Lithium

Office of Intelligence and Counterintelligence

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Lithium - Intro

- Subsurface brines are the dominant raw material for lithium carbonate production worldwide because of lower production costs compared with the mining and processing costs for hard-rock ores.
- Two brine operations in Chile dominate the world market and a facility at a brine deposit in Argentina produced lithium carbonate and lithium chloride.
- A second brine operation was under development in Argentina.
- Most lithium minerals mined were used directly as ore concentrates rather than as feedstock for lithium carbonate and other lithium compounds.

Lithium Market	Share
Batteries	23%
Ceramics and Glass	31%
Greases and Lubricants	10%
Air Treatment	5%
Continuous Casting	4%
Aluminum Production	3%
Other	24%

U.S. Geological Survey, Mineral Commodity Summaries, January 2010, p. 90, "Lithium"

Country	Reserve Base tons Li	Reserves tons	Production ton/yr
US	2,500,000	38,000t {202,160}(661,380)[231,000]	(5,511)
Others	23,000,000	---	---
Bolivia	9,000,000	[32,253,000]	---
Chile	7,500,000	7,500,000{39,9000,000}(31,966,700)[26,389,000]	7,400{39,368}(41,887)
Argentina	2,500,000	800,000{4,256,000}(9,920,700)[15,895,000]	2,200{11,704}(18,188)
China	2,500,000	540,000{2,872,800}(19,841,400)[15,245,000]*	2,300{12,236}(2,205)
Australia	---	580,000{3,085,600}	4,400{23,408}
Brazil	---	190,000{1,010,800}[496,000]	110{582}
Canada	---	180,000{957,600}	480{2,554}
Zimbabwe	---	23,000{122,360}	350{1862}
Portugal	---	---	490{2607}

- **U.S. Geological Survey, Mineral Commodity Summaries, January 2010, p. 90, "Lithium" Li-metal {Lithium Carbonate Equivalent,LCE in brackets}**
- **(http://www.evaporiticosbolivia.org/indexi.php?modulo=temas&opcion=plantafutura)**
- **[5.32 LCE (Li2CO3) = one unit of Lithium Metal,*=China and Tibet, 2008, USGS]**

•(Argonne National Laboratory) a battery capable of providing 100 miles of range for an electric vehicle would contain between **3.4 [18.0 LCE] and 12.7 [67.6 LCE] kg of lithium**, depending on the specific lithium-ion chemistry used and the battery range (Gains and Nelson 2010).

•1 million vehicles = 18,000,000-67,600,000kg = 19,841-74,515 tons LCE (~130,000 tons produced in 2008, **~32,000 tons (~25%) for batteries**)

