LITHIUM

By Joyce A. Ober

After decades as the world's leading producer of lithium and its compounds, the United States was surpassed in 1997 when Chile became the world's largest lithium carbonate producer. Both lithium carbonate operations at the Salar de Atacama produced during the entire year for the first time. An additional lithium carbonate brine operation began producing in Argentina, further shifting lithium production dominance to South America.

The United States maintained its position as leading producer of value-added lithium compounds and also as leading lithium consumer, despite the production shift to South America. Australia, Canada, and Zimbabwe were important sources of lithium ore concentrates.

Because lithium is electrochemically reactive and has other unique properties, there are many commercial lithium products. Producers sell lithium as mineral concentrate, brine, compound, or metal depending on the end use. Most lithium compounds are consumed in the production of ceramics, glass, and primary aluminum.

Legislation and Government Programs

The U.S. Naval Surface Warfare Center in Crane, IN, awarded a $10.5 million contract to recycle lithium batteries that had been used as backup power sources at underground missile silos. ToxCo, Inc., a recycling company based in Anaheim, CA, will process the batteries at its Trail, British Columbia, Canada, plant. Each battery weighs more than 1,200 kilograms and ToxCo will receive and process almost 4,400 batteries during the next 4 years. Aluminum, lithium, nickel, and stainless steel will be recovered from the batteries and returned to use (Scott, 1997).

In 1994, ToxCo developed a process for recycling lithium battery components and opened its facility for the neutralization, disposal, and recycling of lithium batteries, primarily large military types, in Trail (Vimmerstedt and others, 1995, p. 25-26). ToxCo expanded this operation to accommodate the Navy contract. The recycling of the military batteries was expected to begin early in 1998 (Rodlie, 1997). The lithium materials from the recycling operation will be sent to New Zealand for reprocessing by Pacific Lithium Ltd. The resulting lithium carbonate will be marketed in the United States by ToxCo's subsidiary LithChem International (ToxCo Waste Management Ltd., 1997).

Production

The U.S. Geological Survey collects domestic production data for lithium from a voluntary survey of U.S. operations. Two U.S. companies responded to the survey, representing 100% of total production. Production and stock data were withheld from publication to avoid disclosing company proprietary data. *(See table 1.)*

Cyprus Foote Mineral Co. of Kings Mountain, NC, produced about 5,700 tons of lithium carbonate from its brine deposit in Silver Peak, NV (Cyprus Amax Minerals Co., 1998). In addition to its Nevada operation where the company also produces lithium hydroxide, Cyprus Foote, the world's largest lithium company and a subsidiary of Cyprus Amax Minerals Co., owns a spodumene mine in Kings Mountain that has been inactive since 1991. A lithium carbonate plant in Kings Mountain was dismantled in 1994. The company operates a butyllithium plant in New Johnsonville, TN. Cyprus Foote also owns and operates a large lithium operation in Chile.

In December, Cyprus Amax announced its intention to sell its lithium operations in order to concentrate on its core mining interests. The company intended to sell its lithium assets, which are more closely related to chemical manufacturing than mining, to strengthen its financial status and to focus on its coal, copper, and molybdenum operations (Platt's Metals Week, 1997).

FMC Corp., Lithium Div., mines spodumene, a lithium aluminum silicate ore, from pegmatite dikes near Bessemer City, NC. FMC also produces lithium carbonate and a full range of downstream compounds, including lithium metal and some organic lithium compounds, at a chemical plant near the mine and operates a butyllithium plant in Bayport, TX. FMC is developing a large lithium brine operation in Argentina. This project was completed during the last half of the year and was expected to result in the closure of the mine and lithium carbonate plant in North Carolina. All other FMC lithium facilities in the United States were to continue to operate (FMC Corp., 1998).

Lithium carbonate is the most important lithium compound produced from brine and ore deposits. Spodumene was the major raw material required for the production of lithium carbonate in North Carolina, and small amounts of spodumene concentrate were produced for sale. Spodumene is the most common lithium ore, but petalite and lepidolite are other types that are mined in different parts of the world. These three are beneficiated to produce lithium concentrates that can be consumed directly in certain applications. Spodumene concentrates and brines are converted to lithium carbonate and then to other compounds for consumption in other end uses.

