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# GREEN EXTRACTIVISM IN LITHIUM TRIANGLE

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The aim of this paper is to investigate the relationship between lithium mining and the environmental-social aspects of mining in the countries of the lithium triangle by analysing scientific research works and available statistical data, and applying economic theory to green extractivism. We investigate whether the countries of the lithium triangle meet the criteria of the theory of green extractivism. In the context of the theory of green extractivism, we include Bolivian and Argentine regions as sacrifice zones while Chile is relatively successfully building renewable energy sources. In all three countries, we detected the socio-environmental impacts of lithium mining, the most serious problem being the right to water and the threat to the poorest regions.

Key words: lithium, Argentina, Bolivia, Chile, environment, social inequalities
JEL: D63, L72, N56

## 1 INTRODUCTION

Lithium is the lightest known metal, which was discovered by the Swedish scientist Johan August Arfwedson at the beginning of the 19th century, but it was not possible to completely isolate it. It was already named lithium by its discoverer, which means stone in Greek (CAEM, 2023). The new metal was completely isolated a few years later, in 1821 it was isolated by scientists Brande and Davy (Reddy et al., 2020). This led to the belief in commercial lithium metal in Germany at the beginning of the 20th century, which was gradually produced in various industries (glass production, ceramics, metallurgy, chemical industry, medicine). A century later, continued research revealed electrochemical properties that could serve as lithium batteries. The 1950s are considered the beginning of lithium-ion battery research (Reddy et al., 2020). From the 1950s to the 1980s, the USA and Zimbabwe began to dominate lithium production (Bos and Forget, 2021). Today, lithium-ion batteries are part of electrical equipment (mobile phones, tablets, etc.), but their importance is also growing in connection with the transition to

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a low-carbon economy and the concept of electromobility. According to a World Bank report, lithium production is expected to increase by 500% by 2050 precisely in connection with the production of clean energy technologies (World Bank, 2020).

On the other hand, lithium extraction brings certain environmental and social risks to the countries where it is mined. The question arises whether, in order to save the planet, it is right to sacrifice certain fragile regions (Ahmad, 2020), which are threatened by lithium mining. Although lithium extraction in the lithium triangle, which is the subject of our research, does not have such serious environmental impacts as in other countries, certain changes can already be observed today. Water resources are most at risk, air pollution and disruption of ecosystems and biodiversity may occur. Last but not least, mining directly affects the life of local communities and comes into conflict with them.

When researching lithium production capacity, a distinction must be made between lithium as metal and lithium carbonate equivalent (LCE). It is true that 5.3 times more LCE can be produced from lithium metal. In addition to LCE, i.e. Li2CO3, lithium can also be produced from lithium hydroxide (LiOH) and lithium oxide (Li2O) (European Metal Holdings, 2015).

The countries of the lithium triangle are located at the beginning of the global supply chain. A traditional global network consisting of lithium-mining countries (so-called hubs, Latin America and Australasia), producers of lithium derivatives (East Asia, South America and North America), manufacturers of electric batteries, electric smart devices and electric cars (East Asia, in the USA and in EU) (Bos and Forget, 2021), consumers of these products (Global North and China) and battery recycling (China, South Korea, USA) (Statista, 2023a). In this context, we are talking about the so-called lithium geopolitics (Galbo, 2023).

When researching the potential of lithium production, in addition to geographical and geological characteristics, political, social and environmental aspects must also be considered. In each country, the mining of mineral raw materials is legislated differently. The position of key stakeholders, public and private companies, governments and their mandated agencies, changes depending on the set rules.

When examining the potential of countries to produce lithium (or any mineral), it is necessary to distinguish between the capacity of resources and reserves. The term resources refers to all estimated amounts of mineral that can be extracted in the present and the future (if the appropriate conditions are met: price, technology). By reserves, we mean the amount of mineral that can be proven to be extracted at present with the help of available technology and at current prices.

In the paper, we work with the theory of green extractivism, which is defined as extractivism (extraction, use of natural resources) based on the same principles as classical extractivism, but at the same time, emphasis is placed on obtaining such resources that should contribute to a sustainable, emission-neutral economy in order to prevent climate changes, or mitigate them. For some commodities, doubts arise from the point of view of environmental and social approach. The aim of this paper is to investigate the relationship between lithium mining and the environmental-social aspects of mining in the countries of the lithium triangle by analyzing scientific research works and available statistical data, and applying economic theory to green extractivism. We investigate whether the countries of the lithium triangle meet the criteria of the theory of green extractivism. We are aware of the scope of the problem and the significant limitations of the research, we focus on assessing the situation through available information published in the databases of professional journals as well as online reports of journals and agencies and from the census. Information from the census is also considerably limited due to the survey intervals (2010 for Argentina in some parameters and 2012 for Bolivia). At the same time, we describe in detail the lithium industry in the studied countries.

The relationship between lithium mining and socio-environmental impact has received little attention in scientific research. In the Scopus database, we detected 49 articles on Argentina, 29 on Bolivia and 70 on Chile and the impacts of lithium mining. Above all, this and the definition of green extractivism in the lithium triangle are addressed by authors from South America. Most of the information is available in online journals and agencies (Reuters, The Guardian, La Nación, Mongabay, Opinión etc.), we also drew information from the official websites of government agencies. In general, we based ourselves on as many contributions as possible, but we took into account their relevance and the possibility of verifying information in official and professional sources. In fact, there are several times more reports, especially about the impacts of lithium mining on local communities and the environment, but evaluating their relevance is complicated.

