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The Potential of Lithium: Peruvian Case

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ABSTRACT

Lithium is a top-quality mineral in the energy market, with growing demand. It has many applications in medical, nuclear, and energy industries. The purpose of this article is to quantify and analyze the economic potential and projected global demand for lithium annually. It aims to determine Peru's (specifically Puno) positioning in the global context in 2025 and 2030. The article also seeks to identify the main regulatory, environmental, and social challenges to sustainably exploit lithium in Peru.

The study employs applied research (mixed approach), descriptive-correlational scope, and observational, cross-sectional design. The methodology demonstrates the use of statistical techniques to model and make predictions about this energy-transition metal. Academic sources were reviewed to enable a comparative approach and projection into the future of lithium for development in the mining industry.

In the last 10 years, lithium demand has grown, noting a 600% increase in the economy and projected annual growth of +26%. Exponential growth in resources is projected, where econometric, R-multivariable and R-linear models estimate that Peru could supply 1.5% in 2025 and 3% in 2030 of global lithium. Estimated growth of 5–15% in socio-environmental conflicts is projected with the start of lithium exploitation (Peru – Puno).

The global potential of lithium demonstrates exponential growth. Lithium reserves in Puno - Peru would rank 13th between 2025 and 2030. It is necessary to establish a clear regulatory framework to avoid excessive increase in socio-environmental conflicts.

Nomenclature

Symbol	Definition
α	Estimated annual growth rate
b	Exponential growth base
y	Dependent variable (number of articles)
x	Independent variable (year)
a	Constant
y_1	Initial value (2015)
y_2	Final value (2022)
x_1	Initial year (2015)
x_2	Final year (2022)
X	Matrix of independent variable data
y	Vector of dependent variable data
X'	Transposed matrix of X
$X'X^{-1}$	Inverse matrix of X'X
ε	Error term
Y	Dependent variable (production %)
Price	Lithium price (in dollars)
Demand	Global demand for lithium batteries
Investments	Investments in lithium production capacity (in million dollars)
Costs	Lithium extraction cost in the country (in dollars per ton)
β_0	Constant term
β_1, β_2, β_3, β_4	Estimated coefficients

INTRODUCTION

This article focuses on a set of assessments focused on the potential of lithium and the implications it may have in Peru, in order to identify where it is heading, how far it can go in the national and private industry. Peru has a large current reserve of 4.7 million tons which, through research, is presented in mineral deposits and evaporitic sedimentary environments [1] and [2]. The white gold deposit is located in the Corani district, Carabaya province, Puno district, possibly considered one of the ten largest lithium reserves in the world and as a future source of income [3] y [4].

In this context, we focus on two key issues. First, the potential and technological impact of lithium within the global market; the global bibliometric perspective emphasizes the present and future importance of scientific and technological research focused on lithium, which drives the article. Currently, the profitability of this mineral is growing, due to its implication in different industrial aspects given its high efficiency compared to the different metals that are used. The demand for lithium is on the rise due to the high demand for electric vehicles with lithium batteries, since the manufacture of these will reduce environmental pollution. The price of lithium in the last 10 years has increased sixfold in economic value, exports such as lithium carbonate, lithium chloride and lithium hydroxide have a high profitability and market quotations [5]y [6]. White gold, being treated as a strategic mineral for the energy transition, improves the availability of extraction and makes it possible for demand for this metal to multiply its value by 40 in approximately 20 years [7].

Given that the above highlights that all issues are financially important for companies in a given industry (mining), the simple fact that its use occupies 30% of the market makes this mineral have a very large investor attraction for its extraction. Consequently, it is considered the key element for new technologies.

The second relates to the discovery of Puno's white gold, which is considered one of the world's great reserves [8]. However, the project has problems that prevent viability for exploitation; among these, there is the presence of uranium together with lithium and the lack of a regulatory framework to regulate extraction [8], [9]. On the other hand, some observations were made public about the performance of the company promoting the project for non-compliance with environmental regulations in the development of activities, at the same time as the issuance of administrative resolutions that affect the mining rights granted within the field of the deposit [3], [10]. The problem is that lithium is associated with uranium and when extracting the second mineral is exposed, which is very delicate environmentally. Carrying out this activity with the two metals is very complex, because closing a uranium mine costs several million dollars and requires very high standards.

This article contributes in a descriptive and statistical way. First, in explaining the economic growth, technological advance and the inclusion of lithium in the market, in order to analyze the implications in Peru. Evidence is added and provided from market qualifications and studies that may be useful for predicting where the mineral is heading. As far as we know, we are not the first to examine the capacity of this mineral. However, we provide ideas on how better decision making can be leveraged; Thus, in that way the global context around lithium exploitation is pointed out.

Thus, this document is linked to examining the potential, impact and economic benefits in Peru, providing updated information on the extraction of white gold and its associate Uranium in Puno by the company Macusani Yellowcake and the lack of a regulation allowing its exploitation in Peru. Likewise, reviews of official sources were conducted, including that generated by public information published by the company Plateu Energy Metals, as the main interested party in the execution of this project.

RESULTS

Forecast And Evolution Of The Economic And Technological Study Of Lithium In Articles (Academic Sources)

Between 2015 and 2022 there has been exponential growth in the number of articles on lithium economics published in academic databases such as Google Scholar, Scopus, Taylor & Francis, IEEE Xplore, OnePetro and ScienceDirect. Google Scholar contains around 4,050 articles with "lithium economy," while Scopus has approximately 3,702 articles on this topic (Table 1). The Taylor & Francis base has 799 articles, IEEE Xplore 315, OnePetro 220 and ScienceDirect 2,379 relevant articles published in the last 7 years. Although the volume varies between disciplinary and multidisciplinary bases, they all show a clear growing trend in research on the economics of this commodity. This exponential increase in academic literature reflects global interest in a better understanding of supply, demand, prices, policies and technological impact related to lithium. Clearly, in a few years this material has become a highly relevant and studied economic topic across various fields (Figure 1).