Extracting lithium from spodumene entails an energy-intensive chemical recovery process. After mining, spodumene is crushed and undergoes a flotation beneficiation process to produce concentrate. Concentrate is heated to 1,075 °C to 1,100 °C, changing the molecular structure of the mineral and making it more reactive to sulfuric acid. A mixture of finely ground converted spodumene and sulfuric acid is heated to 250 °C, forming lithium sulfate. Water is added to the mixture to dissolve the lithium sulfate. Insoluble portions are then removed by filtration. The purified lithium sulfate solution is treated with soda ash, forming insoluble lithium carbonate that precipitates from solution. The carbonate is separated and dried for sale or use by the producer as feedstock in the production of other lithium compounds.

Production of lithium carbonate from brine is much less energy intensive than production from spodumene. Nevada brines enriched in lithium chloride, averaging about 300 parts per million when operation began in 1966 (Engineering and Mining Journal, 1970), are pumped from the ground and progress through a series of evaporation ponds. Over the course of 12 to 18 months, concentration of the brine increases to 6,000 parts per million lithium through solar evaporation. When the lithium chloride reaches optimum concentration, the liquid is pumped to a recovery plant and treated with soda ash, precipitating lithium carbonate. The carbonate is then removed through filtration, dried, and shipped. Approximately the same process is used to recover lithium from the Chilean brines, with slight adjustments to account for their different chemistries. The brine operation in Argentina uses a different, proprietary technology that allows for the lithium recovery as either carbonate or chloride (FMC Corp., 1998).

Consumption

The aluminum, ceramics and glass, lubricating grease, and synthetic rubber industries consumed most of the lithium minerals and chemicals sold in 1997. Estimated domestic consumption increased slightly from 1996. Ceramics and glass production and aluminum smelters were the largest consumers of lithium carbonate and lithium concentrates in the United States, composing an estimated 20% and 18% of the lithium market, respectively. Other consuming industries were synthetic rubber and pharmaceuticals, 13%; chemical manufacturing, 13%; miscellaneous chemicals, 12%; lubricants, 11%; batteries, 7%; and air treatment, 4% (Cyprus Minerals Co., 1993).

The largest use of lithium compounds in the United States are lithium as carbonate and mineral concentrate additions in ceramics and glass manufacturing processes. These additions lower process melting points, reduce the coefficient of thermal expansion and the viscosity, and eliminate the use of more toxic chemicals. The domestic manufacture of thermal shock-resistant cookware (pyroceramics) consumes the majority of lithium used in the ceramics and glass industry. The manufacture of black-and-white television picture tubes consumes significant amounts of lithium concentrates overseas. Low-iron spodumene and petalite are sources of the lithium used to improve the physical properties of container and bottle glass and as a source of alumina, another important component of the glass. Glass manufacturers use lithium in container and bottle glass, enabling them to produce lighter weight, thinner walled products.

The second largest use, aluminum production, adds lithium carbonate to aluminum potlines to lower the melting point of the bath, allowing a lower operating temperature for the potline, and increasing the electrical conductivity of the bath. These factors contribute to increased production or reduced power consumption, as well as to the indirect benefit of lower fluoride emissions.

The third largest end use for lithium compounds is as catalysts in the production of synthetic rubbers, plastics, and pharmaceuticals. N-butyllithium initiates the reactions between styrene and butadiene that form abrasion-resistant synthetic rubbers that require no vulcanization. Other organic lithium compounds are catalysts for the production of plastics, such as polyethylene. Lithium metal and compounds also are used by pharmaceutical manufacturers in the production of vitamin A, some steroids, an anticholesterol agent, an analgesic, antihistamines, tranquilizers, sleep inducers, contraceptives, and other products. Pharmaceutical-grade lithium carbonate is approved directly for the treatment for manic-depressive psychosis. This is the only treatment approved by the U.S. Food and Drug Administration in which lithium is consumed by the patient.

