SCRREEN SYMPOSIUM

National Technical University of Athens
School of Mining and Metallurgical Engineering

Reducing the lithium supply risk in EU: exploitation of European reserves and novel extraction technologies

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LUBLJANA

Table of contents

A) Lithium Market and Supply Risk

B) Li Reserves (worldwide and in EU)

C) Novel Extraction Technologies (hard rocks)

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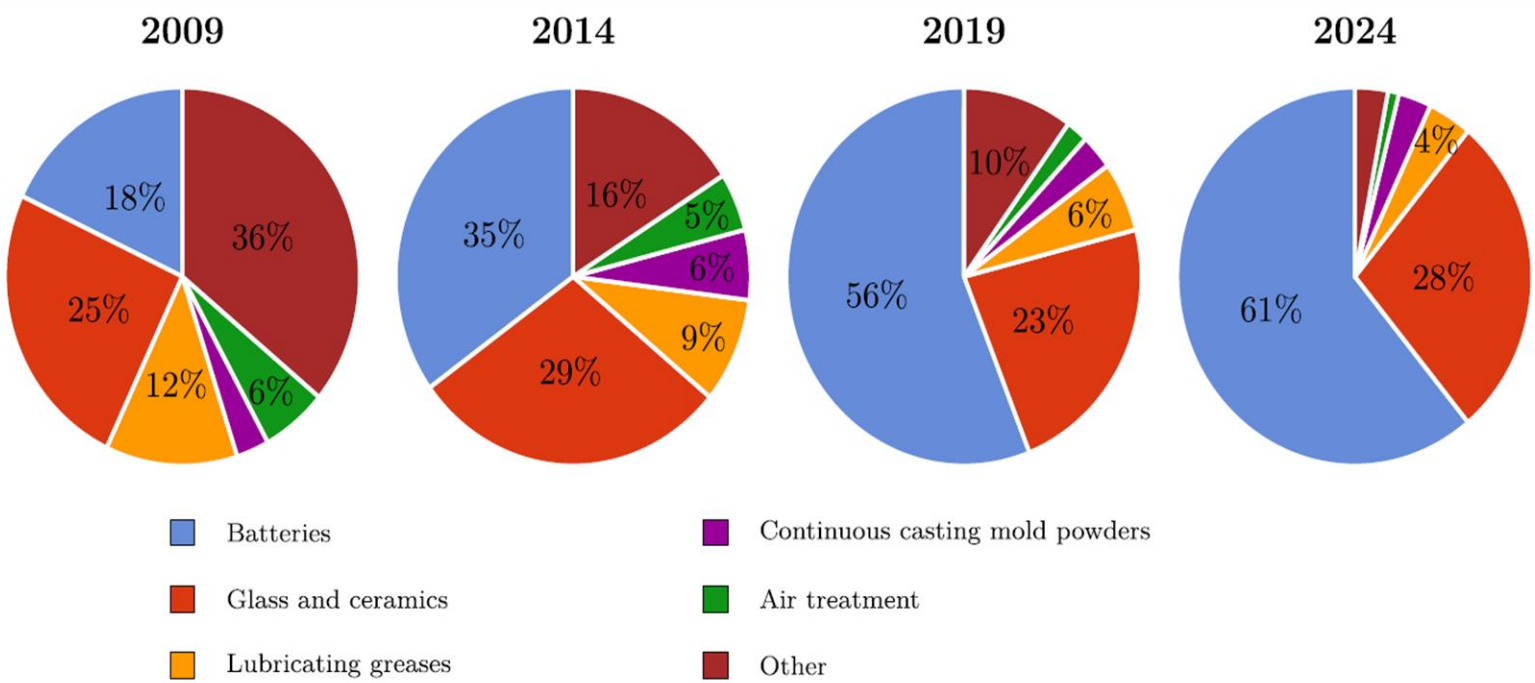
Lithium importance



- **Crucial metal for the Green Energy Transition**
- Construction of rechargeable electric batteries
- Contained as $LiCoO_2$, $LiFePO_4$, $LiMn_2O_4$ in batteries cathodes
- Lithium hydroxide monohydrate ($LiOH{\cdot}H_2O$) precursor material

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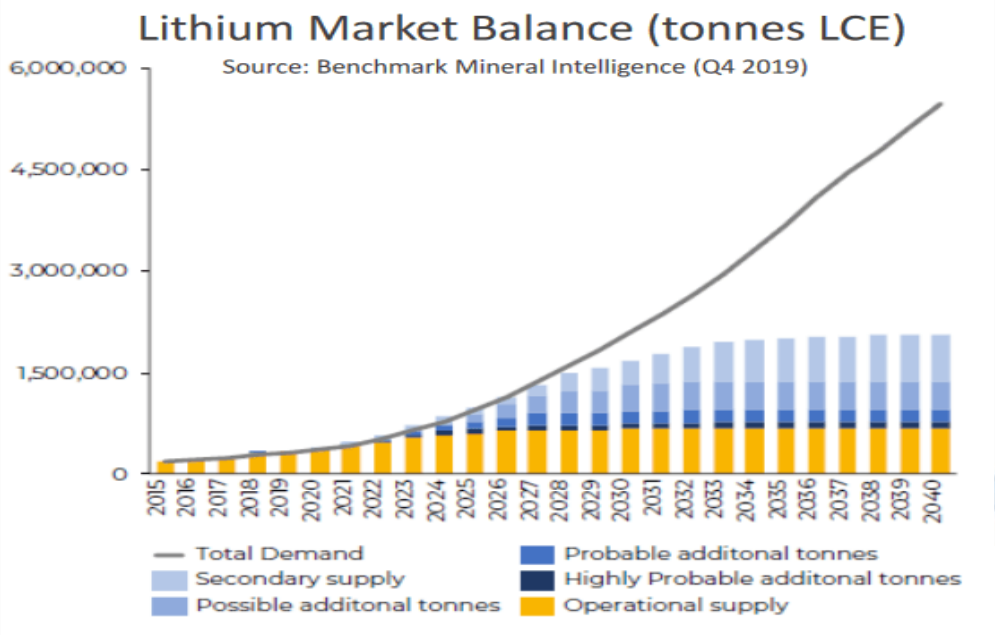
Current supply risk consideration

