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LITHIUM [ADVANCE RELEASE]

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Lithium

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In the United States, one continental brine lithium operation with an associated lithium carbonate plant operated in Silver Peak, NV. Lithium carbonate also began to be 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 2021, lithium consumption in the United States was estimated to be equivalent to 2,000 metric tons (t) of elemental lithium content (table 1) [11,000 t of lithium carbonate equivalent (LCE)], primarily for lithium-based batteries, ceramics and glass, grease, pharmaceuticals, and polymer products. In 2021, the gross weight of lithium compounds imported into the United States increased by 8% and the gross weight of lithium compounds exported increased by 54% from those in 2020 (tables 2, 3). The average annual unit value of lithium carbonate imports (including pharmaceutical grade) decreased by 4% from that in 2020, and the average annual unit value of lithium hydroxide imports increased by 3%. Argentina and Chile were the principal sources of imported lithium carbonate, and Chile and Russia were the principal sources of imported lithium hydroxide (table 3).

By yearend 2021, 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 in China increased by nearly 400% during the year, from an average of $8,150 per metric ton in December 2020 to an average of $39,250 per metric ton in December 2021 (Asian Metal Corp., 2021, p. 11; Benchmark Mineral Intelligence, 2022e, p. 4).

World lithium production in 2021 (excluding United States production) was estimated by the U.S. Geological Survey (USGS) to be 107,000 t of lithium content in minerals and compounds (569,000 t of LCE), a 29% increase from 82,700 t (revised) (440,000 t of LCE) in 2020 owing primarily to increased production of mineral-sourced lithium from Australia and brine-sourced lithium from Chile (table 4). World lithium production increased at a compound annual growth rate (CAGR) of 14% per year from 2011 through 2021 (fig. 1). World lithium consumption in 2021 was estimated by the USGS to be 97,000 t of lithium content (516,000 t of LCE) in minerals and compounds, a 39% increase from that in 2020. World lithium consumption increased at a CAGR of 14% per year from 2011 through 2021 (fig. 1).

Government Actions and Legislation

Executive Order 14017.—In February 2021, the President signed Executive Order 14017, "America's Supply Chains," which directed the U.S. Government to undertake a comprehensive review of critical U.S. supply chains to identify risks, address vulnerabilities, and develop a strategy to promote resilience. Large capacity batteries were one of the four critical products identified. Key areas of focus were to ensure a sustainable critical material supply and processing capacity, expand domestic battery production, and support electric vehicle (EV) and storage adoption (White House, The, 2021, p. 6, 9).

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 provided funding to support research and development on critical minerals mining, processing, manufacturing, and recycling. According to one analysis, approximately $6 billion was potentially available to programs to support a domestic supply chain for the processing, manufacturing, and recycling of battery materials (Atlas Public Policy, 2021, p. 4–5).

National Defense Stockpile.—In 2014, 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). The DLA Strategic Materials' Annual Materials Plan (potential acquisitions) for fiscal year 2021 (October 1, 2020, through September 30, 2021), which represented the maximum quantities of materials that could be acquired during the year, did not include any lithium materials. The Annual Materials Plan (potential acquisitions) for fiscal year 2022 (October 1, 2021, through September 30, 2022) did not include any lithium materials (Defense Logistics Agency Strategic Materials, 2020, 2021).

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 announced that the production capacity of its 5,000-metric-ton-per-year (t/yr) lithium carbonate plant in Silver Peak, NV, was expected to expand to 10,000 t/yr by 2025. About 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 (Albemarle Corp., 2020, p. 12; 2022b, p. 38; Bomgardner, 2021).

Albemarle operated a 5,000-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. Albemarle's global lithium operations were 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 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., 2022b, p. 23–24).

