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Global Overview of the Lithium Market and Opportunities for Chile

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Abstract: Lithium is a metal with a highly promising outlook for future global demand. Its industrial processing relies on two primary methods: production from brines through solar evaporation ponds and production from rock sources via flotation, roasting, and subsequent leaching. Chile is currently the world's second-largest producer of lithium, surpassed only by Australia. However, Chile's lithium production process is significantly advantaged by the exceptionally high lithium concentration in the Salar de Atacama—the highest in the world—and the region's high solar radiation, which enables the most cost-effective solar evaporation process globally. Despite these comparative advantages, Chile's lithium production has stagnated in recent years. This stagnation can be attributed to the need for more flexible legislation surrounding the lithium industry or an increase in the number of CEOLs (Lithium Exploitation Contracts) to regain its position as the leading global producer of lithium. Furthermore, increased investment in national universities and research centers is essential to foster the development and implementation of new, clean technologies for future projects. By addressing these challenges, Chile has the potential to solidify its role as a key player in the global lithium market while promoting sustainable industrial practices.

Keywords: lithium; brines process; new lithium technologies

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1. Introduction

When we talk about lithium, we are indeed referring to a metal with tremendous future potential [1]. This is mainly because it cannot be replaced in most of its applications, which is expected to lead to a steady increase in demand in the medium and long term [2–4]. For this reason, lithium was included in the list of strategic critical materials (since 2020) due to supply scarcity and its significant impact on the global economy projected until

2050 [5,6]. Below is a forecast of the growth in the value of critical metals by 2050 (See Figure 1).

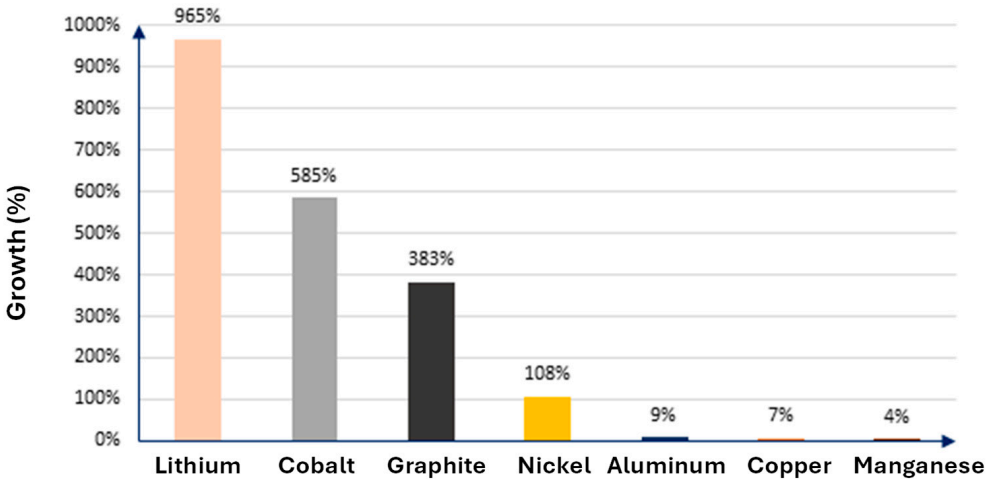


Figure 1. Projection of the value of critical metals for the year 2050 (modified from [7]).

This has mainly been due to the rapid growth of the battery market, where in 2010 this market demanded 23% of lithium usage, in 2017 46%, and by 2023 it encompassed over 80% of lithium usage, with electromobility being the area where a greater growth in demand is observed (see Figure 2). In 2015, 500,000 electric vehicles were sold worldwide; in 2017, 1 million; by 2021, 6.5 million; and by 2023, nearly 14 million were sold (see Figure 3) [8–10]. Currently, the International Energy Agency estimated that 2024 would close with figures indicating that one in every five new cars sold will be electric.