Between 2015 and 2022 there has been a strong increase in research on lithium technology published in academic databases. Google Scholar and Scopus show sustained growth, from around 480 articles in 2015 to more than 2,000 in 2022 for the first, and from 380 to

Table 1. Publication of articles per year

Áreas Temáticas	F. de búsqueda	Cantidad de artículos por año							
		2015	2016	2017	2018	2019	2020	2021	2022
Economía del litio	Google Scholar	90	120	190	290	410	620	930	1400
	Scopus	97	137	204	354	488	641	802	979
	Taylor&Francis	32	41	53	71	94	122	167	219
	IEEE Xplore	8	11	19	26	37	53	72	89
	OnePetro	5	8	11	19	26	37	51	63
	ScienceDirect	89	124	163	212	284	372	497	638
Tecnología del litio	Google Scolar	480	580	720	890	1100	1400	1800	2200
	Scopus	380	450	580	720	890	1100	1400	1700
	Taylor&Francis	36	42	51	63	78	92	115	132
	IEEE Xplore	218	254	302	357	412	489	562	638
	OnePetro	0	0	0	0	0	0	0	0
	ScienceDirect	1210	1390	1630	1920	2280	2690	3130	3580

(Own Source)

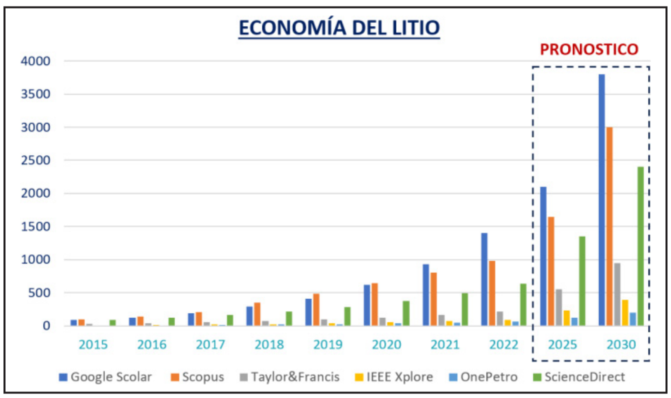

Figure 1. Forecast of the increase in published articles on the lithium economy (Own Source)

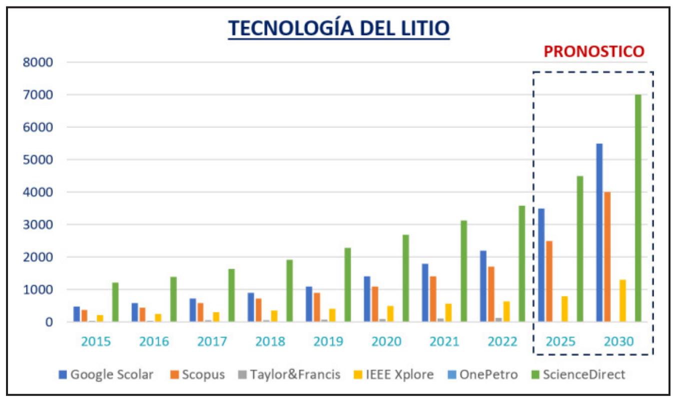

Figure 2. Forecast of the increase in published articles related to lithium technology (own source)

1,700 articles for the second. Although with smaller volumes, Taylor & Francis and IEEE Xplore exhibit similar upward trends over this period. The exception is OnePetro, a base specialized in oil and gas, where lithium technology has little relevance. On the other hand, in the multidisciplinary ScienceDirect there is a strong increase from 1,210 articles in 2015 to more than 3,500 in 2022 on this topic. The proliferation of research reflects innovation in lithium technological applications, such as batteries and electronics, driven by its growing demand. These databases provide quantitative metrics of the rapid advance of scientific and technological knowledge associated with this material in recent years (Figure 2).

The lithium economy has become a highly relevant and rapidly growing academic research topic in recent years. This is evidenced by the exponential proliferation of articles published on this subject since 2015 in major scientific databases.

It is projected that the number of publications on lithium economics and technology will continue to steadily increase over the next decade. Projections based on statistical models estimate between 5,000–6,000 articles in 2025 and 9,000–10,000 in 2030 on lithium economics. In lithium technology, between 11,500–14,500 articles are expected in 2025 and 17,000–23,000 in 2030.

General Formula of an Exponential Model (published articles)

$$y = a * b^2$$

Coefficient b:

$$b = \left(\frac{y_2}{y_1}\right)^{\frac{1}{x_2 - x_1}}$$

Forecast:

Table 2. Forecast of published articles between 2025 and 2030

Thematic Areas	Forecast of Quantity of Items		
	Search Source	**2025**	**2030**
Lithium economics	Google Scolar	2100	3800
	Scopus	1650	3000
	Taylor&Francis	550	950
	IEEE Xplore	230	390
	OnePetro	120	200
	ScienceDirect	1350	2400
Lithium technology	Google Scolar	3500	5500
	Scopus	2500	4000
	Taylor&Francis	—	—
	IEEE Xplore	800	1300
	OnePetro	—	—
	ScienceDirect	4500	7000

(Own source)

GLOBAL LITHIUM RESOURCE POTENTIAL

Latin America possesses almost 60% of global lithium, concentrated in Bolivia, Argentina and Chile. Demand has skyrocketed due to the electric vehicle boom, causing prices to rise 11 times in 2 years. This generates expectations in the region. However, extracting lithium is complex and requires investing in R&D to capture greater value from the battery chain, dominated by Asia. In addition, huge investments are needed to produce lithium carbonate. Currently, few countries manage to extract it profitably. Therefore, although lithium represents an opportunity, a caution and strategic actions are required to materialize its potential as an engine for development (Figure 3).

