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Energy Transition and Sustainability
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The role of lithium reserves in Portugal to fulfil the e-mobility needs from the National Roadmap for Carbon Neutrality 2050

Filipa Amorim, National Laboratory for Energy and Geology – LNEG/Resource Economics Unit
Sofia G. Simoes, National Laboratory for Energy and Geology – LNEG / Resource Economics Unit
Patrícia Fortes, CENSE FCT NOVA University Lisbon
Carlos Nogueira, National Laboratory for Energy and Geology – LNEG /Materials for Energy Unit

Overview of the talk

1. Context of Lithium (Li) markets
2. Map of Li mineralizations reserves in Portugal
3. Goals of this work
4. Methods
5. Take aways from the analysis
6. Limitations and future work

Lithium uses and markets

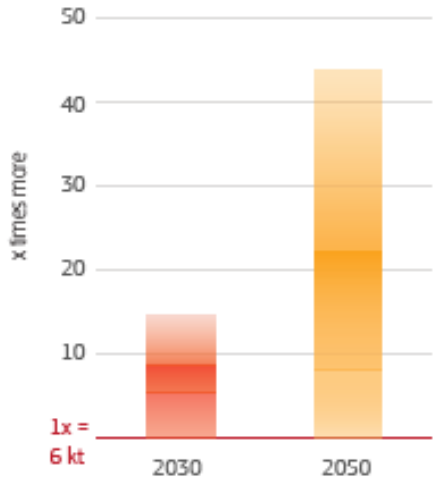
Lithium (Li) is an alkali metal, strategic today given the expectation of a very significant increase in its demand to produce Li-ion batteries for Electric Vehicles, EVs;

There is an emerging **world market** for **lithium carbonate (Li_2CO_3)** and **lithium hydroxide (LiOH)** with great uncertainty on prices evolution, their functioning, main players and the lead time between new investments and effective Li products supply;

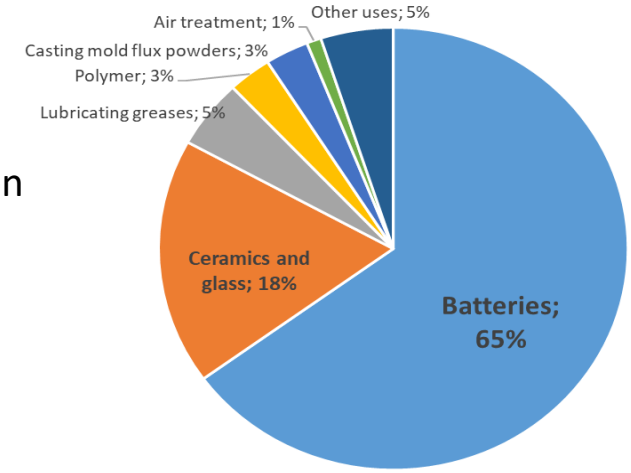
Lithium is highly used **in various industrial** and **battery** applications;

Portugal is 7th largest world producer of Li in the form of materials for ceramics and glass. In EU context, it is the country with the largest Li mineralization reserves, while world's largest reserves are located on USA, Argentina, Canada, Chile, China and Brazil.

Li_2CO_3prices min 99.5% *battery grade* CIF China/Japan/South Korea peaked in late 2017 (~21,400 USD/t) - third Tesla Gigafactory announcement – but these ~ 7,000 USD/t for last few years.



EU annual Li demand for batteries in e-mobility in 2030/2050 compared to today's consumption
https://ec.europa.eu/docsroom/documents/42881



Global End-use markets estimates 2019 USGS2020 https://doi.org/10.3133/mcs2020

Competitiveness and sustainability factors for lithium exploitation in Portugal

Value chain for automotive Li-ion batteries

Portugal has important Li resources, traditionally exploited and used for application in the ceramic and glass industry.

The competitiveness for more noble applications (batteries for EVs) depends on factors:

(i) **degree of geological knowledge** of the resource;

(ii) **national operating costs**;

(iii) **the development within the country of competitive mining-metallurgical processing technologies**;

(iv) **options and costs associated with transport** to end user.