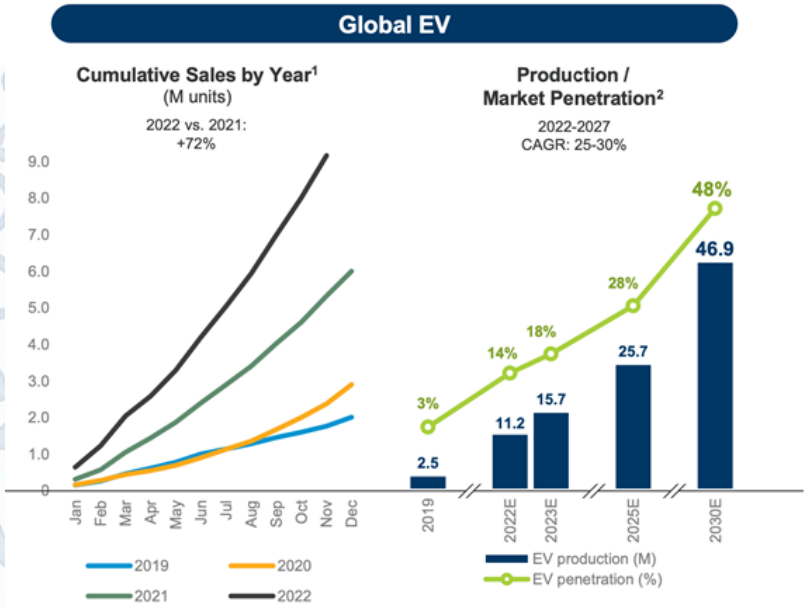
2020 EU criticality assessment of CRM

Demand forecast



Gap between supply and demand until 2040

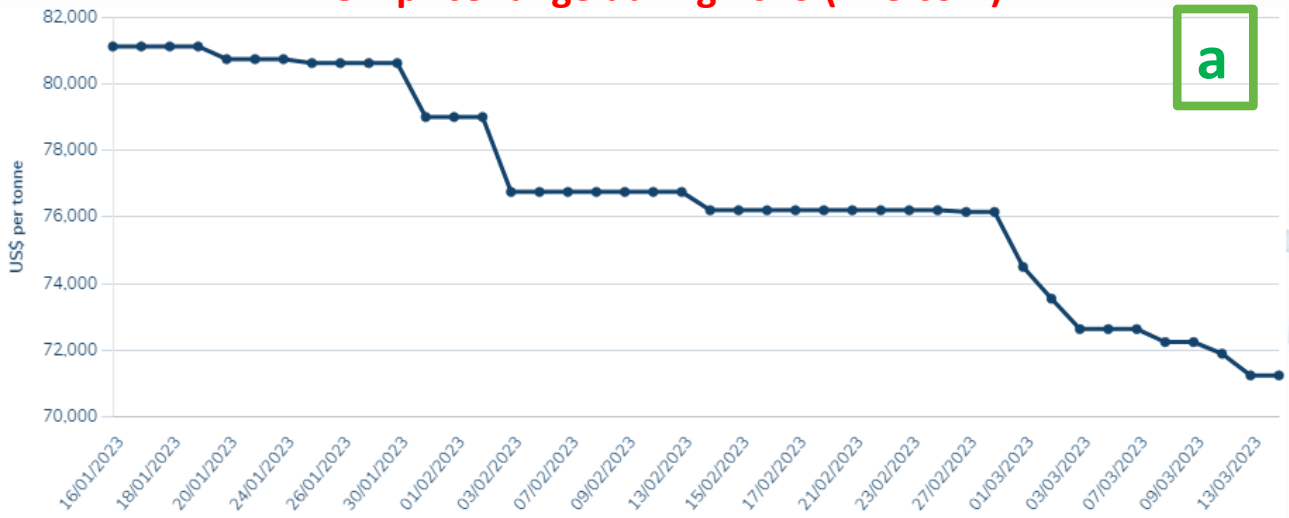
EV units increase by x5 by 2030



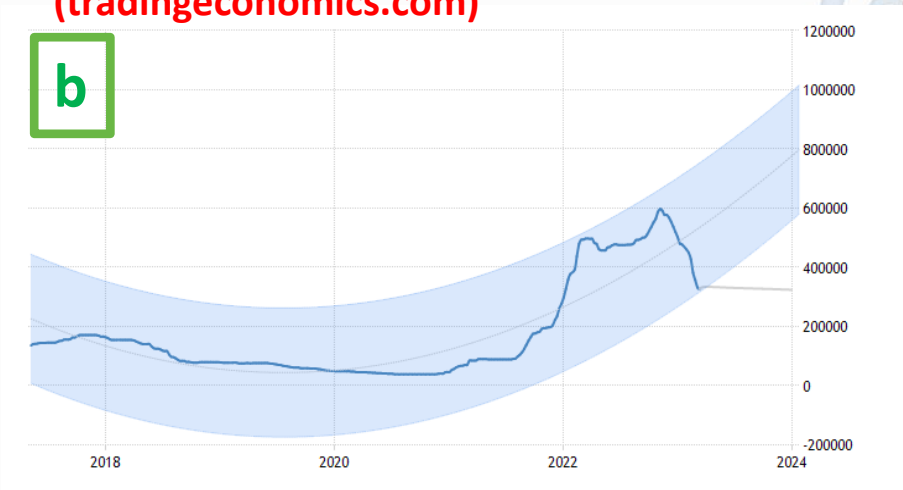
Lithium use by various industries 10 years ago, 5 years ago, currently and in five years (extrapolation) based on the USGS report of 2019; Albemarle

LiOH and Li_2CO_3 prices

LiOH price range during 2023 (lme.com)

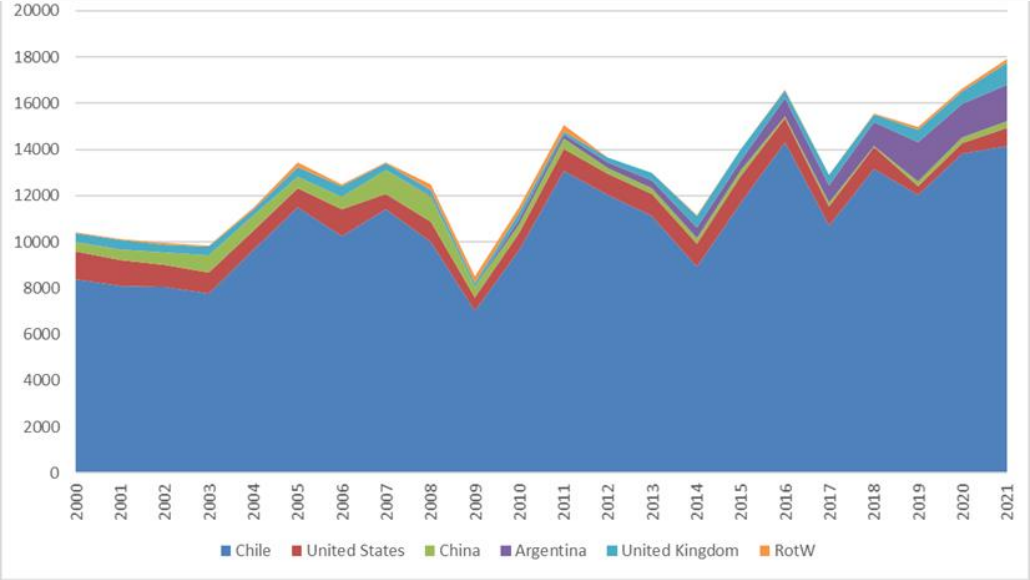


Li_2CO_3 price range last 5 years (tradingeconomics.com)



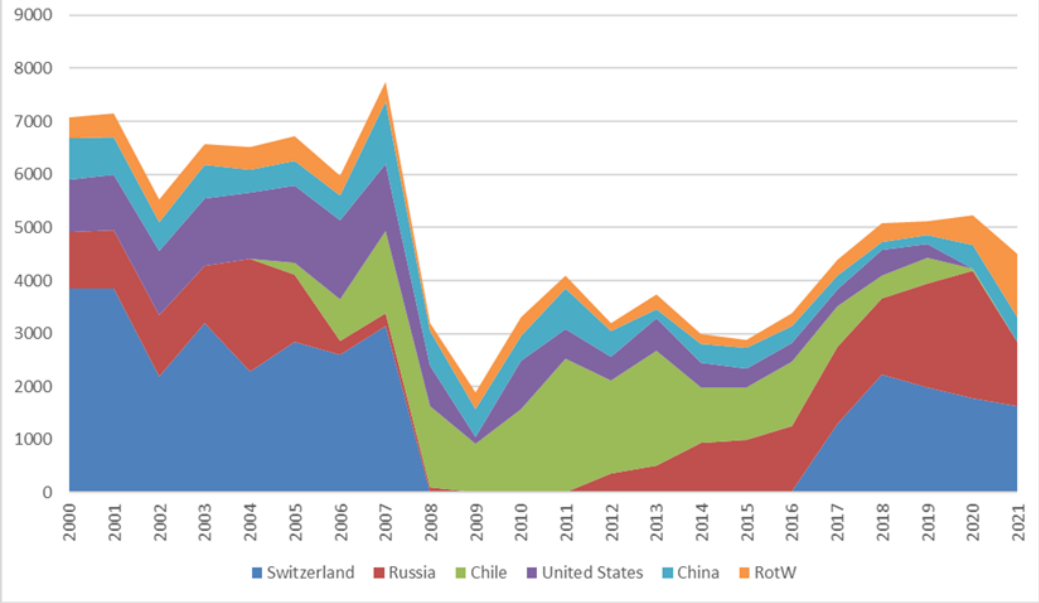
Li_2CO_3 price forecast until 2024 (tradingeconomics.com)

EU reliance



Imports 18.000 of Li_2CO_3 in 2021 (mainly by Chile)