Potencial de Recursos de Litio en el Mundo Anuales (MRM)

According to studies by MRM (Multiple Regression Model), the table shows projections for 2025 and 2030. The model continued to fit reasonably well with an R^2 of 0.82 for the projections (Figure 4).

The results of the econometric model estimated to predict the lithium production percentage of countries

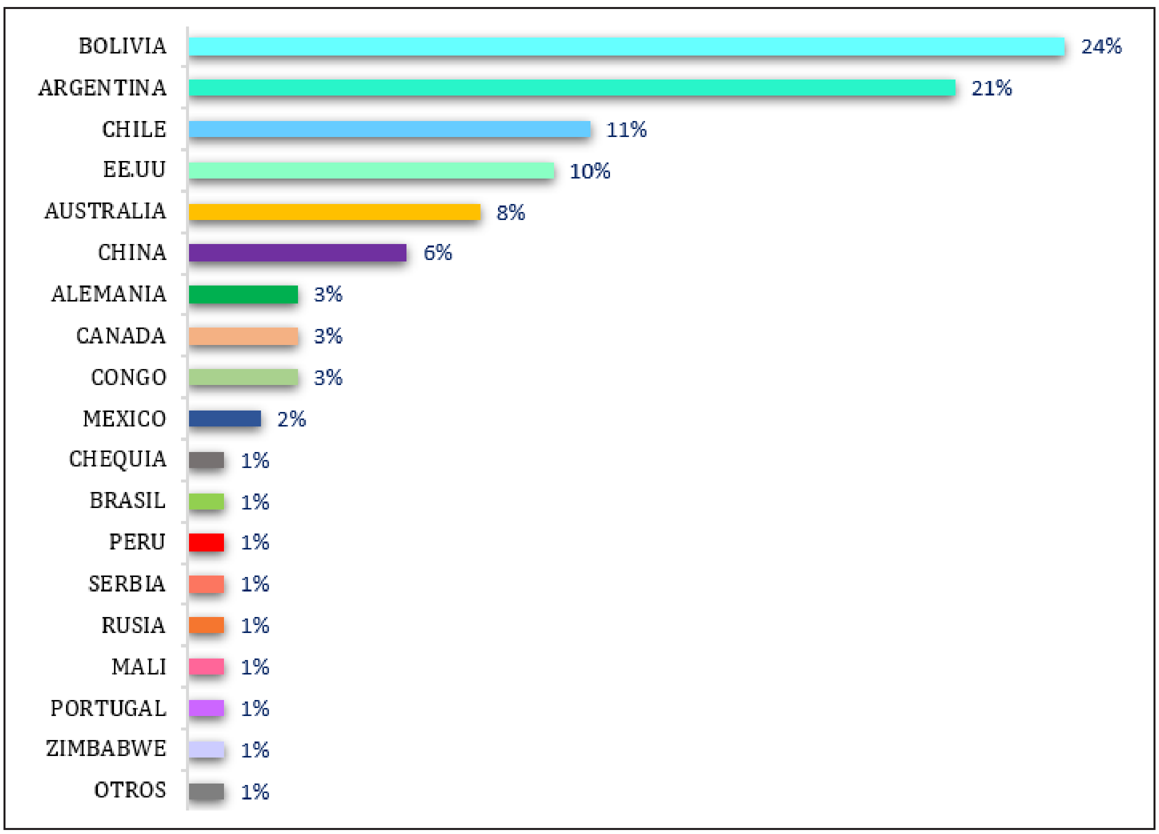

Figure 3. Percentage potential of lithium resources in the world [11]

Pais/Año	2019	2020	2021	2022	2023	2025	2030
Alemania	0.33	3.44	3.48	3.40	3.75	4.16	4.41
Argentina	27.09	23.36	24.87	23.91	23.44	22.16	21.51
Australia	14.10	8.66	8.25	9.19	9.26	10.06	11.31
Austria	0.14	0.07	0.06	0.08	0.07	0.06	-0.09
Bolivia	16.48	28.85	27.06	26.43	24.61	21.46	19.61
Brasil	0.33	0.55	0.61	0.59	0.86	0.96	0.91
Canada	3.66	2.34	3.74	3.65	3.40	3.66	3.81
Chequia	2.38	1.79	1.68	1.64	1.52	1.66	1.71
Chile	15.56	12.37	12.37	12.33	12.89	14.06	14.81
China	8.24	6.18	6.57	6.42	7.97	8.46	9.01
Congo	1.83	4.12	3.87	3.78	3.52	3.86	4.11
España	0.73	0.41	0.39	0.38	0.38	0.36	0.31
Finlandia	0.07	0.07	0.06	0.06	0.08	0.06	-0.09
Ghana	0	0	0.12	0.16	0.21	0.16	0.01
Kazajstán	0.07	0.07	0.06	0.06	0.06	0.06	-0.09
Mali	0.73	1.37	0.90	0.88	0.98	1.06	1.01
Mexico	3.11	2.34	2.19	2.14	1.99	2.16	2.21
Namibia	0.02	0.01	0.06	0.06	0.27	0.26	0.11
Peru	0.24	0.18	1.13	1.11	1.03	1.26	1.31
Portugal	0.24	0.34	0.35	0.34	0.32	0.26	0.21
Rusia	1.83	1.37	0	1.26	1.17	1.36	1.41
Serbia	1.83	1.37	1.55	1.51	1.41	1.56	1.61
Zimbabwe	0.99	0.74	0.64	0.63	0.81	0.86	0.81
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Figure 4. Annual global lithium resource potential (RMR) (own source)

show that: a $1 increase in the price of lithium is associated with a 0.15 percentage point increase in production (positive and statistically significant effect); a 1% increase in global demand for lithium batteries implies a 0.12 percentage point increase in production (positive and significant effect); an increase of $100 million in investments in lithium production capacity in a country is related to a 0.08 percentage point increase in that country's production (positive and significant effect); and a $100 increase in lithium extraction costs in a country entails an estimated 0.06 percentage point decrease in that country's production (negative and significant effect). The model has an adjusted R^2 of 0.79, indicating good explanatory power. Using assumptions about prices, demand, investments and costs, production percentage projections were made for 2025 and 2030.

