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LITHIUM [ADVANCE RELEASE]

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Lithium

By Brian W. Jaskula

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

In the United States, one continental brine lithium operation with an associated lithium carbonate plant operated in Silver Peak, NV. Lithium carbonate also was commercially produced from the brine-sourced waste tailings of a Utah-based magnesium producer. Domestic and imported lithium carbonate, lithium chloride, and lithium hydroxide were consumed directly in industrial applications and used as raw materials for downstream lithium compounds. In 2022, lithium consumption in the United States was estimated to be equivalent to 3,000 metric tons (t) of elemental lithium content (table 1) [16,000 t of lithium carbonate equivalent (LCE)], primarily for lithium-based batteries, ceramics and glass, grease, pharmaceuticals, and polymer products. In 2022, the gross weight of lithium compounds exported from the United States increased by 30%, and the gross weight of lithium compounds imported increased by 23% from those in 2021 (tables 2, 3). The average annual unit value of lithium carbonate imports (including pharmaceutical grade) increased by 65% to $10,100 per metric ton from that in 2021, and the average annual unit value of lithium hydroxide imports increased by 141% to $22,800 per metric ton. Argentina and Chile were the principal sources of imported lithium carbonate, and Chile was the principal source of imported lithium hydroxide (table 3).

By yearend 2022, world lithium consumption and the price of lithium increased considerably owing to strong growth from the lithium-ion (Li-ion) battery market. Spot prices for battery-grade lithium carbonate [minimum 99.5% cost, insurance, and freight (c.i.f.) China] increased by 91% during 2022, from an average of $35,000 per metric ton in January to an average of $67,000 per metric ton in December. Spot prices for battery-grade lithium hydroxide [minimum 56.5% free on board (f.o.b.) China] increased by 126% during 2022, from an average of $35,250 per metric ton in January to an average of $79,500 per metric ton in December (Argus Media group, 2024).

World lithium production in 2022 (excluding United States production) was estimated by the U.S. Geological Survey (USGS) to be 146,000 t of lithium content in minerals and compounds (779,000 t of LCE), a 38% increase from 106,000 t (revised) (566,000 t of LCE) in 2021 owing primarily to increased production of mineral-sourced lithium from Australia, brine-sourced lithium from Chile, and mineral- and brine-sourced lithium from China (table 4). World lithium production increased at a compound annual growth rate (CAGR) of 17% from 2012 through 2022 (fig. 1). World lithium consumption in 2022 was estimated by the USGS to be 142,000 t of lithium content in minerals and compounds (756,000 t of LCE), a 46% increase from the 97,000 t of lithium content (516,000 t of LCE) consumed worldwide in 2021. World lithium consumption increased at a CAGR of 18% from 2012 through 2022 (fig. 1).

Government Actions and Legislation

Infrastructure Investment and Jobs Act.—In November 2021, the President signed the $1.2 trillion Infrastructure Investment and Jobs Act, H.R. 3684. In addition to outlining investments for a wide variety of domestic infrastructure projects, the law provides funding to support research and development on critical minerals mining, processing, manufacturing, and recycling (White House, The, 2023, p. 5, 85). According to one analysis, approximately $6 billion was potentially available to support a domestic supply chain for the processing, manufacturing, and recycling of battery materials (Atlas Public Policy, 2021, p. 4–5). In 2022, the U.S. Department of Energy (DOE) awarded $2.8 billion in grants to 20 manufacturing and processing companies for projects across 12 States to expand domestic manufacturing of batteries for electric vehicles and the electrical grid (White House, The, 2022).

Inflation Reduction Act of 2022, H.R. 5376.—In August 2022, the President signed the $370 billion Inflation Reduction Act of 2022, H.R. 5376. The law establishes the largest investment by the U.S. Government in addressing climate change and incentivizing the onshoring of renewable energy production in U.S. history. The law was structured to accelerate private investment in clean energy solutions in all sectors of the U.S. economy, strengthen supply chains for critical minerals, lower energy costs, and create new domestic jobs (White House, The, 2023, p. 5).

The Inflation Reduction Act's clean vehicle-related tax incentives provided tax credits for buyers of new and used electric vehicles (EVs). Beginning in 2023, to qualify for the maximum $7,500 credit, a new vehicle would need to meet certain standards for North American assembly and critical mineral and battery component content. Specifically, final assembly of the vehicle must be conducted in North America; a minimum of 40% of the battery's critical minerals must have been extracted or processed in the United States or in a country with which the United States has a free trade agreement or have been recycled in North America (the 40% amount increases to 50% in 2024, 60% in 2025, 70% in 2026, and 80% in 2027 and thereafter); and a minimum of 50% of the value of the battery's components must have been manufactured or assembled in North America (the 50% amount increases to 60% in 2024 and 2025, 70% in 2026, 80% in 2027, 90% in 2028, and 100% in 2029 and thereafter). Beginning in 2024, an EV cannot qualify for the clean vehicle tax credit if any of the vehicle's battery components were manufactured or assembled by a "foreign entity of concern." Beginning in 2025, an EV cannot qualify for the clean vehicle tax credit if it contains any critical minerals that were extracted, processed, or recycled by a "foreign entity of concern." The Inflation Reduction Act's clean vehicle-related

tax incentives also provide tax credits to help manufacturers retool existing facilities and build new manufacturing in the United States, and to defray up to 30% of the cost of replacing diesel or gas-powered commercial vehicles with EVs (Congressional Research Service, 2022; White House, The 2023, p. 46, 47, 49).

