working Paper ID-090

Global Value Chains: Graphite in Lithium-ion Batteries for Electric Vehicles

May 2022

Karl Tsuji

Abstract

This working paper focuses on graphite (an anode material), as part of a five-part series that examines the global value chains of successive production stages for lithium-ion battery raw materials.[1] A notable feature of the graphite global value chain is that battery producers can select between natural graphite mined from ore deposits, artificial graphite produced from either calcined petroleum coke or coal tar pitch, or a blend of both depending on the desired performance characteristics. China dominates nearly every stage of the graphite global value chain, despite varying degrees of participation by Japan, South Korea, the United States, and Western Europe along successive stages. To diversify their global value chains, additional graphite firms, particularly those based in Australia, Canada, and India, are integrating their upstream mining or coal tar operations with downstream processing operations to provide anode materials for lithium-ion batteries. Numerous efforts are also underway outside of China (including within the United States) to develop graphite processing and anode manufacturing capacity. Despite such ongoing supply diversification efforts, it will likely require several decades for the United States and other producers to establish such global value chains outside of China.

[1] See Scott and Ireland, “Lithium-Ion Battery Materials for Electric Vehicles and their Global Value Chains,” June 2020; Matthews, “Global Value Chains: Cobalt in Lithium-ion Batteries for Electric Vehicles,” May 2020; LaRocca, “Global Value Chains: Lithium in Lithium-ion Batteries for Electric Vehicles,” July 2020; and Guberman, “Global Value Chains: Nickel in Lithium-ion Batteries for Electric Vehicles,” forthcoming.

Global Value Chains: Graphite in Lithium-ion Batteries for Electric Vehicles

Karl Tsuji

Office of Industries
U.S. International Trade Commission (USITC)

May 2022

The author is staff with the Office of Industries of the U.S. International Trade Commission (USITC). Office of Industries working papers are the result of the ongoing professional research of USITC staff. Working papers are circulated to promote the active exchange of ideas between USITC staff and recognized experts outside the USITC, and to promote professional development of office staff by encouraging outside professional critique of staff research.

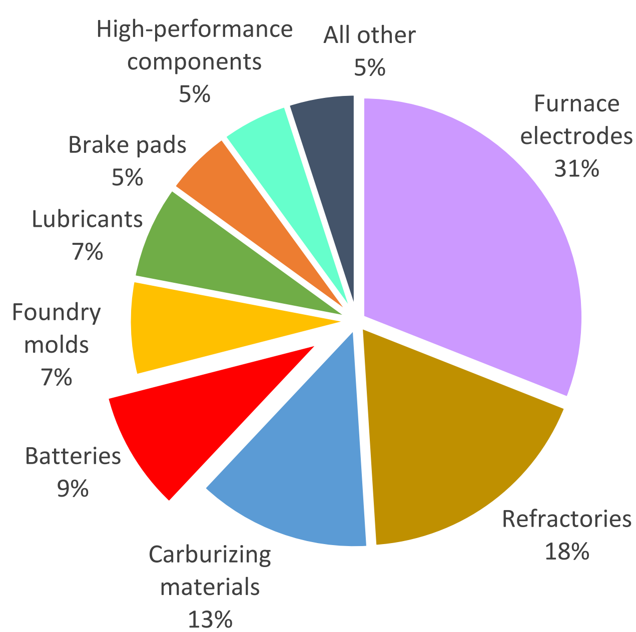
This paper represents solely the views of the author and is not meant to represent the views of the U.S. International Trade Commission or any of its Commissioners. Please direct all correspondence to Karl Tsuji, Office of Industries, U.S. International Trade Commission, 500 E Street, SW, Washington, DC 20436, telephone: 202-205-3434, email: karl.tsuji@usitc.gov.

The author would like to thank Robert Carr, John Fry, Tamar Khachaturian, Sarah Oliver, Andrew David, Sarah Scott, and Robert Ireland for their assistance with this report and Byron Barlow for his production support.

Introduction

Graphite, the most common and stable crystalline allotrope (form) of carbon,[2] is a semi-metallic to dull grey, soft, readily cleavable, multi-layered, tabular (planar) mineral. Graphite has a wide variety of end uses in the metals, nuclear, automotive, high-technology, and other industries (e.g., being mixed with fine clays to form the "lead" core of pencils[3]). Batteries accounted for only about 9 percent of global graphite consumption in 2016 (figure 1). In most types of batteries, including the lithium-ion (Li-ion) batteries that power electric vehicles (EVs), graphite is the negative electrode (anode) material.[4]

Figure 1 Graphite: Global consumption shares by end-uses, 2016



Source: Leading Edge Materials Corp., "About Graphite," accessed August 25, 2018. Underlying statistics are provided in Appendix C.

A key feature of the global value chain (GVC) for graphite,[5] in contrast to those for other Li-ion battery materials, are the two source types for anode materials: 1) natural graphite mined from ore deposits, concentrated in a few major producing countries, and 2) artificial graphite produced from either

[2] Other carbon allotropes include diamonds and fullerenes. Abbreviations and acronyms are provided in Appendix D and a glossary of technical terms is provided in Appendix E.
[3] Increasing the ratio of clay to graphite in the pencil core increases the "hardness" and sharpness of the marks as less graphite is imparted onto the surface of the paper. Pencils.com, "Graphite Grading Scale Explained," retrieved March 4, 2022.
[4] For more specific details about the role of graphite as an anode material, see the "Importance in the Lithium-ion Cell" section below.
[5] This working paper uses the term "global value chains" (GVCs) rather than "global supply chains." Global supply chains refer to the logistical path to deliver a product to market, but analyses of global supply chains do not necessarily consider the value added along each of the successive processing stages. Scott and Ireland, "Lithium-Ion Battery Materials for Electric Vehicles and their Global Value Chains," June 2020, 1–2; Jones, Demirkaya, and Bethmann, "Global Value Chain Analysis: Concepts and Approaches," April 2019, 2–4.

petroleum coke or coal tar, widely available worldwide as by-products of the respective crude-petroleum refining or coal coking processes. Hence, global resource availability concerns for graphite often receive less critical attention than for other Li-ion battery materials (particularly cobalt),[6] where access is constrained by dependence upon a limited number of production source countries, a few countries predominate in the downstream processing and distribution stages, or both. Nevertheless, despite the presence of several countries among the various stages of the graphite anode GVC, the prominence of China in each is notable, particularly as a global supplier of mined natural graphite.

To systematically examine the GVCs of Li-ion battery raw materials consistently across this five-part series,[7] this working paper first provides background information about the active role of graphite in Li-ion batteries. Next, there are successive sections for each graphite production stage: (1) mining and processing of graphite ores into refined natural graphite; (2a) processing of petroleum coke and (2b) coal tar pitch into (2c) refined artificial graphite; and (3) production of battery-grade anode graphite (battery carbons). These sections also include case studies of selected leading producers. Price and international trade trends are then discussed. Finally, the last section examines the GVC measures of international trade in these raw and intermediate materials. Although included in an overview assessment of GVC measures for Li-ion battery materials in a previous article of this series,[8] graphite has not been examined in further detail explicitly in the context of GVC measures along each stage of its GVC.

The raw and intermediate materials that are traded along the GVC at the 6-digit subheading level of the global Harmonized System Description and Coding System (Harmonized System or HS) include (table 1): natural graphite (HS 2504.10), calcined petroleum coke (HS 2713.12), coal tar pitch (HS 2706.00), and artificial graphite (HS 3801.10). However, finished anode graphite is not included in the GVC analysis because battery carbons are classifiable along with numerous other products under broader categories beyond the HS 6-digit subheading level of the *Harmonized Tariff Schedule of the United States* (*HTSUS* or HTS)— i.e., HTS 8545.19.2000 and 8545.19.4000.[9]

[6] Matthews, "Global Value Chains: Cobalt in Lithium-ion Batteries for Electric Vehicles," May 2020.
[7] See Scott and Ireland, "Lithium-Ion Battery Materials for Electric Vehicles and their Global Value Chains," June 2020; Matthews, "Global Value Chains: Cobalt in Lithium-ion Batteries for Electric Vehicles," May 2020; LaRocca, "Global Value Chains: Lithium in Lithium-ion Batteries for Electric Vehicles," July 2020; and Guberman, "Global Value Chains: Nickel in Lithium-ion Batteries for Electric Vehicles," forthcoming.
[8] Scott and Ireland, "Lithium-Ion Battery Materials for Electric Vehicles and their Global Value Chains," June 2020, 16–18.
Other background literature generally tends to include graphite in technology assessments along with other Li-ion battery materials; as industry, project, or technology-development news articles; or consultancy surveys of industry events among individual firms in producing countries along the GVC. See, e.g., Dai, et al., *Update of Bill-of-Materials and Cathode Materials Production for Lithium-ion Batteries in the GREET® Model*, October 31, 2019.
[9] These broader categories beyond the HS 6-digit subheading level preclude global trade statistics.

Table 1 Graphite raw and intermediate materials by Harmonized System (HS) subheadings and major producers

Description	HS subheading	Major producers
Natural graphite	2504.10	China, Brazil, Canada, India, and Mozambique
Coal tar pitch	2708.10	China, Japan, South Korea, and the United States
Petroleum coke, calcined	2713.12	China, India, and the United States
Artificial graphite	3801.10	China, Japan, and the United States
Battery carbons	8545.19	China, Japan, South Korea, the United States, and Western Europe

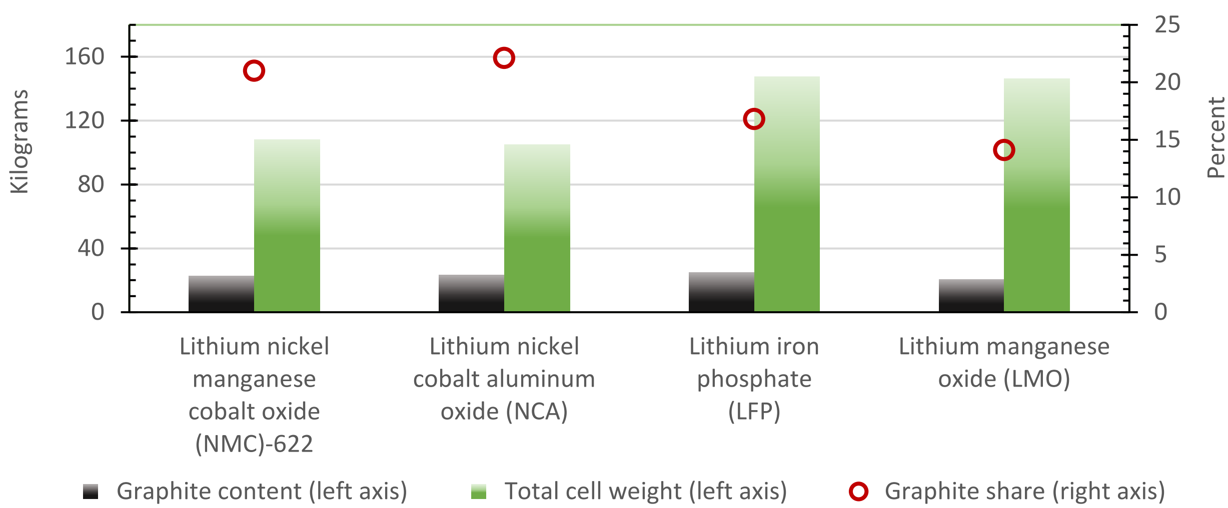
Source: USITC, *HTSUS (2021) Basic Revision 9*, November 18, 2021, 25-2, 27-4, 27-18, 38-4, 85-79.
Note: HS subheading 8545.19: Other than carbon electrodes (carbon brushes, lamp carbons, battery carbons and other articles of graphite or other carbon, with or without metal, of a kind used for electrical purposes).

The Role of Graphite in Lithium-ion Batteries

Share of the Lithium-ion Cell by Volume

According to Tesla Motors Inc's. (Tesla) co-founder Elon Musk, Li-ion cells "...should be called 'Nickel-Graphite,' because primarily the cathode is nickel and the anode side is graphite with silicon oxide… {there's} a little bit of lithium in there, but it's like the salt on the salad."[10] For example, Li-ion batteries in Tesla's Model S electric EVs contain 54 kilograms (119 pounds) of graphite.[11] The more common types of Li-ion cells generally contain more graphite than any other material, typically 14.1–22.1 percent by weight (figure 2).[12]

Figure 2 Graphite: Content and share of total cell weight, for common types of lithium-ion cells for battery-powered electric vehicles



Source: Dai, et al., Update of Bill-of-Materials and Cathode Materials Production for Lithium-ion Batteries in the GREET® Model, October 31, 2019, 14. Underlying statistics are provided in Appendix C.

[10] Benchmark, "Elon Musk: Our Lithium-ion Batteries Should be Called Nickel-Graphite," June 5, 2016.
[11] Lambert, "Breakdown of Raw Materials in Tesla's Batteries and Possible Bottlenecks," November 1, 2016.
[12] Syrah Resources, "Graphite and Its Uses," accessed March 27, 2018.

Importance in the Lithium-ion Cell

Battery manufactures rely on graphite as the active anode material in Li-ion cells because of its voltage (electrical potential) compatibility with the more common types of cathode materials, light weight, porosity, durability, and relative affordability.[13] More specifically, graphite's layered crystalline structure also renders it (1) easy to fabricate due to its softness; (2) a good electrical and thermal conductor; (3) highly stable, even at high temperatures; and (4) chemically unreactive and corrosion resistant.[14]

To function as the active anode material in a Li-ion cell (figure 3), powdered graphite is mixed with a binder and applied as a coating onto a copper foil substrate as the negative current collector.[15] When a secondary (rechargeable) Li-ion cell is fully charged, the graphite anode holds the lithium ions intercalated between the multiple layers (sheets) of hexagonally linked carbon atoms. As the battery discharges, the anode releases the lithium ions into the electrolyte toward the cathode to provide an electric current.[16] Two major advantages provided by graphite for cell performance are: (1) a "flat voltage profile"—steady discharge rate at almost full power over most of its discharge range, down to about 20 percent of the remaining charge level— and (2) no "memory effect"—long-term stability over successive discharging and recharging cycles.[17]

[13] Targay, "Anode Materials," accessed August 26, 2019.

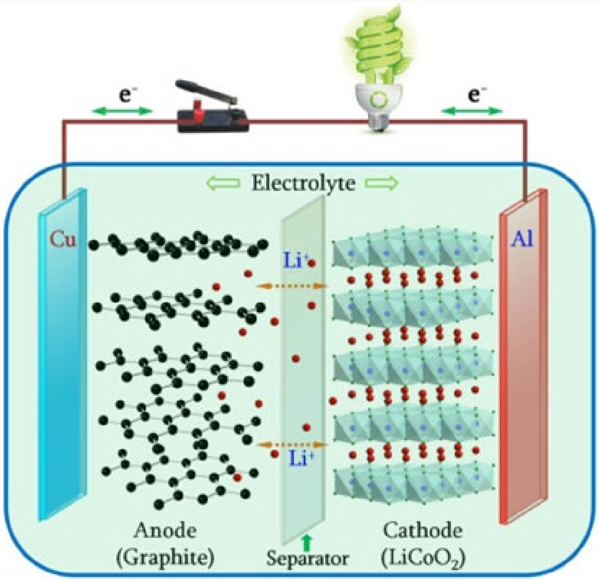
[14] More specifically, the multi-layered net-like structure of crystalline graphite readily parts between the layers of linked carbon atoms and allows for the valence electrons, not linked to neighboring carbon atoms, to move about freely between the carbon layers and conduct electricity. Leading Edge Materials, "About Graphite," accessed August 25, 2018; Focus Graphite, "Graphite 101," accessed August 31, 2018.

[15] Battery University, "How Do Lithium Batteries Work?" June 1, 2018.

[16] For a video schematic showing the movement of the lithium ions between the anode and cathode in a Li-ion battery, during the discharging and recharging cycles, see: USDOE, "How Lithium-ion Batteries Work," accessed October 11, 2019.

[17] Battery University, "How Do Lithium Batteries Work?" June 1, 2018; Northern Graphite, "Lithium Ion Batteries," accessed January 9, 2018.

Figure 3: Graphite: The active anode material in a lithium-ion cell



Source: Liu, Neale, and Cao, "Understanding Electrochemical Potentials of Cathode Materials in Rechargeable Batteries," March 2016, 110.

Performance Characteristics

Manufacturers can choose between three types of graphite for the anode material in their Li-ion batteries: (1) natural (mined) graphite, extracted from graphite-bearing ore deposits; (2) artificial (synthetic or electro) graphite,[18] produced from calcined petroleum coke or coal tar pitch; or (3) blended (composite) graphite, a mixture of both natural and artificial graphite.[19] As an anode material, natural graphite offers the advantages of higher charge-storage capacity and lower cost,[20] but loses capacity more quickly and has lower cycle life than artificial graphite.[21] Conversely, artificial graphite offers advantages of higher purity and consistency,[22] greater stability, and greater operating reliability and consistency; but its production is more highly energy intensive (and hence, more expensive) than for natural graphite.[23] Blends of natural and artificial graphite are formulated based on the performance advantages of each type to produce long-life, high-capacity anode materials at lower costs.

[18] Although "synthetic graphite" is the more common term in the industry press, "artificial graphite" will appear throughout this working paper for consistency with the HS article description (table 2).
[19] These two types of graphite will be referred to as "natural" or "artificial" hereafter, to match the corresponding descriptions in the *Harmonized Tariff Schedule of the United States*.
[20] Leading Edge Materials, "About Graphite," accessed August 25, 2018; Northern Graphite, "About Spherical Graphite," accessed January 9, 2018.
[21] Leading Edge Materials, "About Graphite," accessed August 25, 2018.
[22] Syrah Resources, "Graphite and Its Uses," accessed March 27, 2018; Battery University, "How Does Graphite Work in Li-ion? August 23, 2019.
[23] Leading Edge Materials, "About Graphite," accessed August 25, 2018.

Specific ratios of natural to artificial graphite are not readily available from EV battery manufacturers but blended graphite compositions reportedly contain 40−60 percent natural graphite.[24] An industry monitoring source estimated in 2016 that 65 percent of the active anode material in Li-ion batteries consisted of natural graphite, 30 percent of artificial graphite, and the remaining 5 percent of other materials.[25]

Substitutes

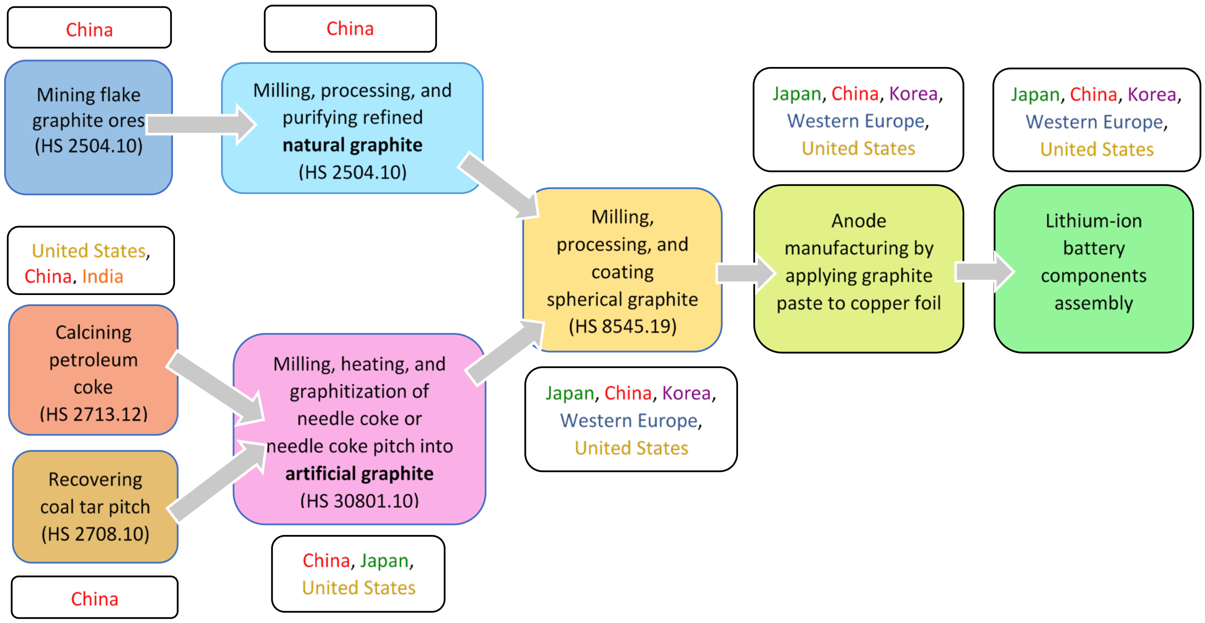
There are currently few viable substitutes for graphite as the anode in Li-ion cells, due to its performance characteristics, ready availability, and relatively low cost. However, other materials are currently under development that could be more effective anode materials with higher energy densities for Li-ion cells,[26] including silicon-enhanced graphite, expanded graphite, and silicon-carbon compounds;[27] graphenes consisting of single layers of linked carbon atoms;[28] and silicon metal, silicon oxides, nano-composite silicon materials, and lithium metal.[29]

Production Processes

An overview of the GVC for both natural and artificial graphite as anode materials in Li-ion batteries, along with the relevant HS classifications and the countries with significant participation in the successive production stages, are shown in figure 4. Despite the presence of several countries among the various production stages of the graphite anode GVC, the prominence of China in each is notable, particularly its predominance as a global supplier of mined natural graphite.

[24] Northern Graphite, "About Spherical Graphite," accessed January 9, 2018.
For example, Panasonic Corp. uses blended graphite as the active anode material in the Li-ion battery packs that it supplies for Tesla's electric vehicles. Benchmark, "Elon Musk: Our Lithium-ion Batteries Should be Called Nickel-Graphite," June 5, 2016; Hatch, "Going Natural: The Solution to Tesla's Graphite Problem," March 25, 2014.
[25] Benchmark, "Graphite Demand from Lithium Ion Batteries to More Than Treble in 4 Years," May 4, 2016.
[26] Scott, "In the Battery Material World, the Anode's Time Has Come," April 7, 2019.
[27] Battery University, "How Do Lithium Batteries Work?" June 1, 2018.
[28] Battery University, "How Does Graphite Work in Li-ion?" August 23, 2019.
[29] Scott, "In the Battery Material World, the Anode's Time Has Come," April 7, 2019.

Figure 4 Graphite: Simplified process flow chart from extraction, through processing, to battery components assembly



Source: Compiled from Asbury Carbons, "An Introduction to Synthetic Graphite," 2006; Battery Minerals, "Spherical Graphite," accessed October 1, 2018; Focus Graphite, "Graphite 101," accessed August 31, 2018; Focus Graphite, "Manufacturing Artificial Graphite," July 2011; Lowe, et al., *Lithium-ion Batteries for Electric Vehicles: the U.S. Value Chain*, October 5, 2010 (revised), 30–33; Moores, "Spherical Graphite: How Is It Made?" August 2, 2013; Morris, "How is Crude Coal Tar Derived?" November 2005. HS classifications compiled from table 1 (above). Significant producing countries compiled from the "Materials" section (below).

The next two sections describe the different processes for natural and artificial graphite to attain both the particle characteristics (size and shape) and the high purity (99.95 percent or higher carbon content)[30] required for battery anode-grade spheroidal-graphite powders.

Natural Graphite

Natural graphite occurs in several forms, with varying degrees of particle sizes, carbon contents, and impurity contents (table 3) but flake graphite is considered the most suitable form for processing into anode materials. The GVC for battery anode-grade natural graphite consists of two successive processing stages to produce spherical graphite. In the mining stage, "small flake" graphite ores,[31] extracted from either open-pit or underground operations, are crushed and ground, prior to undergoing a flotation process to separate-out the graphite from various impurities to attain a concentrate with a 90–97 percent graphite content.[32] The remaining impurities (siliceous ash, sulfur,

[30] Northern Graphite, "About Spherical Graphite," accessed January 9, 2018; Syrah Resources, "Graphite and Its Uses," accessed March 27, 2018.
[31] "Small flake" graphite is readily available and "medium flake" or "large flake" graphite is not economical at current prices. Northern Graphite, "About Spherical Graphite," accessed January 9, 2018.
[32] Leading Edge Materials, "About Graphite," accessed August 25, 2018; Moores, "Spherical Graphite: How Is It Made?" August 2, 2013.

iron, and other metals) are removed either by wet-chemical leeching with strong acids (especially in China)[33] or high-temperature electrical thermal treatment with halogen gasses (outside of China).[34]

Table 2 Natural graphite: Deposit types and characteristics

Description	Leading mine sources	Carbon content (percent)	Advantages	Disadvantages
Flake— more common form, with visible flaky particles	Brazil, China, Mozambique	80–90	Low cost, and low impurities	Inconsistent quality
Amorphous— more common form, with small crystalline particles	China	70–90	Lowest cost	High impurities including ash
Crystalline-vein— least common form, with particle sizes ranging from fine flakes, medium needles, to grainy lumps	Sri Lanka	70-99+	Very high grades	Small deposits, underground, high cost, and small particles

Source: Focus Graphite, “Graphite 101,” accessed August 31, 2018; Kay, “Types of Graphite: Amorphous, Flake and Vein,” June 13, 2018; McLeod, “Stephen Riddle: What Investors Really Need to Know About Graphite,” November 24, 2014; Syrah Resources, “Graphite and Its Uses,” accessed March 27, 2018.

Next, the dried graphite concentrate undergoes fine grinding prior to “spheroidization” by heating to curl the individual flakes into irregularly shaped, porous “micro-balls” (with an average diameter of 10–30 microns[35]), both to increase the packing density and reduce the particle size for more efficient electrical conductivity of the spheroidal (spherical) graphite.[36] This uncoated spheroidal graphite is subsequently coated with pitch or asphalt followed by baking in a furnace to produce coated spheroidal graphite that prevents expansion and exfoliation (uncurling) as the electrolyte intercalates along with the lithium ions among the graphite layers (figure 3).[37]

Artificial Graphite

The GVC for battery anode-grade artificial graphite starts with the production of non-graphitic carbonaceous materials at either a petroleum refinery or a coal coking plant for subsequent crystallization in an electric furnace.

Petroleum refinery operations recover the residual oils that remain from extracting the lower boiling, lower molecular-weight, higher value components during the refining process of crude petroleum. These low-value residual oils are roasted in a coking furnace to drive-off the volatile components which

[33] Although wet-chemical leaching is a relatively low-cost process, it uses extremely caustic hydrofluoric and sulfuric acids to remove the impurities and requires large quantities of fresh water along with neutralizing reagents to rinse the purified graphite. Northern Graphite, “About Spherical Graphite,” accessed January 9, 2018.
[34] Hatch, “Going Natural: The Solution to Tesla’s Graphite Problem,” March 25, 2014.
[35] Hatch, “Going Natural: The Solution to Tesla’s Graphite Problem,” March 25, 2014.
[36] Spheroidal graphite will be referred to as “spherical graphite” hereafter, which is the more common term in both the graphite and battery industries. Moores, “Spherical Graphite: How Is It Made?” August 2, 2013; Battery Minerals, “Spherical Graphite,” accessed October 1, 2018.
[37] Rapp, et al., “Spheroidization of Graphite as Anode Material for Li-Ion Batteries,” June 21, 2016; Hatch, “Going Natural: The Solution to Tesla’s Graphite Problem,” March 25, 2014; Leading Edge Materials, “About Graphite,” accessed August 25, 2018; Steinrötter, “Carbon-Based Anodes— a ‘Rare Earth’ Situation?” February 2011, 70–71; Battery Minerals, “Spherical Graphite,” accessed October 1, 2018.

are recovered for return to the refinery processing stream. The residual solid material, raw (green) petroleum coke, is heated in a rotary kiln to burn-off the volatile residual water and organic compounds to yield calcined petroleum coke,[38] with a carbon content of 97.0–99.5 percent and free of residual hydrocarbons and moisture.[39] Calcined petroleum coke differs by grades, distinguished by micro-structure, depending upon coking operating (temperature and time) conditions and crude oil feedstock quality.[40] However, only about 5 percent of all petroleum coke produced meets the high-purity and structural requirements to be suitable for conversion into artificial graphite,[41] as needle coke (acicular coke) with a fine-grained, needle-like structure resulting from the high degree of liquid crystal alignment in a single flow direction that occurs during the coking process.[42]

Coal coking operations generate coal tar, a thick dark liquid, as a by-product from carboning pulverized metallurgical coal in a reducing atmosphere by forced hot-air drafts through the flues connecting successive individual coking furnaces (coke battery) that drives-off the volatile components to yield solid coke.[43] At a tar distillation facility, water is first removed as the crude coal tar passes through a dehydration column followed by organic volatiles being removed as the dehydrated tar is mixed with hot circulating pitch in a pitch column to yield coal tar pitch.[44] The coal tar pitch is heated in an electric furnace to bake the carbonaceous materials at 800–1,300 degrees Celsius into fine-grained pitch coke (carbonizing).[45]

The needle coke or pitch coke is subsequently heated in an electric furnace at higher temperatures in the range of 2,600–3,300 degrees Celsius to crystallize the aligned carbonaceous materials into graphite (graphitization).[46] Preparing artificial graphite for battery anode applications also increasingly includes spheroidization,[47] like that for natural graphite. The artificial graphite is ground-down prior to spheroidization but is purified by high-temperature electrical thermal treatment to produce uncoated spherical graphite, which is subsequently coated and baked to yield coated spherical graphite.[48]

Technical Limitations

The production processes for both natural graphite and artificial graphite are constrained by different technical limitations. There is significant material yield loss in the production of uncoated spherical graphite from natural graphite, because fine grinding results in 60−70 percent of the ground particles

---

[38] Asbury Carbons, “An Introduction to Synthetic Graphite,” 2006.
[39] Asbury Carbons, “Coke,” accessed August 31, 2020.
[40] Andrews and Lattanzio, *Petroleum Coke: Industry and Environmental Issues*, October 29, 2013, 3–4; Ariyan International, “Petroleum Coke,” accessed August 31, 2020.
[41] Steinrötter, Carbon-Based Anodes— a ‘Rare Earth’ Situation?” February 2011, 72.
[42] Asbury Carbons, “Coke,” accessed August 31, 2020.
[43] Morris, “How is Crude Coal Tar Derived?” November 2005.
[44] Sarna, “Coal Tar and Its Distillation Processes,” December 26, 2018.
[45] Asbury Carbons, “An Introduction to Synthetic Graphite,” 2006; Steinrötter, Carbon-Based Anodes— a ‘Rare Earth’ Situation?” February 2011, 70–71; Syrah Resources, “What is Graphite?” accessed March 27, 2018.
[46] Asbury Carbons, “An Introduction to Synthetic Graphite,” 2006; Steinrötter, Carbon-Based Anodes— a ‘Rare Earth’ Situation?” February 2011, 70–71; Syrah Resources, “What is Graphite?” accessed March 27, 2018.
[47] Rapp, et al., “Spheroidization of Graphite as Anode Material for Li-Ion Batteries,” June 21, 2016.
[48] Leading Edge Materials, “About Graphite,” accessed August 25, 2018; Steinrötter, “Carbon-Based Anodes— a ‘Rare Earth’ Situation?” February 2011, 70–71; Battery Minerals, “Spherical Graphite,” accessed October 1, 2018.

being discarded as too fine to undergo the subsequent spheroidization step.[49] By contrast, there is a lengthy time frame (up to 4–5 months) necessary to attain sufficient crystallization in the production of artificial graphite, compared to 3–5 days for natural graphite,[50] even prior to the subsequent fine-grinding and spheroidization steps.[51] Finally, regardless of whether natural or artificial graphite, the current yield limitation for the spheroidization process is currently estimated at about 50 percent.[52]

Materials

Given the complexity of the GVC for anode graphite materials (figure 4) compared to those for other EV Li-ion battery materials, the successive graphite production stages are presented below, not only to identify the relevant raw and intermediate materials but also to assess the relationships among leading production and processing locations, source country characteristics, and prominent producing firms.

