USGS
science for a changing world

2017 Minerals Yearbook

LITHIUM [ADVANCE RELEASE]

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

September 2020

Lithium

By Brian W. Jaskula

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

In the United States, one lithium brine operation with an associated lithium carbonate plant operated in Silver Peak, NV. 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 2017, lithium consumption in the United States was estimated to be equivalent to 3,000 metric tons (t) of elemental lithium (table 1) [16,000 t of lithium carbonate equivalent (LCE)], primarily owing to demand for lithium-based battery, ceramic and glass, grease, pharmaceutical, and polymer products. In 2017, the gross weight of lithium compounds imported into the United States increased by 7% and the gross weight of exports increased by 29% from those in 2016. Argentina and Chile were the principal sources of imported lithium carbonate, and Chile, China, and Russia were the principal sources of imported lithium hydroxide (table 3).

World lithium production in 2017 (excluding United States production) was estimated to be 68,500 t of lithium contained in minerals and compounds (365,000 t of LCE), about 74% higher than that in 2016 owing primarily to Australia's spodumene production nearly quadrupling. World lithium production increased at a compound annual growth rate (CAGR) of 11% per year from 2007 through 2017 (fig. 1). World lithium consumption was estimated to be approximately 39,700 t of lithium contained in minerals and compounds (211,000 t of LCE), an increase of 5% from that of 2016. More than 70% was consumed by countries in Asia (Roskill Information Services Ltd., 2018, p. 42, 46). World lithium consumption increased at a CAGR of 9% per year from 2007 through 2017 (fig. 1). The average unit value of lithium carbonate imports (including pharmaceutical grade) was about the same as that of 2016, and the average unit value of lithium hydroxide imports increased by 66%. Despite the 74% increase in global lithium production, spot battery-grade lithium carbonate prices in China continued to remain high throughout the year, averaging $25,000 per metric ton at yearend 2017 (Asian Metal Inc., 2018). The rest of the world experienced lower spot lithium carbonate prices owing to the availability of supplies from more diversified sources of lithium than China, which relied greatly on imported spodumene from Australia.

Legislation and Government Programs

National Defense Stockpile.—In 2014, the Defense Logistics Agency Strategic Materials (DLA Strategic Materials), an agency of the 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 2018 (October 1, 2017, through September 30, 2018), which represented the maximum quantities of materials that could be acquired during the year, was 600 kilograms (kg) of lithium-cobalt oxide and 2,160 kg of lithium-nickel-cobalt-aluminum oxide (Defense Logistics Agency Strategic Materials, 2017). At yearend 2017, the NDS held 540 kg of lithium-cobalt oxide and 1,620 kg of lithium-nickel-cobalt-aluminum oxide.

Production

The U.S. Geological Survey (USGS) collected domestic production data for lithium from a voluntary canvass of the only U.S. lithium carbonate producer, Rockwood Lithium Inc. (a subsidiary of Albemarle Corp. of Charlotte, NC). Production and stock data collected from Rockwood Lithium were withheld from publication to avoid disclosing company proprietary data. The company's 6,000-metric-ton-per-year (t/yr) Silver Peak facility was expected to supply lithium carbonate for an additional 20 years at 2017 production levels (Albemarle Corp., 2018b, p. 4).

Albemarle operated a 5,000-t/yr battery-grade lithium hydroxide production facility in Kings Mountain, NC, that used Rockwood Lithium's lithium carbonate as feedstock. Albemarle's other downstream lithium operations in the United States included a plant for producing specialty lithium products in New Johnsonville, TN, and facilities for producing other lithium compounds in Kings Mountain. 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 Meishan 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., 2018b, p. 22–24).

Albemarle owned a 49% interest in Australia's Talison Lithium Pty Ltd., a spodumene producer with an 80,000-t/yr LCE production capacity. Sichuan Tianqi Lithium Industries, Inc., a subsidiary of Chengdu Tianqi (Group) Co., Ltd. (China), owned the remaining interest in Talison. The 2014 acquisition of Talison provided Albemarle with access to another significant lithium reserve, raw material diversity in the form of brines and mineral concentrates, and the flexibility to ramp up production quickly when necessary (Albemarle Corp., 2018b, p. 4–5). Albemarle was the world's leading producer of lithium in 2017, with an estimated 13,000 t of elemental lithium (69,000 t of LCE) produced from its operations in Australia and Chile.

FMC Lithium, a division of FMC Corp. (Philadelphia, PA), produced a full 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 brine operation in Argentina. FMC's other global lithium operations included a lithium hydroxide and butyllithium facility in Zhangjiagang, China; a butyllithium-organometallic compound facility in Bromborough, United Kingdom; an organolithium compound facility in Naoshima, Japan; and an organolithium compound

facility in Patancheru, India. In 2017, FMC increased its lithium hydroxide production capacity to 19,000 t/yr and anticipated reaching its target lithium hydroxide production capacity of 30,000 t/yr by 2019 (FMC Corp., 2018, p. 7).

Lithium resource exploration in the United States has increased significantly in recent years in anticipation of increasing demand for lithium-ion batteries and the recent rise in lithium prices. Approximately 30 mining claims (mostly in Nevada) were in the early exploration to mineral discovery and expansion stages by junior mining companies. Several companies completed preliminary economic assessments (Roskill Information Services Ltd., 2018, p. 171).

Recycling

In 2017, lithium battery recycling projects were in operation or under development in Belgium, Canada, China, Germany, Japan, and the United States. As part of the American Recovery and Reinvestment Act of 2009 (ARRA, Public Law III–5), the U.S. Department of Energy awarded $9.5 million to California-based battery recycler Retriev Technologies Inc. (formerly Toxco Inc.) to construct the first U.S. recycling facility for lithium-ion vehicle batteries. Retriev's new facility in Lancaster, OH, began operation in 2015. The company has been recycling lithium batteries at its facility in Trail, British Columbia, Canada, since 1993 (U.S. Department of Energy, 2013; Retriev Technologies Inc., 2017, p. 8).