National Defense Stockpile.—The Defense Logistics Agency Strategic Materials (DLA Strategic Materials), U.S. Department of Defense, began to acquire selected lithium battery materials for the National Defense Stockpile (NDS) in 2014. The DLA Strategic Materials' Annual Materials Plan (potential acquisitions) for fiscal years 2022 (October 1, 2021, through September 30, 2022) and 2023 (October 1, 2022, through September 30, 2023), which represented the maximum quantities of materials that could be acquired during the year, did not include any lithium materials (Defense Logistics Agency Strategic Materials, 2021, 2022).

Production

The USGS surveyed Albemarle Corp. (Charlotte, NC) and US Magnesium LLC (Salt Lake City, UT), the two commercial lithium producers in the United States. Production and stock data were withheld from publication to avoid disclosing company proprietary data. Albemarle continued work to expand its Silver Peak, NV, lithium carbonate plant in 2022 with the goal of doubling the current production capacity to 10,000 metric tons per year (t/yr) by 2025. Approximately 50% of Silver Peak's lithium carbonate was consumed domestically to produce glass, lubricants, and other industrial products. The remaining 50% was exported to Asia where it was made into battery cathode materials (Bomgardner, 2021; Albemarle Corp., 2023, p. 43).

In 2022, Albemarle was awarded a nearly $150 million grant from the DOE as part of the initial set of projects funded by the Infrastructure Investment and Jobs Act. The grant was awarded to assist in financing the construction of a new commercial-scale U.S.-based mineral concentrator at Albemarle's facility at Kings Mountain, NC. When complete, it would supply up to 350,000 t/yr of spodumene concentrate (Fischer, 2022).

Albemarle operated a 5,500-t/yr battery-grade lithium hydroxide production facility in Kings Mountain, NC, that used Silver Peak's lithium carbonate as feedstock. Kings Mountain also had facilities for producing lithium salts and battery-grade lithium metal products. Albemarle's other downstream lithium operation in the United States included a plant for producing butyllithium and specialty lithium products in New Johnsonville, TN.

In 2022, US Magnesium LLC continued commercial production of lithium carbonate at its 9,000-t/yr-capacity lithium carbonate plant in Delle, UT (US Magnesium LLC, undated). Lithium chloride was extracted from a stockpile of cell salt residue accumulated over the course of 50 years from the production of magnesium. US Magnesium used technology developed in-house to convert the lithium chloride to lithium carbonate. The cell salt residue was estimated to have a 4% lithium content (Tom Tripp, Director of Technical Services and Development, US Magnesium LLC, oral commun., February 24, 2022).

Livent Corp. (Philadelphia, PA), an independent lithium business that was spun off from FMC Corp. in 2018, produced a range of downstream inorganic lithium compounds, lithium metal, and organic lithium compounds at its facility in Bessemer City, NC. The company sourced its lithium carbonate and lithium chloride from its Salar del Hombre Muerto brine operation in Argentina via its local operating subsidiary Minera del Altiplano. Livent's other global lithium operations included a lithium hydroxide and butyllithium facility in Zhangjiagang, China; a butyllithium-organometallic compound facility in Bromborough, United Kingdom; and a butyllithium-organometallic compound facility in Patancheru, India (Livent Corp., 2023, p. 6–8, 11, 34).

Domestic Li-ion Battery Production and Recycling.—Substantial efforts have been taken in recent years by battery and vehicle manufacturers in the United States to construct new large-scale Li-ion battery factories (gigafactories) or to expand existing facilities. Li-ion battery gigafactories are described as factories with more than 1 gigawatthours per year (GWh/yr) in capacity. A gigawatthour (GWh) is a unit of energy equivalent to the consumption of 1 billion watts for 1 hour. In 2022, the United States had an operational capacity of approximately 110 GWh/yr (estimated by the USGS) and accounted for 6.4% of global operational capacity (Pan American Finance LLLP, 2023, p. 9). In the United States, 6 gigafactories were operational and 23 gigafactories were in the planning or construction stage (Benchmark Mineral Intelligence 2023b, c).

In 2022, Tesla Inc.'s (Austin, TX) "Gigafactory 5" began commercial production of Li-ion battery cells in Austin, TX. Operational capacity was 55 GWh/yr, and an additional 145 GWh/yr of capacity was planned. Tesla's pilot operation in Freemont, CA, had an operational capacity of 10 GWh/yr (Benchmark Mineral Intelligence, 2023b).

In 2022, production capacity of LG Chem Ltd.'s (Seoul, Republic of Korea) Li-ion battery cell plant in Holland, MI, was 10 GWh/yr to accommodate production of General Motors Co.'s (GM's) (Detroit, MI) EVs. An additional 15 GWh/yr of production capacity had been planned (Benchmark Mineral Intelligence, 2023a). GM and LG Chem's joint-venture company, Ultium Cells LLC, began commercial production at its 9-GWh/yr-Li-ion battery cell facility in Lordstown, OH, in 2022. An additional 31 GWh/yr of production capacity had been planned (General Motors Co., 2020; Benchmark Mineral Intelligence, 2023b).

In 2022, Envision AESC (Kanagawa, Japan) manufactured 3 GWh/yr of Li-ion battery cells at its production facility in Smyrna, TN. An additional 7 GWh/yr battery capacity expansion had been planned (Benchmark Mineral Intelligence, 2023b).

In 2022, South Korean energy company SK Innovation Co., Ltd. (Seoul, Republic of Korea) began commercial production at the first of two Li-ion battery plants in Commerce, GA, which was to supply automakers Ford and Volkswagen. Li-ion cell capacity of the first battery plant was 9.8 GWh/yr. Li-ion cell capacity of the second battery plant was planned to be 10.1 GWh/yr (Kane, 2020; Benchmark Mineral Intelligence, 2023b).