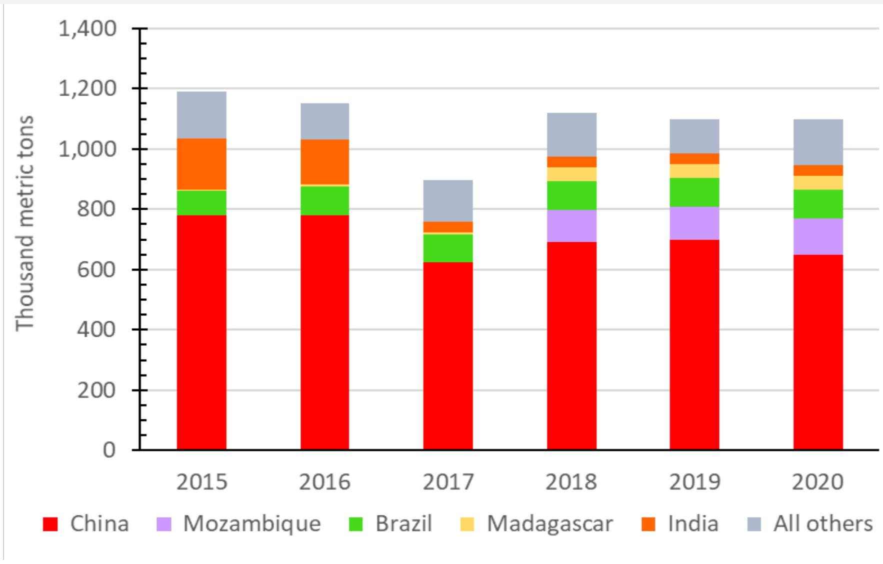
Natural Graphite

Mining Locations and Annual Production

Global output of mined graphite is highly concentrated, with China accounting for almost three-fifths (59.1 percent) and the next four largest countries together exceeded one-quarter (26.9 percent) of the worldwide total in 2020 (figure 5). Reported global mine output of natural graphite steadily declined during 2015−20, with a notable dip in 2017. By contrast, global reserve estimates for graphite ore deposits were revised upward from 230 million metric tons in 2015 to 320 million metric tons by 2020,[53] with new information reported by graphite-producing firms or government agencies in several countries.[54]

[49] Hence, processors must start with three-times the amount of natural graphite to produce the desired amount of uncoated spheroidal graphite. Steinrötter, "Carbon-Based Anodes— a 'Rare Earth' Situation?" February 2011, 70–71; Northern Graphite, "About Spherical Graphite," accessed January 9, 2018.
[50] Burkett, "The Relative Applications and Fundamentals of the Synthetic and Natural Graphite Markets," November 25, 2013.
[51] Focus Graphite, "Manufacturing Artificial Graphite," July 2011.
[52] Rapp, et al., "Spheroidization of Graphite as Anode Material for Li-Ion Batteries," June 21, 2016.
[53] Olson, "Graphite (Natural)," January 2016; January 2021, 73.
[54] The U.S. Geological Survey received new reserves information from Brazil and Turkey in 2015; Madagascar, Mozambique, and Tanzania in 2016 and 2017; Brazil, China, North Korea, Norway, and Vietnam in 2018; Mozambique and Tanzania in 2019; and Brazil, Madagascar, Sri Lanka, and Tanzania in 2020. Olson, "Graphite (Natural)," January 2021; January 2020; February 2019; January 2018; January 2017; January 2016, 73.

Figure 5 Natural graphite: Leading mine producing countries, annual output, 2015–20



Source: Olson, "Graphite (Natural)," January 2021, January 2020, February 2019, January 2018, January 2017, January 2016, 73. Underlying statistics are provided in Appendix C.

Source Country Characteristics

Firms that mine natural graphite are listed in table A.1.[55] However, none are owned by either Li-ion battery or EV manufacturers, as they are not integrated upstream to produce raw materials.

Case Studies

Further details about the natural-graphite mining industry in each of the top-five producing countries (figure 5) are provided in the following case studies. Two additional case studies present the ongoing developments in Canada and the United States as potential future sources of natural graphite for U.S. EV Li-battery manufacturing.

China—Having a predominant role among most stages of the GVC, China is the world's largest producer, processor, and exporter of natural graphite, with commercial-scale spherical graphite production being mostly limited to China, reportedly due to lower labor and energy costs and less stringent environmental restrictions.[56] Commercial-scale mining was traditionally centered in the eastern Province of Shangdong but as production declined with depletion of ore reserves, mining activities shifted to the northeastern Province of Heilongjiang, particularly around Jixi-Mashan and Luobei;[57] and to the north Inner Mongolia region (table A.1).[58]

In 2020, Chinese mines produced more flake (60 percent) than amorphous (40 percent) graphite. Some of the flake graphite is of larger sizes but the majority is of rather smaller sizes (in the +200-mesh

[55] Source country tables are provided in Appendix A.
[56] Roskill, "Natural & Synthetic Graphite, Outlook to 2028," accessed October 16, 2019; Roskill, "Graphite: The Race for Non-Chinese Spherical Graphite Heats Up," April 29, 2019; International Mining, "Natural & Synthetic Graphite, New Report with Forecasts to 2026," June 13, 2017.
[57] Northern Graphite, "The Graphite Supply Problem," accessed October 16, 2019.
[58] Argus Media, "Chinese Graphite Prices to Hold Firm on Tight Supply," December 19, 2018.

range).[59] To reduce particulate emissions from grinding and acid discharges from purifying mined graphite,[60] the Central Government directed (starting in 2014–15) consolidations and shutdowns[61] of amorphous-graphite producers located predominantly in the southwestern Province of Hunan[62] and of flake-graphite producers located predominantly in Heilongjiang Province;[63] and ongoing rounds of inspections and closures of spheroidal graphite processing facilities in Heilongjiang and Shangdong Provinces.[64] Further, as a result of such consolidations, Shenzhen BTR New Energy Materials Inc., the largest Chinese anode-materials producer, is now integrated upstream into graphite production.[65]

Despite ongoing development of existing deposits in Inner Mongolia[66] and discovery of a new major deposit in Heilongjiang Province,[67] China is also increasingly seeking potential sources of low-cost ores abroad to offset the continued rising labor, energy, and environmental-protection costs for its domestic graphite mining and processing industries. In recent years, China reached agreements to import significant quantities of flake graphite from Syrah Resource Ltd's. Balama Mines in Mozambique[68] and from the anticipated output of Northern Graphite Corp. in Canada.[69] Nevertheless, China also exported just over one-fourth (25.5 percent) of its mine output in 2020, with varying degrees of refinement and processing.[70] However, some industry observers reportedly anticipate that China will export less graphite concentrate and more downstream spheroidal graphite and anode materials, as the Central Government continues to restructure the graphite mining sector, require improved mining practices and pollution controls, and promote higher-valued downstream products.[71]

Mozambique— Although currently the world's second-largest producer of natural graphite in 2018–20, Mozambique's Balama deposit in the northern Province of Cabo Delgado (table A.1), is reportedly considered to be the world's largest, with reserves amounting to 1.1 billion metric tons in 2014, far larger than all other known worldwide graphite deposits combined.[72] Syrah Resources Ltd. (Australia) commenced commercial production in late-2017,[73] and produced 104,000 metric tons in full-year

---

[59] Olson, "Graphite (Natural)," January 2021, 72.
[60] Whoriskey, "In Your Phone, In Their Air," October 2, 2016. Behrmann, "Green Batteries' Graphite Adds to China Pollution," April 30, 2014; *Economic Times*, "Eco-friendly US Cars Bring Dirty Rain to China," March 18, 2014.
[61] Roskill, "Roskill: Graphite Market Continuously Shaped by Pollution Controls," June 12, 2019; Roskill, "Graphite: Chinese Flake Closures to Continue Through 2018," July 20, 2018; Lazenby, "Chinese Flake Graphite Consolidation Could Alter Global Supply Structure," April 17, 2014; Mining.com, "Flake Graphite Prices Have Bottomed," May 28, 2013; Barich, "Ghost Towns Hit Graphite Market," December 2012.
[62] Previously, the government consolidated approximately 230 small amorphous graphite mines into a single firm that controls 50–60 percent of the provincial output. Mining.com, "Flake Graphite Prices Have Bottomed," May 28, 2013.
[63] Roskill, "Roskill: Graphite Market Continuously Shaped by Pollution Controls," June 12, 2019.
[64] Roskill, "Roskill: Graphite Market Continuously Shaped by Pollution Controls," June 12, 2019; Roskill, "Graphite: Chinese Flake Closures to Continue Through 2018," July 20, 2018.
[65] International Mining, "Natural & Synthetic Graphite, New Report with Forecasts to 2026," June 13, 2017.
[66] Argus Media, "Chinese Graphite Prices to Hold Firm on Tight Supply," December 19, 2018.
[67] *China Daily*, "Large Graphite Deposit Found in Northeast China's Heilongjiang," February 26, 2019.
[68] Roskill, "Natural & Synthetic Graphite, Outlook to 2028," accessed October 16, 2019.
[69] Junior Mining Network. "Northern Graphite Signs Product Offtake Agreement," June 4, 2018.
[70] Olson, "Graphite (Natural)," January 2021, 73.
[71] *Industrial Minerals*, "Graphite News, Market Brief," accessed April 26, 2018.
[72] Olsen, "Graphite (Advanced Release)," June 2018, 32.4.
[73] Barrera, "9 Top Graphite-mining Countries," August 14, 2019.

2018.[74] Syrah and three other firms based in Australia are among the major firms actively developing Mozambique's graphite deposits.[75]

Brazil—As the world's third-largest producer of natural graphite in 2020, annual Brazilian output rose to 95,000–96,000 metric tons by 2018–20 (figure 5), principally from mines located in the eastern State of Bahia and the southeastern State of Minas Gerais (table A.1). The largest Brazilian producers are Extrativa Metaquimica S.A. (operating in Bahia) and Nacional de Grafite Ltda. (Minas Gerais).[76]

Madagascar—Building upon several large deposits under development, several mines expanded output to propel Madagascar's annual output of natural graphite from 46.9 million metric tons beginning in 2018 to 48.0 million metric tons by 2020.[77] Graphite is produced from five mines located in the central and eastern provinces of the country (table A.1).

India—India's natural-graphite mine output has declined since 2017, after the Ministry of Mines promulgated the revised Mineral Conservation and Development Rules on February 27, 2017, as amended,[78] to steadily lower production levels (figure 5). Graphite mining in India is dominated by eight major producers operating mines located in the eastern State of Odisha and southern State of Tamil Nadu (table A.1). Graphite reserves vary among states, with the southeastern State of Arunachal Pradesh (between the States of Odisha and Tamil Nadu) being the location for the largest share (43 percent) of the country's graphite reserves.[79]

Canada—After remaining relatively steady during 2015–18, Canadian natural-graphite production subsequently declined (figure 5) as only the mines located in Québec recorded output in 2019 onward[80] (table A.1). Recently, Canada attracted increased development interest as a potential North American source of natural graphite for the Panasonic-Tesla joint-venture Li-ion battery "Gigafactory" in Sparks, Nevada.[81] Canadian firms currently preparing for graphite mining and processing, and developing spheroidal graphite production processes include Focus Graphite Inc. (in Lac Knife, Québec),[82] Green

[74] Karinja, "World's Largest Graphite Mine Achieves Commercial Production," January 14, 2019.
[75] Saigal, "Mozambique's Glittering Graphite Mining Boom," January 22, 2019.
[76] Barrera, "9 Top Graphite-mining Countries," August 14, 2019.
[77] Olson, "Graphite (Natural)," January 2020, 72.
[78] Government of India, *Mineral Conservation and Development Rules 2017*, January 2019.
[79] Barrera, "9 Top Graphite-mining Countries," August 14, 2019.
[80] NRC, "Canadian Mineral Production," May 2019.
[81] Barrera, "9 Top Graphite-mining Countries," August 14, 2019; Tesla, "Tesla Gigafactory," accessed October 23, 2019; Tesla, "Panasonic and Tesla Sign Agreement for the Gigafactory," July 30, 2014.
[82] Focus Graphite, "Our Story," accessed October 24, 2019; "Focus Graphite Develops Proprietary Processing Technology for Producing Superfine, High-Performance Graphite for Use in the Production of Lithium-Ion Batteries," February 26, 2015.

Battery Minerals Inc. (Manicouagan Regional County Municipality, Québec),[83] Mason Graphite (Lac Guéret, Québec),[84] and Northern Graphite Corp. (Bissett Creek, Ontario).[85]

United States—Graphite has not been mined on a commercial scale in the United States since 1994, when United Minerals Corp. suspended operations at its mine in Broadwater, Montana.[86] However, two firms are currently developing graphite deposits in Alabama and Alaska, and a third holds a purchase option to reopen a mine in Nevada.

Alabama Graphite Co. Inc., a subsidiary of Canadian parent-company Alabama Graphite Corp. (AGC), holds the development rights to two graphite mine projects in Coosa County and Chilton County, Alabama, and reportedly shipped low-temperature purified coated spheroidal graphite samples[87] from its Coosa Graphite Project to Li-ion battery manufacturers in 2016[88] and 2017.[89] In April 2018, AGC was acquired by U.S.-based Westwater Resources Inc. (WWR), which also announced plans to produce battery anode-grade graphite on a pilot scale from these mines starting in 2019.[90]

Graphite One Resources Inc. (Graphite One) is developing a large-scale, near-surface (low-cost), Graphite Creek deposit located on western Alaska's Seward Peninsula (west of Nome) containing an estimated 5.1 million metric tons of graphite. Moreover, the deposit's flake graphite is considered to have the ideal characteristics for refining into coated spheroidal graphite. Graphite One and the Alaska Industrial Development and Export Authority (AIDEA) located four possible locations in south-central Alaska, with adequate electric-power supplies at reasonable costs, close to port facilities, and transportation infrastructure, for constructing the processing facility to convert the graphite concentrates into coated spheroidal graphite and purified graphite powder.[91]

[83] Green Battery Minerals (formerly Goldcore Resources Ltd.) will be sending the extremely large-sized flake graphite concentrates from its Berkwood Graphite Project to German-based ProGraphite GmbH for purification, spheroidization, and coating as anode materials for test batteries. Duval, "Graphite Demand to Skyrocket with Increased Consumption from Auto Industry," accessed June 14, 2021.
[84] Mason Graphite, "About, Company Overview," 2017; "Lac Guéret Graphite Project," 2017.
[85] Northern Graphite, "Corporate Overview," accessed October 24, 2019; "Bissett Creek Project Overview," accessed October 24, 2019; "Graphite Companies Announce Spherical Graphite Test Facility Begins Operations," October 27, 2016.
[86] Kay, "Graphite Mining in the US," April 19, 2018; *The Diggings*, "United Minerals Co. Mill in Broadwater, MT, Graphite Past Producer," 2018.
[87] Rivera, "The Next Graphite Producers," October 13, 2016.
[88] AGC, "Alabama Graphite Corp. Announces Shipment of American Sourced and Manufactured CSPG Samples," June 23, 2016.
[89] AGC, "Alabama Graphite Corp. Announces Multiple Shipments of American Sourced and Manufactured CSPG Samples; Executes Three Non-Disclosure Agreements," January 10, 2017.
[90] WWR, "Westwater Resources Completes Acquisition of Alabama Graphite," April 23, 2018.
[91] Lasley, "Critical Minerals Alaska – Graphite," February 23, 2018.

Responding to the Governor of Alaska's October-2019 request, the Federal Permitting Improvement Steering Committee (FPISC) designated the Graphite Creek Mine and processing facility as a high-priority infrastructure project, in mid-January 2021, for expediting environmental review and approval under the January-2017 Executive Order 13766.[92] Finally, Global Lithium-ion Graphite (LION) Corp. (Canada) holds a purchase option for the former Chedic Graphite Mine, with an established past production record and potentially large-scale graphite mineralization. The mine's location near Carson City is about 50 miles southwest of Tesla's planned Li-ion battery "Gigafactory" in Sparks, Nevada.[93]

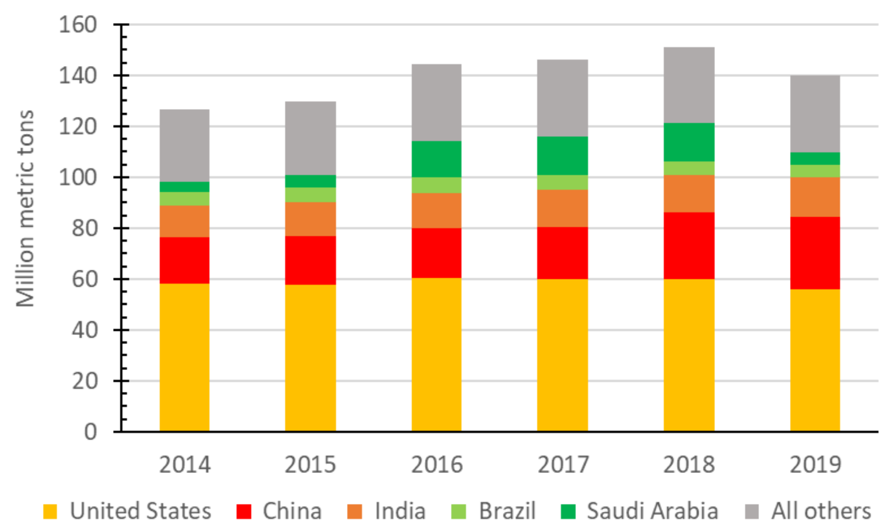
Artificial Graphite

Raw Materials and Artificial Graphite Production

This assessment of the raw material inputs for manufacturing artificial graphite focuses on the precursor, needle coke, which is derived from either petroleum coke or coal tar pitch. The United States was the world's predominant producer of petroleum coke, including that for subsequent calcining (roasting), in 2014 through 2019 (the latest year for which data were available) and accounted for almost two-fifths (39.9 percent) of the reported global total in 2019 (figure 6).[94] China (20.3 percent of the total), and India (11.1 percent) each reported output exceeding 15 million metric tons in 2019. Compared to the relatively stable U.S. annual output, averaging 58.6 million metric tons, China's rose by 55.0 percent to 28.4 million metric tons, and India's rose by 24.7 percent to 15.5 million metric tons over this period. Capacity statistics are not readily available for production of petroleum coke. Moreover, corresponding annual production statistics are not consistently available for coal tar pitch (particularly lacking for China, India, and the United States) or not available at all for downstream needle coke or artificial graphite.

[92] *Northern Miner*, "US Government Gives High Priority Status to Graphite One's Alaskan Project," February 3, 2021; Lasley, "Graphite Creek Nominated High Priority," October 25, 2019; Executive Office of the President, *Expediting Environmental Reviews and Approvals for High Priority Infrastructure Projects*, Exec. Order 13766, January 24, 2017, 82 FR 8657, January 30, 2017.
[93] Jenkins, "Massive Graphite Shortage Looms Over Electric Car Future," October 23, 2019.
[94] The most recent year that data are available.

Figure 6: Petroleum coke: Leading producing countries, 2014–19



Source: UNdata, "Energy Statistics Database, Petroleum Coke," January 6, 2021.
Underlying statistics are provided in Appendix C.

Calcined Petroleum Coke, Coal Tar Pitch, and Needle Coke Production Locations

The GVC for artificial graphite is characterized by lack of integration among raw and intermediate materials producers, along with the lack of corporate participation by either battery manufacturers or EV manufacturers. Firms identified as major producers of calcined petroleum coke are most numerous in the United States (table A.2), followed by those located in China and India (table A.3).[95] Conversely, firms identified as major producers of coal tar are most numerous in China (table A.4), but others are also located in certain other Asian countries, Australia, the United States, and European countries as well (table A.5).[96]

As a specialized product derived from a by-product material, the global supply structure for needle coke is considered highly fragmented despite the presence of a few large suppliers.[97] The majority of global production is petroleum-based rather than coal tar-based. However, most medium-sized petroleum refineries do not have the necessary delayed-coker units nor the complex coking processes to manufacture more specialized products such as needle coke.[98] Moreover, certain refineries capable of producing needle coke may choose not to do so given the longer time frame required to produce needle coke compared to lesser grades of petroleum coke.[99]

---

[95] Production country tables are provided in Appendix A.
[96] Production country tables are provided in Appendix A.
[97] Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report— Insights, Needle Coke Market," August 2019; PR NewsWire, "Global Needle Coke Market 2019–2023," July 2019; Serapio and Daly, "The Graphite Fix: Inside China's Newest Commodity Addiction," September 21, 2017; Wood Mackenzie, "IMO 2020, EVs, and Steel," May 30, 2019.
[98] Wood Mackenzie, "IMO 2020, EVs, and Steel," May 30, 2019.
[99] Serapio and Daly, "The Graphite Fix: Inside China's Newest Commodity Addiction," September 21, 2017.

Needle coke is largely produced in China, Japan, and the United States.[100] However, production capacity reportedly has remained level over the past 10 years outside of China, attributable to the high capital costs, technical challenges, and stringent regulatory processes for approving new needle coke projects. Currently, there are no known new or large-scale upgrading needle coke projects being planned outside of China.[101]

Compared to the more numerous firms that produce either calcined petroleum coke (tables A.2 and A.3) or coal tar (tables A.4 and A.5), fewer firms were identified as specifically producing needle coke, the input raw material required for the subsequent production of artificial graphite. Major producers of needle coke are most numerous in China (table A.6), but there are also major producers located in certain other Asian countries, the United States, and European countries as well (table A.7).[102]

Artificial Graphite Production Locations

Firms that bake needle coke into artificial graphite are listed in tables A.8–A.11.[103] The global artificial-graphite industry is considered not only both highly competitive but also rather consolidated due to the predominance of several major producers, [104] with the top five controlling between 65 percent[105] to more than 75 percent[106] of global production. Mergers and acquisitions, production capacity expansions, and research and development efforts are among the corporate growth strategies adopted by these major producers to penetrate the global artificial graphite market.[107] Moreover, differences in regional demand for graphite electrodes prompted shuttering of artificial-graphite production facilities in Europe, Japan, and North America, with new facilities opening in the emerging Asian markets of China and India.[108] Nevertheless, the Asia-Pacific region— particularly with large demand in China, Japan, and India— followed by North America are the leading global markets for artificial graphite. [109]

Case Studies

Further details about the countries and regions that are prominent along the GVC for artificial graphite are provided in the following case studies. The producing countries and regions are presented below in relative order of prominence, by considering available production statistics, presence of leading global firms, numbers and sizes of firms, industry evolution, etc. Each case study extends across the raw materials and along the production stages, not just merely due to insufficiently and inconsistently available information, but rather to provide more coherent, comprehensive, and concise analyses for the leading producer countries.

---

[100] Globe Newswire, “Global and China Needle Coke Industry (2020 to 2026),” May 21, 2020.
[101] Wood Mackenzie, “IMO 2020, EVs, and Steel,” May 30, 2019.
[102] Production country tables are provided in Appendix A.
[103] Production country tables are provided in Appendix A.
[104] TMR, “Synthetic Graphite Market to Reach Around US$7 Bn by 2026,” July 5, 2019.
[105] Mordor Intelligence, “Synthetic Graphite Market— Growth, Trends, and Forecast (2020–2025),” April 2020.
[106] Research and Markets, “The World Market for Synthetic Graphite, 2019 to 2024,” May 24, 2019.
[107] TMR, “Synthetic Graphite Market to Reach Around US$7 Bn by 2026,” July 5, 2019.
[108] IM, “Natural & Synthetic Graphite, New Report with Forecasts to 2026,” June 13, 2017; Roskill, “Roskill: Batteries Spark Dynamic Change in Graphite Markets,” July 10, 2017.
[109] Mordor Intelligence, “Synthetic Graphite Market— Growth, Trends, and Forecast (2020–2025),” April 2020; Research and Markets, “The World Market for Synthetic Graphite, 2019 to 2024,” May 24, 2019; TMR, “Synthetic Graphite Market to Reach Around US$7 Bn by 2026,” July 5, 2019.

China— Along with being the world's second-largest producer of petroleum coke during 2014–19 (20.3 percent of the reported total in 2019) (figure 6), China is the world's dominant producer of coal tar (71.7 percent of all worldwide production in 2017[110]) with reported production of 18.1 million metric tons in 2018.[111] Producers of calcined petroleum coke, of which Sinoway Carbon Co. Ltd.[112] and Zhenjiang Coking and Gas Group[113] are among the capacity leaders, are predominantly identified in the eastern seaboard provinces between Beijing and Shanghai (table A.3).[114] Despite shutdown of several petroleum coke facilities across the country due to environmental restrictions on carbon emissions,[115] China's production of petroleum coke, whether or not calcined, rose by 55.0 percent (10.1 million metric tons) over 2014–19 (figure 6).

Although coal tar production capacity is widely dispersed across China,[116] it is nevertheless prominent in the northern interior and the northeastern seaboard regions (table A.4), with Shanxi Province accounting for over one-fifth (21 percent) of the nation's total output in 2018.[117] Coal-tar producer and processor Baoshun Technology Co. Ltd. claims the largest production capacity in China, but accounted for only 4.3 percent of the nation's total output in 2018.[118] Constricted output and elimination of outdated capacity from the coal coking industry since 2016 with imposition of supply-side reforms and environmental restrictions also constrained coal tar output. China's coal tar output of 18.1 million metric tons in 2018 represented a 1.5-percent decline from the previous year's level.[119]

Firms identified as major producers of needle coke are predominantly located in China's northern interior and northeastern seaboard regions (table A.6). Despite closure of many older production facilities unable to meet the stricter environmental rules,[120] Chinese producers also recorded significant investments in new needle coke projects in recent years.[121] According to some industry observers, high

---

[110] PR NewsWire, "Global Coal Tar Market Growth, Key Companies Analysis, Size, Share, Demands and Industry Outlook 2019–2024," April 15, 2019.
[111] Globe Newswire, "Outlook on China's Coal Tar Market, 2020–2025," February 12, 2020.
[112] Sinoway began constructing a 630,000 metric tons per year calciner in 2011, with the first phase (280,000 metric tons per year) completed in 2013 and the second phase (350,000 metric tons per year) in 2013. Sinoway is reportedly undertaking a feasibility study for a potential third phase to expand the calciner's total capacity to 1 million metric tons per year. Advisian, "Calciners," accessed August 31, 2020.
[113] ZCGG also claims to be the largest manufacturer of calcined petroleum coke in China, with an annual output capacity of 350,000 metric tons. Advisian, "Calciners," accessed August 31, 2020.
[114] Advisian, "Calciners," accessed August 31, 2020.
[115] Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report— Report Insights, Needle Coke Market," August 2019.
[116] Globe Newswire, "China Coal Tar Industry Report 2019–2025," February 26, 2019.
[117] Globe Newswire, "Outlook on China's Coal Tar Market, 2020–2025," February 12, 2020.
[118] Globe Newswire, "China Coal Tar Industry Report 2019–2025," February 26, 2019.
Other major producers include Baotailong New Materials Co. Ltd., Baowu Carbon Material Technology Co. Ltd., Jinneng Science & Technology Co. Ltd., Kailuan Energy Chemical Co. Ltd., and Shanxi Coking Co. Ltd. Globe Newswire, "Outlook on China's Coal Tar Market, 2020–2025," February 12, 2020.
[119] Globe Newswire, "Outlook on China's Coal Tar Market, 2020–2025," February 12, 2020.
[120] Serapio and Daly, "The Graphite Fix: Inside China's Newest Commodity Addiction," September 21, 2017.
[121] Jinzhou Petrochemical Co. Ltd. expanded its annual capacity to 170,000 metric tons with commencement of production at its phase-II needle coke project in 2019. Other Chinese firms that recorded substantial needle coke capacity expansions include Kaifeng Pingmei New Carbon Material Technology Co. Ltd., TSDR New Energy Materials Co. Ltd., and Zaozhuang Zhenxing Carbon Material Technology Co. Ltd. Globe Newswire, "Global and China Needle Coke Industry (2020 to 2026)," May 21, 2020.

needle coke prices and vertical integration benefits encouraged steelmakers and graphite electrode producers, along with mid-sized petroleum refineries (especially in Shandong Province), to undertake needle coke projects.[122] As a result, Chinese needle coke production capacity expanded six-fold from 160,000 metric tons in 2014 to 970,000 metric tons by 2019. Likewise, China recorded a five-fold output increase from 80,000 metric tons in 2016 to 445,000 metric tons in 2019. Shifting between raw-material sources occurred as expansion of coal tar-based needle coke annual capacity (610,000 metric tons) and production (250,000 metric tons) overtook petroleum coke-based annual capacity (360,000 metric tons) and production (195,000 metric tons) in 2019 for the first time in recent years.[123] Nevertheless, China is a net importer of needle coke, due to its limited ability to produce needle coke of high enough quality and in large enough volumes to sufficiently provide graphite electrodes for electric-arc furnace steelmaking and anode graphite for the growing EV battery industry.[124]

Some industry observers expressed skepticism about the extent of China's announced needle coke capacity expansions, with many projects foreseen as likely to be either delayed or canceled. The majority of new needle coke supply in the coming years will be coal tar-based but raw-material supplies could be limited by environmental controls over metallurgical coke production to protect air quality, particularly during the winter heating season. The few planned petroleum coke-based projects could be challenged by both lack of the required technical expertise and limited feedstock availability of low-sulfur crude petroleum.[125]

China dominates global artificial graphite production and demand, in part as the largest and most rapidly growing producer of Li-ion batteries, which prompted consumption growth for artificial graphite.[126] Chinese artificial graphite production is dominated by numerous major firms— notably BTR New Energy Materials Inc., Fangda Carbon New Material Co. Ltd., Jiangxi Zichen Technology Co. Ltd., Kaifeng Carbon Co. Ltd., Lianyungang Jinli Carbon Co. Ltd., Shanshan Technology, Shenzhen Sinuo Industrial Development Co. Ltd., and Sinosteel Engineering & Technology Co. Ltd.[127]— predominantly located within the eastern central and eastern seaboard provinces between Beijing and Shanghai (table A.8).

Artificial graphite production is a significant emitter of nitrogen dioxide, sulfur dioxide, and particulates from baking the hydrocarbon feedstocks.[128] There are reported concerns expressed about the health hazards from the carbon particulates, volatile organic chemicals, sulfur, and heavy metals released

[122] Wood Mackenzie, "IMO 2020, EVs, and Steel," May 30, 2019.
[123] Globe Newswire, "Global and China Needle Coke Industry (2020 to 2026)," May 21, 2020.
[124] Globe Newswire, "Global and China Needle Coke Industry (2020 to 2026)," May 21, 2020; Wood Mackenzie, "IMO 2020, EVs, and Steel," May 30, 2019.
[125] Wood Mackenzie, "IMO 2020, EVs, and Steel," May 30, 2019.
[126] Mordor Intelligence, "Synthetic Graphite Market— Growth, Trends, and Forecast (2020–2025)," April 2020; Research and Markets, "The World Market for Synthetic Graphite, 2019 to 2024," May 24, 2019.
[127] Mordor Intelligence, "Synthetic Graphite Market— Growth, Trends, and Forecast (2020–2025)," April 2020; Research and Markets, "The World Market for Synthetic Graphite, 2019 to 2024," May 24, 2019; Roskill, "Roskill: Batteries Spark Dynamic Change in Graphite Markets," July 10, 2017; TMR, "Synthetic Graphite Market to Reach Around US$7 Bn by 2026," July 5, 2019.
[128] Whiteside and Finn-Foley, "Supply Chain Looms as Serious Threat to Batteries' Green Reputation," November 25, 2019.

from petroleum coke and coal tar not only in China[129] but also in India[130] and the United States.[131] Nevertheless, stakeholders residing near Chinese petroleum coke, coal tar, and needle coke facilities would be adversely affected by job losses resulting from facilities closures directed by governmental corporate restructuring policies for the broader petroleum refining[132] and metallurgical coking industries;[133] and from seasonal production cutbacks to meet stricter clean-air policies.[134]

India— With annual output rising by 24.7 percent to 15.5 million metric tons during 2014–19 (figure 6), India became the world's third-largest producer of petroleum coke (11.1 percent of the reported total in 2019). Several Indian firms were identified among the world's leading sources of calcined petroleum coke. GOA Carbon Ltd., with three calcining plants and 240,000 metric tons of combined annual capacity, was the first to manufacture and export petroleum coke back in 1993.[135] The Indian Oil Corp. Ltd. (IOCL) is integrated across the three stages of the GVC, from manufacturing raw materials to supplying and distributing calcined petroleum coke to the end-users.[136] Rain CII Ltd. (Rain Carbon Inc. in table A.3), a merchant calciner and major graphite supplier to the world's aluminum and titanium-dioxide industries, also operates in the United States after the firm's July-2007 acquisition of CII Carbon LLC, a large U.S. producer of calcined petroleum coke. Rain Industries facilities in India and the United States combine to produce more than 2.4 million tons per year.[137] Rain Industries Ltd. (Rain Carbon Inc. in table A.5) was also identified as a major producer of coal tar in India.[138] IOCL is integrated down the GVC and is a major Indian source of needle coke (table A.7).[139] As producers of electrodes and other finished forms of graphite, Graphite India Ltd. and HEG Ltd. (table A.9) are also among the world's prominent artificial-graphite producers.[140]

---

[129] Taiwan News, "Coal Tar Spill Pollutes River in Southwest China," May 10, 2009; EJAtlas.org, "Residents Protest Against Foul Air in Weiyuan County," November 18, 2019; Hua, "Petcoke Called Key in Pollution Fight," July 16, 2015; McMahon, "China Is Quietly Burning a Fuel Dirtier Than Coal," July 15, 2015.
[130] Horn, "India May Ban Petcoke, One of Dirtiest Fossil Fuels Exported by Koch Brothers," December 9, 2017.
[131] Behm, "Coal Tar Main Source of Toxicity in Streams," December 25, 2016; Dourson, et al., "A Case Study of Potential Human Health Impacts from Petroleum Coke Transfer Facilities," May 5, 2016. 1061; Hawthorne, "Petcoke Piles Gone, But Another Dangerous Pollutant Discovered in the Air," February 21, 2017; Nagle, "Nicor Neighbors Concerned About Coal Tar," October 23, 2014; Neutkens, "Coal Tar Refiners Sued for Polluting Ponds," January 9, 2019; Stewart, "Dust in the Wind: Regulating Coal and Petcoke Particulate Matter," December 2018/January 2019.
[132] Chen, et al., "Review on the Petroleum Market in China: History, Challenges and Prospects," August 30, 2020.
[133] PR NewsWire, "CRU: China's Supply-side Reform is Hurting Third-party Coke Buyers," October 23, 2018.
[134] Serapio and Daly, "The Graphite Fix: Inside China's Newest Commodity Addiction," September 21, 2017; Wood Mackenzie, "IMO 2020, EVs, and Steel," May 30, 2019.
[135] Advisian, "Calciners," accessed August 31, 2020.
[136] Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report by Application— Report Summary," August 2019.
[137] Advisian, "Calciners," accessed August 31, 2020.
[138] PR NewsWire, "Global Coal Tar Market Growth, Key Companies Analysis, Size, Share, Demands and Industry Outlook 2019–2024," April 15, 2019.
[139] Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report— Insights, Needle Coke Market," August 2019.
[140] Roskill, "Roskill: Batteries Spark Dynamic Change in Graphite Markets," July 10, 2017; TMR, "Synthetic Graphite Market to Reach Around US$7 Bn by 2026," July 5, 2019.