Consumption

In 2017, the global markets for lithium products were estimated to be batteries, 48%; ceramics and glass, 26%; lubricating greases, 7%; polymer production, 5%; continuous casting mold flux powders, 4%; air treatment, 2%; and other uses, 8% (Roskill Information Services Ltd., 2018, p. 43). Other uses may have included agrochemicals, airbag ignition, aluminum alloys, carbon dioxide absorption, cement and concrete additives, dyes and pigments, industrial catalysts, organic synthesis, pharmaceuticals, and scintillation (Albemarle Corp., 2018a).

In 2017, electric vehicles (EVs), hybrid-electric vehicles (HEVs), and plug-in hybrid electric vehicles (PHEVs) accounted for approximately 60% of the global lithium-ion battery market as measured in gigawatthours (GWh). A GWh is a unit of energy equivalent to the consumption of 1 billion watts for 1 hour. Cellular telephones and smartphones accounted for 15% of the lithium-ion battery market; laptop computers, 7%; tablet computers and power tools, 4% each; electric bicycles, motorcycles, and scooters, 2%; drones and household devices, 1%; grid storage, 1%; and other uses, 6%. Global lithium-ion battery consumption increased by an average of 27% per year from 2010 through 2017, reaching an estimated 114 GWh in 2017 from 21 GWh in 2010 (Roskill Information Services Ltd., 2018, p. 184–188).

About 85% of the world's lithium-ion battery cell production capacity was in Asia owing to longstanding public and private investments in lithium-ion battery technology by consumer electronics companies and governments. More than 50% of fully commissioned capacity was in China; Japan and the Republic of Korea had 15% and 20%, respectively. Although lithium-ion battery cell production capacity for all end uses in the United States was small compared with that in those three countries, it was a leader in automotive-specific lithium-ion battery production capacity, accounting for 20% of worldwide capacity (Chung and others, 2016, p. 1–2; Ralph, 2016).

Prices

Customs values for U.S. imports of lithium carbonate and lithium hydroxide were used as an indication of the trends in lithium pricing; producer pricing was not available for lithium carbonate or lithium hydroxide. In 2017, the average customs unit value for imported lithium carbonate was $4.90 per kilogram, about the same as that of 2016. The average customs unit value for imported lithium hydroxide was $15.20 per kilogram, 66% higher than that of 2016. The average unit value of exported lithium carbonate in 2017 was $10.60 per kilogram, 37% higher than that of 2016. The average unit value of exported lithium hydroxide was $10.80 per kilogram, 21% higher than that of 2016. In 2017, the average unit value of exported lithium carbonate was more than double that of imported lithium carbonate, and the average unit value of exported lithium hydroxide was 29% lower than that of imported material. This suggests that domestic lithium carbonate exports were of a higher quality than imports. Import values mostly reflect companies importing their own materials at cost for further processing.

At yearend 2017, Industrial Minerals (2017) reported that the U.S. import price range for lithium carbonate (large contracts, delivered to the continental United States) was $17,000 to $19,000 per metric ton. The price range for 56.5% to 57.5% lithium hydroxide, large contracts, packed in drums or bags, delivered to Europe or the United States was $18,000 to $20,000 per metric ton. The cost, insurance, and freight (c.i.f.) price range for 5% to 6% lithium oxide spodumene delivered to China was $870 to $950 per metric ton. The c.i.f. price range for 7% to 7.5% lithium oxide spodumene delivered to China was $950 to $1,000 per metric ton.

Spot prices for battery-grade lithium carbonate prices in China remained high throughout the year, averaging $25,000 per metric ton at yearend 2017 (Asian Metal Inc., 2018). The rest of the world experienced lower spot prices for lithium carbonate owing to the availability of supplies from more diversified sources. Spot prices for battery-grade lithium hydroxide in China averaged $23,500 per metric ton at yearend 2017 (Asian Metal Inc., 2017a). Battery-grade lithium metal (99.9% Li) prices in China averaged $139,000 per metric ton at yearend 2017, a 14% increase from that of yearend 2016 (Asian Metal Inc., 2017b).

Foreign Trade

In 2017, total exports of lithium compounds, by gross weight, from the United States increased by 29% compared with those of 2016. About 62% of all United States exports of lithium compounds went to Japan, 20% went to Germany, and 7% went to Canada (table 2). Lithium hydroxide accounted for 88% of the total lithium exports in 2017, and lithium carbonate

accounted for the remaining 12%. Exports of lithium carbonate and lithium hydroxide increased by 22% and 30%, respectively, in 2017 compared with those of 2016.

Imports of lithium compounds, by gross weight, into the United States increased by 7% in 2017 compared with those of 2016. About 55% came from Argentina, 38% from Chile, and 3% each from China and Russia (table 3). Lithium concentrates from Australia and Zimbabwe may have entered the United States, but these materials have no unique import code, and disaggregated import data were not available.

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 also 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 was also 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 spodumene resources of North Carolina, the oil field brines of Arkansas, and the geothermal brines of California. Argentina, Australia, and Canada have seen a considerable amount of lithium exploration. At yearend, approximately 45 mining claims in Argentina were in the early exploration to mineral discovery and development stages. About 25 mining claims each in Australia and Canada were in similar exploration and development stages (Roskill Information Services Ltd., 2018, p. 127–128, 131, 138).

Lithium is sold as brines, compounds, metal, mineral concentrates, and most recently, direct-shipping ore 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, rechargeable lithium batteries powered most cellular telephones and laptop computers, as well as most heavy-duty power tools. Automakers were developing and improving lithium batteries for EVs, HEVs, and PHEVs. Rechargeable lithium batteries also were being used in electrical grid storage applications.