The pace of construction of Li-ion battery recycling plants increased considerably in 2022. Approximately 47 companies

in Canada and the United States recycled Li-ion and primary lithium batteries or planned to do so. The 47 companies owned a total of 64 individual recycling facilities, of which 56 were in the United States and 8 were in Canada (U.S. Department of Energy, National Renewable Energy Laboratory, 2023). Automobile companies have increasingly been partnering with battery recyclers to supply the automobile industry with an additional source of battery materials. Cirba Solutions (previously Retriev Technologies Inc.) was reported to be the first company to construct a U.S. facility dedicated to recycling Li-ion batteries for EVs. The facility began operations in Lancaster, OH, in 2015 (Retriev Technologies Inc., 2017, p. 8).

Consumption

In 2022, the global markets for lithium products were estimated to be batteries, 83%; ceramics and glass, 6%; lubricating greases, 3%; continuous casting mold flux powders, 2%; air treatment, 1%; medical, 1%; and other uses, 4% (Benchmark Mineral Intelligence, 2023a). Other uses may have included agrochemicals, airbag ignition, aluminum alloys, carbon dioxide absorption media, cement and concrete additives, dyes and pigments, industrial catalysts, organic synthesis agents, pharmaceuticals, and scintillation counters (Albemarle Corp., undated c).

In 2022, EVs, hybrid-electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs) accounted for 81% of global Li-ion battery consumption as measured in GWh. Portable applications (electric bicycles, motorcycles, scooters, smartphones, consumer electronics, laptop and tablet computers, and power tools) accounted for 10% of Li-ion battery consumption. Grid storage accounted for the remaining 9% (Benchmark Mineral Intelligence, 2023b).

In 2022, battery manufacturers were either active, ramping up, or planning to construct about 1,700 GWh/yr of global production capacity for large EV-sized Li-ion battery cells (Benchmark Mineral Intelligence, 2023c). China accounted for 77.9% of capacity; the United States, 6.4%; the Republic of Korea, 4.5%; Japan, 2.3%; Hungary, 2.2%; and the rest of the world, 6.7% (Pan American Finance LLLP, 2023, p. 9).

Prices

Average annual customs unit values for U.S. imports of lithium carbonate and lithium hydroxide were used as indicators of the trends in lithium pricing; producer prices were not available for lithium carbonate or lithium hydroxide. In 2022, the average annual customs unit value for imported lithium carbonate (including pharmaceutical grade) was $10,100 per metric ton, an increase of 65% from that in 2021 (table 3). The average annual customs unit value for imported lithium hydroxide was $22,800 per metric ton, an increase of 141% from that in 2021. The average annual customs unit value of exported lithium carbonate (including pharmaceutical grade) in 2022 was $7,310 per metric ton, an increase of 31% from that in 2021 (table 2). The average annual customs unit value of exported lithium hydroxide was $31,300 per metric ton, an increase of 167% from that in 2021. In 2022, the average annual customs unit value of exported lithium carbonate was 28% less than that of imported lithium carbonate, and the average annual customs unit value of exported lithium hydroxide was 37% higher than that of imported material. This suggests that domestic lithium hydroxide exports were of a higher quality than imports. Import values mostly reflect companies importing their own materials at cost for further processing.

At yearend 2022, Benchmark Mineral Intelligence (2023d) reported that the U.S. market price for lithium carbonate (c.i.f. North America, ≥99.0%) was $70.00 per kilogram. The price for lithium hydroxide (f.o.b. North America, ≥55.0%) was $71.50 per kilogram. Spodumene concentrate (f.o.b. Australia, 6% lithium oxide) was $6.00 per kilogram. The spot price for lithium carbonate in China averaged $76.00 per kilogram in December 2022. The spot price for lithium hydroxide in China averaged $81.50 per kilogram in December.

Foreign Trade

In 2022, total exports of lithium compounds, by lithium content, from the United States increased by 31% compared with those in 2021 (table 2). The leading destinations of all United States exports of lithium compounds were Japan (49%), Germany (14%), China (11%), and Poland (10%). Lithium hydroxide accounted for 70% of the total lithium exports in 2022, and lithium carbonate accounted for the remaining 30%. Exports of lithium carbonate increased by 39% in 2022 compared with those in 2021, and exports of lithium hydroxide increased by 31%.

Imports of lithium compounds, by lithium content, into the United States increased by 24% in 2022 compared with those in 2021 (table 3). About 54% came from Chile, 44% from Argentina, and 1% from the United Kingdom. Lithium carbonate accounted for 92% of the total lithium imports in 2022, and lithium hydroxide accounted for the remaining 8%.

World Industry Structure

Albemarle's global lithium operations included spodumene extraction operations in Shire of Bridgetown-Greenbushes, Western Australia, Australia, and the Wodgina lithium project in the Pilbara region of Western Australia, Australia; the Kemerton lithium carbonate and lithium hydroxide plant near Bunbury, Western Australia, Australia; a brine extraction operation in Chile's Salar de Atacama; lithium carbonate and lithium chloride plants in La Negra, Chile; lithium carbonate and lithium hydroxide plants in Chengdu, Qinzhou, and Xinyu, China; a butyllithium, lithium chloride, and specialty chemical and metal plant in Langelsheim, Germany; and a butyllithium plant in Taichung, Taiwan (Albemarle Corp., 2023, p. 26; undated a).

Albemarle owned a 49% interest in Australia's Talison Lithium Pty Ltd. (a subsidiary of Sichuan Tianqi Lithium and Albemarle). Talison owned the Greenbushes Mine in Western Australia, Australia, a hard rock operation with a 1,340,000-t/yr spodumene-concentrate production capacity (178,000 t/yr of LCE). Sichuan Tianqi Lithium Industries, Inc., a subsidiary of Chengdu Tianqi (Group) Co., Ltd. (China), owned the remaining interest in Talison (Albemarle Corp., 2023, p. 28, 33; Talison Lithium Pty Ltd., undated).