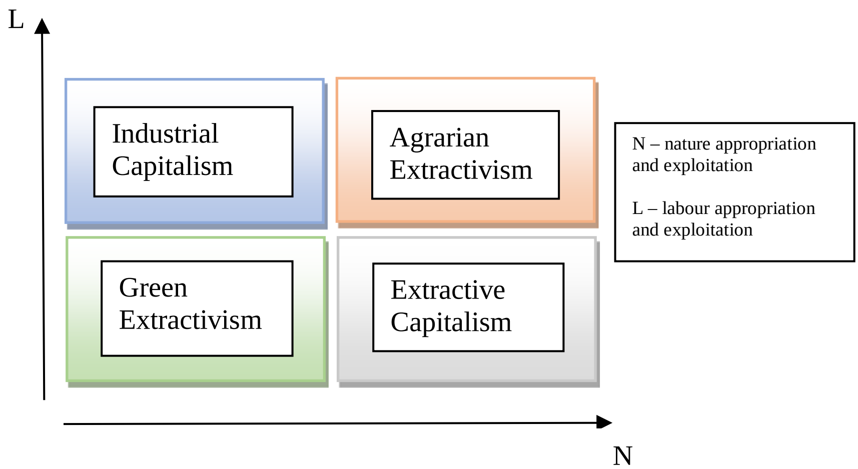
## 2 GREEN EXTRACTIVISM

Green extractivism (mining, use of natural resources) is based on the same principles as classical extractivism, which dates back to the 15th century in the context of Latin America. At the same time, emphasis is placed on acquiring such resources that should contribute to a sustainable, emission-neutral economy with the aim of preventing climate change, or mitigate them. However, the way in which the resources are obtained and also where they are obtained can be controversial. According to Bruno (2022), "it focuses not only on labor exploitation, but also on the appropriation of nature". Petras and Veltmeyer (2014) define extractivism as *"the appropriation of large volumes of natural resources" in order to "export raw materials to global markets"*. Acosta (2013) considers green extractivism as a *"mode of accumulation"* based on the removal of natural resources for export, Gudynas (2021) defines it as *"various ways of organizing the appropriation of natural resources (such as matter, energy or ecological processes) to serve human purposes in their social and environmental context"*.

According to several experts (Tornel, 2023), the differences between the global North and South are deepening. Some talk about the exploitation of the global south, which has not actually ended, and doubt the "greenness" of renewable resources, while *"greening"* creates the impression of fairer results, thus creating new frontiers of mining (Tornel, 2023). According to Batel (2022), *"the acceptance of so-called "renewables" tends to ignore and render invisible the extraction, labor and fossil energy required to build, install, operate and dismantle this infrastructure".*

Green extractivism can also be understood as a concept that justifies the destruction of the environment and social structures in order to achieve sustainable development. Isla (2021) talks about the so-called sacrifice zones. Green extractivism is structural, i.e. systematic, intensive and continuous (Tornel, 2023). The greening of total extractivism can be understood as the highest form of total extractivism. Bruna (2022) distinguishes several forms of total extractivism: mining, energy and agrarian extractivism. The following figure illustrates the individual concepts of extractivism in relation to nature and labor.

Fig. 1: Variation of extractivism and its relation with nature




Source: own processing according to Bruna, 2023.

Each form requires a different degree of involvement of human labor (L) and appropriation of the environment (N): the classic form, extractive capitalism, uses a high degree of N and a low degree of L, industrial capitalism a high degree of L and a low degree of N, agrarian extractivism requires a high rate of both N and L, and on the contrary green extractivism a low rate of both quantities. Extractive capitalism was typical especially at the time of the colonization of the world for colonized economies (the extraction of minerals and their subsequent export to the economy of the colonizer), an example of industrial capitalism is the period of the industrial revolution in England in the 18th century, we historically consider colonized economies in the 17th and 18th centuries after the depletion of minerals to be agrarian extractivism, but we also know the forms of contemporary agrarian extractivism, e.g. soybean cultivation in Argentina (also called as soyization of the economy). Green extractivism is relatively least demanding on production factors N and L, therefore we understand it as the highest form of total extractivism.

Dorn et al. (2022) speak of green extractivism as a smooth continuation of neo-extractivism, which followed the wave of neoliberalism in Latin America. He assesses the situation as urgent in the context of social and environmental inequalities that arise primarily in the global south. He recommends further research into the relationship between man, technology and the environment.

## 3 Lithium triangle in the world economy

The three countries (Argentina, Bolivia and Chile) with the largest lithium resources in South America form the so-called lithium triangle (Fig. 2). According to the U.S. Geological Survey (USGS), identified lithium resources worldwide are distributed as follows: Bolivia, 21 million tons; Argentina, 20 million tons; United States, 12 million tons; Chile, 11 million tons; Australia, 7.9 million tons; China, 6.8 million tons; Germany, 3.2 million tons; Congo (Kinshasa), 3 million tons; Canada, 2.9 million tons; Mexico, 1.7 million tons; Czechia, 1.3 million tons; Serbia, 1.2 million tons; Russia, 1 million tons; Peru, 880,000 tons; Mali, 840,000 tons; Brazil, 730,000 tons; Zimbabwe, 690,000 tons; Spain, 320,000 tons; Portugal, 270,000 tons; Namibia, 230,000 tons; Ghana, 180,000 tons; Finland, 68,000 tons; Austria, 60,000 tons; and Kazakhstan, 50,000 tons. In total, the identified lithium resources amount to about 98 million tons (USGS, 2023), of which the countries of the lithium triangle own at least more than half, according to Ministerio de Desarrollo Productivo de Argentina (2022) even up to 65%.

The largest lithium reserves in the world are located in Chile, 9.3 million tons; Australia, 6.2 million tons; Argentina, 2.7 million tons; China, 2 million tons; United States, 1 million ton; Canada, 930,000 tons; Zimbabwe, 310,000 tons; and Brazil, 250,000 tons (Statista, 2023b).

The sources of lithium that are found in the lithium triangle are in the form of brines. In addition, lithium occurs in nature in other forms: hard-rock reserves, and sediment-hosted deposits (clays), lithium from the oil-fields, geothermal brines, and lithium zeolites. The world's largest sources of lithium (approximately 58% of all sources) are in brines on the salt flats. The largest of them is *Salar de Uyuni*, in the province of *Potosí* in the southwest of Bolivia. Other important brine sources include the *Salar de Atacama* and the *Salar de Maricunga* in *Antofagasta* and *Atacama* provinces in northern Chile, the *Salar del Hombre Muerto in Catamarca* province in northern

Argentina, the *Salar de Olaroz* in *Jujuy* province in northwest Argentina; and the *Coipasa* salt flats in western Bolivia.

Fig. 2: Map of lithium triangle


Source: The Economist, 2017.

