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LITHIUM

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LITHIUM

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In 2006, lithium consumption in the United States was estimated to be 2,500 metric tons (t) of contained lithium, the same as the estimate for 2005 and nearly 32% more than in 2004. The sources for these lithium compounds were a domestic lithium carbonate operation in Nevada and imports from Argentina and Chile.

Chile has been the world's leading producer of lithium carbonate since 1997, the year that it first surpassed the United States in production. Production in Chile was 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 Nevada. Lithium carbonate and lithium chloride also were produced from brines from the Salar del Hombre Muerto in the Andes Mountains in Argentina. China also produced lithium carbonate, but details on the source of production were not available. Australia was, by far, the leading producer of lithium concentrates, and Brazil, Canada, Portugal, and Zimbabwe also produced significant quantities. 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.

Production

The U.S. Geological Survey (USGS) collects domestic production data for lithium from a voluntary canvass of U.S. operations. The single U.S. lithium carbonate producer, Chemetall Foote Corp. (a subsidiary of the German company Chemetall GmbH, 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).

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., produces lithium carbonate from a brine deposit.

FMC Corporation's Lithium Division produced a full range of downstream compounds, lithium metal, and organic lithium compounds at its facilities in Bessemer City, NC, and Bayport, TX. FMC met its lithium carbonate requirements with material produced at its Argentine operation, and, through a long-term contract, Chilean producer Sociedad Química y Minera de Chile S.A. (SQM) agreed to supply FMC with lithium carbonate produced at SQM's brine operation. FMC also produced lithium chloride in Argentina in 2006.

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, the majority of 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 and perhaps soon becoming the leading end use for lithium. SQM listed the main markets for lithium as follows: ceramics and glass, 21%; batteries, 20%; lubricating greases, 17%; pharmaceuticals and polymers, 9%; air conditioning, 7%; primary aluminum production, 5%; and other uses, 20% (Sociedad Química y Minera de Chile S.A., 2006). The "other uses" category represents several smaller end uses including alloys, construction, dyestuffs, industrial bleaching and sanitation, pool chemicals, and specialty inorganics (FMC Corporation, 2006). These figures represent global markets; domestic end uses for lithium materials may not directly correspond to worldwide consumption, but the data necessary for making more reliable estimates are not available.

In 2006, lithium consumption in the United States was estimated to be 2,500 t of contained lithium, the same as the estimate for 2005, 32% higher than in 2004, and 79% higher than in 2003. The recovery can be attributed to increased consumption in all end uses except aluminum owing to the strength in the domestic economy and increased demand in a few rapidly expanding end uses. If lithium concentrates are included in lithium consumption estimates, the leading use of lithium in the United States may be in ceramics and glass manufacturing processes. No lithium concentrates are 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 determine definitive end-use estimates. The addition of lithium as lithium carbonate or lithium concentrates to a glass melt lowers the process melting point, reduces the coefficient of thermal expansion and the viscosity, and eliminates the use of more toxic compounds. The production of ceramics and glass was the only commercial use for lithium mineral concentrates. The manufacture of thermal-shock-resistant cookware (pyroceramics) consumed the majority of lithium used in the ceramics and glass industry. Low-iron spodumene and petalite were sources of the lithium used to improve the physical properties of container and bottle glass, as well as sources of alumina, another important component of glass. Glass manufacturers used lithium in container and bottle glass to produce a lighter weight, thinner walled product. Lithium concentrates are the predominant lithium source for ceramics and glass uses, but lithium carbonate also is used. As energy costs have risen, the addition of lithium to glass furnaces offered the opportunity to reduce the cost of production, improve the final product, and reduce emissions of nitrogen oxides (Fisher, 2006).

Lithium batteries may now be the second-ranked end use for lithium and might become the leading end use in the near future, although most lithium batteries are manufactured in Asia. Many major battery manufacturers marketed some type of lithium battery, exploiting the many advantages of lithium batteries compared with older battery technologies. Battery experts have been working to develop lithium batteries for decades because lithium's natural properties make it the most attractive battery material of all the elements. Lithium battery sales represented two-thirds of the value of rechargeable battery sales worldwide, and growth is expected to continue (Chemical & Engineering News, 2006b). Research and development continued, and innovative rechargeable battery configurations have been introduced to meet the changing requirements of electronic equipment, such as portable telephones, portable computers, and video cameras. Worldwide, rechargeable lithium batteries power more than 60% of cellular telephones and 90% of laptop computers (FMC Corp., 2006). Several automakers were working on lithium batteries for hybrid electric vehicles (HEVs).