Albemarle owned a 60% interest in Australia's MARBL Lithium Joint Venture. MARBL owned the Wodgina Mine in Western Australia, Australia, a hard rock operation with a 750,000-t/yr spodumene-concentrate production capacity (110,000 t/yr of LCE). Mineral Resources Ltd. (Australia) owned the remaining interest in MARBL. The Wodgina Mine began spodumene concentrate production in 2022 after it had been idled following its acquisition in 2019 (Albemarle Corp., 2023, p. 28, 36).

Albemarle owned a 60% interest in the Kemerton lithium carbonate and lithium hydroxide processing plant near Bunbury, Western Australia, Australia. Mineral Resources owned the remaining interest in the plant. Construction was completed in 2022. The Kemerton plant had the capacity to process nearly 1 million t/yr of spodumene concentrate from Talison's Greenbushes Mine (Albemarle Corp., 2023, p. 129; undated b).

In 2022, Livent produced 16,950 t of lithium carbonate in Argentina, which was converted to 21,493 t of lithium hydroxide in China and the United States. The company also produced 4,750 t of lithium chloride in Argentina, which was converted to 2,520 t of butyllithium in China, India, the United Kingdom, and the United States and 88 t of high-purity lithium metal in the United States. Livent's lithium carbonate and lithium chloride production capacities were 18,000 t/yr and 9,000 t/yr, respectively. The company's lithium hydroxide production capacity in China and the United States increased to 30,000 t/yr in 2022 from 25,000 t/yr in 2021. Livent's butyllithium production capacity was 3,265 t/yr, and its high-purity lithium metal production capacity was 250 t/yr (Livent Corp., 2023, p. 8).

Owing to increased lithium consumption and higher lithium prices in 2021 and 2022, Livent resumed lithium carbonate and lithium hydroxide expansion projects that were paused in 2020. A 20,000-t/yr expansion of lithium carbonate production capacity in Argentina was expected to come online in two phases during 2023 and 2024. Engineering work began on a second expansion to add 30,000 t/yr of lithium carbonate production capacity. Upon completion, Livent was expected to have a total of 70,000 t/yr of lithium carbonate production capacity in Argentina. In 2022, construction began for an additional 15,000 t/yr of lithium hydroxide production capacity in China (Livent Corp., 2023, p. 6).

Lithium historically has been mined from two distinct sources—continental brines and hard-rock minerals. In Chile, lithium was recovered from two brine operations on the Salar de Atacama in the Andes Mountains. Concentrated brines were transported to Antofagasta, on the coast of Chile, and processed at two lithium carbonate plants, one lithium chloride plant, and one lithium hydroxide plant. In the Andes Mountains in Argentina, lithium carbonate and lithium chloride were produced from brines from the Salar del Hombre Muerto, and lithium carbonate was produced from brines from the Salar de Olaroz. A substantial percentage of the lithium carbonate produced in South America was exported to the United States. Australia was, by far, the leading producer of lithium mineral concentrates. Brazil, China, Portugal, and Zimbabwe also produced significant quantities of lithium concentrates, most of which were used directly in the production of ceramics and glass. China produced large quantities of lithium carbonate and lithium hydroxide from mineral concentrates, mostly from spodumene imported from Australia. In China, lithium carbonate also was produced from brines from the Zabayu Salt Lake in western Tibet Autonomous Region and from the Dongtai and Xitai Salt Lakes in Qinghai Province.

Worldwide lithium resource exploration has increased significantly in recent years. Exploration in the United States has focused on the continental brine and clay resources of Nevada, the geothermal brines of California, the oilfield brines of Arkansas, the spodumene resources of North Carolina, and the lithium-rich boron and magnesium waste residues in California and Utah, respectively. In recent years, considerable lithium exploration also has taken place in Argentina, Australia, Bolivia, Canada, Chile, China, Mali, Mexico, Zimbabwe, and many other countries in Africa and Europe.

Lithium was sold as brines, compounds, metal, and mineral concentrates depending on the end use. Lithium's low atomic mass, low coefficient of thermal expansion, high electrochemical reactivity, and other unique properties resulted in many commercial lithium products. Lithium's properties make it one of the most attractive battery materials of all the elements. Worldwide, Li-ion batteries powered most electric bicycles, motorcycles, and scooters; most cellular telephones, laptop computers, and tablets; and most power tools. Automakers and battery makers were manufacturing and improving Li-ion batteries for EVs, HEVs, and PHEVs. Li-ion batteries also were used in electrical grid storage applications.

World Review

World lithium production in 2022 (excluding United States production) was estimated by the USGS to be 146,000 t of lithium content in minerals and compounds (779,000 t of LCE), a 38% increase from the 106,000 t (revised) (566,000 t of LCE) in 2021 owing primarily to increased production of mineral-sourced lithium from Australia, brine-sourced lithium from Chile, and mineral- and brine-sourced lithium from China (table 4). The leading producing country was Australia, where production in terms of lithium content was 97% more than that of Chile, the second-ranked producing country. China was the third-ranked lithium-producing country. Production figures for lithium carbonate, lithium chloride, lithium hydroxide, and lithium mineral concentrates in table 4 are reported in gross weight, lithium content, and LCE.