Albemarle owned a 49% interest in Australia's Talison Lithium Pty Ltd (a subsidiary of Sichuan Tianqi Lithium and Albemarle), a spodumene producer with a production capacity of 178,000-t/yr of LCE (Talison Lithium Pty Ltd, 2022). Sichuan Tianqi Lithium Industries, Inc., a subsidiary of Chengdu Tianqi (Group) Co., Ltd. (China), owned the remaining interest in Talison. Albemarle's other lithium operations in Australia included a spodumene mine in Wodgina, Western Australia, and a plant for producing lithium carbonate and lithium hydroxide in Kemerton, Western Australia, that was under construction (Albemarle Corp., 2022b, p. 25). Albemarle's global lithium chemical production capacity was expected to total 175,000 t/yr by the first quarter of 2022 (Norris, 2021, p. 55).

In 2019, US Magnesium LLC began construction of a 10,000-t/yr capacity lithium carbonate plant in Delle, UT (Gillie, 2019). In 2021, lithium carbonate was produced commercially at the plant. 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 contain 4% lithium (Tom Tripp, Director of Technical Services and Development, US Magnesium LLC, oral commun., February 24, 2022). In 2020, Sumitomo Corp. (Tokyo, Japan) entered into an agreement with US Magnesium to sell the lithium carbonate in China, Japan, and the Republic of Korea (Sumitomo Corp., 2020).

In 2021, Rio Tinto Group (London, United Kingdom) commenced limited production of battery-grade lithium carbonate from waste rock via a pilot plant at its boron mine in Boron, CA. The pilot plant had a production capacity of 10-t/yr of lithium carbonate. An industrial-scale plant with a capacity of 5,000 t/yr of battery-grade lithium carbonate was in the early stages of design. The lithium was expected to be extracted from waste piles accumulated during 90 years of boron production (Jamasmie, 2021).

Livent Corp. (Philadelphia, PA), an independent lithium business that was spun off from FMC Corp. in 2018, produced a variety 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., 2022, p. 6–8, 11–12, 34).

In 2021, Livent produced 15,542 t of lithium carbonate in Argentina, which was converted to 19,671 t of lithium hydroxide in China and the United States. The company also produced 3,723 t of lithium chloride in Argentina, which was converted to 2,549 t of butyllithium in China, India, the United Kingdom, and the United States and to 156 t of high-purity lithium metal in the United States. Livent's lithium carbonate, lithium chloride, and lithium hydroxide production capacities were 18,000 t/yr, 9,000 t/yr, and 25,000 t/yr, respectively. Owing to increased lithium consumption and higher lithium prices in 2021, Livent resumed lithium carbonate and lithium hydroxide expansion projects that were paused in 2020. Livent's butyllithium production capacity was 3,265 t/yr, and its high-purity lithium metal production capacity was 250 t/yr (Livent Corp., 2022, p. 6, 8).

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 2021, Benchmark Mineral Intelligence (2022c, p. 3, 9) reported that the United States had an operational capacity of approximately 57 GWh/yr and accounted for 5.5% of global operational capacity. There were 4 operating U.S. gigafactories in 2021 and 17 more were in the planning or construction stages.

In 2017, Tesla Inc. (Austin, TX) began commercial production of Li-ion battery cells at its gigafactory in Nevada. Panasonic Corp. (Osaka, Japan) established a partnership with Tesla to independently manufacture the battery cells within Tesla's gigafactory. With an operational capacity of 37 GWh/yr in 2021, Tesla's gigafactory was among the largest Li-ion battery plants in the world (Randall, 2017; Benchmark Mineral Intelligence, 2022c, p. 3). Tesla also began pilot production of its in-house developed "Roadrunner" Li-ion battery at its Fremont, CA, facility. Production capacity at this facility was 10 GWh/yr (Alvarez, 2020).