World Review

World lithium production in 2017 (excluding U.S. production) was estimated to be 68,500 t of lithium (365,000 t of LCE) contained in minerals and compounds, 74% higher than that in 2016 (table 1). Global lithium production capacity was estimated to be 91,000 t/yr of lithium (485,000 t/yr of LCE), a 57% increase from that of 2016. The leading producing country, by far, was Australia, where spodumene production was nearly four times more than that of 2016. More than 11,000 t of contained lithium (59,000 t of LCE) was sourced, for the first time, from direct-shipping ore (DSO), unprocessed spodumene ore mined in Australia and shipped to China for processing. Chile was the second-ranked lithium-producing country. Based on data from Roskill Information Services Ltd. (2018, p. 22), China was the third-ranked lithium-producing country from 2011 to 2015, and again in 2017. Gross weight production figures for lithium carbonate, lithium chloride, lithium hydroxide, and lithium mineral concentrates are listed in table 4. 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. Additional brine operations were under exploration or development in Argentina, Bolivia, Chile, China, and the United States; new pegmatite mines were under exploration or development in Australia, Austria, Brazil, Canada, China, Congo (Kinshasa), Czechia, Finland, Germany, Ireland, Mali, Namibia, Portugal, Russia, South Africa, Spain, Sweden, the United Kingdom, and Zimbabwe; a jadarite mine was under development in Serbia; and a lithium-bearing clay mine was under development in Mexico. 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.

In 2017, global lithium consumption for air treatment, ceramics and glass, grease, metallurgical powders, polymers, rechargeable batteries, and other industrial applications increased; lithium consumption for primary batteries decreased. An estimated 39,700 t of lithium (211,000 t of LCE) contained in minerals and compounds was consumed worldwide in 2017, a 5% increase from the revised consumption estimate of 37,900 t (202,000 t of LCE) for 2016. China was the leading consumer of lithium minerals and compounds, accounting for 40% of worldwide consumption as reported by Roskill; Japan consumed 19%; the Republic of Korea, 14%; Europe, 12%; North America, 7%; India, 2%; Russia, 1%; and others, 5% (Roskill Information Services Ltd., 2018, p. 42, 46).

According to USGS estimates, total global lithium consumption increased at a CAGR of 9% from 2007 through 2017 (fig. 1). According to Roskill Information Services Ltd. (2018, p. 202), lithium consumption for rechargeable batteries increased at a CAGR of 14% from 2007 through 2017.

Argentina.—Production of lithium carbonate in 2017 was reported to be 26,559 t, an increase of 9% from that of 2016, and production of lithium chloride was 4,501 t, a 30% decrease.

FMC produced 15,153 t of lithium carbonate and 4,501 t of lithium chloride at its 26,000-t/yr LCE facility, which has been operating since 1998, on the Salar de Hombre Muerto in Catamarca Province (Ministerio de Energia y Mineria, 2018). Orocobre Ltd. produced 11,406 t of lithium carbonate at its joint-venture Olaroz Lithium Project [Orocobre (66.5%), Toyota Tsusho Corp. (25%), and the government of Jujuy Province (8.5%)] at the Salar de Olaroz in northwestern Argentina. Production capacity was 17,500 t/yr of battery-grade lithium carbonate (Orocobre Ltd., 2017, p. 3; 2018, p. 3–5).

In 2016, Chile's Sociedad Química y Minera de Chile S.A. (SQM) reached a 50–50 joint-venture agreement with Lithium Americas Corp. to develop the Cauchari-Olaroz Lithium Project on the Puna plateau in northwestern Argentina. In 2017, the joint-venture company, Minera Exar S.A., updated Lithium Americas' 2012 definitive feasibility study of the project including a production capacity of 50,000 t/yr of LCE built in two stages of 25,000 t/yr each. By yearend, evaporation pond construction, production well drilling, and hydrological testing were underway (Lithium Americas Corp., 2017; 2018, p. 2).

Rincon Ltd. (Canada), formerly Enirgi Group Corp., developed proprietary technology to produce lithium directly from nonconcentrated brine at the Salar del Rincon in Salta Province. The technology was expected to reduce processing time from the conventional 18 months to less than 24 hours as well as increase the lithium recovery rate. The company planned to construct a 50,000-t/yr LCE plant. In 2016, a definitive feasibility study of the Salar del Rincon was completed reporting probable reserves of approximately 230,000 t of lithium (1,220,000 t of LCE). In 2017, a lithium carbonate demonstration plant was installed (Enirgi Group Corp., 2014, 2016; Rincon Ltd., 2019, p. 6).

Australia.—In 2017, the government of Western Australia reported total spodumene concentrate production of 1,706,618 t, nearly four times the 440,525 t produced in 2016 (Government of Western Australia, Department of Mines, Industry Regulation and Safety, 2018). Production in 2017 was estimated to be equivalent to approximately 39,900 t of contained lithium (212,000 t of LCE). Talison Lithium Pty Ltd. (a subsidiary of Sichuan Tianqi Lithium and Albemarle) produced an estimated 80,000 t of LCE from its Greenbushes spodumene deposit in Western Australia. Talison's lithium concentrate production capacity was 740,000 t/yr, equivalent to approximately 80,000 t/yr of LCE, or 15,000 t/yr of contained lithium (Albemarle Corp., 2018b, p. 5). Production capacity decreased to 80,000 t/yr of LCE in 2017 from 95,000 t/yr of LCE in 2016 owing to lower grade ore being mined. Sichuan Tianqi Lithium and Albemarle announced plans to increase production capacity of the Greenbushes Mine to 165,000 t/yr of LCE. Commissioning of the expansion was expected to begin in 2019 (Albemarle Corp., 2017b).

Galaxy Resources Ltd. resumed commercial operation in late 2016 at its 210,000-t/yr Mt Cattlin spodumene concentrate operation near Ravensthorpe, Western Australia. In 2017, Galaxy produced 155,679 t of spodumene concentrate with a lithium oxide content of 5.7%, equivalent to 4,110 t of contained lithium (21,900 t of LCE). Mt Cattlin's spodumene ore reserves were reported to be 7,640,000 t, grading at 1.05% lithium oxide (Galaxy Resources Ltd., 2018, p. 14, 105).

Reed Industrial Minerals Pty Ltd., a joint venture among Mineral Resources Ltd., Ganfeng Lithium Co., Ltd., and Neometals Ltd., began commercial spodumene concentrate production at its Mount Marion lithium project in Western Australia in late 2016. In 2017, Reed produced 377,388 t of spodumene concentrate with an estimated lithium oxide content of 5.2%, equivalent to 9,100 t of contained lithium (48,400 t of LCE). Mount Marion's spodumene ore resources were reported to be 77,800,000 t, grading 1.37% lithium oxide. Neometals continued a feasibility study on its proprietary process to produce 20,000 t/yr of battery-grade lithium hydroxide directly from spodumene concentrates (Neometals Ltd., 2017a, p. 5, 6; 2017b, p. 1; 2018, p. 1).