Japan— Annual production of petroleum coke and coal tar by Japan fluctuated over 2014–19 with peaks of 1.3 million metric tons of petroleum coke recorded in 2018[141] and 858,000 metric tons of coal tar in 2017.[142] Japanese needle coke production is more coal tar-based than petroleum coke-based.[143] Japanese petroleum coke and coal tar producers are part of larger multinational industrial conglomerates. Sumitomo Corp. subsidiary Petrocokes Japan Ltd. (Petrocokes), was identified as a supplier of calcined petroleum coke (table A.3); whereas JFE Chemical Corp., Nippon Steel & Sumitomo Metal (C-Chem in table A.5) Co. Ltd., and Mitsubishi Chemical Corp., produce coal tar pitch along with other coal tar products.[144]

C-Chem, JXTG Nippon Oil & Energy Corp. (JX Holdings Inc., in table A.7), Mitsubishi Chemical, and Petrocokes are cited by various industry consultancy sources as major needle coke suppliers operating in Japan.[145] C-Chem is also highlighted as the largest producer of coal tar-based needle coke worldwide, with capacity of 110,000 metric tons per year.[146] Moreover, vertically integrated needle coke producers— C-Chem, Mitsubishi Chemical, and Petrocokes (re: tables A.3, A.5, and A.7)— reportedly have a competitive advantage of captive raw-material input supplies, particularly during periods of price fluctuations.[147] There are numerous Japanese artificial-graphite firms (table A.9), including Hitachi Chemical Co. Ltd., Nippon Carbon Co. Ltd., Showa Denko Carbon, and Tokai Carbon Co. Ltd.— that are among the largest in the global market.[148]

South Korea— Annual production of petroleum coke and coal tar by South Korea fluctuated over 2014–19 with peaks of 408,000 metric tons of petroleum coke recorded in 2018[149] and 648,000 metric tons of coal tar in 2016.[150] South Korean needle coke production is coal tar-based and dominated by POSCO Chemtech Co. Ltd. (tables A.5 and A.7). Access to raw-material input supplies, as a subsidiary of integrated (iron ore and coking coal-based) steelmaker Pohang Iron and Steel Co. Ltd. (POSCO), provides POSCO Chemtech with a similar competitive advantage to its Japanese counterparts. Moreover, POSCO Chemtech is also integrated downstream as a coal tar-based producer of artificial graphite (table A.9).

---

[141] UNdata, "Energy Statistics Database, Petroleum Coke," January 6, 2021.
[142] UNdata, "Energy Statistics Database, Coal Tar," January 8, 2021.
[143] Globe Newswire, "Global and China Needle Coke Industry (2020 to 2026)," May 21, 2020.
[144] PR NewsWire, "Global Coal Tar Market Growth, Key Companies Analysis, Size, Share, Demands and Industry Outlook 2019–2024," April 15, 2019.
[145] PR NewsWire, "Global Needle Coke Market 2019–2023," July 2019; Wood Mackenzie, "IMO 2020, EVs, and Steel," May 30, 2019.
[146] Globe Newswire, "Global and China Needle Coke Industry (2020 to 2026)," May 21, 2020.
[147] Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report— Insights, Needle Coke Market," August 2019.
[148] Mordor Intelligence, "Synthetic Graphite Market— Growth, Trends, and Forecast (2020–2025)," April 2020; Research and Markets, "The World Market for Synthetic Graphite, 2019 to 2024," May 24, 2019; Roskill, "Roskill: Batteries Spark Dynamic Change in Graphite Markets," July 10, 2017; TMR, "Synthetic Graphite Market to Reach Around US$7 Bn by 2026," July 5, 2019.
[149] UNdata, "Energy Statistics Database, Petroleum Coke," January 6, 2021.
[150] UNdata, "Energy Statistics Database, Coal Tar," January 8, 2021.

<u>United States</u>— With numerous large, multinational, and several independent, U.S. petroleum refiners producing petroleum coke,[151] the United States (table A.2) was the world's largest overall supplier of petroleum coke during 2014–19 (39.9 percent of the reported total in 2019 in figure 6). Leading calciners with operations in the United States include multinational petroleum refiners and coke producers Chevron Corp. and Phillips 66 Co.; and merchant producers Oxbow Carbon LLC and Rain Industries Ltd. (Rain CII Carbon LLC and Rain Carbon Inc., in table A.2), that purchase and blend raw petroleum coke for subsequent calcining.[152] Chevron and BP Plc are integrated across the three stages of the GVC, from manufacturing raw materials to supplying and distributing calcined petroleum coke to end-users.[153] Among leading producers of coal tar,[154] Koppers Inc., is identified as having operations in the United States, as well as in Australia (table A.5) and China (table A.4).

Leading producers of needle coke in the United States— GrafTech USA LLC, Phillips 66 (considered the world's largest producer[155]), and Seadrift Coke L.P.[156]— rely on calcined petroleum coke as their raw-material input (table A.7). By contrast, another leading U.S. supplier, Asbury Carbons Inc., sources needle coke from outside suppliers.[157] Vertically integrated needle coke producer Phillips 66 Co. (tables A.2 and A.7) reportedly has a competitive advantage of captive raw-material input supplies, particularly during periods of price fluctuations.[158] Needle coke producers GrafTech USA, Phillips 66, and Seadrift Coke are also vertically integrated downstream into baking needle coke to form artificial graphite (table A.10). By contrast, Asbury Carbons Inc., a leading U.S. supplier of needle coke sourced from outside suppliers[159] is also a leading U.S. producer of artificial graphite with multiple production subsidiaries (Asbury Graphite Mills Inc., and Cummings-Moore Graphite Co., in table A.10).

<u>Europe</u>—Although the supply chain for artificial graphite in Europe is overshadowed by the more voluminous ones operating in the Asia-Pacific and North American regions, some general observations can be provided about the producers and locations identified in tables A.3, A.5, A.7, and A.11. BP Plc, the world's third-largest producer of calcined petroleum coke,[160] operates two petroleum-refinery

---

[151] For a list of major petroleum coke producers in the United States, see: Advisian, "Refiners," accessed August 31, 2020.
[152] Advisian, "Calciner," accessed August 31, 2020; Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report— Summary," August 2019.
[153] Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report by Application— Report Summary," accessed August 2019.
[154] PR NewsWire, "Global Coal Tar Market Growth, Key Companies Analysis, Size, Share, Demands and Industry Outlook 2019–2024," April 15, 2019.
[155] Phillips 66 reportedly claims annual calcining capacities up to 370,000 metric tons across its three facilities in the United States and an additional facility in the United Kingdom (table A-3). Globe Newswire, "Global and China Needle Coke Industry (2020 to 2026)," May 21, 2020; Serapio and Daly, "The Graphite Fix: Inside China's Newest Commodity Addiction," September 21, 2017; Whiteside and Finn-Foley, "Supply Chain Looms as Serious Threat to Batteries' Green Reputation," November 25, 2019; Wood Mackenzie, "IMO 2020, EVs, and Steel," May 30, 2019.
[156] Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report— Insights, Needle Coke Market," August 2019; PR NewsWire, "Global Needle Coke Market 2019–2023," July 2019; Whiteside and Finn-Foley, "Supply Chain Looms as Serious Threat to Batteries' Green Reputation," November 25, 2019.
[157] See: Asbury Carbons, "Coke," accessed August 31, 2020.
[158] Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report— Insights, Needle Coke Market," August 2019.
[159] See: Asbury Carbons, "Coke," accessed August 31, 2020.
[160] Advisia, "Calciners," accessed August 31, 2020.

integrated calciners in Germany (table A.3). Rain Industries Ltd. (Rain Carbon Inc. in table A.5), a major producer of coal tar in India,[161] operates coal tar facilities in Belgium and Germany. Phillips 66 Co., the largest manufacturer of oil-based needle coke in the world,[162] has a needle coke operation in the United Kingdom (table A.7). Among the world's largest producers of artificial graphite operating in Europe are SGL Carbon SE in Germany and Energoprom Group in Russia (table A.11).[163] Russian producers were identified along each stage of the artificial graphite supply chain (tables A.3, A.5, A.7, and A.11). Moreover, Energoprom Group is a vertically integrated producer of artificial graphite (table A.11) from needle coke (table A.7) derived from calcined petroleum coke (table A.3).

Anode Graphite

Processing Locations

The processing of refined graphite suitable for the component anodes for Li-ion batteries is concentrated in certain industrialized regions of the world. Although annual production and capacity statistics are not readily available for individual countries or the broader processing regions, the global Li-ion anode materials industry is concentrated in China (table A.12) followed by Japan (table A.13)—which together reportedly accounted for more than 95 percent of market sales worldwide in 2019—[164]and South Korea (table A.13).[165] The United States (table A.14) and Western Europe (table A.15) are more recent entrants, but are growing quickly.[166] Moreover, even newer graphite firms, based in Australia, Canada, and India are entering the global industry by integrating their upstream mining or coal tar operations with downstream processing operations to provide material suitable for battery anodes.[167]

Case Studies

Firms that process natural or artificial (or a blend of both types of) graphite generally supply to both domestic and foreign Li-ion battery producers that apply the powdered graphite as a coating onto copper foil substrates to form anode battery components. The characteristics of the countries and regions that process graphite into battery anode-grade graphite are examined and compared in the

[161] PR NewsWire, "Global Coal Tar Market Growth, Key Companies Analysis, Size, Share, Demands and Industry Outlook 2019–2024," April 15, 2019.
[162] Globe Newswire, "Global and China Needle Coke Industry (2020 to 2026)," May 21, 2020.
[163] Roskill, "Roskill: Batteries Spark Dynamic Change in Graphite Markets," July 10, 2017.
[164] Moreover, the world's top-five producers of battery-grade graphite— Shenzhen BTR New Energy Materials Inc. (China), Jiangxi Zichen Technology Co. Ltd. (China), Ningbo Shanshan Co. Ltd. (China), Guangdong Kaijin New Energy Technology Co. Ltd. (China), and Hitachi Chemical Co. Ltd. (Japan)— together supplied 69.6 percent of the global market in that year. PR NewsWire, "Global and China Lithium-ion Battery Anode Material Industry Report, 2020–2026," September 4, 2020. Production country tables are provided in Appendix A.
[165] A more recent source mentioned the top-four producers of battery-grade graphite as BTR New Energy Materials Inc. (China), Shanghai Shanshan Technology Co. Ltd. (China), Jiangxi Zichen Technology Co. Ltd. (China), and Posco Chemical Co. Ltd. (South Korea). Noh and Choi, "Posco Chemical to Supply Anodes to GM's EV Platform Ultium in U.S.," April 6, 2021. Production country tables are provided in Appendix A.
[166] Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 15. Production country tables are provided in Appendix A.
[167] Whiteside and Finn-Foley, "Supply Chain Looms as Serious Threat to Batteries' Green Reputation," November 25, 2019.

following case studies. The producing countries and regions are presented below in relative order of prominence, by considering leading global producing firms, industry evolution, technological capabilities, and capital investment activities, within the GVC for anode graphite.

China—Long-term planning and extensive investments to build capacity at every stage of the GVC for anode materials have enabled China to dominate global processing[168] and gain production cost advantages.[169] Even though it is the world's largest producer of natural graphite, China's anode material shipments in 2019 were predominantly of artificial graphite (78.5 percent share or 208,000 metric tons), rather than of natural graphite (18.5 percent share or 49,000 metric tons) or of other carbonaceous materials (3 percent share or 8,000 metric tons).[170] In that same year, 86 percent of the world's total graphite anode material output (natural and artificial) and 100 percent of all natural-graphite anode materials originated in China.[171] Moreover, most of the world's commercial processing capacity to convert flake graphite into anode material-grade uncoated spheroidal graphite currently operates in China.[172] Nevertheless, Chinese-produced uncoated spherical graphite tends to be exported to Japan and South Korea for applying the finished coatings to produce coated spherical graphite.[173]

The Chinese anode material industry predominantly operates in the Pearl River Delta, the Yangtze River Delta (especially Shanghai but also Huzhou), and the central Chinese Provinces of Henan and Hunan (table A.12).[174] Major Chinese anode material producers include Guangdong Kaijin New Energy Technology Co. Ltd., Jiangxi Zheng Tuo New Energy Technology Co. Ltd. (ZETO), Jiangxi Zichen Technology Co. Ltd. (Zichen), Ningbo Shanshan Co. Ltd., Shanghai Shanshan Technology Co. Ltd. (Shanshan Technology), Shenzhen BTR New Energy Materials Inc. (BTR), Shenzhen Sinuo Industrial Development Co. Ltd. (Sinuo), and Shenzhen Xiang Fenghua (XFH) Technology Co. Ltd.[175] Some of these major anode material producers are also integrated upstream as major producers of artificial

[168] Benchmark, "China Controls Sway of Electric Vehicle Power Through Battery Chemicals, Cathode and Anode Production," May 6, 2020; IER, "China Dominates the Global Lithium Battery Market," September 9, 2020; Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 17.
[169] PR NewsWire, "Global and China Lithium-ion Battery Anode Material Industry Report, 2020–2026," September 4, 2020; PR NewsWire, "Global and China Lithium-ion Battery Anode Material Industry Report, 2017–2020," March 22, 2017.
[170] However, information was not readily available from corporate Internet web sites about the extent that Chinese battery anode materials firms ship blended compositions of artificial and natural graphite. PR NewsWire, "Global and China Lithium-ion Battery Anode Material Industry Report, 2020–2026," September 4, 2020.
[171] Benchmark, "China Controls Sway of Electric Vehicle Power Through Battery Chemicals, Cathode and Anode Production," May 6, 2020.
[172] Benchmark, "Elon Musk: Our Lithium-ion Batteries Should be Called Nickel-Graphite," June 5, 2016; Moores, "Spherical Graphite: How Is It Made?" August 2, 2013; Shaw, "Graphite: Natural Graphite Remains on EU Critical Raw Materials List, For Now," September 10, 2020; Shaw, "Graphite: Renascor Signs MoU with Major Chinese Anode Producer," February 5, 2021; Willing, "Graphite Firms Integrate European Battery Supply Chain," September 24, 2020.
Moreover, capacity ownership of this crucial chemical conversion step ensures that global raw material flows to China for value-added production of battery anode materials. Benchmark, "China Controls Sway of Electric Vehicle Power Through Battery Chemicals, Cathode and Anode Production," May 6, 2020.
[173] Moores, "Spherical Graphite: How Is It Made?" August 2, 2013.
[174] PR NewsWire, "Global and China Lithium-ion Battery Anode Material Industry Report, 2017–2020," March 22, 2017.
[175] PR NewsWire, "Global and China Lithium-ion Battery Anode Material Industry Report, 2020–2026," September 4, 2020; Shaw, "Graphite: Renascor Signs MoU with Major Chinese Anode Producer," February 5, 2021.

graphite—notably BTR, Shanshan Technology, Sinuo, and Zichen (table A.8). Anode material industry growth in China reportedly benefitted from both direct government support to develop domestic manufacturers as well as expansions by foreign based (especially Japanese) producers (table A.12) seeking lower production costs which also resulted in technology transfers to Chinese producers.[176]

Some integrated Chinese firms are reportedly adding production capacity to convert natural graphite flake concentrate into uncoated spheroidal graphite for Li-ion battery anode materials.[177] For example, China Minmetals Corp. established a graphite processing subsidiary in December 2019, China Minmetals Group (Heilongjiang) Graphite Industry Co., to produce anode materials from the natural graphite of its Yushuan Mine. The latter is considered the largest graphite mine in Asia (with graphite resources exceeding 1 billion metric tons as of November 2016) and is in Luobei County of Heilongjiang Province.[178] Moreover, Shanshan Technology, BTR, and LuiMao Graphite are building, in association with BAIC Automotive Group, anode material “megafactories” with combined processing capacity of 260,000 metric tons per year.[179]

Alternatively, other Chinese firms are seeking foreign sources of processed graphite. Chinese anode material producer ZETO agreed to a non-binding memorandum of understanding (MoU) with Australian-based Renascor Resources Ltd. (Renascor) in December 2020. Renascor will provide up to 10,000 metric tons of uncoated spheroidal graphite per year over a decade[180] from its Adelaide facility that purifies and processes natural graphite from its Siviour Mine in South Australia.[181] Previously, Shanxi Minguang New Material Technology Co. Ltd. negotiated a similar MoU with Renascor in September 2020 for the same annual tonnages over the same time frame.[182]

Japan— Dating back to the first commercialization of Li-ion batteries by Sony Corp. and Asahi Kasei Corp. in 1991,[183] Japanese firms historically dominated the production of both Li-ion batteries and battery materials with their high domestic market shares[184] and technological prowess.[185] For anode materials, Hitachi Chemical Co. Ltd.[186] (along with South Korean producers LG Chemical Co. Ltd. and

---

[176] Yamaguchi, et al., “Battery/Battery Materials,” July 3, 2012, 17.
[177] Argus Media, “Battery Demand Buoys Graphite Prices,” April 19, 2018.
[178] Daly, “China Minmetals Sets Up Graphite Unit in Battery Materials Push,” December 19, 2019.
[179] Deign, “China Plans Graphite Megafactories to Meet Booming Demand for Battery Storage,” October 26, 2017.
[180] Shaw, “Graphite: Renascor Signs MoU with Major Chinese Anode Producer,” February 5, 2021.
[181] Renascor Resources, “Siviour Graphite Project,” retrieved June 16, 2021.
[182] Shaw, “Graphite: Renascor Signs MoU with Major Chinese Anode Producer,” February 5, 2021.
[183] Asahi Kasei Corp. technicians were the first to apply better-performing graphite rather than petroleum coke as the anode material for Li-ion batteries. The lithium ions intercalated into the layered graphite, which eliminated the previous need for metallic lithium which chemically reacts with the electrolyte in the battery. Dixon-Warren, “The World of Lithium Ion Batteries,” May 13, 2020; Lebedeva, Di Persio, and Boon-Brett, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*, 2016, 26.
[184] Yamaguchi, et al., “Battery/Battery Materials,” July 3, 2012, 15.
[185] PR NewsWire, “Global and China Lithium-ion Battery Anode Material Industry Report, 2020–2026,” September 4, 2020; PR NewsWire, “Global and China Lithium-ion Battery Anode Material Industry Report, 2017–2020,” March 22, 2017; Yamaguchi, et al., “Battery/Battery Materials,” July 3, 2012, 15.
[186] Although Hitachi Chemical was acquired by Showa Denko K.K. on April 28, 2020 and subsequently renamed “Showa Denko Materials Co. Ltd.” in October 1, 2020, the original corporate name is retained in this section, to maintain consistency with the cited reference sources and to distinguish between Hitachi’s and Showa Denko’s existing facilities (in table A-13) prior to the corporate acquisition. Showa Denko Materials, “Announcement of Changing Company's Name,” June 23, 2020.

Samsung SDI) developed the technology to control the expansion and extend the cycle life of natural spheroidal graphite,[187] which enabled them to blend together natural and artificial graphite that provides the advantages of each for producing lower cost, longer life, high-capacity EV Li-ion batteries. An industry source estimates the proprietary blended graphite compositions of Japanese and South Korean anode material producers to contain 40−60 percent natural graphite.[188] To meet customer specifications, anode graphite blends are reportedly also available as 50-50, 30-70, 20-80, etc., ratios of natural-to-artificial graphite.[189]

The leading Japanese producers—large major chemical and materials firms Hitachi Chemical, JFE Chemical Corp., and Mitsubishi Chemical Holdings Corp.; along with mid-sized chemical and materials firms such as Nippon Carbon Co. Ltd. and Nippon Steel Chemical & Material Co. Ltd.[190]—tend to produce anode materials of both types of graphite (table A.13).[191] As large multinational industrial conglomerates, the major Japanese anode material producers are integrated upstream to varying degrees as coal tar-based (table A.5) producers of needle coke (table A.7) and artificial graphite (table A.9).

Since the early-2010s (especially after the disruptions arising from the Fukushima tsunami and earthquake in March 2011), Japanese anode material producers, particularly those lacking sufficient operating scale and financial resources, sought to establish operations overseas (tables A.12 and A.14) and corporate ties with foreign producers (table A.13). Likewise, Japanese battery manufacturers increasingly sought to diversify their materials suppliers with Chinese and South Korean anode material competitors offering lower priced materials. Moreover, technology transfers arising from both Japanese investment abroad and foreign acquisitions in Japan narrowed technological capabilities and broadened global anode material production beyond East Asia.[192] French-based multinational minerals processor Imerys SA announced its acquisition of Japan's Nippon Power Graphite (NPG) in February 2017, that both expands its business into higher value Li-ion battery anode materials production and acquires NPG's patented chemical vapor deposition coating process for coated spheroidal graphite.[193] Under its Swiss-based subsidiary Imerys Graphite & Carbon SA, NPG's facility in Kitakyushu City

---

[187] Northern Graphite, "About Spherical Graphite," accessed January 9, 2018.
Moreover, although spheroidization of graphite was conceptualized in Germany, albeit not patented, which allowed Asian producers to commercialize spheroidal graphite. Moores, "Spherical Graphite: How Is It Made?" August 2, 2013.
[188] Northern Graphite, "About Spherical Graphite," accessed January 9, 2018.
[189] CBP, "The Tariff Classification of Two Surface Modified Graphite Powders from Japan," Customs Ruling No. N094256, March 19, 2010.
[190] PR NewsWire. "Global and China Lithium-ion Battery Anode Material Industry Report, 2020–2026," September 4, 2020; Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 15.
[191] However, information was not readily available from corporate Internet web sites about specific graphite blend compositions. Goldman, Rotondo, and Swallow, *Lithium Ion Battery Industrial Base in the U.S. and Abroad*, December 2019, 12; Lebedeva, Di Persio, and Boon-Brett, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*, 2016, 16; PR NewsWire, "Global and China Lithium-ion Battery Anode Material Industry Report, 2020–2026," September 4, 2020; PR NewsWire, "Global and China Lithium-ion Battery Anode Material Industry Report, 2017–2020," March 22, 2017.
[192] Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 15.
[193] Roskill, "Graphite: Imerys Acquires Nippon Power Graphite," February 22, 2017; Slavnich, "Imerys Graphite & Carbon Acquires CVD Coating Technology," February 23, 2017.

reportedly will continue to primarily supply Asian markets as part of Imerys broader plans to enter the EV GVC.[194]

In response to customer preferences, Japanese anode material producers are also seeking to establish their own graphite GVCs outside of China.[195] For example, Hitachi Chemical invested $90 million to construct another facility in Japan to process 100,000 metric tons of natural graphite a year by 2020. This facility will extend Hitachi Chemical's anode material production further into natural graphite and will expand its overall anode material production capacity four-fold in Japan.[196]

South Korea— The major graphite anode material producers in South Korea are subsidiaries of the indigenous, multinational "chaebol" (conglomerates) in the chemicals, steel, and other industries— LG Chemical Co. Ltd. (a subsidiary of LG Corp.), Samsung SDI (Samsung Group), POSCO Chemical Co. Ltd. (Pohang Iron and Steel Co. (POSCO)), GS Caltex Corp. (GS Group), and SK Group (table A.13).[197] Having the financial resources for acquisitions and product development, low infrastructure costs and a favorable tax code,[198] these major firms expanded their business lines into battery materials reportedly to capture the potential long-term demand growth of this industry segment.[199]

Along with Japanese anode material producer Hitachi Chemical, South Korean producers LG Chemical and Samsung SDI also developed the technology to control expansion and extend the cycle life of natural spheroidal graphite to meet the requirements for EV Li-ion batteries.[200] However, only dominant POSCO Chemical, which is integrated upstream as a coal tar-based producer of needle coke (tables A.5 and A.7) and artificial graphite (table A.9), produces anode materials containing both natural and artificial graphite.[201] Other South Korean anode material producers specialize in artificial graphite but reportedly are highly import reliant.[202]

POSCO Chemical broke ground on a new anode material facility in July 2020, to produce 16,000 metric tons per year in Pohang, South Gyeongsang Province, with construction anticipated to be completed by 2023.[203] However, the firm reportedly scaled back its investment plans for expanding natural-graphite production capacity in 2020 through 2023, with anticipated increased artificial-graphite production capacity in the interim to enhance corporate profitability.[204] Moreover, parent company POSCO signed an MoU with Australian-based Black Rock Mining Ltd. (Black Rock) to jointly develop the Mahenge

---

[194] Roskill, "Graphite: Imerys Acquires Nippon Power Graphite," February 22, 2017.
[195] Crompton, "Opinion: Australia Begins Its Challenge of China's Graphite Crown in EV Batteries," August 2, 2020; Matsumoto, "Australia Challenges China's Graphite Crown in EV Batteries," July 25, 2020.
[196] Benchmark, "China Threat Sparks Hitachi's Four-fold Graphite Anode Expansion," December 16, 2016; Deign, "China Plans Graphite Megafactories to Meet Booming Demand for Battery Storage," October 26, 2017; Moores and Miller, "Hitachi Plans Huge Anode Expansion Amid a Graphite Overhaul in China," January 26, 2017.
[197] Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 15–17.
[198] Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 16–17.
[199] Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 16.
[200] Northern Graphite, "About Spherical Graphite," accessed January 9, 2018.
[201] Noh and Choi, "Posco Chemical to Supply Anodes to GM's EV Platform Ultium in U.S.," April 6, 2021.
[202] However, information was not readily available from corporate Internet web sites about any specific blend compositions of artificial and natural graphite. Won and Lee, "Posco Chemical Breaks Ground for EV Battery Anode Material Factory in Korea," July 3, 2020.
[203] Won and Lee, "Posco Chemical Breaks Ground for EV Battery Anode Material Factory in Korea," July 3, 2020.
[204] Lee, "Posco Slows Down Natural Graphite Expansion Plan," October 26, 2020.

Project in Tanzania,[205] considered one of the largest worldwide, with resources of 212 million metric tons at 7.8 percent total flake graphite content and reserves of 70 million tons at 8.5 percent total flake graphite content. Black Rock's Definitive Feasibility Study for this project provides a four-stage construction schedule to deliver up to 340,000 metric tons per year of 98.5 percent graphite concentrate for 26 years.[206]

United States—U.S. chemicals and materials firms are more recent entrants into the refined (anode) graphite market,[207] through corporate acquisitions and capital expenditures,[208] to extend their business lines into battery materials. These firms reportedly sought to capitalize upon the potentially large scale and long-term demand growth of this industry segment[209] and to reduce their reliance upon East Asian sources for battery materials.[210] Despite lack of domestic mined graphite resources since the mid-1990s,[211] the major U.S.-based chemicals firms 3M Co. and Dow Corning Corp.[212] and certain carbonaceous materials firms (especially Asbury Carbons Inc., SGL Carbon LLC, and Superior Graphite Co.) generally produce both natural and artificial graphite anode materials (table A.14).[213] Several recent corporate developments highlight the ongoing development and expansion of the U.S. anode material industry.

In January 2019, Asbury Carbons, a leading U.S. graphite processor, acquired from Urbix Resources Inc., an emerging U.S. specialty graphite refiner, the natural graphite milling facility located outside of Hermosillo in the Mexican State of Sonora, which produces microcrystalline graphite powders for steelmaking, refractories, and coatings. Moreover, the two firms also signed a letter of intent to pursue joint ventures to develop highly refined graphitic products including purified flake graphite, spherical graphite, graphenes, and graphene-like additives.[214]

Urbix Resources also broke ground in early-2019 for a new graphite-purification facility in Mesa, Arizona. The facility is designed to process up to 36,000 metric tons of high-purity graphite annually as well as being among the world's largest facilities capable of producing various graphene additives. The firm's purification process avoids both hydrofluoric acid and high energy consumption and reportedly will be among the lowest cost in the world for achieving Li-ion battery anode material grades.[215]

---

[205] Crompton, "Opinion: Australia Begins Its Challenge of China's Graphite Crown in EV Batteries," August 2, 2020.
[206] Black Rock Mining, "Our Projects," retrieved June 16, 2021.
[207] Lebedeva, Di Persio, and Boon-Brett, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*, 2016, 16 Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 15.
[208] Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 17.
[209] Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 16.
[210] Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 17.
[211] [This duplicates tezt on page 14; consider deleting or revising] Graphite has not been mined in the United States since 1994 when United Minerals Corp. suspended operations at its mine in Broadwater, Montana. Kay, "Graphite Mining in the US," April 19, 2018; *The Diggings*, "United Minerals Co. Mill in Broadwater, MT, Graphite Past Producer," 2018.
[212] Lebedeva, Di Persio, and Boon-Brett, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*, 2016, 16; Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 15.
[213] However, information was not readily available from corporate Internet web sites about any specific blend compositions of artificial and natural graphite.
[214] Urbix Resources, "Leading U.S. Graphite Companies Will Collaborate Towards High-Purity Graphite, Spherical Graphite and Graphene," February 4, 2019.
[215] Production costs are anticipated to average less than $375.00 per metric ton to purify to 99.95+ percent total graphitic content battery anode materials.