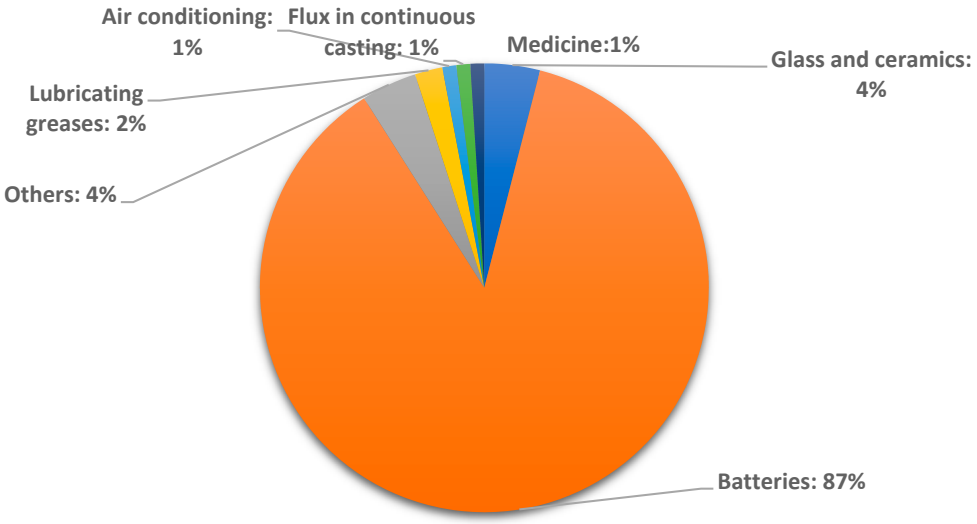


Figure 2. Uses of lithium in the global market (modified from [7]).

The above explains the growth in global lithium demand and the increase in its value since 2020, reaching the historic figure of USD 78,000 per ton of lithium carbonate. Although in 2024 its value significantly declined (USD 12,000 per ton of lithium carbonate), it is expected that its value will rise again in the coming years [7]. Critical metals needed for batteries' fabrication, such as nickel, cobalt, and lithium, are projected to quadruple in value over the next two decades, reaching levels like fossil fuels (according to studies conducted by the International Monetary Fund) [7,11].

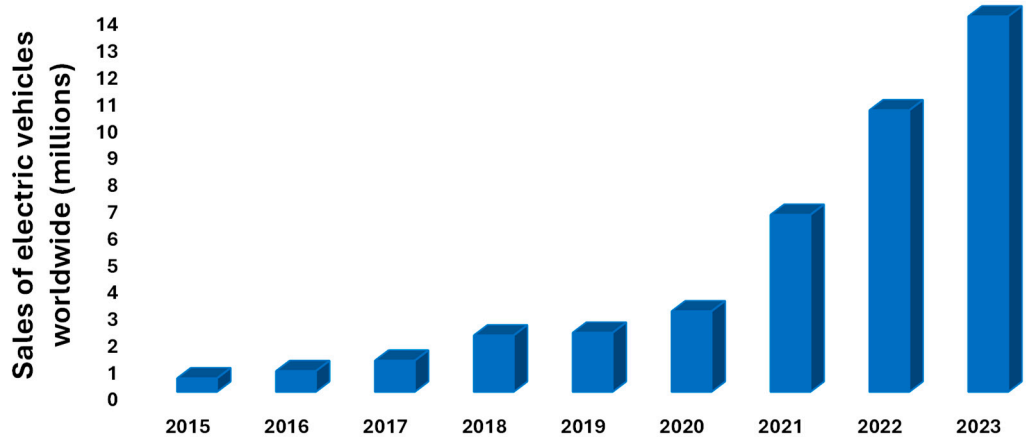


Figure 3. Electric car sales in the world (modified from [7]).

2. Overview of the Lithium Market in Chile

2.1. Lithium in Chilean Economy

Figure 4 shows the export of products in Chile according to data from the Central Bank of Chile (the entity with official data on the economy in Chile), with the main focus being on products related to mining. As we know, Chile is the main exporter of copper worldwide, with copper representing a value close to 9% of its national GDP (Gross Domestic Product); as shown in Figure 4, copper exports represented 45.3% in 2022 [12].