According to the econometric analysis presented and considering other relevant factors, it is roughly projected that Peru would produce between 1–2% of global lithium in 2025, growing to 2–4% by 2030, consolidating itself as a relevant player in the global market for this strategic commodity.

Econometric Model

$$\text{Production} = \beta_0 + \beta_1 * \text{Prices} + \beta_2 * \text{Demand} + \beta_3 * \text{Investments} + \beta_4 * \text{Costs} + \varepsilon$$

Coefficient

$$\beta = X'X^{(-1)X'y}$$

Error coefficient:

$$\varepsilon = Y - X\beta$$

RMR model:

$$y = b_0 = b_1 * x_1 + b_2 * x_2 + \ldots + b_p * x_p$$

THE TECHNOLOGICAL IMPACT OF LITHIUM WITHIN THE GLOBAL MARKET

In the last 10 years, lithium demand has been growing, noting a 600% increase in the economy of this mineral as shown in Figure 5. Global lithium consumption of 93,000 tonnes in 2021 increased 33% over the 70,000 tonnes in 2020. This is largely due to the use of lithium in rechargeable lithium-ion batteries, particularly in electric vehicles, which will continue to grow long-term as the world strives to find less polluting alternatives to the use of fossil fuels. This largely explains the operational increase in the major producing countries such as Australia, China and the lithium triangle (Argentina, Chile and Bolivia), and great expectations exist for Peru's integration into this) shown in Table 3; we expect that by 2030 it will represent 80%

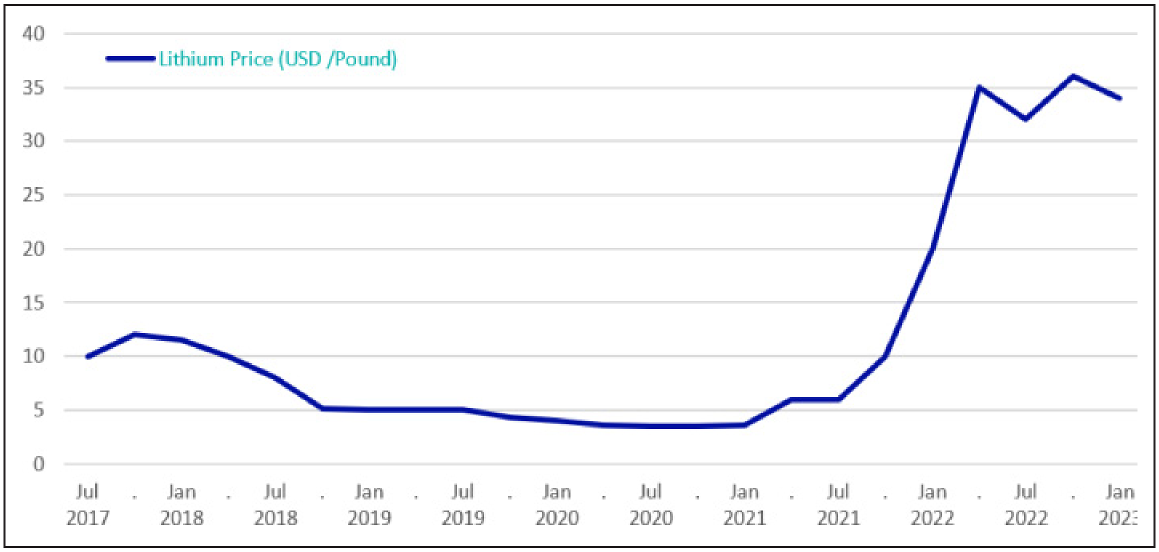

Figure 5. Economic growth of lithium in the last 10 years [5]

Table 3. Annual lithium production

Years/Countries	China (ton)	Australia (ton)	Chile (ton)	Argentina (ton)
2018	7,100	58,800	17,000	6,400
2019	10,800	45,000	19,300	6,300
2020	14,000	40,000	18,000	6,200
2021	14,000	55,300	28,300	5,970
2022	19,000	61,000	39,000	6,200

[6]

growth in the lithium industry (20% per year Figure 6). As we will see below, the batteries of electric cars are overwhelmingly the main demanders, a situation that arose due to the continuous search for less polluting transport alternatives. Consequently, any discussion generated by lithium demand is supported by the boom it has had worldwide in recent years.

The consumption of lithium by chemical compounds is now the most widely used product in the industry, with an increase of around 71% and lithium hydroxide with a decrease of 24%. Similarly, both hydroxides and carbonates can be classified into industrial grades and battery grades according to the purity of their constituents. For carbonates, ndustrial grade generally requires 99.0% purity, while ttery grade requires at least 99.5% purity. As can be seen in Figure 7, battery quality is generally desirable.