Operations are planned to start by the end of 2019, when it will provide toll processing services for graphite producers worldwide, while providing an initial production output of 5,000 metric tons.[216]

Multinational firm Syrah Resources Ltd., considered the world's largest natural graphite producer outside of China,[217] began the initial processing of natural graphite mined from its Balama Graphite Operations in Mozambique[218] into purified spherical graphite that meets battery specifications at its Vidalia, Louisiana anode material facility in July 2020.[219] This is a key accomplishment for this Australia-based firm to become the first vertically integrated anode material producer from natural graphite outside of China.[220] The initial annual graphite purification capacity at this facility is 1,000 metric tons and the initial annual graphite milling capacity is 5,000 metric tons from two milling lines, each with annual capacities of 2,500 metric tons.[221] Syrah Resources is currently expanding the annual anode material production capacity of the existing facility, initially to 10,000 metric tons and subsequently to 40,000 metric tons.[222] The lengthy GVC, from southeastern Africa to North America reportedly provides "an option for geographic diversification" to North American and European automakers seeking alternatives to Chinese sources.[223]

Western Europe—Similar to in the United States, chemicals and materials firms in Western Europe are also more recent entrants to the refined (anode) graphite market,[224] likewise through corporate acquisitions and capital expenditures,[225] to extend their business lines into battery materials. These firms also reportedly sought to capitalize upon the potentially large scale and long-term demand growth of this industry segment[226] and to reduce their reliance upon East Asian sources for battery materials.[227] Despite the existence of potentially high-grade natural graphite deposits in Western Europe, [228] both the major European-based chemicals and materials firms Heraeus Group (Germany), Imerys Graphite & Carbon SA (Switzerland), and SGL Carbon SE Group (Germany),[229] as well as smaller

---

[216] Urbix Resources, "Leading U.S. Graphite Companies Will Collaborate Towards High-Purity Graphite, Spherical Graphite and Graphene," February 4, 2019.
[217] Karinja, "World's Largest Graphite Mine Achieves Commercial Production," January 14, 2019; Barrera, "9 Top Graphite-mining Countries," August 14, 2019; Olsen, "Graphite (Advanced Release), June 2018, 32.4.
[218] The Balama deposit, located in the northern Province of Cabo Delgado, is reportedly considered to be the world's largest, with reserves amounting to 1.1 billion metric tons in 2014, far larger than all other known worldwide graphite deposits combined. Olsen, "Graphite (Advanced Release), June 2018, 32.4.
[219] Crompton, "Opinion: Australia Begins Its Challenge of China's Graphite Crown in EV Batteries," August 2, 2020.
[220] Crompton, "Opinion: Australia Begins Its Challenge of China's Graphite Crown in EV Batteries," August 2, 2020; Matsumoto, "Australia Challenges China's Graphite Crown in EV Batteries," July 25, 2020.
[221] Roskill, "Graphite: The Race for Non-Chinese Spherical Graphite Heats Up," April 29, 2019; Syrah Resources, "Battery Anode Material Project, USA," accessed November 1, 2019; Argus Media, "Syrah Advances Purified Spherical Graphite Production," April 29, 2019.
[222] Crompton, "Opinion: Australia Begins Its Challenge of China's Graphite Crown in EV Batteries," August 2, 2020.
[223] Matsumoto, "Australia Challenges China's Graphite Crown in EV Batteries," July 25, 2020.
[224] Lebedeva, Di Persio, and Boon-Brett, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*, 2016, 16 Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 15.
[225] Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 17.
[226] Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 16.
[227] Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 17.
[228] EBA, "Supply of Graphite from Europe," November 10, 2020.
[229] Lebedeva, Di Persio, and Boon-Brett, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*, 2016, 16; Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 15.

European firms mostly produce artificial graphite anode materials (table A.15).[230] The European Commission included natural graphite on its four successive lists of Critical Raw Materials (CRMs)[231] that pose a high risk of adverse economic impacts from potential supply shortages,[232] in recognition of the importance of graphite for EV battery production in the European Union.[233] Numerous recent corporate developments highlight the ongoing development and expansion of the Western European anode material industry, as discussed below.

From its corporate acquisition of Japanese-based NPG in February 2017, French-based multinational minerals processor Imerys SA expanded its business lines into higher value Li-ion battery anode materials production and acquired NPG's patented chemical vapor deposition coating process for coated spheroidal graphite.[234] Imerys subsidiary Imerys Graphite and Carbon SA produces artificial graphite at Bodio in Switzerland, as well as mines and processes natural graphite in Canada (table A.1) and processes graphite at various locations in both China (table A.12) and Japan (table A.13).[235]

Western Europe is considered relatively rich in potentially high-grade natural graphite deposits, primarily in Scandinavia, with potential to supply the European battery market for decades.[236] In recent years, several outside graphite mining firms have been developing integrated natural graphite GVCs from mining through anode material production in Western Europe in response to both EU officials and EV manufacturers concerns about CRMs.[237]

Australian-based Mineral Commodities Ltd. is currently constructing an anode material plant in Norway that will initially supply 10,000 metric tons per year of coated spherical graphite to European battery producers. The graphite concentrate will be sourced from its Skaland Mine in Norway starting in 2023. The firm also plans to construct two 20,000 metric tons per year modules to process graphite concentrate from its Munglinup Mine in Australia when it starts operations in 2024. Moreover, the new anode material facility will not requiring hydrofluoric acid to purify natural graphite during the purification process of natural graphite.[238]

Australian-based Talga Resources Ltd. (Talga) sought partners to establish a European GVC of sustainable, low-carbon dioxide emitting anode materials for Li-ion batteries using its Swedish mineral assets and proprietary battery materials processing technologies.[239] In early-November 2020, Talga

---

[230] However, information was not readily available from corporate Internet web sites about any specific blend compositions of artificial and natural graphite.
[231] Since the initial EU Raw Materials Initiative list of 2008, the EC included natural graphite on its first list of CRMs in 2011 and in successive revised lists of CRMs issued in 2014, 2017, and 2020. For further information, see EC, "Critical Raw Materials," accessed June 29, 2021.
[232] Anderson, "Critical Materials: EU Releases Updated Critical Raw Materials List," September 4, 2020; Shaw, "Graphite: Natural Graphite Remains on EU Critical Raw Materials List, For Now," September 10, 2020.
[233] Willing, "Graphite Firms Integrate European Battery Supply Chain," September 24, 2020.
[234] Roskill, "Graphite: Imerys Acquires Nippon Power Graphite," February 22, 2017; Slavnich, "Imerys Graphite & Carbon Acquires CVD Coating Technology," February 23, 2017.
[235] Roskill, "Graphite: Imerys Acquires Nippon Power Graphite," February 22, 2017; Slavnich, "Imerys Graphite & Carbon Acquires CVD Coating Technology," February 23, 2017.
[236] EBA, "Supply of Graphite from Europe," November 10, 2020.
[237] Willing, "Graphite Firms Integrate European Battery Supply Chain," September 24, 2020.
[238] Willing, "Graphite Firms Integrate European Battery Supply Chain," September 24, 2020.
[239] EBA, "Supply of Graphite from Europe," November 10, 2020; LKAB, "Talga, Mitsui and LKAB Confirm Intent for Joint Development of the Vittangi Graphite Mine and Battery Anode Production," November 2, 2020.

signed a non-binding letter of intent with Japanese-based Mitsui & Co. Europe Plc (Mitsui) and Swedish-based, parastatal Luossavaara-Kiirunavaara Aktiebolag (LKAB) to jointly develop the Vittangi Mine in northern Sweden and an anode material facility (the Talga Project)[240] after completion of a feasibility study in 2021.[241] The development plans include a 19,000 metric tons per year coated anode facility, to supply the European EV GVC from 2023, which will process flake graphite from the Vittangi Mine at the high-quality Nunasvaara graphite deposit,[242] which will produce 22,000 metric tons per year from 2021.[243]

Canadian-based Leading Edge Materials Corp. is preparing to revive operations at the Woxna Mine north of Stockholm, which previously was shut-down in 2001 amid a slump in graphite prices, as part of its goal of becoming a “one-stop shop” for battery manufacturers. Currently, purified graphite from Woxna is undergoing testing with the goal of producing enough by 2020 to sell to battery manufacturers such as NorthVolt AB, founded by a former Tesla executive with plans to start large-scale EV output in Sweden. Leading Edge Materials also reportedly conferred with several other automakers including BMW.[244]

Indian-based Epsilon Advanced Materials Pvt. Ltd. (EAMPL) and British-based exploration and development company Beowulf Mining PLC signed an MoU in March 2021 for the latter’s subsidiary Oy Fennoscandian Resources Ab to develop a strategic processing hub for natural flake and recycled graphite in Finland and as a base for supplying anode materials into Europe. Beowulf Mining is also developing the Aitolampi graphite deposit in Finland, with graphite resources totaling 1.3 million metric tons of almost perfect crystallinity, an important physical attribute for anode material applications. EAMPL’s 50 metric ton pilot plant utilizes a proprietary technology to process natural graphite flakes for producing battery-grade purified spherical graphite. Finally, EAM also plans to expand its natural graphite flake processing capacity to 25,000 metric tons per year by 2027.[245]

Australia—EcoGraf Ltd. plans to become a fully integrated Australian-based firm with its existing Epanko Mine in Tanzania to produce 60,000 metric tons per year of flake graphite and a planned graphite processing plant in Kwinana, Western Australia. By initially processing 5,000 metric tons per year, rising to 20,000 metric tons per year by 2022,[246] EcoGraf aspires to become a long-term supplier of eco-friendly natural flake and spherical anode material to both established refractory, recarburiser, and lubricant markets as well as to emerging Li-ion battery markets worldwide.[247] By utilizing a proprietary graphite purification process that does not rely on expensive and environmentally hazardous hydrofluoric acid,[248] EcoGraf anticipates its processing costs will be “below the existing

[240] EBA, “Supply of Graphite from Europe,” November 10, 2020.
[241] LKAB, “Talga, Mitsui and LKAB Confirm Intent for Joint development of the Vittangi Graphite Mine and Battery Anode Production,” November 2, 2020.
[242] EBA, “Supply of Graphite from Europe,” November 10, 2020.
[243] Willing, “Graphite Firms Integrate European Battery Supply Chain,” September 24, 2020.
[244] Rolander and Starn, “EV Boom Leads to Reopening of Swedish Graphite Mine,” April 3, 2018.
[245] Holman, “Beowulf, Epsilon Partner to Develop Graphite Processing Hub in Finland,” March 8, 2021.
[246] Willing, “Graphite Firms Integrate European Battery Supply Chain,” September 24, 2020.
[247] EcoGraf Ltd., “Overview,” accessed June 16, 2021.
[248] EcoGraf Ltd., “Recovering Battery-grade Graphite, Without Using Hydrofluoric Acid,” May 9, 2021.

supply from China while providing a diversified supply and low sovereign risk," according to the firm's Managing Director.[249]

Seeking investment opportunities in European battery capacity, as the EU committed €3.2 billion to support GVC development, EcoGraf qualified its high-purity fines with European customers and signed a 10-year agreement with German-based technology group Thyssenkrupp AG's subsidiary Thyssenkrupp Materials Trading GmbH. The agreement covers the sale of approximately 50 percent of planned output of purified spherical graphite and by-product fines from the Kwinana facility[250]—2,310 metric tons of anode material in the first active year and rising to 10,020 metric tons in the third year and thereafter, enough to produce Li-ion batteries for some 370,000 EVs annually.[251]

EcoGraf is also negotiating to supply Japanese and South Korean customers.[252] South Korean-based battery recycler SungEel HiTech Co. Ltd. will be using EcoGraf's proprietary graphite purification process to recover high-grade anode materials along with its own hydrometallurgical technologies to recover cathode materials from scrapped Li-ion batteries in two planned recycling plants to be constructed in South Korea and Europe.[253] Finally, the firm's longer term plans include additional graphite processing facilities in Europe and North America.[254]

Canada— Nouveau Monde Graphite Inc. is concurrently developing its graphite mining, purification, and anode material facilities in Québec to fulfill its aspirations of commencing commercial operations by 2023 as a fully integrated supplier of anode materials to the leading Li-ion battery and EV automobile producers worldwide.[255] The firm's Matawinie Graphite Mine Project, located in Saint-Michel-des-Saints (150 kilometers north of Montréal), offers high-purity mineral reserves and low operating cost potential. The processing facility will be constructed in an industrial park near a major shipping port in Bécancour (approximately 150 kilometers northeast of Montréal), on the Saint Lawrence River.[256]

---

[249] Crompton, "Opinion: Australia Begins Its Challenge of China's Graphite Crown in EV Batteries," August 2, 2020; Matsumoto, "Australia Challenges China's Graphite Crown in EV Batteries," July 25, 2020.
[250] Crompton, "Opinion: Australia Begins Its Challenge of China's Graphite Crown in EV Batteries," August 2, 2020; Willing, "Graphite Firms Integrate European Battery Supply Chain," September 24, 2020.
[251] Matsumoto, "Australia Challenges China's Graphite Crown in EV Batteries," July 25, 2020.
[252] Crompton, "Opinion: Australia Begins Its Challenge of China's Graphite Crown in EV Batteries," August 2, 2020; Matsumoto, "Australia Challenges China's Graphite Crown in EV Batteries," July 25, 2020.
[253] EcoGraf Ltd., "Recovering Battery-grade Graphite, Without Using Hydrofluoric Acid," May 9, 2021. For further information about SungEel HiTech battery recycling operations, see *South China Morning Post*, "SungEel HiTech Leads the Way in Eco-friendly Recycling of Lithium-ion Batteries," April 29, 2020.
[254] Willing, "Graphite Firms Integrate European Battery Supply Chain," September 24, 2020.
[255] Nouveau Monde Graphite, "About Us," accessed June 16, 2021.
[256] Nouveau Monde Graphite, "Operations," accessed June 16, 2021.

The Phase 1 coating line has already started operations and is anticipated to be commissioned in first-quarter 2022 to produce 2,000 metric tons per year of coated spheroidal graphite. The firm is also developing a large-scale Phase 2 anode material facility to process 42,000 metric tons per year of coated spheroidal graphite as anode materials for Li-ion batteries and 3,000 metric tons per of purified graphite for hydrogen fuel cells and 5G heat-dissipation foils.[257]

India—The leading Indian coal tar processor Epsilon Carbon Pvt. Ltd., has integrated downstream by forming the subsidiary EAMPL in August 2020 to produce artificial graphite and anode materials for Li-ion batteries in India and to become a supplier to Li-ion battery and energy storage device producers worldwide.[258] Epsilon Carbon's coal tar facility in the southern state of Karnataka, India's first continuous integrated distillation unit,[259] sources its raw materials from India's largest steel mill, owned by JSW Steel Ltd.[260] EAMPL reportedly anticipates producing 5,000 metric tons per year of anode material at its Karnataka facility, with plans to triple its annual capacity to 15,000 metric tons in 2021 and further expand to 50,000 metric tons by 2025,[261] in anticipation of meeting the Li-ion battery demand of Mahindra & Mahindra Ltd., Tata Motors Ltd., and other Indian automakers already starting or announcing plans to produce EVs for the nation's large domestic motor vehicle market. EAMPL also anticipates Tesla Inc. as a potential customer after the latter selected Karnataka, the same state where Epsilon has its own anode material facility, for its first EV facility in India.[262]

Prices

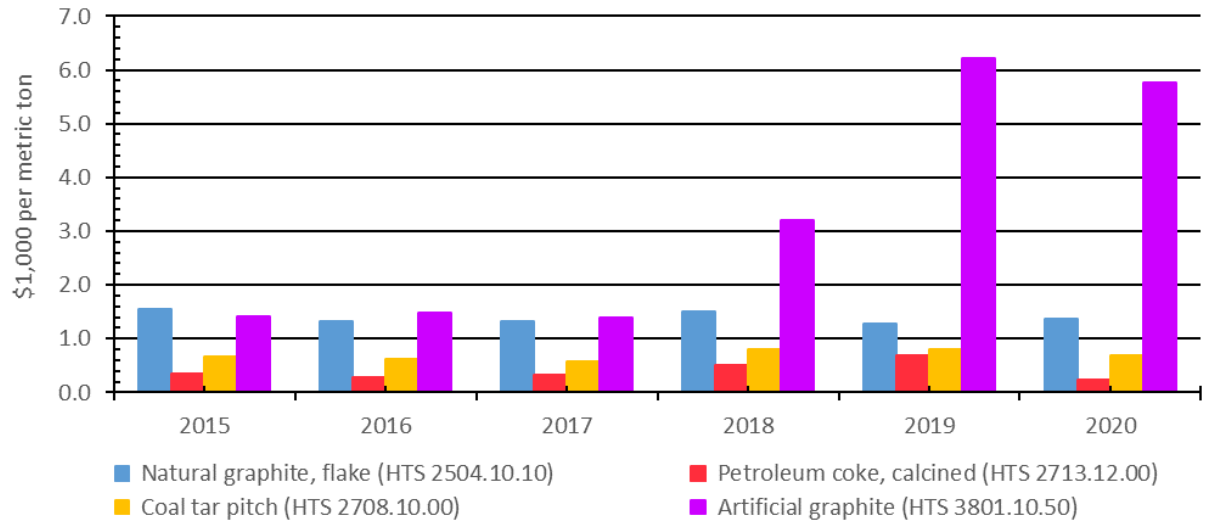
There are posted prices for natural graphite that reflect anticipated longer-term trends, but transaction prices are mostly negotiated between producers and end users,[263] with considerations for carbon content, impurities limits, particle (mesh) size, and shape (flake, amorphous, or vein).[264] Sellers reportedly gain a bargaining advantage if they can provide higher carbon contents and/or larger mesh sizes. Ocean-going transport can account for up to 30 percent of the total price paid by end users.[265]

Prices for both natural and artificial graphite (and its raw or intermediate production materials) are reportedly driven more by the significantly larger derived demand from the metals (particularly steel)

[257] The firm also highlights the contributions along both the mining and processing stages from not only the region's affordable hydroelectricity, skilled workforce, high-quality infrastructure, and a dynamic regional business environment, but also a multi-modal logistical base in proximity to potential U.S. and European customers. Nouveau Monde Graphite, "Progress Report for Phase 1 and Phase 2 of Nouveau Monde's Bécancour Battery Anode Material Plants," June 8, 2021.
[258] Egbaria, "Indian Lithium-ion Battery Plant to Produce Synthetic Graphite," April 14, 2021.
[259] EAMPL, "Company Overview, About Us," retrieved June 30, 2021.
[260] Egbaria, "Indian Lithium-ion Battery Plant to Produce Synthetic Graphite," April 14, 2021.
[261] Business Wire, "Epsilon Advanced Materials Forays into Battery Material Business by Commissioning Manufacturing Facility to Produce Synthetic Graphite Anode Materials for Lithium Batteries," August 24, 2020.
[262] Egbaria, "Indian Lithium-ion Battery Plant to Produce Synthetic Graphite," April 14, 2021.
[263] Focus Graphite, "Graphite 101," accessed August 31, 2018; Moores, "Graphite Prices," May 2013.
[264] Mason Graphite, "Graphite Quick Facts," 2017; EC, *Report on Raw Materials for Battery Applications*, May 17, 2018, 14.
[265] Moores, "Graphite Prices," May 2013.

industries than by Li-ion battery manufacturing.[266] Annual average prices are not readily available on a consistent basis for 2015–20 across the various forms of raw, intermediate, and finished materials. Although the HS and HTS classifications are neither specific to anode graphite materials nor exactly aligned with the successive graphite processing stages (figure 4), U.S. import unit values do provide consistent time series price proxies along the graphite GVC (figure 7). Moreover, both natural and artificial graphite can be traded with varying degrees of processing or blends.[267]

Figure 7 Graphite global value chain: U.S. import unit values by HS subheadings, 2015–20



Source: Compiled from U.S. imports for consumption, unit values (dollars per first unit of quantity), as reported by USITC, DataWeb database, accessed June 7, 2021. Underlying statistics are provided in Appendix C.

Trade

Countries and regions that are prominent among the successive stages of the graphite GVC are also prominent traders of the raw or intermediate products within these stages. There are also several restrictions on international trade at various stages of the graphite GVC, imposed for both trade-policy and geo-political considerations.

Exports and Imports

The global export and import data reported by national customs authorities under the HS subheadings listed below provide broader product coverage across all end-use applications beyond the specific forms of materials being transformed in the successive specific stages along the GVC to produce anode-

[266] Kay, "What is Synthetic Graphite?" July 31, 2018; Roskill, "Roskill: Batteries Spark Dynamic Change in Graphite Markets," July 10, 2017.

In 2016, 69 percent of graphite was consumed worldwide by end uses that are crucial technologies (electrodes, refractories, carburizing materials, and foundry molds) for the steel mill and metal foundry industries (figure 1), compared to only 9 percent for batteries in that same year.

[267] Graphite blends in which the artificial graphite content by weight predominates over that for natural graphite are classifiable under HTS subheading 3801.10.50: Artificial graphite. CBP, "The Tariff Classification of Two Surface Modified Graphite Powders from Japan," Customs Ruling No. N094256, March 19, 2010.

grade graphite (figure 4). To avoid any potential disruptions in the data due to the Covid-19 epidemic upon trade flows in 2020, the following charts show the leading global importers and exporters ranked in the prior-year 2019.[268] China's prominence as the world's largest exporter of natural graphite, coal tar pitch, and artificial graphite; and U.S. prominence as the world's largest exporter of calcined petroleum coke reflect their respective dominant positions as leading global producers of these materials. China is also among the top-five global importers of all GVC graphite materials, except for coal tar pitch, as domestic production is insufficient to meet growing downstream consumption demand. Likewise, the United States is among the top-five importers of coal tar pitch and artificial graphite despite being a major global producer of both.

Natural graphite is traded under HS 2504.10, ranging from raw forms to further refined or processed forms. Global exports are dominated by China, the largest mined graphite producer (figure 5), which accounted for almost two-thirds (65.6 percent) of the world's total exports in 2019 (figure 8a). By contrast, the world's largest importers, Japan, South Korea, the United States, and Germany, are highly dependent upon import sources due to lack of their own domestic graphite mining operations (figure 8b). According to an industry analyst, China was increasingly relying on foreign sources of natural graphite during 2017–19 to meet rising domestic demand by the Li-ion battery sector, as its own deposits are becoming more expensive to mine.[269]

Figure 8a Natural graphite (HS 2504.10): Leading global exporters, 2015–20

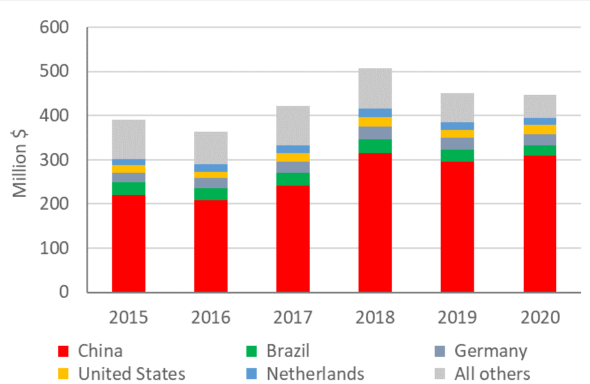
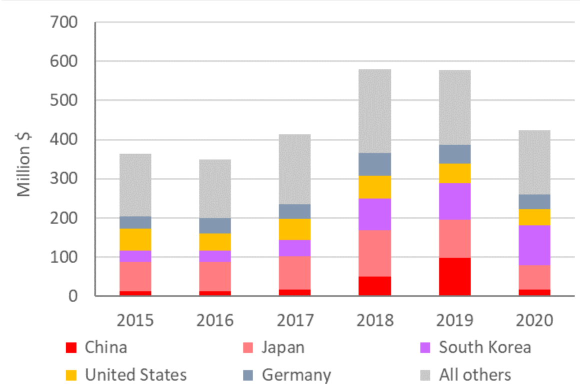


Figure 8b Natural graphite (HS 2504.10): Leading global importers, 2015–20



Source: Compiled from export and import values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 1, 2021. Trade statistics for figures 8–11 are provided in Appendix C.

Global exports of **calcined petroleum coke** (under HS 2713.12), a raw-material input for producing intermediate needle coke and artificial graphite, are dominated by leading petroleum-coke producers the United States and China (figure 6), which together accounted for nearly three-quarters (73.1 percent) of the world's total in 2019 (figure 9a). By contrast, because calcined petroleum coke is also

[268] See the trade statistics in Appendix C for the leading global importers and exporters in figures 8–11 ranked in years 2018, 2019, and 2020.
[269] Shaw, "Graphite: China Continues with Record Levels of Natural Graphite Imports," July 23, 2019.

consumed as a fuel, global imports are more variable and dispersed among the leading importers from year to year (figure 9b).

Figure 9a Calcined petroleum coke (HS 2713.12): Leading global exporters, 2015–20

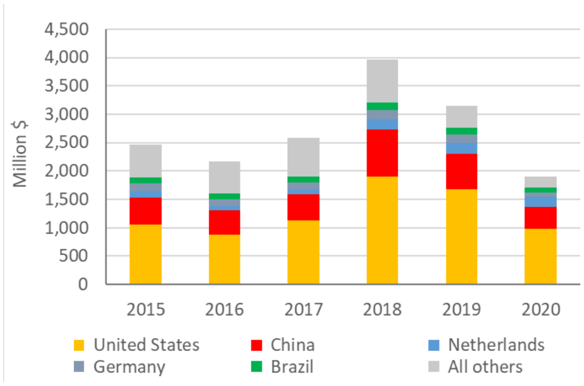
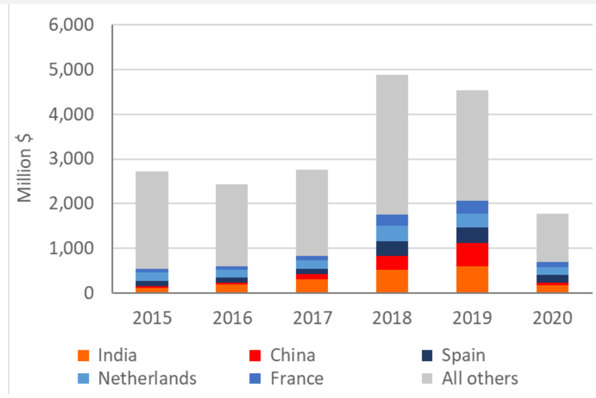


Figure 9b Calcined petroleum coke (HS 2713.12): Leading global importers, 2015–20



Source: Compiled from export and import values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 1, 2021. Trade statistics for figures 8–11 are provided in Appendix C.

For the global trade of **coal tar pitch** (under HS 2708.10), another raw-material input for producing intermediate needle coke and artificial graphite, leading-producer China also recorded the predominant annual shares of global exports but to varying extents over 2015–20 (figure 10a). By contrast, because coal tar pitch is also a raw material for extracting numerous aromatic hydrocarbon compounds, global imports were more dispersed among Qatar, the United States, Norway, Russia, and other leading importers over this period (figure 10b).

Figure 10a Coal tar pitch (HS 2708.10): Leading global exporters, 2015–20

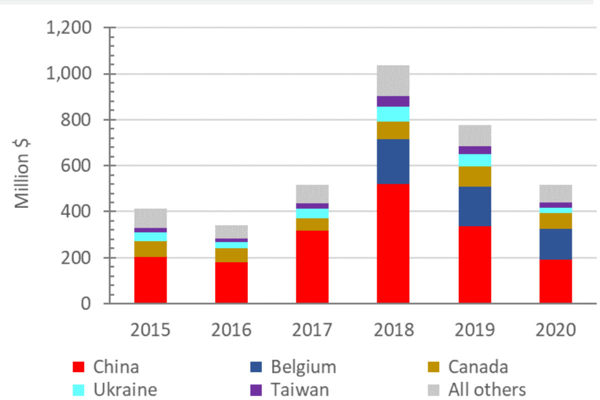
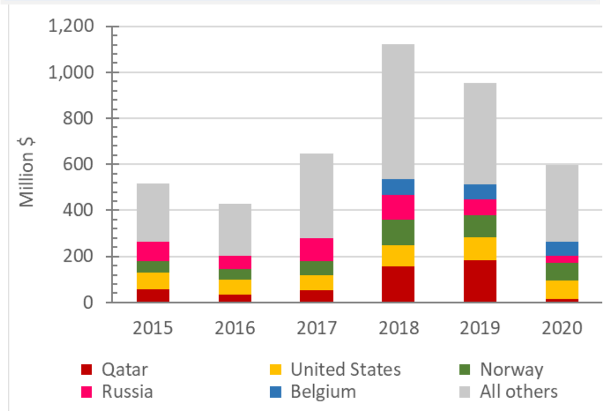


Figure 10b Coal tar pitch (HS 2708.10): Leading global importers, 2015–20



Source: Compiled from export and import values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 7, 2021. Trade statistics for figures 8–11 are provided in Appendix C.

Artificial graphite is traded (under HS 3801.10) either in various raw or processed forms. China and Japan, the leading exporters, together accounted for just under one-half (46.7 percent) of the world's total in 2019 (figure 11a). Global imports were more dispersed as the leading importers recorded shifting annual shares over 2015–20 (figure 11b). Moreover, Japan's annual exports, 1.5–2.7 times its corresponding annual imports, reflect well-established artificial-graphite processing operations and the broad range of products classifiable under the HS subheading. By contrast, South Korea's annual exports-to-imports ratio grew from 0.1 to 0.8, reflecting development of its artificial-graphite processing operations over this six-year period.

Figure 11a Artificial graphite (HS 3801.10): Leading global exporters, 2015–20

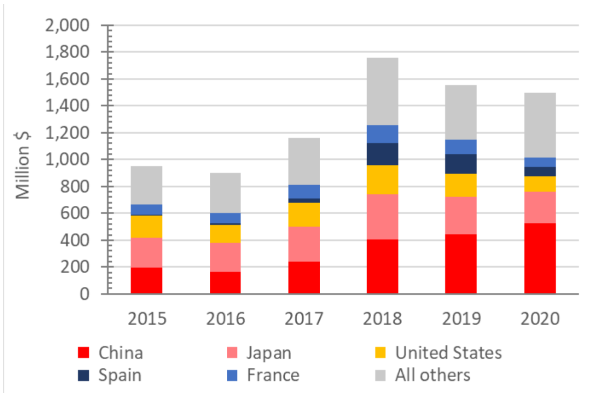
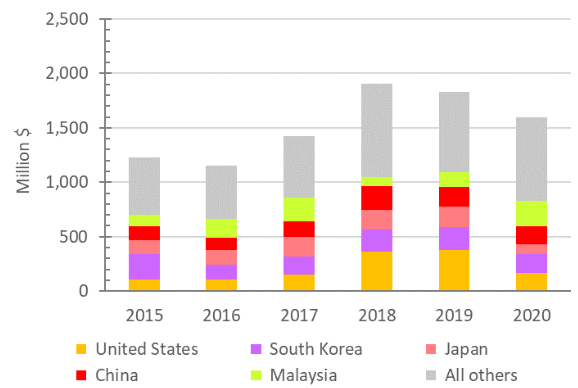


Figure 11b Artificial graphite (HS 3801.10): Leading global importers, 2015–20



Source: Compiled from export and import values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 1, 2021. Trade statistics for figures 8–11 are provided in Appendix C.

Tariff and Nontariff Barriers

International trade in graphite is also subject to various tariff and nontariff restrictions dating back to the mid-2010s.

China— Prior to 2016, Chinese exports of natural graphite were subject to 20 percent duties, 17 percent value-added tax (VAT), quotas, and licensing requirements.[270] The United States filed (on July 13, 2016)[271] a request for consultations with China, regarding these export restrictions on graphite and ten other raw materials, before the World Trade Organization (WTO). Subsequently, at the request of the United States, the WTO established a Dispute Settlement Body (DSB) panel on November 8, 2016.[272] In late-December 2016, China's Ministry of Commerce announced the removal of the export duties and quotas on natural graphite starting at the beginning of 2017.[273] However, further information was not readily available about any changes to China's VAT or licensing requirements.

[270] Olsen, Donald W., "Graphite (Advance Release)," July 2017, 32.5.
[271] WTO, "DS508: China— Export Duties on Certain Raw Materials," November 8, 2016.
[272] USTR, *2017 USTR Report to Congress on China's WTO Compliance*, January 2018, pp. 14, 31, 46; WTO, "Panel Established in Dispute Over Chinese Export Restrictions on Raw Materials," November 8, 2016; WTO, "DS508: China— Export Duties on Certain Raw Materials," November 8, 2016.
[273] Benchmark, "China Begins Graphite Overhaul," January 5, 2017; Benchmark, "A Year in Review: 2016," January 9, 2017; Ghilotti, "Market Mulls Impact to Price as China Scraps Graphite Duty," January 6, 2017; USTR, *2018 Report to Congress On China's WTO Compliance*, February 2019, 34–35.