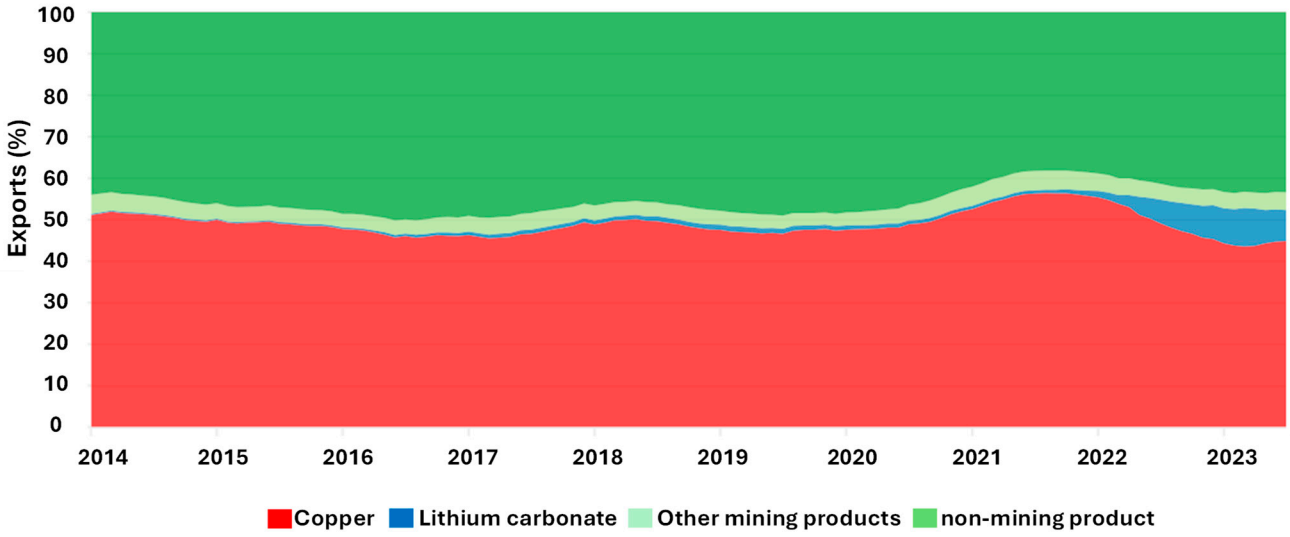


Figure 4. Product exports in Chile (data from [12]).

Regarding lithium, it is currently the second most relevant mining product in exports, mainly highlighting carbonate, and hydroxide in lesser quantities. Between 2013 and 2021, lithium carbonate exports represented, on average, 0.8% of product exports. This figure rose to 8.2% in 2022. China, South Korea, and Japan are the main destinations for these products. This is in addition to the rise in hydroxide exports during the first half of 2023, which reached around 10% of lithium shipments according to customs information [12].

How has lithium impacted the evolution of mining GDP?

Lithium extraction is measured in mining GDP, representing 3.4% of total GDP in 2022. In this last year (2023), lithium grew 10.4% in real terms, contributing 0.9 percentage points to the annual variation in mining [12].

Figure 5 shows the greater weight of carbonate compared to the rest of lithium products.