The multipurpose grease industry was another of the important markets for lithium in 1997. Lithium hydroxide monohydrate was the compound used for the production of lithium lubricants. Lithium-base greases are favored for their retention of lubricating properties over a wide temperature range; good resistance to water, oxidation, and hardening; and formation of a stable grease on cooling after melting. These greases continued to be used in military, industrial, automotive, aircraft, and marine applications.

The use of lithium in batteries and the belief that lithium batteries may be the best way to power electric vehicles (EV's) has spurred tremendous interest in lithium and lithium deposits to provide resources for the anticipated increased demand. Almost all major battery manufacturers marketed some type of lithium batteries, and research and development continued. New battery configurations continue to be developed, and continued interest in EV's drove additional interest in battery research. New, more efficient types of rechargeable (secondary) lithium batteries have been developed and improved to meet the requirements of this market and of electronic equipment, such as portable telephones and video cameras. Work continued on lithium-ion batteries. These batteries are of particular interest because they take advantage of the large power capacity available from lithium batteries with fewer safety problems than encountered when batteries contain lithium metal, a very reactive and volatile material when exposed to air and moisture. Nissan Motor Corp. U.S.A. planned to introduce its first EV available in the United States at the 1998 Los Angeles Auto Show. The four-passenger minivan will be powered by lithium-ion batteries developed jointly by Nissan and Sony Corp. (Advanced Battery Technology, 1998b).

Nonrechargeable (primary) lithium batteries offer improved performance over alkaline batteries at a slightly higher cost and have been commercially available for more than 10 years. They are used in watches, microcomputers, cameras, small appliances, electronic games, and toys. The military purchased large and small lithium batteries for a variety of military applications. The Mars Pathfinder spacecraft, launched in December 1996 by the National Aeronautics and Space Administration (NASA) landed on Mars in July. It contained lithium thionyl chloride batteries that powered communications between Pathfinder and NASA during the journey, provided backup power to the solar-powered Mars rover named "Sojourner" in the event of the failure of the solar panels, and kept Sojourner's electronics operating during the night (ITE Battery Newsletter, 1998).

Aircraft manufacturers in several countries have considered using aluminum-lithium alloys for wing and fuselage skin or structural members in different types of aircraft. Use of these alloys could reduce the weight of the aircraft by more than 10%, allowing significant fuel savings during the life of the aircraft. The alloys, which are 2% to 3% lithium by weight, are attractive to the aircraft and aerospace industries because of their reduced density and superior corrosion resistance compared with those of conventional aluminum alloys. These alloys are not as widely used in aircraft manufacture as was hoped at the initial introduction of the alloys. In airplane construction, these alloys face direct competition from composite materials consisting of boron, graphite, or aramid fibers imbedded in polymers. Reynolds Metals Co. produces an aluminum-lithium alloy that is being used for a fatigue critical aft bulkhead replacement and other parts on the F-16 fighter plane built by Lockheed Martin. The alloy is produced at Reynolds' McCook, IL, plant (Light Metal Age, 1998).

NASA selected a new design by Lockheed Martin Manned Space Systems for the external fuel tank used on the space shuttle (the only part that is not reused) that is made with another Reynolds aluminum-lithium alloy. The super-lightweight tank is constructed of an alloy containing 1% lithium, 4% copper, 0.4% silver, 0.4% magnesium, and the remainder aluminum. This alloy is 30% stronger and 5% less dense than the aluminum alloy previously used. The redesigned fuel tank will weigh about 3,400 kilograms less than the current design; the weight savings can be used to increase the payload capacity for future shuttle missions. The first of 25 of the redesigned tanks was scheduled to be used in May 1998 for the first shuttle launch carrying the portions of the international space station (Light Metal Age, 1998).

Small quantities of other lithium compounds are important to many industries. Lithium chloride and lithium bromide are used in industrial air-conditioning and commercial dehumidification systems and in the production of sophisticated textiles. Sanitizers for swimming pools, commercial glassware, and public restrooms contain lithium hypochlorite, as do dry bleaches for commercial laundries. Lithium metal is used as a scavenger to remove impurities from copper and bronze, and anhydrous lithium chloride is used as a component in fluxes for hard-to-weld metals, such as steel alloys and aluminum.