Hard rock lithium resources are found in Australia, zinwaldite resources in Germany and the Czech Republic, and clay resources in the USA, Mexico, Peru and Serbia. Deposit exploration is underway in most countries, therefore, they contribute only to a small extent to global production.The most important producers of lithium (Australia, Chile, China and Argentina) today ensure the majority of global production (Statista, 2023c).

The countries of the lithium triangle currently have a comparative advantage in lithium production, namely low operating costs (Yang et al., 2021) and the extraction of lithium from brines represents a smaller environmental burden. Similar to oil, there is also talk about the creation of a cartel (so-called OPPROLI) in the case of lithium, which would strengthen the countries of the lithium triangle on the global market.

### 3.1 Argentina

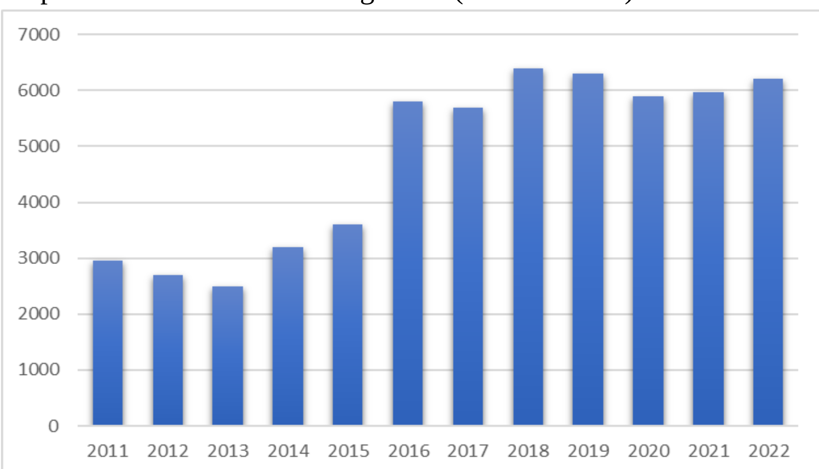
It is estimated that Argentina's lithium resources represent 20% of the world's reserves. The largest reserves are located in the north and northeast of the country: in the

*Salar del Hombre Muerto*, the *Salar de Olaroz*, the *Salar de Ratones*, the *Salar de Centenario*; and the *Salar de Pozuelos* (Desaulty 2023, p. 3) in the provinces of *Jujuy*, *Salta* and *Catamarca*. The resources in Argentina are in the brines as well as in Chile and Bolivia. However, the nature of lithium resources also differs between them: for example, when compared to Chile, the concentration of lithium in Argentine brines is lower and rains occur more often in the territory (Vásquez, 2023). The rain factor is essential in mining, because during the rainy season the solar plains will be flooded, and mining is not possible.

Currently, Argentina is the fourth largest producer of lithium in the world (Statista, 2023d). Lithium production in Argentina in 2022 was 6,200 metric tons. The highest production of lithium was recorded in 2018, when mining reached its peak. In recent years, we have recorded a stable level of lithium production (Figure 3). According to data from CAEM (Argentine Chamber of Mining Entrepreneurs), 40,000 tons of LCE are mined in Argentina.

Argentina exported lithium carbonates worth $ 247 million in 2021, becoming the second largest exporter of this commodity in the world. The largest target markets include China, the USA, Japan, South Korea and France. The fastest growing export markets between 2020 and 2021 were China ($91.1 million), South Korea ($13 million) and Japan ($12.7 million). Lithium carbonates were Argentina's 36th most exported product (OEC, 2023), meaning lithium is not one of the country's most important exports.

Fig 3: Mine production of lithium in Argentina (in metric tons)




Source: own processing according to Statista, 2023d.

In 2022, Argentina's lithium exports grew by 235% compared to the previous year. Over the last year, the share of lithium exports in the total export of minerals in Argentina has also increased, from 6.42% in 2021 to 18% in 2022 (*Dirección de Transparencia e Información Minera*, 2023).

Currently, there are three active lithium mining mines on the territory of Argentina:

- In the *Salar de Olaraz, Jujuy* – the mine is operated by *Sales de Jujuy*, a subsidiary of Allkem based in Australia;
- In the *Salar de Hombre Muerto, Catamarca* – the mine is operated by Livent, based in the USA;
- the *Cauchari* and *Olaroz* Salars, *Jujuy* – the mine is operated by Exar, Lithium Americas and China's Ganfeng Lithium, they only started mining in June 2023 (Lithium Americas, 2023).

It is these provinces together with the national government that form the so-called la mesa del litio (the lithium table), which negotiates the lithium business, agreed that companies in the lithium mining sector would set aside a percentage of their production for industrialization in Argentina (EconoJournal, 2023).

There are up to 38 lithium mining projects in progress in Argentina (Jones, 2023), according to Dorn et al. (2022), the number of projects even varies between 40 and 60. The amount of investment in the mining and processing of lithium since 2020 has reached a value of over $ 4 million, which ranks lithium in 2nd place after copper in the amount of investment to natural resources. In Argenina operate the other foreign companies such as Argentinian Minera Exar and YPF, Argentinian branch of French Eramet – Eramine, South Korean Posco, Chinese Ganfeng Lithium, Gotion High Tech, and Zijin Mining Group, Anglo-Australian Río Tinto, Río Tinto – Rincon Ltd., American-Canadian Lithium Americas – Millennial Lithium, Canadian-Russian Alpha Lithium – Uranium One (Vásquez, 2023; Dorn et al., 2022).

Foreign companies are primarily interested in mining and refining lithium for export, but Gotion High Tech, for example, plans to build capacities for the production of electric batteries. According to the memorandum of understanding between Gotion High-tech and JEMSE (the private-public company *Jujuy* Energy and Mining State Society), they will jointly build a lithium carbonate battery refinery in the free trade zone of *Jujuy* province. JEMSE has committed *"to grant exploration and production rights for potential lithium mineral resources with an exploration area of approximately 17,000 hectares to secure resource supply. The two companies will also carry out follow-up business cooperation in the lithium battery industry, including cathode materials and battery manufacturing, and jointly penetrate the European and American markets"* (Gotion, 2022).

