

POLINARES is a project designed to help identify the main global challenges relating to competition for access to resources, and to propose new approaches to collaborative solutions

POLINARES working paper n. 38
March 2012

Fact Sheet: Lithium



Funded under Socio-economic Sciences & Humanities



The project is funded under Socio-economic Sciences & Humanities grant agreement no. 224516 and is led by the Centre for Energy, Petroleum and Mineral Law and Policy (CEPMLP) at the University of Dundee and includes the following partners: University of Dundee, Clingendael International Energy Programme, Bundesanstalt für Geowissenschaften und Rohstoffe, Centre National de la Recherche Scientifique, ENERDATA, Raw Materials Group, University of Westminster, Fondazione Eni Enrico Mattei, Gulf Research Centre Foundation, The Hague Centre for Strategic Studies, Fraunhofer Institute for Systems and Innovation Research, Osrodek Studiów Wschodnich.

LITHIUM (Li)

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Deposit

Lithium is produced from lithium rich brines (lithium salt) and hard rock ore (lithium minerals).

From the lithium rich brines of salt lakes or salt pans (called salars) comes by far the largest share of the lithium carbonate production and all lithium chloride production. Lithium brines have been the most important source for the production of lithium carbonate and chloride for several years.

The economically most important lithium minerals in lithium mining from hard rock ore are found in pegmatites, especially spodumene, although petalite, amblygonite, eucryptit and lepidolite are also of some interest. The mineral concentrates can be used directly, especially in the glass and ceramic industries. Spodumene, particularly from Australia, is also used for the production of lithium carbonate.

The lithium concentration and the magnesium content as well as the rate of evaporation and geographical location are important factors in the extractability of lithium rich brines from salt lakes. The lithium content in mineable brines is about 0.023 to 0.15%.

The mining of lithium minerals is mainly open pit. The Li_2O content of the ore is about 1 - 4%. Commercial concentrates have a Li_2O content of between 4 and 7.75%.

Application

In 2008: Ceramics and glass 37%, batteries 20%, greases 11%, aluminium production 7%, continuous casting 5%, pharmaceuticals, rubber and thermoplastics 5%, air conditioning systems 5% and other 10% (Roskill 2009).

Basically, the lithium market is different for lithium minerals and lithium / lithium chloride due to the application areas. While the lithium minerals are mainly used as a mineral powder in the glass and ceramic industries as well as in continuous casting, lithium carbonate and lithium chloride are used in the processing of lithium oxide or as a chemical component in various industries. Lithium oxide is among other things the basis for the manufacture of lithium batteries, which are used in hybrid drive systems in the automotive industry.

In recent years the battery sector has increased greatly. The lithium-ion batteries are used in the production of many electronic devices, which, in itself, has an enormous growth potential. Continued strong growth in the battery and accumulator sectors is expected in the future due to the energy and power density achievable by lithium batteries used in hybrid and electric cars.

General Characteristics

Lithium is a silvery-white alkali metal with a very low density (0.534 g/cm^3 at $20 \text{ }^\circ\text{C}$). Of all the elements solid at room temperature it is the lightest. Compared with other alkali metals lithium shows a less high reactivity, which depends very strongly on the purity.

Supply

Source: USGS. Status: Jan. 2011

Reserves (world total): **13 million t Li**

Resources (incl. reserves, world total): **33 million t Li**

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Reserves

World reserves by country. Status: Jan. 2011

Country/Region	t Li	Share [%]
Chile	7,500,000	59.7
China	3,500,000	27.9
Argentina	850,000	6.8
Australia	580,000	4.6
Brazil	64,000	0.5
USA	38,000	0.3
Zimbabwe	23,000	0.2
Portugal	10,000	0.1

HHI: 4,406 (high)

Cr: +0.1

Resources

World resources by country. Status: Jan. 2011

Country/Region	t Li	Share [%]
Chile & Bolivia	16,500,000	50.0
China	5,400,000	16.4
USA	4,000,000	12.1
Argentina	2,600,000	7.9
Brazil	1,000,000	3.0
DR Congo	1,000,000	3.0
Serbia	1,000,000	3.0
Australia	630,000	1.9
Canada	360,000	1.1

HHI: 4,406 (high)

Cr: +0.6

Consumption 2008 (estimated)

21,300 t Li (estimated)

Due to the economic and financial crisis there was a significant decrease in demand in 2009.

Key Consumer

Estimated consumption by country

No data

Production of Li

Status: 2008/2009

2008: 24,300 t Li (estimated world total),~88,000 t lithium carbonate (18.8% Li, conversion factor Li_2CO_3 to Li: x 0.188)

~12,000 t lithium chloride (16.3% Li, conversion factor LiCl to Li: x 0.163)

~340,000 t lithium minerals (0.5 - 3% Li)

2009: 18,540 t Li (estimated world total),~58,500 t lithium carbonate (18.8% Li, conversion factor Li_2CO_3 to Li: x 0.188)

~8,000 t lithium chloride (16.3% Li, conversion factor LiCl to Li: x 0.163)

~340,000 t lithium minerals (0.5 - 3% Li)

Key Producer

Production by country in 2008/2009

Country/Region	2008		2009	
	t Li	Share [%]	t Li	Share [%]
Chile	10,580	44	5,620	30
Australia	5,580	23	6,280	34
Argentina	3,158	13	2,220	12
China	1,684	7	1,590	9
USA	1,500	6	1,500	8
Canada	665	3	310	2
Zimbabwe	488	2	400	2
Portugal	407	2	447	2
Brazil	204	1	160	1
Spain	22	0.1	16	0.1

In 2009 about 18,540 t of lithium were produced, a decrease of 24% on 2008 (24,300 t lithium). Approximately 10,200 t (55%) were extracted from lithium brines (lithium carbonate and lithium chloride) and 8,300 t (45%) were mined from lithium minerals.

