Assessing the Opportunities and Risks of Extraction in the Lithium Triangle

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submitted to
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for
Senior Thesis
Spring 2024
April 22, 2024
Abstract

Climate change mitigation efforts have grown in recent years, giving rise to energy transition technologies, including electric vehicles and grid storage, which rely heavily on lithium. The resulting acceleration of lithium demand poses an opportunity for Argentina, Bolivia, and Chile – collectively referred to as the Lithium Triangle, where more than half of the world’s lithium resources are found – to produce lithium as a way of generating revenue that can be redistributed to increase social well-being. Despite the enticing opportunity, lithium extraction has several socioecological and economic risks that may make lithium extraction a futile endeavor. This thesis aims to assess the geographical conditions, governance frameworks, and socioenvironmental risks of lithium extraction within each country to recommend risk mitigation measures. This thesis finds evidence of violations of indigenous rights, particularly regarding the free, prior, and informed consent process required prior to lithium mining operations, as well as instances of misbehavior by mining companies. The paper concludes that for lithium extraction in the Lithium Triangle to truly increase social well-being, important changes must be made.

*Keywords*: lithium extraction, energy transition, indigenous rights, green extractivism
Acknowledgements

I extend my heartfelt thanks to my friends who have shown me unwavering love and support throughout my academic journey. I especially appreciate all the fun moments and laughs shared; they truly kept me going.

I would like to thank Professor Ascher for introducing me to the world of natural resource policy, which led me to explore this project, and for equipping me with the tools to think critically about the world. Thank you for instilling in me a greater sense of curiosity. Equally important, I have Professor Ascher to thank for teaching me about fish elevators.

Sobre todo, le quiero dar las gracias a mi familia por todo su apoyo y amor que me ha permitido llegar hasta este punto. No estaría aquí sin los sacrificios y abrazos de mis papás. Me han enseñado el valor de la determinación y humildad. Todo lo hago por ustedes. Si se pudo.
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Section 1: Introduction

Lithium is a highly relevant metal in a world seeking to expand its technological capabilities and achieve a clean energy transition. The mineral’s range of applications, especially in the sectors of electric mobility, energy storage, and consumer electronics, has sparked discussion about the economic opportunities of lithium extraction (Martin et al., 2017). With over 60 percent of global lithium resources in Argentina, Bolivia, and Chile – often referred to as the Lithium Triangle – it is possible that successful participation in lithium extraction improves the economic standing of these countries and the well-being of their respective citizens (Pell, 2023, p. 179). In such a case, not engaging in lithium extraction could be a missed opportunity, especially in light of the high poverty and inequality levels in the Lithium Triangle countries. Alternatively, investing in lithium extraction could be a fruitless venture, for example, if lithium demand is stunted by technological developments that make lithium less desirable, or if excessive competition renders extraction unprofitable.

The choice to invest in lithium extraction depends on weighing its potential benefits – improvement of economic standing and employment opportunities – and risks – harm to the environment and vulnerable communities and unprofitability. Adequate policies can guide the Lithium Triangle countries in striking a balance between opportunities and risks of lithium extraction. However, shall the costs outweigh the benefits in a particular country, that country may find it best to improve social well-being via other avenues.

Argentina, Bolivia, and Chile have substantial lithium deposits at varying stages of extraction and exploration, in competition with China and Australia. The 2024 Mineral Commodity Summaries report highlights global lithium resources and reserves; the latter indicates what is economically extractable at the time of determination. In terms of resources,
Bolivia is the global leader with 23 million tons of lithium, followed by Argentina with 22 million tons, Chile with 11 million tons, Australia with 8.7 million tons, and China with 6.8 million tons. Despite its leading position in lithium resources, Chile, Australia, Argentina, and China rank highest in lithium reserves\(^1\) with 9.3 million tons, 6.2 million tons, 3.6 million tons, and 3.0 million tons, respectively. Data on Bolivian reserves is not currently available (U.S. Geological Survey, 2024, p. 110). In terms of current lithium production, Australia accounts for 48 percent of global lithium production, followed by Chile with 24 percent, China with 18 percent, and Argentina with 5 percent (U.S. Geological Survey, 2024, p. 110). Bolivia has not made significant progress in lithium production, with a majority of its projects at a pilot-scale or producing small volumes of lithium. Within the Lithium Triangle, Chile produces the most lithium.

The governance frameworks and political atmospheres of the Lithium Triangle countries will significantly influence the future of lithium production in each country. Both Chile and Bolivia have centralized models for managing lithium extraction, with Chile’s economic development agency managing extraction done by private companies and Bolivia’s state-owned enterprise conducting the extraction itself. Argentina, on the other hand, utilizes a decentralized model, allowing provinces to manage mining activities. Political atmospheres also differ among the three countries. In Argentina, the recently elected right-wing president, Javier Milei, has announced plans for austerity measures and devalued the Argentine peso by more than 50 percent, sparking civil unrest just 45 days after taking office (Nicas & Herrera, 2024). The political instability in Argentina casts doubt on its ability to expand its reach in lithium

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\(^1\) A resource is a concentration of a naturally occurring material in or on Earth’s crust that can currently or potentially be economically extracted. Reserves, a subset of resources, can be economically extracted or produced at the time of determination (U.S. Geological Survey, 2024, p. 205).
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extraction, whether managed by private or state entities, despite its accelerating investment in lithium extraction projects (Kingsbury, 2023, p. 583). In Bolivia, limited resources and relatively strong legal protection of indigenous rights make the feasibility of extracting lithium uncertain. Chile has the most established lithium market in the Lithium Triangle and considerable expertise in mineral extraction (i.e., copper), though the ongoing formulation of a new Chilean constitution may influence the prospects of resource extraction (Piscopo & Siavelis, 2021). The governance framework for lithium deposits established in each country shapes their approach to engaging with multinational corporations. The political stability and atmosphere of each country may also affect their ability to attract investments in their lithium industry.