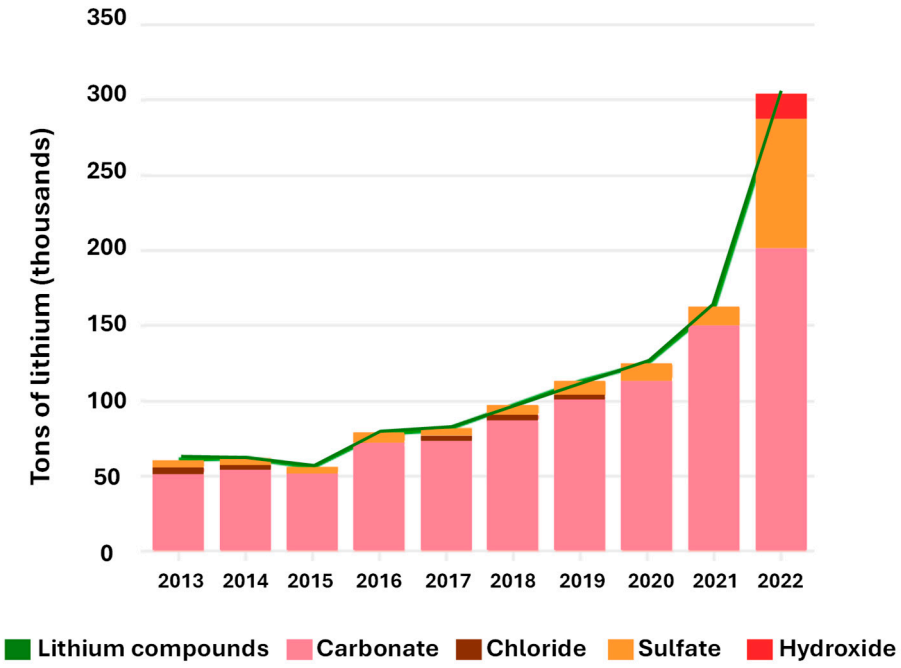


Figure 5. Breakdown of lithium production in Chile (data from [12]).

What are the current productive chains associated with lithium?

Based on the latest input–output matrix, the productive chains of mining that include lithium extraction are estimated (Figure 6). This means the capacity to drag production from other industries through its demand for intermediate goods. The results show that business services is the sector with the greatest chain derived from lithium production, mainly due to the demand for architectural and engineering services.

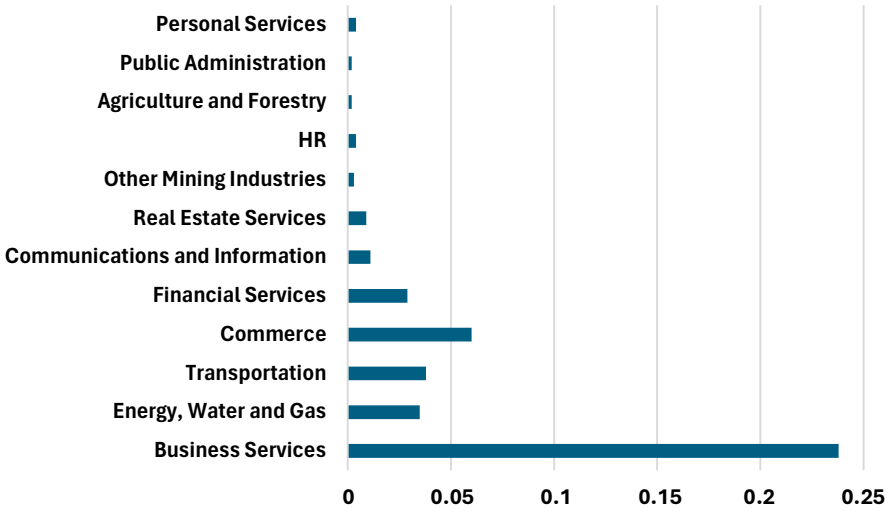


Figure 6. Productive chains associated with lithium (data from [12]). Coefficients correspond to the sum of the backward linkages according to the inverse Leontief matrix without considering the activity itself and Other mining activities correspond to non-ferrous metal mining.

2.2. Lithium Mining Industry

Currently in the country, both the SQM and Albemarle companies extract lithium from well brines through the solar evaporation process [13,14]. This involves transferring brine through a succession of ponds, where the lithium concentration increases from an initial 0.2% in the brine (light blue) to 6% (yellow) over 18 months, while other minerals like potassium, magnesium, boron, and others settle out (see Figure 7). This process is the most

efficient and cost-effective worldwide and uses only the water present in the brines. It has often been claimed that lithium companies in Chile have high water consumption, which is not true (as it only considers the water within the brines) [15,16]. Furthermore, requiring a drastic change in this industry could risk losing this unique comparative advantage of our salt flats (the highest concentration of lithium in brines globally, with ~1800 ppm in the Salar de Atacama, accompanied by high solar radiation and a favorable magnesium-to-lithium ratio that currently makes us more competitive than other salt flats in neighboring countries) [7] (see Table 1).