The production of lithium salts (lithium carbonate and lithium chloride) amounted to around 66,500 t (in Li: 12,300 t), of which 8,000 t was lithium chloride (~1,300 t lithium content) and 58,500 t was lithium carbonate (~11,000 t lithium content). Some of the lithium carbonate production (about 11,000 t Li_2CO_3) was converted from lithium minerals in China. Higher grade spodumene, imported from Australia, was predominantly used (80 - 100%; Jaskula 2010a) for this. Chile (Salar de Atacama) has been by far the major producer of lithium salts. China, Argentina and the USA have also been important lithium carbonate or lithium chloride producers.

Country/Region	2008		2009	
	t Li from brine	Share [%]	t Li from brine	Share [%]
Chile	10,580	65	5,620	55
Argentina	3,160	19	2,220	22
China	940	6	846	8
USA	estimated 1,500	9	estimated 1,500	15

In 2009 about 340,000 t hard rock ore were mined. Australia was by far the largest producing country of lithium mineral concentrate.

Country Concentration (HHI) and Country Risk (Cr)

2008

HHI: 2,696 (high)

Cr: +0.93

2009

HHI: 2,362 (high)

Cr: +0.91

76% of primary production was mined in Chile, Argentina and Australia, and the total known production of lithium carbonate and lithium chloride concentrate in Chile, Argentina, China and the United States.

The country concentration for mine production and the possibility of the lithium carbonate producer exercising market power is problematic. However, the share accounted for by low risk countries like Chile, Australia, USA and Canada means that the country risk remains benign.

Recycling

Additional quantities of supply could reach the market via recycling, especially through the recovery of batteries and accumulators. So far, however, lithium has not been recovered in significant quantities. The currently implemented large-scale methods for the processing and recycling of lithium-ion battery systems have so far been targeted mainly at the recovery of cobalt, nickel and copper.

Largest Companies

Data source: Raw Materials Group Stockholm/www.rmg.se

2008

Companies	Share of world production [%]
Talison Minerals Pty. Ltd. (Australia)	22.6
Rockwood Holdings Inc. (USA)	21.7
FMC Corp. (USA)	13.5
Sociedad Quimica y Minera de Chile SA (SQM)	26.9
of which	
Potash Corp of Saskatchewan Inc. (SQM, Canada)	11.5
Yara International ASA (SQM, Norway)	11.5
Israel Chemicals Ltd. (SQM, Israel)	3.8
Africa Resources Ltd. (Zimbabwe)	~2.5
Cabot Corp (USA)	~2.5
Sociedade Mineira de Pegmatites Lda. (Portugal)	~1.2
Cia Brasileira de Litio (Brazil)	<1
Arqueana de Minerios e Metais (Brazil)	<1

(cumul. share of world 2009: 92.45%)

LITHIUM (Li)

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2009

Companies	Share of world production [%]
Talison Lithium Ltd. (Australia)	25.3
Rockwood Holdings Inc. (USA)	10.0
FMC Corp (USA)	14.1
Sociedad Quimica y Minera de Chile SA (SQM)	27.7
of which	
Potash Corp of Saskatchewan Inc. (SQM, Canada)	11.9
Yara International ASA (SQM, Norway)	11.9
Israel Chemicals Ltd. (SQM, Israel)	4.0
Africa Resources Ltd. (Zimbabwe)	
Cabot Corp. (USA)	3.5
Sociedade Mineira de Pegmatites Lda. (Portugal)	1.8
Cia Brasileira de Litio (Brazil)	1.8
Arqueana de Minerios e Metais (Brazil)	0.6

(cumul. share of world 2009: 84.70%)

In 2009 the four biggest lithium mining companies had a combined global lithium mine production share of over 77%. The largest lithium mining companies were Sociedad Quimica y Minera de Chile SA (SQM) followed by Talison Minerals Pty. Ltd. (Australia), FMC Corp. (USA), and Rockwood Holdings Inc. (USA). Only four companies accounted for 100% of the production of lithium carbonate and lithium chloride. The market leader, with 40% share of world production, was the Chilean company Sociedad Quimica y Minera de Chile SA (SQM), which extracts lithium carbonate and chloride from the Salar de Atacama. The second largest producer, with an estimated 21% share of world production, was the FMC Corp., a diversified chemical company, which extracts lithium salt from the Salar de Hombre Muerto in Argentina. The American company Chemetall Foote (a subsidiary of Rockwood Specialties Group) had a global share of 15%, down from 31% in 2008. Chemetall produces lithium carbonate from brine at Silver Peak (Nevada, USA) and the Salar de Atacama (through the company Sociedad Chilena de Litio). Chinese companies, such as China Xinjiang Nonferrous Metals Corporation (Xinjiang), Sichuan Tianqi Industry Group (Sichuan), Sichuan Guorun (Sichuan) produce lithium carbonate from locally mined and imported lithium minerals (spodumene from Australia).

Company Concentration (HHI)

2008: HHI: 1,465 (cumul. share of world 2008 92.45%)**2009: HHI: 1,254** (cumul. share of world 2009 84.70%)

Production Method

Solar evaporation (brines), partly as a by-product of potash

Open pit or underground (minerals)

Brines: The most cost effective lithium sources are brine deposits, where lithium can be recovered as a by-product of potash. The salt-rich brines are pumped from beneath the crust on the salt lake (salar) and filtered into a series of large, shallow ponds. Over a period of 18 - 24 months the lithium brine solution is concentrated by solar evaporation and wind to a concentration of 6% lithium after which lithium extraction takes place. Following this battery grade lithium carbonate can be produced. The extraction process is a low cost/high margin process. The lithium content in mineable brines is about 0.023 to 0.15%.