Mineral Resources Ltd. commenced commercial production of lithium DSO from its Wodgina spodumene mine in Pilbara, Western Australia, in April 2017. By yearend, the mine had produced 2.8 million metric tons (Mt) of unprocessed spodumene ore, 88% of which was shipped directly to China for processing. The ore contained 11,300 t of elemental lithium (60,000 t of LCE). Wodgina's spodumene resource was reported to be 198 Mt, grading 1.18% lithium oxide (Mineral Resources Ltd., 2017a, b; 2018, p. 6).

China's Sichuan Tianqi Lithium planned to build a 24,000-t/yr lithium hydroxide plant in Kwinana, Western Australia, with plant commissioning expected in late 2018. The spodumene concentrate would be sourced from Sichuan Tianqi Lithium's subsidiary, Talison. In 2017, Sichuan Tianqi Lithium announced plans to double production capacity to 48,000 t/yr beginning in late 2019 (Paul, 2016; Ingram, 2017).

Canada.—Nemaska Lithium Inc. continued work on its Whabouchi Mine and lithium carbonate and lithium hydroxide plant in Quebec. Initial production capacity was anticipated to be 27,500 t/yr of lithium hydroxide and 3,250 t/yr of lithium carbonate using a proprietary membrane electrolysis process to produce high-purity lithium hydroxide directly from spodumene concentrate. The new technology was expected to reduce processing costs by using electricity to replace caustic soda and by eliminating the production, handling, and disposal of sodium sulfate. In the first half of 2017, Nemaska produced a 1,050-t bulk sample of spodumene concentrate averaging 6.2% lithium oxide. In September, Nemaska began production of lithium hydroxide from this spodumene concentrate sample at its 500-t/yr lithium hydroxide plant (Nemaska Lithium Inc., 2016; 2018, p. 4, 7).

Chile.—In 2017, the Government of Chile reported production of 73,563 t of lithium carbonate, an increase of 4% from that of 2016; 2,535 t of lithium chloride, an increase of 43%; and 5,280 t of lithium hydroxide, a decrease of 5% (Servicio Nacional de Geología y Minería, 2018, p. 112–113). SQM produced an estimated 48,000 t of lithium carbonate and 5,280 t of lithium hydroxide. The company accounted for 23% of global lithium chemical sales and sold 49,700 t of LCE in 2017, the same as that of 2016. SQM's value of sales increased by 25% to $645 million owing to an upturn in lithium prices. In 2017, the company's lithium products were distributed throughout the world, with 78%, by value of sales, going to Asia; 14% to Europe; 7% to North America; and 1% to Central America and South 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. SQM's lithium carbonate production capacity was 48,000 t/yr in 2017, and its lithium hydroxide production capacity was 6,000 t/yr. Owing to rapidly increasing demand for lithium carbonate and lithium hydroxide from electric vehicle battery manufacturers, SQM announced that it would increase its lithium carbonate and lithium hydroxide capacities to 70,000 t/yr and 13,500 t/yr, respectively, in 2018. SQM planned to further increase its lithium carbonate capacity to 100,000 t/yr in 2019 (Sociedad Química y Minera de Chile S.A., 2018a, p. 22–23; 2018b).

Albemarle produced an estimated 25,600 t of lithium carbonate and 2,540 t of lithium chloride. It commissioned its new 20,000-t/yr lithium carbonate 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, and used lithium carbonate and lithium chloride from its operations in Chile as feedstock for some of its downstream chemical production in France, Germany, Taiwan, and the United States. Albemarle planned to increase its lithium carbonate and lithium chloride capacity in Chile to 80,000 t/yr of LCE by 2021 (Albemarle Corp., 2017a, p. 53; 2018b, p. 22–24).

China.—China was the only country that commercially produced large quantities of lithium carbonate and lithium hydroxide from domestic and imported mineral concentrates. Lithium brine deposits were estimated to contain 78% of China's lithium resources, and lithium mineral deposits were estimated to contain the remaining 22%. In 2017, China produced an estimated 36,400 t of LCE from domestic sources, a 43% increase from the revised 2016 production of 25,400 t. China ranked third in lithium production, after Australia and Chile. Production capacity of China's mineral producers was 40,500 t/yr of LCE, and brine-based production capacity was 34,800 t/yr. China's spodumene and lepidolite production was mostly within Sichuan Province but also took place in Hunan Province, Jiangxi Province, and Xinjiang Uyghur Autonomous Region. China's brine was extracted in the Qinghai and Tibet Provinces (Roskill Information Services Ltd., 2018, p. 146–147).

In 2017, total lithium consumption in China was estimated to have been 84,000 t of LCE (Roskill Information Services Ltd., 2018, p. 45), an increase of 4% from that of 2016. The rapid expansion of China's spodumene-based lithium carbonate 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 Talison in Australia, to account for approximately one-half of the world's lithium compound production from 2012 to 2016 and 66% of production in 2017.

Outlook

SQM and lithium market analysts Global Lithium LLC and Roskill developed forecasts of world lithium consumption levels to 2022 that ranged from 374,000 to 475,000 t/yr of LCE and averaged approximately 420,000 t/yr of LCE (Lowry, 2017; Jimenez, 2018, p. 11; Roskill Information Services Ltd., 2018, p. 10). The CAGR in world lithium consumption from 2017 through 2022 is expected to be between 12% and 18%.

Lithium supply security has become a top priority for technology companies in Asia. Strategic alliances and joint ventures have been, and continue to be, established with lithium exploration companies worldwide to ensure reliable, diversified supplies of lithium for Asia's battery and vehicle manufacturers. With lithium carbonate and (or) lithium hydroxide being one of the lowest cost components of a lithium-ion battery, the issue of concern is not price, but rather supply security.