Lithium mining itself brings many challenges, but mining technology is constantly advancing. An example is the company Eramine, which, together with China's Tsingshan, is developing a project in the Salar Centenario Ratones in the province of Salta, developing a process that promises higher speed, higher yields and lower water consumption compared to traditional evaporation ponds (Vásquez, 2023). Some companies are also involved in building solar energy capacities. JEMSE, financed by China's Exim Bank, contracted with Chinese firms PowerChina and Shanghai Electric Power Construction to build approximately 1.18 million solar panels. It is the largest solar park in South America, JEMSE also participated in building the so-called solar villages (Dorn et al., 2022).

Despite the fact that the Argentine economy has long been one of the more regulated, Argentina has taken a liberal approach to developing its lithium industry. In general, the mining energy is considered one of the key areas of the Argentine economy. Foreign investments are welcome, Argentine legislation allows 100% foreign ownership to a single shareholder (Doussoulin and Mougenot, 2022). Argentina can be described as the most liberal in the entire lithium triangle in the granting of concessions for lithium mining. The Argentine government receives revenue from lithium mining through a 3% mining fee (Marmolejo Cervantes, Garduño-Rivera, 2022).

Since the 1990s, the Argentine economy has been liberalized under the auspices of the International Monetary Fund and the so-called Washington Consensus. The national mining policy approved during the Menem administration was also maintained by subsequent governments. The government has managed to attract a lot of investment in the mining industry. Many laws and regulations from the 1990s are still valid today. The steps of successive governments led to various economic problems and even bankruptcies. However, the lithium sector is immune to crises (Vásquez, 2023). The expansion of the mining industry continued until 2004, when Argentina was the ninth most attractive destination for mining investment (Dorn et al., 2022). The development of mining (and agriculture) continued even during the administration of Néstor Kirchner (2003-2007) and Cristina Kirchner (2007-2015), despite the higher degree of regulation of the Argentine economy. The Mauricio Macri administration (2015-2019) brought an even more favorable environment for investments. We call this period the period of neo-extractivism in Argentina. Argentina remains an economy strongly oriented to the development of the mining and agricultural sectors even during the period of the current president Alberto Fernández, who continues the policies of President C. Kirchner. At the same time, the leadership of Argentina refers to the connection of mining with the so-called green and bioeconomy (Dorn et al., 2022). As for the attitude towards the mining industry, specifically lithium, it seems to be consistent across the political spectrum.

It should be clarified that within the framework of Argentine legislation, decision-making on lithium mining is in the hands of the provinces. The decentralization of the rules leads to different attitudes of the provinces: the province of Salta is an example of the most market friendly attitude towards lithium. The provincial government in Salta managed to attract not only lithium mining companies, but also electronic and automotive companies (Toyota and Mitsubishi) (Barandián, 2018). It is industries with a higher added value that could help the Argentine economy turn around reprimarization and start the transformation.

The province where lithium mining is currently taking place is *Jujuy*, where lithium is considered a strategic raw material (as in Chile) and a driving force of socio-economic development (as in Bolivia) (Barandián, 2018; Dorn et al., 2022). The local government of *Jujuy* created JEMSE, whose mission is to support the sustainable productive transformation of the province of *Jujuy*, promoting public-private alliances through the development of mining, renewable energies and their complementary activities. The vision is the right energy transformation of Argentina. It should be noted, however, that JEMSE's participation in mining decisions is considerably limited, as it only owns minority shares in mining companies. New research centers are being created in Jujuy, foreign experts are guests for the purpose of developing research in industries related to lithium mining, and conferences on lithium battery research are held regularly. An already announced project is the planned lithium-ion battery factory in the Perico industrial park (GlobalData, 2023). The project is implemented by the locally operating company Jujuy Litio (JEMSE 40%, Seri 60%) and will include a pilot plant for the assembly of lithium batteries and the production of cells. In the final phase, it will also include the production of electrodes (Dorn et al., 2022).

In 2021, the Argentine government announced the intention of YPF, in collaboration with the University of *La Plata*, several Argentine ministries, to build a factory for the production of lithium batteries in the city of *La Plata*. In April 2023, this factory, called UniLab, was opened (Bloomberg, 2023). The equipment was supplied mainly from China and it is the first ever factory for the production of electric batteries in South America.

### 3.2 Bolivia

*Salar de Uyuni* is located in Bolivia, a salt flat with the largest lithium resources in the world. *Salar de Uyuni*, in the department of *Potosí* in the southeast of the country, covers an area of 10,582 km2 at an altitude of 3,653 m. In addition to lithium, the brine contains boron, sodium chloride, magnesium, potassium and sulfate (Haferburga et al., 2017). Another potential source of lithium is the *Salar de Coipasa*, which extends in the department of *Oruro* in Bolivia and *Colchan* in Chile (Lopez et al., 2023).

Despite the largest resources in the world, lithium production in Bolivia is only in a pilot program. In addition, Bolivian resources contain a small concentration of lithium compared to other countries of the lithium triangle (Vásquez, 2023), the brine contains a lot of magnesium salts, which, together with the long rainy season and flooding of salt lakes, makes lithium mining difficult. Production of lithium carbonate peaked in 2019 (421 metric tons), then production slowed down due to the Covid-19 pandemic (Statista, 2023e). The production of lithium carbonate as well as the mining of lithium itself is carried out by the state-owned company *Yacimientos de Litio Boliviano*.

Research on *Salar de Uyuni* began already in the 1970s under the auspices of the French scientist Francois Risacher (YLB, 2023a). The interest of foreign companies in lithium mining has been thwarted several times. For example in 1991, the American company FMC started mining lithium in Argentina after a failure in Bolivia (Bos and Forget, 2021).