Hard rock: The hard rock mining of lithium minerals occurs mainly in open pits. The processing takes place mechanically by means of flotation. In order to produce lithium carbonate, spodumene and petalite must first be thermally treated. This is followed by a wet chemical digestion and finally sodium carbonate precipitation to produce lithium carbonate. The Li_2O content of the ore is about 1 - 4%. Commercial concentrates have a Li_2O content between 4 and 7.75%.

Stages of Production

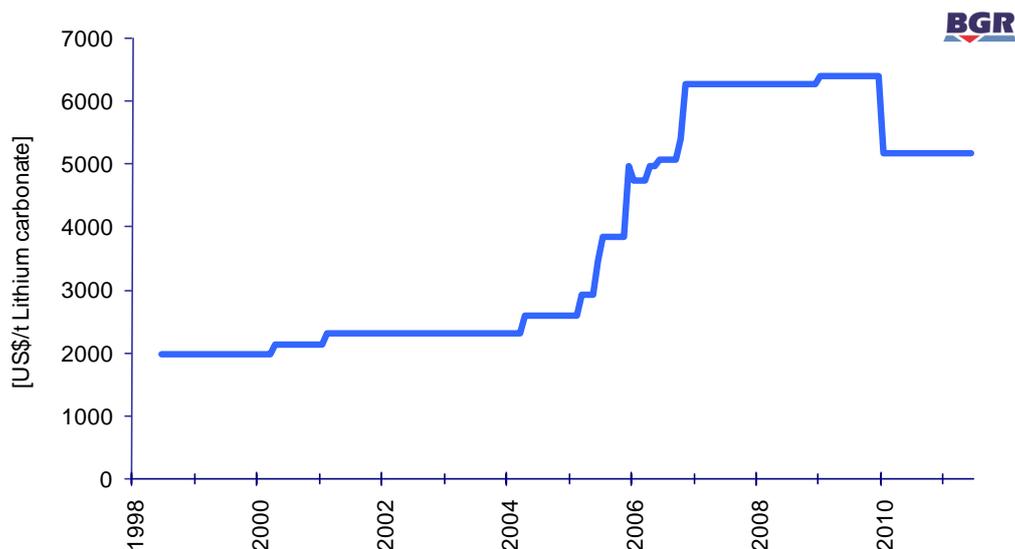
Brine is pumped to the surface → concentration through solar evaporation in a series of evaporation ponds → extraction of lithium carbonate in a separate plant with soda ash and lime.

Lithium mineral mining (spodumene) → concentration (crushing, heavy media separation, ball milling, classification, flotation and/or magnetic separation, filtering, washing and drying) → production of lithium compounds (sulphuric acid roast leach process or lime-roast process).

Price Development

Lithium carbonate, large contracts

Lithium carbonate price, USA, delivered continental, large contracts



Between 1998 and 2009, the annual average price for lithium carbonate more than tripled. Between 2003 and 2007 the annual average price for lithium carbonate had grown particularly strongly by 170%. This was caused by the increased global demand for lithium batteries and lithium chemicals as well as market domination by the two largest producers of lithium carbonate. Due to the sharp drop in demand in 2009 the price declined in January 2010.

The purpose of the price cut was, among other things, a revitalization of low lithium demand. Another reason could be that SQM, which dominates the market, reduced future prices in order to push competitors off the market.

Trade

Import/Export

Lithium is traded in purchase contracts between buyer and seller.

Depending on the use, lithium is traded primarily as lithium carbonate, chloride, hydroxide, mineral concentrate or, less frequently, as metal.

Lithium mineral concentrates are exported from Australia, Canada, and Zimbabwe. Spodumene concentrates produced in Australia are mainly exported to Asia, including China as well as Europe and North America. Spodumene concentrates produced in Canada are primarily supplied to the USA, South Korea and Europe. South Africa is the main market for petalite, produced in Zimbabwe, although material entering South Africa may be forwarded to Europe and Asia (Roskill 2009).

Lithium carbonate is the main form in which lithium enters international trade. World trade was around 68,000 t in 2008. Chile dominates lithium carbonate exports accounting for 63% of total world exports in 2008. Other significant producers of lithium carbonate are Argentina, the USA and China, together accounting for a quarter of total exports in 2008. The four primary producing countries exported 88% of total exports. Almost all lithium carbonate production (~77% of world production, ~90% of production without China) is traded internationally, as neither Chile nor Argentina has a significant domestic market for lithium carbonate, in contrast to the USA and China which do (Roskill 2009).

Six countries accounted for around 90% of the world total lithium carbonate imports in 2008: USA (28%), Japan (21%), Germany (16%), Belgium (11%), South Korea (9%) and China (6%) (Roskill 2009).