Argentina, Chile, China, and the United States were the leading producers of brine-based lithium carbonate. Australia, Brazil, Canada, China, Portugal, and Zimbabwe were the leading producers of lithium minerals. The United States produced lithium carbonate from a continental lithium brine operation, brine-sourced magnesium waste tailings, and pilot-plant lithium carbonate production from boron waste tailings. Additional brine deposits were being explored or were under development in Argentina, Bolivia, Canada, Chile, China, and the United States. New pegmatite mines were under consideration or in development in Australia, Austria, Brazil, Canada, China, Congo (Kinshasa), Czechia, Ethiopia, France, Finland, Germany, Ghana, India, Iran, Kazakhstan, Mali, Namibia, Nigeria, Peru, Portugal, Russia, Rwanda,

Spain, Sweden, Thailand, Turkey, the United Kingdom, the United States, and Zimbabwe. A jadarite mine was under consideration in Serbia. Lithium-bearing clay mines were in various stages of development or exploration in Mexico and the United States. Continental brine-sourced, geothermal, and oilfield-based direct lithium extraction operations were in various stages of development or exploration in many countries in Asia, Europe, North America, and South America, with Germany and the United States estimated by the USGS to have some advanced operations. Pegmatites containing lithium minerals also have been identified in Afghanistan and Mozambique but have not been developed. Lithium also has been identified in subsurface brines in Afghanistan and Israel. Companies in China, France, Germany, Japan, the Republic of Korea, Russia, Taiwan, the United Kingdom, and the United States produced downstream lithium compounds from imported lithium carbonate, lithium chloride, and lithium hydroxide.

In 2022, global lithium consumption for air treatment, batteries, medical, metallurgical powders, and other industrial applications increased from that in 2021. Glass, ceramics, and lubricants applications decreased (Benchmark Mineral Intelligence, 2023a). The USGS estimated that 142,000 t of lithium content in minerals and compounds (756,000 t of LCE) was consumed worldwide in 2022, a 46% increase from the estimated consumption of 97,000 t (516,000 t of LCE) in 2021. For lithium minerals and compounds consumed solely in battery applications in 2022, China was the leading consumer, accounting for 53% of worldwide consumption; Europe consumed 22%; North America, 16%; Asia other than China, 7%; and other, 2% (Benchmark Mineral Intelligence, 2023a). According to USGS estimates, total global lithium consumption increased at a CAGR of 18% from 2012 through 2022 (fig. 1).

Argentina.—Production of lithium carbonate in 2022 was reported to be 30,909 t, an increase of 8% from that in 2021, and production of lithium chloride was 4,750 t, an increase of 28% (table 4). Livent produced 16,950 t of lithium carbonate and 4,750 t of lithium chloride at its 26,000-t/yr LCE facility, which had been operating since 1998, on the Salar de Hombre Muerto in Catamarca Province (Livent Corp., 2023, p. 7, 8). In 2022, Allkem Ltd. (a new company formed in 2021 from the merger of Orocobre Ltd. and Australia's Galaxy Resources Ltd.) produced 13,959 t of lithium carbonate at its Olaroz Lithium Project at the Salar de Olaroz in northwestern Argentina. Production capacity was 17,500 t/yr of battery-grade lithium carbonate. Allkem planned to increase lithium carbonate production capacity to 42,500 t/yr by 2024 (Allkem Ltd., 2022b; 2023a, p. 10–11).

Lithium Americas Corp. and Ganfeng Lithium Co. Ltd., co-owners of the Argentine joint-venture company, Minera Exar S.A., completed substantial construction of stage 1 of the Cauchari-Olaroz lithium project on the Puna Plateau in northwestern Argentina. Minera Exar planned the stage 1 production capacity to reach 40,000 t/yr of LCE, with commissioning expected in mid-2023. Minera Exar also was planning for a stage 2 expansion of an additional 20,000 t/yr of LCE production capacity, with construction expected to commence following the completion of stage 1 (Lithium Americas Corp., 2023, p. 3).

Approximately 40 lithium projects by additional companies were in various stages of development and construction in Argentina. Six junior operations had begun construction, five junior operations had completed either prefeasibility or definitive feasibility studies, and five junior operations had completed preliminary economic assessments (Ministerio de Economia Argentina, 2023, p. 4).

Australia.—In 2022, the government of Western Australia reported total spodumene concentrate production of 2.684 million metric tons (Mt), an increase of 35% from its production of 1.986 Mt in 2021 (Government of Western Australia, Department of Mines, Industry Regulation and Safety, 2023). Spodumene concentrate production in 2022 was equivalent to 74,723 t of lithium content (397,748 t of LCE). Talison produced 37,535 t of lithium content (200,000 t of LCE) from its Greenbushes spodumene deposit in Western Australia, an increase of 69% from its production of 22,169 t of lithium content in 2021 (Australian Government, Department of Industry, Science, Energy, and Resources, 2021a, p. 144; 2021b, p. 151; 2022a, p. 150; 2022b, p. 152; 2022c, p. 170; 2022d, p. 160; 2023, p. 154). Talison reported its 2022 lithium concentrate production capacity was 1,340,000 t/yr (178,000 t/yr of LCE). Production capacity was expected to increase in 2023 with the addition of a new lithium-processing plant (Talison Lithium Pty Ltd., undated).

In 2022, MARBL Lithium Joint Venture [owned by Albemarle (60%) and Mineral Resources Ltd. (40%)] began spodumene concentrate production at its Wodgina Mine in Pilbara, Western Australia. The mine had been idle since 2019. Wodgina's spodumene resource was reported to be 259 Mt, grading 1.17% lithium oxide; the operation had a lithium recovery rate of 65% (Mineral Resources Ltd., 2019, p. 14; Albemarle Corp., 2023, p. 28, 36).

In 2022, Albemarle and Mineral Resources' Kemerton mineral conversion plant in Kemerton, Western Australia, completed construction. The plant was designed to convert spodumene from Talison's Greenbushes Mine and MARBL's Wodgina Mine into lithium carbonate and lithium hydroxide. The Kemerton plant had an initial spodumene concentrate processing capacity of 1,000,000 t/yr (Albemarle Corp., 2023, p. 26, 33; undated b).