Nonrechargeable lithium batteries offer improved performance compared with alkaline batteries at a slightly higher cost and have been commercially available for more than 10 years. They are used in cameras, electronic games, microcomputers, small appliances, toys, and watches. The military purchases lithium batteries for a variety of applications.

The multipurpose grease industry was an important market for lithium in 2006. Lithium hydroxide monohydrate was the compound used to produce lithium lubricants. Lithium-base greases were 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 are used in aircraft, automotive, industrial, marine, and military applications.

Another large end use for lithium compounds was as catalysts and reagents in the production of synthetic rubbers, plastics, and pharmaceuticals. N-butyllithium, an organic lithium compound, was used to initiate the reactions between styrene and butadiene to form abrasion-resistant synthetic rubbers that require no vulcanization. Other organic lithium compounds were used as catalysts for the production of plastics, such as polyethylene. Lithium metal and organic compounds also were used as catalysts in the production of pharmaceuticals, including anticholesterol agents, antihistamines, contraceptives, sleep inducers, steroids, tranquilizers, vitamin A, and other products. Pharmaceutical-grade lithium carbonate was used in the treatment of manic-depressive psychosis, the only treatment approved by the U.S. Food and Drug Administration in which lithium was consumed by the patient.

The use of lithium in primary aluminum production has decreased steadily since 2000 in the United States, as domestic aluminum production declined. Adding lithium carbonate to aluminum potlines lowers the melting point of the cryolite bath, allows a lower operating temperature for the cells, increases the electrical conductivity, and decreases bath viscosity. These factors contribute to increased production without changing any other operating conditions, especially in older smelters, like those in North America. Lithium carbonate additions also have the potential environmental benefit of reducing fluorine emissions by 20% to 30% (Chemetall GmbH, undated).

Small quantities of other lithium compounds were important to many industries. Aircraft manufacturers in several countries sometimes use aluminum-lithium alloys for wing and fuselage skin or for structural members in different types of aircraft to reduce the weight of the aircraft by more than 10%, allowing significant fuel savings during the life of the aircraft. Lithium was being used increasingly as a concrete additive to prevent or mitigate premature deterioration of concrete through alkali silica reactivity. Lithium compounds were added to fast-setting cements, floor screeds, joint sealing mortars, and cement-base adhesives to accelerate setting and hardening rates (FMC, 2006; Chemetall GmbH, undated).

Lithium chloride and lithium bromide were used in industrial air-conditioning and commercial dehumidification systems and in the production of sophisticated textiles. Sanitizers for commercial glassware, public restrooms, and swimming pools contained lithium hypochlorite, as did dry bleaches for commercial laundries. Lithium metal was used as a scavenger to remove impurities from bronze and copper, and anhydrous lithium chloride was used as a component in fluxes for hard-to-weld metals, such as aluminum and steel alloys.

Prices

Lithium pricing became very competitive when SQM entered the market in 1998, and it has been difficult to obtain reliable price information since that time. Companies may announce price hikes, but they are reported relative only to previous prices. Producers negotiate with consumers on an individual basis; price information is not usually reported.

In recent years, customs values for lithium carbonate imports to the United States seemed to be a good indication of the trends in lithium pricing, although they never exactly reflected the producers' prices for lithium carbonate. Import data indicated that lithium carbonate and lithium hydroxide prices increased significantly in 2006. The average customs unit value for imported lithium carbonate, calculated by dividing the total value of imports by the total kilograms, was $2.32 per kilogram, about 59% higher than in 2005, a result of increased global demand, especially for lithium batteries. The average unit value of exported lithium carbonate was about the same in 2006 as in the previous year and more than 40% higher the average unit value of imported material. This suggests that the material being exported from the United States may be higher quality lithium carbonate than what is imported.

Admiralty Resources Ltd., an Australian company that was developing a second lithium brine operation in Argentina, reported that the price of lithium carbonate increased to $5,500 per metric ton from $2,750 per ton in 2006 as a result of increased demand for lithium for batteries. Demand rose faster than anticipated by the industry. Established producers were unable to entirely satisfy the expanded demand, causing the escalation of lithium carbonate prices. Lithium hydroxide was reported to have reached $7,000 per ton (Industrial Minerals, 2006a; Admiralty Resources NL, 2007, p. 20).