Trends in Exploration Activity

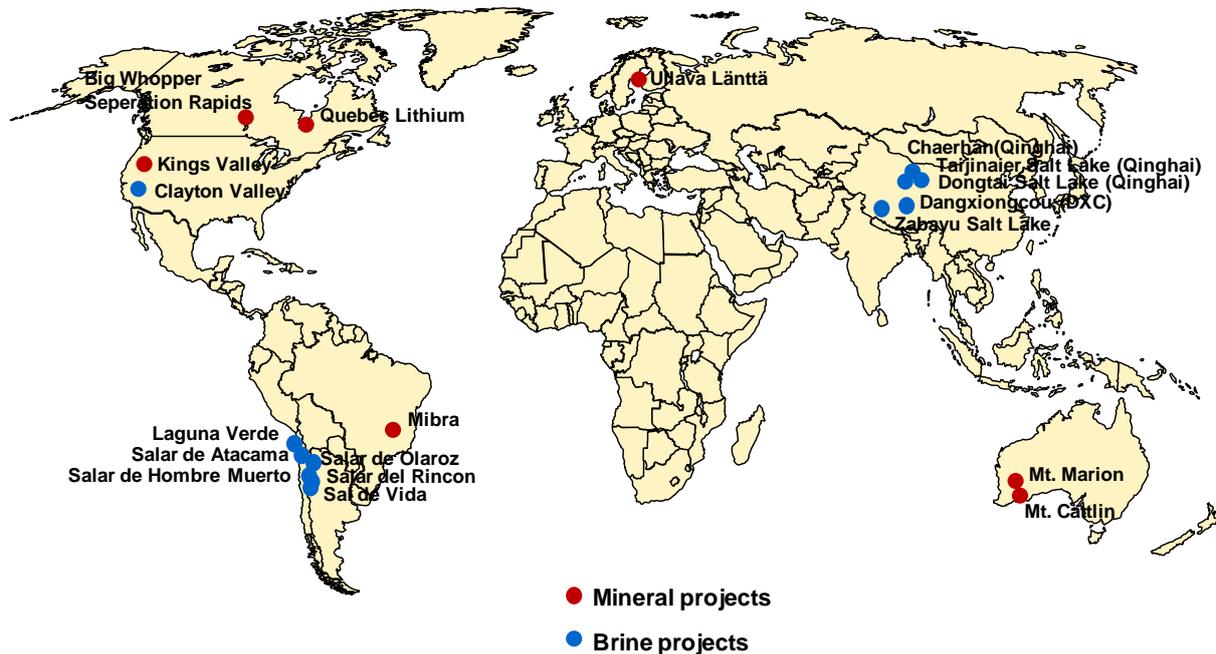
There are a large number of new known mining projects of different status and quality.

For brine deposits, the largest additional annual production capacity is planned in China, Argentina and Chile.

For hard rock deposits, the largest additional annual production capacity is planned in Australia, the USA and Canada.

The implementation of projects and, in particular the production of lithium carbonate from lithium minerals, is dependent on the lithium carbonate price: from a lithium carbonate price of over 6,000 US\$/t production is worth the effort for many companies. Japanese and South Korean companies and the Canadian company Magna are currently active in securing their supplies of lithium by participating in new mining projects.

Selected lithium projects 2010



Other

Owing to the increasingly low-cost of lithium extraction from brine in Chile and Argentina, and especially due to lithium by-product extraction by SQM in Chile since the mid-1990s, many mining companies which mined lithium minerals were driven out of the market. In the USA and Russia the mining of lithium minerals has ceased since the late 1990s. Australia, by way of contrast, has strongly expanded its mine production.

China is currently the only country which produces large amounts of lithium carbonate from lithium minerals, mainly from imported Australian spodumene.

Due to the increased demand for lithium carbonate the conversion of spodumene to lithium carbonate has also increased in China. The strong price increase for lithium carbonate to over 5,000 to 6,000 US\$/t since 2005 has led to the profitable production of lithium carbonate from spodumene.

Trends

Based on geological reserves and resources the long term future supply of lithium carbonate is secure. The static life time for global lithium reserves can be termed as relaxed, since sufficiently high reserves have already been well explored and known.

Long-term lithium demand will be dominated, by the battery, glass and ceramics, greases, air conditioning and aluminum production sectors. An enormous growth in demand is expected due to the use of lithium-ion batteries for hybrid and electric cars. However, information about the expected development of electric vehicles, number of the new registrations with lithium-ion batteries, and the percentage of each type of vehicle vary greatly.

If all planned exploration and mining projects actually begin production, the high demand for lithium can be easily met.

Conflict / Supply Risk

Price manipulation by market power: the low cost producer SQM could force smaller and new companies out of the market by keeping prices artificially low. The consequences of this may be delays to new mining projects stifling company diversity and risking supply.