Production capacity of LG Chem Ltd.'s (Seoul, Republic of Korea) Li-ion battery cell plant in Holland, MI, was 7 GWh/yr to accommodate production of General Motors Co. (GM) (Detroit, MI) electric vehicles (Benchmark Mineral Intelligence, 2022c, p. 3). In 2020, GM and LG Chem formed a new joint-venture company, Ultium Cells LLC, and began construction on a 35-GWh/yr Li-ion battery cell production facility in Lordstown, OH. Battery production was expected to begin in 2022 (General Motors Co., 2020; Colthorpe, 2021).

In 2021, 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 was planned to be operational by 2026 (Benchmark Mineral Intelligence, 2022c, p. 3).

In 2019, South Korean energy company SK Innovation Co., Ltd. (Seoul, Republic of Korea) began constructing the first of two Li-ion battery plants in Commerce, GA, which was expected to supply automakers Ford and Volkswagen. Li-ion cell capacity of the first battery plant was 9.8 GWh/yr, with production expected to begin in 2022. Li-ion cell capacity of

the second battery plant was 11.7 GWh/yr, with production expected to begin in 2023 (Kane, 2020; Mulholland, 2021).

The pace of construction of Li-ion battery recycling plants increased considerably in 2021. Approximately 35 companies in Canada and the United States and 39 companies in Europe recycled Li-ion and primary lithium batteries or planned to do so. Automobile companies have partnered with battery recyclers to supply the automobile industry with an additional source of battery materials. Cirba Solutions (previously Retriev Technologies Inc.) was estimated to be the first company to construct a U.S. facility dedicated to recycling Li-ion batteries for electric vehicles. The facility began operations in Lancaster, OH, in 2015 (Retriev Technologies Inc., 2017, p. 8).

To improve new Li-ion battery recycling techniques and new battery designs, the U.S. Department of Energy's (DOE's) Vehicle Technologies Office collaborated with DOE's Argonne National Laboratory, the National Renewable Energy Laboratory, the Oak Ridge National Laboratory, and several universities to establish DOE's first advanced battery recycling research and development facility called the ReCell Center. The Center planned to develop technologies to cost-effectively reclaim and recycle critical materials from all lithium-based battery technologies, help the United States establish a globally competitive recycling industry, and reduce U.S. reliance on foreign supplies of raw materials (Gillard and others, 2019, p. 4, 18; U.S. Department of Energy, 2019).

Consumption

In 2021, the global markets for lithium products were estimated to be batteries, 73%; ceramics and glass, 10%; lubricating greases, 5%; continuous casting mold flux powders, 3%; air treatment, 2%; medical, 1%; and other uses, 6% (Benchmark Mineral Intelligence, 2022a). 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., 2022a).

In 2021, EVs, hybrid-electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs) accounted for 79% of global Li-ion battery consumption as measured in GWh. Portable applications (electric bicycles, motorcycles and scooters, smartphones, consumer electronics, laptop and tablet computers, and power tools) accounted for 16% of Li-ion battery consumption. Grid storage accounted for the remaining 5% (Benchmark Mineral Intelligence, 2022b).

In 2021, battery manufacturers were either active, ramping up, or planning to construct 1,030 GWh/yr of global production capacity for large EV-sized Li-ion battery cells. Approximately 78% of global production capacity was in China, 8% in Europe, 5.5% in the United States, and the rest of the world (mostly Asia excluding China) accounted for the remaining 8.5% (Benchmark Mineral Intelligence, 2022c, p. 9).

Prices

Average 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 2021, the average customs unit value for imported lithium carbonate was $6.20 per kilogram, a decrease of 4% from that in 2020. The average customs unit value for imported lithium hydroxide was $9.50 per kilogram, an increase of 3% from that in 2020 (table 3). The average unit value of exported lithium carbonate in 2021 was $5.60 per kilogram, 42% lower than that in 2020. The average unit value of exported lithium hydroxide was $11.70 per kilogram, an increase of 6% from that in 2020 (table 2). In 2021, the average unit value of exported lithium carbonate was 11% less than that of imported lithium carbonate, and the average unit value of exported lithium hydroxide was 23% higher than that of imported material. This suggests that domestic lithium hydroxide exports were of a higher quality than imports. Import values typically reflect companies importing their own materials at cost for further processing.

