LITHIUM

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In 2004, lithium consumption in the United States was estimated to be 1,900 metric tons (t) of contained lithium, nearly 36% more than the estimate for 2003 and 73% more than in 2002. Increased U.S. consumption likely is a result of a general improvement in the domestic economy that created additional consumption in most industrial uses and significantly increased demand for lithium in battery applications. Lithium compounds consumed in the United States were produced at a single domestic operation in Nevada and imported 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 and two lithium carbonate plants in Antofagasta. In the United States, production continued at a single 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 in Argentina. China was the only country producing lithium carbonate from lithium minerals. Australia was, by far, the leading producer of lithium concentrates, but 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), 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. (SCL) produces lithium carbonate and lithium hydroxide from a brine deposit.

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 Bayport, TX. FMC met its lithium carbonate requirements with material produced at its Argentine operation and through a long-term agreement with Chilean producer Sociedad Quimica y Minera de Chile S.A. (SQM) to supply it with lithium carbonate produced at SQM's brine operation. FMC also produced lithium chloride in Argentina in 2004.

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. Most lithium compounds and minerals are consumed in the production of ceramics, glass, and primary aluminum. The consumption of various lithium compounds in lithium batteries, the use of organic lithium compounds as industrial catalysts, and lithium compound additions to concrete are growth markets.

In 2004, lithium consumption in the United States was estimated to be 1,900 t of contained lithium, nearly 36% more than the estimate for 2003 and 73% more than in 2002. The recent recovery can be attributed to the recovery of consumption in all end uses except aluminum as a result of the upswing in the domestic economy and increased demand in a few rapidly expanding end uses.

The aluminum, ceramics and glass, lubricating grease, and synthetic rubber industries used most of the lithium minerals and compounds consumed in 2004. Primary aluminum production has been low since 2002 but still a significant consumer of lithium carbonate.

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.

Primary aluminum production is believed to be the second leading use of lithium in the United States, although at lower levels than before the closure of several aluminum smelters in 2001. 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. Lithium carbonate additions have the environmental benefit of reducing fluorine emissions by 20% to 30% (Chemetall GmbH, undated§[1]).

Domestically, another large end use for lithium compounds was as catalysts 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 an analgesic, anticholesterol agents, antihistamines, contraceptives, sleep inducers, steroids, tranquilizers, vitamin A, and other products. Lithium catalysts were used in the production of protease inhibitors, important drugs in the treatment of human immunodeficiency virus type 1/acquired immunodeficiency syndrome (HIV-AIDS) (Schmitt, 2001). 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 multipurpose grease industry was another important market for lithium in 2004. Lithium hydroxide monohydrate was the compound used in the production of lithium lubricants. Lithium-based 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.

Many major battery manufacturers marketed some type of lithium battery. Two major advantages of lithium batteries are their even discharge over time and their low tendency to self-discharge that gives them long shelf lives. Research and development continued, and innovative rechargeable battery configurations continued to be developed 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., 2005§). Lithium-ion batteries were of particular interest for these applications because they take advantage of the large power capacity of lithium batteries with fewer safety problems than are encountered when batteries contain lithium metal, a very reactive and volatile material when exposed to air and moisture.

Use of lithium-ion batteries in aerospace applications is growing. The National Aeronautics and Space Administration (NASA) has used them to power Mars probes, and space agencies in other countries have begun to use them in satellites. Northrop-Grumman Corp. planned to use lithium-ion batteries in its next generation of unmanned aerial vehicles. Lithium-ion batteries represent a significant reduction in weight, a very important factor for aerospace activities, when they replace more traditional battery chemistries such as nickel hydrogen (Aviation Week & Space Technology, 2004).

Nonrechargeable (primary) 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.

Aircraft manufacturers in several countries have considered using aluminum-lithium alloys for wing and fuselage skin or for 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, were attractive to the aircraft and aerospace industries because of their reduced density and improved corrosion resistance compared with conventional aluminum alloys. These alloys, however, have not been as widely used in aircraft manufacture as a result of direct competition from composite materials consisting of aramid, boron, or graphite fibers embedded in polymers. The superlightweight external fuel tank for the NASA space shuttle was made with another aluminum alloy.