Sources

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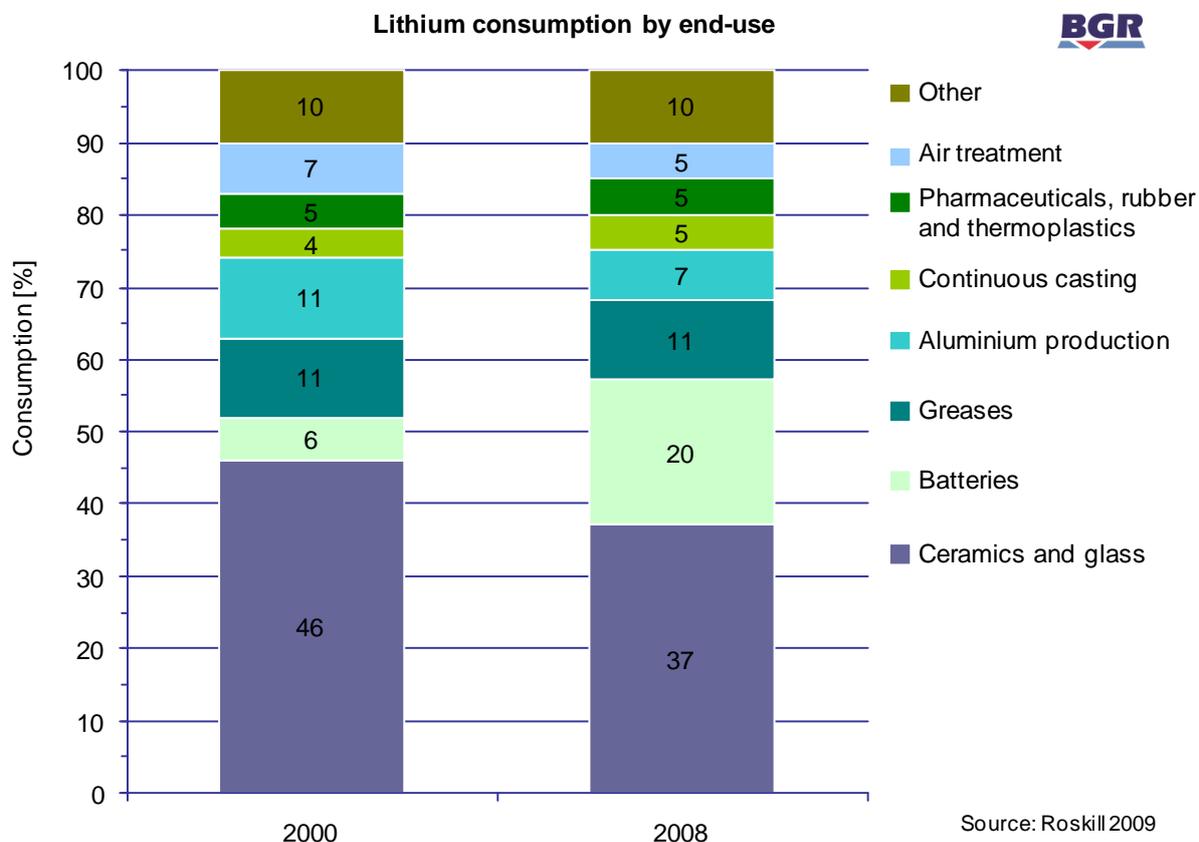
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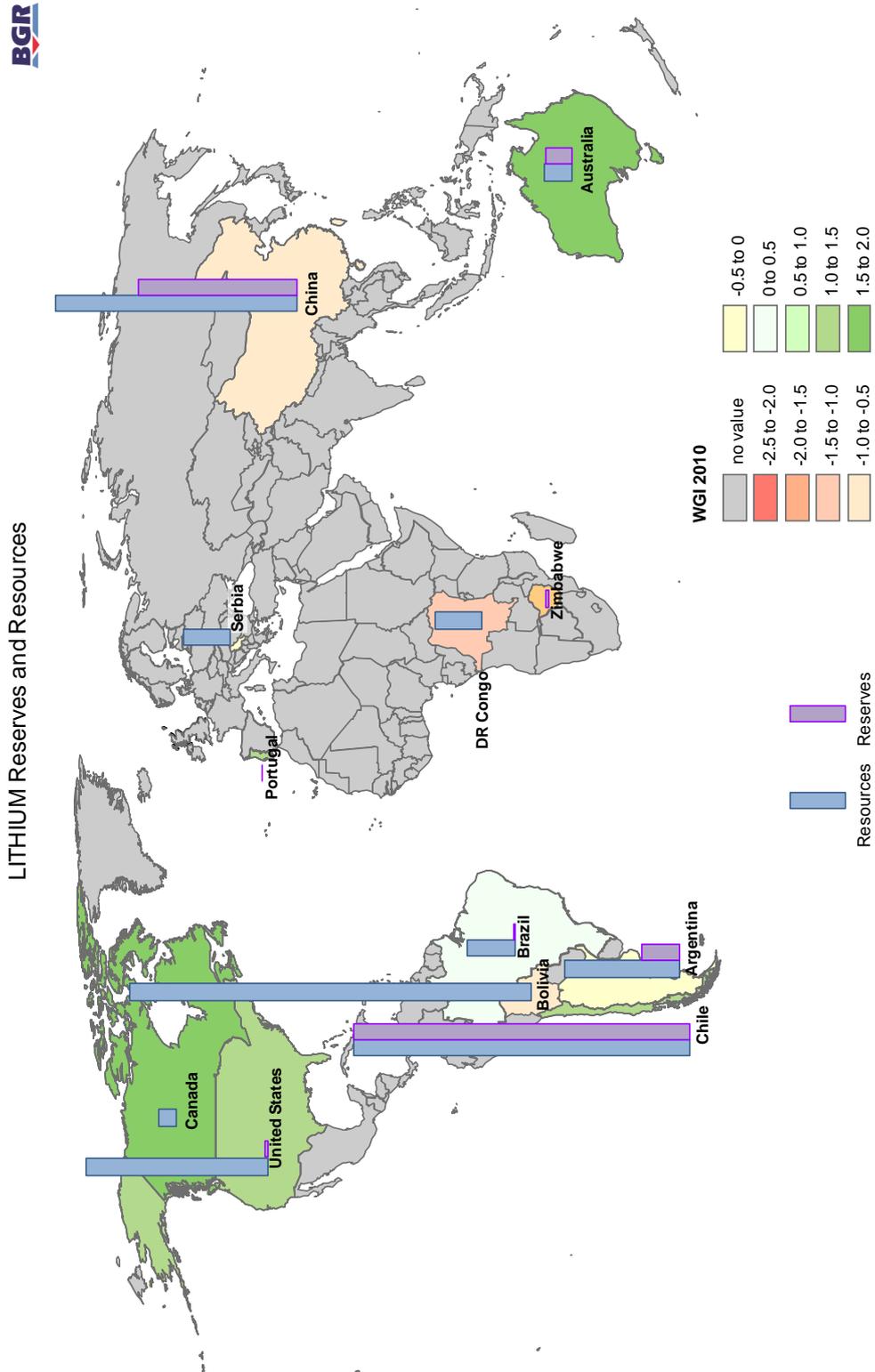
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Lithium Consumption by End-Use