At yearend 2021, Benchmark Mineral Intelligence (2022e, p. 1, 4) reported that the U.S. import price for lithium carbonate [cost, insurance, and freight (c.i.f.) North America, ≥99.0%] was $18.50 per kilogram. The price for lithium hydroxide [free on board (f.o.b.) North America, ≥55.0%] was $20.00 per kilogram. Spodumene concentrate (f.o.b. Australia, 6% lithium oxide) was $1.65 per kilogram. The spot price for battery-grade lithium carbonate in China averaged $39.25 per kilogram in December 2021. The spot price for battery-grade lithium hydroxide in China averaged $32.65 per kilogram in December.

Foreign Trade

In 2021, total exports of lithium compounds, by lithium content, from the United States increased by 56% compared with those in 2020 (table 2). The leading destinations of all United States exports of lithium compounds were Japan (46%), Germany (14%), Russia (11%), and Belgium (8%). Lithium hydroxide accounted for 72% of the total lithium exports in 2021, and lithium carbonate accounted for the remaining 28%. Exports of lithium carbonate increased by 132% in 2021 compared with those in 2020, and exports of lithium hydroxide increased by 38%.

Imports of lithium compounds, by lithium content, into the United States increased by 7% in 2021 compared with those in 2020. About 52% came from Chile, 45% from Argentina, and 2% from Russia (table 3).

World Industry Structure

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 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 oil field 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, Canada, Chile, China, and many other countries in Africa and Europe.

Lithium is 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 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 2021 (excluding United States production) was estimated by the USGS to be 107,000 t of lithium contained in minerals and compounds (569,000 t of LCE), a 29% increase from 82,700 t (revised) (440,000 t of LCE) in 2020 owing primarily to increased production of mineral-sourced lithium from Australia and brine-sourced lithium from Chile (table 4). The leading producing country was Australia, where production in terms of lithium content was 96% 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, China, Portugal, and Zimbabwe were the leading producers of lithium minerals. The United States produced lithium carbonate from a continental brine lithium operation, brine-sourced magnesium waste tailings, and limited pilot-plant lithium carbonate production from boron waste tailings. Additional brine deposits were being explored or were under development in Argentina, Bolivia, Chile, China, and the United States. New pegmatite mines were under consideration or development in Australia, Austria, Brazil, Canada, China, Congo (Kinshasa), Czechia, Ethiopia, Finland, Germany, Ghana, Ireland, Kazakhstan, Mali, Namibia, Nigeria, Peru, Portugal, Russia, Spain, Sweden, Thailand, Turkey, the United Kingdom, the United States, and Zimbabwe. Lithium-bearing clay mines were in various stages of development or exploration in Mexico and the United States. 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 to have some advanced operations. Pegmatites containing lithium minerals also have been identified in Afghanistan, France, India, 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 2021, global lithium consumption for air treatment, batteries, glass and ceramics, lubricants and grease, medical, metallurgical powders, and other industrial applications all increased from that in 2020 (Benchmark Mineral Intelligence, 2022a). The USGS estimated that 97,000 t of lithium (516,000 t of LCE) contained in minerals and compounds was consumed worldwide in 2021, a 39% increase from Roskill's (2021, p. 7) estimated consumption of 70,000 t (373,000 t of LCE) for 2020. For lithium minerals and compounds consumed solely in battery applications in 2021, China was the leading consumer, accounting for 47% of worldwide consumption; Europe consumed 26%; North America, 17%; the rest of Asia, 7%; South America, 1%; and other, 2% (Benchmark Mineral Intelligence, 2022a). According to USGS estimates, total global lithium consumption increased at a CAGR of 14% from 2011 through 2021 (fig. 1).