Pilbara Minerals Ltd.'s Pilgangoora lithium-tantalum project in Western Australia's Pilbara region was Western Australia's second-ranked spodumene producer after Talison. In 2022, the Pilgangoora Project produced 14,423 t of lithium content (76,780 t of LCE), an increase of 59% from its production of 9,054 t of lithium content in 2021. Pilbara's spodumene resource was reported to be 223 Mt, grading 1.27% lithium oxide (Australian Government, Department of Industry, Science, Energy, and Resources, 2021a, p. 143; 2021b, p. 150; 2022a, p. 150; 2022b, p. 151; 2022c, p. 169; 2022d, p. 160; 2023, p. 155; Roskill Information Services Ltd., 2021, p. 9).

In 2022, the Mt Marion lithium project, a joint venture between Mineral Resources and Jiangxi Ganfeng Lithium Co., Ltd., produced 12,834 t of lithium content (68,320 t of LCE), an increase of 7% from its production of 11,971 t of lithium content

in 2021 (Australian Government, Department of Industry, Science, Energy, and Resources, 2021a, p. 144; 2021b, p. 151; 2022a, p. 151; 2022b, p. 152; 2022c, p. 170; 2022d, p. 161; 2023, p. 155).

In 2022, Allkem produced 2,990 t of lithium content (15,920 t of LCE) at its Mt Cattlin operation near Ravensthorpe, Western Australia, a decrease of 53% from its production of 6,405 t of lithium content in 2021. Mt Cattlin's spodumene ore reserves were reported to be 8.2 Mt, grading 1.29% lithium oxide (Roskill Information Services Ltd., 2021, p. 9; Allkem Ltd., 2022a, b, c, d, 2023b).

Chile.—In 2022, the Government of Chile reported production of 201,950 t of lithium carbonate, an increase of 34% from that in 2021; 15,763 t of lithium hydroxide, an increase of 30%; and no production of lithium chloride. The Government of Chile also began providing data for lithium sulfate, with reported production of 85,528 t (Servicio Nacional de Geología y Minería, 2023, p. 74–76). Sociedad Química y Minera de Chile S.A. (SQM) produced 153,000 t of lithium carbonate and 15,763 t of lithium hydroxide. The company sold 156,800 t of LCE in 2022, a 55% increase from that in 2021. SQM's value of sales increased nearly ninefold to $8,153 million in 2022 from $936 million in 2021 owing to much higher lithium prices. In 2022, 93% of the company's lithium products, by sales value, went to Asia and other locations, 5% to Europe, and 2% to North America. SQM's lithium was recovered from its brine operation at the Salar de Atacama and processed into lithium carbonate and lithium hydroxide in Antofagasta. Owing to increasing demand for lithium carbonate and lithium hydroxide from EV battery manufacturers, SQM increased its Chilean lithium carbonate and lithium hydroxide production capacities to 180,000 t/yr and 30,000 t/yr, respectively, in 2021. SQM planned for further lithium carbonate and lithium hydroxide capacity expansions to 210,000 t/yr and 40,000 t/yr, respectively, in 2023 (Sociedad Química y Minera de Chile S.A., 2022, p. 4; 2023, p. 81–82, 115).

In 2022, Albemarle reported production of 53,000 t of lithium carbonate in Chile. Construction of its third La Negra lithium carbonate conversion plant was completed in 2022, increasing Albemarle's total lithium carbonate and lithium chloride production capacity in Chile to 80,000 t/yr of LCE, almost double the 44,000 t/yr of LCE production capacity in 2021. Albemarle used lithium carbonate and lithium chloride from its operations in Chile as feedstock for some of its downstream chemical production in Germany, Taiwan, and the United States (Lazzaro, 2022; Albemarle Corp., 2023, p. 26, 29).

China.—China produced large quantities of lithium carbonate and lithium hydroxide from domestic brine sources and domestic and imported mineral concentrates. In 2022, Benchmark Mineral Intelligence reported that China produced approximately 120,000 t of LCE from domestic sources, a 60% increase from 2021 production of 75,000 t owing to increases in brine-sourced output and mineral-sourced mining capacity. China ranked third in global lithium production, after Australia and Chile. Ten Chinese lithium brine operations, seven lepidolite mines, and four spodumene mines were in operation in 2022. Brine-sourced lithium accounted for 55% of China's domestic lithium production, lepidolite-sourced lithium accounted for 32%, and spodumene-sourced lithium accounted for 13% (Benchmark Mineral Intelligence, 2023a). Most of China's lepidolite and spodumene production was in Jiangxi and Sichuan Provinces, although some also took place in Hunan Province and Xinjiang Uyghur Autonomous Region. China's brine was extracted in the Qinghai Province and Tibet Autonomous Region (Roskill Information Services Ltd., 2020, p. 225–231; 2021, p. 9).

The substantial expansion of China's mineral-based lithium carbonate, lithium chloride, and lithium hydroxide production facilities in recent years has significantly affected the global lithium supply chain and enabled mineral-sourced lithium, the majority of which was mined by Australia, to account for the majority of production in 2022. China was the world's leading producer of refined lithium chemicals. According to Benchmark Mineral Intelligence (2023a), China produced 216,000 t of lithium carbonate in 2022; of that total, spodumene was the feedstock for 139,500 t of lithium carbonate, brine was the feedstock for 47,500 t, and lepidolite was the feedstock for 29,000 t. China produced 12,500 t of lithium chloride; of that total, spodumene was the feedstock for 12,000 t of lithium carbonate, and brine was the feedstock for 500 t. Additionally, China produced 169,060 t of lithium hydroxide; of that total, spodumene was the feedstock for 157,060 t, and lithium carbonate was the feedstock for the remaining 12,000 t.