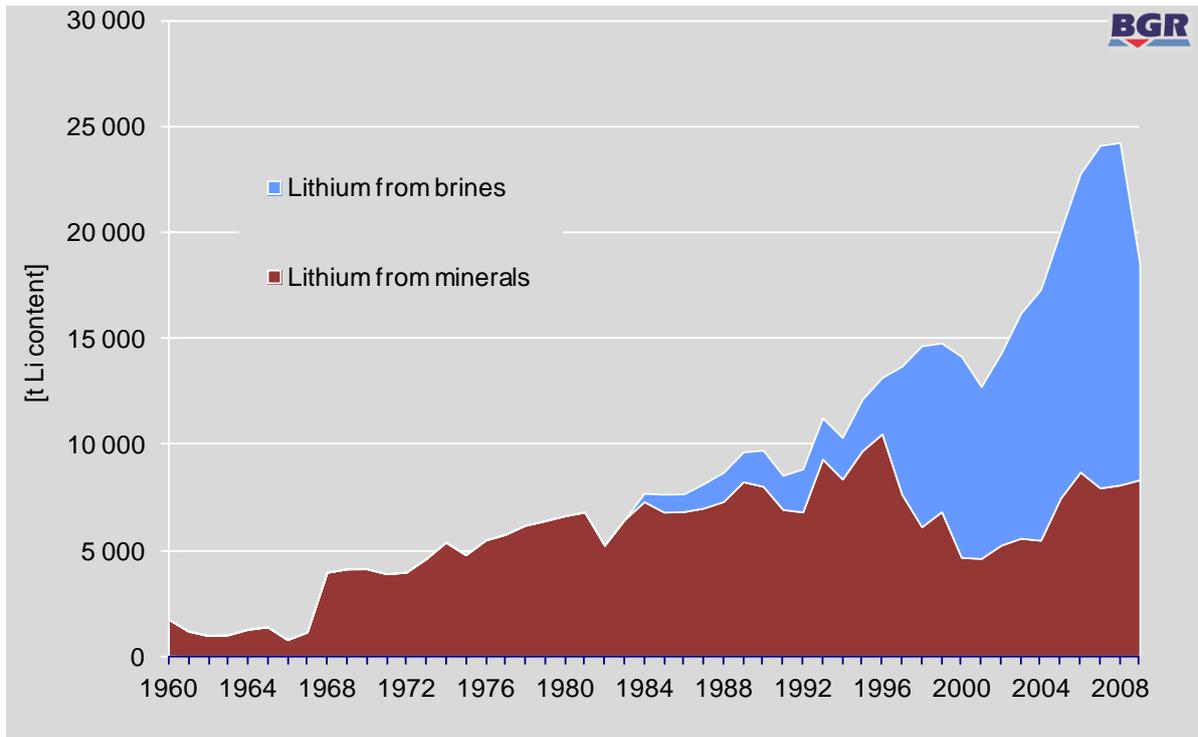
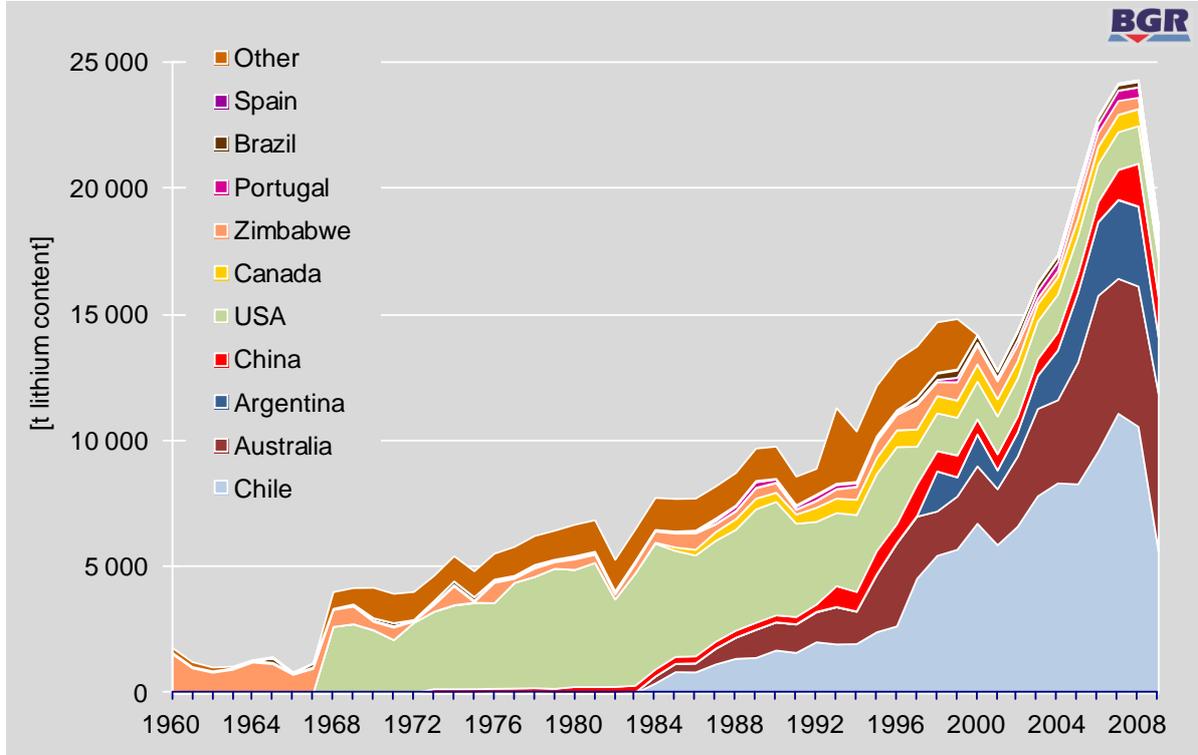