Imports from the United States of both natural and artificial graphite were subjected to a 10 percent tariff and spheroidal graphite imports were subjected to a 25 percent tariff, effective June 1, 2019. China's actions reportedly were in response to the U.S. announcement of increased section 301 tariffs from 10 percent to 25 percent on certain graphite products from China, effective May 10, 2019.[274]

Iran— International sanctions on trade of graphite (along with raw or semi-finished metals, coal, and industrial process software) originating in Iran were lifted on January 16, 2016, when the International Atomic Energy Agency (IAEA) verified that Iran implemented its nuclear-related commitments under the Joint Comprehensive Plan of Action (JCPOA). However, sanctions relief applies only to graphite for end uses consistent with the JCPOA,[275] as graphite is a neutron-moderating material in nuclear reactor cores.[276]

United States— Natural graphite (imported under HTS 2504.10.10 and 2504.10.50) is not subject to the Office of the United States Trade Representative's (USTR's) additional duties on imports of products originating in China under Section 301 of the Trade Act of 1974, as amended (19 U.S.C. §2411). However, calcined petroleum coke (imported under HTS 2713.12.00), coal tar (HTS 2706.00.00), coal tar pitch (HTS 2708.10.00), artificial graphite (imported under HTS 3801.10.50) and battery carbons (and other products imported under HTS 8545.19.20 and 8545.19.40), are among the products enumerated in USTR's third-list of (Tranche-3) products originating in China that are subject to initial 10 percent ad valorem additional duties under Section 301, effective September 24, 2018.[277] The scheduled duty increase to 25 percent ad valorem, effective May 10, 2019.[278]

Global Value Chain Analysis

GVC measures to assess the extent of participation by countries trading intermediate goods leading to integration into a final good are presented below based on the availability of relevant trade data.[279] Several trade-data based indicators reveal the prominence of a country's participation at intermediate-product levels as products cross borders along the EV Li-ion battery GVC. However, these indicators also have shortcomings, mostly due to data being collected under broad HS categories covering a wider range of related products beyond the specific intermediate good of interest rather than being specific to anode graphite materials.[280] Four HS-6 subheadings capture the international trade for the three relevant forms of graphite— natural unprocessed (HS 2504.10), intermediate material inputs (HS 2708.10, coal tar pitch, and HS 2713.12 and HS 2713.12, calcined petroleum coke, which are the

[274] Roskill, "Graphite: China-US Trade War Reaches Graphite Industry," June 10, 2019; Shendruk and Timmons, "All 2,493 US Products Targeted by China's New 25% Tariffs," May 13, 2019.
[275] OFAC, "Guidance Relating to the Lifting of Certain U.S. Sanctions Pursuant to the Joint Comprehensive Plan of Action on Implementation Day," January 16, 2016; "Frequently Asked Questions Relating to the Lifting of Certain U.S. Sanctions Under the Joint Comprehensive Plan of Action (JCPOA) on Implementation Day," December 15, 2016.
[276] For more information, see: IAEA, "Graphite in the Advanced Gas Reactor Fleet," accessed November 17, 2019.
[277] USTR, *Notice of Modification of Section 301 Action: China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation*, Federal Register (83 FR 47974), September 21, 2018.
[278] USTR, *Notice of Modification of Section 301 Action: China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation*, Federal Register (84 FR 20459), May 9, 2019.
[279] Other GVC indicators, such as TiVA are available at the industry, rather than intermediate product level. OECD, "Trade in Value Added," 2019.
[280] WCO, "What is the Harmonized System?" accessed December 11, 2019.

feedstocks for producing needle coke and artificial graphite), and artificial refined (HS 3801.10)[281]— for the trade-based GVC measures. The GVC measures included in this section are the Coverage Ratio, Grubel-Lloyd Index, and Revealed Comparative Advantage.[282]

The **Coverage Ratio** is a broad measure of a country's position in the GVC. This ratio compares a country's imports with its exports. Lower values indicate that a country is upstream, as countries tend to export more and import fewer intermediate goods at the beginning of the supply chain. Conversely, higher values indicate that a country is downstream, as countries tend to export fewer and import more intermediate goods near the end of the supply chain. A coverage ratio below those of other anode material GVC countries in table 4 is consistent for the United States as the world's leading petroleum coke producer (figure 6) and exporter of intermediate-product calcined petroleum coke (figure 9a). Likewise, China's low coverage ratio is consistent with its global status as the predominant supplier (producer and exporter) of natural graphite (figures 5 and 8a) and leading exporter of intermediate-product coal tar pitch (figure 10a). Higher coverage ratios for other countries (e.g., France, Germany, and South Korea) are consistent with their higher import dependence for natural graphite (figure 8b), intermediate products (figures 9b and 10b), and artificial graphite (figure 11b) for their graphite processing operations toward the end of the GVC.

Table 3 Graphite global value chain measures, selected countries, 2019
Coverage ratio in percent.

Country	Coverage Ratio	Grubel-Lloyd Index	Revealed Comparative Advantage
Canada	117.7	0.9	0.9
China	48.3	0.7	2.1
France	242.3	0.6	0.8
Germany	152.3	0.8	0.5
India	615.4	0.3	1.0
Japan	101.6	1.0	1.4
South Korea	299.5	0.5	0.6
United States	35.5	0.5	3.5

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheadings 2504.10, 2708.10, 2713.12, and 3801.10, accessed June 17, 2021. Underlying measures are provided in Appendix B.

The **Grubel-Lloyd (GL) Index** provides country-level information on intra-materials trade. This measure compares absolute net exports of an intermediate good with total trade (sum of exports and imports) of that same good. A higher index value reflects more intra-materials trade. At a value of 1.0 (100 percent), a country exports as much of a good as it imports, an indicator that it may be operating in multiple stages of production. Conversely, if the value is zero, the country either only exports or imports the intermediate good, a reflection of less intra-materials trade. Lower values are likely outcomes for countries involved in anode material processing and Li-ion battery manufacturing. However, when a country's goods are traded across borders multiple times, some double counting may occur in measures that combine imports and exports for the GVC phases. China's higher GL index in

[281] These HS-6 subheadings do not exclusively pertain to graphite as anode materials for Li-ion batteries but rather they also include graphitic materials with varying degrees of processing.
[282] For further information about these measures and calculations, see Ahmad, et al., "Indicators on Global Value Chains: A Guide for Empirical Work," July 6, 2017.
The following synopses for each of these three measures are compiled from Scott and Ireland, "Lithium-Ion Battery Materials for Electric Vehicles and their Global Value Chains," June 2020, 11–13.

2019 (table 4), than in the immediate prior (0.4 in 2018) and later (0.3 in 2020) years, reflects increased imports of natural graphite (figure 8b) and calcined petroleum coke (figure 9b). Otherwise, the lower GL index values in 2018 and 2020 are consistent with China's dual characteristics as not only the world's leading supplier (figures 5, 8a–11a) and processor, but also as the leading consumer, along most stages of the anode material GVC, despite sending uncoated spheroidal graphite to Japan or South Korea for the final coating operations. Higher GL indices for Japan, Canada, Germany, and France reflect the greater extent of intra-materials trade along successive stages of the graphite GVC by these countries (figures 8a–11a, 8b–11b). The GL index for the United States, a major processor and trader among most stages of the graphite GVC, would have been higher but for its status as the world's predominant producer of petroleum coke (figure 6) and leading exporter of calcined petroleum coke (figure 9a).

The **Revealed Comparative Advantage (RCA) Ratio** measures the intensity with which a country exports a product. The RCA ratio is the proportion of the country's exports of an intermediate good to its total goods exports, compared to (divided by) the proportion of total global exports of the intermediate good to total global goods exports. An RCA ratio greater than 1.0 (100 percent) suggests a country has a comparative advantage (i.e., exporting more than its "fair" share), while a ratio less than 1.0 (100 percent) suggests a comparative disadvantage. The highest RCA ratios in table 4 are consistent for both the United States as the world's predominant producer of petroleum coke (figure 6) and exporter of calcined petroleum coke (figure 9a) and China as the world's predominant supplier of natural graphite (figures 5 and 8a). High RCA ratios for Japan reflect extensive processing of intermediate materials and exporting of artificial graphite (figures 11a and 11b). The other selected countries with RCA ratios at or below 100 percent in table 4 exhibit greater import dependence for materials in their processing operations along successive stages of the graphite GVC.

Both the trade statistics and GVC measures align with the prior descriptive analysis highlighting export advantages (via both the coverage and RCA ratios) for China of upstream natural graphite and for the United States for intermediate petroleum coke products. The higher GL indices for Canada, Germany, Japan, and South Korea reflect their intra-materials trading and extensive processing operations, not only for producing anode materials but also including other more prominent graphite end-use applications.

Outlook

The GVC for graphite anode materials is unique among those for Li-ion battery materials, being available from two alternative sources, as either artificial graphite manufactured from the byproducts of petroleum refining or coal coking or as natural graphite processed from mined natural deposits, the latter being the only primary source for Li-ion battery cathode and electrolyte materials. Although both types compete in the battery anode materials market, and most producers rely on a blend of both, there is a preference for the lower electrical resistance and greater consistency offered by artificial graphite for advanced (especially NCA and NMC-811) battery technologies (figure 2). However, such reliance may be partly offset as natural-graphite producers shift downstream to higher purity coated spheroidal graphite capable of competing with artificial graphite's energy densities and performance in the battery anode materials market.[283]

Although steelmaking is anticipated to remain the largest graphite consuming sector, the batteries sector is considered a driver of future growth.[284] Global graphite consumption by Li-ion batteries is anticipated to grow to just below 447,000 metric tons in 2021 and increase four-fold thereafter by 2030.[285] China has developed production capacity at every stage of the battery GVC and is well positioned to capture much of the projected growth in Li-ion battery-related demand for graphite. China's approach to controlling the global trade flows of graphite and other Li-ion battery materials recognizes that controlling the processing stage is more crucial than just owning the raw material sources.[286] According to a graphite industry source, "{T}here's the potential of {China} stepping up supplies and bringing down prices to drive foreign rivals into a corner, just like they're doing with rare earths."[287]

Both to meet anticipated rising demand as automakers develop EVs and to allay customer concerns of potential supply-disruptions, numerous non-Chinese graphite mining and coal tar firms are attempting to become fully integrated producers that also purify and process graphite. Further, many existing non-Chinese firms involved in the processing stage have announced plans to add capacity and new firms have announced plans to enter the processing market. Nevertheless, even with these significant announced investments, the United States may need 20–30 years to establish high volume and robust GVCs outside of China. Finally, opposition on environmental grounds can be anticipated in many developed countries to the establishment of new graphite mines and hydrocarbon and graphite processing facilities to provide the anode materials, which could further delay the development of new GVCs.[288]

[283] Whiteside and Finn-Foley, "Supply Chain Looms as Serious Threat to Batteries' Green Reputation," November 25, 2019.
[284] Whiteside and Finn-Foley, "Supply Chain Looms as Serious Threat to Batteries' Green Reputation," November 25, 2019.
[285] Bloomberg New Energy Finance (BNEF) Ltd. revised its forecasts for annual Li-ion battery demand exceeding 2.7 terawatt-hours per year by 2030, a 35-percent increase from its previous year's forecast. Passenger vehicles are forecasted to represent 72 percent of the overall EV market, as sales rise to 14 million by 2025 from just over 3 million in 2020. Mining.com, "CHART: Study Predicts Over 400% Increase in Copper, Lithium, Nickel Battery Demand," June 30, 2021.
[286] IER, "China Dominates the Global Lithium Battery Market," September 9, 2020.
[287] Matsumoto, "Australia Challenges China's Graphite Crown in EV Batteries," July 25, 2020.
[288] IER, "China Dominates the Global Lithium Battery Market," September 9, 2020.

Appendix A

Global Value Chain Production Locations for Graphite

Table A.1 Natural graphite: Firms and mine locations

Firm name (foreign headquarters location)	Mine location	State, province, region, county, etc.	Country
Extrativa Metaquimica S.A.	Maiquinique	Bahia State	Brazil
JMN Mineracao S.A.	Mateus Leme	Minas Gerais State	Brazil
Nacional de Grafite Ltda.	Itapecerica, Pedra Azul, Salto da Divisa	Minas Gerais State	Brazil
Imerys Graphite & Carbon (Switzerland)	Saint Aime du Lac des Iles	Québec Province	Canada
Eagle Graphite Corp.	Black Crystal	British Columbia Province	Canada
Ontario Graphite Ltd.	Kearney	Ontario Province	Canada
Timcal Ltd.	Lac des Iles	Québec Province	Canada
Jixi Aoyu Graphite Co. Ltd.	Jixi, Luobei	Heilongjiang Province	China
Nei Mongol Xinghe Jingxin Graphite Co. Ltd.	Xinghe County	Nei Mongol Autonomous Region	China
Shenzhen BTR New Energy Materials Inc.	Changyuan	Heilongjiang Province	China
China Minmetals Corp.	Yushuan, Luobei County	Heilongjiang Province	China
Graphit Kropfmühl GmbH	Kropfmühl	Bavaria State	Germany
Agrawal Graphite Industries Ltd.	Belpara District	Odisha State	India
Tamil Nadu Minerals Ltd.	Sivaganga District	Tamil Nadu State	India
Yeongchon Graphite	Yeongchon	Hwangnam Province	North Korea
Etablissements Gallois S.A.	Artsirakambo Mine, Brickaville; Marovinsty Mine, Vatomandry; Ambalafotaka Mine, Toamasina;	Atsinanana Province	Madagascar
Graphmada Equity Pte. Ltd. (Stratmin Global Resources plc., United Kingdom)	Antsirabe Loharano	Vakinankaratra Province Arivonimamo Province	Madagascar
Grafitos Mexicanos, S.A. de C.V.	Lourdes, Topiyeca, San Juan	Sonora State	Mexico
GK Ancuabe Graphite Mine S.A. (Germany)	Ancuabe	Cabo Delgado Province	Mozambique
Syrah Resources Ltd. (Australia)	Balama	Cabo Delgado Province	Mozambique
Imreys Graphite & Carbon (Switzerland)	Otjiwarongo	Otjozondjupa Region	Namibia
Skaland Graphite AS (LNS Group)	Traelen Mine, Skaland	Troms County	Norway
Kahatagaha Graphite Lanka Ltd.	Kahatagaha Mine	North Western Province	Sri Lanka
Bogala Graphite Lanka Plc. (Germany)	Bogala Mine	Sabaragamuwa Province	Sri Lanka
Sakura Pvt. Ltd.	Ragedara Mine	Central Province	Sri Lanka
Leading Edge Materials Corp. (Canada)	Woxna	Gävleborg County	Sweden

Firm name (foreign headquarters location)	Mine location	State, province, region, county, etc.	Country
Zavalyevskiy graphite complex	Zavalyevskiy	Autonomous Republic of Crimea	Ukraine
Zimbabwe German Graphite Mines Ltd.	Lynx Graphite Mine, Karoi	Mashonaland West Province	Zimbabwe

Source: Compiled from Barrera, "9 Top Graphite-mining Countries," August 14, 2019; Olson, "Graphite (Natural)," January 2021, January 2020, February 2019, January 2018, January 2017, January 2016, 72–73; individual company Internet web sites.

Table A.2 Calcined petroleum coke: Firms and production facility locations within the United States

Firm name (foreign headquarters location)	Headquarters location	Facility location(s)
Aminco Resources	White Plains, NY	White Plains, NY
Asbury Carbons Inc.	Asbury, NJ	DeQuincy, LA Kittanning, PA Rodeo, CA Sunbury, PA
BP Plc. (United Kingdom)	Houston, TX	Cherry Point (Ferndale), WA
Carbon Graphite Materials Inc.	Brocton, NY	Brocton, NY
Chevron Corp.	San Ramon, CA	El Segundo, CA Pasadena, TX Pascagoula, MS Richmond, CA
Flint Hills Resources LLC	Wichita, KS	Corpus Christi West, TX Pine Bend (Rosemont), MN
Husky Energy Inc. (Canada)	Dublin, OH	Lima, OH
Marathon Ashland Petroleum Corp. LP	Findlay, OH	Garyville, LA Robinson, IL Wilmington, CA
Motiva Enterprises LLC (Saudi Arabia)	Houston, TX	Port Arthur, TX
Oxbow Carbon LLC	West Palm Beach, FL	Baton Rouge, LA Enid, OK Port Arthur, TX
Phillips 66 Co.	Houston, TX	Belle Chasse, LA Lake Charles (Westlake), LA Ponca City, OK
Rain CII Carbon LLC (Rain Industries Ltd., India)	Covington, LA	Chalmette, LA Gramercy, LA Lake Charles, LA Norco, LA Purvis, MS
Rain Carbon Inc. (Rain Industries Ltd., India)	Stamford, CT	Stamford, CT
Shell Chemicals LP (Netherlands)	Houston, TX	Deer Park, TX Geismar, LA Mobile, AL Norco, LA Puget Sound (Anacortas), WA
Superior Graphite Co.	Chicago, IL	Chicago, IL Hopkinsville, KY

Source: Compiled from Advisian, "Calciners," accessed August 31, 2020; Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report— Summary," August 2019; USDOE, EIA, Table 3. Capacity of Operable Petroleum Refineries by State as of January 1, 2020, *Refinery Capacity Report 2020*, June 22, 2020; individual company Internet web sites.

Table A.3 Calcined petroleum coke: Firms and production facility locations outside the United States

Firm name (acronym or foreign headquarters location)	Facility location(s)	State, province, canton, county, municipality, etc.	Country
Oxbow Carbon LLC (United States)	La Plata	Buenos Aires Province	Argentina
PetroCoque S.A. Industria e Comercio	Cubãto	São Paulo State	Brazil
Asbury Carbons Inc. (United States)	Burlington Chateauguay	Ontario Province Québec Province	Canada
Aminco Resources LLC (United States)	Beijing	Beijing Municipality	China
Cocan Graphite Mill Inc.	Wuhan	Hubei Province	China
Hebei Qianlong Carbon Co. Ltd.	Shijiazhuang	Hebei Province	China
Ningxia Wanboda Carbons & Graphite Co. Ltd.	Yinchuan	Ningxia Province	China
Shandong KeYu Energy Co. Ltd.	Binzhou	Shandong Province	China
Sinoway Carbon Co.[a]	Weifang	Shandong Province	China
Weifang Lianxing New Materials Technology Co. Ltd.	Weifang	Shandong Province	China
Zhenhua Carbon Technology Co. Ltd.	Linyi	Shandong Province	China
Zhenjiang Coking & Gas Group Co.	Zhenjiang	Jiangsu Province	China
BP Plc. (United Kingdom)	Gelsenkirchen Lingen	North Rhine-Westphalia State Lower Saxony State	Germany
Mineralölraffinerie Oberrhein GmbH Co. KG (MiRO)	Karlsruhe	Baden-Württemberg State	Germany
Atha Group	Haldia	West Bengal State	India
Nayara Energy Ltd. (formerly Essar Oil Ltd.)	Vadinar	Gujarat State	India
GOA Carbon	Bilaspur Goa Paradeep Visakhapatnam	Chattisgarh State Goa State Odisha State Andhra Pradesh State	India
Graphite India Ltd.	Barauni	Bihar State	India
HPCL-Mittal Energy Ltd. (HMEL)			India
India Carbon Ltd.	Budge Budge Guwahati	West Bengal State Assam State	India
Indian Oil Corp. Ltd. (IOCL)	Paradeep	Odisha State	India
Rain Carbon Inc. (RCI, Rain Industries Ltd.)	Visakhapatnam	Andhra Pradesh State	India
Petrocokes Japan Ltd. (Sumitomo Corp.)	Tokyo	Tokyo Metropolis	Japan
Carbograph	Maastricht	Limburg Province	Netherlands
Elsid S.A.	Titu	Dâmbovița County	Romania
Energoprom (EPM) Group	Novosibirsk	Novosibirsk Oblast	Russia
Aminco Resources LLC (United States)	Zürich	Zürich Canton	Switzerland
Abu Dhabi National Oil Co. (ADNOC)	Ruwais	Abu Dhabi Municipality	United Arab Emirates
Henze International LLC	Dubai	Dubai Municipality	United Arab Emirates
Phillips 66 Co. (United States)	South Killingholme	Lincolnshire County	United Kingdom

Source: Compiled from Advisian, "Calciners," accessed August 31, 2020; Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report— Summary," August 2019; individual company Internet web sites.
Notes: Sinoway Carbon is a joint venture between Sinoway Carbon Energy Holdings Ltd. and Dubai Holding LLC. (United Arab Emirates). HMEL is a joint venture between Hindustan Petroleum Corp. Ltd. (HPCL) and Mittal Energy Investment Pte Ltd. (Singapore).

Table A.4 Coal tar: Firms and production facility locations in China

Firm name (foreign headquarters location)	Facility location(s)	Province, region, or municipality	Country
Ansteel Group Corp., Chemical Division	Anshan City	Liaoning Province	China
Baoshun Technology Co. Ltd.	Anyang Juye Fukang	Henan Province Shandong Province Xinjiang Autonomous Region	China
Baotailong New Materials Co. Ltd.	Qitaihe	Heilongjiang Province	China
Baowu Carbon Material Technology Co. Ltd.	Shanghai	Shanghai Municipality	China
Guanghui Energy Co. Ltd.	Ürümqi	Xinjiang Autonomous Region	China
Himadri Chemicals & Industries Ltd. (India)	Longkou	Shangdong Province	China
Huanghua Xinnuo Lixing Fine Chemical Industry Co. Ltd.	Huanghua	Hebei Province	China
Jiangxi Black Cat Carbon Black Inc. Ltd.	Chaoyang Hancheng Handan Jingdezhen Jining Taiyuan Tangshan Wuhai	Liaoning Province Shaanxi Province Hebei Province Jiangxi Province Shangdong Province Shanxi Province Hebei Province Inner Mongolia	China
Jinneng Science & Technology Co. Ltd.	Qihe Industrial Park	Shandong Province	China
Kailuan Energy Chemical Co. Ltd.	Tangshan	Hebei Province	China
Koppers Inc. (United States)	Tangshan	Hebei Province	China
Ma Steel OCI (South Korea)	Maanshan	Anhui Province	China
Shaanxi Coal & Chemical Industry Group Co. Ltd.	Beiyuan Shenmu	Shaanxi Province Shaanxi Province	China
Shandong OCI (South Korea)	Zaozhuang City	Shangdong Province	China
Shanxi Coking Co. Ltd.	Linfen City	Shanxi Province	China
Shanxi Meijin Energy Co. Ltd.	Taiyuan	Shanxi Province	China
Shanxi Sunlight Coking Group Co. Ltd.	Hejin City	Shanxi Province	China

Source: Compiled from Globe Newswire, “Outlook on China's Coal Tar Market, 2020–2025,” February 12, 2020; PR NewsWire, “Global Coal Tar Market Growth, Key Companies Analysis, Size, Share, Demands and Industry Outlook 2019–2024,” April 15, 2019; individual company Internet web sites.

Table A.5 Coal tar: Firms and production facility locations outside of China

Firm name (acronym or foreign headquarters location)	Facility location(s)	State, province, county, oblast, prefecture, or municipality	Country
Koppers Inc. (United States)	Mayfield	New South Wales State	Australia
Rain Carbon Inc. (RCI, Rain Industries Ltd.)	Zelzate	East Flanders Province	Belgium
Rain Carbon Inc. (RCI, Rain Industries Ltd.)	Hamilton	Ontario Province	Canada
Koppers Inc. (United States)	Nyborg	Funen County	Denmark
Rain Carbon Inc. (RCI, Rain Industries Ltd.)	Castrop - Rauxel	North Rhine-Westphalia State	Germany
Rain Carbon Inc. (RCI, Rain Industries Ltd.)	Visakhapatnam	Andhra Pradesh State	India
Himadri Chemicals & Industries Ltd.	Hooghly Korba Liluah I & II Visakhapatnam	West Bengal State Chattisgarh State West Bengal State Andhra Pradesh State	India
C-Chem (Nippon Steel Chemical & Material) Co. Ltd.	Hirohata (Himeji) Kashima Kitakyushu	Hyogo Prefecture Ibaragi Prefecture Fukuoka Prefecture	Japan
JFE Chemical Corp.	Chiba City Kasaoka Kurashiki	Chiba Prefecture Okayama Prefecture Okayama Prefecture	Japan
Mitsubishi Chemical Corp.	Kakogawa	Hyogo Prefecture	Japan
Oriental Chemical Industry (OCI)	Gwangyang Pohang	South Jeolla Province North Gyeongsang Province	South Korea
POSCO Chemical Co. Ltd.	Sejong City	Sejong Special Self-governing City	South Korea
Rütgers Severtar (Rain Industries Ltd. and PAO Severstal joint venture)	Cherepovets	Vologda Oblast	Russia
Jiangxi Blackcat Singapore Ptd. Ltd. (China)	Singapore	Singapore	Singapore
Koppers Inc.	FollansbeeStickney	West VirginiaIllinois	United States

Source: Compiled from PR NewsWire, "Global Coal Tar Market Growth, Key Companies Analysis, Size, Share, Demands and Industry Outlook 2019–2024," April 15, 2019; individual company Internet web sites.

Table A.6 Needle coke: Firms and production facility locations in China

Firm name (acronym or parent firm)	Facility location(s)	Province, region, or municipality	Country	Raw material
Anhui Masteel Chemical Energy Technology Co. Ltd.	Ma'anshan	Anhui Province	China	Coal tar pitch
Anshan Kaitan Thermal Energy New Materials Co. Ltd.	Anshan	Liaoning Province	China	Coal tar pitch
Baotailong New Materials (Qitaihe Baotailong Coal & Coal Chemicals Public) Co. Ltd.	Qitaihe City	Heilongjiang Province Jilin Province Liaoning Province	China	Coal tar pitch
Baowu Carbon Material Technology Co. Ltd.	Shanghai	Shanghai Municipality	China	Coal tar pitch
Fangda Carbon New Material Technology Co. Ltd.	Lanzhou City	Gansu Province	China	Coal tar pitch
Henan Baoshun Fine Chemical Co. Ltd.	Anyang Fukang City Juye	Henan Province Xinjiang Uygur Autonomous Region Shandong Province	China	Coal tar pitch
Henan Kaitan New Materials Co. Ltd.	Xuchang	Henan Province	China	Coal tar pitch
Jinzhou Petrochemical Co. Ltd. (China National Petroleum Corp. (CNPC))	Jinzhou	Liaoning Province	China	Petroleum coke
Kaifeng Pingmei New Carbon Materials Technology Co. Ltd.	Kaifeng	Henan Province	China	Coal tar pitch
Pingdingshan Xuyang Xingyu New Material Co. Ltd.	Pingdingshan	Henan Province	China	Coal tar pitch
Shandong Jingyang Technology Co. Ltd.	Binzhou City	Shangdong Province	China	Petroleum coke
Shandong Yida New Material Co. Ltd.	Jining	Shangdong Province	China	Petroleum coke
Shanxi Hongte Coal Chemical Industry Co. Ltd.	Lvliang	Shanxi Province	China	Coal tar pitch
Shanxi Jinzhou Chemical Industry Co. Ltd.	Lvliang	Shanxi Province	China	Coal tar pitch
Sinopec Shanghai Petrochemical Co. Ltd.	Shanghai	Shanghai Municipality	China	Petroleum coke
Tangshan Dongri (TSDR) New Energy Materials Co. Ltd.	Tangshan	Hebei Province	China	Coal tar pitch
Wuhai Baohua Wanchen Coal Chemical Co. Ltd.	Wuhai City	Inner Mongolia Autonomous Region	China	Coal tar pitch
Zaozhuang Zhenxing Carbon Material Technology Co. Ltd.	Zaozhuang	Shangdong Province	China	Coal tar pitch

Source: Compiled from ICC SINO, "In-depth Analysis Report on China Needle Coke and the Application Market," January 18, 2018; Globe Newswire, "Global and China Needle Coke Industry (2020 to 2026)," May 21, 2020; Serapio and Daly, "The Graphite Fix: Inside China's Newest Commodity Addiction," September 21, 2017; individual company Internet web sites.

Table A.7 Needle coke: Firms and production facility locations outside of China

Firm name (acronym, parent firm, or foreign headquarters location)	Facility location(s)	State, prefecture, province, oblast, county, etc.	Country	Raw material
Graphite India Ltd.	Bangalore Barauni	Karnataka State Bihar State	India	Petroleum coke
Indian Oil Corp. Ltd. (IOCL)	Paradeep	Odisha State	India	Petroleum coke
JX Holdings Inc. (JXTG Nippon Oil & Energy Corp.)	Marifu	Yamaguchi Prefecture	Japan	Petroleum coke
Petrocokes Japan Ltd. (Sumitomo Corp.)	Kurashiki	Okayama Prefecture	Japan	Petroleum coke
Mitsubishi Chemical Corp.	Sakaide	Kagawa Prefecture	Japan	Coal tar pitch
C-Chem (Nippon Steel Chemical & Material) Co. Ltd.	Hirohata Kashima Kitakyushu	Hyogo Prefecture Ibaragi Prefecture Fukuoka Prefecture	Japan	Coal tar pitch
POSCO Chemical Co. Ltd. (Pohang Iron and Steel Co. Ltd.)	Sejong City	Sejong Special Self-governing City	South Korea	Coal tar pitch
PMC Tech Co.[a]	Gwangyang	South Jeolla Province	South Korea	Petroleum coke
GrafTech Mexico S.A. de C.V. (GrafTech International Ltd., United States)	Apodaca	Nuevo León State	Mexico	Petroleum coke
Energoprom (EPM) Group	Novosibirsk	Novosibirsk Oblast	Russia	Petroleum coke
Gazprom Neft PJSC	Omsk	Omsk Oblast	Russia	Petroleum coke
Phillips 66 Co. (United States)	Humber (South Killingholme)	Lincolnshire County	United Kingdom	Petroleum coke
GrafTech USA LLC (GrafTech International Ltd.)	St. Marys	Pennsylvania	United States	Petroleum coke
Phillips 66 Co.	Belle Chasse	Louisiana	United States	Petroleum coke
Seadrift Coke L.P. (GrafTech International Ltd.)	Port Lavaca	Texas	United States	Petroleum coke

Source: Compiled from Globe Newswire, "Global and China Needle Coke Industry (2020 to 2026)," May 21, 2020; Grand View Research, "Calcined Petcoke Market Size, Share & Trends Report— Insights, Needle Coke Market," August 2019; PR NewsWire, "Global Needle Coke Market 2019–2023," July 2019; Serapio and Daly, "The Graphite Fix: Inside China's Newest Commodity Addiction," September 21, 2017; Wood Mackenzie, "IMO 2020, EVs, and Steel," May 30, 2019; individual company Internet web sites.
Note: PMC Tech is a joint venture between Mitsubishi Chemical Corp. (Japan) & POSCO Chemical Co. Ltd. (South Korea).

Table A.8 Artificial graphite: Firms and production facility locations in China

Firm name (foreign headquarters location)	Facility location(s)	Province or municipality	Country
BTR New Energy Materials Inc.	Shenzhen	Guangdong Province	China
Cocan (Hubei) Graphite Mill Inc.	Wuhan	Hubei Province	China
Fangda Carbon New Material Co. Ltd.			China
Guiyang Chemetal import & Export Co.	Guiyang	Guizhou Province	China
Hitachi Chemical (Yantai) Co. Ltd. (Japan)	Yantai	Shandong Province	China
Hubei Wanrun New Energy Technology	Shiyan City	Hubei Province	China
Jiangxi Zichen Technology Co. Ltd.	Jiangsu	Jiangxi Province	China
Johnson Matthey Battery Materials (United Kingdom)	Changzhou	Jiangsu Province	China
Kaifeng Carbon Co. Ltd. (KFCC, Zhongping Energy & Chemical Group)	Kaifeng	Henan Province	China
Lianyungang Jinli Carbon Co. Ltd.	Lianyungang	Jiangsu Province	China
Panasonic Procurement Shanghai (Japan)	Shanghai	Shanghai Municipality	China
Ping Du Shi Hua Dong Graphite Factory	Pingdu, Qindao	Shandong Province	China
Qingdao Kropfmuehl Graphite Co. Ltd.	Qingdao	Shandong Province	China
Qingdao Tianze Leather Products Co.	Chengyang Qindao	Shandong Province	China
Qingdao Tianhe Carbon Co. Ltd.	Laixi City	Shandong Province	China
Shanghai Shanshan Technology Co. Ltd.	Shanghai	Shanghai Municipality	China
Shengsa Carbon Enterprise Ltd.	Shijiazhuang	Hebei Province	China
Shenzhen Sinuo Industrial Development Co. Ltd.	Shenzhen City	Guangdong Province	China
Sinosteel Engineering & Technology Co. Ltd.			China
Wanxiang a123 System Asia Co. Ltd.	Hangzhou	Zhejiang Province	China

Source: Compiled from Research and Markets, "The World Market for Synthetic Graphite, 2019 to 2024," May 24, 2019; Roskill, "Roskill: Batteries Spark Dynamic Change in Graphite Markets," July 10, 2017; Mordor Intelligence, "Synthetic Graphite Market— Growth, Trends, and Forecast (2020–2025)," April 2020; TMR, "Synthetic Graphite Market to Reach Around US$7 Bn by 2026," July 5, 2019; individual company Internet web sites.