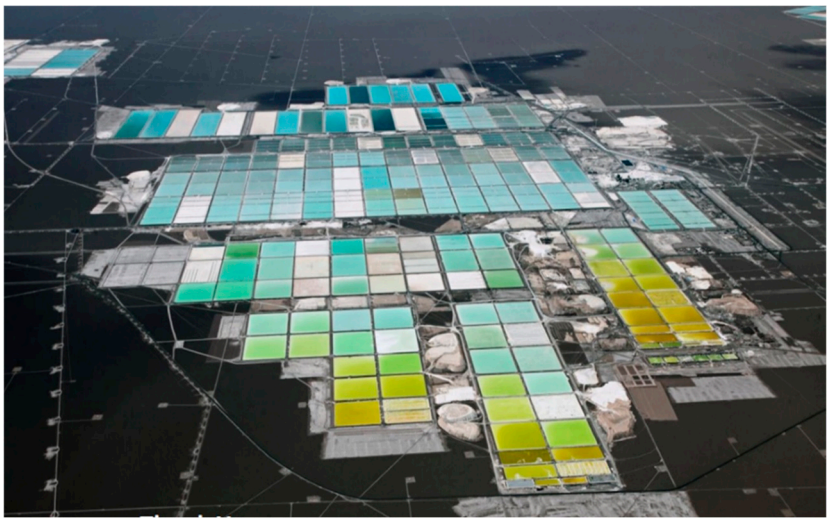


Figure 7. SQM solar evaporation ponds, Salar de Atacama [7].

Table 1. Chemical concentration of elements in brines from various salt flats around the world [16].

Deposit Characteristics (mg/L)									
Deposit	**Li**	**K**	**Mg**	**Ca**	**SO_4**	**B**	**Mg/Li**	**SiO_4/Li**	**Ca/Li**
Salar de Atacama Average	1835	22,626	11,741	379	20,000	783	6.4	10.9	0.2
Salinas Grandes Salt Flats	775	9289	2117	1450	1036	232	2.7	1.3	1.9
Dead Man's Salt	744	7404	1020	636	10,236	420	1.4	13.8	0.9
Salar de Hombre Muerto EastSide	745	8318	1781		8642		2.4	11.6	
Silver Peak	245	5655	352	213	7576	85	1.4	30.9	0.9
Salar de Olaroz (production Wells)	774	6227	2005	416	18,630	1136	2.6	24.1	0.5
Cauchari Salt Flat	618	5127	1770	476	19,110	1360	2.9	30.9	0.8
Salar de Uyuni Average	424	8719	7872	557	10,342	2442	18.6	24.4	1.3
Rincon Salt Flats	397	7513	3419	494	12,209	331	8.6	30.7	1.2
Maricunga Salt Flat	1036	8869	8247	11,919	1095	634	8.0	1.1	11.5

At present, various technologies are being developed to optimize the process of lithium extraction from brines, with Direct Lithium Extraction (DLE) being one of the most frequently mentioned and/or studied. This is primarily because solar evaporation only allows for the extraction of between 40% and 60% of the lithium present in the brines, and it is hoped that this figure could be optimized to up to 90% (as estimated with the use of DLE) [7]. However, this type of technology significantly increases the consumption of fresh water, and its energy use is up to 10 times higher than the current process in Chile [17]. Additionally, these methods do not currently allow for the recovery of other minerals, such as potassium, which is crucial for the commercial offerings of this type of industry. The same could be said for other technological options, such as Ion Exchange [18]. It is also

important to mention the recent advances in membrane technologies focused on the lithium industry. For example, Crown Ether-based membranes (CE-membranes), metal–organic frameworks (MOFs), and two-dimensional materials featuring precisely defined openings have demonstrated significant effectiveness in recovering lithium [19]. In our opinion, the natural comparative advantages offered by Salar de Atacama (solar evaporation in ponds) should not be overlooked, and to this, a subsequent process incorporating new technologies (a hybrid process) could be added.

2.3. Advantages of Lithium Carbonate and Hydroxide Production from Brines in Chile Compared to Spodumene Mining in Australia