Argentina.—Production of lithium carbonate in 2021 was reported to be 28,520 t, an increase of 6% from that in 2020, and production of lithium chloride was 3,723 t, a decrease of 23% (table 4). Livent produced 15,542 t of lithium carbonate and 3,723 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 planned to increase lithium carbonate production capacity to approximately 60,000 t/yr in multiple phases over time. Allkem Ltd. (a new company formed in 2021 from the merger of Orocobre Ltd. and Australia's Galaxy Resources Ltd.) produced 12,978 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 (Orocobre Ltd., 2021a, p. 9; 2021b, p. 4; 2021c, p. 4; Allkem Ltd., 2022, p. 1; Livent Corp., 2022, p. 6, 8).

Lithium Americas Corp. and Ganfeng Lithium Co. Ltd., co-owners of the Argentine joint-venture company Minera Exar S.A., continued development on 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 initial production anticipated to begin in 2022. Minera Exar also began development planning for a Stage 2 expansion of an additional 20,000 t/yr of LCE

production capacity, with construction commencing in late 2022 (Lithium Americas Corp., 2021).

Approximately 35 lithium projects by additional companies were in various stages of development and construction in Argentina. About 16 junior operations have completed feasibility studies, and 5 have begun construction (Ministerio de Economia Argentina, 2021, p. 3).

Australia.—In 2021, the government of the State of Western Australia reported total spodumene concentrate production of 1.986 million metric tons (Mt), an increase of 39% from its production of 1.427 Mt in 2020 (Government of Western Australia, Department of Mines, Industry Regulation, and Safety, 2022). Spodumene concentrate production was equivalent to 55,281 t of lithium content (294,261 t of LCE). Talison Lithium Pty Ltd produced 22,169 t of lithium content (118,000 t of LCE) from its Greenbushes spodumene deposit in Western Australia (Australian Government, Department of Industry, Science, Energy, and Resources, 2021a, p. 144; 2021b, p. 151; 2022, p. 170). Talison's lithium concentrate production capacity was reported to be 33,500 t/yr of lithium content (178,000 t/yr of LCE) in 2020 (Roskill Information Services Ltd., 2020, p. 9). No production capacity increase was announced for 2021.

In 2019, Albemarle acquired a 60% interest in the Wodgina spodumene mine in Pilbara, Western Australia, from Mineral Resources Ltd. and formed a joint venture named MARBL Lithium Joint Venture. The mine was placed on care-and-maintenance status in 2019. In 2021, MARBL announced its intention to resume spodumene concentrate production at the mine, with the production restart expected in 2022. Wodgina's spodumene resource was reported to be 259 Mt, grading 1.17% lithium oxide, with a lithium recovery rate of 65% (Mineral Resources Ltd., 2019, p. 14; Albemarle Corp., 2022b, p. 32).

In 2021, Albemarle completed construction of the first phase of a mineral conversion plant in Kemerton, Western Australia, that would convert spodumene from Albemarle's Talison and Wodgina sites to lithium hydroxide. Commercial production from the plant was to begin in 2022. The Kemerton plant was expected to have an initial lithium hydroxide production capacity of 50,000 t/yr of LCE, with an ability to expand to 100,000 t/yr of LCE over time (Albemarle Corp., 2021, p. 31; 2022b, p. 24).

The Mt Marion lithium project, a joint venture between Mineral Resources and Ganfeng Lithium Co., Ltd., was Western Australia's second-ranked spodumene producer after Talison. In 2021, the Mt Marion operation produced 11,971 t of lithium content (63,700 t of LCE) (Australian Government, Department of Industry, Science, Energy, and Resources, 2021a, p. 144; 2021b, p. 151; 2022, p. 170).

Pilbara Minerals Ltd. produced 9,054 t of lithium content (48,200 t LCE) at its Pilgangoora Lithium-Tantalum Project in Western Australia's Pilbara region. 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; 2022, p. 169; Roskill Information Services Ltd., 2021, p. 9).