Most global automobile manufacturers have started incorporating lithium-ion batteries in current and future generations of EVs, HEVs, and PHEVs. In 2017, new vehicle models with lithium-ion batteries were to be introduced into the U.S. market by companies such as BAIC Motor Co., Ltd.; Bavarian Motor Works AG (BMW); BYD Co., Ltd.; Daimler AG (Mercedes-Benz); Ford Motor Co.; General Motors Co.; Jaguar Land Rover Automotive PLC; Mitsubishi Motors; Nissan Motor Co. Ltd.; Tesla Motors, Inc.; and Volkswagen Group. Major automobile manufacturers formed partnerships with established battery manufacturers to build battery plants for EVs and HEVs and to begin mass production of automotive lithium-ion batteries.

In anticipation of robust electric vehicle battery demand, vigorous efforts were underway by battery companies worldwide to construct new large-scale lithium-ion battery factories (megafactories) or to expand existing facilities. Lithium-ion battery megafactories are defined by Benchmark Mineral Intelligence as factories with more than 1 gigawatthour per year (GWh/yr) in capacity. By mid-2018, 50 megafactories with a combined battery capacity of 212 GWh/yr either were ramping up or being planned for construction throughout Asia, Europe, and North America. By 2023, battery capacity was expected to increase to 564 GWh/yr, with China accounting for 59% of the world's lithium-ion battery production capacity, Europe and the rest of Asia accounting for 16% and 14% of capacity, respectively, and North America accounting for the remaining capacity (Benchmark Mineral Intelligence, 2018).

References Cited

Albemarle Corp., 2017a, Albemarle investor day: Charlotte, NC, Albemarle Corp. presentation, March 16, 135 p. (Accessed September 27, 2017, at https://investors.albemarle.com/static-files/3f193c43-bc7e-4b05-ae1a-bf15735fb1d5.)

Albemarle Corp., 2017b, Albemarle positioned to double lithium concentrate production at Greenbushes facility: Charlotte, NC, Albemarle Corp. press release, March 16, 2 p. (Accessed September 27, 2017, at https://investors.albemarle.com/node/12081/pdf.)

Albemarle Corp., 2018a, Applications: Charlotte, NC, Albemarle Corp. (Accessed September 7, 2018, at https://www.albemarle.com/businesses/lithium/markets--applications.)

Albemarle Corp., 2018b, Form 10–K—2017: U.S. Securities and Exchange Commission, 147 p. (Accessed March 10, 2018, at https://investors.albemarle.com/static-files/4894e87c-6670-4983-92aa-94ed0fe766fa.)

Asian Metal Inc., 2017a, Chinese lithium hydroxide prices firm: Beijing, China, Asian Metal Inc., December 28. (Accessed February 15, 2018, via http://www.asianmetal.com.)

Asian Metal Inc., 2017b, Chinese lithium metal prices up: Beijing, China, Asian Metal Inc., November 9. (Accessed February 15, 2018, via http://www.asianmetal.com.)

Asian Metal Inc., 2018, Chinese lithium carbonate market sees limited deals: Beijing, China, Asian Metal Inc., January 5. (Accessed February 15, 2018, via http://www.asianmetal.com.)

Benchmark Mineral Intelligence, 2018, Tesla's gigafactory to be world's biggest battery plant, but China will dominate electric vehicle lithium-ion production for next decade: Benchmark Mineral Intelligence, August 5. (Accessed September 8, 2018, at https://www.benchmarkminerals.com/teslas-gigafactory-to-be-worlds-biggest-battery-plant-but-china-will-dominate-electric-vehicle-lithium-ion-production-for-next-decade/.)

Chung, Donald, Elgqvist, Emma, and Santhanagopalan, Shriram, 2016, Automotive lithium-ion cell manufacturing—Regional cost structures and supply chain considerations: U.S. Department of Energy, April, 20 p. (Accessed June 9, 2016, at http://www.nrel.gov/docs/fy16osti/66086.pdf.)

Defense Logistics Agency Strategic Materials, 2017, Annual Materials Plan for FY 2018 (potential acquisitions): Fort Belvoir, VA, Defense Logistics Agency Strategic Materials, October 1, 1 p. (Accessed October 16, 2017, at http://www.dla.mil/Portals/104/Documents/StrategicMaterials/Announcements/3135%20FY18%20AMP_ACQ.pdf?ver=2017-09-29-133651-237.)

Enirgi Group Corp., 2014, Enirgi Group validates revolutionary new proprietary lithium extraction technology: Toronto, Ontario, Canada, Enirgi Group Corp. press release, October 29, 2 p. (Accessed November 4, 2014, at https://www.globenewswire.com/news-release/2014/10/29/677908/10105194/en/Enirgi-Group-Validates-Revolutionary-New-Proprietary-Lithium-Extraction-Technology.html.)

Enirgi Group Corp., 2016, Enirgi Group announces positive results of definitive feasibility study for Salar del Rincón Lithium Project: Toronto, Ontario, Canada, Enirgi Group Corp. press release, July 7, 13 p. (Accessed September 12, 2016, at https://finance.yahoo.com/news/enirgi-group-announces-positive-results-180919697.html.)

FMC Corp., 2018, Annual report—2017: Philadelphia, PA, FMC Corp., February, 98 p. (Accessed July 30, 2018, at https://materials.proxyvote.com/Approved/302491/20180227/AR10K_349309.PDF.)

Galaxy Resources Ltd., 2018, Annual report—Year ended 31 December 2017: Applecross, Western Australia, Australia, Galaxy Resources Ltd., March, 112 p. (Accessed April 20, 2018, at http://www.gxy.com/Investor/Annual%20Report%2031%20Dec%202017.pdf.)

Government of Western Australia, Department of Mines, Industry Regulation and Safety, 2018, Latest statistics release—2017–18 major commodities resources file: Perth, Western Australia, Australia, Government of Western Australia, Department of Mines, Industry Regulation and Safety. (Accessed December 20, 2018, via http://www.dmp.wa.gov.au/About-Us-Careers/Latest-Statistics-Release-4081.aspx.)