Lithium was being used increasingly as a concrete additive for two reasons. Small additions of lithium can prevent or mitigate premature deterioration of concrete through alkali silica reactivity (ASR). In ASR, silica in the aggregate reacts with the alkali in the cement binder producing a silica gel that then absorbs water and expands sufficiently to create cracks in the concrete (FMC Corp., 2005§). Lithium compounds also are added to fast-setting cements, floor screeds, joint sealing mortars, and cement based adhesives to accelerate setting and hardening rates (Chemetall GmbH, undated§).

Small quantities of other lithium compounds were important to many industries. For example, 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 has become very competitive since SQM entered the market in 1998. It has become difficult to obtain reliable price information from companies or trade publications. Companies may announce price hikes, but they are reported relative only to previous

[1]References that include a section mark (§) are found in the Internet References Cited section.

prices. Producers negotiate with consumers on an individual basis; price information is not usually reported.

Customs values for lithium carbonate imports to the United States are a good indication of the trends in lithium pricing, although they have never exactly reflected the producers' prices for lithium carbonate. In 2004, the average customs unit value for imported lithium carbonate was $1.72 per kilogram, about 11% higher than in 2003.

Foreign Trade

In 2004, total exports of lithium compounds from the United States increased by 11% compared with that of 2003. About 62% of all U.S. exports of lithium compounds went to China, Germany, India, Japan, the Republic of Korea, and Russia, all with more than 500 t. The remainder was divided among many other countries (table 2).

Imports of lithium compounds increased by 32% in 2004 as the domestic economy continued to improve. In 2004, 68% of lithium chemical imports came from Chile, 31% came from Argentina, and 1% 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. 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.

The total world lithium market was estimated to be about 13,200 t of lithium contained in minerals and compounds in 2002, the latest year for which this type of information was available. About 10,200 t of lithium was consumed as compounds, and the remainder, as concentrates (Crossley, 2003b). More recent data are unavailable, but some estimates on growth can be made based on recent growth rates reported by SQM. That company estimated demand for their lithium materials to have grown by 5% to 7% per year during the past 5 years (Harris, 2005). Assuming similar growth for all lithium compounds consumption, total consumption of lithium in minerals and compounds in 2004 can be estimated to be about 14,800 t, with 11,500 t in compounds.

Argentina.—Lithium carbonate production of 4,970 t and lithium chloride production of 6,303 t were reported for 2004, an average increase of 49% from production reported in 2003. FMC's Argentine facility 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). Production of both compounds reached record levels in 2004, with lithium chloride production surpassing reported capacity. It is not known whether the plant was expanded or if improved efficiencies made the extra production possible.

Australia.—Sons of Gwalia Ltd. is the leading lithium mineral producer with 60% of world lithium concentrate capacity. It produces spodumene concentrates at the Greenbushes Mine in Western Australia. The company markets products ranging from 2.2% to 3.5% lithium (Crossley, 2003b). Production in Australia has increased to about 124,000 t in 2003 from about 79,000 t in 2002. Official production data were not available for 2004 but was estimated to be at least 125,000 t. Spodumene concentrates are sold for consumption in ceramics and glass and is also exported to China where it is used as a raw material for the production of lithium carbonate.

Chile.—With two large brine operations at the Salar de Atacama and their associated lithium carbonate plants, Chile was the leading lithium carbonate producer in the world. Chemetall Foote's plant first produced lithium carbonate in 1984, and current capacity is about 14,500 t/yr. The plant uses this lithium carbonate as feedstock for some of its downstream chemical production in the United States and supplies the operations of its parent company, Chemetall, in Germany and Taiwan (Chemetall GmbH, undated§). SQM completed its first full year of production in 1997 with the capacity to produce about 23,000 t/yr of lithium carbonate (Schmitt, 2001). Both Chilean companies transported concentrated brines from the Salar de Atacama to lithium carbonate plants in Antofagasta.