Lithium extraction poses an opportunity to improve social welfare, though it comes with environmental and social costs. Historically, mineral extraction in Latin America has involved the exploitation of resources to the benefit of developed countries, often at the expense of the short- and long-term well-being of communities in extraction regions and their environments. However, other cases indicate that under adequate resource management and mitigation of socioecological risks, resource extraction can generate redistributable profits and consequently, improve social welfare. Thus, positive social outcomes from lithium extraction are contingent on achieving a management model that effectively mitigates socioecological risks.

Communities near lithium extraction regions in the Lithium Triangle have expressed concern about several ecological issues they attribute to lithium mining. For one, the water-intensive nature of lithium extraction raises concerns about water availability in regions with lithium operations due to the interconnectivity of brine (saline water) and freshwater sources. The hydrological balance of the system can be disrupted in cases of excessive brine extraction (Flexer et al., 2018). On average, the production of one ton of lithium carbonate requires half a
million liters of brine water (Flexer et al., 2018). Given the extreme aridity of the Lithium Triangle region, the water intensity of lithium extraction exacerbates hydrological vulnerability and threatens local communities’ largely agrarian lifestyles (Voskoboynik & Andreucci, 2022, p. 795). Water imbalances detrimentally affect other aspects of the environment as well, particularly by harming flora and fauna, subsiding land, and changing landscapes (Voskoboynik and Andreucci 2022, p. 795). Pollution is another concern: toxic chemicals from lithium processing and trace amounts of lithium contaminate air, bodies of water, and soil (Kaunda, 2020, p. 241). The pollution threatens the health of neighboring communities, ecological integrity, and biological diversity. Mitigation strategies, however, do exist. For example, water treatment and recycling, minimization of waste products, more effective processing of lithium brines, and alternative technologies have gained some traction (Kaunda, 2020). Regulation also plays a key role in mitigating the environmental impacts of lithium extraction. It is also important to note that when comparing the two currently economical sources of lithium – brine and hard rock – lithium extraction from brine has a lower environmental impact.

The development of lithium plants offers hope for generating employment opportunities, particularly for local people. Despite some generation of employment opportunities, however, each Lithium Triangle country faces obstacles in realizing the provision of equitable jobs, especially at the local level. Lithium employment is often limited to precarious, low-skill jobs subject to poor work conditions and health risks (Wanger, 2011, p. 205). A more general concern about the employment in extractive industries stems from historical instances of dependence on mining operations, which left a significant portion of dependent communities unemployed following mine closures (e.g., coal mines). Bearing this in mind, community dependence on lithium – a mineral with a somewhat uncertain future, as will be explained in later sections –
provide a reason for wariness. If these concerns are mitigated, however, lithium extraction may provide reliable and fair employment opportunities for people of the Lithium Triangle, particularly local communities.

Given the various risks of lithium extraction, the Lithium Triangle countries need to weigh the costs and benefits of extraction in order to decide if further engagement in lithium mining is worthwhile. Should they opt to continue extracting, effective mitigation strategies and policies must be in place. Such policies will need to consider the role of and protections for various stakeholders, namely government, local communities, and mining companies. A potential tool for minimizing the socioecological risks of extraction and benefiting communities is an agreement between affected communities and mining companies – Community Development Agreement (CDA). CDAs center community participation in the management of lithium operations, a crucial aspect of promoting an equitable use of the resource. This, in turn, helps minimize conflict between mining companies and communities.

The degree of benefit (i.e., revenues) as well as risk sharing shall also be considered. With local communities burdened disproportionately by extraction, fair compensation must be addressed. Well-constructed contracts between governments and mining companies that seek access to concessions and potential arrangements between mining companies and local communities are the determinants for fair revenue-sharing.

So long as lithium remains technologically relevant and extraction profitable, lithium may serve as a global decarbonization tool as well as an economic stimulant for the Lithium Triangle – a seemingly enticing opportunity. However, Lithium Triangle countries must proceed with caution to prevent the exacerbation of social inequality and environmental degradation. Each country faces both distinct and overlapping challenges in striking a balance between the
opportunities and risks of extraction. This paper aims to assess where each country is in terms of finding that balance and provide recommendations accordingly. Section 2 will provide a technical (geological and economic) background of lithium extraction broadly and look at the current state of lithium extraction in each Lithium Triangle country. Country-specific recommendations are provided. Section 3 presents the opportunities and risks of lithium extraction and ends with an analysis of whether each country is currently equipped to strike a balance between those opportunities and risks. Synthesizing the information from previous sections, section 4 identifies shared challenges within the three countries to provide general recommendations for the Lithium Triangle. Lastly, section 5 provides final insights.

Section 2: Background

Lithium Deposits

Lithium can be derived from multiple formations. Pegmatite, a type of hard rock, contains lithium-bearing minerals, such as spodumene (Tadesse et al., 2019, p. 171). Brines, including continental, geothermal, and oilfield brines, are another primary source of lithium. Clays, such as claystone, also constitute lithium resources (U.S. Geological Survey, 2024, p. 110). With lithium concentrated in continental brine (59 percent of lithium resources) and hard rock (25 percent of lithium resources), commercial lithium extraction relies on these two lithium sources (Vizureanu, 2020, p. 190). While estimates for lithium reserves vary, when comparing relative quantities of types of lithium resources globally, brine resources are larger than those in hard rock. Brine lithium resources are concentrated in the Lithium Triangle; hard rock lithium resources are concentrated in China and Australia (Bustos-Gallardo et al., 2021).
The Lithium Triangle consists of salt flats, or salares, in northern Chile, southwest Bolivia, and northwest Argentina, which make up more than half of the world’s lithium resources. The name “Lithium Triangle” initially included Chile’s Salar de Atacama, Bolivia’s Salar de Uyuni, and Argentina’s Salar de Hombre Muerto, but it is loosely used to describe salares close to the triangular region it originally outlined (Flexer et al., 2018; Steinmetz & Salvi,
Beneath the salares lies the key to lithium production: brine. Via a process known as evaporitic technology, underground brine – an aqueous saline solution of high ionic strength and rich in lithium – is pumped to the surface and allowed to sit in open air man-made evaporation ponds where solar radiation and wind facilitate the evaporation of water, leaving behind concentrated brine (Flexer et al., 2018, p. 1190). Pumping of large amounts of brine significantly accelerates the naturally occurring evaporation process of the salar (Bustos-Gallardo et al., 2021, p. 183). Upon reaching an optimal concentration level of lithium chloride, the concentrated brine (consisting of many ions, including lithium) is then transported to processing facilities. The addition of sodium carbonate to the concentrated brine, in addition to other filtration processes, yields crystallized lithium carbonate, a key raw material used for the synthesis of lithium-ion batteries. The process takes between 12 to 24 months from pumping of salar brine to production of lithium salts (Flexer et al., 2018, p. 1190).