Industrial Minerals, 2017, IM's December price movements: Industrial Minerals, December 22. (Accessed January 19, 2018, via http://indmin.com.)

Ingram, Tess, 2017, Tianqi Lithium approves $300m Kwinana lithium plant expansion: The Australian Financial Review [Melbourne, Victoria, Australia], October 27. (Accessed January 20, 2018, at https://www.afr.com/business/mining/tianqi-lithium-approves-300m-kwinana-lithium-plant-expansion-20171026-gz95h7.)

Jimenez, Daniel, 2018, Lithium market outlook: Santiago, Chile, Sociedad Química y Minera de Chile S.A. presentation, August 8, 35 p. (Accessed December 1, 2018, at http://s1.q4cdn.com/793210788/files/doc_news/2018/6/Foro-del-Litio-2018-Lithium-Market-Update-20180808-FINAL.pdf.)

Lithium Americas Corp., 2017, Lithium Americas announces positive feasibility study for stage 1 of the Cauchari-Olaroz Lithium Project: Vancouver, British Columbia, Canada, Lithium Americas Corp. press release, March 29. (Accessed April 20, 2017, at http://www.lithiumamericas.com/news/lithium-americas-announces-positive-feasibility-study-for-stage-1-of-the--cauchari-olaroz-lithium-project-.)

Lithium Americas Corp., 2018, Consolidated financial statements December 31, 2017: Vancouver, British Columbia, Canada, Lithium Americas Corp., 70 p. (Accessed May 25, 2018, at https://www.lithiumamericas.com/_resources/pdf/investors/financials/2017/YearEndDecember312017.pdf.)

Lowry, Joe, 2017, Updated supply and demand to 2025: LinkedIn, August 7. (Accessed October 20, 2017, at https://www.linkedin.com/pulse/updated-supply-demand-2025-joe-lowry?trk=portfolio_article-card_title.)

Mineral Resources Ltd., 2017a, First shipment of DSO from Wodgina: Applecross, Western Australia, Australia, Mineral Resources Ltd. press release, April 18. (Accessed September 15, 2017, at http://clients3.weblink.com.au/pdf/MIN/01848470.pdf.)

Mineral Resources Ltd., 2017b, Update—Lithium operations: Applecross, Western Australia, Australia, Mineral Resources Ltd. press release, October 20. (Accessed October 29, 2017, at http://clients3.weblink.com.au/pdf/MIN/01910518.pdf.)

Mineral Resources Ltd., 2018, Quarterly exploration and mining activities report—October to December Q2 FY2018: Applecross, Western Australia, Australia, Mineral Resources Ltd., January 31, 8 p. (Accessed March 17, 2018, at http://clients3.weblink.com.au/pdf/MIN/01946254.pdf.)

Ministerio de Energia y Mineria, 2018, Centro de Informacion Minera de Argentina [Mining Information Center of Argentina]: Buenos Aires, Argentina, Ministerio de Energia y Mineria. (Accessed August 6, 2018, at http://cima.minem.gob.ar/dataset/620/produccion.)

Nemaska Lithium Inc., 2016, Nemaska Lithium provides progress report on mine site and phase 1 plant: Quebec City, Quebec, Canada, Nemaska Lithium Inc. press release, December 12. (Accessed January 10, 2017, at http://www.nemaskalithium.com/en/investors/press-releases/2016/c9777810-db09-4d48-9b81-239e4eac0efb/.)

Nemaska Lithium Inc., 2018, Management discussion & analysis—Period ended December 31, 2017—Second quarter: Quebec City, Quebec, Canada, Nemaska Lithium Inc., February 13, 39 p. (Accessed March 23, 2018, at https://www.nemaskalithium.com/assets/documents/financialdocuments/nemaska-lithium-mda-2017-12-31-sedar.pdf.)

Neometals Ltd., 2017a, Annual report 2017: West Perth, Western Australia, Australia, Neometals Ltd., 104 p. (Accessed December 5, 2017, at http://member.afraccess.com/media?id=CMN://6A856411&filename=20171023/NMT_01911272.pdf.)

Neometals Ltd., 2017b, Quarterly activities report for the quarter ended 31 December 2016: West Perth, Western Australia, Australia, Neometals Ltd., January 31, 12 p. (Accessed February 5, 2017, at http://www.neometals.com.au/reports/695-QADec2016Final.pdf.)

Neometals Ltd., 2018, Half-year report for the 6 months ended 31 December 2017: West Perth, Western Australia, Australia, Neometals Ltd., March 5, 21 p. (Accessed April 25, 2018, at https://www.neometals.com.au/reports/2018-03-09-1335-HalfYearAc.pdf.)

Orocobre Ltd., 2017, Quarterly report of operations for the period ended 30 June 2017: Brisbane, Queensland, Australia, Orocobre Ltd., July 19, 18 p. (Accessed November 3, 2017, at https://www.orocobre.com/wp/?mdocs-file=3259.)

Orocobre Ltd., 2018, Quarterly report of operations for the period ended 31 December 2017: Brisbane, Queensland, Australia, Orocobre Ltd., January 16, 26 p. (Accessed April 19, 2018, at https://www.orocobre.com/wp/?mdocs-file=3609.)

Paul, Sonali, 2016, China's Tianqi Lithium to build $300 mln plant in Australia: Thomson Reuters, September 6. (Accessed September 8, 2018, at http://www.reuters.com/article/tianqi-lithium-australia-idUSL3N1BI2PW.)

Ralph, Julia, 2016, The rise of lithium—Demand set to surge: London, United Kingdom, CRU Group, April 14. (Accessed May 23, 2016, at http://rockstone-research.com/index.php/en/news/385-The-Rise-Of-Lithium:-Demand-Set-To-Surge.)

Retriev Technologies Inc., 2017, Lessons from recycling multiple types of batteries—Public workshop on lead-acid batteries and alternatives: Anaheim, CA, Retriev Technologies Inc., November 6, 29 p. (Accessed July 1, 2018, at https://dtsc.ca.gov/wp-content/uploads/sites/31/2018/10/Tod-Coy_Lead-acid-Batteries-Workshop_11-6-2017.pdf.)