In 2004, SQM was producing at its full capacity of 27,000 t/yr and planned to increase capacity to 40,000 t/yr by 2008. The company reported that its share of the world lithium carbonate market has grown to 40%. SQM intended to begin producing lithium hydroxide in Chile late in 2005 at a new 6,000-t/yr plant (Harris, 2005).

China.—China is the only country that continued to produce lithium carbonate from spodumene. It used domestic spodumene from several small mines, and additional deposits were being investigated. Imported Australian spodumene was used as raw material for lithium carbonate production and in ceramics and glass applications. Additional lithium carbonate was imported into China from Chile and the United States. Lithium brines were believed to be the largest lithium resources in China, containing 80% of the country's reserves. Production from brine deposits was reported for the first time in 2003, but quantity data were not available. Lithium carbonate plants using brine from the Qinghai and Xitai Jinaer Salt Lakes were under development. These deposits are in very remote areas and have more magnesium than other producing brine deposits; these factors may influence how much success China achieves in the lithium industry (Crossley, 2003a).

Outlook

The performance of the domestic lithium industry remains closely tied to the ceramics and glass and primary aluminum industries in the United States and to the U.S. economy in general. Changes in consumption of lithium in these industries are important factors determining the performance of the entire lithium industry. With nearly one-third of U.S. aluminum capacity idle since 2001, lithium consumption remained depressed, and prospects for recovery are low. Increases in USGS estimated lithium consumption indicate improved consumption in other areas; consumption of lithium in batteries is probably the leading growth area, but statistics to quantify that market are not available.

Prospects for growth are very different from a global perspective. The market for lithium batteries is increasing in value by 12% to 15% per year, and the volume of sales is increasing at an even higher rate of 25% to 30%. The differences in these growth rates indicate that as the sales of batteries increase, the price per unit is decreasing. A large proportion of these devices are produced in Asia, so growth in this application is not a large influence on lithium consumption in the United States.

Lithium-ion and lithium-polymer batteries appear to have the greatest potential for growth. First introduced in 1993, the market for these rechargeable batteries was estimated to be $3.5 billion in 2003. Most lithium batteries that are sold are the lithium-ion type, but lithium-polymer batteries are gaining in popularity and represent about 10% of the battery market. Lithium-polymer batteries are more attractive to many original equipment manufacturers because they can be constructed in unusual shapes to more easily fit into the devices that they power (Crossley, 2003b).

The use of lithium batteries in electric vehicles (EVs) was believed to offer the potential for future growth in lithium demand for quite some time. Battery-powered EVs have not become as popular as was expected, and they appear to have lost favor with many automakers. Instead, carmakers have shifted focus to developing hybrid electric vehicles (HEVs) that contain small internal combustion engines and battery-powered electric motors. These vehicles are growing in popularity, and more models are being developed. Most current HEVs incorporate nickel metal hydride batteries, but improved lithium batteries could replace them in future generations of HEVs, creating increased demand for lithium. The successful development of fuel cell technology to power automobiles in the future, however, could render battery-powered vehicles obsolete.

Lithium producers had diverse opinions on what areas offer the most potential for growth. One producer reported surprising growth in construction uses, especially in fast-setting concrete. Another company saw its largest growth in the use of organic lithium compounds used as pharmaceutical catalysts. Lithium bromide consumption 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.

Based on differing reports from a variety of sources, some conclusions can be drawn. Domestic consumption is likely to continue to increase. Aluminum production and ceramics and glass will remain the leading end uses in the near term, although not as dominant as in the past. Continued closures at aluminum smelters could result in permanent shutdowns with no chance of increased lithium consumption at those locations. The closure of the thermal-shock-resistant cookware factory in West Virginia, once the single leading lithium concentrate consumer in the world, eliminated a major consumer of those products. Increased popularity of glass cooktops is a growing market for lithium concentrates, but consumption will increase in Europe, not the United States. The largest growth area is in batteries, but lithium batteries are mostly produced in Asia, so this end use will have minimal effect on domestic lithium consumption. Growth in other lithium end uses will continue, but probably at modest rates.