The social challenge of prospecting & exploration and exploitation projects reveals the urge for **transparency** and **rigorous quantification of environmental and social impacts.**

Li minerals exploitation projects in Portugal

9 regions with litiniferous potential in Portugal

(1) Serra de Arga

(2) Barroso-Alvão

(3) Seixoso-Vieiros

(4) Almendra

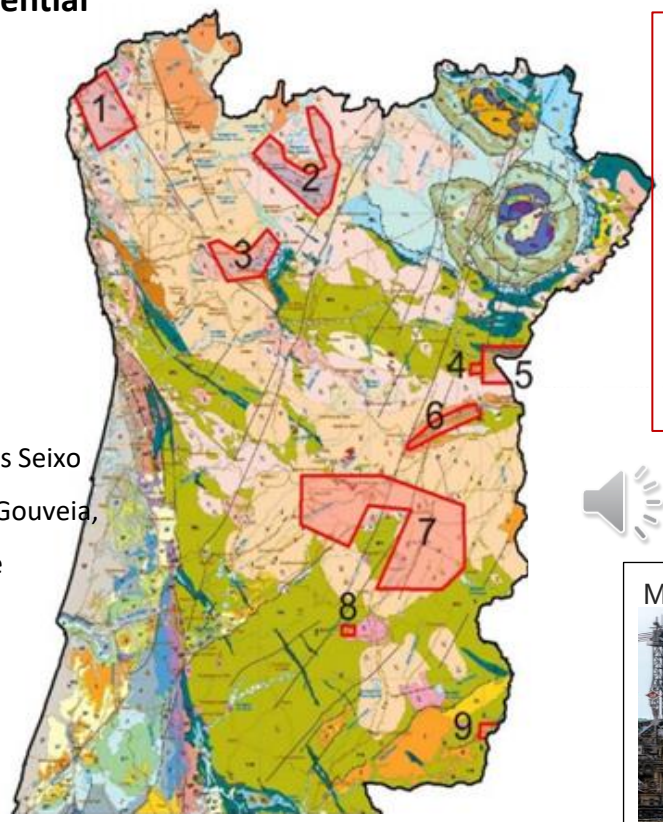
(5) Barca de Alva

(6) Massueime

(7) Guarda (includes Seixo Amarelo-Gonçalo, Gouveia, Sabugal, Bendada e Mangualde)

(8) Argemela

(9) Segura



Resource

1032.7 kt LCE

(Li_2CO_3 equiva.)

From 4 concessions (out of 8) with activity in 1998-2017 period

Estimated Resources 48,4Mt pegmatite (~0.86% Li_2O) ↔ 194kt Li metal ↔ 419kt Li_2O

From 8 concessions with activity in 1998-2017 period

***Proven Reserves* 10,7Mt pegmatite (~1.06% Li_2O)** ↔ *53kt Li metal ↔ 113kt Li_2O*

SOURCES: *Dinis & Horgan DGEG (2017) Statistics data. 1998-2017;* ***NOTE:*** *Conversion fator of Li_2CO_3 equivalente (LCE) to Li metal: 5.323*

the concentration and quantities of Li are heterogenous depending on the mineral occurrence

MINING PROJECTS UNDER ANALYSIS IN PORTUGAL

- **Barroso -** Boticas & Montalegre - Licensing phase, confirmed econ. viability. Exports of spodumene concentrate by sea;
- **Alvarrões** - Guarda (Gonçalo/ Seixo Amarelo) - EIA Phase. Exports of spodumene concentrate to Canada.
- **Argemela** - Covilhã & Fundão - Pre-EIA phase. Aim for exports
- **Sepeda** - Montalegre - Phase pre EIA. Aim for exports.

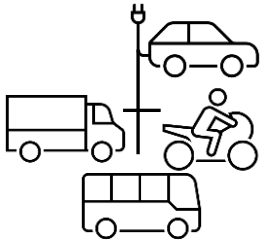
Most frequent Lithium mineral rocks in Portugal	Concentration (% Li)		
	In Li mineral	Cut-off rates	Average % in Li concentrate
Spodumene	3.7	0.2-1.5	3.3
Lepidolite (* Trilitionite ** Polylitionite)	2.6 */ 3.6**	0.2 - 2.0	1.5 - 2.5
Petalite	2.3	0.4-1.1	1.4
Amblygonite/Montebrasite	4.7	0.1-1.0	2.6-3.4

hdl.handle.net/10400.9/3333

Goals of this work

Assess quantitatively the role of the potential ***of Li reserves, from lithium mining projects in Portugal, to support the needs of electric mobility within the transitions to a carbon neutral economy in 2050,*** *as foreseen in the National Roadmap for Carbon Neutrality 2050 (RNC2050).*

