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LITHIUM

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LITHIUM

By Brian W. Jaskula

Domestic survey data and tables were prepared by Susan M. Weaver, statistical assistant, and the world production table was prepared by Lisa D. Miller, international data coordinator.

In 2009, lithium consumption in the United States was estimated to be 1,300 metric tons (t) of contained lithium, 43% less than the consumption in 2008 and 46% less than in 2007. Decreased U.S. consumption was primarily the result of deteriorating market conditions for lithium-based products in the United States owing to the worldwide economic downturn. Consumers may have run down their existing inventory of lithium compounds in 2009 instead of purchasing new. Therefore, actual lithium consumption may have been greater than the 1,300 t reported, but no data were available to support a higher estimate. Lithium carbonate consumed in industrial applications and used as a raw material for other lithium compounds in the United States was produced at a domestic brine operation in Nevada and imported from Argentina and Chile.

Lithium has historically been mined from two distinct sources—continental brines and hard rock ore. Chile was the world's leading producer of lithium carbonate with production from two lithium brine operations on the Salar de Atacama in the Andes Mountains. Concentrated brines were processed at two lithium carbonate plants in Antofagasta. In the United States, production continued at a lithium brine operation with an associated lithium carbonate plant in Silver Peak, NV. Lithium carbonate and lithium chloride also were produced from brines from the Salar del Hombre Muerto in the Andes Mountains in Argentina. In China, lithium carbonate was produced from brines from the Zabayu Salt Lake in western Tibet and from the Dongtai and Xitai Salt Lakes in Qinghai Province.

Australia was, by far, the leading producer of lithium mineral concentrates, and Brazil, Canada, China, Portugal, and Zimbabwe also produced significant quantities. China was the only country that produced large quantities of lithium carbonate from concentrates, mostly from imported Australian spodumene. A large percentage of the lithium carbonate produced in South America was exported to the United States for consumption in industrial applications and as feed material for the production of downstream lithium compounds, such as lithium hydroxide monohydrate, lithium metal, and organic lithium compounds.

Despite the reduced consumption of lithium in 2009, worldwide lithium resource exploration (led predominantly by Australian and Canadian startup companies) more than doubled compared with that of 2008. The continental brine and clay resources of Nevada were a major focus of this exploration in the United States, as were the pegmatite and oil brine resources of Canada, and the pegmatite resources of Australia. Additionally, Argentina, Bolivia, and Chile saw significant exploration of their continental brines.

Legislation and Government Programs

Under the authority of the American Recovery and Reinvestment Act of 2009 (ARRA; Public Law 111–5), the U.S. Department of Energy (DOE) awarded $1.5 billion in grants to accelerate the development of U.S. manufacturing and production capacity of batteries for electric-drive vehicles and battery recycling. The grants represent the largest single investment in advanced battery technology for hybrid and electric-drive vehicles ever made, and lithium-ion battery technology figured prominently in the awards (U.S. Department of Energy, 2009b). ARRA also funded grants for Smart Grid demonstration and energy storage projects that included large-scale lithium-ion batteries for energy storage (U.S. Department of Energy, 2009c).

As part of its Advanced Technology Vehicles Manufacturing Incentive Program, the DOE loaned Nissan North America, Inc. $1.6 billion to convert its Smyrna, TN, plant to produce electric cars and lithium-ion battery packs. Tesla Motors received a $465 million loan from the DOE to build an automobile manufacturing facility in southern California and a facility in Palo Alto, CA, to assemble lithium-ion battery packs, electric motors, and electric-drive trains (U.S. Department of Energy, 2009a). Fisker Automotive, Inc. received $528 million for the development and production of two lines of lithium-ion battery powered plug-in hybrid electric vehicles (U.S. Department of Energy, 2009d).

Recycling

To begin the process of ramping up their respective lithium battery recycling infrastructures, the Governments of the United States and Germany invested in a private energy company in 2009. As part of ARRA, the DOE awarded $9.5 million to California-based battery recycler Toxco, Inc. to construct the first U.S. recycling facility for lithium-ion vehicle batteries. The company has recycled lithium metal and lithium-ion batteries since 1992 at its Canadian facility in British Columbia. Toxco planned to expand its existing facility in Lancaster, OH, that currently recycles the nickel-metal hydride and lead-acid batteries from hybrid-electric vehicles (Hamilton, 2009). In Germany, Chemetall GmbH was awarded $8.4 million by the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety to set up a pilot plant at the company's Langelsheim facility for the recycling of lithium-ion batteries (Rockwood Holdings, Inc., 2010, p. 5, 17). Japan's Nippon Mining & Metals Co., Ltd. announced plans to open a commercial-scale plant to recycle lithium-ion batteries. The commercial operation was planned to open in 2011 after the completion of a pilot plant demonstration (Platts Metals Week, 2009).