**Economics of Brine Extraction**

**Low operation costs.** The geographical and climatic conditions of the Lithium Triangle, particularly the high altitude of salares, strong solar radiation and winds, and typically low rainfall, make the evaporitic process cost-effective (Flexer et al., 2018, p. 1190). In fact, extracting via evaporation ponds is both the least expensive lithium extraction process and has the highest profit margin (Heredia et al., 2020, p. 216).

**Salar complexities.** Despite its operational cost-effectiveness, the evaporitic process is slow; it is not suited for timely responses to demand changes. The process is also dependent on weather and climate conditions (which may change due to climate change) and only suitable for brine with a high lithium ratio relative to other ionic compounds (Flexer et al., 2018). For example, brines with large concentrations of magnesium and sulphate cannot be subjected to
evaporitic technology, given the costly process of separating lithium from other compounds. In less extreme cases, lithium recovery rates from brines with a complex ionic makeup are relatively lower. Additionally, pumping of brine, along with other disturbances to the hydrological balance of salar regions, causes the water table to fall, reducing evaporation rates – a phenomena referred to as damping capacity (Marazuela et al., 2019). Under significant reductions to evaporation rates due to pumping, the damping capacity could be detrimental to the efficiency of lithium extraction.

**Long prospection and pilot period.** Another challenge of navigating salares is the complexity and uniqueness of each salar. Given the difference in geographical and climatic conditions as well as chemical compositions among salar brines, every lithium brine project is different. Therefore, projects considering the possibility of utilizing evaporitic technology face a long prospection and pilot period of up to 10 years – a period with no revenues (Flexer et al., 2018, p. 1193; Barandiarán, 2019, p. 386). This may be a disincentive for investors.

**High start-up costs and scaling up challenges.** The favorable climatic conditions of most Lithium Triangle deposits—high elevation, strong solar irradiation and winds, low rainfall and humidity—of the Lithium Triangle create conditions that keep operational costs low. The disadvantage, however, is the high upfront costs (i.e., capital costs) and long exploration/pilot period of lithium brine mines. Flexer et al. (2018) suggests that the economic and technological challenges of lithium brine extraction are the reason for the limitation of five functional (those that have moved past the pilot stage) facilities globally.
Environmental Impacts of Brine Extraction

**Water-intensive extraction.** The key environmental concern of the evaporitic process of extraction is water usage. Two types of water are used for lithium extraction: brine water left to evaporate in evaporation ponds and water obtained from freshwater aquifers for industrial processing of the highly concentrated post-evaporation brine. Most of the former water source is lost to evaporation (over 90 percent), though given its extremely high salt content, absent lithium extraction, it would have no alternative use neither for drinking water nor irrigation (Vera et al., 2023, p. 151; Flexer et al., 2018, p. 1194). The evaporitic process removes an average of approximately 500 m$^3$ of brine water and 50 m$^3$ of freshwater (for recovery and treatment) per ton of lithium carbonate that is produced – relatively high rates, especially in consideration of the water scarcity in the region (Baspineiro et al., 2020, p. 3). Ingrid Garces, a professor of Chemical Engineering and Mineral Process at the University of Antofagasta, indicates that in the Salar de Atacama in Chile, the largest source of global lithium production, 2 million liters of briny water are used to produce one ton of lithium (Chile Sustentable, 2019).

Though brine does not have an alternative use (i.e., drinking water or for agricultural purposes), its extraction at high volumes threatens the regional water balance between brine and freshwater sources. Pumping brine creates a depression cone around the pumping area. Gradually, and dependent on the rate of pumping, the cone extends until it meets the boundaries of the freshwater aquifer (Flexer et al., 2018). Freshwater sources, at that point, can infiltrate the salar (depending on the permeability of the aquifer), becoming briny water to compensate for what is lost to evaporation. Due to this process, high rates of pumping threaten the level of nearby freshwater sources and the water table in the surrounding soil. Evidence of desertification in the area has been found (Vera et al., 2023). High rates of brine extraction diminish
communities’ access to freshwater, while decreasing the productivity of brine operations due to the infiltration of freshwater into the salar that reduces the lithium concentration in the brine.

Source: Vera et al. (2023)

**Waste.** Among the various salts in salar brine, only lithium carbonate salts are industrially processed, leaving behind large quantities of non-lithium carbonate salts to accumulate as waste on the edge of the salares (Flexer et al., 2018). Waste can be found in waste storage ponds, tailings piles, and processed waters and consists of toxic chemicals utilized in the processing of lithium and trace amounts of lithium (Kaunda et al., 2020, p. 241). These residues may pose a threat to the integrity of nearby ecosystems. In the Salar de Atacama in Chile, for example, one study finds that lithium brine extraction is negatively correlated with the abundance of two flamingo species (Gutiérrez et al., 2022). Though there is some evidence showing the impact of waste on flora and fauna in the area (e.g., detrimental to soil ecology and aquatic life), it remains limited, underscoring the need for further research on the potential
ecological impacts of residues with high salt concentrations, among others (Kaunda et al., 2020, p. 241; Baspineiro et al., 2020). In terms of human health impacts, the toxic composition of lithium extraction waste has detrimental health impacts, including those on human metabolism and neuronal communication (Kaunda, 2020, p. 241).