Allkem produced 6,405 t of lithium content (34,100 t of LCE) at its Mt Cattlin operation near Ravensthorpe, Western Australia. 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., 2022, p. 1).

Chile.—In 2021, the Government of Chile reported production of 150,348 t of lithium carbonate, an increase of 32% from that in 2020; 12,129 t of lithium hydroxide, an increase of 34%; and no production of lithium chloride. Sociedad Química y Minera de Chile S.A. (SQM) produced 108,400 t of lithium carbonate and 12,129 t of lithium hydroxide. The company accounted for 19% of global lithium chemical sales volumes and sold 101,100 t of LCE in 2021, a 57% increase from that in 2020. SQM's value of sales increased by 144% to $936 million owing to higher lithium prices. In 2021, 86% of the company's lithium products, by sales value, went to Asia and other locations, 8% went to Europe; and 5% 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 lithium carbonate and lithium hydroxide production capacities to 180,000 t/yr and 30,000 t/yr, respectively, in 2021. SQM also planned for further lithium carbonate and lithium hydroxide capacity expansions to 210,000 t/yr and 40,000 t/yr, respectively, by 2024 (Servicio Nacional de Geología y Minería, 2022, p. 118–119; Sociedad Química y Minera de Chile S.A., 2022, p. 21–23, 34, 57, 79–80).

Albemarle produced about 42,000 t of lithium carbonate in Chile in 2021. It commissioned a 20,000-t/yr lithium carbonate conversion plant in La Negra in 2017, increasing its total lithium carbonate and lithium chloride production capacity in Chile to 44,000 t/yr of LCE. 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. Albemarle completed construction of a third lithium carbonate conversion plant in 2021; production was expected to begin in 2022. The new La Negra plant would increase Albemarle's total lithium carbonate and lithium chloride capacity in Chile to 80,000 t/yr of LCE (Norris, 2021, p. 63; Albemarle Corp., 2022b, p. 35).

China.—China produced large quantities of lithium carbonate and lithium hydroxide from domestic and imported mineral concentrates. In 2021, China was estimated by the USGS to have produced 75,000 t of LCE from domestic sources, a 6% increase from 2020 production of 70,600 t owing to increases in brine-sourced output and mineral-sourced mining capacity. China ranked third in lithium production, after Australia and Chile. Six Chinese lithium brine operations and six lithium mineral mines were in operation; brine-sourced lithium and mineral-sourced lithium each accounted for 50% of China's lithium mine production. Production capacity of the brine-based operations was 65,000 t/yr of LCE, and mineral-based production capacity was 75,700 t/yr of LCE. China's lepidolite, mica, petalite, and spodumene production was mostly within Jiangxi and Sichuan Provinces but also took place in Hunan Province and Xinjiang Uyghur Autonomous Region. China's brine was extracted in Qinghai and Tibet Provinces (Roskill Information Services Ltd., 2020, p. 225–231; 2021, p. 9).

The rapid 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 2021. China is the world's leading producer of refined lithium chemicals. According to Benchmark Mineral Intelligence (2022a), China produced 146,000 t of lithium carbonate in 2021. Of that total, spodumene was the feedstock for 102,000 t of lithium carbonate, brine was the feedstock for 34,500 t, and lepidolite was the feedstock for 9,500 t. China produced 12,000 t of lithium chloride, of which the feedstock was spodumene. Additionally, China produced 124,320 t of lithium hydroxide. Of that total, spodumene was the feedstock for 113,320 t, whereas lithium carbonate was the feedstock for the remaining 11,000 t of lithium hydroxide produced.