Production

The U.S. Geological Survey (USGS) collects domestic production data for lithium from a voluntary canvass of U.S.

operations. The only U.S. lithium carbonate producer, Chemetall Foote Corp. (a subsidiary of the German company Chemetall, which is owned by Rockwood Holdings, Inc., of Princeton, NJ) responded to the survey, representing 100% of total production. Production and stock data were withheld from publication to avoid disclosing company proprietary data (table 1). It is known, however, that production decreased in 2009 from that of 2008 owing to the worldwide economic downturn.

Chemetall Foote produced lithium carbonate from brines near Silver Peak, NV. The company's other U.S. lithium operations included a lithium hydroxide plant in Silver Peak; a butyllithium plant in New Johnsonville, TN; and facilities for producing downstream lithium compounds in Kings Mountain, NC. Chemetall Foote's subsidiary in Chile, Sociedad Chilena de Litio Ltda., produced lithium carbonate and lithium chloride from a brine deposit.

In August, the DOE awarded Chemetall Foote $28.4 million to expand and upgrade the production of lithium compounds used in batteries at the company's Silver Peak and Kings Mountain processing plants (Rockwood Holdings, Inc., 2010, p. 80).

FMC Corp.'s Lithium Division produced a full range of downstream compounds, lithium metal, and organic lithium compounds at its facilities in Bessemer City, NC, and, until March 2009, Bayport, TX. In response to the weaker market conditions for lithium-based products resulting from the worldwide economic downturn, FMC closed its Bayport butyllithium facility and consolidated all U.S. butyllithium production at its Bessemer City facility (FMC Lithium, 2009). The company met its lithium carbonate and lithium chloride requirements with material produced at its operation in Argentina. In March, the DOE awarded a $3 million grant to FMC's Center for Lithium Energy and Advanced Research to scale up production of a proprietary product known as stabilized lithium metal power used for high-energy Li-ion battery cathodes (Jackson, 2010).

In May and September, American Lithium Minerals, Inc. acquired several lithium brine prospects in Esmeralda County, NV, from GeoXplor Corp., a private Nevada company. The lithium brine prospects were within the Great Basin Province of the southwestern United States. In September, the company announced that a gravity survey and electromagnetic survey would be conducted on one of the prospects to delineate the appropriate drill targets (American Lithium Minerals Inc., 2009a; 2009b).

California-based Simbol Mining Corp. purchased and relocated the assets and intellectual property of Limtech Lithium Industries, Inc., a Canadian lithium processing company which previously sold high-purity lithium carbonate to battery manufacturers in Japan. Simbol planned to use the 500-metric-ton-per-year (t/yr) lithium carbonate processing plant to extract lithium and other high-value mineral commodities used in batteries from geothermal fluids by using a unique reverse osmosis process. If successful, Simbol's geothermal brine process would eliminate the need for solar evaporation, a crucial and lengthy process in more common lithium brine operations (Moores, 2010c).

In February, Rodinia Minerals, Inc. (Vancouver, British Columbia, Canada) acquired 250 unpatented mining claims in Clayton Valley, Esmeralda County, NV, from GeoXplor Corp. The mining claims were adjacent to Chemetall Foote's lithium brine operation. By yearend, Rodinia completed gravity and two-dimensional seismic surveys of the claims and began a three-hole drilling program to test the lithium-bearing aquifers (Rodinia Minerals, Inc., 2009a, b).

In December, Western Lithium Canada Corp. (Vancouver, British Columbia, Canada) completed the drilling process on the second of its five lithium-rich hectorite clay deposits at its Kings Valley, NV, project. The drilling operation, from which core samples would be evaluated in an independent technical and economic assessment in early 2010, was performed to determine if additional years of mine life could be added to the hectorite operation. The second deposit was approximately seven times larger than the first deposit. Based on exploration of the area performed by Chevron Resources, Inc. (a subsidiary of Chevron Corp.) in the 1980s, Western Lithium Canada Corp. estimated that 2 million metric tons (Mt) of contained lithium may be available (Western Lithium Canada Corp., 2009; 2010).