**Potential environmental mitigation strategies.** Given the limitations of evaporitic technology, alternative technologies are being explored. Direct lithium extraction (DLE), for example, refers to alternative technologies that avoid the use of brine evaporation ponds. DLE technologies tend to have a shorter waiting period from the pumping of brine to processing of lithium carbonate, lower capital costs, and reduced reliance on solar radiation and wind (Ezama et al., 2018). DLE is suspected to require less brine and freshwater, though current DLE technologies, namely the DLE plant at Salar de Hombre Muerto in Argentina, show that that is not always the case. The DLE facility was more water-intensive than other facilities using conventional evaporation technology. Also, though small-scale pilot DLE projects exist, there are few large-scale facilities due to the complexity and distinctiveness of each salar’s chemical system as well as the technological challenges that make scaling up difficult (Vera et al., 2023). Further research and advancements in DLE technology are necessary to increase its adoption on a large scale.

Another proposed alternative entails reinjecting residual brines back into salares post-lithium recovery, though the process poses ecological risks as well as risk of brine dilution (Flexer et al., 2018, p. 1199). Reinjection would alter the complex and fragile aquatic system and given the limited knowledge of the impacts of current brine reinjections, there is uncertainty around the impacts – geological and socioecological – of reinjection. A physical change to
salarès through reinjection also poses the risk of altering the chemical composition of the brine (Petavratzi et al., 2022, p. 681). This may impact lithium mining operations.

Despite numerous possible alternative technologies, no universal alternative has been established due to varying brine conditions (i.e., specific magnesium-lithium ratios, climatic factors). The diverse salar conditions necessitate the use of different technological extraction processes tailored to each salar’s unique characteristics.

Comparing Lithium Sources

*Continental Brine vs. Hard Rock*

**Costs.** One advantage of hard rock ore extraction compared to lithium brine extraction is the lower start-up costs. Brine evaporation does, however, have greater ease of exploration (Hancock et al. 2018, p. 553). In terms of operational (production) costs, lithium extraction from salar brines is the most energy-saving and cost-effective compared to that from clays and hard rock, making salar-based lithium extraction the most competitive (Zheng et al., 2023, p. 564). This is, in part, due to shallower drilling, a faster production set-up, and less capital required for extraction from lithium brine (Hancock et al., 2018, p. 553).

Lithium extraction from hard-rock sources yields either lithium carbonate or lithium hydroxide, while brines yield lithium carbonate that needs further processing to be converted into lithium hydroxide – the preferred lithium product of vehicle and battery manufacturers, such as Tesla and Panasonic (Graham et al., 2021, p. 14). Thus, despite lithium hard rock’s higher cost of extraction, it faces the advantage of not needing further processing via a costly conversion method.
**Geological and geographical considerations.** Lithium resources in continental brine are more abundant than hard rock resources, though concentrated in only four countries (the Lithium Triangle and China). Hard rock is more geographically widespread, making it less susceptible to supply disruptions. Additionally, while brine requires more processing to remove non-lithium ions (e.g., magnesium, potassium), well-studied hard rock deposits are mostly composed of lithium (Kesler et al., 2012). In the case of hard rock, a main disadvantage is the difficulty of exploration given topographical complexities that make rocks hard to sample for extraction viability. Brine extraction faces challenges related to the remoteness of salares, which increase transportation costs and require power, water, and labor networks (Hancock et al., 2018, p. 553). Also, as mentioned previously, each salar has unique geological characteristics that call for in-depth analyses and tailored technological processes.

**Responsiveness to demand.** Salar-extracted lithium has a long waiting period (12 to 24 months) for the evaporative process to yield lithium salts, posing a challenge for matching demand shifts (Kesler et al., 2012). In contrast, lithium production from hard rock extraction is more adaptable to changes in demand, since its timeline from extraction to production is about one to two months (Jorratt, 2022, p. 31).

**Environmental Impact.** In terms of environmental impact, lithium brine extraction is less environmentally damaging compared to traditional hard rock mining (Dorn & Peyré, 2020, p. 74). The production of both lithium carbonate\(^2\) and hydroxide (lithium products used in lithium batteries) from brine, conducted in the Lithium Triangle, is less water-intensive and produces fewer life cycle greenhouse gas emissions per ton compared to hard rock lithium.

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\(^2\) The Lithium Triangle primarily produces lithium carbonate.
extraction (Kelly et al., 2021). The main environmental concerns of lithium extraction from brine are water usage and the need for chemical concentrates and their disposal. For lithium extraction from hard rock ore, environmental risks stem from the need for deep land excavation, the use of acids, and pollution caused by the roasting process (Hancock et al., 2018, p. 553). Both types of extraction pose threats to the biodiversity of ecosystems in the location of extraction and the well-being of communities, though extraction from ore requires greater levels of energy and resources, leading to greater environmental harm (Gao et al., 2023).

**Scalability and long-term potential.** Kesler et al. (2012) concludes that continental brine deposits have more potential for large-scale and long-term lithium production compared to hard rock. Supporting this idea, a study comparing a subset of projects in Canada to those in Argentina and Chile finds that lithium brine projects have a longer expected mine life relative to hard rock (spodumene) projects (Ibarra-Gutierrez et al., 2020). However, while brine has several advantages over hard rock lithium deposits, including greater abundance and lower operational costs, hard rock remains relevant due to its wider geographic distribution (decreases susceptibility to disruptions in supply) and high lithium composition. The latter reason varies depending on the salares being compared. Bearing in mind the acceleration of lithium demand and the complexities of brine extraction – risk of hydrological imbalance under high volumes of brine extraction and the required chemical brine processing, especially extensive for brines with lower lithium compositions – hard rock sources of lithium are likely to remain relevant. However, to compete with brine deposits over the long term, further exploration of pegmatite deposits is necessary (Kesler et al., 2012).

**Continental Brine vs. Other Brine Types**
The higher relative composition of continental brine makes it commercially viable, while the extraction of other brine types has not yet become economical. Compared to seawater, geothermal, and oilfield brine, continental brine (found in salares) has a higher lithium content (Song et al., 2017, p. 293; Clarke, 2013, p. 48).