Outlook

Lithium supply security has become a top priority for vehicle and technology companies worldwide. Strategic alliances and joint ventures continue to be established with commercial lithium companies and lithium exploration companies worldwide to ensure reliable, diversified supplies of lithium for battery and vehicle manufacturers.

In anticipation of robust EV battery demand, vigorous efforts are underway by battery companies worldwide to construct new large-scale Li-ion battery factories (gigafactories) or to expand existing facilities. At the end of 2022, Benchmark Mineral Intelligence (2023c) reported that gigafactories with a combined battery capacity of approximately 1,700 GWh/yr either were active, ramping up, or being planned for construction throughout Asia, Europe, and North America. By 2031, battery capacity is expected to increase to 8,000 GWh/yr, with China accounting for 68% of the world's Li-ion battery production capacity, Europe accounting for 15%, North America accounting for 13%, and the rest of the world (mostly Asia excluding China) accounting for the remainder.

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TABLE 1
SALIENT LITHIUM STATISTICS[1]

(Metric tons, lithium content)

	2018	2019	2020	2021	2022
United States:					
Production	W	W	W	W	W
Exports[2]	1,660	1,660	1,200	1,870	2,440
Imports[2]	3,420	2,620	2,460	2,640	3,270
Consumption[e, 3]	3,000	2,000	2,000	2,000	3,000
Rest of world, production[4, 5]	91,800	84,400	82,700	106,000 [r]	146,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through July 21, 2023. Data are rounded to no more than three significant digits.
[2]Compounds. Source: U.S. Census Bureau.
[3]Rounded to one significant digit to avoid disclosing company proprietary data.
[4]Lithium content of mineral concentrate, lithium carbonate, and lithium chloride.
[5]May include estimated data.

TABLE 2
U.S. EXPORTS OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY OR LOCALITY[1]

Compound and country or locality	2021 Gross weight (metric tons)	2021 Value[2] (thousands)	2022 Gross weight (metric tons)	2022 Value[2] (thousands)
Lithium carbonate:				
Belgium	4	$14	5	$19
Canada	55	261	444	2,050
Chile	9	32	7	25
China	5	16	1	5
Colombia	41	149	6	23
France	18	263	--	--
Germany	700	4,940	1,430	9,940
India	385	2,060	--	--
Israel	--	--	27	96
Japan	304	1,820	1,610	12,200
Russia	1,050	3,980	190	1,130
Taiwan	72	260	81	292
United Kingdom	2	6	14	50
Other	15 r	54 r	1	3
Total	2,660	13,900	3,820	25,800
Total Li content	500	XX	719	XX
Lithium carbonate, U.S.P.:[3]				
Argentina	6	39	--	--
Australia	--	--	8	378
Belgium	62	536	--	--
China	19	315	25	451
India	6	227	34	1,530
Mexico	55	542	4	61
Netherlands	5	43	3	94
Other	(4)	73	3	180
Total	153	1,770	78	2,700
Total Li content	29	XX	15	XX
Lithium hydroxide:				
Argentina	125	1,370	286	2,980
Australia	192	2,080	15	356
Belgium	778	8,300	139	5,200
Canada	305	1,920	337	5,460
Chile	6	102	(4)	21
China	(4)	15	1,400	22,000
Colombia	1	21	9	314
Ecuador	4	34	(4)	50
Egypt	44	370	--	--
Germany	767	9,250	369	6,830
India	--	--	16	375
Italy	--	--	5	768
Japan	4,830	55,300	4,680	134,000
Korea, Republic of	628	7,090	1,050	18,500
Lithuania	--	--	9	150
Mexico	4	71	6	359
Netherlands	1	124	283	3,510
Poland	(4)	25	1,330	99,800
Saudi Arabia	144	981	--	--
Singapore	81	951	206	7,800
Taiwan	59	732	40	3,020
Thailand	80	863	101	6,410
United Kingdom	52	3,740	41	4,550
Other	19 r	1,620 r	6	1,100
Total	8,120	95,000	10,300	324,000
Total Li content	1,340	XX	1,710	XX

rRevised. XX Not applicable. -- Zero.
[1]Table includes data available through July 21, 2023. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Free alongside ship values.
[3]Pharmaceutical-grade lithium carbonate.
[4]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY OR LOCALITY[1]

Compound and country or locality	2021 Gross weight (metric tons)	2021 Value[2] (thousands)	2022 Gross weight (metric tons)	2022 Value[2] (thousands)
Lithium carbonate:				
Argentina	6,280	$34,200	7,680	$51,400
Belgium	36	223	--	--
Chile	5,800	39,500	8,070	108,000
China	88	938	18	276
India	10	131	3	51
Japan	20	148	9	82
Netherlands	10	68	128	1,610
United Kingdom	17	231	114	1,420
Other	(3)	12	(3)	47
Total	12,300	75,500	16,000	163,000
Total Li content	2,310	XX	3,010	XX
Lithium carbonate, U.S.P.,[4] India	(3)	5	12	50
Lithium carbonate, U.S.P.,[4] India, Li content	(3)	XX	2	XX
Lithium hydroxide:				
Chile	1,650	15,200	1,300	32,400
China	35	279	66	518
Germany	39	219	72	409
Japan	12	65	--	--
Russia	238	2,980	43	993
United Kingdom	1	33	28	167
Other	4	60	2	34
Total	1,980	18,800	1,510	34,500
Total Li content	329	XX	251	XX

XX Not applicable. -- Zero.
[1]Table includes data available through July 21, 2023. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Customs value.
[3]Less than ½ unit.
[4]Pharmaceutical-grade lithium carbonate.

Source: U.S. Census Bureau.