Imports around 5.000 of LiOH in 2021 (mainly by Switzerland and Russia)



Eurostat data 2021

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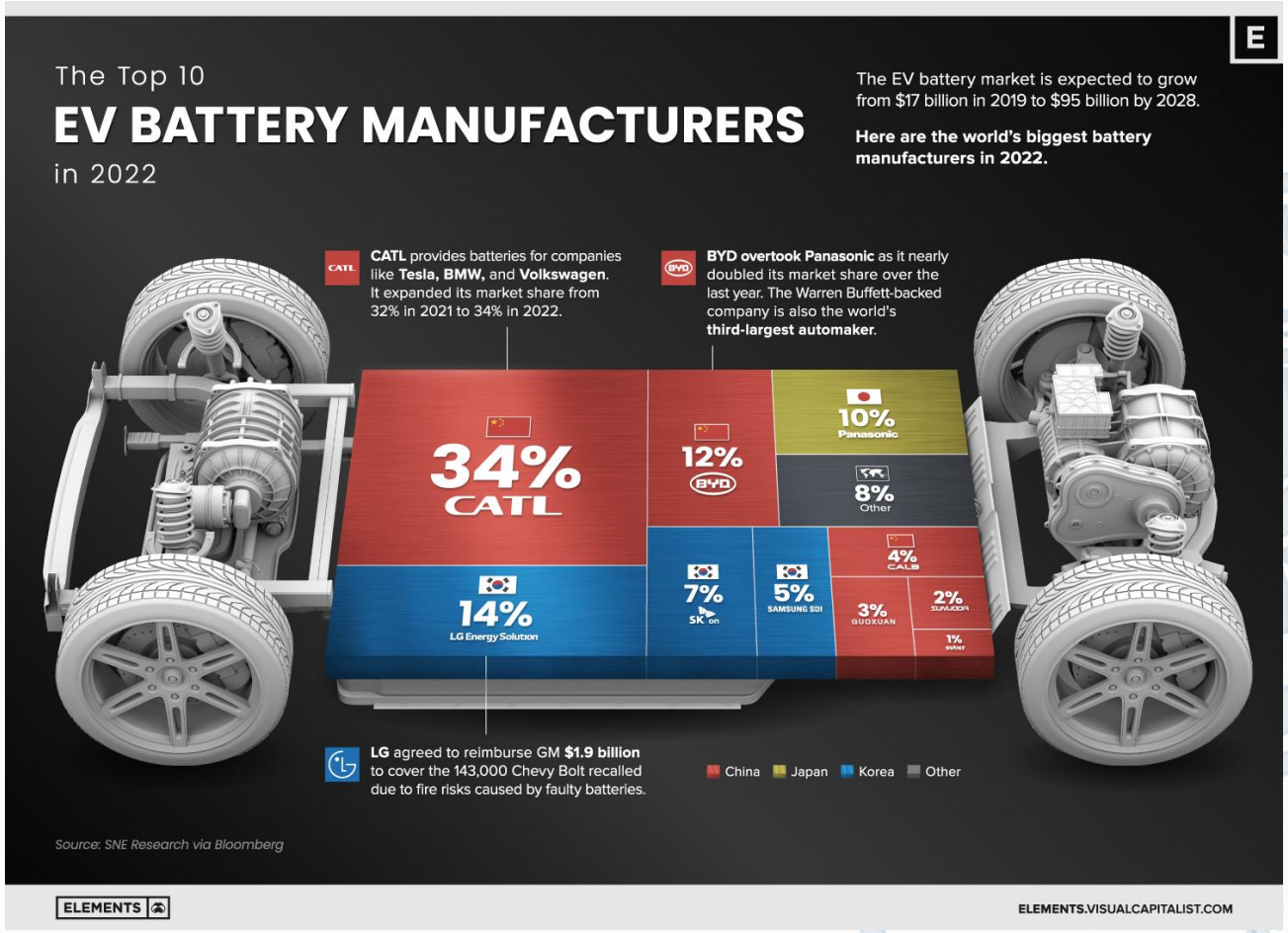
Lithium extraction companies

Albemarle (US) activated in Australia, US, Chile

SQM (Chile-brines)

Miningdigital.com, 2021

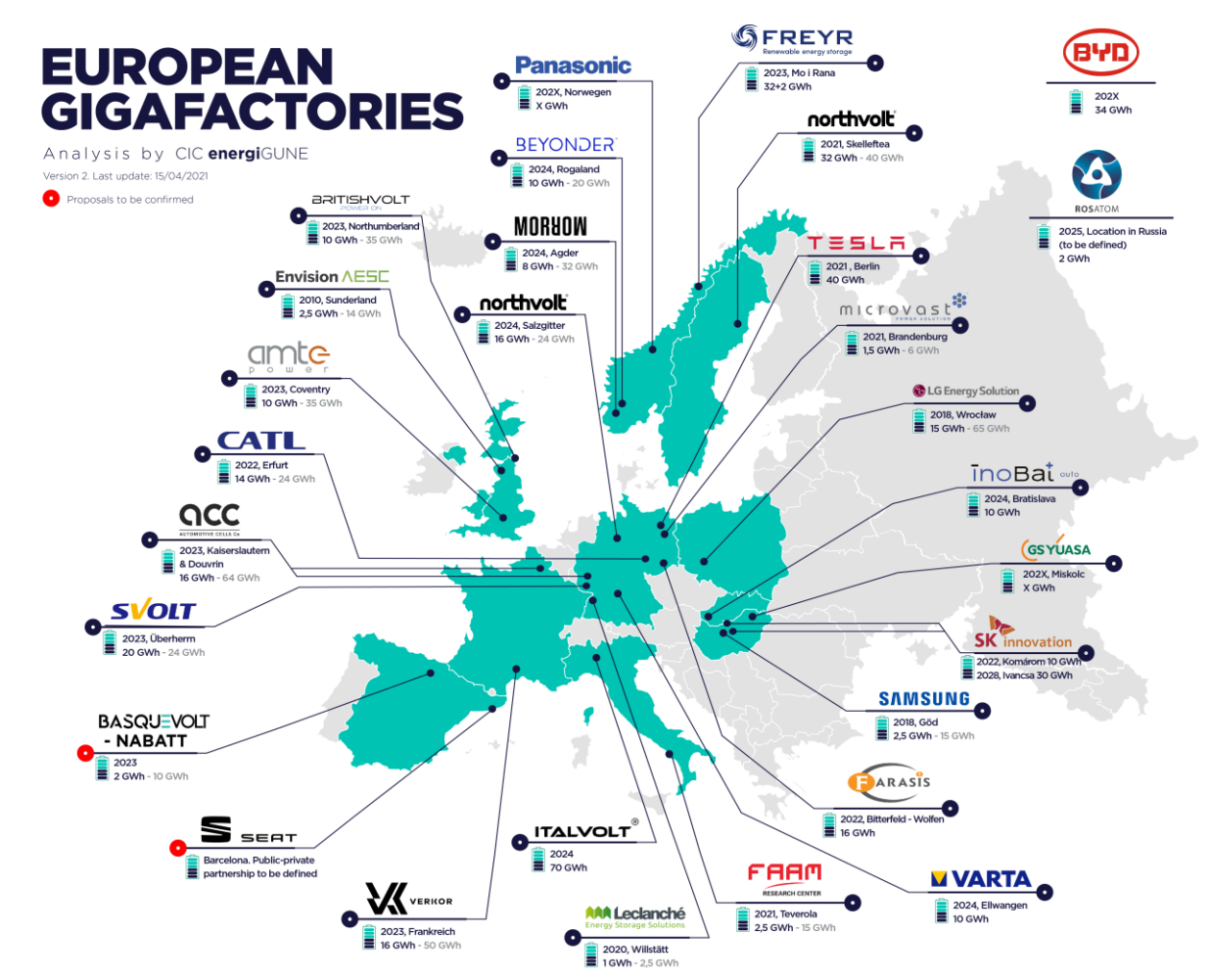
Li-ion batteries factories



No EU Company included in 10 largest battery factories worldwide

Li-ion batteries factories

Announced European Gigafactories



24 Gigafactories for Li-Ion **Battery** cells announced

Enough to equip about 9 million **Electric Vehicles** per year

Table of contents

A) Lithium Market and Supply Risk

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C) Novel Extraction Technologies (hard rocks)