Prices

Although yearend published prices for lithium carbonate were slightly higher than in 1996, actual prices paid by customers were believed to be significantly lower. The vigorous entrance into the market of Minsal S.A., a Chilean company with an aggressive pricing strategy, forced Cyprus Foote and FMC to reduce their prices comparably. Lithium hydroxide monohydrate increased about 4%, and technical-grade lithium metal increased about 7%. Price changes varied by compound, but overall, prices were stable. *(See table 2.)*

Foreign Trade

Total U.S. exports of lithium compounds were nearly 13% lower in 1997 than in 1996. This decrease was at least partly due to the competition for overseas customers from Minsal. About 62% of all U.S. exports of lithium compounds were to Canada, Germany, Japan, and the United Kingdom. Exports of lithium carbonate to these countries decreased 40% in 1997, indicating that the new producer had a major impact on the world market.

Imports of lithium compounds increased 10%. Imports should increase dramatically during the next 2 years when FMC's Argentina operation reaches full production and the North Carolina carbonate plant closes. Chile accounted for 97% of all imports. Lithium ore concentrates from Australia, Canada, and Zimbabwe were believed to have been consumed in the United States, but no import statistics were available. *(See tables 3 and 4.)*

World Review

A small number of countries throughout the world produced lithium ore and brine. Chile and the United States were the leading producers of lithium carbonate. Argentina produced small quantities of ore concentrates and was expected to become a leading lithium carbonate producer by the turn of the century. Significant quantities of lithium compounds and ore concentrates also were produced in Australia, Canada, Chile, China, Portugal, Russia, and Zimbabwe. Brazil and Namibia produced smaller quantities, primarily concentrates. Rwanda, South Africa, and Zaire are past producers of concentrates. Pegmatites containing lithium minerals have been identified in Austria, France, India, Ireland, Mozambique, Spain, and Sweden, but economic conditions have not favored development of the deposits. Lithium has been identified in subsurface brines in Bolivia, China, and Israel. Companies in France, Germany, Japan, and the United Kingdom produced downstream lithium compounds from imported lithium carbonate.

Argentina.—FMC produced its first lithium carbonate from its lithium brine operation on the Salar de Hombre Muerto in the Argentine Andes. A proprietary selective purification process developed by FMC reduces the number of steps required to recover lithium chloride from the brine and reduces the cost of production compared with other lithium brine operations. Lithium chloride production was scheduled to begin in 1998. Reserves at the Salar should last at least 75 years at design capacity (FMC Corp., 1998). Design capacity is about 20,000 tons of lithium carbonate equivalent (Kendall, 1997, p. 51).

Australia.—Gwalia Consolidated Ltd. is the largest producer of lithium ore concentrates in the world and the only lithium producer in Australia. In 1997, the company closed its lithium carbonate plant. The plant, which began operating in 1996, had technical problems from the start. By the time those problems had been solved, the market had eroded to the point that the project could not be profitable under the prevailing conditions. Gwalia was investigating the viability of the project if a byproduct analcite (a sodium aluminum silicate) was included in the calculations. The company's spodumene concentrate production and sales remained strong (Industrial Minerals, 1997a).

Canada.—In addition to the spodumene mine and concentrating plant operated by Tantalum Mining Corp., a subsidiary of Hudson Bay Mining Co., at Bernic Lake, Manitoba, development of three additional lithium projects were under consideration in Canada. One of the projects could produce lithium metal from purchased lithium carbonate, one may develop a petalite deposit for the production of ore concentrates, and one was to develop a spodumene mine and a lithium carbonate plant.

The continued interest in lithium batteries and the potential growth of the industry if electric vehicles are powered by lithium batteries have prompted Lithos Corp. of Montreal to develop the technology for producing lithium metal directly from lithium carbonate, eliminating the need to convert it to lithium chloride first. The company believes that its process could cut the production cost for lithium metal by up to 25%. During the year, Lithos created a subsidiary, Limtech Inc., devoted to their lithium metal project. All the lithium assets of Lithos were transferred to Limtech, including the spodumene deposits, patents for the novel lithium metal production technology, and the commercial rights to these patents (Lithos Corp., 1997). Construction of a pilot plant for the production of 20 to 30 tons per year of lithium metal was planned for 1998 (North American Mineral News, 1997).