Foreign Trade

In 2006, total exports of lithium compounds from the United States decreased 11.6% compared with those of 2005. About 61% of all U.S. exports of lithium compounds went to Germany and Japan. The remainder was divided among many other countries (table 2).

Imports of lithium compounds decreased by 8% in 2006. Of the 17,500 t of lithium compounds imported, 60% of lithium chemical imports came from Chile, 37% came from Argentina, and 3% from other countries (table 3). Lithium concentrates from Australia, Canada, and Zimbabwe may have entered the United States, but because these materials have no unique import code, no import data were available.

World Review

A small number of countries throughout the world produced lithium concentrates and brine. 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 Argentina, Australia, Brazil, Canada, Portugal, Russia, and Zimbabwe. Congo (Kinshasa), Namibia, Rwanda, and South Africa produced concentrates in the past. Production figures for lithium mineral concentrates, lithium carbonate, and lithium chloride are listed in table 4. 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, Taiwan, and the United Kingdom produced downstream lithium compounds from imported lithium carbonate.

Estimates of the total world lithium market averaged 15,000 t of lithium contained in minerals and compounds in 2005, the latest year for which this type of information was available (Industrial Minerals, 2006b). Based on earlier information that estimated the lithium chemical market as about 80% of the entire lithium consumption, about 12,000 t was consumed in chemicals and the remainder as mineral concentrates in the ceramics and glass industry (Ebensperger and others, 2005).

Argentina.—FMC has been operating its Argentine facility at the Salar de Hombre Muerto since 1998. It was designed to produce about 12,000 metric tons per year (t/yr) of lithium carbonate and about 5,500 t/yr of lithium chloride (North American Mineral News, 1998). According to lithium chloride and lithium carbonate production data provided by the Government of Argentina to the USGS, lithium chloride production has significantly exceeded design capacity since 2004, indicating that perhaps expansions were made to lithium chloride capacity to reach about 8,500 t/yr. Although lithium carbonate production remained below design capacity, production has increased steadily since 2002 when production was first reported and was estimated at 8,000 t in 2006.

Work at Admiralty Resources NL's lithium brine project at the Salar del Rincón in Salta Province progressed. In 2006, the company was focusing effort in the following areas: 1) development of an economically viable processes for recovering lithium carbonate, lithium chloride, and lithium hydroxide from concentrated brines, 2) advancement in understanding the geology and hydrology of the salar, and 3) establishment of a base of probable customers (Admiralty Resources NL, 2007, p. 8-9). By the end of the 2006, Admiralty completed a pumping test at its first production well. Based on data collected during the test, the company estimated that the deposit contained 1.4 million metric tons of recoverable lithium. Work began on the construction of evaporation ponds to enable production to begin in July 2008. Plans include the initial production of 10,000 t lithium carbonate, 4,000 t lithium hydroxide, and 3,000 t lithium chloride, most of which will be sold in Japan, followed by Europe and the United States (Industrial Minerals, 2006a).

Australia.—About 60% of the world's supply of lithium minerals was produced at Sons of Gwalia Ltd.'s Greenbushes spodumene mine. The company reported that its deposit is the largest spodumene deposit in the world (Department of Industry and Resources, 2006, p. 28). Although the company was undergoing a restructuring as a result of insolvency, spodumene production continued at record pace. Spodumene concentrates were sold worldwide for consumption in ceramics and glass and were exported to China where it also is used in glass and perhaps as a raw material for the production of lithium carbonate.

Canada.—Tantalum Mining Corp. of Canada Ltd. (a subsidiary of Hudson Bay Mining Co.) has operated a spodumene mine and concentrating plant at Bernic Lake, Manitoba, on a commercial scale since 1986. Having worked toward developing the Separation Rapids petalite deposit near Kenora, Ontario, since 1998, Avalon Venture Ltd. provided a 300-t bulk sample of crushed petalite to a potential customer for evaluation in 2006 (Industrial Minerals, 2006c). GlobeStar Mining Corp. conducted a detailed drilling program at a pegmatite deposit near Moblan, Quebec. The company was exploring the possibility of producing spodumene and other minerals for use in the ceramics and glass industry (Fisher, 2006).