The case of Bolivia is more specific than the other countries of the lithium triangle. The biggest obstacle to lithium mining is legislative and political reasons. In 2006, Evo Morales, a critic of private companies and neoliberalism, who introduced a series of nationalizations, took office. In 2008, President Morales announced a strategic plan for the development of Bolivian lithium (Hancock, Ralph and Ali, 2018) and nationalized lithium production. In relation to natural resources, there have been significant changes, with the new constitution of 2009, resources were recognized as the property of the people, and the rights of the indigenous population (they make up over 60% of the population) were generally strengthened. It has been established that indigenous peoples have the right to be consulted before the exploitation of resources on the territory where they live begins. The Bolivian government first applied the so-called resource nationalism and announced investment in exploration in Salar de Uyuni. The plan included three phases: a pilot (exploration), an industrial phase (mining, production of lithium ubiquitate), and a phase for the production of electric batteries (Hancock, Ralph and Ali, 2018) in order to avoid dependence on primary commodities. Gradually, however, the Bolivian government's approach to foreign investments softened, in 2014 Bolivia signed a political agreement for cooperation in the development of the lithium industry with the Netherlands. This was followed by cooperation with the German firm ACI Systems with the intention of building four plants for the production of lithium hydroxide and lithium batteries (Marmolejo Cervantes, Garduño and Rivera, 2022). ACI System was designated as a strategic partner. Although the agreement was interrupted, cooperation is currently underway.

Cooperation with China in the field of lithium deepened after 2015. Currently, cooperation is underway with the Chinese consortium Catl Brunp and Cmoc, China Molybdenum and Contemporary Amperex Technology. According to the latest news, Chinese companies are developing a new technology called of direct lithium extraction, which raises certain concerns (waste management, non-use of other salts and minerals in the brine, environmental risks). Bolivia plans to produce lithium batteries by 2025 with the help of Chinese partner Contemporary Amperex Technology (NikkeiAsia, 2023).

A moderate resource nationalism can be talked about mainly in the period 2017-2019. In 2017, the state company *Yacimientos de Litio Bolivianos* was created to develop mining processes. The originally determined 60% for Bolivia in the joint ventures was changed to 51%, through YLB. The mining industry is overseen at all stages by the Bolivian state miner company Comibol (2023).

Bolivia's approach to lithium can be characterized by a high degree of resource nationalism and the creation of public-private partnerships with foreign corporations, to varying degrees over time. It is a specific model whose goal is to ensure the industrialization of lithium (strategy of brine industrialization) without the dominant role of international corporations. The goal is *"to avoid the historical link between mineral extraction by foreign corporations, continued community/indigenous poverty and conflict, environmental damage and resource depletion"* (Hancock, Ralph and Ali, 2018).

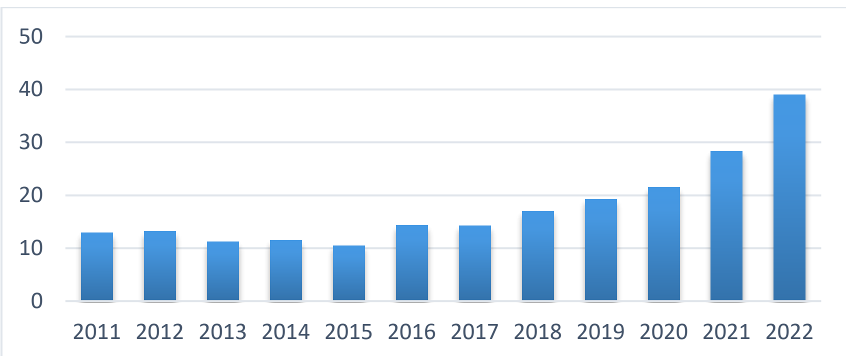
Bolivia is also aiming to transform its economy and transition to renewables, and lithium can significantly contribute to the transition to a low-carbon economy. Bolivia has set a goal of producing 79% of energy from renewable sources by 2030 (Hancock, Ralph and Ali, 2018). YLP has signed a contract with local car manufacturer Quantum Motors to produce electric vehicles (Marmolejo Cervantes, Garduño - Rivera, 2022).

### 3.3 Chile

Chile is the country that has the most proven lithium reserves in the world (9.3 million metric tons), which corresponds to 52% of the world's reserves in the form of brine (CCHEN, 2020). Chile is the fourth country with 11% of the world's resources.

The most important reserves are located in the north of Chile: in the *Salar de Atacama* in *San Pedro* and *Atacama* and in *the Salar de Maricunga* in *Copiapó*. Up to a third of global production is produced on the territory of Chile. Lithium mining began in the 80s of the 20th century, but only in the last decade has there been a boom in both production and export. Lithium mining experienced a more significant expansion from 1997 (4,500 tons) to 2017 (14,100 tons) (LIU, W. et al. 2019). Currently, mining reaches 39 thousand metric tons and lithium production is on the rise (Figure 4). Currently, lithium is considered a strategic raw material in Chile (Barandiarán, 2019) and Chile declares that lithium is crucial for the country's economy and will have growing potential in the future.

Fig. 4: Lithium mine production in Chile (in 1,000 metric tons)




Source: own processing according to STATISTA, 2023f.

Chiles foreign trade in lithium is growing in both quantity and value. Even in 2022, lithium became Chile's third most exported commodity after copper and various copper derivatives and products in dolars. Even ten years ago, lithium was not even considered a strategic raw material, and it was not even in 15th place in the commodity structure of exports (TradeMap, 2023).

In Chile, mining takes place only in the *Salar de Atacama*, where at the same time the largest lithium reserves in the world are located. In addition, the brine from this salt flat contains the highest concentration of lithium in the world (Vásquez, 2023).

Mining and processing of lithium is ensured by 2 private companies of the company: the Chilean company *Sociedad Química y Minera de Chile* (SQM), which is also the largest producer of lithium in the world, and the American company Albemarle. Both companies have a lithium mining plant in *Salar de Atacama*, SQM processes lithium in a plant in *Salar de Carmen* (SQM, 2023) and Albemarle in a chemical plant in La Negra, 27 km from the city of *Antofagasta* (Albemarle, 2023). The companies have been operating on the market for a long time, since the 80s and 90s of the 20th century, basically no new mine has been put into operation for about 30 years.

The largest exploration project is taking place in the *Salar de Maricunga*. Lithium has not yet been produced here also due to environmental concerns. The *Salar de Maricunga* area is only a tenth of the *Salar the Atacama*, and has the second highest concentration of lithium (Codelco, 2023). The Chilean company Codelco has been exploring it since December 2020, investing approximately $ 23 million (LT, 2023). Mining is expected to begin within a few years. However, Codelco's mining is complicated by the ownership rights of other private companies in the *Salar de Maricunga*: Simco (an alliance between the Asian fund Simbalik and the Errázuriz group) and *Minera Salar Blanco* (a subsidiary of the Australian company Lithium Power International), which have announced an interest in lithium exploration. Under the Proyecto Blanco project, *Minera Salar Blanco* plans to start in 2023 with an initial investment of US$700 million (Minera Salar Blanco, 2023). In the future, cooperation between the companies is not ruled out.