Batteries are expected to account for 95% of white gold demand by 2030, with only 1% of battery consumption related to other lithium uses in industry, as shown in Figure 8. Figure 9 shows the base scenario and the electric vehicle scenario. [12] stated that lithium demand will grow by around 500,000 tonnes of lithium carbonate

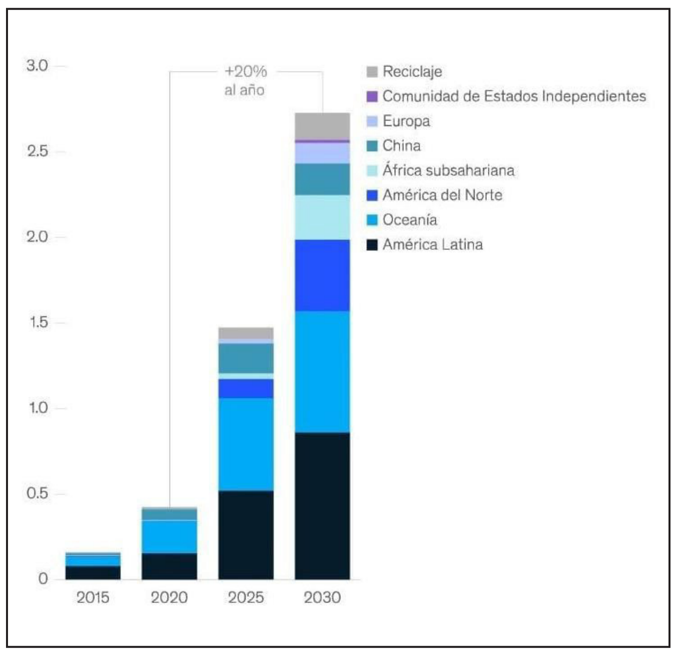

Figure 6. Lithium production by source, estimated supply for 2025 to 2030 [12]

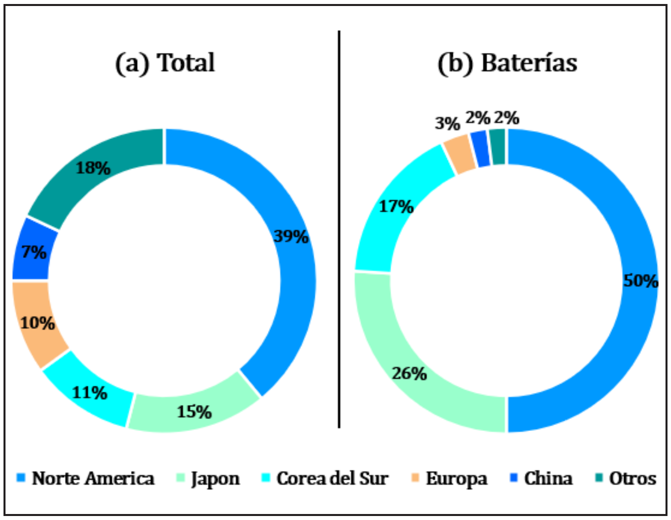

Figure 7. Aggregated lithium consumption (a) and for batteries (b) in 2019 [13]

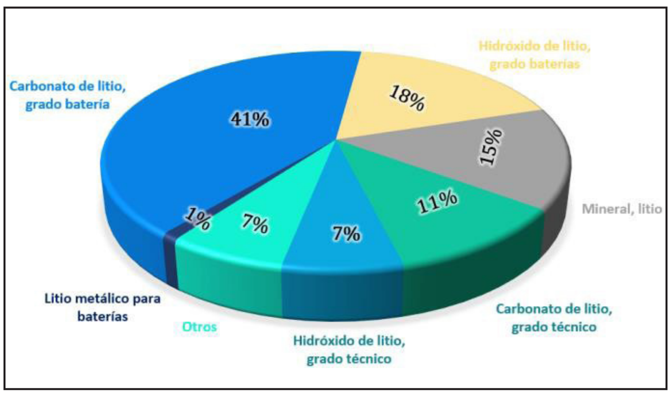

Figure 8. Global lithium consumption by product 2019 [14]

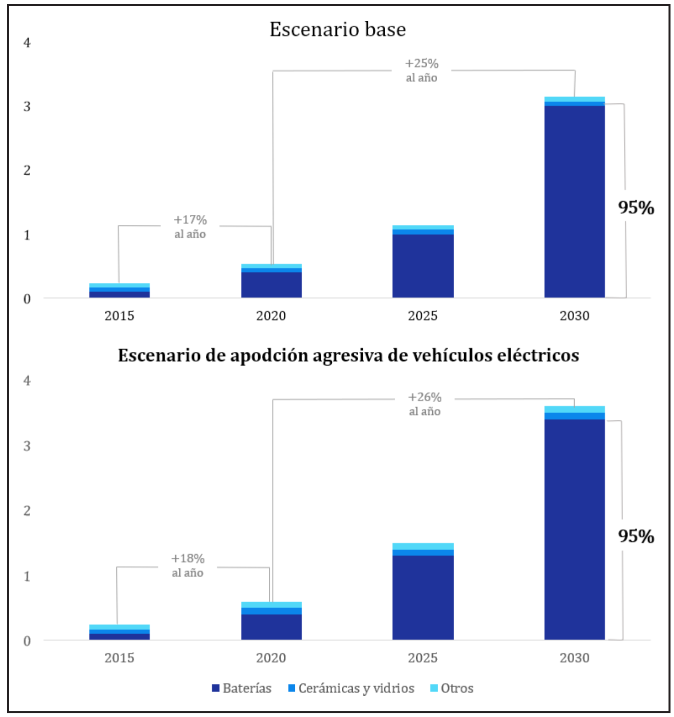

Figure 9. Lithium demand by end use, million metric tonnes [15]