Chile.—SQM reported strong revenues from its lithium products as a result of increased sales and higher prices in 2006. Sales volume at 30,400 t was 8% higher than in 2005, but the value of sales was up by 58% to $128.9 million as a result of significantly increased prices. Primary growth markets were batteries in Asia and glass in Europe. The use of lithium continuous casting powders used in the steel industry in Asia was an important and expanding new market. Lithium hydroxide markets were growing, generating price increases of 30% compared with those of 2005. The company's expansion of its lithium carbonate capacity to 40,000 t/yr was expected to be completed in 2008 (Sociedad Química y Minera de Chile S.A., 2007). Rockwood Holdings reported unfavorable weather conditions at Chemetall's evaporating ponds that resulted in lower lithium carbonate production than usual. This, coupled with strong demand for lithium compounds, resulted in shortages of lithium compounds (Rockwood Holdings, Inc., 2007, p. 24).

China.—China is the only country that continued to produce large quantities of lithium carbonate from spodumene. China Xinjuang Nonferrous Metals Corporation of Mingyuan produced lithium carbonate from domestic and imported Australian ore (Ebensperger and others, 2005). Additional lithium carbonate was imported into China from Chile and the United States. Lithium brines were thought to be the largest lithium resources in China, containing 80% of the country's reserves (Crossley, 2003).

China was developing a project to recover lithium carbonate from the brines of the Zabayu salt lake in Tibet. Capacity was expected to be 5,000 t/yr (Chinanews, 2005). Sterling Group Ventures Ltd. of Canada was working on another lithium carbonate project at a saline lake in Tibet. Production was expected to be about 5,000 t/yr when all the technical details were resolved (Industrial Minerals, 2006d).

Outlook

Although traditional markets are still important to the lithium industry, batteries are rapidly gaining in importance and could very soon be the major market for lithium materials of all kinds.

The global market for lithium batteries has been increasing by more than 20% per year in the past few years. Lithium-ion and lithium-polymer batteries appear to have the greatest potential for growth. The world market for these rechargeable batteries was estimated to be $4 billion in 2005 (Chemical & Engineering News, 2006b). Other lithium markets are also growing but at lower rates than batteries. Lithium producers had diverse opinions on what other areas offer the most potential for growth. One producer reported growth in construction uses, especially in fast-setting concrete. Another company experienced its largest growth in the use of organic lithium compounds used as pharmaceutical catalysts. Lithium bromide consumption for air conditioning was reported to be increasing by some producers, but on the decline, especially in the United States, by another. Better estimates of actual markets were not possible because details that closely define these markets were not publicly available.

Lithium batteries hold tremendous potential for continued growth. Although some safety issues remain, new technologies are being developed with more stable cathode materials. Improvements in performance have been significant. The energy density of lithium-ion batteries is more than twice what it was when they were introduced in 1991 (Chemical & Engineering News, 2006a).

Larger lithium batteries were being incorporated in new products. In 2006, heavy-duty tool manufacturers, Milwaukee Electric Tools Corp., Dewalt Industrial Tool Co., and Robert Bosch Tool Corp., introduced complete lines of tools designed around lithium-ion batteries. They were expected to eventually replace tools using nickel cadmium batteries. The lithium-ion batteries deliver up to 50% more power, longer running time, and more charging cycles than the comparable nickel cadmium batteries, but at a premium price (Kirzan, 2006).

Although hybrid HEVs almost exclusively used nickel metal hydride batteries in 2006, major automobile manufacturers announced plans to develop lithium-ion batteries for use in future generations of this type of vehicle. General Motors Corp., Toyota Motors Corp., and Volkswagen AG were working on lithium-ion technology. In addition, interest was increasing for plug-in hybrid vehicles (PHEVs) that would have a longer pure-electric driving range, meaning that the batteries would be significantly larger than those in the HEVs that were operating in 2006. The use of lithium-ion batteries in HEVs and PHEVs could create tremendous increases in demand for lithium. As demand and prices rise, lithium resources that had been considered uneconomic might once again yield economically feasible raw materials for the production of lithium carbonate.