Consumption

Lithium is sold as brines, compounds, metal, or mineral concentrates depending on the end use. Lithium's electrochemical reactivity and other unique properties have resulted in many commercial lithium products. For many years, most lithium compounds and minerals were used in the production of ceramics, glass, and primary aluminum. Growth in lithium battery use and decreased use of lithium in aluminum production has resulted in batteries gaining market share. For 2009, Chilean lithium producer Sociedad Química y Minera de Chile S.A. (SQM) listed the main global markets for lithium products as follows—ceramics and glass, 30%; batteries, 21%; lubricating greases, 10%; air treatment, 5%; metallurgical, 5%; primary aluminum production, 3%; and other uses, 26% (de Solminihac, 2010, p. 11). The "other uses" category represented several smaller end uses that may have included alloys, construction, dyestuffs, industrial bleaching and sanitation, pool chemicals, and specialty inorganics (FMC Corp., 2008). Roskill Information Services Ltd. offered different consumption estimates for 2009 but confirmed that ceramics and glass remained the top global market for lithium. Roskill's estimates were ceramics and glass, 31%; batteries, 23%; lubricating greases, 9%; primary aluminum production, 6%; air treatment, 6%; continuous casting, 4%; rubber and thermoplastics, 4%; pharmaceuticals, 2%; and other uses, 15% (Baylis, 2010, p. 11). Domestic end uses for lithium materials may not directly correspond to worldwide consumption, but the data necessary for making more reliable estimates were not available.

In 2009, the decline in U.S. lithium consumption could be attributed to decreased consumption in most end uses owing to a slowdown in the economy that began in the second half of 2008. If lithium concentrates were included in lithium consumption estimates, the leading use of lithium in the United States likely was in ceramics and glass manufacturing processes. No lithium concentrates, however, were produced in the United States for direct application in ceramics and glass manufacture, and import statistics do not specifically identify lithium ore imports, making it difficult to accurately estimate end uses.

In 2009, most lithium batteries were manufactured in Asia, with 39% of lithium-ion battery production concentrated in Japan, 36% in China, and 20% in the Republic of Korea (Evans, 2009). Lithium's natural properties make it one of the most attractive battery materials of all the elements. In 2008 (the most recent year for which data are available) lithium-ion battery production represented 75% of the total portable rechargeable battery market worldwide, and growth was expected to continue (SBI Reports, 2009). Worldwide, rechargeable lithium batteries powered most cellular telephones and laptop computers, as well as many heavy-duty power tools. Automakers were working on lithium batteries for hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), and pure electric vehicles (EV).

U.S. primary aluminum production, and lithium consumption in that end use, declined during 2009 because aluminum production was curtailed owing to a significant drop in the price of aluminum in the second half of 2008, which continued throughout 2009 (Bray, 2010).

Additional information concerning other lithium end uses can be found in the lithium chapter of the 2006 U.S. Geological Survey Minerals Yearbook, volume I, Metals and Minerals.

Prices

Customs values for lithium carbonate imports to the United States were used as an indication of the trends in lithium pricing, although they never exactly reflected the producers' prices for lithium carbonate. The average customs unit value for imported lithium carbonate was $4.53 per kilogram, slightly higher than that of 2008. The average unit customs value of lithium hydroxide decreased about 6%. The average unit value of exported lithium carbonate was 19% higher than in 2008 and more than 50% higher than the average unit value of imported carbonate. This suggests that the material exported from the United States was higher quality lithium carbonate than that which was imported.

In September, SQM announced that it would reduce its lithium carbonate and lithium hydroxide prices by 20% for contracts effective January 2010. The company indicated that its lithium carbonate prices, which ranged from $6.20–$6.60 per kilogram in 2009, would be lowered to $5.10–$5.30 per kilogram (Tran, 2010).

At yearend, glass-grade spodumene (5% lithium oxide) was reported to be selling for $363 to $408 per metric ton. Australian spodumene producer Talison Lithium Ltd. (formally Talison Minerals Pty. Ltd.) announced in November that it would increase prices for technical-grade spodumene for contracts effective January 2010. The prices are expected to increase to $380 to $430 per metric ton (Industrial Minerals, 2009b; 2009d).

Foreign Trade

In 2009, total exports of lithium compounds from the United States decreased 35% compared with those of 2008. About 34% of all U.S. exports of lithium compounds went to Japan, while 18% went to Germany, and 13% went to the United Kingdom. The remainder was divided among many other countries (table 2).

Imports of lithium compounds decreased by 40% in 2009 compared with those of 2008. Of the 10,000 t of lithium compounds imported, 61% came from Argentina, 33% from Chile, and the remainder from several other countries (table 3). This was the first year that most lithium imports originated from Argentina, rather than Chile. Lithium concentrates from Australia, Canada, and (or) Zimbabwe may have entered the United States, but because these materials have no unique import code, no import data were available. The United States was the largest importer of lithium carbonate and lithium chloride in the world.

World Review

World lithium production (excluding U.S. production) was estimated to be 18,800 t of lithium contained in minerals and compounds in 2009, a decrease of 27% from that of 2008. Gross weight production figures for lithium carbonate, lithium chloride, and lithium mineral concentrates are listed in table 4. Argentina, Chile, China, and the United States were the leading producers of lithium carbonate. Significant quantities of lithium compounds and concentrates also were produced in Australia, Brazil, Canada, Portugal, and Zimbabwe. Congo (Kinshasa), Namibia, Russia, Rwanda, and South Africa have produced concentrates in the past. Several brine operations were under development in Argentina; spodumene mining operations were under development in Australia, Canada, and Finland; and a jadarite mining operation was under development in Serbia. Pegmatites containing lithium minerals have been identified in Afghanistan, Austria, France, India, Ireland, Mozambique, Spain, Sweden, and Zaire, but economic conditions have not favored development of the deposits. Lithium has been identified in subsurface brines in Bolivia and Israel. Companies in France, Germany, Japan, the Republic of Korea, Russia, Taiwan, and the United Kingdom produced downstream lithium compounds from imported lithium carbonate.