Rincon Ltd., 2019, Rincon lithium project overview: Toronto, Ontario, Canada, Rincon Ltd. presentation, February, 15 p. (Accessed March 1, 2019, at http://www.rinconltd.com/wp-content/uploads/2019/02/Rincon-Lithium-project-summary-Corporate-presentation-February-2019.pdf.)

Roskill Information Services Ltd., 2018, Lithium—Global industry, markets and outlook 2018 (15th ed.): London, United Kingdom, Roskill Information Services Ltd., June, 432 p.

Servicio Nacional de Geología y Minería, 2018, Anuario de la mineria de Chile, 2017 [Chilean mining yearbook, 2017]: Santiago, Chile, Servicio Nacional de Geología y Minería, 274 p. (Accessed August 30, 2018, at https://www.sernageomin.cl/wp-content/uploads/2018/06/Anuario_2017.pdf.)

Sociedad Química y Minera de Chile S.A., 2018a, Annual report—2017: Santiago, Chile, Sociedad Química y Minera de Chile S.A., April, 403 p. (Accessed May 9, 2018, at http://s1.q4cdn.com/793210788/files/doc_financials/2017/Memoria-Anual-2017_eng.pdf.)

Sociedad Química y Minera de Chile S.A., 2018b, SQM 2017 results: Santiago, Chile, Sociedad Química y Minera de Chile S.A. presentation, March 1, 10 p. (Accessed May 9, 2018, at http://s1.q4cdn.com/793210788/files/doc_financials/2017/q4/SQM-CorpPres_4Q17_final.pdf.)

U.S. Department of Energy, 2013, Energy storage research and development 2012 progress report: U.S. Department of Energy. (Accessed April 17, 2013, via http://energy.gov/eere/vehicles/fy-2012-progress-report-energy-storage-rd.)

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Historical Statistics for Mineral and Material Commodities in the United States. Data Series 140.
Lithium. Ch. in Critical Mineral Resources of the United States—Economic and Environmental Geology and Prospects for Future Supply, Professional Paper 1802, 2017.
Lithium. Ch. in Mineral Commodity Summaries, annual.
Lithium. International Strategic Minerals Inventory Summary Report, Circular 930–I, 1990.
Lithium (Li). Ch. in Metal Prices in the United States Through 2010, Scientific Investigations Report 2012–5188, 2013.
Lithium Resources and Requirements by the Year 2000. Professional Paper 1005, 1976.

Other

Lithium. Ch. in Minerals Facts and Problems, U.S. Bureau of Mines Bulletin 675, 1985.
Lithium. U.S. Bureau of Mines Information Circular 9102, 1986.

TABLE 1
SALIENT LITHIUM STATISTICS[1]

(Metric tons of contained lithium)

	2013	2014	2015	2016	2017
United States:					
Production	870 [2]	W	W	W	W
Exports[3]	1,230	1,420	1,790	1,520	1,960
Imports[3]	2,210	2,120	2,750	3,140	3,330
Consumption[e]	1,800	2,000 [4]	2,000 [4]	3,000 [4]	3,000 [4]
Rest of world, production[5]	29,100 [r]	31,300 [r]	31,700 [r]	39,300 [r]	68,500

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Table includes data available through July 31, 2019. Data are rounded to no more than three significant digits.
[2]Source: Rockwood Holdings, Inc., 2014, 2013 annual report: Rockwood Holdings, Inc., p. 16.
[3]Compounds. Source: U.S. Census Bureau.
[4]Rounded to one significant digit to avoid disclosing company proprietary data.
[5]Mineral concentrate, lithium carbonate, lithium chloride, and lithium hydroxide.

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

Compound and country or locality	2016 Gross weight (metric tons)	2016 Value[2] (thousands)	2017 Gross weight (metric tons)	2017 Value[2] (thousands)
Lithium carbonate:				
Australia	10	$73	1	$14
Belgium	5	40	2	5
Canada	52	227	74	336
Colombia	1	12	3	11
Germany	903	5,340	944	7,370
India	42	284	--	--
Japan	--	--	166	2,180
Korea, Republic of	5	19	39	534
Panama	(3)	6	5	19
Taiwan	3	33	73	947
Other	17 r	119 r	2	17
Total	1,040	6,150	1,310	11,400
Total Li content	195	XX	246	XX
Lithium carbonate, U.S.P.:[4]				
Belgium	1	39	3	80
India	57	1,940	86	3,200
Israel	1	40	3	85
Korea, Republic of	10	391	--	--
Mexico	16	16	--	--
Other	23 r	298 r	3	108
Total	108	2,720	94	3,480
Total Li content	20	XX	18	XX
Lithium hydroxide:				
Argentina	204	1,750	175	2,320
Australia	30	278	45	661
Belgium	325	2,380 r	378	5,290
Canada	428	1,850	700	4,120
Chile	10	67	24	209
China	140	1,460	93	1,350
Colombia	23	222	10	108
Egypt	116	1,010	44	493
France	(3)	66	4	47
Germany	757	5,230	1,340	13,700
India	45	599	(3)	7
Japan	4,920	46,100	7,100	76,100
Korea, Republic of	142	1,600	75	858
Mexico	76	807	27	580
Nigeria	--	--	5	40
Peru	12	127	10	190
Saudi Arabia	72	483	10	100
Singapore	49	604	28	454
South Africa	4	282	1	138
Taiwan	342	3,110	62	915
Thailand	166	1,790	166	2,860
Trinidad and Tobago	2	29	4	67
United Kingdom	18	167	3	230
Other	25 r	535 r	4	269
Total	7,910	70,600	10,300	111,000
Total Li content	1,300 r	XX	1,700	XX

rRevised. XX Not applicable. -- Zero.
[1]Table includes data available through July 31, 2019. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Free alongside ship value.
[3]Less than ½ unit.
[4]Pharmaceutical-grade lithium carbonate.

