Competitiveness of Portuguese Lithium

September 2020

Lithium demand will grow worldwide driven by electric mobility.

Lithium (Li) is a strategic alkali metal given the expectations of a very significant increase in its demand for the production of Li-ion batteries for electric vehicles (EV), including in Europe (EU), where Germany, France and the United Kingdom announced they will abandon the production of internal combustion engines vehicles by 2040. In 2020, Li was included in **the EU's list of critical raw materials**.

There is an emerging world market for **lithium carbonate** (Li_2CO_3) and **lithium hydroxide** (LiOH), with enormous uncertainty on price evolution, its functioning, main players and the lead time between new investments and effective Li supply. One of the main constraints on the Li world market is the degree of technological development within the Li value chain (extraction, mineral and metallurgical processing, and global demand).

Lithium is highly used in various industrial and battery applications

Lithium is present in seawater and in the earth's crust. It is usually obtained by two ways: mining of **hard igneous rocks** (in minerals such as spodumene, petalite, lepidolite, feldspar, amblygonite-montebrasite) and then processed, or obtained in the form of **brine** from which it is extracted via evaporation / membranes. The most commercialized Li compounds are **lithium hydroxide** (LiOH) for applications in battery components and **lithium carbonate** (Li_2CO_3) for industrial applications or in batteries. Both compounds are used to produce cathodic material and electrolytes for ion batteries. Globally in 2019, 65% of lithium was used in batteries, 18% in ceramics and glass, 5% in lubricants, 3% in the metallurgical / steel industry, 3% in polymers, 1% in gases and air purification and 1% in other uses. Europe consumes 24% of the world's exploration of Li, for use in the pharmaceutical, metallurgical, polymer, ceramic and glass industries. Of these, 2% come from small mines in Portugal, basically from pegmatitic deposits.

Competitiveness and sustainability factors for Lithium exploration in Portugal

Portugal has important Li resources, traditionally exploited and used for application in the ceramic and glass industry. However, its competitiveness for more noble applications, such as batteries for EVs, depends on the following factors: (i) **degree of geological knowledge of the resource**, i.e., number of known occurrences and the concentration of the ore; (ii) **national operating costs**; (iii) the **capacity to process the extracted ore**, implying the development in the country of competitive mining-metallurgical processing technologies, (iv) options and costs associated with **transport** to the end user. The social challenge of prospecting and exploration and exploitation projects reveals the urge for transparency and rigorous quantification of environmental and social impacts.

Parameters for some Li mines	Wabouchi Canada	Pilgangoora Australia	Keliber Finland	Average literat.*
Stripping ratio	2.2	2.9	5.9	3.1
OPEX [$/t ore]	73.46	33.73	93.08	59.51
Mining [$/t ore]	11.43	10.38	38.27	15
Process. [$/t ore]	53.86	13.74	54.81	40.45
General [$/t ore]	-	5.48	-	3.98
Transport [$/t ore]	8,17	4.13	-	6.15
Cut-off grades	0.43 %Li	0.43 %Li	0.50 %Li	0.32 %Li
Li Content	77-87% Spod	83% Spod	80-90% Spod	70% Spod
	2.87-3.25 %Li	3.1 %Li	2.98-3.36 %Li	2.61 %Li
Life of Mine [years]	20(+6)	13.2	16.2	15.7
CAPEX [M$]	455.9	528.1	180.4	315.7

In Portugal...

Portugal is the 7th largest world producer of Li [α] (782t Li contained in 2017). In the EU, it is the country with the largest known reserves. The world's largest reserves are located in the USA, Argentina, Canada, Chile, China and Brazil.

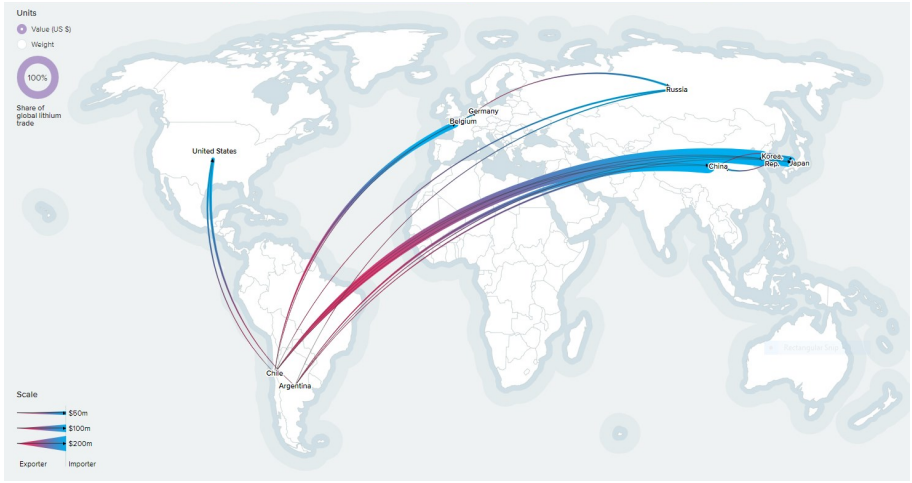
* doi: 10.1016/j.resourpol.2019.05.002; doi: 10.1016/j.resourpol.2020.101707; α in the form of materials for ceramics