- **Use of Solar Energy:** Lithium extraction from brines relies on solar energy for evaporation in ponds, significantly reducing fossil energy consumption and operational costs. In contrast, hard-rock mining requires energy-intensive thermal and chemical processes.
- **Lower Production Costs:** Production costs in Chile range between USD 3000 and 5000 per ton of LCE, compared to USD 10,000–15,000 for spodumene mining in Australia. This makes the Chilean model more competitive, especially during periods of low lithium prices [7,16].
- **Opportunity for Advanced Technology Integration:** Chile has the potential to combine Direct Lithium Extraction (DLE) technology with solar evaporation, significantly improving lithium recovery rates and reducing processing time. This hybrid approach could maximize productivity from unexplored salars.
- **Availability of Multiple Salars:** Chile boasts several untapped salars, representing a strategic lithium reserve. Furthermore, desalination technologies could be implemented to reduce water footprint and minimize the impact on freshwater use in these arid regions.
- **Cleaner Chemical Processes:** Production in Chile does not require aggressive acids for refining. In contrast, spodumene mining in Australia involves acid roasting and calcination at high temperatures, increasing the chemical and energy footprint.
- **Lower Carbon Footprint:** Brine-based processes generate significantly fewer CO_2 emissions compared to hard-rock mining. This is due to the use of solar energy and the elimination of carbon-intensive stages like crushing, grinding, and calcination.
- **Elimination of Energy-Intensive Rock Processing:** Crushing and grinding of rocks are not required, which are highly energy-intensive processes involving heavy machinery in spodumene mining.
- **Reinjection of Brines:** In brine extraction, treated brines can be reinjected into the salar, contributing to the sustainability of the hydrological system and reducing environmental impact.
- **Resilience to Lithium Price Fluctuations:** Thanks to its low operating costs, the Chilean model is more competitive during periods of low lithium prices, ensuring its long-term viability compared to the higher costs of hard-rock mining.
- **Lower Dependency on Heavy Mining Infrastructure:** Brine extraction does not require large-scale mining operations or the transportation of solid materials, simplifying logistics and reducing environmental and social impacts.
- **Sustainability and Social Acceptance:** The reduced water footprint, along with technologies like desalination and brine reinjection, strengthens the sustainable profile of production in Chile, facilitating greater acceptance by local communities and regulators.

The use of solar energy, the potential integration of technologies like DLE, the existence of vast undeveloped salars, and the less invasive chemical processes make this approach

more sustainable and competitive. In a global market in transition, the Chilean model stands out as a more resilient solution aligned with energy transition and sustainability goals.

2.4. Chile's Lithium Industry Compared to Other Countries

Due to the significant advances in the exploration of new lithium deposits, resources have increased significantly worldwide, totaling around 86 million tons in 2020 and 105 million tons in 2023, representing an increase of 18% in three years.

Figure 8 shows the world's lithium resources where the largest reported resources are located in the so-called lithium triangle in South America, where lithium resources in continental brine total around 56 million tons, representing 53.3% of the identified resources.