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	2016		2017	
	Gross weight (metric tons)	Value[2] (thousands)	Gross weight (metric tons)	Value[2] (thousands)
Lithium carbonate:				
Argentina	10,500	$54,000	9,830	$47,600
Canada	4	28	5	$12
Chile	4,660 r	21,000	6,140	30,400
China	333	1,060	23	77
India	--	--	9	24
Japan	(3)	2	76	763
United Kingdom	10	31	38	105
Other	5 r	29 r	3	21
Total	15,600	76,100	16,100	79,000
Total Li content	2,920	XX	3,030	XX
Lithium carbonate, U.S.P.,[4] India	16	508	--	--
Lithium carbonate, U.S.P.,[4] India, Li content	3	XX	--	XX
Lithium hydroxide:				
Belgium	--	--	37	430
Canada	4	24	2	12
Chile	830	6,830	662	10,800
China	127	1,490	543	9,250
Korea, Republic of	1	20	17	313
Romania	45	248	--	--
Russia	266	3,010	561	6,980
Taiwan	--	--	5	29
Other	3 r	62 r	2	89
Total	1,280	11,700	1,830	27,900
Total Li content	211	XX	302	XX

rRevised. XX Not applicable. -- Zero.
[1]Table includes data available through July 31, 2019. 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, gross weight)

Country or locality[2]	2013	2014	2015	2016	2017
Argentina, subsurface brine:					
Lithium carbonate	9,248	11,698	21,111 r	24,409 r	26,559
Lithium chloride	5,156	7,370	5,848	6,468 r	4,501
Australia, spodumene	405,119 r	444,546 r	433,846 r	440,525 r	1,706,618
Brazil, concentrates	7,982	8,519	5,781 r	6,000 r, e	6,000 e
Chile, subsurface brine:					
Lithium carbonate	52,358	55,074	50,418	70,831 r	73,563
Lithium chloride	4,091	2,985	2,069	1,775 r	2,535
Lithium hydroxide	4,197	4,194	3,888	5,576 r	5,280
China, lithium carbonate equivalent[3]	19,068 r	18,810 r	20,470 r	25,400 r	36,339
Portugal, lepidolite	19,940	17,459	17,120	25,800	50,743
United States, lithium carbonate	4,600 [4]	W	W	W	W
Zimbabwe, amblygonite, eucryptite, lepidolite, and petalite	50,000 e	50,000 e	50,000 e	50,000 e	40,000

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

[1]Table includes data available through August 22, 2018. All data are reported unless otherwise noted. Estimated data are rounded to no more than three significant digits.

[2]Countries and (or) localities in addition to those listed may have produced small quantities of lithium minerals, but available information was inadequate to make reliable estimates of output.

[3]Produced from subsurface brine and concentrates.

[4]Source: Rockwood Holdings, Inc., 2014, 2013 annual report: Rockwood Holdings, Inc., p. 16.

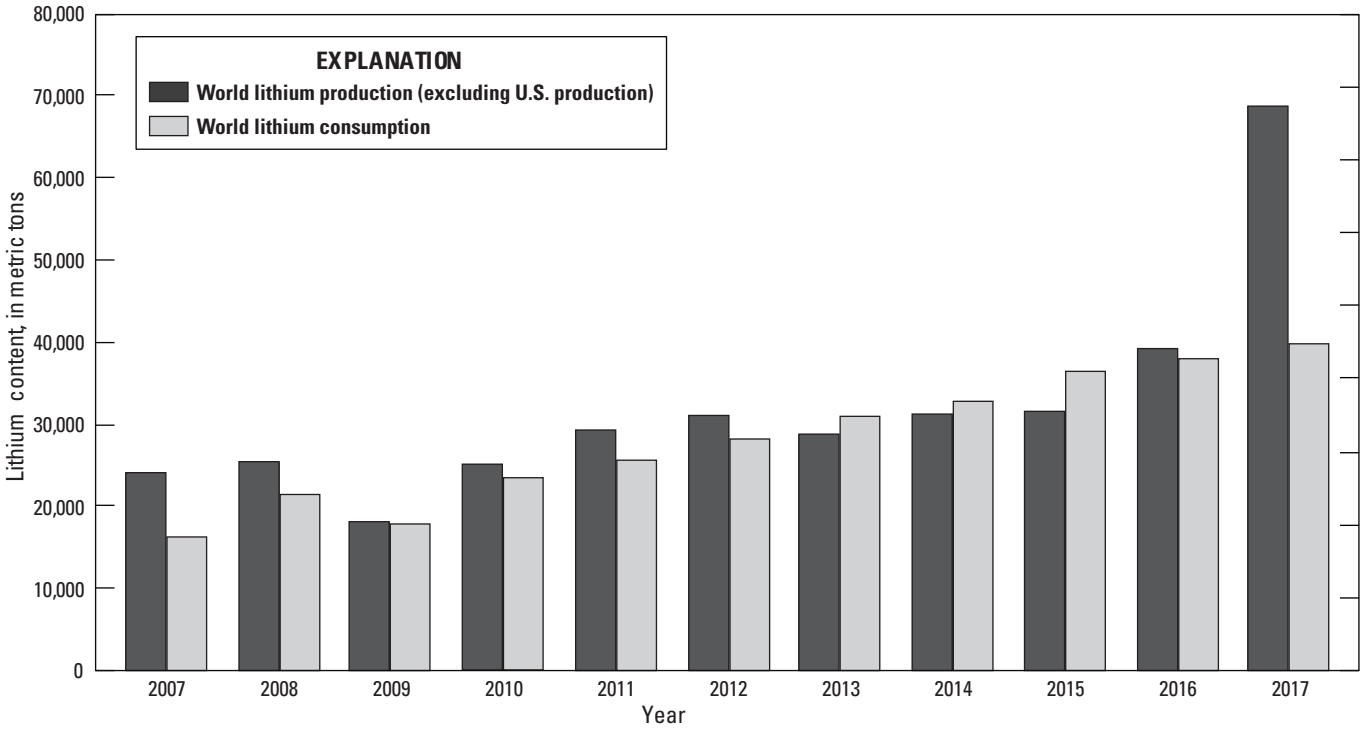

Figure 1. Estimated world lithium production (excluding U.S. production) and consumption from 2007 through 2017.