**The Lithium Triangle’s Advantage and Environmental Challenges**

As of now, salar brine is the most economically extractable source of lithium due to low cost of operation via the evaporitic process that makes use of naturally occurring processes – an advantage for the Lithium Triangle. Although brine extraction has a lower environmental impact when compared to hard rock, the detrimental impacts of continuous pumping of lithium salar brine on the environment and local communities cannot be ignored. Notably, continuous pumping also poses threats to the productivity of evaporitic lithium extraction due to the potential for brine dilution, which yields lower lithium recovery rates. Risks of freshwater depletion and environmental contamination and their subsequent impacts should be considered when assessing the benefits and costs of lithium extraction.

**Lithium Extraction in Bolivia**

*Salar de Uyuni*

Bolivia is home to the largest salar in the world, with an area of 10,582 km². Relative to Argentine and Chilean brines, the brine found in the Salar de Uyuni has a higher magnesium to lithium ratio, resulting in higher lithium extraction costs. Specifically, compared to Chile’s Salar de Atacama, Bolivia’s Salar de Uyuni, with 18 grams of magnesium per gram of lithium, has about three times the magnesium concentration (Sanchez-Lopez, 2019a, p. 1332-5). The rainy conditions, flooding of salares, and greater cloud cover that results in lower sun intensity further
increase the cost of lithium extraction in the area by decreasing the rate of evaporation. Both the climatic conditions and brine composition of the Salar de Uyuni puts Bolivia at an economic disadvantage compared to Argentine and Chilean counterparts (Aguirre, 2022, p. 190; Hancock et al., 2018, p. 552). Additional challenges for Bolivian lithium extraction include limited access to the sea for exporting, technological constraints – especially for more extensive processing of brine with a lower lithium concentration – and a lack of qualified labor (Castro et al., 2021, p. 118).

**Management of Lithium Production in Bolivia**

**History of lithium extraction.** Of the Lithium Triangle countries, Bolivia was the first to begin exploring its salares as a source of lithium in 1973 when NASA commenced exploration in the Salar de Uyuni (Sanchez-Lopez, 2019a, p. 1325). From 1985 to 2003, Bolivia attempted to build its lithium industry by private means, though it failed due to discontent of regional
organizations with the absence of a bidding process (Obaya, 2019). Following this failure, former President Evo Morales asserted goals and a plan for reinitiating efforts to build the Bolivian lithium industry. In 2008, he declared lithium a strategic resource and national priority, marking the beginning of a post-neoliberal Bolivian lithium project (Sanchez-Lopez, 2019b, p. 18; Yacimientos de Litio Bolivianos, n.d.). The lithium project consists of three phases: 1) research and development and construction of pilot plants (lithium carbonate and potassium chloride), 2) industrial-scale production, and 3) production of lithium batteries and cathodic materials (Jorratt, 2022, p. 34).

**Resource nationalism.** Bolivia’s 2009 Constitution establishes national sovereignty over natural resources for the benefit for Bolivian constituents and promises communities a consultation prior to extractive activities (Hancock et al., 2018, p. 554; United Nations Economic and Social Council, 2009). In line with the belief that nationalizing natural resources would protect the Bolivian people and allow the rents to be to their benefit, contrary to pre-constitutional changes, Morales’ vision consisted of a vertically integrated lithium industry (Hancock et al., 2018). That is, lithium extraction, processing, and battery production would occur in-state, providing Bolivians with job and industry development opportunities.

In April 2017, under Law 928, the Bolivian parliament approved the formation of the strategic state-owned enterprise Yacimientos de Litio Bolivianos (YLB) overseen by the Ministry of Energy, previously Gerencia Nacional de Recursos Evaporíticos (GNRE) under the state mining company, Corporación Minera de Bolivia (Comibol). YLB manages all stages of the lithium production process, from prospecting to industrialization and commercialization (Revette, 2016, p.150; International Energy Agency, 2022). While Bolivian policy does not allow for the participation of foreign enterprises in the extraction process – which it does itself –
it allows public-private partnerships in the downstream processes (e.g., lithium industrialization processes). However, the state retains majority ownership. Such partnerships have been formed (Sanchez-Lopez, 2023, p. 39; Hancock et al., 2018, p. 555).

**Politics of extraction.** The nationalist endeavor, which seeks to assert itself in every part of the lithium chain, may stem from underlying political motives. At the inauguration of the YLB industrial lithium carbonate plant in Potosí in December 2023, current President Luis Arce states, “Today, we are demonstrating that economic management by the State far exceeds the neoliberal approach of the right.” In an interview, the president of YLB, Karla Calderón, echoes Luis Arce’s stance on the vision for the expansion of lithium in Bolivia, stating “Welcome to a new chapter for our country, that of industrialization” (Fuentes, 2023). Like the Morales regime, the Arce government views Bolivia’s expansion of the lithium industry as a means of pursuing industrialization for economic development via a nationalist and post-neoliberal approach.

**Considerations of Bolivia’s model.** There are a few considerations regarding Bolivia’s management of lithium production through a state-owned enterprise. For one, state majority ownership means that the state bears most of the risk. If lithium has disappointing outcomes, a risk which will be discussed in the following section, this could result in significant losses for the state and the Bolivian people. Secondly, the ease of transfer of technological expertise from foreign to Bolivian hands, such as in its partnerships with China, if not accounted for, can interfere with the autonomy Bolivia seeks.

Bolivia’s emphasis on adding value at every step of the lithium production chain may lead to misallocation of government funds into downstream lithium ventures (i.e., processing and
manufacturing of batteries and cathodes\(^3\) that may be unprofitable. Entities (e.g., governments) that position themselves to operate in parts of a supply chain in which they hold a comparative advantage – what they are especially good at – tend to reap greater financial benefits than those which take on operations outside of their expertise. Thus, the idea that adding value at every point of the lithium chain equates to increasing profits neglects this consideration. In the case of Bolivia, a lack of qualified and specialized labor, the need for costly and suitable technologies for processing low-grade brine, and absence of other infrastructure (e.g., extraction, transportation) pose significant challenges for Bolivia’s lithium industry (Hancock et al., 2018, p. 552; Ghorbani et al., 2024, p. 13). Financially, these concerns are especially important to consider in assessing the financial sustainability of Bolivia’s lithium project. It is a possibility that a value-added approach may negatively affect net margins. Bolivia will need to assess whether the lithium project is a worthwhile investment.