Table A.9 Artificial graphite: Firms and production facility locations within Asia outside of China

Firm name (foreign headquarters location)	Facility location(s)	State, prefecture, or municipality	Country
Graphite India Ltd.	Bangalore Nasik	Karnataka State Maharashtra State	India
HEG Ltd.	Mandideep Noida	Madhya Pradesh State Uttar Pradesh State	India
Hitachi Chemical Co. Ltd.	Chiyoda Tokyo	Tokyo Metropolis Tokyo Metropolis	Japan
Hitachi Finenext Transport Systems	Hitachi	Ibaraki Prefecture	Japan
Inabata & Co. Ltd.	Tokyo	Tokyo Metropolis	Japan
Inabata America corp.	Tokyo	Tokyo Metropolis	Japan
JFE Chemical Corp.	Tokyo	Tokyo Metropolis	Japan
Marubeni Tetsugen Co. Ltd.	Tokyo	Tokyo Metropolis	Japan
Mitsubishi Chemical Industries Ltd.	Sakaide	Kagawa Prefecture	Japan
Mitsubishi Corp.	Chuo-Ku	Tokyo Metropolis	Japan
Nippon Carbon Co. Ltd.	Tokyo	Tokyo Metropolis	Japan
Panasonic Corp.	Osaka	Osaka Prefecture	Japan
SGL Carbon Japan Ltd. (Germany)	Minato-Ku	Tokyo Metropolis	Japan
Showa Denko Carbon Inc.	Tokyo	Tokyo Metropolis	Japan
Tokai Carbon Co. Ltd.	Minato-Ku	Tokyo Metropolis	Japan
LG Chemical	Seoul	Seoul Special Metropolitan City	South Korea
POSCO Chemical Co. Ltd.	Sejong City	Sejong Special Autonomous City	South Korea
SGL Carbon Sdn Bhd (Germany)	Kuala Langat	Selangor State	Malaysia
Anitech Material Corp.	Taipei	Taipei Special Municipality	Taiwan
China Steel Chemical Corp.	Kaohsiung	Kaohsiung Special Municipality	Taiwan

Source: Compiled from Research and Markets, "The World Market for Synthetic Graphite, 2019 to 2024," May 24, 2019; Roskill, "Roskill: Batteries Spark Dynamic Change in Graphite Markets," July 10, 2017; Mordor Intelligence, "Synthetic Graphite Market— Growth, Trends, and Forecast (2020–2025)," April 2020; TMR, "Synthetic Graphite Market to Reach Around US$7 Bn by 2026," July 5, 2019; individual company Internet web sites.

Table A.10 Artificial graphite: Firms and production facility locations within North America

Firm name (short name, parent firm, or foreign headquarters location)	Headquarters location	Facility location(s)
Asbury Graphite Mills Inc. (Asbury Carbon Inc.)	Asbury, NJ	Asbury, NJ DeQuincy, LA Kittanning, PA Rodeo, CA Sunbury, PA
Cummings-Moore Graphite Co. (Asbury Graphite Mills Inc.)	Detroit, MI	Detroit, MI Port Huron, MI
Dow Chemical Corp. (Dow)	Midland, MI	Midland, MI
E.I. DuPont de Nemours & Co. Inc. (DuPont)	Wilmington, DE	Wilmington, DE
GrafTech Mexico S.A. de C.V. (GrafTech International Ltd., United States)	Apodaca, NL	Apodaca, NL
GrafTech USA LLC (GrafTech International Ltd.)	Brooklyn Heights, OH	Port Lavaca, TX
Mersen USA (France)	Saint Marys, PA	Columbia, TN Saint Marys, PA
Phillips 66 Co.	Houston, TX	Belle Chasse, LA
Seadrift Coke L.P. (GrafTech International Ltd.)	Brooklyn Heights, OH	St. Marys, PA
Shamokin Carbon (Shamokin Filler Co. Inc.)	Coal Township, PA	Coal Township, PA
SGL Carbon LLC (Germany)	Charlotte, NC	Morganton, NC Saint Marys, PA Sinking Spring, PA
SGL Carbon Technic Inc. LLC (Germany)	Strongsville, OH	Strongsville, OH
Showa Denko Carbon Inc. (Japan)	Ridgeville, SC	Ridgeville, SC
Superior Graphite Co.	Chicago, IL	Chicago, IL Hopkinsville, KY

Source: Compiled from Research and Markets, "The World Market for Synthetic Graphite, 2019 to 2024," May 24, 2019; Roskill, "Roskill: Batteries Spark Dynamic Change in Graphite Markets," July 10, 2017; Mordor Intelligence, "Synthetic Graphite Market— Growth, Trends, and Forecast (2020–2025)," April 2020; Whiteside and Finn-Foley, "Supply Chain Looms as Serious Threat to Batteries' Green Reputation," November 25, 2019; individual company Internet web sites.
Note: Dow and PuPont merged to form DowDuPont, effective August 31, 2017, but split apart again, effective June 1, 2019.

Table A.11 Artificial graphite: Firms and production facility within Europe and Sub-Saharan Africa
n.s. = not specified.

Firm name (parent firm or foreign headquarters location)	Facility location(s)	Department, state, canton, municipality, etc.	Country
Graphite Týn Spol. S.R.O. (Graphit Kropfmühl GmbH, Germany)	Týn nad Vltavou	South Bohemia Region	Czechia
Carbone Savoie	Venissieux	Auvergne-Rhône-Alpes Department	France
GrafTech France S.N.C. (GrafTech International Ltd., United States)	Calais	Pas-de-Calais Department	France
Mersen	La Défense	Paris metropolitan area	France
SGL Carbon S.A. (Germany)	Passy	Paris Department	France
Graphite Cova GmbH (Graphite India Ltd., India)	Nuremberg	Bavaria State	Germany
Metzeler Schaum GMBH	Memmingen	Bavaria State	Germany
SGL Acotech GMBH	Meitingen	Bavaria State	Germany
SGL Carbon SE	Bonn Meitngen	North Rhine-Westphalia State Bavaria State	Germany
Power Stand Development Ltd.	Toamasina	Atsinanana region	Madagascar
SGL Carbon Polska (Germany)	n.s.	n.s.	Poland
DonCarb Graphite LLC (EPM Group)	Chelyabinsk Novocherkassk	Chelyabinsk Oblast Rostov Oblast	Russia
Energoprom (EPM) Group	Novosibirsk	Novosibirsk Oblast	Russia
Sumitomo Corp. Central Eurasia LLC (Japan)	Moscow	Central Federal District	Russia
SGL Carbon S.A. (Germany)	A. Coruña	A. Coruña Province	Spain
Superior Graphite Europe (United States)	Sundsvall	Västernorrland County	Sweden
GrafTech Iberica S.L. (GrafTech International Ltd., United States)	Ororbia	Navarra Province	Spain
SGL Carbon S.A. (Germany)	A Coruña	A Coruña Province	Spain
Superior Graphite Europe (United States)	Sundsvall	Västernorrland County	Sweden
BASF Colors & Effects (Germany)	Basel	Basel-Stadt Canton	Switzerland
BASF Schweia AG Lager Planzer Transport AG (Germany)	Birsfelden	Basel-Landschaft Canton	Switzerland
Imerys Graphite & Carbon	Bodio	Ticino Canton	Switzerland
Thermo Fisher	Runcorn	Cheshire County	United Kingdom

Source: Compiled from Research and Markets, “The World Market for Synthetic Graphite, 2019 to 2024,” May 24, 2019; Roskill, “Roskill: Batteries Spark Dynamic Change in Graphite Markets,” July 10, 2017; Mordor Intelligence, “Synthetic Graphite Market— Growth, Trends, and Forecast (2020–2025),” April 2020; TMR, “Synthetic Graphite Market to Reach Around US$7 Bn by 2026,” July 5, 2019; individual company Internet web sites.

Table A.12 Battery-grade graphite: Firms and production facility locations within China
n.s. = not specified.

Firm name (short name, parent firm, or foreign headquarters location)	Facility location(s)	Country	Graphite type(s)
Cocan Graphite Mill Inc.	Wuhan	China	Natural, artificial
Dalian Hongguang Lithium Industry Co. Ltd. (HGL)	Dalian	China	Natural, artificial
Guangdong Kaijin New Energy Technology Co. Ltd.	Dongguan City	China	Artificial
Hitachi Chemical Co. Ltd. (Japan)	Yantai	China	Artificial
Hunan Shinzoom Technology Co. Ltd. (Shinzoom)	Changsha	China	Natural, artificial
Huzhou Chuangya Power Battery Material Co. Ltd. (CHNM)	Huzhou	China	Artificial
Jiangxi Zheng Tuo New Energy Technology Co. Ltd. (ZETO)	Yichun	China	Natural, artificial
Jiangxi Zichen Technology Co. Ltd. (Zichen)	Fengxin Industrial Park, Yichun	China	Natural, artificial
LuiMao Graphite Co. Ltd.	n.s.	China	Natural
Morgan AM&T Hairong (Changsha Hairong New Materials) Co. Ltd. (United Kingdom)	Changsha	China	Natural
Mitsubishi Chemical Holdings Corp. (Japan)[a]	Tsingtao (Qingdao)	China	n.s.
Ningbo Shanshan Co. Ltd.	Ningbo	China	Artificial
Osaka Gas Chemicals Group (Japan)	Shanghai	China	Artificial
Qingdao Kropfmühl Graphite Co. Ltd. (Germany)	Qingdao	China	Natural, artificial
SGL Carbon SE Group (Germany)	Shanghai Yangquan	China China	Artificial Artificial
Shanghai Shanshan Technology Co. Ltd. (Shanshan Technology)	Changsha Chenzhou Dongguan Langfang Ningbo Shanghai	China China China China China China	Natural, artificial Natural, artificial Natural, artificial Natural, artificial Natural, artificial Natural, artificial
Shanxi Minguang New Material Technology Co. Ltd.	n.s.	China	Natural
Shenzhen BTR New Energy Materials Inc. (BTR)	Jixi Tianjin Zhang Zhuang Town New Industrial Park	China China China	Natural Artificial n.s.
Shenzhen Sinuo Industrial Development Co. Ltd. (Sinuo)	Ji'an	China	Artificial
Shenzhen Xiang Fenghua ("XFH") Technology Co. Ltd.	Shenzhen	China	Natural, artificial
Tianjin Kimwan Carbon Technology and Development (Kimwan)	Tianjin	China	n.s.

Source: Compiled from Deign, "China Plans Graphite Megafactories to Meet Booming Demand for Battery Storage," October 26, 2017; PR NewsWire, "Global and China Lithium-ion Battery Anode Material Industry Report, 2020–2026," September 4, 2020; Shaw, "Graphite: Renascor Signs MoU with Major Chinese Anode Producer," February 5, 2021; Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 17; individual company Internet web sites.
Note: Mitsubishi Chemical Holdings Corp. is a member of the Mitsubishi Group which also owns Mitsubishi Motors Co.

Table A.13 Battery-grade graphite: Firms and production facility locations within Asia outside of China

Firm name (parent firm or foreign headquarters location)	Facility location(s)	Country or location	Graphite type(s)
Hitachi Chemical Co. Ltd. (Showa Denko K.K.)[a]	Matsudo	Japan	Natural, artificial
	Shimodate (Chikusei)	Japan	Natural, artificial
	Yamazaki (Hitachi)	Japan	Natural, artificial
JFE Chemical Corp.	Chiba City	Japan	Natural, artificial
	Kasaoka	Japan	Natural, artificial
	Kurashiki	Japan	Natural, artificial
Kureha Corp.	Iwaki	Japan	Natural, artificial
Mitsubishi Chemical Holdings Corp.	Sakaide	Japan	Natural, artificial
Nippon Carbon Co. Ltd.	Toyama City	Japan	Natural, artificial
	Shiga City	Japan	Natural, artificial
	Yamanashi City	Japan	Natural, artificial
Nippon Power Graphite Co. Ltd. (Imerys Graphite & Carbon SA (Switzerland))	Kitakyushu City	Japan	Natural
Nippon Steel Chemical & Material Co. Ltd.	Tokyo	Japan	Artificial
Osaka Gas Chemicals Group	Hirakata	Japan	Artificial
SGL Carbon Japan Ltd. (Germany)	Tokyo	Japan	Artificial
Showa Denko K.K.	Nagano CIty	Japan	Artificial
	Omachi	Japan	Artificial
Tokai Carbon Co. Ltd.	Hofu	Japan	Natural, artificial
GS Caltex Corp. (South Korea-United States)	Seoul	South Korea	Artificial
LG Chemical Co. Ltd.	Seoul	South Korea	Artificial
LS Mtron Carbonics	Anyang	South Korea	Artificial
POSCO Chemical Co. Ltd. (Pohang Iron and Steel Co. (POSCO) Ltd.)[f]	Jeonui Industrial Complex,	South Korea	Natural, artificial
	Sejong City	South Korea	Natural, artificial
Samsung SDI[e]	Yongin	South Korea	Artificial
SK Innovation Co. Ltd.[e]	Seoul	South Korea	Artificial
China Steel Chemical Corp.	Tunghai Village	Taiwan	Artificial

Source: Compiled from Benchmark, "China Threat Sparks Hitachi's Four-fold Graphite Anode Expansion," December 16, 2016; Goldman, Rotondo, and Swallow, *Lithium Ion Battery Industrial Base in the U.S. and Abroad*, December 2019, 12; Lebedeva, Di Persio, and Boon-Brett, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*, 2016, 16; PR NewsWire. "Global and China Lithium-ion Battery Anode Material Industry Report, 2020–2026," September 4, 2020; PR NewsWire, "Global and China Lithium-ion Battery Anode Material Industry Report, 2017–2020," March 22, 2017; Roskill, "Graphite: Imerys Acquires Nippon Power Graphite," February 22, 2017; Slavnich, "Imerys Graphite & Carbon Acquires CVD Coating Technology," February 23, 2017; Showa Denko Materials, "Announcement of Changing Company's Name," June 23, 2020; Yamaguchi, et al., "Battery/Battery Materials," July 3, 2012, 15–17; individual company Internet web sites.
Notes: Hitachi Chemical was acquired by Showa Denko K.K. in April 2020 and renamed as "Showa Denko Materials Co. Ltd." in October 2020. However, the original corporate name is retained in this section, in part to distinguish between Hitachi Chemical's and Showa Denko's existing facilities in this table prior to the corporate acquisition. Mitsubishi Chemical Holdings is a member of the Mitsubishi Group which also owns lithium-ion (Li-ion) battery and electric vehicle manufacturer Mitsubishi Motors Co. Nippon Power Graphite was acquired by Imerys Graphite & Carbon SA (Switzerland) in February 2017. Li-ion battery producer GS Caltex is a joint venture between Chevron (United States) and battery-producer GS Energy (South Korea). LG Chemical and SK Innovation are also Li-ion battery producers. POSCO Chemical was acquired from LS Mitron Carbonics (South Korea) in 2010.

Table A.14 Battery-grade graphite: Firms and production facility locations within North America

Firm name (parent company or foreign headquarters location)	Headquarters location	Facility location(s)	Graphite type(s)
Asbury Carbons Inc. (United States)	Asbury, NJ	Burlington, ON (Canada)	Natural
		Chateauguay, PQ (Canada)	Natural
Imerys Graphite & Carbon SA (Switzerland)		Terrebonne, PQ (Canada)	Natural, artificial
Asbury Carbons Inc. (United States)	Asbury, NJ	Hermosillo, SON (Mexico)	Natural
3M Co.	St. Paul, MN	St. Paul, MN	Natural, artificial
Asbury Graphite Mills Inc. (Asbury Carbons Inc.)	Asbury, NJ	Asbury, NJ	Natural, artificial
		DeQuincy, LA	Natural, artificial
		Kittanning, PA	Natural, artificial
Cummings-Moore Graphite Co.	Detroit, MI	Detroit, MI	Natural, artificial
Dow Chemical Co.	Midland, MI	Midland, MI	Artificial
Hitachi Chemical Co. of America Ltd. (Japan)	San Jose, CA	San Jose, CA	Artificial
SGL Carbon LLC (Germany)	Charlotte, NC	Morganton, NC	Artificial
		Saint Marys, PA	Artificial
		Sinking Spring, PA	Artificial
SGL Carbon Technic Inc. LLC (Germany)	Strongsville, OH	Strongsville, OH	Natural, artificial
SGL Technic Inc. LLC (Germany)	Valencia, CA	Valencia, CA	Natural
SGL Specialty Graphite Division (Germany)	Saint Marys, PA	Saint Marys, PA	Artificial
Superior Graphite Co.	Chicago, IL	Chicago, IL	Natural, artificial
		Hopkinsville, KY	Natural, artificial
Syrah Technologies LLC (Australia)	Vidalia, LA	Vidalia, LA	Natural
Urbix Resources LLC	Mesa, AZ	Mesa, AZ	Natural

Source: Compiled from Argus Media, “Syrah Advances Purified Spherical Graphite Production,” April 29, 2019; Lebedeva, Di Persio, and Boon-Brett, *Lithium Ion Battery Value Chain and Related Opportunities for Europe*, 2016, 16; Roskill, “Graphite: The Race for Non-Chinese Spherical Graphite Heats Up,” April 29, 2019; Showa Denko Materials, “Announcement of Changing Company's Name,” June 23, 2020; Syrah Resources, “Battery Anode Material Project, USA,” accessed November 1, 2019; Urbix Resources, “Leading U.S. Graphite Companies Will Collaborate Towards High-Purity Graphite, Spherical Graphite and Graphene,” February 4, 2019; Yamaguchi, et al., “Battery/Battery Materials,” July 3, 2012, 15–16; individual company Internet web sites.
Note: Hitachi Chemical Co. of America was renamed as “Showa Denko Materials America Inc.,” effective October 1, 2020.

Table A.15 Battery-grade graphite: Firms and production facility locations within Western Europe

Firm name (foreign headquarters location)	Facility location(s)	Country	Graphite type(s)
Imerys Graphite & Carbon SA (Switzerland)	Willebroek	Belgium	Natural, artificial
Targray Group (Canada)	Straznicka	Czechia	Natural, artificial
SGL Carbon SE Group (Germany)	Passy	France	Artificial
	Saint Martin d'Heres	France	Artificial
Heraeus Group	Kleinostheim	Germany	Artificial
SGL Carbon SE Group	Bonn	Germany	Artificial
	Meitingen	Germany	Artificial
Targray Group (Canada)	Wilhelmsfeld	Germany	Natural, artificial
SGL Carbon SE Group (Germany)	Verdello	Italy	Artificial
SGL Carbon SE Group	Bonn	Germany	Artificial
	Meitingen	Germany	Artificial
SGL Carbon SE Group (Germany)	Nowy Sącz	Poland	Artificial
	Racibórz	Poland	Artificial
Imerys Graphite and Carbon SA	Bodio	Switzerland	Artificial

Source: Compiled from Lebedeva, Persio, and Boon-Brett, Lithium Ion Battery Value China and Related Opportunities for Europe, 2016, 16; Roskill, “Graphite: Imerys Acquires Nippon Power Graphite,” February 22, 2017; Slavnich, “Imerys Graphite & Carbon Acquires CVD Coating Technology,” February 23, 2017; Yamaguchi, et al., “Battery/Battery Materials,” July 3, 2012, 15–16; individual company Internet web sites.

Appendix B

Global Value Chain Measures Analysis for Graphite

Table B.1 Unprocessed graphite, 2018

Percent of value.

Country	Coverage Ratio: Unprocessed Imports to Unprocessed Exports	Unprocessed Graphite Exports to All Graphite Exports	Unprocessed Imports to All Graphite Imports	Trade in Unprocessed to All Graphite Trade	Unprocessed Exports to All Goods Exports	Unprocessed Imports to All Goods Imports	Trade in Unprocessed to All Goods Trade
Canada	30.5	14.2	2.3	6.4	0.0	0.0	0.0
China	15.9	15.2	8.5	13.7	0.0	0.0	0.0
France	2473.1	0.1	1.5	0.9	0.0	0.0	0.0
Germany	192.7	9.2	12.8	11.3	0.0	0.0	0.0
India	9,462.1	0.2	4.6	3.6	0.0	0.0	0.0
Japan	1,275.9	2.4	31.6	16.9	0.0	0.0	0.0
Korea	5,953.7	1.4	27.1	20.8	0.0	0.0	0.0
United States	275.8	1.0	9.3	2.8	0.0	0.0	0.0

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheading 2504.10, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Table B.2 Intermediate graphite, 2018

Percent of value.

Country	Coverage Ratio: Intermediate Graphite Imports to Intermediate Exports	Intermediate Graphite Exports to All Graphite Exports	Intermediate Graphite Imports to All Graphite Imports	Trade in Intermediate Graphite to All Graphite Trade	Intermediate Graphite Exports to All Goods Exports	Intermediate Graphite Imports to All Goods Imports	Trade in Intermediate Graphite to All Goods Trade
Canada	218.3	78.3	89.5	85.7	0.0	0.0	0.0
China	24.2	65.2	55.4	63.0	0.1	0.0	0.0
France	215.0	51.1	85.2	70.3	0.0	0.0	0.0
Germany	172.9	49.9	62.5	57.2	0.0	0.0	0.0
India	333.7	87.7	91.1	90.3	0.1	0.1	0.1
Japan	196.9	10.2	20.4	15.3	0.0	0.0	0.0
Korea	58.8	17.6	3.4	6.8	0.0	0.0	0.0
United States	10.7	89.0	32.9	76.4	0.1	0.0	0.1

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheadings 2708.10 and 2713.12, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Table B.3 Refined graphite, 2018
Percent of value.

Country	Coverage Ratio: Refined Imports to Refined Exports	Refined Exports to All Graphite Exports	Refined Imports to All Graphite Imports	Trade in Refined to All Graphite Trade	Refined Exports to All Goods Exports	Refined Imports to All Goods Imports	Trade in Refined to All Goods Trade
Canada	208.9	7.5	8.2	7.9	0.0	0.0	0.0
China	52.5	19.6	36.1	23.2	0.0	0.0	0.0
France	35.4	48.8	13.4	28.8	0.0	0.0	0.0
Germany	83.6	40.9	24.7	31.5	0.0	0.0	0.0
India	112.8	12.1	4.3	6.1	0.0	0.0	0.0
Japan	54.3	87.3	48.0	67.8	0.0	0.0	0.0
Korea	265.0	81.0	69.5	72.3	0.0	0.0	0.0
United States	167.3	10.0	57.8	20.7	0.0	0.0	0.0

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheading 3801.10, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Table B.4 Graphite global value chain measures, selected countries, 2018
Coverage ratio in percent.

Country	Coverage Ratio	Grubel-Lloyd Index	Revealed Comparative Advantage
Canada	191.0	0.7	0.7
China	28.5	0.4	2.2
France	129.1	0.9	1.2
Germany	138.2	0.8	0.5
India	321.4	0.5	1.6
Japan	98.7	1.0	1.4
Korea	308.7	0.5	0.4
United States	28.93	0.4	3.4

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheadings 2504.10, 2708.10, 2713.12, and 3801.10, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Table B.5 Unprocessed graphite, 2019
Percent of value.

Country	Coverage Ratio: Unprocessed Imports to Unprocessed Exports	Unprocessed Graphite Exports to All Graphite Exports	Unprocessed Imports to All Graphite Imports	Trade in Unprocessed to All Graphite Trade	Unprocessed Exports to All Goods Exports	Unprocessed Imports to All Goods Imports	Trade in Unprocessed to All Goods Trade
Canada	10.6	13.2	1.2	6.7	0.0	0.0	0.0
China	33.4	17.5	12.1	15.7	0.0	0.0	0.0
France	1,599.9	0.2	1.3	1.0	0.0	0.0	0.0
Germany	178.4	10.6	12.5	11.7	0.0	0.0	0.0
India	13,524.0	0.2	4.4	3.8	0.0	0.0	0.0
Japan	1,163.4	2.5	28.9	15.8	0.0	0.0	0.0
Korea	14,122.3	0.6	29.7	22.4	0.0	0.0	0.0
United States	275.5	1.0	7.6	2.7	0.0	0.0	0.0

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheading 2504.10, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Table B.6 Intermediate graphite, 2019
Percent of value.

Country	Coverage Ratio: Intermediate Graphite Imports to Intermediate Exports	Intermediate Graphite Exports to All Graphite Exports	Intermediate Graphite Imports to All Graphite Imports	Trade in Intermediate Graphite to All Graphite Trade	Intermediate Graphite Exports to All Goods Exports	Intermediate Graphite Imports to All Goods Imports	Trade in Intermediate Graphite to All Goods Trade
Canada	127.6	79.9	86.7	83.6	0.0	0.0	0.0
China	56.7	56.5	66.3	59.7	0.0	0.0	0.0
France	736.4	29.4	89.3	71.8	0.0	0.1	0.0
Germany	177.1	54.7	63.6	60.0	0.0	0.0	0.0
India	664.7	84.5	91.2	90.3	0.0	0.1	0.1
Japan	120.7	12.7	15.1	13.9	0.0	0.0	0.0
Korea	83.4	9.4	2.6	4.3	0.0	0.0	0.0
United States	14.1	90.1	35.8	75.9	0.1	0.0	0.0

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheadings 2708.10 and 2713.12, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Table B.7 Refined graphite, 2019
Percent of value.

Country	Coverage Ratio: Refined Imports to Refined Exports	Refined Exports to All Graphite Exports	Refined Imports to All Graphite Imports	Trade in Refined to All Graphite Trade	Refined Exports to All Goods Exports	Refined Imports to All Goods Imports	Trade in Refined to All Goods Trade
Canada	207.3	6.9	12.2	9.7	0.0	0.0	0.0
China	40.2	26.1	21.7	24.6	0.0	0.0	0.0
France	32.6	70.4	9.5	27.3	0.0	0.0	0.0
Germany	105.3	34.7	24.0	28.2	0.0	0.0	0.0
India	176.3	15.3	4.4	5.9	0.0	0.0	0.0
Japan	67.1	84.7	56.0	70.3	0.0	0.0	0.0
Korea	225.4	90.0	67.7	73.3	0.0	0.0	0.0
United States	225.6	8.9	56.5	21.4	0.0	0.0	0.0

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheading 3801.10, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Table B.8 Graphite global value chain measures, selected countries, 2019

Coverage ratio in percent.

Country	Coverage Ratio	Grubel-Lloyd Index	Revealed Comparative Advantage
Canada	117.7	0.9	0.9
China	48.3	0.7	2.1
France	242.3	0.6	0.8
Germany	152.3	0.8	0.5
India	615.4	0.3	1.0
Japan	101.6	1.0	1.4
Korea	299.5	0.5	0.6
United States	35.5	0.5	3.5

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheadings 2504.10, 2708.10, 2713.12, and 3801.10, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Table B.9 Unprocessed graphite, 2020

Percent of value.

Country	Coverage Ratio: Unprocessed Imports to Unprocessed Exports	Unprocessed Graphite Exports to All Graphite Exports	Unprocessed Imports to All Graphite Imports	Trade in Unprocessed to All Graphite Trade	Unprocessed Exports to All Goods Exports	Unprocessed Imports to All Goods Imports	Trade in Unprocessed to All Goods Trade
Canada	17.7	10.5	1.3	5.0	0.0	0.0	0.0
China	5.4	21.7	6.9	19.6	0.0	0.0	0.0
France	3,371.6	0.2	2.0	1.5	0.0	0.0	0.0
Germany	149.6	12.5	16.2	14.5	0.0	0.0	0.0
India	3,925.7	0.8	9.8	7.8	0.0	0.0	0.0
Japan	682.5	3.7	35.8	16.9	0.0	0.0	0.0
Korea	9,023.4	0.7	36.2	23.3	0.0	0.0	0.0
United States	206.3	1.8	12.3	4.2	0.0	0.0	0.0

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheading 2504.10, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Table B.10 Intermediate graphite, 2020
Percent of value.

Country	Coverage Ratio: Intermediate Graphite Imports to Intermediate Exports	Intermediate Graphite Exports to All Graphite Exports	Intermediate Graphite Imports to All Graphite Imports	Trade in Intermediate Graphite to All Graphite Trade	Intermediate Graphite Exports to All Goods Exports	Intermediate Graphite Imports to All Goods Imports	Trade in Intermediate Graphite to All Goods Trade
Canada	172.5	77.2	89.9	84.7	0.0	0.0	0.0
China	10.3	41.4	25.0	39.0	0.0	0.0	0.0
France	4,284.7	5.2	87.5	64.4	0.0	0.0	0.0
Germany	122.4	41.7	44.1	43.0	0.0	0.0	0.0
India	330.7	82.4	80.5	80.9	0.0	0.0	0.0
Japan	931.4	1.0	13.4	6.1	0.0	0.0	0.0
Korea	49.0	8.7	2.4	4.7	0.0	0.0	0.0
United States	12.5	88.5	37.1	76.6	0.1	0.0	0.0

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheadings 2708.10 and 2713.12, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Table B.11 Refined graphite, 2020
Percent of value.

Country	Coverage Ratio: Refined Imports to Refined Exports	Refined Exports to All Graphite Exports	Refined Imports to All Graphite Imports	Trade in Refined to All Graphite Trade	Refined Exports to All Goods Exports	Refined Imports to All Goods Imports	Trade in Refined to All Goods Trade
Canada	106.9	12.3	8.9	10.3	0.0	0.0	0.0
China	31.6	36.9	68.1	41.5	0.0	0.0	0.0
France	28.4	94.6	10.5	34.2	0.0	0.0	0.0
Germany	100.7	45.8	39.7	42.5	0.0	0.0	0.0
India	196.2	16.7	9.7	11.3	0.0	0.0	0.0
Japan	37.3	95.3	50.8	77.0	0.0	0.0	0.0
Korea	118.4	90.6	61.4	72.0	0.0	0.0	0.0
United States	154.7	9.8	50.6	19.2	0.0	0.0	0.0

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheading 3801.10, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Table B.12 Graphite global value chain measures, selected countries, 2020
Coverage ratio in percent.

Country	Coverage Ratio	Grubel-Lloyd Index	Revealed Comparative Advantage
Canada	148.1	0.8	1.0
China	17.1	0.3	2.0
France	255.6	0.6	0.6
Germany	115.9	0.9	0.5
India	338.7	0.5	0.9
Japan	70.0	0.8	1.4
Korea	174.7	0.7	1.2
United States	29.9	0.5	2.9

Source: Staff calculations, IHS Markit, Global Trade Atlas database, HS subheadings 2504.10, 2708.10, 2713.12, and 3801.10, accessed June 17, 2021, https://connect.ihsmarkit.com/gta/standard-reports.

Appendix C

Data Tables for Figures

Table C.1 Graphite: Global consumption shares by end-uses, 2016
In percentages.

End use	Share (percent)
Furnace electrodes	31
Refractories	18
Carburizing materials	13
Batteries	9
Foundry molds	7
Lubricants	7
Brake pads	5
High-performance components	5
All other	5
Total	100

Source: Leading Edge Materials Corp., "About Graphite," Accessed August 25, 2018, http://leadingedgematerials.com/graphite/.
Note: These data correspond to figure 1.

Table C.2 Graphite: Content and share of total cell weight, for common types of lithium-ion cells for battery-powered electric vehicles
Graphite contents and total cell weights in kilograms. Graphite shares in percentages.

Battery designation	Graphite content	Total cell weight	Graphite share
Lithium nickel manganese cobalt oxide (NMC)-622	22.73	108.03	21.0
Lithium nickel cobalt aluminum oxide (NCA)	23.18	104.96	22.1
Lithium iron phosphate (LFP)	24.85	147.58	16.8
Lithium manganese oxide (LMO)	20.56	146.29	14.1

Source: Dai, et al., *Update of Bill-of-Materials and Cathode Materials Production for Lithium-ion Batteries in the GREET® Model*, October 31, 2019, 14, https://greet.es.anl.gov/publication-update_bom_cm.
Note: These data correspond to figure 2.

Table C.3 Natural graphite: Leading producing countries, annual mine output, 2015–20
In thousands of metric tons. n.r. = none reported.