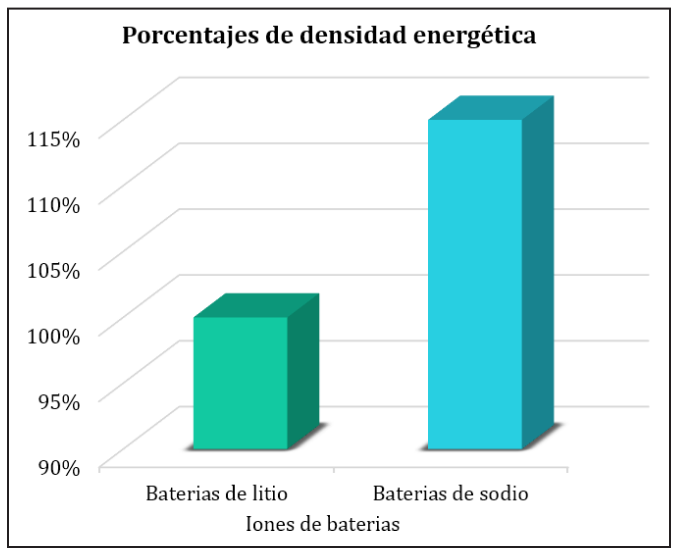

Figure 10. Percentage of energy density in lithium and sodium batteries (petrovite) [18]

(2021–2030), which the industry believes will be enough to meet the battery demand shown in Figure 9.

The discovery of Petrovite should not be overlooked, as[16] mentions the properties of this mineral in research conducted in Russia suggest using the sodium from this valuable mineral, indicating that this mineral will replace lithium in battery manufacturing in the not-too-distant future. Sodium ions offer 15% more energy density as seen in Figure 10 in batteries it is proposed that they will soon be used in electric vehicles (sodium ions will be mass produced from this year according to [17]). In addition, Natron's sodium ion batteries do not experience thermal leaks, making them safe for transportation and disposal without risk of fire; that said, the mineral discovered on December 28, 2020 is currently being applied in batteries by the aforementioned companies showing great effectiveness.

Lithium demand projection in electric cars. As mentioned above, the main source of lithium demand in recent years comes from the transportation sector, especially in relation to the demand for light electric vehicles. This trend is expected to continue gradually as internal combustion engine vehicles begin to be gradually replaced by less polluting alternatives. In this context, any lithium demand forecast will depend first on the growth prospects of the electric vehicle industry. In summary, the lithium demand forecast

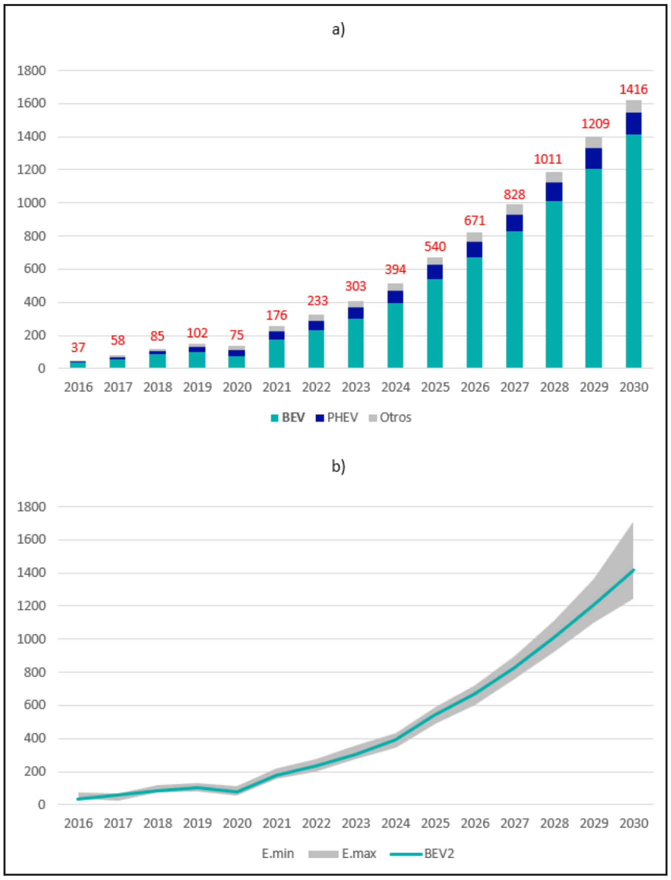

Figure 11. Lithium demand by electric vehicles (a) and demand with maximum and minimum expected scenarios (b) [13]

for electric vehicles according to Gonzales is observed in Figure 11.

THE DISCOVERY OF LITHIUM IN PUNO

[1] Plateau Energy Metals held a press conference where, according to one of the executives present, claimed to have discovered a "lithium lake" in the Puno region. According to Ulises Solís, general manager of Macusani Yellocake, the incredible discovery of lithium in Falchani contains an average of 3,500 ppm of the metal, seven times more than the richest salars in Chile and Argentina. [10]] the General Manager of Macusani Yellowcake has reported that the resources discovered in the exploration work amount to 4.7 million tons of lithium. This amount places Falchani as the sixth largest project of its kind in the world as seen in Figure 12.

Likewise, preparations had begun for an environmental impact study that was to be completed in August of this year. Mine construction took place in 2021, paving the way for mining in 2022. The goal is to reach 100,000 tons and consolidate ourselves as the world's leading producer. According to Benchmark Minerals Intelligence (BMI), it will generate solid financial returns and will be in the second lowest quarter of operating costs. In addition, according to the available resource information, the project is valued at $1.55 billion, with an internal rate of return of 19.7% and a payback period of 4.7 years. An average annual production of around 63,000 tons will also be seen, with a mine life of 33 years. Table 4 shows the production phase.