With the inclusion of *Salar de Marucunga*, lithium production in Chile could triple. At the same time, research into extraction methods is still ongoing, which will also help to increase production. Despite Chile's efforts and natural factors (the highest concentration of lithium in brines), Argentina is believed to be able to overtake Chile in production in a few years. The biggest influence is attributed to the market friendly policy of Argentina (a high number towards investments in mining and processing of lithium. On the contrary, Chile is much more strict in granting permits for mining of lithium. It is paradoxical considering the orientation of the Chilean economy - for a long time it applies one of the most liberal economic models in Latin America. Lithium production is state-controlled and only SQM and Albemarle can operate under strict production quotas and requirements to sell up to 25 percent of production at discounted prices to local buyers.

Royalty rates can also be very high, Chile has a variability system, rates fluctuate between 6.8 and 40% of the export price of lithium (Vásquez, 2023). Both companies therefore pay high rates at current prices, SQM paid the state $ 5 billion in 2022 (LT, 2023). The main role in the regulation of lithium mining is played by Chile Commission for Nuclear Energy (CCHEN). According to Article 8 of Act 16.319 on the establishment of CCHEN, lithium is classified as a mineral of national interest and only the Commission may grant a permit for lithium mining, the so-called CEOL (special lithium operation contract). To date, the Commission has granted nine CEOLs: *Codelco Pedernales y Maricunga* (Codelco for short) in 2018, *Minera Salar Blanco*, Cominor, Simbalik, SQM (1996 and 2018) and Albemarle (1980 and 2016) (CCHEN, 2023).

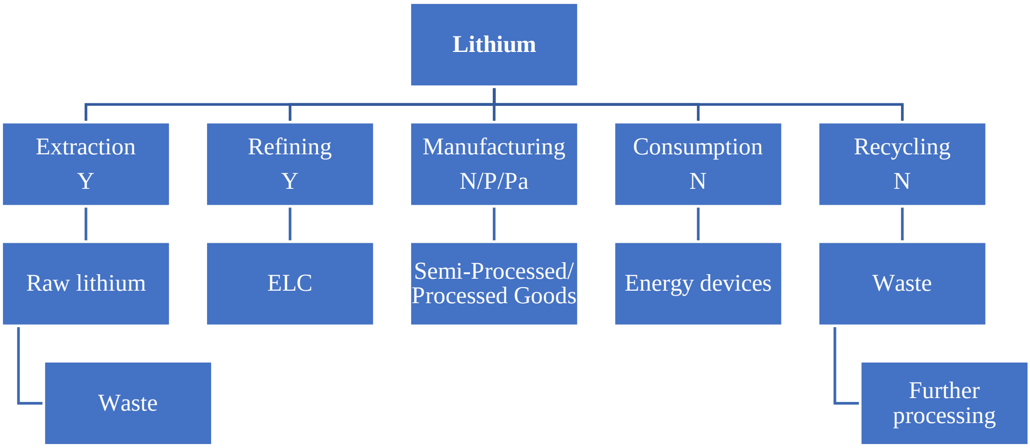
In the future, a new constitution may also play a role (which enshrines the protection of nature and natural resources for future generations, the relationship of harmonious balance between people, nature, etc.), but the proposal of which has not yet been approved by the population in a referendum. However, a new proposal is being prepared by the end of 2023, and given the agenda of the current government, pressure to protect the environment can be expected. In the spring of 2023, the president of Chile, Gabriel Boric, announced that he planned to nationalize lithium mining. Its goal is the protection of the environment and at the same time the industrialization of Chile also in the context of lithium processing. Even China's BYD Co announced plans to build a $290 million lithium cathode factory in Chile's northern Antofagasta region (Reuters, 2023).

However, lithium has a role to play in the transition to a low-carbon society, so we do not expect its mining to be at risk. Various researches in the energy field are currently underway, also under the auspices of CCHEN.

## 4 GREEN EXTRACTIVISM IN LITHIUM TRIANGLE

According to the theory of Bruna (2022), the countries of the lithium triangle can be defined as the so-called extractive economies. The following diagram describes the material transformation of lithium in the context of the countries of the lithium triangle, which are located at the beginning of the global supply chain. They are active in the first two stages (extraction, refining), to a large extent compared to other countries in the world. We consider them net producers and exporters. Due to production, they also have to bear the impacts it brings (waste, environmental degradation, social impacts). Waste is not so voluminous in the case of pumping lithium from brines, because mainly the pumped water is returned to the brines. Manufacturing of lithium batteries, i.e. the third phase, is not actively underway yet. Pilot programs in cooperation with foreign investors are announced. The third and fourth degrees are partially represented. Only in Argentina, a factory for the production of electric batteries was opened in 2023. In Argentina, Bolivia and Chile represented only slightly through the production and subsequent consumption of solar energy. However, there are relatively large unused capacities in this direction, which is also the subject of other country plans (Fig. 5).

Fig. 5: The five stages of material transformation and value capture of lithium in lithium triangle




Notes: Y – the activity is carried out in the lithium triangle, N – the activity is not carried out in the lithium triangle, P – planned activity in the next years, Pa – partially.
Source: own processing according to Bos and Forget, 2021.

Lithium, as a metal that has the ability to store energy, is a critical element not only for electromobility but also for renewable energy sources. Lithium-ion batteries are also used in building capacities of renewable energy sources. Among the countries of the lithium triangle, Chile is clearly the leader in renewable energy, but its capacities have fluctuated over the last decade. Currently, the emphasis is on building the capacities of renewable energy sources. Argentina has several solar energy projects in the works in regions where lithium is mined. Bolivia, the least developed country of the triangle, has an ambitious goal of producing 79% of renewable energy by 2030 and the goal of achieving full electrification of the country by 2025 (Lopez et al., 2021). It should be noted that the electric batteries placed in the structures do not come from national economies. In the future, all three countries are trying to reverse this trend. The countries of the lithium triangle, especially Bolivia, have excellent conditions for generating solar energy.