**Current state of the Bolivian lithium project.** Despite early exploration and government enthusiasm about the prospect of lithium extraction, Bolivia has made slow progress in developing its lithium industry. A key factor behind the sluggish progress is the deterrence of foreign investment due to the nationalization of lithium production (Ghorbani et al., 2024, p. 13). To date, only the first phase of the lithium project (construction of lithium carbonate and potassium chloride pilot plants) has been accomplished in its entirety, despite investments of US $19 million, US $485 million, and US $400 million in research, construction of industrial plants, and construction of downstream (industrialization) plants, respectively (Jorratt, 2022; CEPAL, 2023, p. 29).

\(^3\) Key battery component
The state enterprise, which did its own extraction, made its first sale of industrial-grade lithium carbonate (9.3 tons) to a Chinese company in August 2016 (Yacimientos de Litio Bolivianos, n.d.). In December 2023, Bolivia inaugurated its first industrial-scale lithium carbonate plant, although its completion was fraught with difficulties. Franklin Molina, the Minister of Hydrocarbons and Energy, notes that he was told the lithium plant's financial and physical progress reached 60 and 57 percent, respectively. After site inspection, it was discovered that only approximately 20 percent of the plant had been built – a discovery that called for “extensive work” and re-engineering of the project (Fuentes, 2023). Discrepancies between reported and actual progress suggest inefficiency or mismanagement of the project.

Hurdles in achieving efficient construction, which required additional work to steer the project back on track, likely increasing project costs. These accomplishments mark a step in the right direction for completing phase two (industrial-scale production); however, Bolivia has significant work to do before it can match the industrial-scale production of its Lithium Triangle counterparts.

In terms of battery production – part of the third phase – Bolivia inaugurated a pilot scale battery plant in 2014, six years after it was announced. The plant was a turnkey project completed by the Chinese company LinYiDake Co. Ltda (Yacimientos de Litio Bolivianos, n.d.). Nevertheless, Juan Carlos Zuleta, an economist for the National Lithium Commission in Chile, critiques Bolivia’s battery plant, calling it a costly training program without clear direction or adequate expertise. Bolivia is not producing its own lithium or cathodes at the scale necessary to manufacture batteries with domestic inputs, meaning that it must import these inputs (Rodríguez).

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4 A turnkey project refers to a project in which a contractor (in this case, China) takes full responsibility for completing the project, from engineering to a final product (e.g., battery plant). “Turnkey” suggests that the owner only needs to turn the key to begin operations (Mishra, 2023).
Cuahutencos & Boric, 2015). Bolivia will likely need to substantially increase its lithium production to be able to economically produce batteries at an industrial scale. In addition, Chinese manufacturers – the leading battery manufacturers (by far) globally – are producing batteries more strategically by sourcing lithium from other countries. This places Bolivia’s arguably directionless battery industry at a disadvantage.

Evo Morales’ plans to continue expansion into downstream activities in partnership with ACI Systems in 2019 were halted by community protests (Sanchez-Lopez, 2023, p. 38). Current President Luis Arce emphasized plans to increase international presence in Bolivia’s lithium industry during his presidential campaign, which has materialized in the form of a “corporate consortium” with the Chinese group CBC made in 2023. The corporate consortium between YLB and CBC sets forth plans for the construction of two lithium production plants planned to utilize DLE technology. CBC will coordinate extraction activities with YLB. It is important to emphasize that this is not a contract as the legal framework to permit non-YLB extraction is not currently in place. According to Arce, YLB will retain full control of extraction and commercialization, though there are community concerns that this may be the first step towards the denationalization of the Bolivian lithium industry – a claim refuted by Arce and YLB president. Despite community demands for more information, there is little to no transparency from the state about the specific terms of the corporate consortium or what comes next (Bouchard, 2023).

**Socioecological Concerns**

**Demographics.** Bolivia has a 39 percent poverty rate, and 59 percent of the population in Potosí where the Salar de Uyuni is located lives in extreme poverty (Davalos, 2022; Sanchez-Lopez, 2019, p. 1324). Bolivia has a large indigenous population: over 60 percent of Bolivians
are indigenous and there are 36 recognized tribal groups (Hancock et al., 2018, p. 552). Thus, the successful extraction of lithium, if done equitably and sustainably, may serve as a tool to alleviate poverty, especially at the regional level.

**Employment.** Despite the expectation for extraction activities to generate employment opportunities, the opportunities that have materialized have primarily been low-skill jobs. Only a minority of the Bolivian lithium project workforce has consisted of well-trained professionals, many of which study and stay abroad due to low salaries that make employment for Bolivian state institutions unattractive. The scarcity of qualified, high-skill Bolivian labor in lithium operations contributes to challenges in more quickly developing the lithium project (Ströbele-Gregor, 2015, p. 39)

**Violations of Free, Prior, and Informed Consent.** The Bolivian Constitution promises indigenous communities the right to consultation, autonomy, and self-governance over activities that may affect their livelihoods. More specifically, they are guaranteed the right to free, prior, and informed consent prior to mining activities – a right protected by the International Labour Organization Convention (ILO) 169 that Bolivia ratified in 1991 (International Labour Organization, n.d. - b). Mining operations need to attain an environmental permit – Environmental Impact Statement and the Certificate of Waiver – before beginning operations. Both an Environmental Impact Assessment Study and an Environmental Monitoring Report (the latter shows compliance and mitigation measures) are required to gain an environmental permit (CEPAL, 2023).