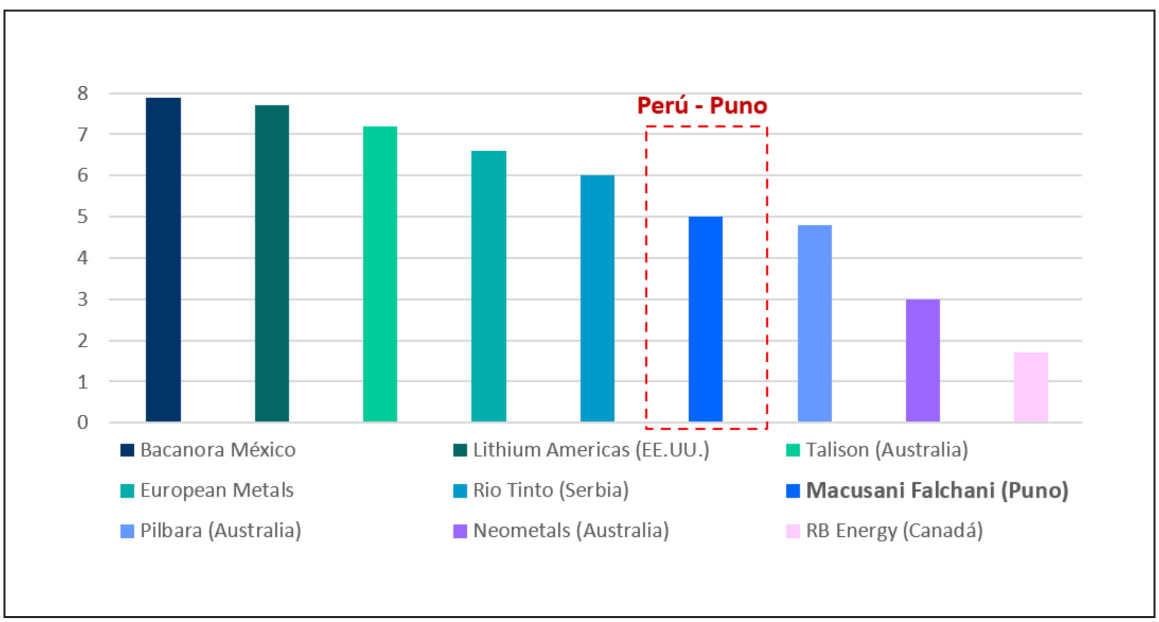

Figure 12. Largest hard rock lithium projects in the world (mineral resources in million tonnes) [19]

Table 4. Lithium production phase in Puno

Phases	Years	Approximations (tons per year)
1	1–7	22,000
2	8–12	45,000
3	13–33	85,000

[1]

Currently the exploitation of lithium and uranium is being reviewed again by MINEM. The fundraising challenge is to create a clear regulatory framework. As part of the development of the annual PDAC 2022 exploration and mining conference, the possibility of developing lithium and uranium in the country was discussed again. This time, the possibility of developing this activity was left open by the Ministry of Energy and Mines (MINEM) itself. So, with that in mind, Minister Herrera indicated that from her portfolio she will promote clear regulations regarding the exploitation of lithium and uranium; especially for the first, which is currently a key element for the production of batteries for electric cars; therefore, its high demand in the world. "We must be clear that the mantles at the Latin American level, particularly lithium, are being worked in a unified way for their extraction with the corresponding standards," said the minister.

Regulatory framework. It is necessary for the government to approve a specific regulation for lithium, which completes and improves the current General Mining Law. If a better regulatory framework is approved, it would attract greater national and foreign investment for the exploration and exploitation of lithium. This would generate employment and royalties. Peru could become an important producer and exporter of lithium. It would benefit from the growing global demand for this strategic mineral for batteries and technology. However, it is key that lithium exploitation is done in a sustainable manner, with environmental protection, prior consultation with communities, and promoting productive linkages.

The challenge will be to achieve a balance between economic, social and environmental aspects. Proper regulation would help achieve this goal.

The lithium boom in South America has brought with it increases in socio-environmental conflicts. Chile has seen an increase of 15–20% according to NGOs, with demands for access to water, compensation and oversight. It is estimated that Argentina started with low mining social conflict (5%) which with the incipient development of lithium mining would have registered a moderate 10% increase, currently reaching 15%. Bolivia does not yet commercially exploit lithium, but a potential increase of 25–30% is estimated due to its fragile social balances. Australia, with established mining, has only seen a marginal 5% increase. China, as an importer, sees more pollution from processing than social conflicts. Chile and Bolivia are the most prone to significant increases in social problems due to lithium, needing proactive management. The average increase is estimated at 15–20%.%.

Figure 13. Social conflicts in Perú, Argentina, Chile and Bolivia (Own source)

Peru is at an early stage, with currently low social tensions of 5–10%, but with projections of a 15–25% increase with large-scale exploitation, which could be mitigated with good social management practices.

DISCUSSION

The Technological Impact on the Lithium Economy Within the Global Market

In the results of this work, the growth that coincides with the research carried out by [20], [21], could be seen, a sales percentage of 33% of electric vehicles, but, it has a variation in the results of the cited authors; in which adds in his research that sales of electric vehicles went from 450 thousand to 2.1 million (2015 to 2019), represented as a percentage would be 28% of global vehicle sales and Melisa indicates that the percentage in those same years is 30 %.

The onages produced by the countries mentioned in the results of Table 1 coincide with the tons of production in metric tons with the publication made by [22] and [23]. But they have a variation with respect to the countries Australia (55,000), Chile (26,000) and Argentina (6,200). And the last author mentioned varies with the production of China (14,000).