World lithium consumption was reported by SQM to be 16,000 to 17,000 t of lithium contained in minerals and compounds in 2009, a decrease of approximately 25% from SQM's consumption estimate of 2008 (de Solminihac, 2010, p. 10). A different accounting of total world lithium consumption was reported by Roskill Information Services, which indicated consumption to be 18,600 t of lithium contained in minerals and compounds in 2009, a decrease of approximately 15% from Roskill's consumption estimate of 2008 (Baylis, 2010, p. 10, 13). The difference in consumption figures was most likely owing to differing estimations of consumer drawdown of existing lithium inventory. All industrial lithium demand sectors, including battery production, were negatively affected by the global economic downturn.

Total lithium consumption growth averaged 6% growth per year between 2004 and 2008, while lithium battery consumption growth averaged 21% per year during the same timeframe (de Solminihac, 2010, p. 10). Using Roskill's figure for total lithium consumption and the company's recent research that estimated the lithium chemical market to be about 75% of total lithium consumption, an estimated 14,000 t of lithium was consumed in chemicals and the remainder as mineral concentrates in the ceramics and glass industry in 2009 (Baylis, 2010, p. 5).

In 2008, China and Europe were estimated to be the largest consumers of lithium in the world, at 29% and 28% of total consumption, respectively. Other consumers included Japan, 18%; North America, 13%; Republic of Korea, 5%; India, 3%; South America, 2%; Russia, 1%; and other, 1% (Roskill Information Services Ltd., 2009, p. 155).

Argentina.—FMC has been operating its facility at the Salar de Hombre Muerto since 1998. It was initially designed to produce about 12,000 t/yr of lithium carbonate and about 5,500 t/yr of lithium chloride (North American Mineral News, 1998). In 2009, its lithium carbonate production capacity was 17,000 t/yr (Moores, 2009b). Lithium chloride production was more than 8,800 t in 2007. Production of lithium carbonate was estimated to be 7,000 t, a decrease of 30% from that of 2008. Production of lithium chloride was estimated to be 5,500 t, a decrease of 29% from that of 2008.

In 2009, Sentient's Rincon Lithium Ltd. continued ramping up pilot production at the Salar del Rincón in Salta Province and expected to achieve a lithium carbonate production rate of 1,500 t/yr in 2010. The lithium operation was designed to produce 10,000 t/yr of lithium carbonate, 4,000 t/yr of lithium hydroxide, and 3,000 t/yr of lithium chloride (Industrial Minerals, 2010a).

Australian exploration company Orocobre Ltd. announced in 2009 that its Olaroz lithium project at the Salar de Olaroz in northwestern Argentina contained 1.5 Mt inferred lithium carbonate resources. A scoping study was completed indicating the potential to develop a long-life operation with production of 15,000 t/yr of lithium carbonate. Orocobre also established a joint venture with Japanese trading house Toyota Tsusho Corp. Toyota Tsusho, a key supplier to Toyota Motor Corp. and several large Asian technology companies including Panasonic Corp. and Sanyo Electric Co., Ltd., anticipated using the joint venture as a means to secure low-cost lithium for its automotive and battery industry partners (Industrial Minerals, 2010b).

In 2009, Canadian exploration company Lithium Americas Corp. formed the Cauchari–Olaroz Salars project on the Puna plateau in northwestern Argentina. By yearend, a surface brine program, seismic geophysical program, nine reverse circulation drill holes, and five diamond drill holes were completed. The company entered into a strategic investment agreement with the Japanese firm Mitsubishi Corp., and completed a strategic investment agreement with Canadian car parts manufacturer Magna International Inc. The companies purchased 4.1% and 13.3%, respectively, of Lithium America's common shares in an effort to secure low-cost lithium supplies for their respective company's electric vehicle batteries (Hoffman and Keenan, 2010; Lithium Americas Corp., 2010, p. iv, 9–12).

Canadian-based resource company Lithium One Inc. formed the Sal de Vida lithium brine project at the Salar del Hombre Muerto. The company conducted systematic sampling of the near-surface brine during the fourth quarter of 2009. A drilling program was also initiated in December (Lithium One Inc., 2010, p. 2–3).