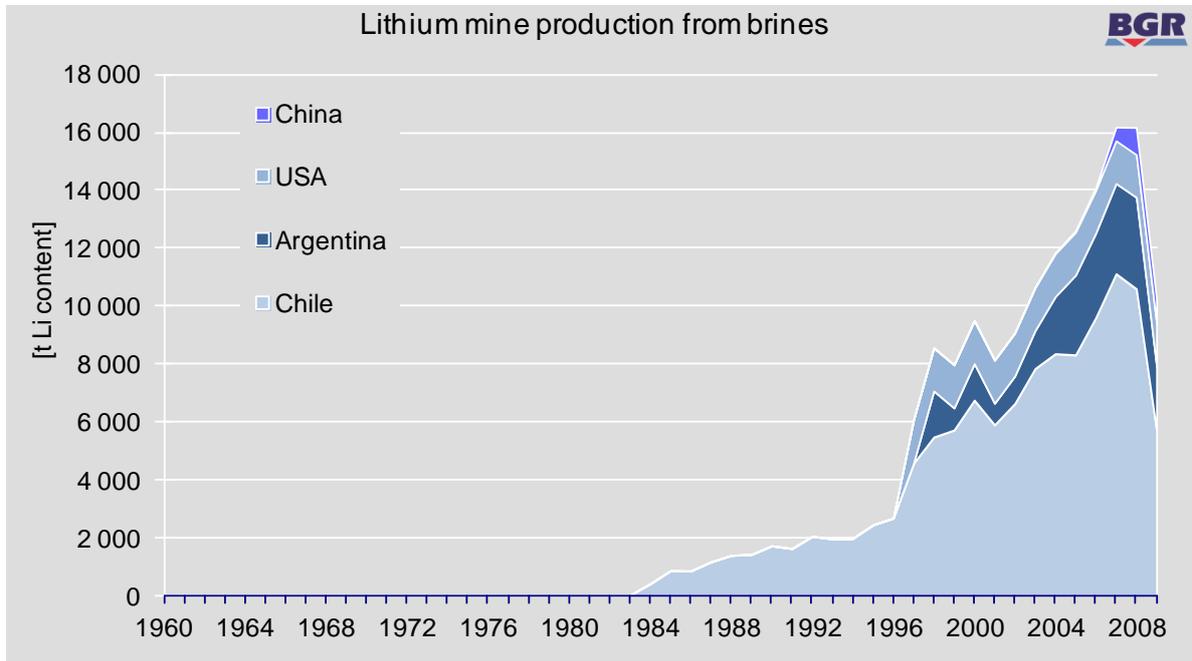


Million tonnes	Bolivia	Chile	China	USA	Argentina	Brazil	DR Congo	Serbia	Australia	Canada	Zimbabwe	Portugal
Resources	9	7.5	5.4	4	2.6	1	1	1	0.63	0.36		
Reserves		7.5	3.5	0.038	0.85	0.064			0.58		0.023	0.01