Avalon Ventures Ltd. was working to outline reserves at its Separation Rapids rare metals property in northwest Ontario. Earlier drilling determined the principal mineral in the Big Whopper deposit to be petalite (lithium aluminum silicate) containing 1.5% to 1.6% lithium oxide; the deposit also contains cesium, rubidium, and tantalum. Avalon was considering the development of a surface mine and a processing plant for the production of petalite concentrates for use in ceramics and glass (Skillings Mining Review, 1997).

Raymor Resources Ltd. was considering the development of a spodumene deposit in Quebec for the purpose of producing lithium carbonate. Raymor's La Motte property is in the Abitibi region of Quebec and the company has identified reserves totaling about 7 million tons at 1.07% lithium oxide. The deposit is amenable to surface mining (Raymor Resources Ltd., 1997).

Chile.—Minsal operated its lithium carbonate operation at the Salar de Atacama for the first full year, producing about 9,000 tons and reaching the plant's design capacity of 20,000 tons per year by the end of 1997 (Phosphorus and Potassium, 1998). The reduction in U.S. exports of lithium carbonate, especially to Canada, Germany, and Japan, indicated that Minsal may have captured some of the market that has traditionally received lithium made in the United States. Minsal's strategy since entering the market has been to offer its lithium carbonate at a significantly lower price than Cyprus Foote or FMC in order to capture market share. A longer-term goal was to expand the market for lithium carbonate by making lower-cost lithium a more attractive input to cost-sensitive processes (Industrial Minerals, 1997c). For example, additions of lithium hydroxide to some concrete have been shown to prevent the abnormal expansion that causes premature cracking attributed to alkali silica reactivity. The price of lithium hydroxide, however, has been too high to encourage the use of lithium to improve the quality of the concrete (Stark, 1993). Substantially reduced lithium prices could make this application more attractive. In December, Minsal made its first shipment of lithium carbonate to Russia. A Russian company agreed to purchase about 30% of Minsal's annual production to produce downstream lithium chemicals for sale to customers in the former Soviet Union. Minsal's low prices were competitive with those offered by a lithium carbonate producer in Russia (Industrial Minerals, 1997b).

Cyprus Foote began operating a lithium brine project at the Salar de Atacama in 1984. The company reported production of 13,000 tons of lithium from its lithium carbonate plant, also in Antofagasta, in 1997 (Cyprus Amax Minerals Co., 1998). With both plants at the Salar operating for the entire year, Chile became the largest lithium producer in the world. Its dominance will increase when Minsal doubles production and when FMC closes its mine in North Carolina, both are expected in 1998.

New Zealand.—Pacific Lithium Ltd. of Aukland has a long-term agreement with ToxCo to purchase most of ToxCo's lithium salts from its Trail, British Columbia, operation and much of the lithium hydroxide monohydrate ToxCo acquired from the Department of Energy in 1996. Pacific Lithium will convert the ToxCo material to high-grade lithium carbonate that can then be used in various forms for lithium batteries (ToxCo Waste Management Ltd., 1997). Pacific Lithium also is developing a process for adsorbing and processing lithium contained in geothermal brines and seawater. If successful, this process would greatly expand the lithium resources worldwide (Pacific Lithium Ltd., 1997).

Geochemistry Research Ltd. is working on a process to remove lithium, silica, and other chemicals from the waste water from geothermal power generators. The Wairakel geothermal powerplant is believed to be polluting the Wacked River with arsenic, boron, and lithium from the plant's waste water. Geochemistry Research, working in cooperation with the Government of New Zealand, has patented a process for recovering high-grade silica from the waste water for use in the paper industry. Research continues for recovering the lithium values (Advanced Battery Technology, 1998a).

Outlook

The health of the lithium industry continues to be closely tied to the performance of the primary aluminum industry, the ceramics and glass industry, and the economy in general. Changes in consumption of lithium in these industries determines the performance of the entire lithium industry. Because these uses represent such a high percentage of the total lithium market, growth in other areas has a much smaller influence. Demand for N-butyllithium is expected to continue to increase, and domestic producers have increased production capacity to meet that demand. Demand for lithium metal for batteries and to some extent for alloys will probably increase, but total consumption of metal will remain low in comparison with the demand for lithium compounds.