In December, Rodinia Minerals Inc. acquired a lithium deposit in the Salar de Salinas Grandes, in Jujuy Province. Previous studies on the brine chemistry in the salar found lithium concentrations in excess of 400 parts per million and a magnesium-to-lithium ratio of 3.75:1 (Metal-Pages, 2009).

Australia.—About 70% of the world's supply of lithium minerals was produced by Talison Lithium from its deposit in Western Australia, which reportedly is the largest spodumene deposit in the world (Department of Mines and Petroleum, 2009, p. 46). The company reported spodumene production of approximately 197,000 t in 2009 from its 260,000-t/yr plant, a decrease of 18% from that of 2008 (Department of Mines and Petroleum, 2010, p. 21; Talison Lithium Ltd., 2010). Lower grade spodumene was exported to China where it was converted into a range of lithium chemicals. Higher-grade spodumene was exported to Asia, Europe, and the United States where it was consumed by the ceramics, foundry, glass, and steel industries. In 2009, to meet future lithium demand, Talison continued improvements at the high-grade and low-grade sections of their lithium minerals plant with additional equipment and a new process to increase the lithia content in their spodumene concentrate (Geoscience Australia, 2009, p. 41).

In November, Galaxy Resources Ltd. officially broke ground at its Mount Cattlin spodumene operation, near Ravensthorpe in Western Australia. A definitive feasibility study for its Jiangsu lithium carbonate processing plant in Jiangsu Province of China was completed in October, and construction for the Jiangsu plant was scheduled to commence during the second quarter of 2010. Battery-grade lithium carbonate production capacity was set at 17,000 t/yr. An offtake agreement between Galaxy Resources and Mitsubishi was finalized and signed in February 2010, which gave Mitsubishi a significant portion of Galaxy's lithium carbonate production (Galaxy Resources Ltd., 2010, p. 4–11).

Bolivia.—Bolivia's undeveloped Salar de Uyuni is the largest salt flat in the world, with an area of more than 11,000 square kilometers. In August, Bolivia's state mining company Corporación Minera de Bolivia (Comibol) began a program to re-evaluate the Salar de Uyuni's lithium resources. Comibol planned to invest between $300 million and $400 million in a 30,000-t/yr lithium carbonate plant (Moores, 2009a). New World Resource Corp. announced it had acquired the Pastos Grandes brine property in southwestern Bolivia and initiated a brine sampling program. Further testing was planned for 2010 (New World Resource Corp., 2010).

Canada.—Tantalum Mining Corp. of Canada Ltd. (a subsidiary of Hudson Bay Mining and Smelting Co.), which had operated a spodumene mine and concentrating plant at Bernic Lake, Manitoba, on a commercial scale since 1986, suspended operations in September owing to the reduction in demand for spodumene concentrates in the ceramics and glass sector (Industrial Minerals, 2009e). Its most recent reported spodumene concentrate production capacity was 24,000 t/yr (Cabot Corp., 2002).

GlobeStar Mining Corp. estimated mineral resources of its pegmatite deposit near Moblan, Quebec, and predicted spodumene concentrate production of 22,000 t/yr. Exploration continued in 2009 (GlobeStar Mining Corp., undated).

Canada Lithium Corp. was evaluating the possibility of reopening the Quebec Lithium property–an underground mine, surface concentration plant, and chemical plant that operated from 1955 to 1965 and produced lithium carbonate, lithium chloride, lithium hydroxide monohydrate, and spodumene concentrate. Canada Lithium signed a marketing agreement with Mitsui and Co. Ltd. of Japan for exclusive rights to market the company's lithium in China, Japan, and the Republic of Korea. The company also completed a prefeasibility study indicating that the property had the potential to produce approximately 19,300 t/yr of battery-grade lithium carbonate (Canada Lithium Corp., 2010, p. 10).

Channel Resources Ltd. acquired the Fox Creek lithium brine project in Alberta from Polaris Capital Ltd. and initiated a brine sampling program. A previous study of the area by the Government of Alberta indicated potentially economic concentrations of lithium in the aquifer, comparable with those of the brine found in Clayton Valley, NV (Channel Resources Ltd., 2010, pg. 2–4). Lithium One completed two pegmatite drilling programs at its James Bay lithium project in Quebec (Lithium One, Inc., 2010, p. 11).

Chile.—With a reported 31% of the world lithium market, SQM reported a downturn in revenues from its lithium products as a result of the global economic slowdown in 2009. Sales volume, at 21,300 t, was 24% lower than in 2008, and the value of sales declined by 32% to $117.8 million. SQM's lithium carbonate production capacity was 42,000 t/yr, and its lithium hydroxide capacity was 6,000 t/yr in 2009; lithium capacity utilization rate was 57% (de Solminihac, 2010, p. 16; Sociedad Química y Minera de Chile S.A., 2010, p. 34, 55).