Producer	2015	2016	2017	2018	2019	2020
China	780	780	625	693	700	650
Mozambique	n.r.	n.r.	n.r.	104	107	120
Brazil	80	95	90	95	96	95
Madagascar	5	8	9	47	48	47
India	170	149	35	35	35	34
All other	155	118	138	146	114	154
World	1,190	1,150	897	1,120	1,100	1,100

Source: Olson, “Graphite (Natural),” *Mineral Commodity Summaries*, January 2021, January 2020, February 2019, January 2018, January 2017, January 2016, 73, https://www.usgs.gov/centers/nmic/graphite-statistics-and-information.
Note: These data correspond to figure 5.

Table C.4 Petroleum coke: Leading producing countries, 2014–19
In millions of metric tons.

Producer	2014	2015	2016	2017	2018	2019
United States	58.1	57.9	60.5	59.7	59.7	55.9
China	18.3	19.0	19.5	20.5	26.6	28.4
India	12.4	13.3	13.9	14.8	14.7	15.5
Brazil	5.4	5.7	5.8	5.6	5.1	5.0
Saudi Arabia	4.0	4.9	14.5	15.2	15.3	4.8
All others	28.4	29.0	30.2	30.2	29.4	30.4
World	126.7	129.7	144.4	146.1	150.8	140.1

Source: UNdata, "Energy Statistics Database, Petroleum Coke," January 6, 2021, http://data.un.org/Data.aspx?d=EDATA&f=cmID%3APK.
Note: These data correspond to figure 6.

Table C.5 Graphite global value chain: U.S. import unit values by HS subheadings, 2015–20
In dollars per metric ton.

Year	Natural graphite, flake (HTS 2504.10.10)	Petroleum coke, calcined (HTS 2713.12.00)	Coal tar pitch (HTS 2708.10.00)	Artificial graphite (HTS 3801.10.50)
2015	1,539	355	660	1,413
2016	1,317	291	620	1,477
2017	1,322	332	570	1,399
2018	1,514	500	810	3,205
2019	1,286	679	810	6,215
2020	1,374	241	680	5,773

Source: Compiled from U.S. imports for consumption, unit values (dollars per first unit of quantity), as reported by USITC, DataWeb database, accessed June 7, 2021, https://dataweb.usitc.gov/.
Note: These data correspond to figure 7.

Table C.6a Natural graphite (HS 2504.10): Leading global exporters, 2015–20
In millions of dollars.

Exporter	2015	2016	2017	2018	2019	2020
China	221.1	207.7	241.3	315.0	295.7	308.7
Brazil	28.1	27.3	28.7	31.1	27.2	24.7
Germany	22.2	23.5	24.9	29.6	26.3	25.2
United States	16.2	13.9	19.7	21.1	18.5	19.9
Netherlands	13.7	16.7	18.9	20.0	17.4	16.4
All others	90.3	75.2	88.2	90.7	65.9	52.4
Reporting total	391.5	364.3	421.7	507.5	451.0	447.4

Source: Compiled from export values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 1, 2021, https://connect.ihsmarkit.com/gta/standard-reports.
Note: These data correspond to figure 8a.

Table C.6b Natural graphite (HS 2504.10): Leading global importers, 2015–20
In millions of dollars.

Importer	2015	2016	2017	2018	2019	2020
China	13.5	13.0	16.7	50.0	98.8	16.8
Japan	75.1	74.5	84.9	119.3	97.7	62.9
South Korea	29.2	29.8	42.7	81.1	92.1	102.1
United States	54.5	42.8	52.8	58.1	51.0	41.1
Germany	31.6	39.3	38.6	57.0	46.9	37.7
All others	160.5	150.4	178.1	213.2	190.7	164.1
Reporting total	364.5	349.7	413.9	578.6	577.3	424.7

Source: Compiled from import values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 1, 2021, https://connect.ihsmarkit.com/gta/standard-reports.
Note: These data correspond to figure 8b.

Table C.7a Calcined petroleum coke (HS 2713.12): Leading global exporters, 2015–20
In millions of dollars.

Exporter	2015	2016	2017	2018	2019	2020
United States	1,052.9	884.5	1,127.7	1,901.4	1,676.2	975.7
China	471.1	419.8	469.6	827.4	621.0	398.1
Netherlands	120.9	82.0	84.9	177.7	204.5	168.2
Germany	134.7	116.2	121.3	161.0	135.1	84.0
Brazil	110.4	100.4	105.2	146.9	120.4	76.9
All others	571.2	560.8	674.9	743.3	384.4	193.2
Reporting total	2,461.3	2,163.7	2,583.7	3,957.6	3,141.7	1,896.0

Source: Compiled from export values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 1, 2021, https://connect.ihsmarkit.com/gta/standard-reports.
Note: These data correspond to figure 9a.

Table C.7b Calcined petroleum coke (HS 2713.12): Leading global importers, 2015–20
In millions of dollars.

Importer	2015	2016	2017	2018	2019	2020
India	112.4	192.2	306.1	515.4	585.2	170.9
China	41.1	29.8	114.9	313.2	532.5	52.2
Spain	108.8	113.4	114.3	325.5	341.0	187.0
Netherlands	189.2	175.5	191.7	355.7	322.3	167.8
France	94.0	91.6	93.2	234.6	289.2	121.2
All others	2,179.2	1,822.2	1,947.4	3,133.5	2,472.5	1,067.5
Reporting total	2,724.7	2,424.7	2,767.6	4,877.9	4,542.7	1,766.4

Source: Compiled from import values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 1, 2021, https://connect.ihsmarkit.com/gta/standard-reports.
Note: These data correspond to figure 9b.

Table C.8a Coal tar pitch (HS 2708.10): Leading global exporters, 2015–20
In millions of dollars. n.r. = none reported.

Exporter	2015	2016	2017	2018	2019	2020
China	201.4	181.6	316.9	521.3	335.5	189.8
Belgium	n.r.	n.r.	n.r.	192.2	174.3	135.2
Canada	69.9	60.2	53.8	79.7	87.9	70.2
Ukraine	39.8	27.3	41.0	61.6	51.7	23.1
Taiwan	18.5	13.8	26.2	46.8	34.4	22.6
All others	84.2	57.4	76.9	133.9	92.2	74.0
Reporting total	413.8	340.2	514.8	1,035.5	776.0	514.9

Source: Compiled from export values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 1, 2021, https://connect.ihsmarkit.com/gta/standard-reports.
Note: These data correspond to figure 10a.

Table C.8b Coal tar pitch (HS 2708.10): Leading global importers, 2015–20
In millions of dollars. n.r. = none reported.

Importer	2015	2016	2017	2018	2019	2020
Qatar	57.5	34.9	54.6	155.6	182.7	15.5
United States	73.8	65.7	61.9	92.7	102.0	78.6
Norway	48.8	44.9	64.9	111.8	94.9	77.9
Russia	82.7	56.1	99.2	108.2	69.1	32.2
Belgium	n.r.	n.r.	n.r.	67.4	64.8	59.2
All others	253.1	228.6	367.4	584.6	438.0	333.4
Reporting total	515.9	430.1	647.9	1,120.3	951.6	596.8

Source: Compiled from import values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 1, 2021, https://connect.ihsmarkit.com/gta/standard-reports.
Note: These data correspond to figure 10b.

Table C.9a Artificial graphite (HS 3801.10): Leading global exporters, 2015–20
In millions of dollars.

Exporter	2015	2016	2017	2018	2019	2020
China	195.5	164.6	240.4	404.8	441.9	524.2
Japan	221.0	212.5	260.1	334.3	282.4	239.0
United States	164.4	133.3	179.4	215.9	167.3	109.5
Spain	9.6	16.3	31.8	169.0	146.5	73.1
France	76.0	74.2	97.0	133.4	111.4	70.1
All others	287.2	299.3	353.5	502.4	402.7	480.8
Reporting total	953.6	900.2	1,162.3	1,759.8	1,552.1	1,496.6

Source: Compiled from export values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 1, 2021, https://connect.ihsmarkit.com/gta/standard-reports.
Note: These data correspond to figure 11a.

Table C.9b Artificial graphite (HS 3801.10): Leading global importers, 2015–20
In millions of dollars.

Importer	2015	2016	2017	2018	2019	2020
United States	106.9	104.5	150.4	361.1	377.4	169.4
South Korea	233.6	139.3	170.0	207.8	210.4	173.3
Japan	130.9	132.0	178.0	181.4	189.6	89.2
China	120.8	116.6	144.9	212.6	177.4	165.7
Malaysia	107.7	174.2	218.9	87.1	135.2	232.5
All others	528.1	483.1	559.8	858.7	742.7	766.7
Reporting total	1,227.9	1,149.7	1,421.9	1,908.6	1,832.7	1,596.8

Source: Compiled from import values as reported by national customs authorities to UN Comtrade. IHS Markit, Global Trade Atlas, accessed June 1, 2021, https://connect.ihsmarkit.com/gta/standard-reports.
Note: These data correspond to figure 11b.

Appendix D

Abbreviations and acronyms

Table D.1 Abbreviations and acronyms

Abbreviation or acronym	Definition
CBP	U.S. Customs and Border Protection
DSB	(WTO) Dispute Settlement Body
EC	European Commission
EERE	(USDOE) Office of Energy Efficiency & Renewable Energy
EV	Electric vehicle
GL index	Grubel-Lloyd index
GVC	Global value chain
HS	Harmonized Commodity Description and Coding System or Harmonized System
HTSUS or HTS	*Harmonized Tariff Schedule of the United States*
IAEA	International Atomic Energy Agency
IER	Institute for Energy Research
JCPOA	Joint Comprehensive Plan of Action
LFP	Lithium-iron-phosphate battery
Li-ion	Lithium ion
LMO	Lithium-manganese-oxide battery
MoU	Memorandum of understanding
NCA	Lithium-nickel-cobalt-aluminum-oxide battery
NMC-622	Lithium-nickel-manganese-cobalt-oxide battery with a cathode consisting of 60-percent nickel, 20-percent manganese, and 20-percent cobalt
NRC	Natural Resources Canada
OECD	Organization for Economic Co-operation and Development
OFAC	U.S. (Department of the Treasury) Office of Foreign Assets Control
RCA	Revealed Comparative Advantage
UNdata	United Nations Database
USITC	U.S. International Trade Commission
USDOE	U.S. Department of Energy
USTR	Office of the United States Trade Representative
VAT	Value-added tax
WCO	World Customs Organization
WTO	World Trade Organization

Appendix E
Glossary

Table E.1 Glossary

Term	Definition
Amorphous graphite	The most common form, of low carbon content and high impurities; occurring as massive lumps of small particles; but considered less suitable for most end uses, despite its very low cost.
Anode	The negative electrode, which is the source of electrons flowing in the opposite direction of the lithium ions flowing from the positive electrode (cathode) to generate an electrical current as a lithium-ion (“Li-ion”) battery discharges.
Artificial graphite	Manufactured by heating needle coke and allowing time for the carbon to crystallize into flake graphite, that is also referred to as “synthetic graphite” or “electro-graphite.”
Battery	A group of individual cells operating together as an electric-power supply unit to deliver electrical energy.
Blended graphite	A mix of natural and synthetic graphite that is also referred to as “composite graphite.”
Calcined petroleum coke	A black solid, highly carbonaceous material produced by heating raw petroleum coke in a kiln furnace to drive off the residual volatile water and organic compounds.
Cell	A single electric-power supply unit that delivers electrical energy transformed from its stored chemical energy.
Coal tar	A dark liquid containing various aromatic hydrocarbons recovered as a by-product from the coking process of metallurgical coal.
Coal tar pitch	A black solid, highly carbonaceous material hot-extracted from dehydrated coal tar.
Coated spheroidal graphite	After spheroidization, the uncoated spheroidal graphite is coated with pitch or asphalt followed by baking to prevent expansion and exfoliation (uncurling) of the flakes as the electrolyte intercalates along with the lithium ions among the graphite layers in the anode of a lithium-ion cell.
Coverage Ratio	A broad GVC measure of a country’s position in the value chain and compares the country’s intermediate-good imports with its exports.
Crystalline-vein graphite	The least common form, of high carbon content; occurring as fine flakes, medium needles, or grainy lumps in small deposits; but its high cost is too restrictive for most end uses.
Flake graphite	A less common form, of medium-high carbon content with low impurities but of inconsistent quality; occurring as visible, readily separable flaky particles; with many well-established end uses, due to its low cost, but also for emerging technology applications including Li-ion batteries.
Graphite	The stable allotrope (form) of carbon, occurring as a semi-metallic to dull grey, soft, readily cleavable, multi-layered, tabular (planar) mineral; other carbon allotropes include diamonds and fullerenes.
Grubel-Lloyd index	A GVC measure of country-level intra-materials trade that compares absolute net exports of an intermediate good with total trade (sum of exports and imports) of that same good.
Micron	A micrometer, which is one-millionth of a meter or one-thousandth of a millimeter.

Term	Definition
Natural graphite	Extracted from graphite-bearing ore deposits, in the forms of flakes or small crystals, that is also referred to as “mined graphite.”
Needle coke	Also referred to as “acicular coke,” a premium grade of calcined petroleum coke or coal tar pitch with the fine-grained carbonaceous materials aligned in a single flow direction, that is suitable for production of artificial graphite.
Petroleum coke	A black, solid, carbonaceous material produced by roasting the residual oils remaining from the petroleum refining process in a coking furnace to drive-off the volatiles.
Primary battery or cell	A battery or cell that is non-rechargeable, being designed for single-use applications followed by either recycling or disposal.
Revealed Comparative Advantage	A GVC measure of the intensity with which a country exports a product, calculated as the proportion of the country’s exports of an intermediate good to its total goods exports, compared to (divided by) the proportion of total global exports of the intermediate good to total global goods exports.
Secondary battery or cell	A battery or cell that is rechargeable, in contrast to a primary one which is non-rechargeable.
Spheroidal graphite	Heat-treated graphite, also referred to as “spherical graphite,” consisting of individual flakes curled into porous “micro-balls” averaging 10–30 microns in diameter.
Spheroidization	The heat-treatment process that converts graphite into spheroidal graphite by curling individual graphite flakes.

Bibliography

Advisian Downstream and Market Services, The Carbon Group (Advisian). "Calciners." Accessed August 31, 2020. https://www.petcokes.com/page/calciners.

Advisian Downstream and Market Services, The Carbon Group (Advisian). "Refiners." Accessed August 31, 2020. https://www.petcokes.com/page/refiners.

Ahmad, Nadim, Timon Bohn, Nanno Mulder, Marcel Vaillant, and Dayna Zaclicever. "Indicators on Global Value Chains: A Guide for Empirical Work." *OECD Statistics Working Papers*, July 6, 2017. http://dx.doi.org/10.1787/8502992f-en.

Alabama Graphite Corp. (AGC). "Alabama Graphite Corp. Announces Multiple Shipments of American Sourced and Manufactured CSPG Samples to United States Department of Defense (DoD) Lithium-ion Battery Solutions Providers; Executes Three Non-Disclosure Agreements with DoD and non-DoD Entities." News release, January 10, 2017. https://www.westwaterresources.net/docs/default-source/alabama-graphite-news-releases/agc-ships-cspg-samples-to-us-dod-battery-providers-executes-3-non-disclosure-agreements_jan-2017.pdf?sfvrsn=bd9e37cf_2.

Alabama Graphite Corp. (AGC). "Alabama Graphite Corp. Announces Shipment of American Sourced and Manufactured CSPG Samples to United States Department of Defense (DoD) Lithium-ion Battery Solutions Provider." News release, June 23, 2016. https://www.westwaterresources.net/docs/default-source/alabama-graphite-news-releases/agc-ships-american-sourced-cspg-samples-to-us-dod-battery-manufacturer_june-2016.pdf?sfvrsn=b09e37cf_2.

Anderson, Jack. "Critical Materials: EU Releases Updated Critical Raw Materials List." Roskill Information Services Ltd., September 4, 2020. https://roskill.com/news/critical-materials-eu-releases-updated-critical-raw-materials-list/.

Andrews, Anthony, and Richard K. Lattanzio. *Petroleum Coke: Industry and Environmental Issues*. CRS Report R43263. Washington, DC: Congressional Research Service (CRS), October 29, 2013. https://digital.library.unt.edu/ark:/67531/metadc806317/m1/1/.

Argus Media Ltd. "Battery Demand Buoys Graphite Prices," April 19, 2018. https://www.argusmedia.com/en/news/1665208-battery-demand-buoys-graphite-prices.

Argus Media Ltd. "Chinese Graphite Prices to Hold Firm on Tight Supply," December 19, 2018. https://www.argusmedia.com/en/news/1814182-chinese-graphite-prices-to-hold-firm-on-tight-supply.

Argus Media Ltd. "Syrah Advances Purified Spherical Graphite Production," April 29, 2019. https://www.argusmedia.com/en/news/1892787-syrah-advances-purified-spherical-graphite-production.

Ariyan International Inc. "Petroleum Coke (Petcoke)." Accessed August 31, 2020. https://www.ariyancorp.com/petroleum-coke-petcoke/.

Asbury Carbons Inc. "An Introduction to Synthetic Graphite." Asbury, NJ: Technical Services Department, 2006. https://asbury.com/pdf/SyntheticGraphitePartI.pdf.

Asbury Carbons Inc. "Coke." Accessed August 31, 2020.

Asenbauer, Jakob, Tobias Eisenmann, Matthias Kuenzel, Arefeh Kazzazi, Zhen Chen, and Dominic Bresser. "The Success Story of Graphite as a Lithium-ion Anode Material – Fundamentals, Remaining Challenges, and Recent Developments Including Silicon (Oxide) Composites." *Sustainable Energy Fuels*. London: The Royal Society of Chemistry, November 2020. 5387–5416. https://pubs.rsc.org/en/content/articlepdf/2020/se/d0se00175a.

Barich, Anthony. "Ghost Towns Hit Graphite Market." ResourceStocks, December 2012. http://www.talgaresources.com/irm/PDF/1263_0/GhostTownsHitGraphiteMarket.

Barrera, Priscila. "9 Top Graphite-mining Countries." *Graphite Investing News*, August 14, 2019. https://investingnews.com/daily/resource-investing/battery-metals-investing/graphite-investing/top-graphite-producing-countries-china-india-brazil-canada/.

Battery Minerals Ltd. "Spherical Graphite (SPG)," Accessed October 1, 2018. https://www.batteryminerals.com/our-business/spherical-graphite-process/.

Battery University. "How Do Lithium Batteries Work?" Article No. BU-204, June 1, 2018. https://batteryuniversity.com/learn/article/lithium_based_batteries.

Battery University. "How Does Graphite Work in Li-ion?" Article No. BU-309, August 23, 2019. https://batteryuniversity.com/learn/article/lithium_based_batteries.

Behm, Donald. "Coal Tar Main Source of Toxicity in Streams." Milwaukee Journal Sentinel, December 25, 2016. https://www.jsonline.com/story/news/local/milwaukee/2016/12/25/coal-tar-main-source-toxicity-streams/95790590/.

Behrmann, Elisabeth. "Green Batteries' Graphite Adds to China Pollution." Bloomberg.com, April 30, 2014. https://www.bloomberg.com/news/articles/2014-03-14/teslas-in-california-help-bring-dirty-rain-to-china.

Benchmark Mineral Intelligence Ltd. (Benchmark). "A Year in Review: 2016." London: Benchmark, January 9, 2017. https://www.benchmarkminerals.com/a-year-in-review-2016/.

Benchmark Mineral Intelligence Ltd. (Benchmark). "China Begins Graphite Overhaul." London: Benchmark, January 5, 2017. https://www.benchmarkminerals.com/china-begins-graphite-overhaul/#:~:text=China%20has%20begun%20an%20overhaul,levy%20that%20will%20become%20law.

Benchmark Mineral Intelligence Ltd. (Benchmark). "China Controls Sway of Electric Vehicle Power Through Battery Chemicals, Cathode and Anode Production." London: Benchmark, May 6, 2020. https://www.benchmarkminerals.com/membership/china-controls-sway-of-electric-vehicle-power-through-battery-chemicals-cathode-and-anode-production/.

Benchmark Mineral Intelligence Ltd. (Benchmark). "China Threat Sparks Hitachi's Four-fold Graphite Anode Expansion." London: Benchmark, December 16, 2016. https://www.benchmarkminerals.com/china-threat-sparks-hitachis-five-fold-graphite-anode-expansion/.

Benchmark Mineral Intelligence Ltd. (Benchmark). "Elon Musk: Our Lithium-ion Batteries Should be Called Nickel-Graphite," London: Benchmark, June 5, 2016. http://www.benchmarkminerals.com/elon-musk-our-lithium-ion-batteries-should-be-called-nickel-graphite/.

Benchmark Mineral Intelligence Ltd. (Benchmark). "Graphite Demand from Lithium Ion Batteries to More Than Treble in 4 Years," London: Benchmark, May 2016. https://www.benchmarkminerals.com/graphite-demand-from-lithium-ion-batteries-to-more-than-treble-in-4-years/.

Black Rock Mining Ltd. (Black Rock). "Our Projects," ©2021. Accessed June 16, 2021. https://blackrockmining.com.au/our-projects/.

Burkett, Thomas. "The Relative Applications and Fundamentals of the Synthetic and Natural Graphite Markets." New York: Third Industrial Minerals Graphite & Graphene Conference, November 25, 2013. http://www.indmin.com/events/download.ashx/document/speaker/6609/a0ID000000X0jmwMAB/Presentation.

Business Wire Inc. "Epsilon Advanced Materials Forays into Battery Material Business by Commissioning Manufacturing Facility to Produce Synthetic Graphite Anode Materials for Lithium Batteries," August 24, 2020. https://www.businesswire.com/news/home/20200824005246/en/Epsilon-Advanced-Materials-Forays-Into-Battery-Material-Business-by-Commissioning-Manufacturing-Facility-to-Produce-Synthetic-Graphite-Anode-Materials-for-Lithium-Batteries.

Chemical Book Inc. "Coal Tar," ©2017. Accessed October 30, 2020. https://www.chemicalbook.com/ChemicalProductProperty_EN_CB3116616.htm.

Chen, Si-Yuan, Qi Zhang, Benjamin Mclellan, and Tian-Tian Zhang. "Review on the Petroleum Market in China: History, Challenges and Prospects." Abstract. *Petroleum Science*, August 30, 2020. https://link.springer.com/article/10.1007/s12182-020-00501-6.

China Daily. "Large Graphite Deposit Found in Northeast China's Heilongjiang," February 26, 2019. http://www.chinadaily.com.cn/a/201902/26/WS5c74e092a3106c65c34eb7d5.html.

Crompton, Paul. "Opinion: Australia Begins Its Challenge of China's Graphite Crown in EV Batteries." *Batteries and Energy Storage Technology* (*BEST*), August 2, 2020. https://www.bestmag.co.uk/indnews/opinion-australia-begins-its-challenge-chinas-graphite-crown-ev-batteries.

Dai, Qiang, Jarod C. Kelly, Jennifer Dunn, and Pahola Thathiana Benavides. *Update of Bill-of-Materials and Cathode Materials Production for Lithium-ion Batteries in the GREET® Model*. Lemont, IL: Argonne National Laboratory, Energy Systems Division, October 31, 2018. https://greet.es.anl.gov/publication-update_bom_cm.

Daly, Thomas. "China Minmetals Sets Up Graphite Unit in Battery Materials Push." Mining.com, December 19, 2019. https://www.mining.com/web/china-minmetals-sets-up-graphite-unit-in-battery-materials-push/.

Deign, Jason. "China Plans Graphite Megafactories to Meet Booming Demand for Battery Storage." Greentechmedia.com, October 26, 2017. https://www.greentechmedia.com/articles/read/china-builds-graphite-megafactories-for-battery-storage.

Dixon-Warren, Sinjin. "The World of Lithium Ion Batteries." Boise, Idaho: EETech Media LLC, May 13, 2020. https://eepower.com/technical-articles/changing-the-world-with-lithium-ion-batteries/#.

Dourson, Michael L., Lyle R. Chinkin, David L. MacIntosh, Jennifer A. Finn, Kathleen W. Brown, Stephen B. Reid, and Jeanelle M. Martinez. "A Case Study of Potential Human Health Impacts from Petroleum Coke Transfer Facilities." *Journal of the Air & Waste Management Association*. Abstract. Vol. 66, Issue 11, May 5, 2016. 1061–1076. https://www.tandfonline.com/doi/full/10.1080/10962247.2016.1180328.

Duval, David. "Graphite Demand to Skyrocket with Increased Consumption from Auto Industry." *Resource World*. Accessed June 14, 2021. https://resourceworld.com/graphite-demand-to-skyrocket-with-increased-consumption-from-auto-industry/.

EcoGraf Ltd. "Overview." Accessed June 16, 2021. https://www.ecograf.com.au/overview/.

EcoGraf Ltd. "Recovering Battery-grade Graphite, Without Using Hydrofluoric Acid." News release, May 9, 2021. https://batteryindustry.tech/recovering-battery-grade-graphite-without-using-hydrofluoric-acid/.

Economic Times. "Eco-friendly US Cars Bring Dirty Rain to China," March 18, 2014. https://economictimes.indiatimes.com/auto-technology/eco-friendly-us-cars-bring-dirty-rain-to-china/articleshow/32238394.cms?from=mdr.

Egbaria, Fouad. "Indian Lithium-ion Battery Plant to Produce Synthetic Graphite." *Metal Miner*, April 14, 2021. https://agmetalminer.com/2021/04/14/indian-lithium-ion-battery-plant-to-produce-synthetic-graphite/.

EJAtlas.org. "Residents Protest Against Foul Air in Weiyuan County, Sichuan, China." EJAtlas.org, November 18, 2019. https://www.ejatlas.org/print/residents-protest-against-foul-air-in-weiyuan-county-sichuan-china.

Epsilon Advanced Materials Pvt. Ltd. (EAMPL). "Company Overview, About Us," ©2020. Accessed June 30, 2021. https://www.epsilonam.com/company-overview/.

European Battery Alliance (EBA). "Supply of Graphite from Europe." Brussels: EBA, November 10, 2020. https://www.eba250.com/supply-of-graphite-from-europe/?cn-reloaded=1.

European Commission (EC). "Critical Raw Materials." Brussels: EC. Accessed June 29, 2021. https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en.

European Commission (EC). *Report on Raw Materials for Battery Applications*. SWD(2018) 245/2 Final. Brussels: EC, May 17, 2018. https://ec.europa.eu/transport/sites/transport/files/3rd-mobility-pack/swd20180245.pdf.

Executive Office of the President. *Expediting Environmental Reviews and Approvals for High Priority Infrastructure Projects*. Executive Order 13766, January 24, 2017. 82 FR 8657, January 30, 2017. https://www.govinfo.gov/content/pkg/FR-2017-01-30/pdf/2017-02029.pdf.

Focus Graphite Inc. "Focus Graphite Develops Proprietary Processing Technology for Producing Superfine, High-Performance Graphite for Use in the Production of Lithium-Ion Batteries." February 26, 2015. http://www.focusgraphite.com/news-releases/focus-graphite-develops-proprietary-processing-technology-for-producing-superfine-high-performance-graphite-for-use-in-the-production-of-lithium-ion-batteries/.

Focus Graphite Inc. "Graphite 101." Accessed August 31, 2018. http://www.focusgrapite.com/technology/.

Focus Graphite Inc. "Manufacturing Artificial Graphite." *Focus Mersen*, July 2011. https://www.pssurvival.com/PS/Tools/Welding/Manufacturing_Artificial_Graphite-2016.pdf.

Focus Graphite Inc. "Our Story." Accessed October 24, 2019. http://www.focusgraphite.com/our-story/.

Ghilotti, Davide. "Market Mulls Impact to Price as China Scraps Graphite Duty," Fastmarkets, January 6, 2017. https://www.indmin.com/Article/3650819/Graphite-PricingNews/Market-mulls-impact-to-price-as-China-scraps-graphite-duty.html.

Globe Newswire. "China Coal Tar Industry Report 2019–2025." News release. Dublin Ireland: Research and Markets, February 26, 2019. https://www.globenewswire.com/news-release/2019/02/26/1742153/0/en/China-Coal-Tar-Industry-Report-2019-2025.html.

Globe Newswire. "Global and China Needle Coke Industry (2020 to 2026) - Featuring Phillips 66, C-Chem & GrafTech International Among Others." Dublin Ireland: Research and Markets, May 21, 2020. https://www.globenewswire.com/fr/news-release/2020/05/21/2037010/0/en/Global-and-China-Needle-Coke-Industry-2020-to-2026-Featuring-Phillips-66-C-Chem-GrafTech-International-Among-Others.html.

Globe Newswire. "Outlook on China's Coal Tar Market, 2020–2025— Featuring Profiles of 14 Global and Chinese Coal Tar Processing Enterprises." Dublin Ireland: Research and Markets, February 12, 2020. https://www.globenewswire.com/news-release/2020/02/12/1983625/0/en/Outlook-on-China-s-Coal-Tar-Market-2020-2025-Featuring-Profiles-of-14-Global-and-Chinese-Coal-Tar-Processing-Enterprises.html.

Goldberg, Theodore. “Valero's Benicia Refinery Now Target of Several Probes into Pollution Releases.” San Francisco, CA: KQED Inc., March 26, 2019. https://www.kqed.org/news/11735237/valeros-benicia-refinery-now-target-of-several-probes-into-pollution-releases.

Goldman, Abby R., Frank S. Rotondo, and Jessica G. Swallow. *Lithium Ion Battery Industrial Base in the U.S. and Abroad*. IDA Doc. No. D-11032. Alexandria, VA: Institute for Defense Analysis (IDA), December 2019. https://www.ida.org/-/media/feature/publications/l/li/lithium-ion-battery-industrial-base-in-the-us-and-abroad/d-11032.ashx.

Government of India. *Mineral Conservation and Development Rules 2017*. New Delhi, Ministry of Mines, January 2019. https://ibm.gov.in/writereaddata/files/05082019150233MCDR%202017.pdf.

Grand View Research Inc. “Calcined Petcoke Market Size, Share & Trends Report by Application, Regional Outlook, Competitive Strategies, and Segment Forecasts, 2019 to 2025— Report Insights, Needle Coke Market.” Report ID No. GVR-3-68038-492-5. San Francisco, CA: Grand View Research Inc., August 2019. https://www.grandviewresearch.com/industry-analysis/needle-coke-market.

Grand View Research Inc. “Calcined Petcoke Market Size, Share & Trends Report by Application, Regional Outlook, Competitive Strategies, and Segment Forecasts, 2019 to 2025— Report Summary.” Report ID No. GVR5792. San Francisco, CA: Grand View Research Inc., August 2019. https://www.grandviewresearch.com/industry-analysis/calcined-petroleum-coke-market#:~:text=The%20calcined%20petcoke%20market%20is%20characterized%20by%20the%20presence%20of,ArcelorMittal%20operating%20in%20key%20areas.

Guberman, David. “Global Value Chains: Lithium in Lithium-ion Batteries for Electric Vehicles.” Staff working paper. U.S. International Trade Commission, forthcoming.

Hatch, Gareth. “Going Natural: The Solution to Tesla’s Graphite Problem.” Technology Metals Research LLC, March 25, 2014. https://www.techmetalsresearch.com/going-natural-the-solution-to-teslas-graphite-problem/.

Hawthorne, Michael. “Petcoke Piles Gone, But Another Dangerous Pollutant Discovered in the Air.” *Chicago Tribune*, February 21, 2017. https://www.chicagotribune.com/news/breaking/ct-manganese-pollution-chicago-met-20170218-story.html.

Holman, Jacqueline. “Beowulf, Epsilon Partner to Develop Graphite Processing Hub in Finland.” S&P Global Platts, March 8, 2021. https://www.spglobal.com/platts/en/market-insights/latest-news/metals/030821-beowulf-epsilon-partner-to-develop-graphite-processing-hub-in-finland.

Holman, Jacqueline. “High Graphite Prices Spur New Ex-China Developments.” *Mining Journal*, June 7, 2019. https://www.mining-journal.com/research/news/1364780/high-graphite-prices-spur-new-ex-china-developments.

Horn, Steven. “India May Ban Petcoke, One of Dirtiest Fossil Fuels Exported by Koch Brothers.” Seattle, WA: DeSmogBlog, December 9, 2017. https://www.desmogblog.com/2017/12/09/petcoke-koch-brothers-ban-india.