The world market for Lithium

Lithium brine extraction operations have gained predominance since the 1990s as these are relatively cheaper than hard rock extraction. The *Lithium Triangle* made up of Chile, Bolivia and Argentina is the richest region, where it is estimated that 70% of the world's reserves are located. Since 2008/2009 there has been a rapid expansion of mining capacity, mostly supported by hard rock mining projects in Australia. Currently, brine extraction has almost identical relative weight as hard rock mining extraction. There are other marginal forms of extraction (e.g. clays), and R & D & I in the form of extraction and of processing the mineral may trigger changes in the Li world market.

Li's market is currently quite small, recent and includes 4 major incumbent players - Albermale (USA); SQM (Chile); Sichaun Tianqi (China); FMC (USA). **It is still a very dynamic market and a small event can bring significant changes**. In fact, transactions on the Li market do not take place on an "organized exchange", but through bilateral contracts between large companies that only voluntarily announce the terms agreed in their contracts. For this reason, spot prices are not really relevant, unless they begin to promote the emergence of a stock market. In June 2019, Li's price development was announced on the London Metals Exchange (LME) with *Fastmarkets MB*. However, the 4 major players opposed this initiative by announcing that they would not participate in the definition of this price benchmark, i.e., they would not inform the markets about volumes and prices transacted by them.

Within the traded Li compounds, it can be expected that in the future the increase in demand for LiOH will be greater than the demand for Li_2CO_3, leading to a decoupling of price developments. An increase in demand for EV batteries with cathodes that include Nickel instead of Cobalt (e.g.: NCM 881, NCM 662) is anticipated. This evolution is uncertain, being dependent on certain technical and economic challenges assumed by the EV battery industry.



World trade of Lithium carbonate, in 2017, in USD

The largest exporters (pink) are Chile, Argentina, China and Australia (not included in the figure) Despite Australia is one of the biggest Li producers, it exports it as spodumene concentrate).

The largest importers (blue) are China, Japan, South Korea and the United States (USA).

SOURCE: CHATHAMHOUSE (resourcetrade.earth)

Market prices for Lithium

The price of Li in the three world markets (EU / USA, China / Japan / South Korea, China) is currently in a period of low prices. The (weekly) price of Li_2CO_3 min 99.5% battery grade was 7,250 USD/t, while the (weekly) price of LiOH min 56.5% battery grade was 9,400 USD/t on the London Metal Exchange, LME spot CIF price China / Japan / South Korea, between 16 Jul-6 Aug 2020.

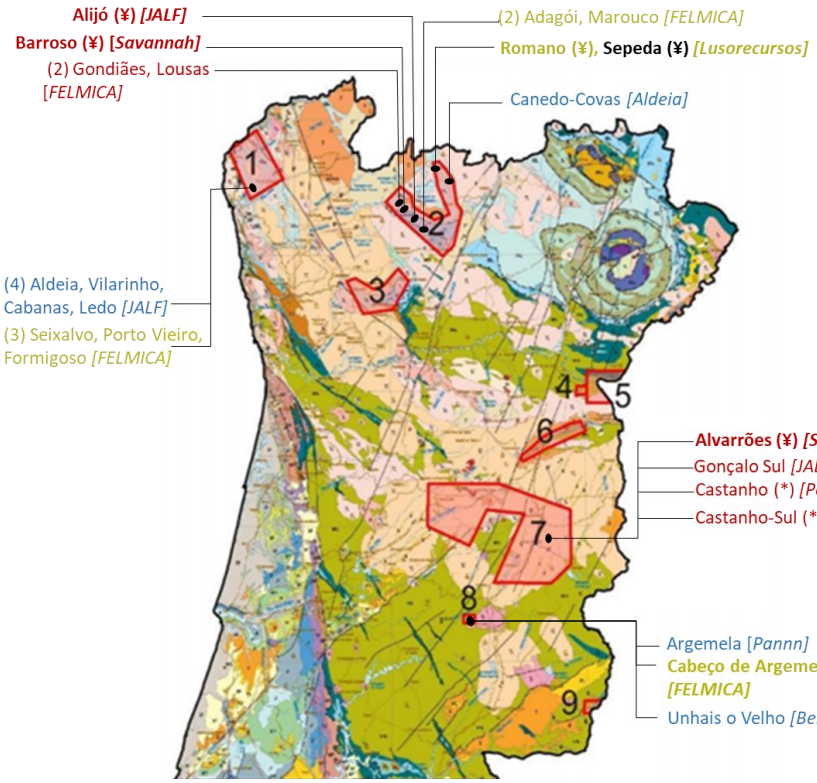
The Li_2CO_3 min 99.5% *battery grade* prices CIF China / Japão/ Coreia do Sul peaked in late 2017 (21,400 USD/t) when the announcement of the installation of the third Tesla giga-factory in the USA, with a production capacity of 35 GWh / year in 2020. The installation of the fourth EU giga-factory in Berlin was announced late 2019 and took Portugal out of the list.