Lithium mining leads to environmental impacts: it disrupts biodiversity and fragile ecosystems (Hancock, Ralph and Ali, 2018, Lopez, 2021; Liu et al., 2019), endangers *flamingos* and *vicuñas* (Vasquez, 2023), wetland habitat (Alam and Sepúlveda, 2022), both underground and fresh water are pumped out (Díaz Paz, 2022).

The *Laguna Santa Rosa* wetland area is partially threatened by lithium mining, but this has not been fully confirmed by research. The exceptional weather situation also played a role, when significant rainfall hit the region in 2015, and thus the downward trend of the groundwater in the southern edge of the *Salar de Maricunga* was not demonstrated (Alam and Sepúlveda, 2022). However, wetlands continue to be among the most endangered ecosystems on earth. The production of LCE creates several tons worth of waste for each country. We found the least information about environmental degradation or its risks in Bolivia, which is connected to the late onset of lithium mining in this country.

Another significant problem with lithium mining in the lithium triangle is the excessive use and withdrawal of water in the driest regions of the Earth. There is a threat of a lack of fresh water for local communities, even contamination of water needed for agriculture (Khakmardan et al., 2023; Ahmad, 2020). Despite the fact that both Argentina and Chile have established monitoring institutes to monitor water level change (Ahmad, 2020; Vasquez, 2023), there is pressure on local communities and disputes over the right to water in the areas.

In Bolivia, resources are defined by the 2009 constitution as the property of the people, and the indigenous population has the right to be consulted by law before the resource is used (Hancock, Ralph and Ali, 2018). Chile is the only country in Latin America that does not recognize the indigenous population in its constitution (IWGIA, 2023), therefore it does not even publish the available statistics on the shares of the Indian population in the regions.

Based on data from the population census of Bolivia and Argentina, it is clear that the areas affected by lithium mining are inhabited by indigenous people. In both cases, these are the regions with the highest shares of Indian population in the country, although with significant differences between countries in terms of the overall population structure. Bolivia is the most indigenous country in South America, it belongs to the most diversified countries in this regard. Currently, there are up to 36 different ethnic groups living in Bolivia. In the *Potosí* region, up to 53% of the population identifies itself as Native American based on their mother tongue, while it is not entirely clear what percentage of the population using Castilian as their mother tongue identifies as Native American. We assume that the real share of indigenous people is even higher. At the same time, Potosí is the poorest region of Bolivia.

In Argentina, traditionally the country with the highest proportion of population of European origin, indigenous people live in the provinces of *Jujuy* 7.9%, *Salta* 6.6%, and *Catamarca* 1.9%. In the case of the first two, the shares are high, only 2 Argentine provinces (*Chubut*, *Neuquén*) achieve a higher share of indigenous people. However, in the provinces of *Jujuy* and *Salta* live the highest number of indigenous people in the whole of Argentina in total terms. At the same time, we detected a high level of poverty and destitution (equivalent to extreme poverty) in these regions: in *Salta* 40% of the population lives in poverty and 6.9% in destitution, in *Jujuy* 41.8% in poverty and 8.5% in destitution, in *Catamarca* 44.3% in poverty and 6.6% in destitution (Indec, 2022).

Despite incomplete data on the poverty rate in the affected regions and the poverty rate of indigenous people in the affected regions, reports indicate that it is this population that comes into conflict with the mining companies and their intentions most often. It is possible to state many clashes with local communities and their opposition to mining. The most common reasons are water problems (shortage, unresolved water rights, threats to freshwater flows), lack of information about planned projects of mining companies, the violation of indigenous rights, lack of benefits and royalties from mining for local communities (Opinión, 2023; Reuters, 2023); Ahmad, 2020; Desaulty, 2023, Díaz Paz, 2022; Dorn et al., 2022; Jerez et al., 2021). The table 1 summarizes other aspects as (Statista, 2023g, h, i).

In Bolivia, we can observe a higher participation of indigenous people and in general the population living in the affected area than in the other two countries. It has to do with the history of Bolivia and the *Potosí* region, traditionally suffering from extractivism since colonial times (silver) and later in relation to natural gas and water, resulting in protests. It was from these riots that former President Morales gained political power. He is committed to supporting local communities and organizations (FRUTCAS[2], COMCIPO[3]). Despite the governments' efforts to industrialize lithium, the aforementioned organizations were also partially successful: they achieved the exclusion of foreign mining companies in the first two phases, the cancellation of the contract with a foreign company in 2019 (Obaya, 2021), within the framework of Bolivia's strategic plan for the industrialization of lithium. Their successes can be partially attributed to their relatively close relationship with former President Morales.

At the same time, the territory of *Potosí* (specifically the provinces of *Nor Lipez*, *Enrique Baldiviezo* and *Sud Lipez*) has been included in the Community Lands of Origin (*Tierra Comunitaria de Origen*) since 2010, according to which the property rights to the territory belong to indigenous groups and the property is inalienable, indivisible, non-foundable and tax-free (Sanchez and Lopez, 2021).

Tab. 1: Selected aspects of lithium extraction

| | ***Argentina*** | ***Bolivia*** | ***Chile*** |
|---|---|---|---|
| **Mining area** | *Salar del Hombre Muerto, Salar de Olaroz, Salar de Cauchari* | *Salar de Uyuni* | *Salar de Atacama* |
| **Survey area** | *Salar de Olaroz, Salar de Cauchari, Salar Tolillar, Salar De Rincón, Salar Tres Quebradas, Salar de Jujuy* | *Salar de Uyuni* | *Salar de Maricunga* |