Total lithium carbonate production capacity for Chemetall Foote's operations in Chile and the United States increased to 31,000 t/yr in 2009. Production capacity was planned to increase to 33,000 t/yr by 2010; 40,000 t/yr by 2015; and 50,000 t/yr by 2020. Further increases to 65,000 t/yr would depend on market conditions. In addition, Chemetall planned to increase lithium hydroxide production capacity to 5,000 t/yr by 2010; 10,000 t/yr by 2015; and 15,000 t/yr by 2020 depending on market conditions. The company used lithium carbonate from Chile as feedstock for some of its downstream chemical production in Germany, Taiwan, and the United States. Chemetall reported a 50% share of the global market for its lithium products, with lithium carbonate accounting for 30% of the global market (Haber, 2009, p. 11; Industrial Minerals, 2009a; Haber, 2010, p. 14).

China.—China was the only country that continued to produce large quantities of lithium carbonate from both domestic and imported spodumene. Domestic lithium mineral concentrates were thought to be low grade and were most likely used in glass and ceramic applications. Higher grade spodumene concentrates imported from Australia were generally used in the production of battery-grade lithium carbonate. Ronghui (Jiangsu Province), Sichuan Tianqi Lithium Industries, Inc. (Sichuan Province), and Xinjiang Non-Ferrous Metals Industry Group, Ltd. (Xinjiang Province) were 80% to 100% reliant on Australian spodumene. Current lithium carbonate production capacity in China from minerals was estimated to be 41,000 t/yr; however, 2009 production was estimated to be about 15,500 t, well below capacity. Additional lithium carbonate was imported into China from Argentina and Chile. Lithium minerals were estimated to contain 35% of China's lithium reserves, while lithium brines were estimated to contain the remaining 65% of the reserves (Baylis, 2009, p. 6–7, 11, 13; Roskill Information Services Ltd., 2009, p. 89–91).

Chinese brine producers continued to have production problems in 2009, resulting in lithium output falling below expectations. The Tibet Lithium New Technology Development Co. had operated a 5,000-t/yr lithium carbonate plant at the Zabayu Salt Lake in western Tibet since 2005, with production capacity expected to eventually increase to 20,000 t/yr. CITIC Guoan Lithium Science & Technology Co., Ltd.'s 35,000-t/yr lithium carbonate plant (currently operating at a rate of 5,000 t/yr) was brought online in 2007 at the Taijinaier Salt Lake in Qinghai Province and was the largest lithium carbonate plant in China. In 2009, CITIC formed a joint venture with Chengdu Chemphys Chemical Industry Co., Ltd. of Sichuan, and signed a letter of intent with Japan's Toyota Tsusho to provide battery-grade lithium carbonate (Tahil, 2007, p. 10, 13; Baylis, 2010, p. 19). Qinghai Salt Lake Industry Group Co., Ltd. operated a 3,000-t/yr lithium carbonate plant at the Dongtai Salt Lake in Qinghai Province. Production capacity was expected to eventually increase to 20,000 t/yr. Total lithium carbonate production in 2009 from these three brine operations was estimated to be 4,100 t, well below their total capacity of 13,000 t/yr. Qinghai Salt Lake Lanke Lithium Industry Co., Ltd. completed construction of a 10,000-t/yr lithium carbonate project in the Chaerhan Salt Lake zone in Qinghai Province and produced 400 t of lithium carbonate in 2009 (Baylis, 2009, p. 11; Baylis, 2010, p. 19).

Finland.—In 2008, Norwegian mining company Nordic Mining ASA purchased a controlling stake in Finnish spodumene mining company Keliber Oy. The company then acquired a lithium deposit in the Lantta area of western Finland and planned to establish a 4,000-t/yr lithium carbonate plant, with production scheduled to begin in 2010. In 2009, Nordic investigated other lithium deposits surrounding the Lantta mine. When production begins, Nordic was expected to be the first European producer of lithium carbonate from domestic ore (Industrial Minerals, 2008; Nordic Mining ASA, 2010, p. 16).

Korea, Republic of.—As part of the Republic of Korea's effort to secure stable long-term supplies of lithium for its growing automobile, battery, and electronics industries, the Government partnered with key companies in the Republic of Korea, including POSCO and SK Energy, to acquire lithium from a broad range of sources and countries. In 2009, the Government of the Republic of Korea obtained technology to extract lithium from sea water. In early 2010, the Government signed an agreement with POSCO and the Korea Institute of Geoscience and Mineral Resources to conduct joint research and build a pilot plant for the commercial production of lithium from sea water. Construction was scheduled to be completed by 2014 (Moores, 2010a; Korea.net, 2010).

Serbia.—Jadarite, a new mineral species discovered in 2004 by Rio Tinto plc (London, United Kingdom) at Jadar was found to contain a high percentage of lithium oxide. In 2009, Rio Tinto announced plans to start lithium carbonate production in approximately 2015 and considered further development (Industrial Minerals, 2009c).