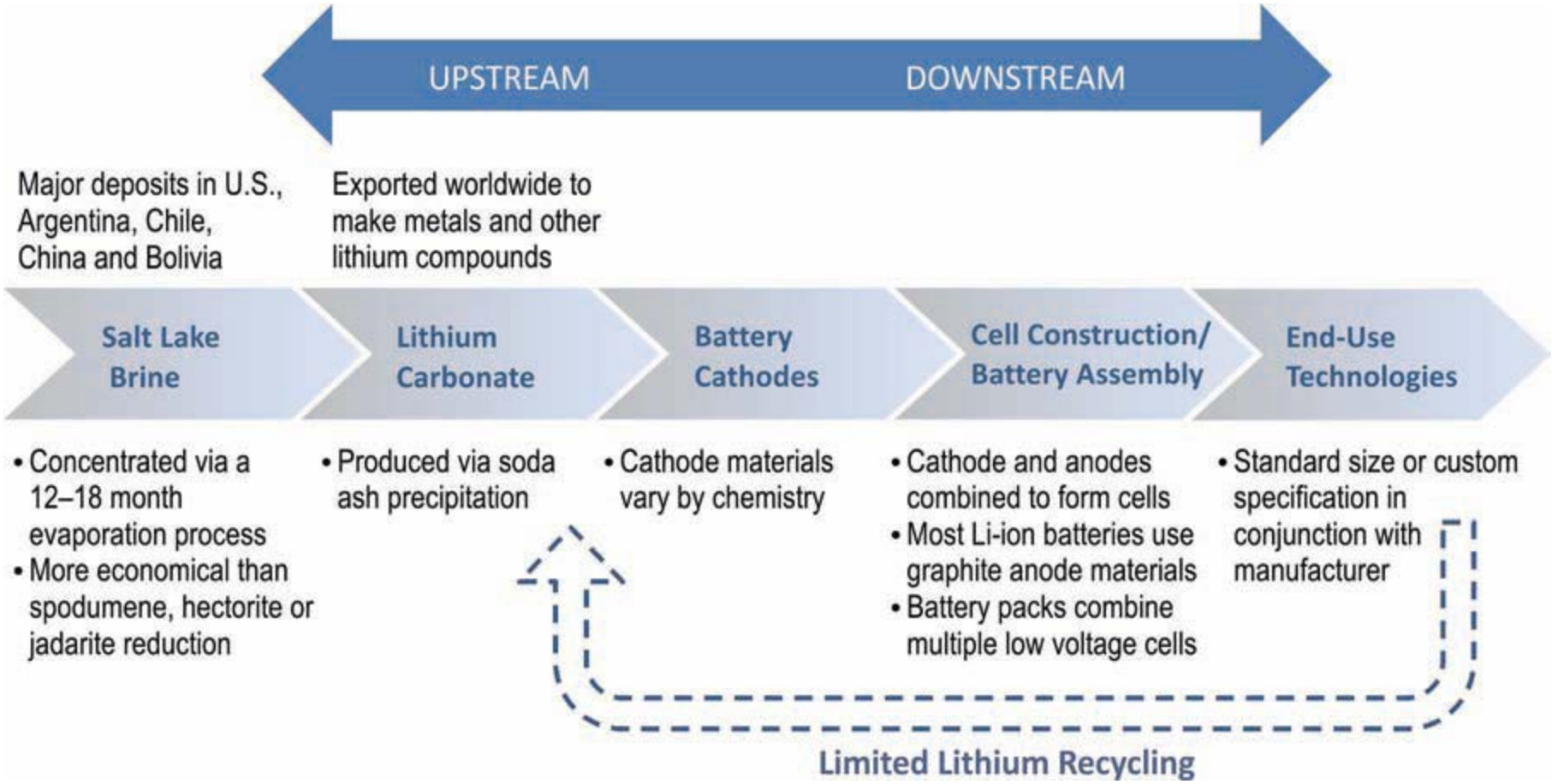
•The process starts with concentrating the lithium chloride by evaporating salty water in shallow pools **for 12 to 18 months**, which is then treated with sodium carbonate (soda ash) to precipitate out the lithium carbonate.

•Lithium carbonate has also been produced from spodumene (a silicate of lithium and aluminum) and hectorite clay deposits, but recovery from these sources is more expensive (USGS 2009).

The DOE Critical Materials Strategy 2010

DOE CRITICAL MATERIALS STRATEGY DEC 2010

Department of Energy



Recycle and Re-use

Various programs seek to recover and recycle lithium-ion batteries. These include prominently placed recycling drop-off locations in retail establishments for consumer electronics batteries, as well as recent efforts to promote recycling of EV and PHEV batteries as these vehicles enter the market in larger numbers.

Current recycling programs focus more on preventing improper disposal of hazardous battery materials and recovering battery materials that are more valuable than lithium.

However, if lithium recovery becomes more cost effective, recycling programs and design features provide a mechanism to enable larger scale lithium recycling.

Another potential application for lithium batteries that have reached the end of their useful life for vehicle applications is in **stationary applications such as grid storage**.

Gains, L., and P. Nelson. 2010. Lithium-Ion Batteries: Examining Material Demand and Recycling Issues. Argonne, IL: Argonne National Laboratory.