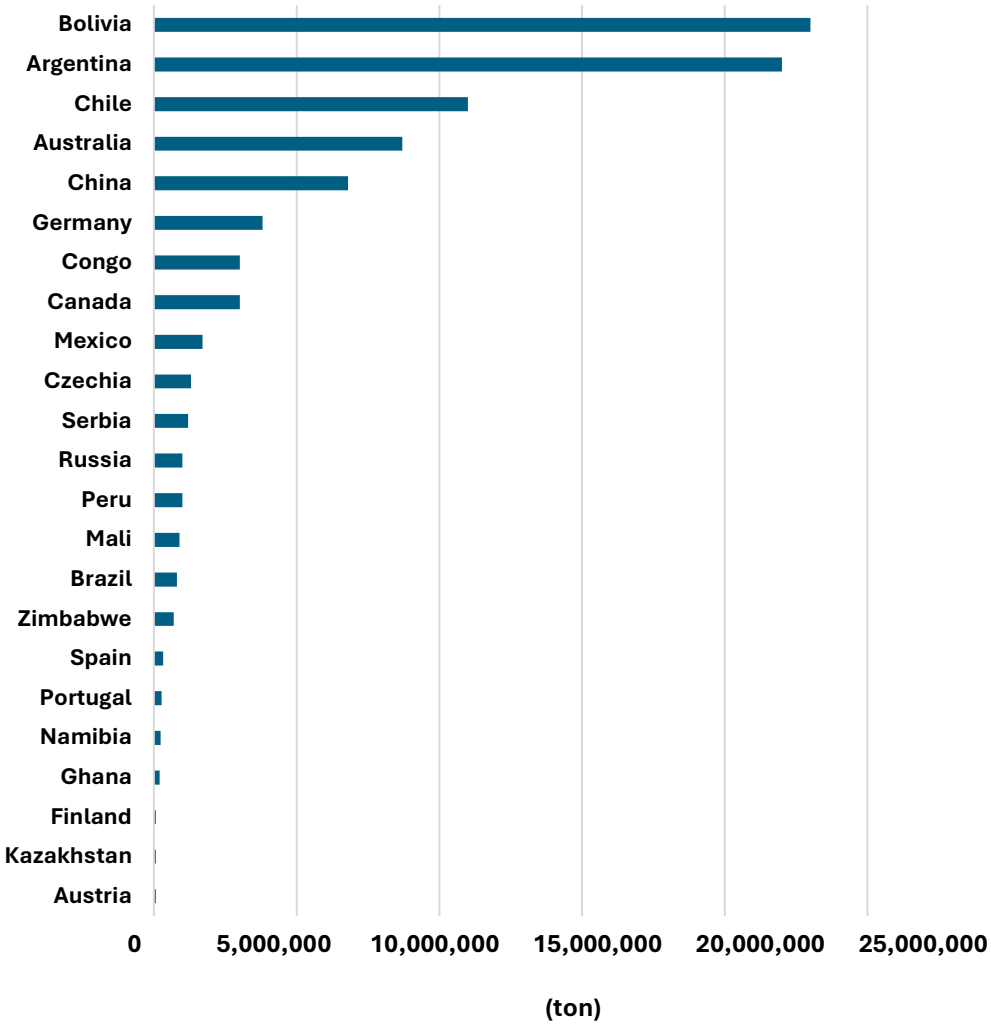


Figure 8. Lithium resources in the world in 2023 (modified data from [7]).

Although the largest lithium deposits are reported in Bolivia, with 23 million tons, the complex chemical composition of the brine and low lithium concentration, added to the less favorable climatic conditions compared to the reality of Salar de Atacama (Chile), have made large-scale lithium production in Bolivia complex.

As can be seen in Figure 9, Chile, with 9.3 million tons of lithium, has the largest lithium reserves in the world through its continental lithium brine deposits, where Salar de Atacama stands out, with the most concentrated lithium brines on record. However, in lithium production, it is surpassed by Australia; in Australia, it is easier to invest in and process environmental permits (see Figure 10).

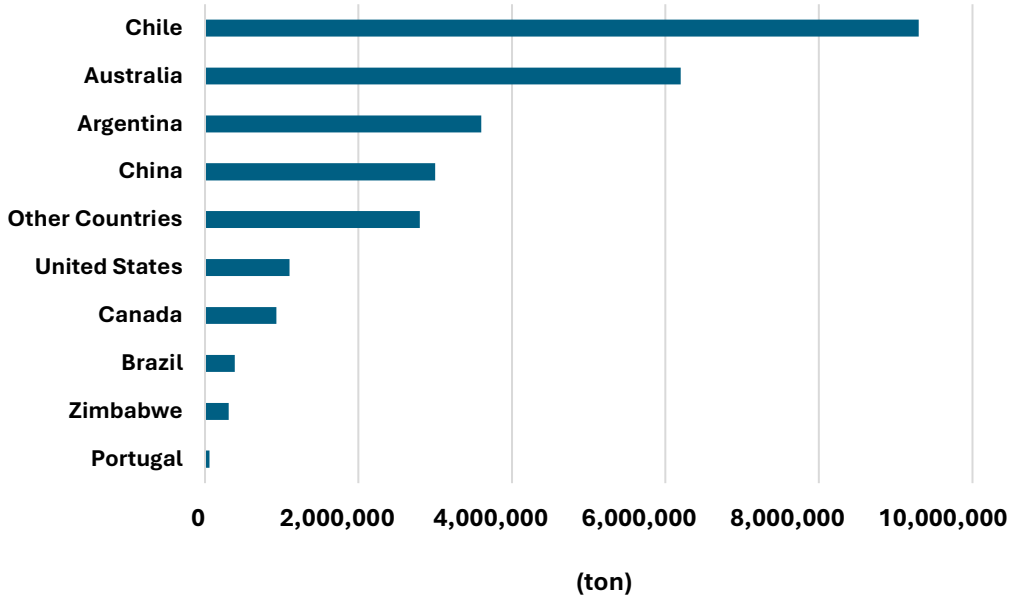


Figure 9. Lithium reserves in the world in 2023 (modified data from [7]).