Lithium-ion and lithium-polymer batteries appear to possess the greatest potential for growth for the entire lithium industry. The lithium-polymer battery sales have been predicted to exceed $500 million per year within 10 years, a tremendous increase considering that sales of this type of battery were limited in 1997 (Chemical Week, 1997). Add a comparable increase in the sales of lithium-ion batteries, and the figures are astounding. There are no estimates, however, of the amount of lithium required for these batteries.

Too many unknowns remain to allow for a reliable forecast of the quantity of lithium that will be required for the future EV market. Not only is there the question of whether lithium will be part of the superior EV batteries, but will batteries or fuel cells be the preferred sources of power? In addition, there are questions as to when and if EV's will comprise a significant portion of new car sales in the United States and around the world. Sales and leases currently lag behind expectations.

Other markets should remain stable with slight growth. Lithium demand could increase dramatically also, if the technology for nuclear fusion were perfected. This is not expected to take place within the next 25 years, and perhaps never.

New uses of lithium in the remediation of premature deterioration of concrete through alkali silica reactivity could present another large market for lithium compounds; it may, however, take a few years for lithium hydroxide monohydrate additions to become common, if at all. Other uses of lithium to combat structural deterioration of concrete also are being investigated, but it is too early to predict if these new uses will ever become a significant market.

References Cited

Advanced Battery Technology, 1998a, New Zealand—More sources of lithium?: Advanced Battery Technology, v. 34, no. 2, p. 9.

———1998b, Nissan minivan uses Li-ion technology: Advanced Battery Technology, v. 34, no. 2, p. 24-25.

Chemical Week, 1997, Lithium battery growth: Chemical Week, v. 159, no. 31, August 3, p. 41.

Cyprus Amax Minerals Co., 1998, Cyprus Amax 10-K report 1997: Englewood, CO, Cyprus Amax Minerals Co., p. 14.

Cyprus Minerals Co., 1993, Cyprus Minerals annual report 1992: Englewood, CO, Cyprus Minerals Co., p. 14.

Engineering and Mining Journal, 1970, Silver Peak gives bright look to Foote Mineral's lithium picture: Engineering and Mining Journal, v. 171, no. 4, p. 72.

FMC Corp., 1998, FMC annual report 1998: Chicago, IL, FMC Corp., p. 23, 25.

Industrial Minerals, 1997a, Gwalia closes lithium carbonate plant: Industrial Minerals, no. 359, p. 8.

———1997b, Minsal makes first Li_2CO_3 shipment: Industrial Minerals, no. 363, p. 13.

———1997c, Minsal's master plan: Industrial Minerals, no. 359, p. 7.

ITE Battery Newsletter, 1998, Three lithium-thionyl chloride batteries from Saft America: ITE Battery Newsletter, no. 1, p. 6.

Kendall, Tom, 1997, New project round-up—South America: Industrial Minerals, no. 352, p. 51-57.

Light Metal Age, 1998, Aluminum-lithium alloys: Light Metal Age, v. 56, no. 1-2, p. 102-105.

Lithos Corp., 1997, Corporation Lithos—creation of the subsidiary Limtech and nomination of its new CEO: Montreal, Quebec, Canada, Lithos Corp. press release, September 5, 2 p.

North American Mineral News, 1997, Lithium project progress: North American Mineral News, no. 27, p. 16.

Pacific Lithium Ltd., 1997, Company brochure: Aukland, New Zealand, Pacific Lithium Ltd., 6 p.

Platt's Metals Week, 1997, Cyprus Amax to sell Li unit to focus on core businesses: Platt's Metals Week, v. 68, no. 50, December 15, p. 8.

Phosphorus and Potassium, 1998, Set fair for the future: Phosphorus and Potassium, no. 212, p. 16-20.

Raymor Resources Ltd., 1997, Raymor Resources makes significant progress in development of its lithium property: Quebec City, Quebec, Canada, Raymor Resources Ltd. press release, September 19, 2 p.