TABLE 4
LITHIUM MINERALS AND BRINE: WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Metric tons)

Country or locality[2]	2018			2019			2020			2021			2022		
	Gross weight	Lithium content[3]	LCE[3, 4]	Gross weight	Lithium content[3]	LCE[3, 4]	Gross weight	Lithium content[3]	LCE[3, 4]	Gross weight	Lithium content[3]	LCE[3, 4]	Gross weight	Lithium content[3]	LCE[3, 4]
Argentina, subsurface brine:															
Lithium carbonate	29,707	5,585	29,707	29,994	5,639	29,994	26,911	5,059	26,911	28,520	5,362	28,520	30,909	5,811	30,909
Lithium chloride	5,005	816	4,343	4,284	698	3,717	4,836	788	4,196	3,723	607	3,230	4,750	774	4,121
Australia, spodumene	1,965,910	54,731	291,333	1,587,980	44,209	235,326	1,427,380	39,738	211,527	1,985,670	55,281	294,261	2,684,000	74,723	397,748
Brazil, concentrate	41,000	1,141	6,076	33,700	938	4,994	57,500	1,601	8,521	60,000 e	1,670 e	8,890 r, e	94,500 e	2,630 e	14,000 e
Canada, spodumene	114,000	2,433	12,952	9,000	192	1,023	--	--	--	--	--	--	18,500 e	515 e	2,740 e
Chile, subsurface brine:															
Lithium carbonate	87,029	16,361	87,029	100,787	18,948	100,787	114,260	21,481	114,260	150,348	28,265	150,348	201,950	37,967	201,950
Lithium chloride	3,826	624	3,320	1,886	307	1,636	--	--	--	--	--	--	--	--	--
Lithium hydroxide[5]	6,468	1,067	5,681	9,934	1,639	8,725	9,030	1,490	7,931	12,129	2,001	10,653	15,763	2,601	13,845
China, lithium carbonate equivalent[6]	37,800	7,106	37,800	57,500	10,810	57,500	70,600	13,273	70,600	75,000 e	14,100 e	75,000 e	120,000 e	22,600 e	120,000 e
Namibia, lepidolite	30,000	258	1,373	--	--	--	--	--	--	--	--	--	--	--	--
Portugal, lepidolite	76,818	1,152	6,134	59,912	899	4,784	23,185	348	1,851	18,533 r	278 r	1,480 r	25,000 e	375 e	2,000 e
United States, lithium carbonate	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Zimbabwe, petalite, lepidolite	80,000	1,600	8,517	60,400 e	1,210 r, e	6,430 e	20,859	417	2,221	35,500 e	710 e	3,780 r, e	51,600 e	1,030 e	5,490 e
Total[7]	2,470,000	91,800	489,000	1,950,000	84,400 r	446,000	1,750,000	82,700	440,000	2,360,000 r	106,000 r	566,000 r	3,230,000	146,000	779,000

eEstimated. rRevised. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Table includes data available through July 18, 2023. All data are reported unless otherwise noted; totals may include estimated data. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]In addition to the countries and (or) localities listed, other nations may have produced small quantities of lithium minerals, but available information was inadequate to make reliable estimates of output.

[3]Calculated from data reported in gross weight.

[4]Lithium carbonate equivalent.

[5]Brine-sourced lithium hydroxide is produced from lithium carbonate, and therefore not included in world production total to avoid double counting.

[6]Produced from subsurface brine and domestic concentrates.

[7]Excludes U.S. production.

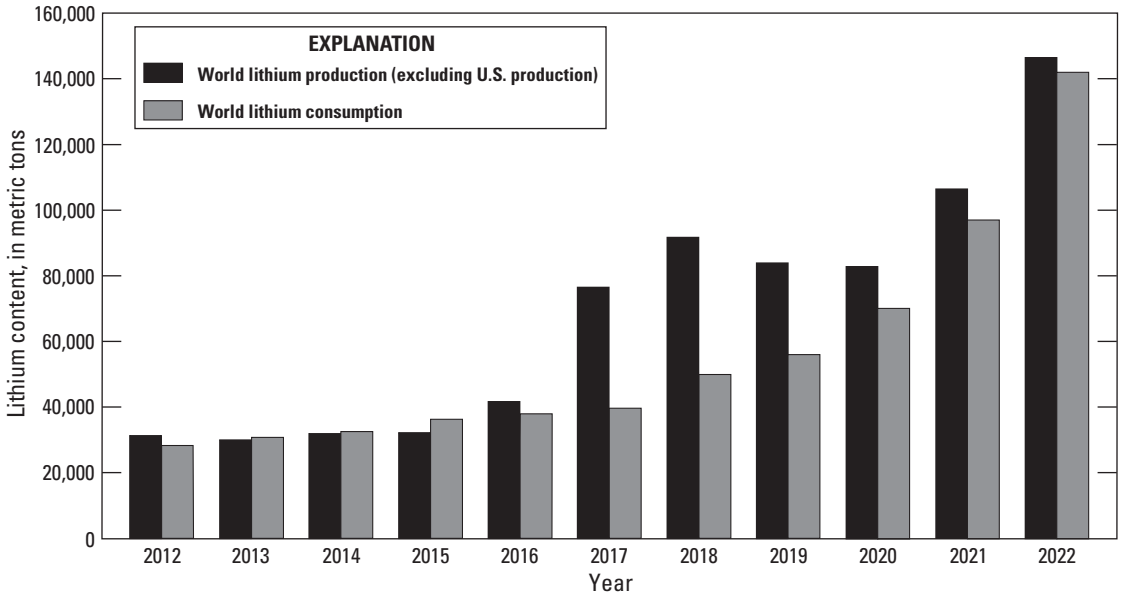

Figure 1. Estimated world lithium production (excluding U.S. production) and consumption from 2012 through 2022. Production data estimated by the U.S. Geological Survey (USGS). Consumption data estimated by Roskill Information Services Ltd. and the USGS.