Outlook

Lithium supply security has become a top priority for vehicle and technology companies worldwide. Strategic alliances and joint ventures have been and 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 gigafactories. At the end of 2021, Benchmark Mineral Intelligence (2022d) reported that gigafactories with a combined battery capacity of 1,100 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)

	2017	2018	2019	2020	2021
United States:					
Production	W	W	W	W	W
Exports[2]	1,960	1,660	1,660	1,200 [r]	1,870
Imports[2]	3,330	3,420	2,620	2,460	2,640
Consumption[e, 3]	3,000	3,000	2,000	2,000	2,000
Rest of world, production[4, 5]	76,400	91,800	83,800 [r]	82,700 [r]	107,000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through August 1, 2022. 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	2020 Gross weight (metric tons)	2020 Value[2] (thousands)	2021 Gross weight (metric tons)	2021 Value[2] (thousands)
Lithium carbonate:				
Belgium	9	$31	4	$14
Canada	67	293	55	261
Chile	5	19	9	32
China	--	--	5	16
Colombia	48	172	41	149
Finland	5	104	--	--
France	--	--	18	263
Germany	563	6,090	700	4,940
India	274	1,550	385	2,060
Japan	--	--	304	1,820
Russia	--	--	1,050	3,980
Taiwan	26	95	72	260
Other	4	22	17	60
Total	1,000	8,380	2,660	13,900
Total lithium content	188	XX	500	XX
Lithium carbonate, U.S.P.:[3]				
Argentina	--	--	6	39
Belgium	2	59	62	536
China	--	--	19	315
India	81	2,070	6	227
Israel	5	235	--	--
Mexico	124	803	55	542
Netherlands	--	--	5	43
Other	1 r	23 r	(4)	73
Total	213	3,190	153	1,770
Total lithium content	40	XX	29	XX
Lithium hydroxide:				
Argentina	149	1,980	125	1,370
Australia	30	432	192	2,080
Belgium	99	828	778	8,300
Canada	224	1,240	305	1,920
Chile	6	101	6	102
Colombia	4	63	1	21
Ecuador	2	25	4	34
Egypt	44	495	44	370
France	8	451	(4)	261
Germany	200	3,400	767	9,250
Indonesia	6	101	--	--
Japan	4,630 r	49,700	4,830	55,300
Korea, Republic of	58	922	628	7,090
Mexico	6	105	4	71
Netherlands	183	1,640	1	124
Saudi Arabia	108	845	144	981
Singapore	33	716	81	951
Taiwan	3	22	59	732
Thailand	69	609	80	863
United Arab Emirates	7	129	4	151
United Kingdom	7	795	52	3,740
Other	8 r	534 r	14	1,250
Total	5,890 r	65,100	8,120	95,000
Total lithium content	972 r	XX	1,340	XX

rRevised. XX Not applicable. -- Zero.

[1]Table includes data available through July 25, 2022. 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.

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

Compound and country or locality	2020 Gross weight (metric tons)	2020 Value[2] (thousands)	2021 Gross weight (metric tons)	2021 Value[2] (thousands)
Lithium carbonate:				
Argentina	7,440	$39,300	6,280	$34,200
Belgium	--	--	36	223
Chile	4,010	33,600	5,800	39,500
China	174	1,850	88	938
India	--	--	10	131
Japan	4	77	20	148
Netherlands	13	104	10	68
Russia	5	42	--	--
United Kingdom	17	121	17	231
Other	--	--	(3)	12
Total	11,700	75,100	12,300	75,500
Total Li content	2,190	XX	2,310	XX
Lithium carbonate, U.S.P.,[4] India	(3)	10	(3)	5
Lithium carbonate, U.S.P.,[4] India, lithium content	(3)	XX	(3)	XX
Lithium hydroxide:				
Chile	710	6,730	1,650	15,200
China	29	207 r	35	279
Germany	100	557	39	219
Japan	11	87	12	65
Romania	6	466	--	--
Russia	732	6,400	238	2,980
United Kingdom	6	185	1	33
Other	1	40	4	60
Total	1,600	14,700	1,980	18,800
Total lithium content	265	XX	329	XX