Global availability of terrestrial Lithium resources

Lithium resources

Hard rocks silicate species

Sedimentary	Pegmatite
Smectites	Spodumene
Illites	Lepidolite
Jadarite	Petalite
Searlesite	Zinnwaldite
Zeolites	Amblygonite
Combinations & Others	Eucryptite

Accumulations of saline groundwater from the weathering of initial hard rocks

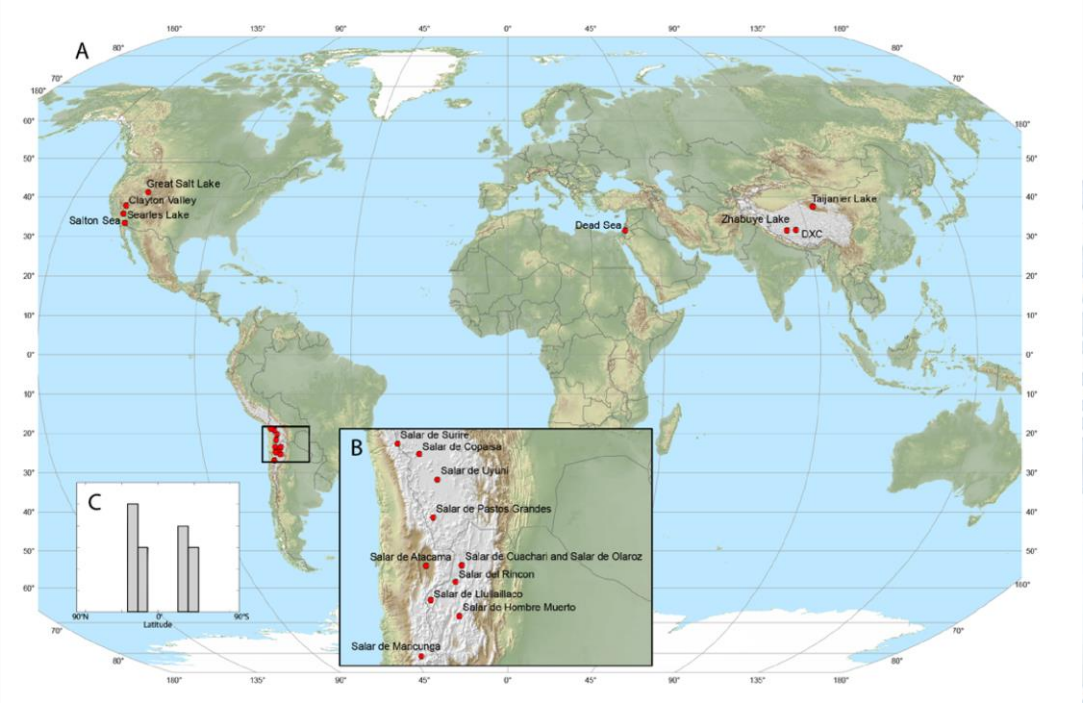
Brine

Global availability of terrestrial Lithium resources

Lithium brines

- Economic brines have Li concentrations in the range of 200 to 4,000 mg/L
- 35% of Li world production originates by the brines
- Brine resources worldwide are larger (70%)

Chile, Argentina and Bolivia “Lithium Triangle”

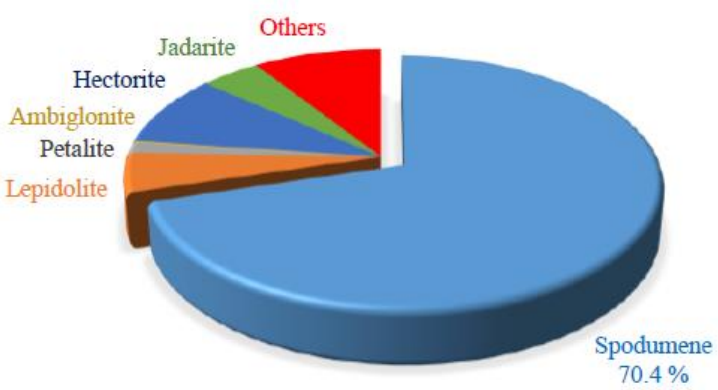


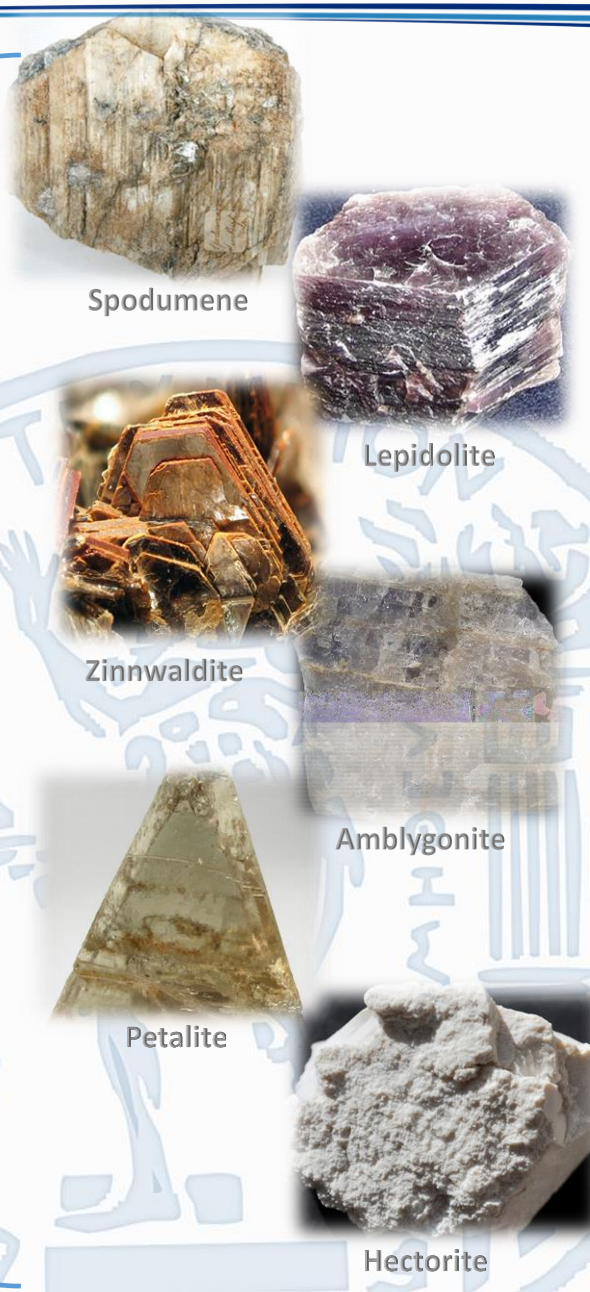
A Preliminary Deposit Model for Lithium Brines, 2013, USGS; SCRREEN Lithium factsheet 2023

Global availability of terrestrial Lithium resources

Lithium minerals

Lithium Source		Formula	Li (%)
Spodumene		$LiAlSi_2O_6$	3.73
Lepidolite		$K(Li,Al)_3(Si,Al)_4O_{10}(F,OH)_2$	3.58
Zinnwaldite		$KLiFeAl(AlSi_3)O10(F,OH)_2$	1.59
Amblygonite		$(Li,Na)Al(PO_4)(F,OH)$	3.44
Petalite		$LiAlSi_4O_{10}$	2.09
Clays	Hectorite	$Na_{0,3}(Mg,Li)_3Si_4O_{10}(OH)_2$	0.54
	Montmorillonite	$(Na,Ca)_{0,3}(Al,Mg)_2Si_4O_{10}(OH)_2.n(H_2O)$	Not specified