New extraction projects in Argentina, Australia and Chile are expected to add 500,000 t LCE /year to the market by 2025. It is estimated that demand from electric car makers, such as Tesla, or smartphone producers, like Apple and Samsung, or for stationary storage to e-grid it will be insufficient to drive a big price hike.

The **Li market prices are lower than other metal mineral market prices** (e.g. **cobalt** price is ~ 33,000 USD/t), being closer to **copper** market prices (~ 6,400 USD/t). Li's prices are expected to remain low until 2030, although some analysts anticipate a rise as early as 2021. As mentioned, the price decoupling of LiOH and Li_2CO_3 battery grade may occur, although there is still great uncertainty on this.

SOURCE: doi: 10.1016/j.resourpol.2019.05.002; *LME; tradingeconomics.com; entrevistas da INN a Emily Hersh e Rodney Hooper; Roskill*

Lithium Exploitation in Portugal



9 regions with lithium potential in Portugal
(1) Serra de Arga, (2) Barroso-Alvão, (3) Seixoso-Vieiros, (4) Almendra, (5) Barca de Alva-Escalhão, (6) Massueime, (7) Guarda (Seixo Amarelo-Gonçalo, Gouveia, Sabugal, Bendada and Mangualde), (8) Argemela and (9) Segura
the concentration and amount of Li is heterogeneous in the different occurrences

Resource
601.5 kt LCE
(Li_2CO_3 equiva.)

8 concessions with activity 1998-2017 (red)
→ Estimated **Resources** 22.7Mt lithium pegmatite (~1.07% Li_2O) ↔ 113kt Li metal ↔ 243kt Li_2O
*Estimated **Reserves** 10.7Mt pegmatite (~1.06% Li_2O) ↔ 53kt Li metal ↔ 113kt Li_2O*

Resource
1032.7 kt LCE
(Li_2CO_3 equiva.)

4 concessions with most recent resource estimate Li (¥)
→Estimated **Resources** 48.4Mt pegmatite (~0.86% Li_2O) ↔ 194 kt Li metal ↔ 419kt Li_2O

Caption: *JALF: José Aldeia Lagoa & Filho, Lda.; SMC: Sociedade Mineira Carolinos, Lda.| Concessions with mining activity 1998-2017 | Concessions with exploration rights contracts | Concessions with contracts for prospecting and research |* (¥) concessions with most recent estimates | (*) No Li concessions in 2020. *There are still +78 concessions requests (9 exploitation,1 experimental exploitation, 68 prospecting & search). Conversion factor of Li metal for Li_2CO_3 equivalent: 5.323*

SOURCES: *LNEG (2010), Dinis & Horgan (2017) Statistics data. 1998-10 DGEG (sept 2020): https://www.dgeg.gov.pt/pt/areas-setoriais/geologia/depositos-minerais-minas/publicitacao-de-atribuicao-de-direitos* ***NOTE:*** *Values reported by companies on their mineral inventory of extractive projects for ceramic raw materials, not necessarily obeying the criteria of international standards for "Reserves" and "Resources".*

Most frequent Lithium Mineral rocks in Portugal	Concentration (% Li)		
	In Li mineral	Cut-off rates	Average % in Li concentrate
Spodumene	3.7	0.2-1.5	3.3
Lepidolite	2.6 */ 3.6**	0.2 - 2.0	1.5 - 2.5
Petalite	2.3	0.4-1.1	1.4
Amblygonite/ Montebrasite	4.7	0.1-1.0	2.6-3.4