[2] The Regional Federation of Peasants from the Southwest of Potosí
[3] The Potosinista Civic Committee

| | | | |
|---|---|---|---|
| **Strategic importance** | partially | yes | yes |
| **Reserves/ resources (in million tons)** | 2.7/ 20 | N/A / 21 | 9.3/ 11 |
| **Mining administration** | decentralized | centralized | centralized |
| **Nationalization of the sector** | no | yes | no * |
| **Economic policy** | liberalism | state-run/ resource nacionalism | regulated by the state |
| **The opportunity for local communities to be involved in decision-making** | partially | yes | no |
| **Renewable energy (share of total production)** | 9.2% | 18.4% | 89% |
| **Building renewable energy capacities** | yes | yes | yes |
| **Expected start of production of lithium batteries** | 2023 (already open) | 2025 | 2025 |
| **Proportion of indigenous population** | 1.9% - 7.9% | 53% | N/A |
| **Poverty rate in the regions** | 40- 44.3% | N/A | N/A |
| **Declared environmental impact** | the decrease freshwater, the decrease of biodiversit y, massive water withdra wals, waste, water contamination | waste | the decrease in the water level, massive water withdrawals, waste degradation in vegetation and fauna |
| **Area of environmental impact** | *Salta, Catamarca* | *Salar de Uyuni, Potosí* | *Atacama, Laguna Santa Rosa, San Pedro* |
| **Conflict with local communities** | Water consumption, social injustices, lack of information and participation, displacement of peasant communities, the violation of indigenous rights | ownership rights, royalties from extraction, benefits | water consumption, water injustices and lack of water |
| **Area of conflict with local communities** | *Salta, Catamarca, Jujuy* | *Salar de Uyuni* | *Atacama* |
| **Mitigation projects** | yes | N/A | yes |

Note: N/A – no available data, *in plan.
Source: own processing.

Through civic organizations, the population in the area is partially informed, but the current situation does not meet the demands and expectations of local communities. Despite the declared rights, lithium belongs to the state, which decides on its treatment. *De facto*, local communities do not have decision-making rights. According to Sanchez and Lopez (2021), this is a contradiction where*, "regardless of any legal and symbolic recognition in the original territories, they* (local communities) *lack real decision-making power, especially in relation to mineral resources.*"

We detected projects and compensations in Chile and Argentina (e.g. SQM, 2023, Albemarle 2023) that are intended to mitigate the impacts of lithium mining, especially the disruption of traditional ways of life. The mining companies themselves employ workers from local communities either voluntarily or in fulfillment of set quotas, which increases their standard of living. Minare Exar in Argentina disclosed that 65% of its employees are indigenous, earning above-average wages for the region (Ahmad, 2020). It is difficult to trace the reported financial compensations to local communities, but some information indicates that there are violations of the declared values. Companies are committed to creating social values and supporting local communities. However, the results of these projects are not clear from secondary sources (information in the press and on the websites of mining companies).

However, it is not only negative impacts. Among the positives we include the placement of solar panels and the increase in capacity for solar energy in the region. In poor regions, this can lead to breaking out of energy poverty and universal energy availability. On the other hand, renewable energy capacities in Argentina and Bolivia have significant reserves: in Argentina they contribute only 9.2% to the total energy production and in Bolivia 18.4%. We consider only Chile as an economy that is transitioning to a low-carbon economy. According to Isla (2021), we include the Argentine and Bolivian regions in the so-called sacrifice zones, because by mining lithium they contribute to the creation of low-carbon societies in other regions, but they themselves are not moving towards this.

Barandián (2018) offers the concept of mining 2.0, i.e. carrying out mining activities without abusing the rights of local communities. From the point of view of this perspective, it is necessary to carry out several reforms and changes: strengthen the rights, awareness of the population in the territory and compensation for them, increase their living standards, qualifications and find them a full-fledged place in the mining economy of the regions.

According to Dorn et al. (2022) argue that the economies of the lithium triangle have adopted green extractivism. In Argentina, we can also talk about agrarian extractivism (due to the soy business). Argentina's economy is struggling with the reprimarization of the economy, which the mining sector has also contributed to. At the same time, if the Argentine government's intentions are fulfilled and the lithium battery production capacity is expanded, it may lead to a reversal of the reprimarization of the economy. Bolivia and Chile do not struggle with reprimarization, because they were never sufficiently industrialized. In the future, if they want to gain/maintain competitiveness, they should move to produce products with higher added value.

## 5 Conclusions

In the paper, we examine the lithium industry and the so-called industrialization of lithium in the countries of the lithium triangle. All three countries possess substantial world resources and reserves, and two of them (Argentina and Chile) are among the world's largest producers and exporters of LCE. The importance of lithium to their economies is growing, production has increased in all three countries over the last 10 years, while we are seeing a delay in production in Bolivia. The countries have ambitious plans for the transition to the use of renewable energy sources and a higher level of industrialization of lithium (production of electric batteries). In Argentina, a plant has already been opened, two more announced the planned opening in 2025. From an economic point of view, Argentina has the greatest potential for the expansion of lithium industrialization due to the application of liberalism and decentralization.

The fact remains that mining regions are poor regions and some of them have a high proportion of indigenous people. It is the center with local communities that is most alarming in the context of mining. These are primarily rights to water, which is used in the evaporation of lithium. Other problems are emerging waste, threat to habitats, traditional way of life, etc. Mining companies respond to protests by local populations with partial compensation in the form of direct payments or by integrating local populations into corporate structures. Environmental impacts were only partially proven by research. The problem is not given as much attention as it demands.

The positions of the countries differ in relation to the theories of green extractivism: we can classify the Argentine and Bolivian regions as sacrifice zones. At the same time, it is important to add that in Bolivia the local indigenous communities have a stronger negotiating position than in Argentina and Chile.

If countries adopt the necessary changes and strategies, lithium industrialization has the potential to facilitate the transition of the studied countries and neighbors in Latin America to renewable resources and achieve energy sovereignty of the region. So far, Chile is the closest with 89 percent representation of renewable sources in total energy production.

Last but not least, research on lithium resources is still ongoing and the position of the countries of the lithium triangle will depend on the potential amount of lithium discovered in other regions. Mining methods are also constantly being improved, and other players will enter the global market as mining costs decrease. Time and technology will change its structure of the global lithium supply chain. The countries of the global South no longer have to play such an important role, i.e. and the lithium triangle. For this reason, countries should take advantage of their strategic position today.

We consider the contribution of the article to be the processing of the definition of green extractivism in the Slovak scientific space, its application to the lithium triangle, and the definition of opportunities and threats in the lithium triangle. Further research should focus on a deeper analysis of the impact of lithium extraction on the most vulnerable population, its decision-making powers, the level of information and the transparency of the actions of mining companies not only towards them but also towards the environment.

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