rRevised. XX Not applicable. -- Zero.
[1]Table includes data available through July 25, 2022. 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]	2017			2018			2019			2020			2021		
	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	26,559	4,993	26,559	29,707	5,585	29,707	29,994	5,639	29,994	26,911	5,059	26,911	28,520	5,362	28,520
Lithium chloride	4,501	734	3,905	5,005	816	4,343	4,284	698	3,717	4,836	788	4,196	3,723	607	3,230
Australia, spodumene	1,706,618	47,512	252,908	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
Brazil, concentrate	10,547	294	1,563	41,000	1,141	6,076	33,700 r	938 r	4,994 r	57,500 r	1,601 r	8,521 r	60,000 e	1,670	8,892
Canada, spodumene	--	--	--	114,000	2,433	12,952	9,000	192	1,023	--	--	--	--	--	--
Chile, subsurface brine:															
Lithium carbonate	73,563	13,830	73,563	87,029	16,361	87,029	100,787	18,948	100,787	114,260	21,481	114,260	150,348	28,265	150,348
Lithium chloride	2,535	413	2,199	3,826	624	3,320	1,886	307	1,636	--	--	--	--	--	--
Lithium hydroxide[5]	5,280	871	4,637	6,468	1,067	5,681	9,934	1,639	8,725	9,030	1,490	7,931	12,129	2,001	10,653
China, lithium carbonate equivalent[6]	37,300	7,012	37,300	37,800	7,106	37,800	57,500	10,810	57,500	70,600	13,273	70,600	75,000 e	14,100	75,000
Namibia, lepidolite	--	--	--	30,000	258	1,373	--	--	--	--	--	--	--	--	--
Portugal, lepidolite	52,741	791	4,211	76,818	1,152	6,134	59,912	899	4,784	23,185	348	1,851	60,000 e	900	4,791
United States, lithium carbonate	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Zimbabwe, petalite, lepidolite	40,000	800	4,258	80,000	1,600	8,517	60,400 e	1,208	6,430	20,859	417	2,221	35,500 e	710	3,779
Total[7]	1,950,000	76,400	406,000	2,470,000	91,800	489,000	1,950,000	83,800 r	446,000 r	1,750,000 r	82,700 r	440,000 r	2,400,000	107,000	569,000

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

[1]Table includes data available through August 1, 2022. 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.

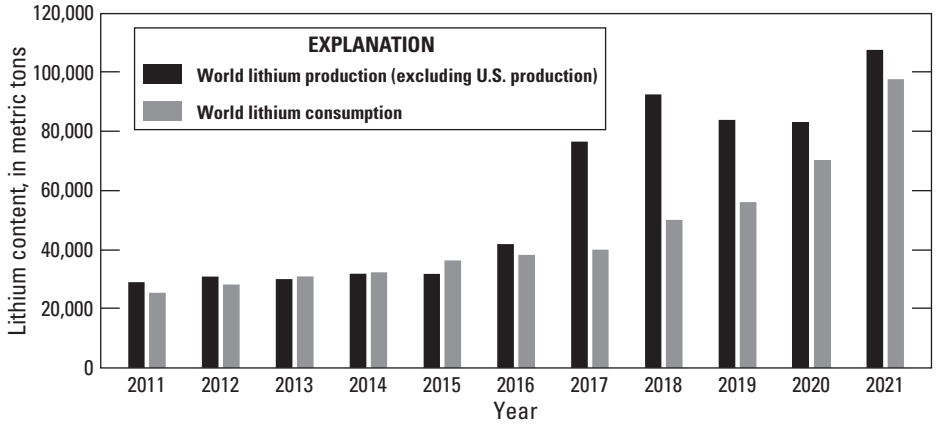

Figure 1. Estimated world lithium production (excluding U.S. production) and consumption from 2011 through 2021. Production data estimated by the U.S. Geological Survey (USGS). Consumption data estimated by Roskill Information Services Ltd. and the USGS.