The Discovery of Puno's White Gold

Different sources indicates that it is not possible to exploit uranium and lithium, because they are found together, there is a long and complicated road ahead, although there are laws for this type of operation in Peru. But, according to the scope of the results of Macusani Yellowcake, he mentions that there is a distance of about 30 kilometers between the lithium mineralized areas (Falchani) and uranium (Macusani). Whose drilling in Macursani was positive and generated further exploration and lithium deposits increased from 2.5 to 4.7 million tons.

[24] Estimates an investment of $2,089 million in lithium in Puno, of which $587 million correspond to the first phase (initial capex) indicated in Table 2. The information in this paper on the resources available by Benchmark Minerals Intelligence (BMI), the project is valued at $1.55 billion, with an internal rate of return of 19.7% and a payback period of 4.7 years. According to [25],], it indicates that lithium resources are 4.5 million tons, in the results obtained in the article the General Manager of Macusani Yellowcake reports that the resources discovered in the exploration work amount to 4.7 million tons of lithium, which coincides with that mentioned by [21] although it adds the amount of uranium production being 124 million pounds. According to [26] reported in a publication that the Chilean Blanco Project will annually produce 20,000 tons of very good grade lithium carbonate, with a useful life of 20 years, the initial investment in said project is US$ 2,100 million.

[27] Indicates that although Law 31283 exists (The law that declares the research, extraction and industrialization of lithium and its derivatives to be of public necessity, national interest and strategic resource), dated July 15, 2021, there are no regulations for said standard; but, according to the results shown in this article, Minister Herrera on June 14, 2022 indicates that work is already underway on clear regulations regarding the exploitation of lithium and uranium, which coincides with [28] which adds that the regulatory framework will guarantee its use. In Chile, according to the Latin American Observatory of Environmental Conflicts [29], the regulatory framework is organized by the regulatory companies.

CONCLUSIONS

Lithium has become a key strategic resource for technological development and the global energy transition. Through an econometric model it was estimated that its demand will grow steadily driven by sectors such as electric vehicles and electronics. It is projected that by 2030 Chile will provide 21% of global lithium, Argentina 19% and Australia 14%, while Peru emerges as a new player with 3% of the market (1.50% for 2025); and, according to studies conducted by Multiple Regression Model) position Peru with 2025 – 1.26% and 2030 – 1.31% globally.

Academic research on lithium also exhibits rapid exponential growth. Between 9,000–10,000 articles on lithium economics are forecasted in 2030, and 17,000–23,000 on its technology. This reflects global innovation and interest in this mineral.

Peru has important lithium reserves, estimated at 4.7 million tons in Puno, positioning itself as the sixth largest project in the world. Its exploitation requires adequate regulation that balances economic, social and environmental aspects. It is estimated that lithium mining would increase socio-environmental conflicts by 15–25%, a manageable level with good practices.

The article comprehensively analyzes the global lithium context and incorporates projections with econometric, multiple and simple regression models on its demand, production and prices to 2025 – 2030. It also presents updated statistics on reserves in Puno and describes the challenges for its exploitation in Peru. Lithium represents an opportunity for economic diversification with a sustainable approach, but institutional capabilities and prior consultation are needed to ensure responsible use. The country has enormous potential to become a relevant player in the mining of this strategic resource.

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Thermal Runaway Pressures as a Function of Free Space in Sealed Containers for Lithium Titanate Cells

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ABSTRACT

Electric vehicles powered by lithium-ion (Li-ion) batteries are being developed by mining vehicle manufacturers as a replacement for diesel-powered vehicles. Explosion-proof (XP) enclosures are frequently employed to enclose electrical ignition sources in gaseous underground mines to prevent the spread of an internal methane-air explosion to a nearby explosive atmosphere. Due to thermal runaway (TR), Li-ion batteries have the potential to cause pressurized explosions in an enclosed structure. Past research has shown the potential for well-confined Li-ion cell TR to drive pressures beyond the conventional pressure specification for XP enclosures. Researchers at the National Institute for Occupational Safety and Health (NIOSH) used an Accelerating Rate Calorimeter (ARC) to induce thermal runaway of Lithium Titanate or Lithium Titanium Oxide (LTO) type 18650 cells enclosed within containers with various volumes and found an inverse power relationship between the TR pressure and available free space. The results were similar in magnitude to that of lithium iron phosphate (LFP) cells, which were used in prior testing. Temperatures, gas amounts, and TR pressure-rise rates were also recorded. The data indicate that with enough free space, the pressures can be lowered below the conventional pressure specification for XP enclosures.

INTRODUCTION

It has been known that the use of diesel-powered equipment results in generating diesel particulate matter (DPM) which is a known carcinogen [1]. Past NIOSH research has shown that underground mineworkers are at particular risk of DPM exposure [2]. Mine operators can attempt to mitigate this risk by providing enough ventilation to dilute the DPM below safe limits. The hierarchy of controls dictates the elimination of the DPM source as the best way to control the risk. For this reason, among others, mine vehicle manufacturers are developing battery electric vehicle (BEV) versions of their current equipment. Due to their high energy density, lithium-ion batteries (LIB) are one of the most common choices for manufacturers of BEVs when they transition away from diesel-powered vehicles [3]. Due to the high energy demands in mining, BEVs utilize a vast number of individual battery cells wired in series and parallel to achieve the necessary voltage and current requirements, normally in the range of hundreds of kilowatt-hours of capacity.

In the consumer sector, there have been several accidents involving a Li-ion battery in everything from small portable devices to large commuter transports to entire cargo ships [4–6]. Events of LIB failures in mines have also occurred [7 & 8]. Accidents of lithium-ion battery TR in mines will become more prominent and more ubiquitous