From 2010 to 2013, which marked the beginning of the lithium project in Bolivia, the external relations and communications office was established and focused on community consultations. The consultations focused on informing communities of the socioeconomic
impacts of lithium brine evaporation and establishing a strong relationship between YLB and communities. The consultations, however, were exclusionary – only 33 out of 329 communities were visited – and merely informative, rather than empowering or participatory. That is, communities are presented with information that they do not always understand and are not given the opportunity to negotiate (Sanchez-Lopez, 2019b, p. 25). Per the ILO Convention 169 definition of free, prior, and informed consent, a consultation is not just dispersion of information (International Labour Organization Indigenous, n.d.-a). The “consultation” process executed was not a true consultation; instead, it was a one-way flow of communication.

Another violation of the FPIC doctrine applies to the consultations for the lithium industrial plant, which took place in August 2018, long after design approval and plant construction. It also received its environmental license after construction had been completed (Sanchez-Lopez, 2019b, p. 28).

Inadequate community consultations violate the rights of indigenous communities, while also increasing the risk of failure for mining operations. For example, negatively affected community members may seek to sabotage lithium projects (e.g., adding some type of substance to brine evaporation ponds, obstructing roads at lithium facilities, etc.) as a form of resistance.

**Social opposition.** Controversy within local communities has emerged in response to project planning delays, foreign enterprises constructing infrastructure, lack of transparency, type of technology used, and implications for the environment and local communities (Sanchez-Lopez, 2019, p.1326). Community organizations have responded, showing varying levels of support for the lithium project. The civil organization Civic Committee Potosí Department (COMCIPO) has demonstrated opposition to the lithium project. In 2019, YLB signed a joint partnership with the private German company ACI Systems Alemania for the construction of an
electric vehicle battery and lithium hydroxide plant. COMCIPO protested the contract, claiming that the lithium project would not benefit the local communities and contradicted the Bolivian mining law. In response to public resistance to the project, President Morales overturned the contract (DW, 2019; Sanchez-Lopez, 2021).

**Intra-community conflict.** Protests against ACI Systems revealed the split views within local communities regarding the desired future of lithium in Bolivia. The COMCIPO-led protests represented social resistance from the city of Potosí to the partnership. The grassroots organization Regional Federation of Peasants from the Southwest of Potosí (FRUTCAS) opposed the protests, claiming that “if the civic leaders of the capital continue to handle the issue of lithium with personal interests,” the Southwest Potosí region would call for its own indigenous autonomous body (El Potosí, 2019). FRUTCAS has an optimistic view about the future of lithium in Bolivia; hence, its opposition to protests that led to contract cancellation. Sanchez-Lopez argues that this occurrence embodies an urban-rural divide within Potosí about lithium extraction (2021).

Protests only exacerbated a social divide that had been brewing since “consultations” between 2010 and 2013 were being conducted. In that process, the external relations and communications office involved the grassroots organization Regional Federation of Peasants from the Southwest of Potosí (FRUTCAS) in the community participation. Fieldwork from Sanchez-Lopez indicates that there is some skepticism amongst communities about the organization’s legitimacy and representability of the collective. For instance, one interviewee noted that the organization is selective and meets in communities where they have support (2019b, p. 25). Bolivia faces the challenge of reconciling differing lithium visions among Potosí communities.
Lack of transparency. The only publicly available environmental information consists of the Environmental Impact Statements. Other important information, including Environmental Impact Assessments of potassium chloride and lithium carbonate plants and about the lithium exploration process, however, is not publicly available. Moreover, records of the 2018 consultation process (i.e., process, participants, or agreements) for the industrial lithium plant, which occurred after the plant’s construction, are not publicly available (Sanchez-Lopez, 2019b, p. 28). There is a clear need for increased transparency of environmental information in Bolivia, and as is evident from the YLB and CBC corporate consortium issue discussed previously, the Bolivian state is not responsive to community demands for increased transparency in extraction issues.

Future concern: mining royalty distribution. Bolivian mining law (Law No. 535, 2014) stipulates the distribution of mining royalties: 85 percent for the producing Departmental Autonomous Government and 15 percent to the producing Municipal Autonomous Governments. The Salar de Uyuni is categorized as a Fiscal Reserve, putting its access and management in the hands of the state. The Fiscal Reserve categorization also means that no municipality has jurisdiction over the area in which the Salar de Uyuni is located. Consequently, 100 percent of the mining royalties go to the Departmental Government of Potosí. Sanchez-Lopez postulates that once lithium production increases in the Salar de Uyuni, issues of income inequality and uneven development between urban and rural areas will be exacerbated with the current structure of mining royalty distribution (2019b).

Environmental impacts. Bolivian environmentalists distrust the government’s environmental evaluations, seeing them solely as a legal formality. In addition to this, the required addition of toxic chemicals in the processing of lithium poses threats of leakage through
leaching, spilling, or atmospheric emissions – detrimental to both the salar ecosystem as well as the local communities that depend on it, including quinoa producers, other agricultural producers, and individuals in the ecotourism industry (Valle & Holmes, 2013, p. 116). More general environmental concerns of lithium extraction apply to the case of Bolivia, though limited disclosure of environmental information may be a cause for seemingly minimal reporting of environmental impacts in the Salar de Uyuni.

**Recommendations for Bolivian Lithium Extraction**

**Reassess the profitability of the vertically integrated model.** The former government of Evo Morales envisioned lithium as an economic opportunity with rents that should be protected for the benefit of the Bolivian people. The vision materialized in the form of nationalization of the lithium industry with plans for achieving a vertically integrated model (i.e., from extraction of brine to production of batteries). However, Bolivia faces competitive disadvantages given unfavorable geographic and geological conditions (i.e., rainy climatic conditions and low-grade lithium brine), especially relative to Chilean and Argentine counterparts. For lithium extraction in Bolivia to serve as an opportunity to increase social well-being, the Bolivian government needs to ensure that the lithium business model is profitable. Bolivia’s slow progress and ongoing challenges in expanding its lithium industry may be indicators of the costliness and potential unprofitability of the endeavor, especially if challenges continue arising. It could be that the greater vision of Bolivian industrialization is driving forward a potentially economically unworthwhile project. The Bolivian government needs to assess the risks of continuing the lithium venture, from extraction to downstream battery production.
The first consideration is whether brine extraction and processing are profitable given the relatively low lithium concentration found in the Salar de Uyuni brine, which necessitates costly processes. The next consideration is determining the financial prudence, or lack thereof, of participating in lithium downstream business ventures (i.e., battery production). If engagement in such activities is rooted in the belief that adding value in the lithium chain is inherently beneficial without consideration of their profitability, Bolivia may be making a costly mistake. If that is the case, Bolivia would benefit, instead, from engaging in business ventures where it enjoys a comparative advantage.