* Trilitionite; ** Polylitionite

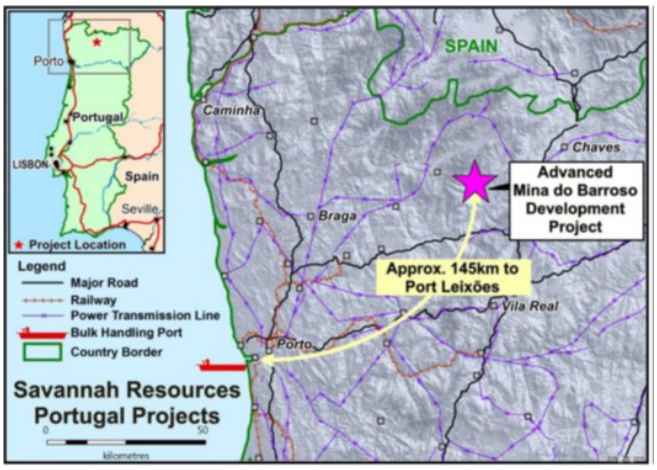
The current legislation requires the Environmental Impact Study (EIA) for the mining phase, but not for the prospecting phase. The mining activity is the center of economic dynamism in rural areas. However, its negative impacts, especially environmental ones, have motivated several demonstrations against by numerous civic and environmental movements.

Mina do Barroso (Savannah Lithium)

Located in Montalegre, Vila Real district, close to the Peneda-Gerês Natural Park. This is the largest conventional lithium (spodumene) exploration project in Western Europe that aims to extract 1.3 Mt of litiniferous pegmatite per year, corresponding to a production of 175 kt / year of spodumene concentrate (6% Li2O), during the 11 years of the mine life. This is equivalent to 25 kt / year of lithium carbonate. The project is estimated to support the creation of 300 direct jobs in the construction phase for an initial investment of 98.1 M €. In the operation phase, direct employment will be on average 215 workers. The project foresees that 86% of the production is destined for exports.

University of Minho, july 2020

Source: https://minadobarroso.com/impacto-socio-economico/



FONTE: Savannah Resources

Competitiveness analysis

The promotion of Li encouraged by the Portuguese government (RCM nº 11/2018) seeks to exploit this national resource in an integrated industrial way, locating a significant part of the value chain in Portugal. Emphasis is placed on the **phase of geological knowledge,** on the business models for the creation of **mining-metallurgical processing units** and on the innovation and research projects for the **recovery of lithium from used Li batteries**. However, according to current investments foreseen in the battery value chain in the EU, Portugal only appears identified at the level of exploration and processing of Li and not in the development of materials for batteries.

The **Barroso Li mining project**, which is more advanced than the rest of known projects in EU (with a possible start operation in 2021), has the shortest duration (11 years) of all the European projects in preparation (see table below), aiming to export 86% of the volume extracted from **concentrate of spodumene** (6% Li_2O). Other projects in the EU focus on Li compounds with a higher market value (e.g.: lithium hydroxide or carbonates).

The **cost-competitiveness of the exploitation of the Portuguese Li is in line with the other known EU projects**. However, its **sustainability needs further clarification** along the environmental, social, and intergenerational pillars.

PROJECTS IN PORTUGAL

- **Barroso** - Boticas & Montalegre - Licensing phase, with to be confirmed economic viability. Exports of spodumene conc. foreseen by sea;
- **Alvarrões** - Guarda (Gonçalo/ Seixo Amarelo) - EIA Phase. Exports of spodumene conc. foreseen to Canada.
- **Argemela** - Covilhã & Fundão - Pre-EIA phase. Aiming for exports
- **Romano** - Montalegre - Phase prior to the EIA. Aiming for exports.

Li Exploitation Projects under analysis in the EU & world context — financial indicators