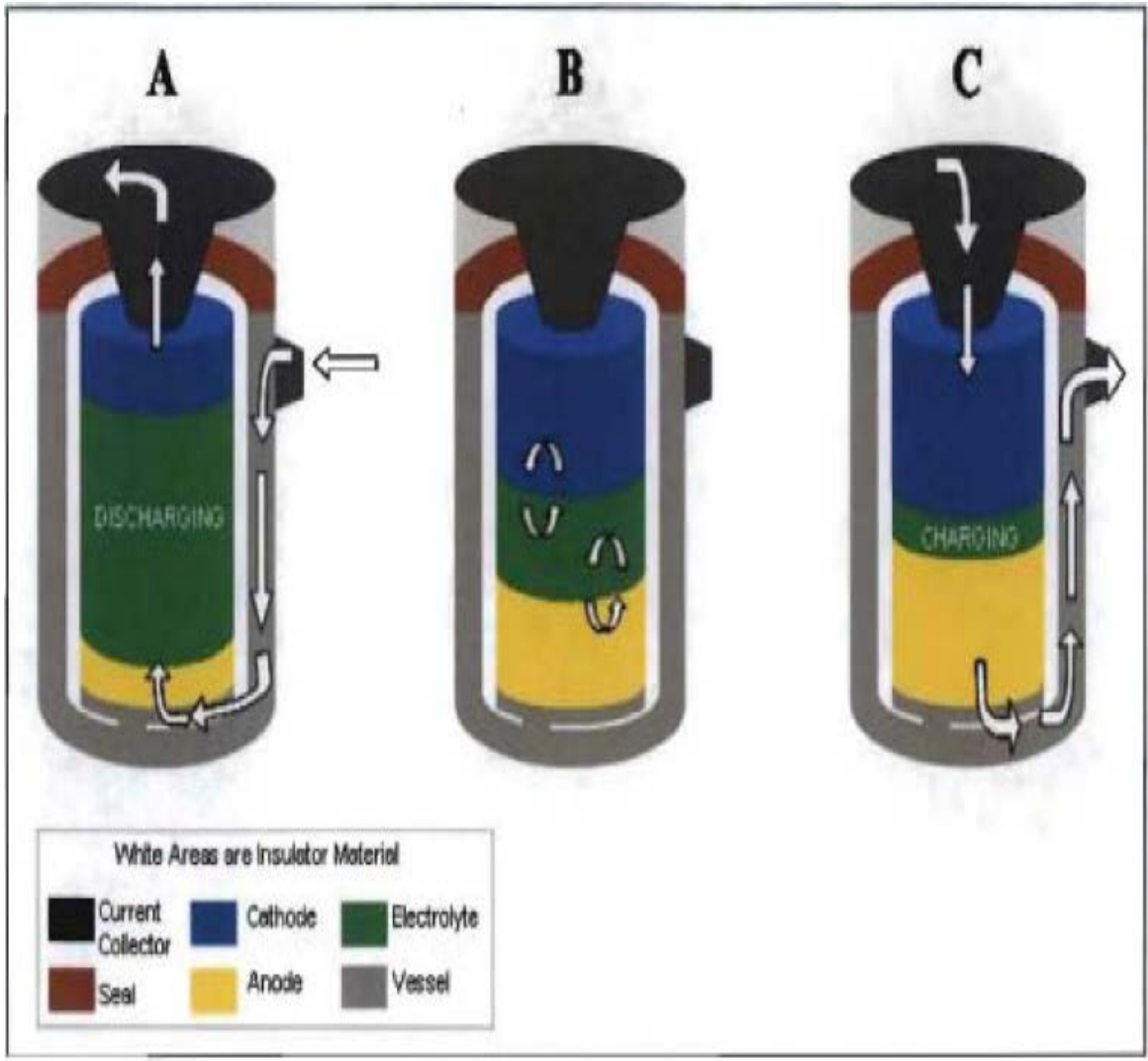
Future Uses - Lithium and Nuclear Reactions