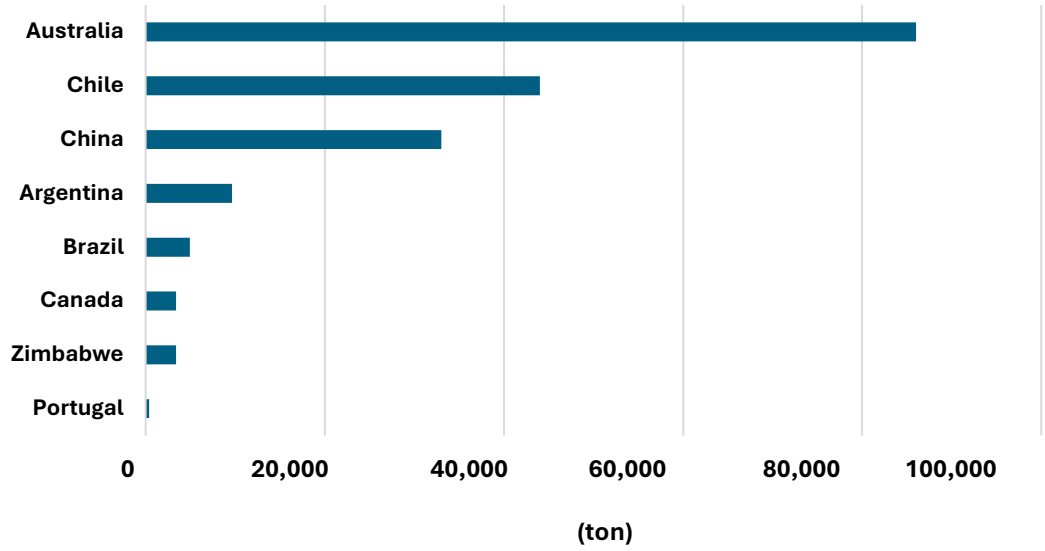


Figure 10. Lithium mine production in the world in 2023 (modified data from [7]).

2.5. Lithium-Ion Battery Market in Chile

On the other hand, in the lithium-ion battery market, there has been frequent mention of Chile's supposed "comparative advantage" for manufacturing these due to the processing of high-purity lithium carbonate. However, this is completely mistaken, for the following reasons:

Most of a battery's cost is in its materials (59% of its cost). This 59% is then divided among the various types of materials, with 30% of the cost attributed to the battery's cathode. It is important to note that cobalt represents 60% of the cathode's cost. Lithium, on the other hand, is an essential element for the functioning of lithium-ion batteries, accounting for approximately 7% of the total cost [18,20,21]. However, despite lithium being a strategic and fundamental component for battery manufacturing, it is also necessary to have graphite, manganese, nickel, and cobalt, all elements in which Chile currently lacks a significant industry and which together represent a greater cost in battery production [7].

3. Final Reflection

Chile was once the leading producer of lithium, later surpassed by Australia, and projections indicate that, without an increase in production, it could be overtaken in the coming years by China and Argentina [7]. This highlights the need to make legislation more flexible regarding this industry or to increase the number of CEOLs (Lithium Exploitation Contracts) to regain a strong position in the global market for this commodity. Additionally, according to various lawyers in Chile, it is necessary to improve the legal framework of CEOLs, which are an important part of the national lithium strategy. This strategy is based on public–private partnerships that require certainty to be able to make their investments [22].

Contrary to the belief of many, it is more crucial to continue growing and strengthening the lithium extraction industry, both in terms of production and sustainability, rather than losing focus on other industries that stem from it. Developing lithium mining can take between 6 and 7 years (following the granting of government exploitation permits) [7] due to the need for capital, technical complexity, environmental impact studies, and the delays typically associated with these processes (for example, negotiations with neighboring communities). In contrast, the construction of a lithium battery Gigafactory only takes 2 years.

Chile has the most advanced industry in processing lithium carbonate and hydroxide with the highest efficiency in cost and sustainability globally, which makes me optimistic about its future positioning, if exploitation flexibility is improved. Additionally, the country's universities, together with industry, are making significant strides in exploring new technologies related to lithium.

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