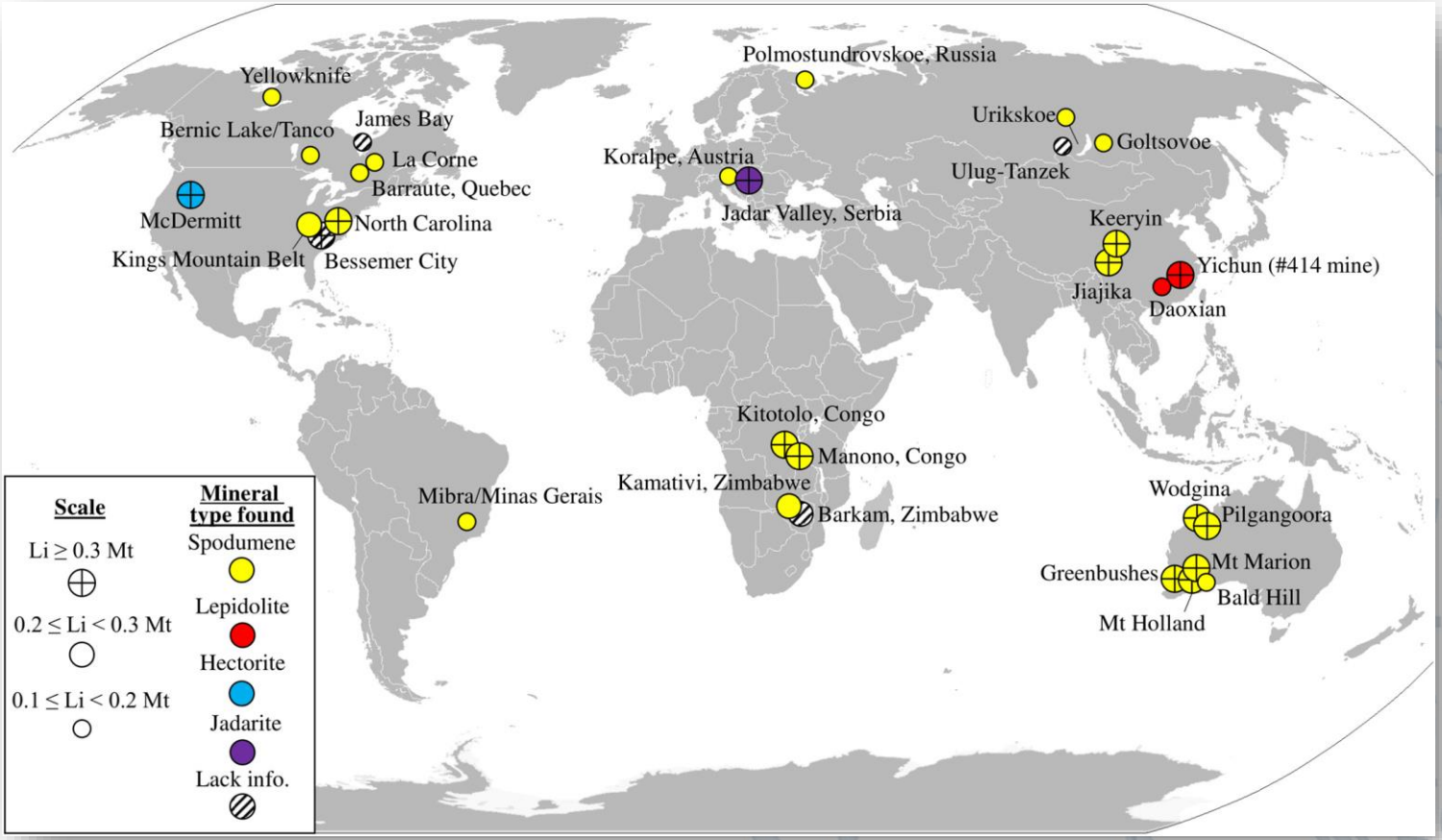




Vikström, H., Davidsson, S., Höök, M., 2013. Lithium availability and future production outlooks. Appl. Energy, 110, 252-266.

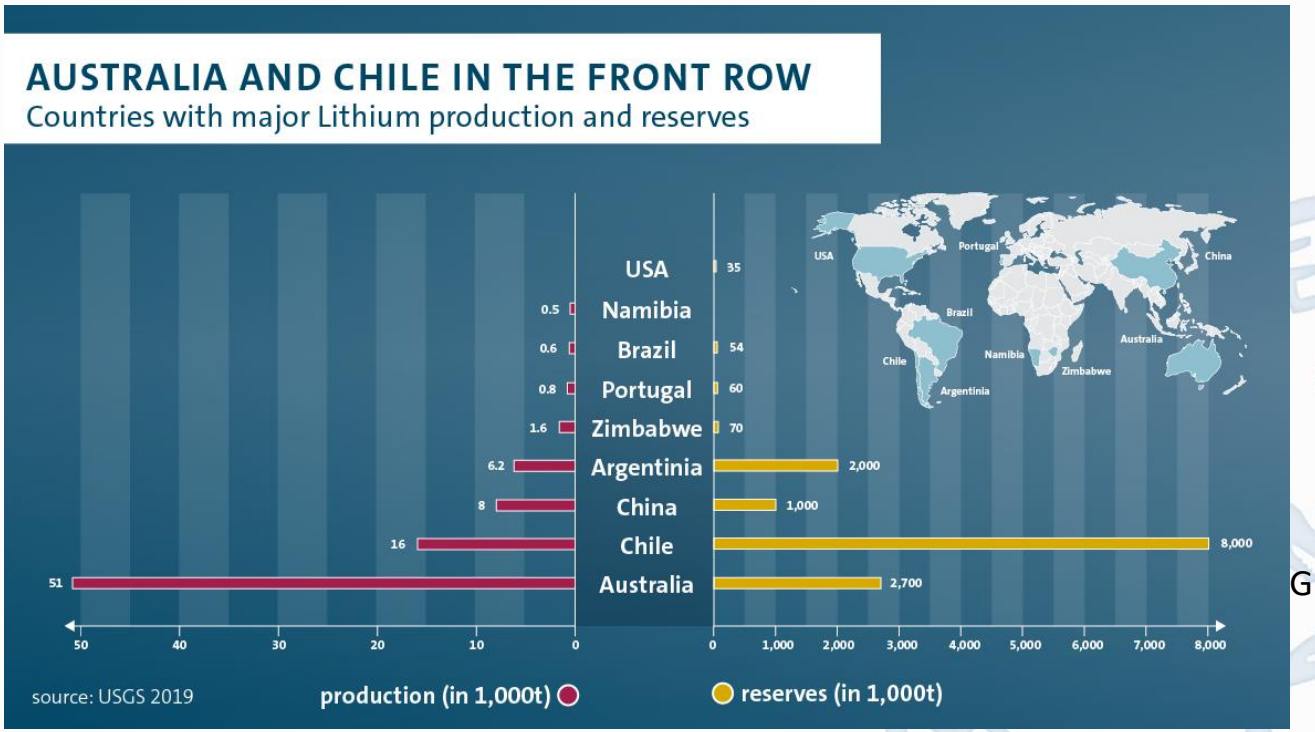
Distribution of major Li mineral deposits (≥0.1 Mt) of the world.