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TABLE 1
SALIENT LITHIUM STATISTICS[1]

(Metric tons of contained lithium)

	2002	2003	2004	2005	2006
United States:					
Production	W	W	W	W	W
Exports[2]	1,620	1,520	1,690	1,720	1,500
Imports[2]	1,920	2,200	2,910	3,580	3,260
Consumption, estimated	1,100	1,400	1,900	2,500	2,500
Rest of world, production[3]	16,400	19,100	20,300	21,000 [r]	21,000 [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]

	2005		2006	
Compound and country	Gross weight (metric tons)	Value[2] (thousands)	Gross weight (metric tons)	Value[2] (thousands)
Lithium carbonate:				
Brazil	77	$1,480	6	$22
Canada	60	219	57	212
China	797	2,930	60	215
Germany	1,030	2,840	956	2,910
India	49	182	10	47
Japan	1,170	3,100	1,310	4,440
Malaysia	19	47	76	257
Netherlands	169	430	194	543
Thailand	148	561	12	52
United Kingdom	242	651	320	1,060
Vietnam	54	147	--	--
Other	143 r	494 r	93	474
Total	3,960	13,100	3,100	10,200
Lithium carbonate, U.S.P.:[3]				
Australia	51	155	--	--
China	144	319	17	56
Philippines	11	30	--	--
United Kingdom	21	36	2	32
Other	5 r	101 r	11	202
Total	232 r	641	30	290
Lithium hydroxide:				
Argentina	133	602	91	456
Australia	153	511	68	353
Belgium	179	514	39	110
Canada	156	655	189	774
China	180	645	55	300
Colombia	49	216	79	438
Egypt	34	128	80	407
Germany	931	2,540	1,040	3,720
India	399	1,580	91	684
Japan	1,310	5,500	1,990	11,300
Korea, Republic of	262	1,120	263	1,470
Mexico	171	626	67	421
Netherlands	210	524	196	774
Philippines	61	209	16	88
Russia	523	1,370	424	1,950
Saudi Arabia	56	205	56	225
Singapore	114	454	36	179
South Africa	84	591	125	1,000
Sweden	95	234	131	506
Thailand	215	682	231	1,290
Ukraine	80	272	--	--
United Kingdom	89	257	116	398
Venezuela	1	10	64	263
Other	137 r	648 r	89	732
Total	5,620	20,100	5,540	27,900

[r]Revised. -- 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.

Source: U.S. Census Bureau.

TABLE 3

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

Compound and country	2005 Gross weight (metric tons)	2005 Value[2] (thousands)	2006 Gross weight (metric tons)	2006 Value[2] (thousands)
Lithium carbonate:				
Argentina	4,630	$9,600	6,540	$19,100
Chile	14,300	17,700	9,840	18,700
Other	39	146	94	293
Total	18,900	27,500	16,500	38,200
Lithium hydroxide:				
Chile	54	172	591	3,650
China	1	10	49	305
Germany	(3)	22	24	316
India	--	--	265	1,510
Norway	48	93	49	94
United Kingdom	13	76	11	62
Other	8	79 r	8	106
Total	124	452 r	997	6,040

[r]Revised. -- Zero.

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

[2]Customs value.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 4

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

(Metric tons)

Country[3]	2002	2003	2004	2005	2006
Argentina:[4]					
Lithium carbonate	906 [5]	2,850	4,970 [5]	7,300 [r, 5]	8,000
Lithium chloride	4,729 [5]	4,700	6,303 [5]	8,400 [r, 5]	8,500
Australia, spodumene	79,085 [5]	124,410 [5]	118,451 [5]	173,635 [r, 5]	175,000
Brazil, concentrates	12,046 [5]	12,100	12,100	12,100	12,100
Canada, spodumene[6]	22,500	22,500	22,500	22,500	22,500
Chile, carbonate from subsurface brine	35,242 [5]	41,667 [5]	43,971 [5]	43,595 [r, 5]	43,600
China, carbonate	13,000	13,500	14,000	15,000	15,000
Portugal, lepidolite	16,325 [5]	16,000	16,000	16,000	16,000
Russia, minerals not specified[7]	2,000	2,000	2,200	2,200	2,200
United States, subsurface brine	W	W	W	W	W
Zimbabwe, amblygonite, eucryptite, lepidolite, petalite, spodumene	33,172 [5]	12,131 [5]	13,710 [5]	37,499 [r, 5]	30,000

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

[1]Table includes data available through April 23, 2007.

[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 sources, prompting major revisions in how lithium production was reported.

[5]Reported figure.

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

[7]Lithium contained in concentrates and brine.These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available. Other countries from the Commonwealth of Independent States, including Uzbekistan, could have produced or could be producing lithium, but information is not available for estimating production levels.