Rodlie, Lana, 1997, ToxCo wins huge contract: The Trail Times, July 11, p. 1.

Scott, Gary, 1997, Claremont firm wins large contract: Claremont Courier, August 2, p. 5.

Skillings Mining Review, 1997, Avalon Ventures Ltd.'s Separation Rapids rare metals property near Kenora in northwestern Ontario: Skillings Mining Review, v. 86, no. 47, November 22, p. 4-5.

Stark, D., Morgan, B., and Okamoto, P., 1993, Eliminating or minimizing alkali-silica reactivity: National Highway Council, Strategic Highway Research Program, SHRP-C-343, 104 p.

Toxco Waste Management Ltd., 1997, Major breakthrough at Toxco: Trail, British Columbia, Canada, Toxco Waste Management Ltd. press release, February 10, 1 p.

Vimmerstedt, L.J., Shan Ring, and Hammel, C.J., 1995, Current status of environmental, health, and safety issues of lithium ion electric vehicle batteries: National Renewable Energy Laboratory Report NREL/TP-473-7673, 50 p.

SOURCES OF INFORMATION

U.S. Geological Survey Publications

International Strategic Minerals Inventory summary report—Lithium, U.S. Geological Survey Circular 930-I, 1990.

Lithium. Ch. in Mineral Commodity Summaries, annual.[1]

Lithium. Ch. in United States mineral resources, U.S. Geological Survey Professional Paper 820, 1973.

Other

Canadian Minerals Yearbook, annual.

Chemical Market Reporter, weekly.

Chemical Week, weekly.

Engineering and Mining Journal, monthly.

European Chemical News (London), monthly.

Industrial Minerals (London), monthly.

Roskill Information Services Ltd. (London; last reported on lithium in 1994).

[1]Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
SALIENT LITHIUM STATISTICS 1/

(Metric tons of contained lithium)

	1993	1994	1995	1996	1997
United States:					
Production	W	W	W	W	W
Producers' stock changes	W	W	W	W	W
Imports 2/	810	851	1,140	884	978
Exports 2/	1,700	1,700	1,900	2,310 r/	2,010
Consumption:					
Apparent	W	W	W	W	W
Estimated	2,300	2,500	2,600	2,700	2,800
Rest of world: Production 3/	9,430 r/	8,550 r/	11,700 r/	13,800 r/	14,400 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits.
2/ Compounds.
3/ Mineral concentrate and carbonate.

TABLE 2
DOMESTIC YEAREND PRODUCERS' AVERAGE PRICES OF LITHIUM AND LITHIUM COMPOUNDS

	1996		1997	
	Dollars per pound	Dollars per kilogram	Dollars per pound	Dollars per kilogram
Lithium bromide, 54% brine: Truckload lots, delivered in drums	6.06	13.35	5.89	12.96
Lithium carbonate, technical: Truckload lots, delivered	1.97	4.34	2.03	4.47
Lithium chloride, anhydrous, purfied: Truckload lots, delivered	5.13	11.30	5.00	11.00
Lithium fluoride	7.70	16.96	7.43	16.35
Lithium hydroxide monohydrate: Truckload lots, delivered	2.50	5.51	2.61	5.74
Lithium metal ingot, technical grade: 1,000-pound lots, delivered	40.60	89.43	43.33	95.33
N-butylithium in n-hexane (15%): Truckload lots, delivered	20.40	44.93	20.40	44.88

Source: U.S. lithium producers (1996) and Chemical Market Reporter. V. 253, no. 1, January 5, 1998. p. 23-26. Chemical prices for week ending January 2, 1998.