Project	Phase	Beginning Op.(LoM)	Country	Typo	Product	k tpa	NPV M€	IRR	Paybk Period
Whabouchi (Nemaska)	Pre-commercial	2018 (20+6)	Canada	Open-pit Underground	LiOH-H_2O Li_2CO_3	32.7	784 (8%)*	30.3%	2,7
Pilgangoora (Alura Mining)	Commercial DFS Sep2016	2018 (26)	Australia	Open-pit	Spod.	220.0	237 (10%)*	46.6%	2,1
Sonora (Bacanora)	Pre-comercial DFS Jan2018	2023E (19)	Mexico	Clays	Li_2CO_3	33.3	459 (8%)*	25.0%	5,0
Cauchart-Olaroz (Lithium Americas)	Pre-commercial DFS Aug2019 (update –final)	2021E (40)	Argentina	Brine	Li_2CO_3	40.0	1531 (8%)*	23.5%	4,0
Keliber Oy (Keliber)**	Pre-commercial DFS Feb2019 (update –final)	2019E (16.2)	Finland	Open-pit	Li_2CO_3 LiOH	113.0 12.1	384 (8%)	24.0%	4,1
Barroso (Savannah)	Project DFS Q22020E	2021E (11.2)	Portugal	Open-pit	Spod.	175.0	204 (8%)*	48.6%	2,1
Wolfsberg (EuropeanLithium)	Project DFS Q42020E	2022E (n.e.)	Austria	n.e.	LiOH	10.1	n.e	n.e	n.e.
San Jose (Infinity Lithium)	Project PFS Aug2019	2022E (30)	Spain	Open-pit	Spod. LiOH	525.0 16.5	n.e.	n.e	n.e.
Cinovec (EuropeanMetals)	Project PFS Aug2019	n.e. (21)	Chec Republic	Underground	LiOH-H_2O or Li_2CO_3	25.2 22.5	939 (8%)*	28.8%	n.e.
Zinnwald (Deutsch Lithium)	Project PFS May2019	n.e. (30)	Germany	n.e.	LiF	n.e.	428 (8%)	21.5%	n.e.

LoM—Life of Mine; PFS — Pre-viability Study ; DFS — Definitive Economic viability study; E—expected; Spod.— Spodumene Concentrate (6% Li_2O); Li_2CO_3

Recommendations

- Li mining projects in Europe seem to be structured according to an **integrated industrial project rationale**, with Li being extracted, processed and converted into Li_2CO_3 or LiOH. See for example, the Keliber (FI) project that restructured its final economic feasibility study in 2019, replacing the final output for LiOH, the most sought after in the markets for batteries, and extending the useful life of industrial activity beyond mine life. In this way, its financial indicators improved.
- The "**Lithium" Working Group in Portugal** created by the Secretary of State for Energy in 2016/17 recognizes that it is necessary to **deepen the knowledge of the geological resource but also to carry out studies related to the beneficiation phases (laboratory and industrial) that can support a strategy based on its installation and promoting added value nationally** - there is a need for national research and innovation related to **recycling of Li minerals used in batteries** under a circular economy logic. In Dec-2019, the European Commission approved funding (IPCEI) of 3.2 billion euros for projects that make Li batteries more durable and environmentally friendly, integrating 7 Member States (Finland, Germany, Sweden, Italy, France, Poland and Belgium).
- Savannah Resources / University of Minho estimate the creation of between **600 and 800 jobs in Barroso** mining project (200 direct and 400 to 600 indirect). However, the method used has limitations for prospective analyzes and the **socio-economic benefits should be studied in more detail.**
- **Information** on the various ore mining projects (in operation and planned) in the world presents enormous uncertainty and variability in the reporting format, which makes comparative competitiveness analysis difficult.
- There is need to **quantify mining risks to natural capital** (taking into account climate change and efforts to prevent it) and to account it strategically in conservation plans and policies.
- **Transparency in communication and respect for local environmental and societal values** is essential, as evidenced in the multiple challenges across Europe, but stronger in the Iberian countries of Southern Europe where projects are on the threshold of protected natural heritage (Barroso / PT, Parque Born in Peneda and Gerês, San Jos de Valdeflorez / ES, 2 kms from Cáceres World Heritage City and the Valhondo Valley or Sierra de la Mosca).

More information

European Battery Alliance
https://eba250.com

EIT Raw Materials — Lithium Project
https://eitrawmaterials.eu/project/liref/

Certification of Raw Materials
https://www.cera-standard.org/

World Mining Data
https://www.world-mining-data.info/

World Open Database of Minerals
https://www.mindat.org/

Locations of mining Potential in Portugal
https://geoportal.lneg.pt/pt/bds/siorminp/#!/

Barroso mine—Savannah Lithium
https://minadobarroso.com/

Lithium trade data
https://tradingeconomics.com/commodity/lithium

OCDE Trade Raw Materials
https://www.oecd.org/trade/topics/trade-in-raw-materials/

RCM n.º 11/2018 Strategic framework Li
https://dre.pt/home/-/dre/114610495/details/maximized

Working Group Report on Li Portugal
https://edm.pt/wp-content/uploads/2018/03/ResExec_Li.pdf

Map of concessions DGEG
https://geoapps.dgeg.gov.pt/sigdgeg/

Mining Watch Portugal
https://miningwatch.pt

How to reconcile mining and metallurgical exploration, aiming at carbon neutrality, with the preservation of natural capital safeguarded also by civic and environmental movements?