Spodumene is the most significant Li-bearing species



H. Li, et al, Hydrometallurgy 189 (2019): Data of Australia from Geology Survey of Western Australia (2018), data outside Australia from Gruber et al. (2011), Kesler et al. (2012), Liu et al. (2017) and Vikström et al. (2013)

World production and reserves of lithium



Global production in 2020 (WMD)

Global production of Li_2O	Global Producers
186 thousand tonnes	Australia 47% Chile 27% China 15% Argentina 7% RoW 4%

EU reserves and industrial activities in lithium

Company	European Metals	Infinity Lithium	Imerys	Savanna	Bacanora	Keliber	European Lithium
Project	Cinovec	San Jose	Beauvoir	Mino do Baroso	Zinnwald	Keliber	Wolfsberg
Country	Czech Republic	Spain	France	Portugal	Germany	Finland	Austria
Mineral	Zinnwaldite	Zinnwaldite	Mica	Spodumene	Zinnwaldite	Spodumene	Spodumene
Li_2O(%)	0.42	0.86	0.9	1.06	0.76	1.16	1.0
Resources (Li carbonate equivalent) in Mt	7	1.6	1.0	0.7	0.38	0.29	0.27
Product	Li_2CO_3/LiOH	LiOH	LiOH	Spodumene	LiOH	LiOH	LiOH
Production per year	≈30000	15000	34000	175000	12000	15000	10000
STATUS FS	**In progress**	**In progress**	**2024/ 2028 Project begins**	**Scoping Study 2019**	**2023**	**2019**	**PFS 2018**

Currently there is no battery grade lithium carbonate production in EU

Cinovec Lithium-Tin Project, Czech Republic

Deposit's characteristics

- The largest primary Li resource in Europe.
- Reserves > 50 mt of ore with > 0.4 wt.% Li_2O
- Indicated + inferred resources are estimated to be 660 mt
- Li is contained mainly in Zinnwaldite mica phase

Operational planning and status

- The project is expected to provide 360,000 t/a of mica concentrate to produce both LiOH and Li_2CO_3
- Lifetime: 21 years
- Feasibility study in progress

nsenergybusiness, 2021; europeanmet.com

Table of contents

A) Lithium Market and Supply Risk

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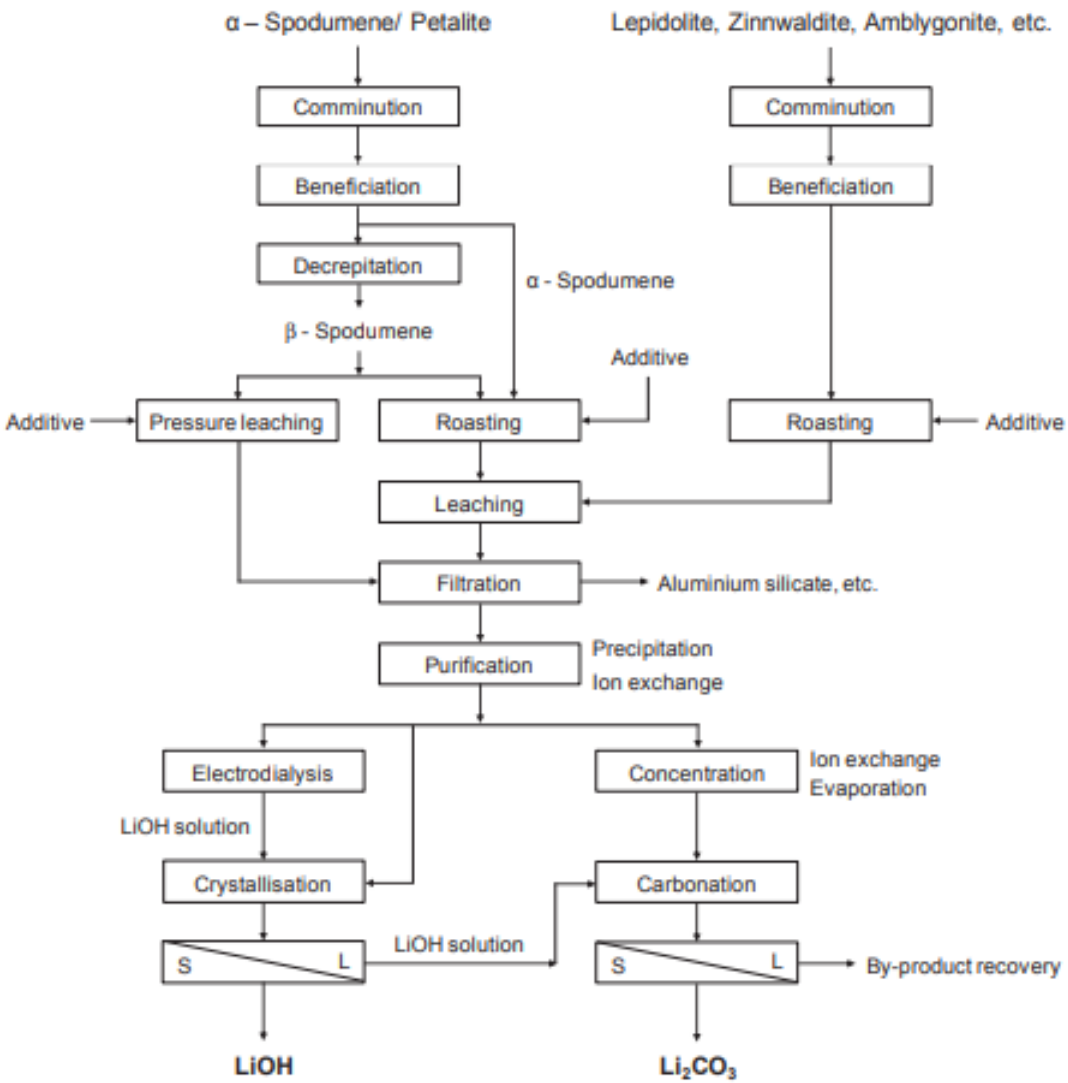
Lithium hard rocks processing

Conventional process

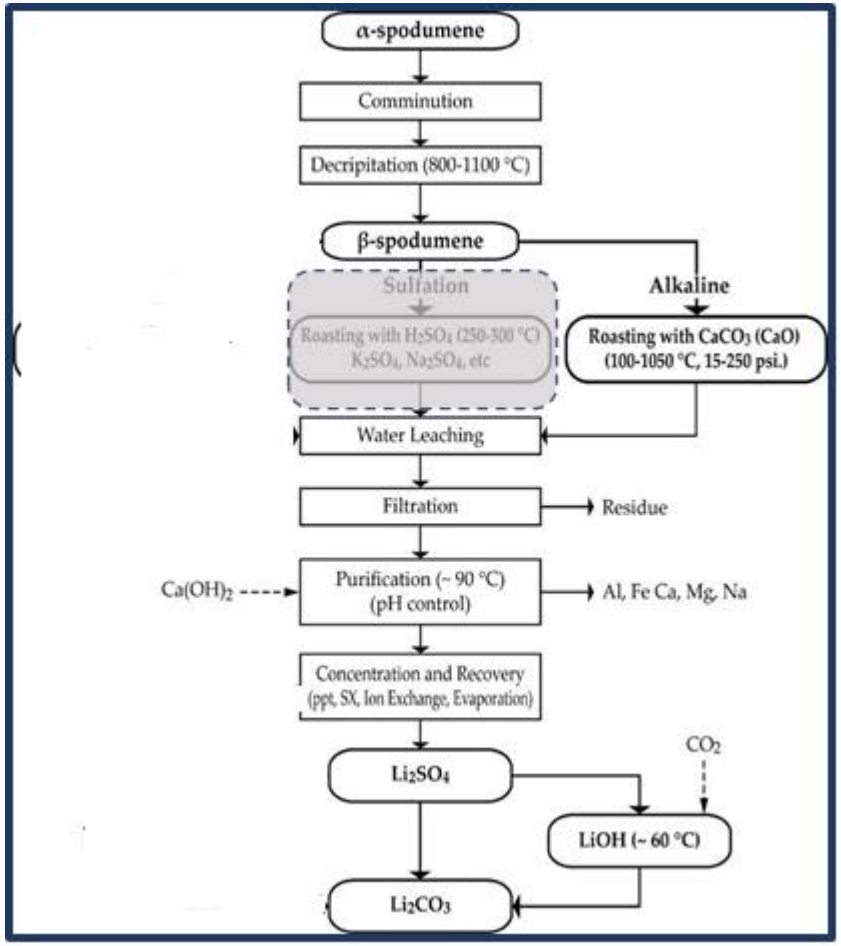


- Elevated temperature for α- to β- spodumene transformation (1100 °C)
- Energy-consuming/hazardous sulfuric acid roasting step
- Difficulty in producing high purity lithium carbonate Relatively low lithium recovery
- High amounts of waste to be disposed