TABLE 3
U.S. EXPORTS OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY 1/

Compound and country	1996 Gross weight (metric tons)	1996 Value (thousands)	1997 Gross weight (metric tons)	1997 Value (thousands)
Lithium carbonate:				
Australia	80	$367	34	$214
Belgium	60	213	12	42
Canada	1,100	2,860	794	2,850
China	16	57	163	562
France	73	221	10	36
Germany	1,460	4,520	268	998
India	44	172	49	158
Japan	2,700	10,500	1,820	6,570
Korea, Republic of	84	289	245	900
Mexico	189	697	94	310
Netherlands	493	1,710	166	594
Taiwan	75	276	75	237
United Kingdom	1,290	4,580	1,070	4,040
Venezuela	1	4	2	8
Other	209 r/	758 r/	149	542
Total	7,870	27,200 r/	4,950	18,100
Lithium carbonate U.S.P.: 2/				
Argentina	3	10	--	--
The Bahamas	--	--	14	28
Germany	--	--	5	6
India	10	38	(3/)	10
Japan	(3/)	7	25	57
Korea, Republic of	1	7	1	7
Mexico	--	--	7	13
Netherlands Antilles	--	--	7	14
Netherlands	--	--	15	31
United Kingdom	2	153	2	31
Other	(3/) r/	5 r/	1	26
Total	16	220	77	223
Lithium hydroxide:				
Argentina	76	320	87	373
Australia	149	660	205	871
Canada	117	476	104	417
Chile	121	424	97	373
China	13	57	232	716
Germany	981	3,720	1,160	4,780
Hong Kong	--	--	58	161
India	353	1,400	783	3,330
Japan	1,100	5,350	994	4,740
Korea, Republic of	240	1,040	187	803
Mexico	137	555	167	739
Netherlands	30	128	91	321
New Zealand	34	90	112	361
Philippines	65	318	57	270
Singapore	82	362	151	666
Thailand	138	604	104	412
Taiwan	18	76	361	1,180
United Kingdom	356	1,470	364	1,460
Other	375 r/	1,900 r/	370	2,250
Total	4,390	18,900	5,680	24,200

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Pharmaceutical-grade lithium carbonate.
3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 4

U.S. IMPORTS FOR CONSUMPTION OF LITHIUM CHEMICALS 1/

Compounds	1996 Quantity (metric tons)	1996 Value 2/ (thousands)	1997 Quantity (metric tons)	1997 Value 2/ (thousands)
Lithium carbonate:				
Chile	4,330	$11,700	5,050	$9,940
China	72	245	--	--
Japan	8	47	5	37
New Zealand	--	--	35	150
Switzerland	180	510	--	--
Other	1	12	1	27
Total	4,590	12,500	5,090	10,200
Lithium hydroxide:				
China	108	449	66	269
Japan	15	898	16	170
Mexico	--	--	26	139
Switzerland	1	38	--	--
Other	2	54	5	104
Total	126	1,440	113	682

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Customs value.

Source: Bureau of the Census.

TABLE 5

LITHIUM MINERALS AND BRINE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country 3/	1993	1994	1995	1996	1997 e/
Argentina, spodumene and amblygonite e/	300	400	400	400	400
Australia, spodumene	52,900 e/	45,987	81,841	117,944	88,399 4/
Brazil, concentrates e/	1,600	1,600	1,600	1,600	1,600
Canada, spodumene e/ 5/	18,900	20,000	41,900 r/	54,000 r/	50,000
Chile, carbonate from subsurface brine	10,369	10,439	12,943 r/	14,180 r/	22,000
China, carbonate e/	8,248	9,050	12,800	15,000	15,500
Namibia, concentrates, chiefly petalite	742	1,861	2,611	2,081 r/	2,000
Portugal, lepidolite	13,289	11,352	10,000 e/	8,740 r/	9,000
Russia (minerals not specified) e/ 6/ 7/	3,000 r/	2,000 r/	2,000 r/	2,000 r/	2,000
United States, spodumene and subsurface brine	W	W	W	W	W
Zimbabwe 8/	18,064	25,279	33,498 r/	30,929 r/	35,000

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Table includes data available through March 31, 1998.

2/ Estimated data are rounded to three significant digits.

3/ In addition to the countries listed, other nations may produce small quantities of lithium minerals, but output is not reported, and no valid basis is available for estimating production levels.

4/ Reported figure.

5/ Based on all of Canada's spodumene concentrates (Tantalum Mining Corp. of Canada Ltd.'s Tanco property).

6/ These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available.

7/ Lithium contained in concentrates and brine.

8/ Amblygonite, eucryptite, lepidolite, petalite, and spodumene.