- Lithium-6 is valued as a source material for tritium production and as a neutron absorber in nuclear fusion.
- Natural lithium contains about 7.5% lithium-6 used in nuclear weapons. Lithium-7 used in **nuclear reactor coolants**.
- Lithium fluoride as highly enriched in the lithium-7 isotope forms the basic constituent of the fluoride salt mixture LiF-BeF2 that used in **liquid-fluoride nuclear reactors.**
- Lithium fluoride is exceptionally chemically stable and LiF-BeF2 mixtures have low melting points.
- In addition, 7Li, Be, and F are among the few nuclides with low enough thermal neutron capture cross-sections to not poison the fission reactions inside a nuclear fission reactor.
- Lithium will be used in future fusion reactors to produce tritium to be used with deuterium as the fuel.

http://en.wikipedia.org/wiki/Lithium

Future Use? The Liquid Battery

- All liquid battery
- Possibly cheaper and more reliable than others
- Energy storage for intermittent renewable energy
- Liquid electrodes
- Molten salt electrolytes (*such as* **lithium sulfate**)
- $6.9 million grant -Department of Energy's ARPA-E
- $4 million grant from oil company Total
- Investment from Bill Gates
- Resource constraints?
- http://news.cnet.com/8301-11128_3-20064404-54.html



Alternative view - The Market for Lithium

- ***TRU Group Inc, January 18, 2011 –***
- **The seemingly unstoppable supply growth will cause such huge overcapacity** that the stability of the industry will be threatened.
- Pipeline projects and expansions could increase capacity by about 40,000 tpy Li-contained in the next decade – double what the industry needs.
- **Existing lithium chemical producers have the in-ground resources and ability to meet nearly all market requirements by expanding capacity.**
- Lithium carbonate prices fell precipitately to $4500 per t in 2010 and will remain depressed.
- Lower prices and fierce competition through 2020 is bad news for the lithium new project promoters who will find it impossible to compete against the distinctive natural cost advantage of brine-based producers Chemetall-SCL, FMC and SQM.
- TRU's veteran lithium geologist Dr Ihor I. Kunasz "It's simple, the existing players have three times the lithium concentration and also reserves that dwarf any of the new players. In addition SQM by far the world's largest lithium supplier has for many years re-injected excess lithium produced into the Salar de Atacama adding to the lithium resource of the salar".
- http://trugroup.com/Lithium-Market-Conference.html

CONSTRAINTS - LITHIUM AND WATER - BOLIVIA

- Water Bolivia, per capita renewable resource (cu meters per) is falling (31,307 in 2008 compared to ~35,000 in 2003) http://www.tradingeconomics.com/bolivia/renewable-internal-freshwater-resources-per-capita-cubic-meters-wb-data.html

- Title: Estimating the Opportunity Cost of Lithium Extraction in the Salar de Uyuni, Bolivia Author: Aguilar-Fernandez, Rodrigo http://dukespace.lib.duke.edu/dspace/handle/10161/1554

  - The Salar de Uyuni in Bolivia holds the largest source of lithium in the world; however, its extraction will bring a trade off with the environment.
  - Due to the arid nature of the climate, the Salar de Uyuni basin has a sensitive ecosystem heavily dependent on water resources. Consequently, local people's subsistence and well-being also depend on water resources on a daily basis.
  - **Studies conducted in the Salar de Uyuni basin concluded that using the same spring as a production input, water consumption for lithium extraction and crop irrigation cannot simultaneously take place.**
  - Thus, the fresh water use from the San Geronimo River creates two mutually exclusive projects, lithium mining and quinoa crop with irrigation, generating different gains to the economy of the region.
  - The results indicate that even after subtracting the opportunity cost of not conducting the quinoa irrigation project and reducing the uncertainty of the model parameters, the net present value (NPV) of the lithium extraction project is still positive and large relative to the economy of the study area.