Outlook

The amount of lithium consumed globally for use in batteries increased by more than 20% per year during the past few years, although growth was less in 2009 owing to the global economic downturn. Demand for lithium-ion batteries appears to have the greatest potential for growth. Global sales of these rechargeable batteries were estimated to be $7.7 billion in 2009, with sales projected to increase by 13% per year to nearly $12 billion by 2013 (Credit Suisse Group AG, 2009). Other lithium end uses were increasing also but at lower rates than batteries. Roskill (2009, p. 156) indicated that annual growth in lithium consumed for pharmaceuticals had averaged 17% from 2000 to 2008, while lithium consumed for continuous casting and greases had 8-year growth rates of 8% and 6%, respectively. Roskill estimated that total world lithium consumption would increase to approximately 27,600 t in 2013, an increase of 48% from Roskill's consumption estimate for 2009 (Baylis, 2010, p. 13).

What was apparent in 2009 and will likely continue in the future was the tendency for Asian technology companies to invest in the development of lithium operations in other countries to ensure a stable supply of lithium for their battery industries. With lithium carbonate being one of the lowest cost components of a lithium-ion battery, the issue to be addressed was not cost difference or production efficiency but supply security attained by acquiring lithium from a number of different lithium sources (Moores, 2010b).

Research in nanotechnology, the understanding and control of matter at dimensions of approximately 1 to 100 nanometers, has advanced lithium-ion battery technology and further improvements are probable. By altering the nanostructures of the lithium-ion battery's anode and cathode, researchers have been able to increase battery storage capacity, output power, lifespan, and stability, while decreasing the time required to charge the battery (Harrop, 2008). Used in power tools, nanotechnology has enabled lithium-ion batteries to provide power surges of up to 10 times that of conventional lithium-ion batteries (Bullis, 2008). In hybrid vehicles, power surges from lithium-ion batteries enable a vehicle to accelerate faster than with other batteries of the same size (Pontin, 2007). A promising new technology, the lithium metal-air battery, may be capable of delivering 10 times more energy density than today's best lithium-ion technology, effectively offering the same energy density as gasoline. Development of lithium metal-air battery technology was expected to take between 5 and 10 years (Luoma, 2009).

Increased use of larger lithium-ion batteries can be attributed in part to use in heavy-duty power tools because lithium-ion batteries are continuously replacing nickel-cadmium batteries in power tools despite the current economic downturn and the somewhat higher prices that lithium-ion battery power tools generally command (Rockwood Holdings, Inc., 2009). According to a leading manufacturer of power tools, 70% of all cordless power tools in Europe were powered by lithium-ion batteries in 2009. The manufacturer expected lithium-ion power tools to account for 90% of the cordless power tool market by 2011 (Hartung, 2010).

Most global automobile manufacturers have announced plans to use lithium-ion batteries in current and future generations of HEVs, PHEVs, and EVs, in order of expected market entry. HEVs, PHEVs and EVs with lithium-ion batteries from companies such as BYD Co., Ltd. (China), Daimler AG (Germany), and Tesla Motors, Inc. (United States) saw limited release in 2009. Lithium-ion HEVs, PHEVs, and EVs are scheduled for release in 2010 by General Motors Company, Hyundai Group, Mitsubishi Motors Corp., Nissan Motor Company, Ltd., Toyota Motor Corp., and Volkswagen Group. Major automobile manufacturers have also formed partnerships with established battery manufacturers to build battery plants for hybrid vehicles and begin mass production of lithium-ion batteries. The worldwide market for lithium-ion batteries used in transportation was expected to increase to approximately $8 billion by 2015 from $876 million in 2010, largely fueled by government subsidies and incentives (Pike Research, 2009).

Pike Research indicated that utility-scale applications would be the downstream beneficiaries of the widespread research and innovation on lithium-ion battery development for the transportation sector. Of 11 competing energy storage technologies analyzed by Pike Research, lithium-ion batteries were forecast to be the fastest growing category for utility-scale applications, growing to a $1.1 billion worldwide business by 2018 (Reuters, 2009).

The use of lithium-ion batteries in HEVs, PHEVs, and EVs could greatly increase demand for lithium. As demand and prices rise, spodumene and other lithium resources that had been considered uneconomic might once again yield economically feasible raw materials for the production of lithium carbonate. New lithium mineral operations under development throughout the world in 2009 specifically to produce battery-grade lithium carbonate demonstrated a renewed interest in lithium exploration and development.