Other high temperature routes. Alkaline process

Potential processes

$CaCO_3$ /CaO/$Ca(OH)_2$ roasting case 100 - 1050 °C



Replacing of sulfuric acid process step (dense acid at 250 °C) →
Roasting with various reagrent up to 1050 °C

- ✓ Potentially more economic
- ✓ Nonaggressive nature of reagents
- ✓ Water-soluble products

- High energy requirement for the decomposition of limestone
- High CO_2 emissions

Fosu, 2020

Potential processes

Proposed methodologies for the processing o β-spodumene

Roasting using various reagents such as: CaO, Na_2CO_3, Na_2SO_4, $CaCl_2$ or chlorination instead of conventional H_2SO_4 leaching

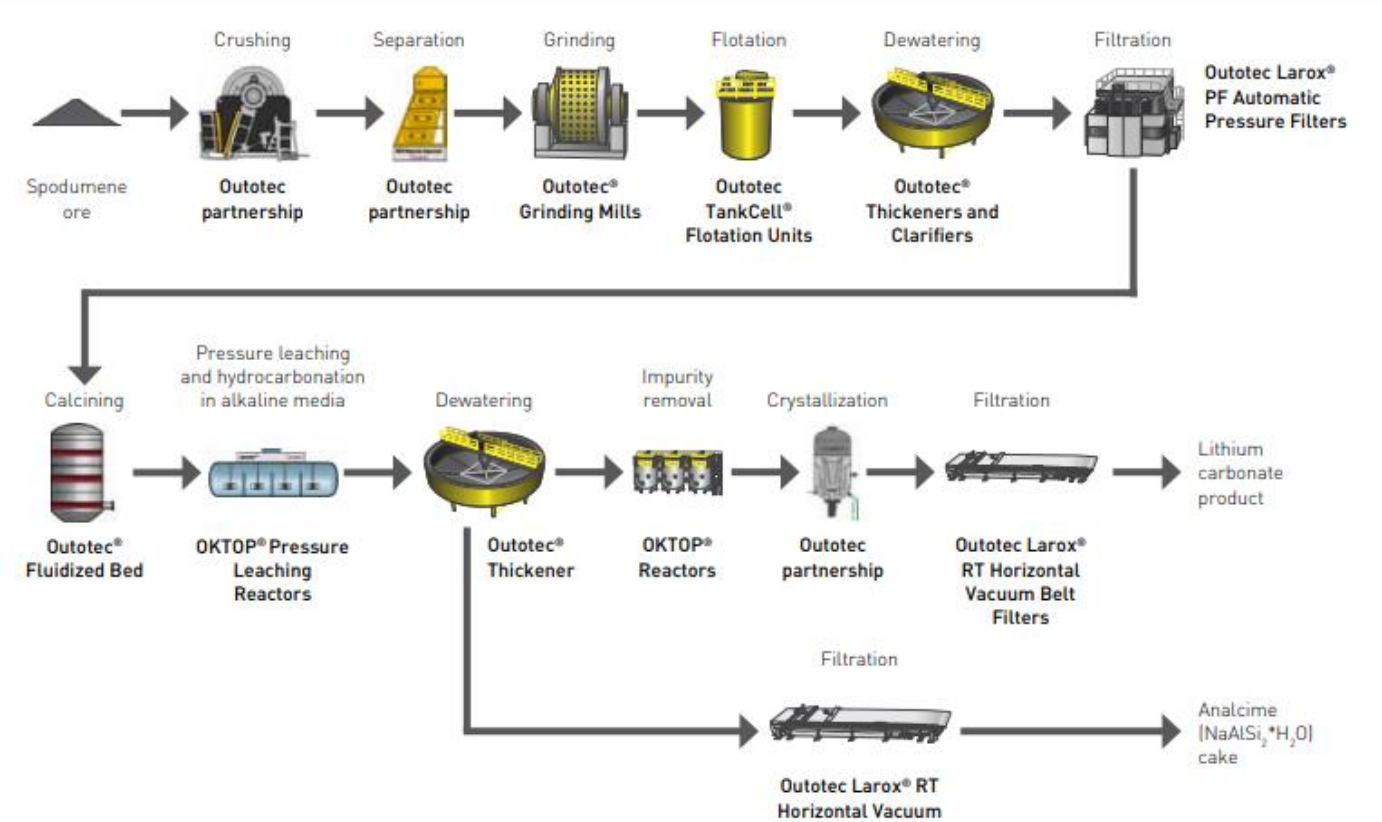
Process	Experimental Conditions						Product	Recovery/%
	Roasting			Leaching				
	Reagent	Temp./ °C	Time/min.	Time/hr	Temp./ °C	Lixiviant		
Sulfating	Conc.·H_2SO_4	200–300	30–60	-	-	H_2O	Li_2SO_4	85
	Na_2SO_4 + CaO	-	-	3	230	Na_2SO_4 + CaO	Li_2SO_4	93.30
	Na_2SO_4 + NaOH	200–300	-	3	230	Na_2SO_4 + NaOH	Li_2SO_4	90.70
	$(NH_4)_2SO_4$	150–370	-	-	-	NH_3 (aq)	Li_2SO_4	-
	$CaSO_4$ + $CaCO_3$	1000–1150	120–180	-	-	H_2O	Li_2SO_4	85–90
	Conc. H_2SO_4	250–300	-	1	-	H_2O	Li_2SO_4	86
	H_2O+O_2 + SO_3	350–425	10-40	-	-	H_2O	Li_2SO_4	97
Alkaline	CaO + H_2O	100–205	60			H_2O	LiOH	~97
	CaO + H_2O	1000–1230			100	H_2O	LiOH	80
Chlorination	KCl, NaCl	1000–1050	15–60	-	85	H_2O/HCl	LiCl	85–97.50
	Cl_2	1100	150	-	-	-	LiCl	-
	$CaCl_2$	900	120	-	60	H_2O	LiCl	90.2
	$CaCl_2$	800–1200	-	-	-	Alcohol	LiCl	9.5–98.5
Carbonizing	Na_2CO_3	525–675	10–120	-	-	H_2O, NH_4^+ (aq)	Li_2CO_3	75–97
	Na_2CO_3	150–250	10–120	–	-	H_2O	Li_2CO_3	~94
	Na_2CO_3 + NaCl	~923	120	-	-	H_2O	Li_2CO_3	70
Fluorination	NaF	600	120	0.5	25	HF	LiF	90

* roasting of spodumene done in the alpha phase.

Fosu, 2020

Potential processes

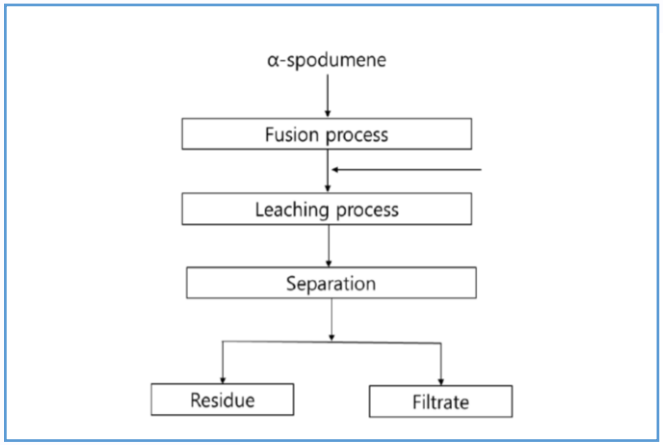
1st case Cleantech - Outotec



LiOH in two-stages: Alkaline leaching of β-spodumene with Na_2CO_3 in an autoclave at a temperature of about 220 ◦C, followed by crystallization of battery grade lithium hydroxide monohydrate