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TABLE 1
SALIENT LITHIUM STATISTICS[1]

(Metric tons of contained lithium)

	2000	2001	2002	2003	2004
United States:					
Production	W	W	W	W	W
Exports[2]	1,310	1,480	1,620	1,520	1,690
Imports[2]	2,880	1,990	1,920	2,200	2,910
Estimated consumption	2,800	1,400	1,100	1,400	1,900
Rest of world, production[3]	16,400 r	15,400 r	16,400 r	19,100 r	20,200 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]

	2003		2004	
Compound and country	Gross weight (metric tons)	Value[2] (thousands)	Gross weight (metric tons)	Value[2] (thousands)
Lithium carbonate:				
Canada	124	$443	126	$451
China	251	903	771	2,750
Germany	1,000	3,040	795	2,380
India	39	134	63	169
Japan	686	2,850	634	2,280
Korea, Republic of	182	520	329	874
Netherlands	64	232	105	378
Taiwan	54	123	33	80
United Kingdom	150	531	177	743
Other	111 r	377 r	135	481
Total	2,660	9,160	3,170	10,600
Lithium carbonate, U.S.P.:[3]				
China	313	659	668	1,210
United Kingdom	--	--	56	103
Other	7 r	89 r	14	287
Total	320	748	738	1,600

See footnotes at end of table.

TABLE 2—Continued

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

Compound and country	2003 Gross weight (metric tons)	2003 Value[2] (thousands)	2004 Gross weight (metric tons)	2004 Value[2] (thousands)
Lithium hydroxide:				
Argentina	89	256	166	642
Australia	229	901	226	810
Belgium	528	2,310	410	1,260
Canada	110	436	150	609
Chile	77	260	37	122
Egypt	32	195	83	240
Germany	740	2,090	701	1,930
India	713	2,250	505	1,430
Japan	968	4,090	1,200	4,570
Korea, Republic of	256	924	278	1,010
Mexico	104	313	190	676
Netherlands	163	532	160	423
New Zealand	295	689	123	762
Russia	351	866	572	1,820
Singapore	79	461	107	317
South Africa	131	797	119	325
Spain	53	247	16	40
Sweden	49	127	56	132
Taiwan	49	232	57	272
Thailand	180	474	181	488
Ukraine	119	317	34	92
United Kingdom	242	1,090	118	651
Other	272 r	1,560 r	297	1,420
Total	5,830	21,400	5,780	20,000

[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	2003 Gross weight (metric tons)	2003 Value[2] (thousands)	2004 Gross weight (metric tons)	2004 Value[2] (thousands)
Lithium carbonate:				
Argentina	3,110	$5,790	4,850	$11,200
Chile	8,430	12,000	10,500	15,200
Other	45 r	199 r	47	165
Total	11,600	18,000	15,400	26,500
Lithium hydroxide:				
China	63	189	16	38
United Kingdom	22	165	11	59
Other	26 r	247 r	37	136
Total	111	601	64	233

[r]Revised.

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

[2]Customs value.

Source: U.S. Census Bureau.

TABLE 4

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

(Metric tons)

Country[3]	2000	2001	2002	2003[e]	2004[e]
Argentina:[4]					
Lithium carbonate	2,161	--	906	2,850 r, 5	4,970 5
Lithium chloride	5,182	4,512	4,729	4,700	6,303 5
Australia, spodumene	65,504 r	79,859 r	79,085 r	124,410 r, 5	125,000
Brazil, concentrates	10,875	9,084 r	12,046	12,100	12,100
Canada, spodumene[e, 6]	22,500	22,500	22,500	22,500	22,500
Chile, carbonate from subsurface brine	35,869	31,320	35,242 r	41,667 r, 5	42,500
China, carbonate[e]	13,000	13,000	13,000	13,500	14,000
Portugal, lepidolite	9,352	11,571 r	16,325 r	16,000 r, 5	16,000
Russia, unspecified[e, 7, 8, 9]	2,000	2,000	2,000	2,000	2,200
United States, subsurface brine	W	W	W	W	W
Zimbabwe, amblygonite, eucryptite, lepidolite, petalite, and spodumene	37,914	36,103	33,172 r	12,131 r, 5	12,000

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

[1]Table includes data available through March 28, 2005.

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

[8]Lithium contained in concentrates and brine.

[9]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.