Bolivian Lithium Projects

- Pilot project , 400 tonnes per year
- “Lithium Industrialization plant” **40-60k tonnes/year planned (2014)**
- World production about 118k tonnes/ year
- Extremely arid area
- Precipitation 100-200 mm/year, evaporation 1300-1700 mm/yr (4.2-5.5 ft/yr)
- Fresh water need for 2014 plant estimated at **4000-4200 cu m/day** from Rio San Geronimo
- Torrez& Ramirez (2006) plant in Chile uses around 8208 cu m/day
- Total estimated average daily recharge of Rio San Geronimo **5800 cu m/day**
- Assumed life of lithium resource 20 years
- Salar de Uyuni reserves about 5.5 ,milliom tones in brine 423 mg/lt (.035%)
- 4000-4200 X 365 = 1,460,000-1,533,000 cu m/yr , x 264.172052gal/m3 = 385,691,190-404,975,750 gal/yr
- Gallons per tonne = **6428-10124 gallons per tonne**

Estimating the opportunity cost of lithium extraction in the salar de uyuni, bolivia, Master Project , Rodrigo Aguilar-Fernandez, Dec 2009, Duke University

- **The Bolivian deposit is contaminated with magnesium**, which is also true at the Atacama deposit in Chile, except that while the Mg/Li ratio there is 6.4 to 1, the deposit is 0.15% Lithium.
- At Hombre Muerto the Argentinean deposit, the Mg/Li ratio is only1.37 to 1, making it easier to produce, even though the grade is lower, at only 0.062% Li.
- **Unfortunately the Bolivian deposit has only a 0.028% lithium, and a Mg/Li ratio of 19.9:1 so that it has both a poorer grade, and a higher Mg content.**
- To add to these disadvantages, being high in the Andes means that evaporation is not as fast, and so processing costs go even further. This is especially true since the lake apparently floods every year, slowing evaporation even further.
- For the moment, the production of much lithium from Bolivia might be a bit further in the future than they currently expect. Which is perhaps why **the plant [keeps getting] pushed further and further into the future.** By November last it had been put back to 2014.
- Japan's Sumitomo and Mitsubishi, and South Korea's state-run Korea Resources Corporation, are helping the Bolivian government find the best way to extract lithium from Uyuni "free of charge," but will be the preferential buyers of Bolivia's lithium carbonate.
- Geothermal power plants draw hot brine from underground as a power source, and these brines can contain dissolved minerals. Thus, for example the seven Geothermal plants at the Salton Sea are reported to be able to produce up to 16,000 tons of lithium per year. The facilities are better known as a source of zinc (pdf). However the potential as a source of lithium is becoming increasingly recognized.

http://www.energybulletin.net/node/51641

http://www.evaporiticosbolivia.org/indexi.php?modulo=temas&opcion=plantafutura

Producción Mundial de Litio extraída de Salares

Estimado a 5 años

País	Inversionista	Empresa	Salar	Reservas (MM TM Li2CO3 equivalente)	Producción actual TM/año (en Li2CO3 eqv)	Producción estimada TM/año (en Li2CO3 eqv)	% Part. En mercado
Chile	Potash Corp.	SQM	Atacama	21	30,000	45,000	25.42%
Chile	Chemetall	Sociedad Chilena de Litio	Atacama	8	18,000	25,000	14.12%
Argentina	FMC	Minera de los Andes	Hombre Muerto	3	16,500	22,000	12.43%
Argentina	Admiralty Resources	Admiralty Resources	Rincón	6	0	15,000	8.47%
China	China Int.Trust Investment Co.	Qinghai Citic Guoan	West Taijnar	3.4	0	15,000	8.47%
China	Pacific Lithium Ltd.	Qinghai Lithium	East Taijnar	3.4	0	15,000	8.47%
China	Tibet Minerals Development C.	Zabuye Lithium	Zabuye	2	2,000	10,000	5.65%
U.S.A.	Chemetall	Chemetall Foote	Silver Peack	0.6	5,000	5,000	2.82%
China	Sterling Group Ventures, Inc.	Sterling	DangXiongCuo	9.5	0	5,000	2.82%
Sumas				113	71,500	177,000	100%

- Besides batteries, what new demands for lithium will arise in the future? (nuclear, liquid battery etc)
- Given problems with water and the quality of the reserves, will Bolivia be able to develop it's lithium reserves?
- What are the "real" lithium reserves of the world?
- What technology will be needed to exploit them?
- What role will recycling and reuse play in the lithium supply chain?