RNC2050
Carbon Neutrality Roadmap



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Methods

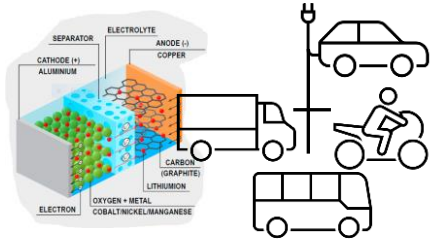
SUPPLY of Li minerals

- ✓ Identification and characterization of the known Portuguese reserves of lithium mineral projects under prospect & exploration and exploitation phases
- ✓ Quantification of Li from extraction to its final use, including expected losses of the Li within the Li-On batteries value chain.

DEMAND for Li compounds

- ✓ Quantification of the expected evolution of Li demand needs in the Portuguese carbon neutral **transport sector** in 2030 and in 2050 (RNC2050 - *Pelotão, PL*; *Camisola Amarela*, CA).
- For each e-mobility modes (Bus, Cars, Trucks & Lorries and Motorcycles), identification of **specific Li content per vehicle type**

RNC2050
Carbon Neutrality Roadmap



BALANCE between Li supply & needs in 2030 / 2050

- % national reserves of Li to satisfy national e-mobility needs

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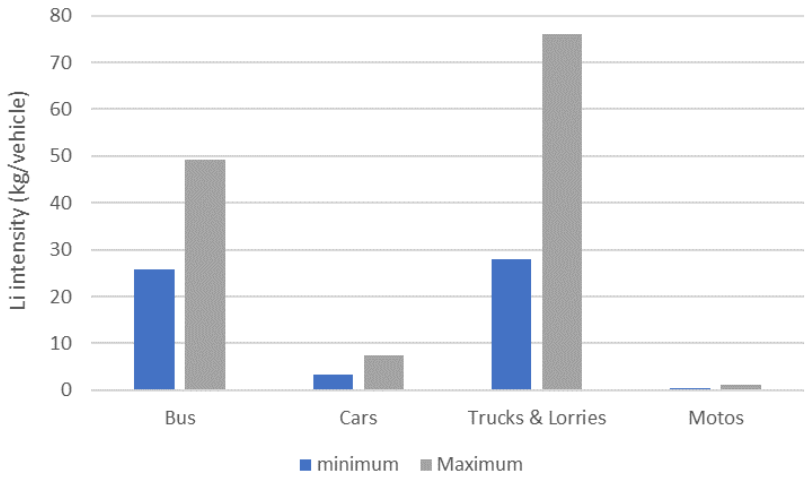
Lithium needs for e-mobility in Portugal

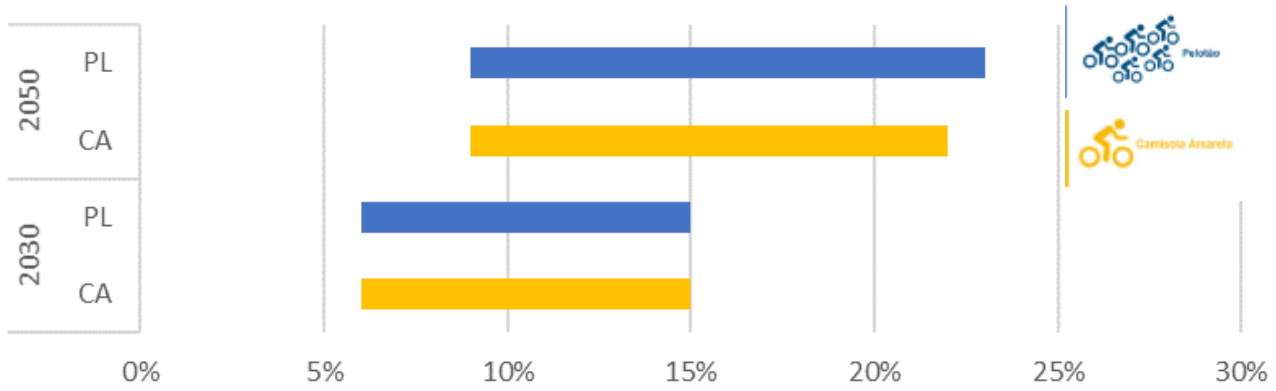
Li intensity (kg/vehicle) Maximum and minimum scenarios