New research processes

2nd case Fusion - Carbonising Calcination

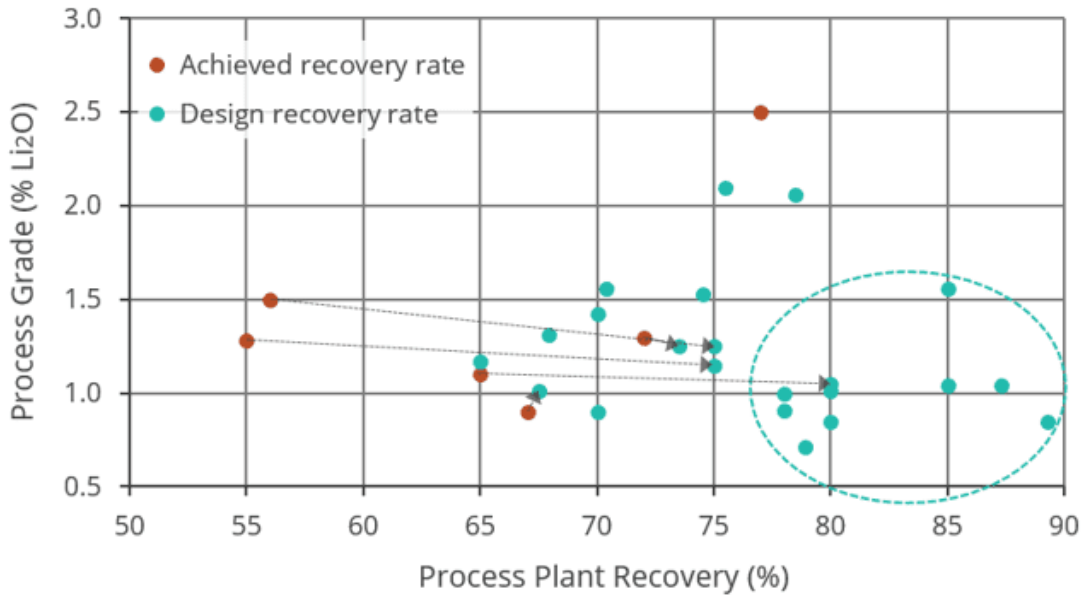


Spodumene + $Na_2CO_3 \rightarrow Li_2CO_3 + Na_2O.Al_2O_3.4SiO_2$
between 525 - 675 ◦C followed by water leaching between 90 and 225 ◦C

- ✓ **Possibility of using Na_2CO_3 as the only reactant to produce Li_2CO_3 of high purity**
- ✓ **Short processing time**

- **High impurities content.**
- **Sophisticated purification steps**

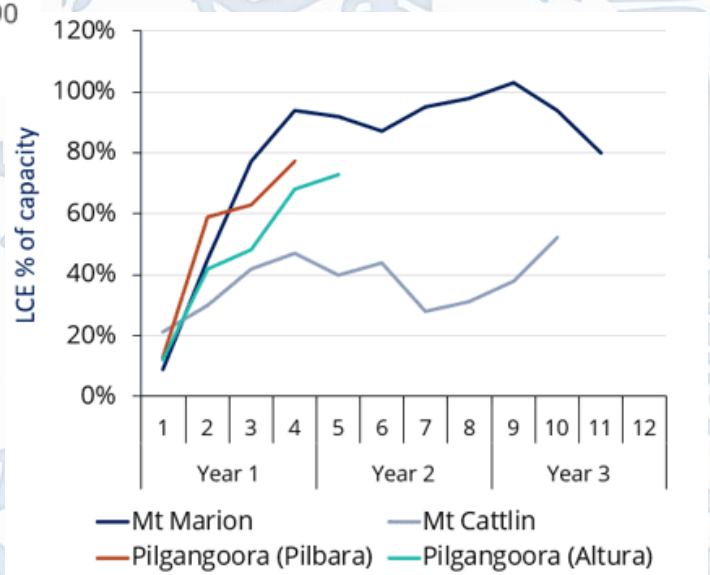
Designed vs actual performance



Recovery rates

Achievement of satisfactory recovery rate is time consuming

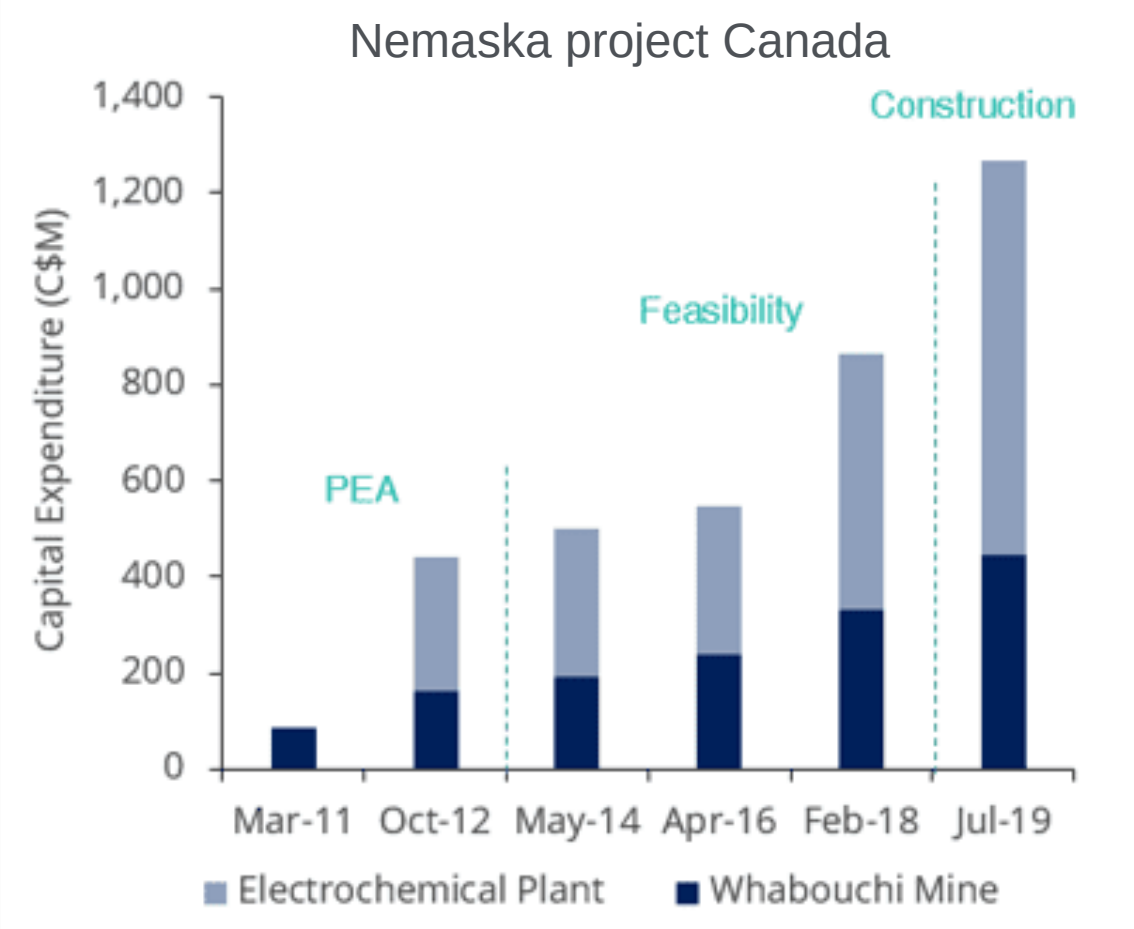
Source: Roskill – Lithium Cost Model Service



Spodumene recovery rates can be impacted by several factors:

- ore grade, mineralogy, presence of gangue minerals
- Accurate identification of the deposit structure
- plant design

Designed vs actual performance



Capex evolution of Nemaska's integrated lithium hydroxide project

Source: Roskill/Company reports

Potential risks of utilising new and commercial unproven processing technologies within the development of a project.

High importance of detailed and extensive engineering work before financing and construction

Factors that drive the future availability of Lithium and its supply risk

(1) Progress in battery design, leading to less Li used amount per specific energy (watt hour)

(2) Progress in Li recycling from end-of-life products

(3) The discovery of new, economically exploitable, Li deposits and the investments made in their development

- **Existence of several mature mining/metallurgical projects in EU countries**
- **The development of various novel extraction methodologies applied in hard rocks that can increase the recovery rates in EU Li projects**

Thank you!