Historical Mine Production

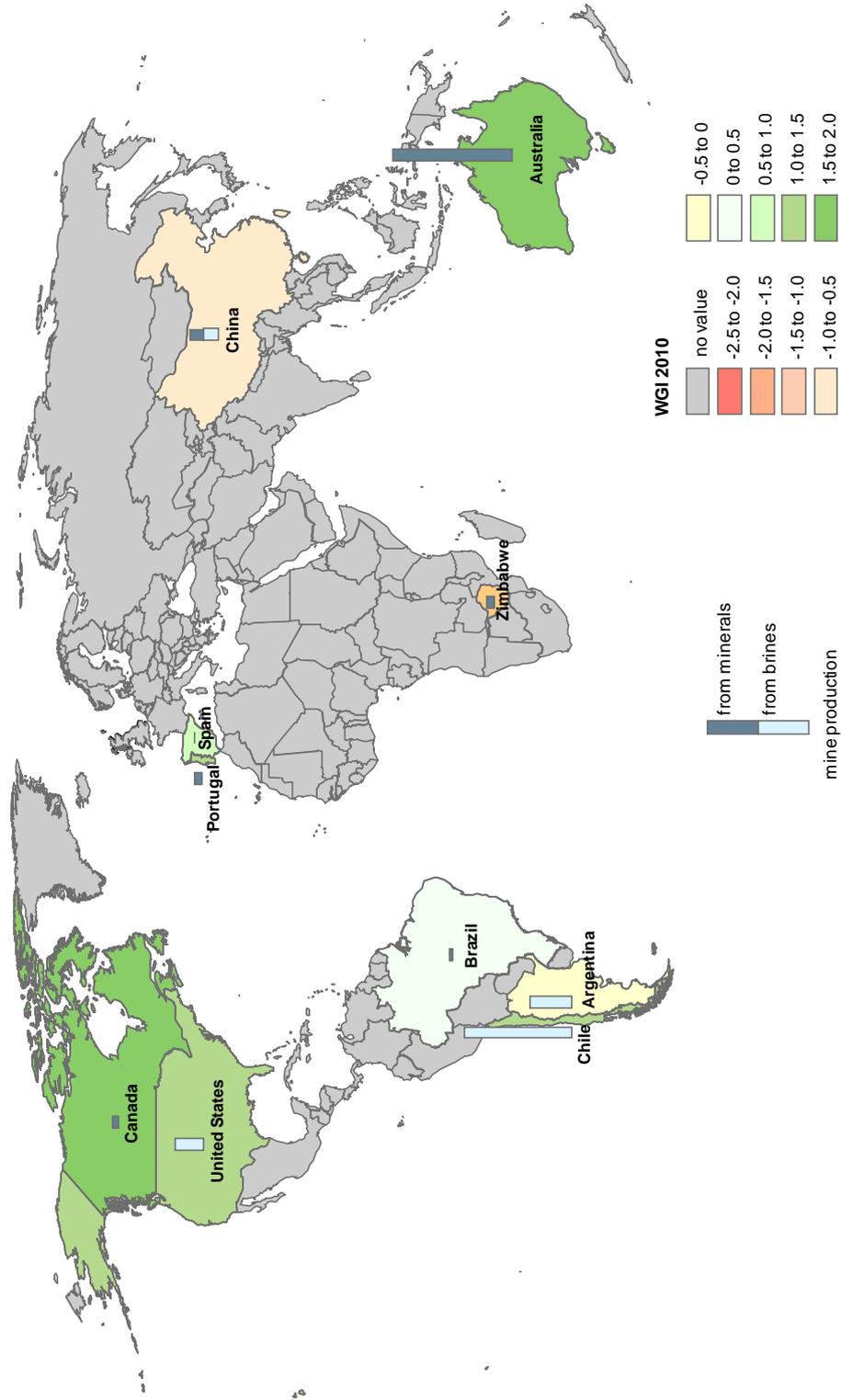
1960 - 2009







LITHIUM mine production 2009



	Australia	Chile	Argentina	China	USA	Portugal	Zimbabwe	Canada	Brazil
tonnes	6,280	5,620	2,220	1,590	1,500	447	400	310	160

Resources

World resources

A concentration of naturally occurring solid, liquid, or gaseous material in or on the earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible (USGS 2011). Resources are known (to various levels of certainty), but their economic viability has not been established. The potential resources are as yet not known but by geological reasoning they can be expected to be discovered by means of modern exploration technologies (Wellmer 2008).

Resources include reserves.

Energy resources: the energy resources which are either proved but are at present not economically recoverable, or which are not demonstrated, but can be expected for geological reasons. In the case of oil, natural gas and uranium, only recoverable amounts are considered reserves. For coal this term is used for all in-place resources.

Resources do not include reserves.

Resources are not distributed evenly across the world. Regions and countries with rich occurrences or high production of mineral or energy raw materials do not necessarily coincide with regions and countries with high demand.

Reserves

World reserves

The share of the total resources that can be economically extracted or produced with available technology at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials (USGS 2011, Wellmer 2008).

Energy reserves: the portion of energy resources which is known in detail and can be recovered economically using current technologies. Accordingly, the amount of reserves depends on the current prices as well as on technological progress.

Country Concentration (HHI)

HHI: sum of squared values of raw materials production (in %) in each country.

The country concentration can be measured by the Herfindahl-Hirschman Index (HHI). The Herfindahl-Hirschman Index is the sum of squared values of raw materials production (in %) in each country (Rosenau-Tornow et al. 2009). Scores between 1,000 and 1,800 have been defined as benchmarks for moderate supply risk (US Department of Justice and Federal Trade Commission 1997) scores above 1,800 are problematic, and scores below 1,000 are relaxed.

Country Risk (Cr)

Cr: Sum of global raw materials production (P, in % for each country) weighted with the Governance Index (WGI) of the World Bank for each country.

The World Bank's 'Worldwide Governance Indicators' (WGI) are used to classify the countries' stability (World Bank Group 2010). Six governance indicators (Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law and the Control of Corruption) are measured in units ranging from about -2.5 to 2.5, with higher values corresponding to better governance outcomes. The country risk (Cr) is the sum of global raw materials production for each country weighted with the Governance Indicator of the World Bank for each country.

In relation to the World Bank scale for country risks, countries with a country risk minus 0.5 are classified as problematic, whereas values above 0.5 as non-critical.

Company Concentration (HHI)

HHI: sum of squared values of raw materials production (in %) of each company.

The company concentration (market power) can be measured by the Herfindahl-Hirschman Index (HHI). The Herfindahl-Hirschman Index is the sum of squared values of raw materials production (in %) in each country (Rosenau-Tornow et al. 2009). Scores between 1,000 and 1,800 have been defined as benchmarks for moderate supply risk (US Department of Justice and Federal Trade Commission 1997) scores above 1,800 are problematic, and scores below 1,000 are relaxed.

Prices

fob: free on board; term of sale signifying that freight from the producer to the consumer is paid for by the purchaser.

cif: cost, insurance, freight; term of sale signifying that the price invoiced or quoted by a seller includes insurance and all other charges up to the named port of destination.

real price: A price that has been adjusted to remove the effect of changes in the purchasing power of the dollar. Real prices, which are expressed in constant dollars, usually reflect buying power relative to a base year.

Abbreviation

Mt: million tonnes
ppm: parts per million
t: (metric) tonnes
oz tr: troy ounce

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