Hosokawa Micron Corp. "Applications, Energy (Battery), LIB Anode, Graphite." Accessed October 3, 2019. https://www.hosokawamicron.co.jp/en/applications/1013.

Hua, Shengdun. "Petcoke Called Key in Pollution Fight." China Daily USA, July 16, 2015. http://usa.chinadaily.com.cn/china/2015-07/16/content_21304058.htm.

ICC SINO. "In-depth Analysis Report on China Needle Coke and the Application Market." News release. Shanghai: ICC SINO, January 18, 2018. http://www.iccsino.com/news/show-htm-itemid-11385.html.

IHS_Markit. Global Trade Atlas database, ©2021. Accessed June 1 and 17, 2021. https://connect.ihsmarkit.com/gta/standard-reports.

Industrial Minerals. "Graphite News, Market Brief." Accessed April 26, 2018. http://www.indmin.com/Graphite.html.

Institute for Energy Research (IER). "China Dominates the Global Lithium Battery Market." Washington, DC: IER, September 9, 2020. https://www.instituteforenergyresearch.org/renewable/china-dominates-the-global-lithium-battery-market/.

International Atomic Energy Agency (IAEA). "Graphite in the Advanced Gas Reactor Fleet." Vienna: IAEA, *A General Overview of Graphite Core Project Team Related Projects*. Accessed November 17, 2019. https://nucleus.iaea.org/sites/graphiteknowledgebase/wiki/Guide_to_Graphite/Home.aspx.

International Mining. "Natural & Synthetic Graphite, New Report with Forecasts to 2026," June 13, 2017. https://im-mining.com/2017/06/13/natural-synthetic-graphite-new-report-forecasts-2026/.

Jenkins, Ian. "Massive Graphite Shortage Looms Over Electric Car Future." PR NewsWire, October 23, 2019. https://www.prnewswire.com/news-releases/massive-graphite-shortage-looms-over-electric-car-future-652471503.html.

Jones, Lin, Meryem Demirkaya, and Erika Bethmann. "Global Value Chain Analysis: Concepts and Approaches." Journal of International Commerce and Economics, U.S. International Trade Commission, April 2019. https://www.usitc.gov/publications/332/journals/concepts_approaches_in_gvc_research_final_april_18.pdf.

Junior Mining Network. "Northern Graphite Signs Product Offtake Agreement," June 4, 2018. https://www.juniorminingnetwork.com/junior-miner-news/press-releases/1073-tsx-venture/ngc/47732-northern-graphite-signs-product-offtake-agreement.html.

Karinja, Filip. "World's Largest Graphite Mine Achieves Commercial Production." SmallCaps.com, January 14, 2019. https://smallcaps.com.au/worlds-largest-graphite-mine-achieves-commercial-production/.

Kay, Amanda. "Graphite Mining in the US." *Graphite Investing News*, April 19, 2018. https://investingnews.com/daily/resource-investing/critical-metals-investing/graphite-investing/graphite-mining-in-the-us/.

Kay, Amanda. "Types of Graphite: Amorphous, Flake and Vein." *Graphite Investing News*, June 13, 2018. https://investingnews.com/daily/resource-investing/critical-metals-investing/graphite-investing/types-of-graphite-amorphous-flake-and-vein/.

Kay, Amanda. "What is Synthetic Graphite?" *Graphite Investing News*, July 31, 2018. https://investingnews.com/daily/resource-investing/critical-metals-investing/graphite-investing/what-is-synthetic-graphite-asbury-carbons-stephen-riddle-explains/.

Lambert, Frederic. "Breakdown of Raw Materials in Tesla's Batteries and Possible Bottlenecks." Electrek Co., November 1, 2016. https://electrek.co/2016/11/01/breakdown-raw-materials-tesla-batteries-possible-bottleneck/.

LaRocca, Gregory M. "Global Value Chains: Lithium in Lithium-ion Batteries for Electric Vehicles." Staff working paper ID-069. U.S. International Trade Commission, July 2020. https://www.usitc.gov/sites/default/files/publications/332/working_papers/no_id_069_gvc_lithium-ion_batteries_electric_vehicles_final_compliant.pdf.

Lasley, Shane. "Critical Minerals Alaska – Graphite." *Mining News*, February 23, 2018. https://www.miningnewsnorth.com/story/2018/02/01/in-depth/critical-minerals-alaska-graphite/5022.html.

Lasley, Shane. "Graphite Creek Nominated High Priority." *Mining News*, October 25, 2019. https://www.miningnewsnorth.com/story/2019/10/18/news/graphite-creek-nominated-high-priority/5961.html.

Lazenby, Henry. "Chinese Flake Graphite Consolidation Could Alter Global Supply Structure." Mining Weekly, April 17, 2014. http://www.miningweekly.com/article/chinese-flake-graphite-consolidation-could-alter-global-supply-structure-2014-04-17.

Leading Edge Materials Corp. "About Graphite." Accessed August 25, 2018. http://leadingedgematerials.com/graphite/.

Lebedeva, Natalia, Franco Di Persio, and Lois Boon-Bret. *Lithium Ion Battery Value Chain and Related Opportunities for Europe, 2016*. Ispra, Italy: European Commission (EC), Joint Research Centre (JRC), 2017. https://op.europa.eu/en/publication-detail/-/publication/349a7d1a-61f9-11e7-9dbe-01aa75ed71a1/language-en.

Lee, Stanley. "Posco Slows Down Natural Graphite Expansion Plan." The Elec Inc., Korea Electronics Industry Media, October 26, 2020. http://www.thelec.net/news/articleView.html?idxno=1777.

Liu, Chaofeng, Zachary G. Neale, and Guozhong Cao. "Understanding Electrochemical Potentials of Cathode Materials in Rechargeable Batteries." *Materials Today*. Kidlington, United Kingdom: Elsevier Ltd., March 2016. 109–123 https://www.researchgate.net/figure/Schematic-of-the-configuration-of-rechargeable-Li-ion-batteries-Na-ion-Mg-ion-or_fig8_284136761.

Lowe, Mary, Saori Tokuoka, Tali Trigg, and Gary Gereffi. *Lithium-ion Batteries for Electric Vehicles: the U.S. Value Chain*. Durham, NC: Duke University, Center on Globalization, Governance & Competitiveness, October 5, 2010 (revised). https://gvcc.duke.edu/wp-content/uploads/Lowe_Lithium-Ion_Batteries_CGGC_10-05-10_revised.pdf.

Luossavaara-Kiirunavaara Aktiebolag (LKAB). "Talga, Mitsui and LKAB Confirm Intent for Joint development of the Vittangi Graphite Mine and Battery Anode Production." Press release, November 2, 2020. https://www.lkab.com/en/news-room/press-releases/talga-mitsui-and-lkab-confirm-intent-for-joint-development-of-the-vittangi-graphite-mine-and-battery-anode-production/?aid=16447.

Mason Graphite Inc. "About, Company Overview," 2017. http://www.masongraphite.com/about/company-overview/default.aspx.

Mason Graphite Inc. "Lac Guéret Graphite Project," 2017. http://www.masongraphite.com/projects/lac-gueret-graphite-project/default.aspx.

Mason Graphite Inc. "Graphite Quick Facts," 2017. http://www.masongraphite.com/investors/about-graphite/default.aspx.

Matsumoto, Fumi. "Australia Challenges China's Graphite Crown in EV Batteries." Nikkei Asia. Nikkei Inc., July 25, 2020. https://asia.nikkei.com/Business/Automobiles/Australia-challenges-China-s-graphite-crown-in-EV-batteries.

Matthews, Daniel. "Global Value Chains: Cobalt in Lithium-ion Batteries for Electric Vehicles." Staff working paper ID-067. U.S. International Trade Commission, May 2020. https://www.usitc.gov/sites/default/files/publications/332/working_papers/id_wp_cobalt_final_052120-compliant.pdf.

McLeod, Charlotte. "Simon Moores on Spherical Graphite and the Benefits of Exploration." *Graphite Investing News*, November 26, 2013. https://investingnews.com/daily/resource-investing/critical-metals-investing/graphite-investing/simon-moores-on-spherical-graphite-and-the-benefits-of-exploration/.

McLeod, Charlotte. "Stephen Riddle: What Investors Really Need to Know About Graphite." *Graphite Investing News*, November 24, 2014. https://investingnews.com/daily/resource-investing/critical-metals-investing/graphite-investing/asbury-carbons-stephen-riddle-graphite-china-tesla/.

McMahon, Jeffrey. "China Is Quietly Burning a Fuel Dirtier Than Coal— And Buying It from the US." *Forbes*, July 15, 2015. https://www.forbes.com/sites/jeffmcmahon/2015/07/15/chinas-pollution-quagmire-and-its-alberta-tar-sands-connection/?sh=40bdb2bd166c.

Mining.com. "CHART: Study Predicts Over 400% Increase in Copper, Lithium, Nickel Battery Demand," June 30, 2021. https://go.pardot.com/e/398282/-lithium-nickel-battery-demand/217wz7m/1587125132?h=c9OpiJHADOVMU98zQPm4r654x5kRgLwkF0xse6U8xs8.

Mining.com. "Flake Graphite Prices Have Bottomed," May 28, 2013. https://www.mining.com/web/flake-graphite-prices-have-bottomed/.

Moores, Simon. “Graphite Prices.” Saint Jean Carbon Inc., May 2013. http://www.saintjeancarbon.com/index.php/graphene/graphite/prices/.

Moores, Simon. “Spherical Graphite: How Is It Made?” *Industrial Minerals*, August 2, 2013. http://www.indmin.com/Article/3238613/Spherical-graphite-how-is-it-made.html.

Moores, Simon and Andrew Miller. “Hitachi Plans Huge Anode Expansion Amid a Graphite Overhaul in China.” London: Benchmark Mineral Intelligence Ltd., January 26, 2017. https://www.benchmarkminerals.com/membership/hitachi-plans-huge-anode-expansion-amid-a-graphite-overhaul-in-china/.

Mordor Intelligence LLP. “Synthetic Graphite Market— Growth, Trends, and Forecast (2020–2025).” Hyderabad, India: Mordor Intelligence LLP, April 2020. https://www.reportlinker.com/p05881488/Synthetic-Graphite-Market-Growth-Trends-and-Forecast.html?utm_source=GNW.

Morris, Mark. “How is Crude Coal Tar Derived?” Coopers Creek Chemical Corp. November 2005. http://www.truthaboutcoaltar.com/pdf/How_is_Crude_Coal_Tar_Derived.pdf.

Nagle, Maria. “Nicor Neighbors Concerned About Coal Tar.” Bloomington, IL: *The Pantagraph*, October 23, 2014. https://www.pantagraph.com/news/local/nicor-neighbors-concerned-about-coal-tar/article_a4a6be3b-4041-5473-87ec-6b75e6279001.html.

Natural Resources Canada (NRC). “Canadian Mineral Production.” Ottawa: Department of Natural Resources Canada, May 2019. https://www.nrcan.gc.ca/science-data/science-research/earth-sciences/earth-sciences-resources/earth-sciences-federal-programs/canadian-mineral-production/17722.

Neutkens, Debra. “Coal Tar Refiners Sued for Polluting Ponds.” White Bear Lake, MN: Press Publications, January 9, 2019. https://www.presspubs.com/white_bear/news/coal-tar-refiners-sued-for-polluting-ponds/article_9f894164-1441-11e9-9f36-d3dc28165078.html.

Noh, Hyun, and Mira Choi. “Posco Chemical to Supply Anodes to GM’s EV Platform Ultium in U.S.” Pulse by Maeil Business News Korea, April 6, 2021. https://pulsenews.co.kr/view.php?sc=30800028&year=2021&no=327918.

Northern Graphite Corp. “About Spherical Graphite (“SPG”).” Accessed January 9, 2018. http://www.northerngraphite.com/_resources/media/SPG-Summary-2.pdf.

Northern Graphite Corp. “Bissett Creek Project Overview.” Accessed October 24, 2019. http://www.northerngraphite.com/project/bissett-creek-project/overview/.

Northern Graphite Corp. “Corporate Overview.” Accessed October 24, 2019. http://www.northerngraphite.com/corporate/corporate-overview/.

Northern Graphite Corp. “Graphite Companies Announce Spherical Graphite Test Facility Begins Operations,” October 27, 2016. http://www.northerngraphite.com/_resources/news/20160927.pdf.

Northern Graphite Corp. “Lithium Ion Batteries.” Accessed January 9, 2018. http://www.northerngraphite.com/about-graphite/graphite-growth-markets/lithium-ion-batteries/.

Northern Graphite Corp. “The Graphite Supply Problem.” Accessed January 9, 2018. http://www.northerngraphite.com/about-graphite/the-graphite-supply-problem/.

Northern Miner. “US Government Gives High Priority Status to Graphite One’s Alaskan Project,” February 3, 2021. https://www.mining.com/us-government-gives-high-priority-status-to-graphite-ones-alaskan-project/.

Nouveau Monde Graphite Inc. “About Us.” Accessed June 16, 2021. https://nouveaumonde.group/about-us/.

Nouveau Monde Graphite Inc. “Find Your Solution.” Accessed June 16, 2021. https://nouveaumonde.group/solutions/#find-solution.

Nouveau Monde Graphite Inc. “Operations.” Accessed June 16, 2021. https://nouveaumonde.group/operations/#advanced-materials-plant.

Nouveau Monde Graphite Inc. “Progress Report for Phase 1 and Phase 2 of Nouveau Monde’s Bécancour Battery Anode Material Plants.” Press release. L'Ange-Gardien, Québec: Nouveau Monde Graphite Inc., June 8, 2021. https://nouveaumonde.group/becancour-plants-update/.

Olsen, Donald W. "Graphite (Advanced Release)." *2015 Minerals Yearbook (Advanced Release)*. U.S. Geological Survey, June 2018. 32.1–32.13. https://minerals.usgs.gov/minerals/pubs/commodity/graphite/myb1-2015-graph.pdf.

Olsen, Donald W. “Graphite (Natural).” *Mineral Commodity Summaries*. Reston, VA: U.S. Geological Survey, various years. 72–73. Accessed various dates. https://www.usgs.gov/centers/nmic/graphite-statistics-and-information.

Olvetti, Elsa A., Gerbrand Ceder, Gabrielle G. Gaustad, and Xinkai Fu. “Lithium-Ion Battery Supply Chain Considerations: Analysis of Potential Bottlenecks in Critical Metals.” *Joule*, 1. October 11, 2017. 229–243. https://www.cell.com/joule/pdf/S2542-4351(17)30044-2.pdf.

Organization for Economic Co-operation and Development (OECD). “Trade in Value Added.” 2019. https://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm.

Pell, Robert. “Battery Grade Graphite: It’s Not All About Carbon.” London: Minviro Ltd., May 19, 2020. https://www.minviro.com/battery-grade-graphite-its-not-all-about-carbon/.

PR NewsWire. “CRU: China's Supply-side Reform is Hurting Third-party Coke Buyers.” Chicago, IL: PR NewsWire, October 23, 2018. https://www.prnewswire.com/news-releases/cru-chinas-supply-side-reform-is-hurting-third-party-coke-buyers-300735035.html.

PR NewsWire. “Global and China Lithium-ion Battery Anode Material Industry Report, 2020–2026, with Profiles of 15 Anode Material Manufacturers and 3 Lithium Titanate Manufacturers.” News release. Charing (Kent Co.), United Kingdom; Report Buyer Ltd., September 4, 2020. https://www.prnewswire.com/news-releases/global-and-chinese-lithium-ion-battery-anode-material-market-report-2020-2026-with-profiles-of-15-anode-material-manufacturers-and-3-lithium-titanate-manufacturers-301124433.html.

PR NewsWire. “Global and China Lithium-ion Battery Anode Material Industry Report, 2017–2020.” News release. Charing (Kent Co.), United Kingdom; Report Buyer Ltd., March 22, 2017. https://www.prnewswire.com/news-releases/global-and-china-lithium-ion-battery-anode-material-industry-report-2017-2020-300428020.html.

PR NewsWire. “Global Coal Tar Market Growth, Key Companies Analysis, Size, Share, Demands and Industry Outlook 2019–2024.” News release. Hadapsar (Pune City), India: ReportsnReports, April 15, 2019. https://www.prnewswire.com/in/news-releases/global-coal-tar-market-growth-key-companies-analysis-size-share-demands-and-industry-outlook-2019-2024-reportsnreports-837117948.html.

PR NewsWire. “Global Needle Coke Market 2019–2023.” Chicago, IL: PR NewsWire, July 2019. https://www.prnewswire.com/news-releases/the-global-needle-coke-market-at-a-cagr-of-6-during-the-forecast-period-300897349.html.

Rapp, M., M. Mundszinger, S. Farsi, U. Golla-Schindler, U. Kaiser, and M. Wachtler. “Spheroidization of Graphite as Anode Material for Li-Ion Batteries: Spheroidization Process and Material Texture and Morphology.” Abstract. Chicago: 18th International Meeting on Batteries, June 21, 2016. https://ecs.confex.com/ecs/imlb2016/webprogram/Paper76389.html.

Renascor Resources Ltd. “Siviour Graphite Project,” ©2021. Accessed June 16, 2021. https://renascor.com.au/graphite-projects/.

Research and Markets. “The World Market for Synthetic Graphite, 2019 to 2024— Top 5 Players Account for More Than 75% of the Market Share.” Dublin, United Kingdom: Research and Markets, May 24, 2019. https://www.globenewswire.com/news-release/2019/05/24/1843054/0/en/The-World-Market-for-Synthetic-Graphite-2019-to-2024-Top-5-Players-Account-for-More-Than-75-of-the-Market-Share.html#:~:text=The%20top%205%20players%20account,Ltd%2C%20and%20Hitachi%20Chemical%20Co.

Rivera, Pia. “The Next Graphite Producers.” *Investing News*, October 13, 2016. https://investingnews.com/daily/resource-investing/battery-metals-investing/graphite-investing/next-graphite-producers-eagle-elcora-bass-metals-leading-edge-materials-energizer-hexagon/.

Rolander, Niclas, and Jesper Starn. “EV Boom Leads to Reopening of Swedish Graphite Mine.” *Automotive News Europe*, April 3, 2018. https://europe.autonews.com/article/20180403/ANE/180409918/ev-boom-leads-to-reopening-of-swedish-graphite-mine.

Roskill Information Services Ltd. (Roskill). "Graphite: China-US Trade War Reaches Graphite Industry," June 10, 2019. https://roskill.com/news/graphite-china-us-trade-war-reaches-graphite-industry/.

Roskill Information Services Ltd. (Roskill). "Graphite: Chinese Flake Closures to Continue Through 2018," Roskill, July 20, 2018. https://roskill.com/news/graphite-chinese-flake-closures-to-continue-through-2018/.

Roskill Information Services Ltd. (Roskill). "Graphite: Imerys Acquires Nippon Power Graphite." Roskill, February 22, 2017. https://roskill.com/news/graphite-imerys-acquires-nippon-power-graphite/.

Roskill Information Services Ltd. (Roskill). "Graphite: The Race for Non-Chinese Spherical Graphite Heats Up." Kitco.com, April 29, 2019. https://www.kitco.com/commentaries/2019-04-29/Graphite-The-race-for-non-Chinese-spherical-graphite-heats-up.html.

Roskill Information Services Ltd. (Roskill). "Natural & Synthetic Graphite, Outlook to 2028, 12th Edition," Roskill. Accessed October 16, 2019. https://roskill.com/market-report/natural-synthetic-graphite/.

Roskill Information Services Ltd. (Roskill). "Roskill: Batteries Spark Dynamic Change in Graphite Markets." PR NewsWire, July 10, 2017. https://www.prnewswire.com/news-releases/roskill-batteries-spark-dynamic-change-in-graphite-markets-633556553.html.

Roskill Information Services Ltd. (Roskill). "Roskill: Graphite Market Continuously Shaped by Pollution Controls," Globenewswire.com, June 12, 2019. https://www.globenewswire.com/news-release/2019/06/12/1867350/0/en/Roskill-Graphite-market-continuously-shaped-by-pollution-controls.html.

Saigal, Kanika. "Mozambique's Glittering Graphite Mining Boom." *The Africa Report*. Paris: Jeune Afrique Media Group (JAMG), January 22, 2019. https://www.theafricareport.com/412/mining-mozambique-glittering-graphite/#.

Sarna, Satyendra Kumar. "Coal Tar and Its Distillation Processes." IspatGuru.com, December 26, 2018. https://www.ispatguru.com/coal-tar-and-its-distillation-processes/.

Scott, Alexander. "In the Battery Materials World, the Anode's Time Has Come." *Chemical & Engineering News*, April 7, 2019. https://cen.acs.org/materials/energy-storage/battery-materials-world-anodes-time/97/i14.

Scott, Sarah, and Robert Ireland. "Lithium-Ion Battery Materials for Electric Vehicles and their Global Value Chains." Staff working paper ID-068. U.S. International Trade Commission, June 2020. https://www.usitc.gov/sites/default/files/publications/332/working_papers/gvc_overview_scott_ireland_508_final_061120.pdf.

Serapio, Manolo Jr. and Thomas Daly. "The Graphite Fix: Inside China's Newest Commodity Addiction." Reuters, September 21, 2017. https://www.reuters.com/article/us-china-steel-graphiteelectrode/the-graphite-fix-inside-chinas-newest-commodity-addiction-idUSKCN1BW0S2.

Shaw, Suzanne. “Graphite: China Continues with Record Levels of Natural Graphite Imports.” Linkedin.com, July 23, 2019. https://www.linkedin.com/pulse/graphite-china-continues-record-levels-natural-imports-sue-shaw.

Shaw, Suzanne. “Graphite: Natural Graphite Remains on EU Critical Raw Materials List, For Now.” London: Roskill Information Services Ltd., September 10, 2020. https://roskill.com/news/graphite-natural-graphite-remains-on-eu-critical-raw-materials-list-for-now/.

Shaw, Suzanne. “Graphite: Renascor Signs MoU with Major Chinese Anode Producer.” London: Roskill Information Services Ltd., February 5, 2021. https://roskill.com/news/graphite-renascor-signs-mou-with-major-chinese-anode-producer/.

Shendruk, Amanda, and Heather Timmons. “All 2,493 US Products Targeted by China’s New 25% Tariffs.” Quartz, May 13, 2019. https://qz.com/1618238/all-2493-items-targeted-by-chinas-tariffs-in-us-trade-war/.

Showa Denko Materials Co. Ltd. “Announcement of Changing Company's Name.” News release, June 23, 2020. https://www.mc.showadenko.com/english/information/2020/n_200623y4p.html.

Slavnich, Dean. “Imerys Graphite & Carbon Acquires CVD Coating Technology.” *Engine + Powertrain Technology International*, February 23, 2017. https://www.enginetechnologyinternational.com/news/metallurgy/imerys-graphite-carbon-acquires-cvd-coating-technology.html.

South China Morning Post. “SungEel HiTech Leads the Way in Eco-friendly Recycling of Lithium-ion Batteries,” April 29, 2020. https://www.scmp.com/country-reports/country-reports/topics/south-korea-business-report-2020/article/3079850/sungeel.

Steinrötter, Michael. “Carbon-Based Anodes— a ‘Rare Earth’ Situation?” *BEST*, February 2011. 65–75. http://www.northerngraphite.com/_resources/media/SGL-Graphite-Article-Feb-2011.pdf.

Stewart, Leslie. “Dust in the Wind: Regulating Coal and Petcoke Particulate Matter.” Bay Area Monitor. Oakland, CA: League of Women Voters of the Bay Area, December 2018/January 2019. https://bayareamonitor.org/article/dust-in-the-wind-regulating-coal-and-petcoke-particulate-matter/.

Syrah Resources Ltd. “Balama Graphite Operation, Mozambique.” Accessed November 1, 2019. http://www.syrahresources.com.au/balama-project.

Syrah Resources Ltd. “Battery Anode Material Project, USA.” Accessed November 1, 2019. http://www.syrahresources.com.au/spherical-graphite-project.

Syrah Resources Ltd. “Graphite and Its Uses.” Accessed March 27, 2018. http://www.syrahresources.com.au/graphite-and-its-uses.

Syrah Resources Ltd. “What is Graphite?” Accessed March 27, 2018. http://www.syrahresources.com.au/what-is-graphite.

Taiwan News. “Coal Tar Spill Pollutes River in Southwest China,” May 10, 2009. https://www.taiwannews.com.tw/en/news/944720.

Targay Technology International Inc. (Targay). “Anode Materials.” Accessed August 26, 2019. https://www.targray.com/li-ion-battery/anode-materials.

Teliska, Margaret. “Lower Graphite Production in China Could Mean Higher Battery Prices.” Axios.com, February 28, 2019. https://www.axios.com/lower-graphite-production-in-china-could-mean-higher-battery-prices-5aa5c9dd-1ca5-482f-bc08-51107da8cfe7.html.

Tesla Motors (Tesla) Inc. “Panasonic and Tesla Sign Agreement for the Gigafactory,” July 30, 2014. https://www.tesla.com/blog/panasonic-and-tesla-sign-agreement-gigafactory.

Tesla Motors (Tesla) Inc. “Tesla Gigafactory.” Accessed October 23, 2019. https://www.tesla.com/gigafactory.

The Diggings. "United Minerals Co. Mill in Broadwater, MT, Graphite Past Producer,” 2018. https://thediggings.com/mines/usgs10246026.

Transparency Market Research (TMR). “Synthetic Graphite Market to Reach Around US$7 Bn by 2026; Increasing Production of Steel to Surge Market, Says TMR.” Albany NY: TMR, July 5, 2019. https://www.prnewswire.com/news-releases/synthetic-graphite-market-to-reach-around-us-7-bn-by-2026-increasing-production-of-steel-to-surge-market-says-tmr-300880276.html.

United Nations Data (UNdata). “Energy Statistics Database, Coal Tar.” New York: UN Statistics Division, January 8, 2021. http://data.un.org/Data.aspx?d=EDATA&f=cmID%3ACT.

United Nations Data (UNdata). “Energy Statistics Database, Petroleum Coke.” New York: UN Statistics Division, January 6, 2021. http://data.un.org/Data.aspx?d=EDATA&f=cmID%3APK.

Urbix Resources LLC. “Leading U.S. Graphite Companies Will Collaborate Towards High-Purity Graphite, Spherical Graphite and Graphene.” Everyone’s Internet News (EIN) Presswire, February 4, 2019. https://www.einnews.com/pr_news/475559221/leading-u-s-graphite-companies-will-collaborate-towards-high-purity-graphite-spherical-graphite-and-graphene.

U.S. Customs and Border Protection (CBP). “The Tariff Classification of Two Surface Modified Graphite Powders from Japan.” Customs Ruling No. N094256. March 19, 2010. https://rulings.cbp.gov/ruling/N094256.

U.S. Department of Energy (USDOE). “How Lithium-ion Batteries Work.” Washington, DC: USDOE, Office of Energy Efficiency & Renewable Energy (EERE). Accessed October 11, 2019. https://www.energy.gov/eere/articles/how-does-lithium-ion-battery-work.

U.S. Department of Energy (USDOE). *Refinery Capacity Report 2020*. Washington, DC: USDOE, Energy Information Administration (EIA), June 22, 2020. https://www.eia.gov/petroleum/refinerycapacity/.

U.S. International Trade Commission (USITC). DataWeb database, ©2021. Accessed June 7, 2021https://dataweb.usitc.gov/trade.

U.S. International Trade Commission (USITC). *Harmonized Tariff Schedule of the United States (2021) Basic Revision 9*. Publication No. 5249. November 18, 2021. https://hts.usitc.gov/current.

U.S. Office of Foreign Assets Control (OFAC). "Guidance Relating to the Lifting of Certain U.S. Sanctions Pursuant to the Joint Comprehensive Plan of Action on Implementation Day." U.S. Department of the Treasury, OFAC, January 16, 2016. https://home.treasury.gov/system/files/126/implement_guide_jcpoa.pdf.

U.S. Office of Foreign Assets Control (OFAC). "Frequently Asked Questions Relating to the Lifting of Certain U.S. Sanctions Under the Joint Comprehensive Plan of Action (JCPOA) on Implementation Day." U.S. Department of the Treasury, OFAC, December 15, 2016. https://home.treasury.gov/system/files/126/jcpoa_faqs.pdf.

(Office of the) United States Trade Representative (USTR). *2018 Report to Congress On China's WTO Compliance*, February 2019. https://ustr.gov/sites/default/files/2018-USTR-Report-to-Congress-on-China's-WTO-Compliance.pdf.

(Office of the) United States Trade Representative (USTR). *2017 USTR Report to Congress on China's WTO Compliance*, January 2018. https://ustr.gov/sites/default/files/files/Press/Reports/China%202017%20WTO%20Report.pdf.

(Office of the) United States Trade Representative (USTR). *Notice of Modification of Section 301 Action: China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation*. Federal Register (84 FR 20459), May 9, 2019. https://ustr.gov/sites/default/files/enforcement/301Investigations/84_FR_20459.pdf.

(Office of the) United States Trade Representative (USTR). *Notice of Modification of Section 301 Action: China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation*. Federal Register (83 FR 47974), September 21, 2018. https://ustr.gov/sites/default/files/enforcement/301Investigations/83%20FR%2047974.pdf.

Pencils.com. "Graphite Grading Scale Explained." Stockton, CA: Cedar Products Co., ©2022. Accessed March 4, 2022. https://pencils.com/pages/hb-graphite-grading-scale.

Westwater Resources Inc. (WWR). "Westwater Resources Completes Acquisition of Alabama Graphite," April 23, 2018. https://www.westwaterresources.net/docs/default-source/news-release/alabama-graphite-acquisition-(release-version).pdf?sfvrsn=3e3137cf_0.

Whiteside, James and Daniel Finn-Foley. "Supply Chain Looms as Serious Threat to Batteries' Green Reputation." Edinburgh, United Kingdom: Wood Mackenzie, Greentech Media (GTM), November 25, 2019. https://www.greentechmedia.com/articles/read/graphite-the-biggest-threat-to-batteries-green-reputation.

Whoriskey, Peter. "In Your Phone, In Their Air." *Washington Post*, October 2, 2016. https://www.washingtonpost.com/graphics/business/batteries/graphite-mining-pollution-in-china/.

Willing, Nicole. “Graphite Firms Integrate European Battery Supply Chain.” London: Argus Media Ltd., September 24, 2020. https://www.argusmedia.com/en/news/2144154-graphite-firms-integrate-european-battery-supply-chain.

Won, Ho-sup, and Ha-yeon Lee. “Posco Chemical Breaks Ground for EV Battery Anode Material Factory in Korea,” Pulse by Maeil Business Newspaper, July 3, 2020. https://pulsenews.co.kr/view.php?year=2020&no=683094.

Wood Mackenzie. “IMO 2020, EVs, and Steel— a Perfect Storm in the Needle Coke Sector?” Edinburgh, United Kingdom: Wood Mackenzine, May 30, 2019. https://www.mining.com/web/imo-2020-evs-steel-perfect-storm-needle-coke-sector/.

World Customs Organization (WCO). “What is the Harmonized System?” Accessed December 11, 2019. http://www.wcoomd.org/en/topics/nomenclature/overview/what-is-the-harmonized-system.aspx.

World Trade Organization (WTO). “DS508: China— Export Duties on Certain Raw Materials,” November 8, 2016. https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds508_e.htm.

World Trade Organization (WTO). “Panel Established in Dispute Over Chinese Export Restrictions on Raw Materials,” November 8, 2016. https://www.wto.org/english/news_e/news16_e/dsb_08nov16_e.htm.

Yamaguchi, Jun, Masami Sawato, John Sung, A-Hyung Cho, and Patrick Jobin. “Battery/Battery Materials.” New York: Credit Suisse Securities Research & Analytics, July 3, 2012. https://research-doc.credit-suisse.com/docView?language=ENG&format=PDF&source=em&document_id=983135241&serialid=Y2obAQFHSFcORhxJvbBE9kPu7E%2FNEiL%2B92MfdXYzXJM%3D.

Zhang, Yifei. “Chinese Graphite Industry, Market Opportunity and Industry Outlook,” Inner Mongolia Rising Energy Group Ltd. Accessed October 30, 2020. http://www.indmin.com/events/download.ashx/document/speaker/6562/a0ID000000X0jaDMAR/Presentation.

Zhu, Sirui. “Game of Mines.” Reuters, June 7, 2019. https://graphics.reuters.com/ELECTRIC-VEHICLES-METALS/010092JB38P/index.html.