- Li intensity considered constant until 2050;
- Recycling potential of Li in batteries inexistente in the period;

Sources:
doi.org/10.1016/j.rser.2018.03.002
doi.org/10.1016/j.rser.2014.04.018
zeeus.eu/uploads/publications/documents/zeeus-ebus-report-internet.pdf
www.proterra.com/vehicles/zx5-electric-bus/range/

% national reserves of Li to satisfy national **mobility needs in 2030 and 2050**



RNC2050 available at:
//unfccc.int/sites/default/files/resource/RNC2050_EN_PT%20Long%20Term%20Strategy.pdf

Limitations of analysis and future work

Limitations

- The concentration and quantities of Li are heterogenous, depending on the mineral occurrences, but this analysis has been made on average terms, assuming that the concentration values of lithium in the all minerals enable the economic viability of the projects;
- Battery developments underway, which may change the Li requirements in the e-mobility batteries in near future have been disregarded.

Future work

- Include the impact of expected needs of the transition for decarbonisation with relevant implications for Li demand in Portugal also accounted for in RNC2050 (ex.: RES technologies, stationary storage);
- Assess if remaining of Portuguese Lithium reserves could cover European needs for Lithium for different uses;
- Updated sources of reliable information (including international standards criteria) and refine assumptions.

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Laboratório Nacional de Energia e Geologia, I. P.

www.lneg.pt

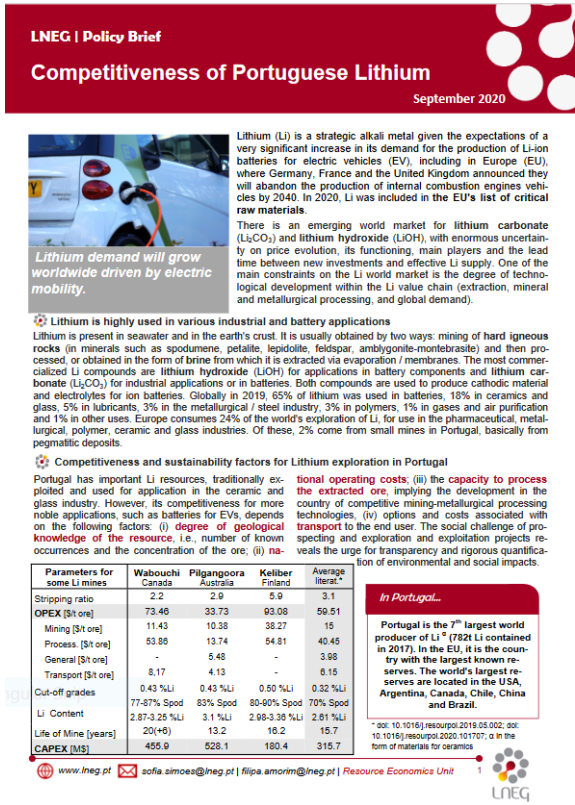
Thank you for your attention!

Resource Economics Unit

http://www.lneg.pt

sofia.simoes@lneg.pt
filipa.amorim@lneg.pt

LNEG's **Resource Economics Unit** (UER) is crosscutting the Energy and Geology areas of LNEG. It develops I&D&D activities and decision-support for both public policymakers and the private sector on energy and geology resource economics, towards carbon neutrality and sustainable resource exploitation and use. The unit applies **techno-economic & social analytical approaches** in the fields of: (1) Sustainable energy systems, (2) Resource use for energy production and consumption, (3) Classification of national geological deposits and energy resources in a global economy, (4) Economic and social impact of the energy transition, (5) Circular economy, including design of products, services, systems and business models, and (6) Sustainable public procurement.



LNEG | Policy Brief

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 [$/t ore]	8.17	4.13	-	6.15
Cut-off grades	0.43 %Li	0.43 %Li	0.50 %Li	0.32 %Li
	77-87% Spod	83% Spod	80-90% Spod	70% Spod
Li Content	2.87-3.25 %Li	3.1 %Li	2.98-3.36 %Li	2.61 %Li
Life of Mine [years]	20(+6)	13.2	16.2	15.7
CAPEX [M$]	455.9	528.1	180.4	315.7

In Portugal...

Portugal is the 7th largest world producer of Li [*] (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

www.lneg.pt | sofia.simoes@lneg.pt | filipa.amorim@lneg.pt | Resource Economics Unit 1

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