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TABLE 1

SALIENT LITHIUM STATISTICS[1]

(Metric tons of contained lithium)

	2005	2006	2007	2008	2009
United States:					
Production	W	W	W	W	W
Exports[2]	1,720	1,500	1,440	1,450	919
Imports[2]	3,580	3,260	3,140	3,160	1,890
Consumption[e]	2,500	2,500	2,400	2,300	1,300
Rest of world, production[3]	21,500 [r]	24,300 [r]	25,400 [r]	25,800 [r]	18,800 [e]

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

[1]Data are rounded to no more than three significant digits.

[2]Compounds. Source: U.S. Census Bureau.

[3]Mineral concentrate and lithium carbonate.

TABLE 2

U.S. EXPORTS OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY[1]

	2008		2009	
Compound and country	Gross weight (metric tons)	Value[2] (thousands)	Gross weight (metric tons)	Value[2] (thousands)
Lithium carbonate:				
Australia	52	$373	11	$88
Canada	164	611	157	662
Germany	561	3,490	576	3,970
India	37	157	37	238
Japan	1,290	7,710	--	--
Korea, Republic of	100	678	80	514
Kuwait	--	--	42	831
Malaysia	117	693	--	--
Mexico	--	--	20	175
United Kingdom	313	1,160	53	241
Other	26	109	19	83
Total	2,660	15,000	995	6,800
Lithium carbonate, U.S.P.:[3]				
Australia	--	--	13	75
India	12	130	6	166
Mexico	20	4	--	--
United Kingdom	15	137	(4)	9
Other	10	533	11	76
Total	57	804	30	326
Lithium hydroxide:				
Argentina	146	1,600	65	556
Australia	41	313	64	478
Canada	107	446	90	438
China	123	867	37	345
Colombia	74	510	63	521
Egypt	58	394	73	493
Germany	996	5,860	397	2,490
India	267	1,500	81	436
Japan	2,210	16,400	1,870	14,200
Korea, Republic of	268	2,100	249	1,750
Mexico	70	584	68	322
Netherlands	230	1,250	99	535
Peru	17	126	6	40
Russia	315	1,680	63	348
Saudi Arabia	55	388	89	742
Singapore	53	344	21	318
South Africa	79	824	77	690
Taiwan	85	588	56	357
Thailand	240	1,590	155	933
United Kingdom	102	1,620	673	4,380
Venezuela	56	496	78	704
Vietnam	30	229	24	180
Other	58	959	10	347
Total	5,680	40,700	4,400	31,600

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship values.

[3]Pharmaceutical-grade lithium carbonate.

[4]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF LITHIUM CHEMICALS BY COMPOUND AND COUNTRY[1]

Compound and country	2008 Gross weight (metric tons)	2008 Value[2] (thousands)	2009 Gross weight (metric tons)	2009 Value[2] (thousands)
Lithium carbonate:				
Argentina	7,300	$33,600	6,220	$29,700
Chile	8,110	34,400	2,900	11,400
China	14	75	107	454
Other	7 r	122 r	26	269
Total	15,400	68,200	9,250	41,900
Lithium carbonate, U.S.P., Chile[3]	341	1,890	--	--
Lithium hydroxide:				
Chile	816	5,410	510	3,070
China	279	1,480	306	1,440
Germany	2	27	13	526
India	20	187	28	188
Japan	7	131	15	81
Norway	24	54	21	54
Romania	3	17	--	--
United Kingdom	11	58	37	201
Other	2 r	39 r	2	30
Total	1,160	7,400	932	5,580

[r]Revised. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Customs value.

[3]Pharmaceutical-grade lithium carbonate.

Source: U.S. Census Bureau.

TABLE 4

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

(Metric tons)

Country[3]	2005	2006	2007	2008	2009[e]
Argentina:[4]					
Lithium carbonate	7,288	8,228	8,863	9,984 r	7,000
Lithium chloride	8,416	8,336	8,828 r	7,800	5,500
Australia, spodumene	173,635	222,101	192,277	239,528 r	200,000
Brazil, concentrates	8,924	8,585	7,991	8,000 e	8,000 p
Canada, spodumene[e, 5]	22,500	22,500	22,500	22,000	10,000
Chile:[4]					
Lithim carbonate from subsurface brine	43,091 r	46,241 r	51,292 r	48,469 r	25,154 [6]
Lithium chloride	681	1,166	4,185	4,362 r	2,397 [6]
Lithium hydroxide	504	3,794	4,160	4,050	2,987 [6]
China, carbonate[e]	15,000	15,000	16,000	17,500	20,000
Portugal, lepidolite	26,185	28,497	34,755	-- r	--
United States, subsurface brine	W	W	W	W	W
Zimbabwe, amblygonite, eucryptite, lepidolite, petalite, and spodumene[e]	37,499 [6]	30,000	30,000	25,000	20,000

[e]Estimated. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Table includes data available through March 20, 2010.

[2]Estimated data are rounded to no more than 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]New information was available from Argentine and Chilean sources, prompting major revisions in how lithium production was reported.

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

[6]Reported figure.