Bolivia’s attempt to enter the downstream lithium market (i.e., cathodes and batteries) is a high-risk investment. China is a clear industry leader, and its expansion plans indicate that it will likely continue to lead the downstream industry in the short and medium term. China, thus, enjoys a comparative advantage, creating uncertainty as to whether Bolivian-producer batteries are going to be attractive for battery buyers. Though Bolivia has had a working pilot-scale battery plant since 2014, no significant results have been seen yet, potentially due to the lack of adequate expertise. Using domestic input may make battery production more economical for Bolivia, though to reach industrial-scale battery production levels, it would mean first reaching industrial-scale lithium production. In this case, Bolivia would need to strengthen its upstream activities for downstream activities to make financial sense. However, Bolivia does not expect to ramp up production until about 2030. Given the dynamic nature of the lithium market, in the six-year period, an increase in global battery production may lead to a decrease in lithium battery prices, among other risks. At that point, Bolivia may have a hard time catching up and finding profitability in the cathode and battery markets.
With these considerations in mind, it is apparent that Bolivia faces high uncertainty and risk shall it choose to continue with its plans for vertical integration. It is a possibility that even if brine extraction is unprofitable, the state proceeds with its plans for politically motivated reasons. If the main objective of lithium extraction is to increase social well-being and the lithium project is unprofitable, funds may be better spent on social programs.

**Provide indigenous communities a true FPIC process.** Though the legal framework for protection of local indigenous communities is in place to safeguard these communities, Bolivia has thus far not respected FPIC rights. Section 4 of this thesis will provide recommendations on how to do so.

**Increase environmental transparency.** Currently, the state discloses minimal information about the lithium project, which keeps the Bolivian people uninformed about project details and its social impact. As section 4 will elucidate, environmental information can serve as a tool to safeguard communities. Thus, it is imperative that the state increase its provision of publicly accessible information regarding the state lithium project.

**Increase (high skill) employment opportunities for Bolivians.** Employment opportunities in parts of the lithium project necessitating more specialized knowledge are limited. If Bolivia hopes to increase its autonomy, it should invest in equipping a larger percent of the Bolivian labor force with the knowledge and expertise necessary to operate the lithium project. Bolivia should also consider implementing local employment quotas – not limited to high skill employment – particularly for public-private partnerships projects, while ensuring labor conditions are adequate.

**Consider addressing stipulations about distribution of royalties.** Though Bolivia is not yet producing significant amounts of lithium, if it hopes to increase its lithium production, it
should be prepared to address issues with distribution of revenues given the worsening rural and urban social divide. In consideration of the fact that 100 percent of mining royalties go to the departmental government, without further specifications that would designate certain quantities to rural versus urban regions, problems may arise (Sanchez-Lopez 2019). Preventative measures should be taken, such as making specifications about royalty distribution, especially in light of growing urban-rural tensions.

**Lithium Extraction in Chile**

**Salar de Atacama**

The Salar de Atacama in northeastern Chile is the country’s largest source of lithium – the third largest salar in the Lithium Triangle, following the Salar de Uyuni in Bolivia and Salar de Hombre Muerto in Argentina – though there are 60 other salares in the country (van Pampus et al., 2023, p. 2; Maxwell & Mora, 2020, p. 58). Chile’s two largest brines together make up 64 percent of world reserves (Cabello, 2021). Furthermore, Chilean salares enjoy high quality brines (high lithium concentration), adequate climatic conditions, and proximity to ports. Consequently, production costs of lithium extraction are some of the lowest in the world (Cabello, 2021, p. 2; Lunde Seefeldt, 2020, p. 739).

The only currently ongoing lithium operations are in the Salar de Atacama, which experiences brine with a high lithium concentration, moderate magnesium to lithium ratio, and low dilution due to minimal rainfall (Gobierno de Chile, n.d.; Muñoz et al., 2023, p. 65). From the period of 1996 to 2019, lithium production (overwhelming in the form of lithium carbonate) in Chile has increased from 14.2 million tons to 111.2 million tons of lithium at an average annual growth rate of 9.4 percent (Jorratt, 2022).
Management of Lithium Extraction in Chile

In 1979, lithium became a non-concessionable and strategic resource amid interest in its nuclear fusion applications, especially relevant during the Cold War. Lithium remains categorized as a strategic resource today. New lithium projects must be approved by the Chilean Nuclear Energy Commission, (CCEN) (Bustos-Gallardo et al., 2021). The economic development agency, Production Development Corporation (CORFO), regulates lithium mining operations in the Salar de Atacama (Gobierno de Chile, n.d.).

The Chilean state holds ownership over lithium resources, but unlike Bolivia, allows private entities to develop them. To engage in lithium extraction or value-added operations, private companies must enter a direct partnership with CORFO in the Salar de Atacama and with the state-owned copper mining company, Codelco, in the Salar de Pedernales. The state retains a majority share in public-private partnerships (Gobierno de Chile, n.d.).

Brine operations in the Salar de Atacama commenced in 1984 under operations by Sociedad Chilena de Litio Ltda. (SCL), followed by SQM in 1995 (Maxwell & Mora, 2020, p. 58). Currently, U.S.-based Albemarle and Chilean Sociedad Química y Minera de Chile S.A. (SQM) – both private companies – have lithium operations in the Salar de Atacama, operating through lithium concessions given to CORFO in 1979 before changes to mining law restricted exploitation of lithium to the state, state enterprises, or private firms awarded a presidential decree (Bustos-Gallardo et al., 2021, p.182; Estrategia Nacional del Litio). To an extent, the non-concessionable assignation given to lithium explains the lack of new lithium brine operations in the last two decades (Maxwell & Mora, 2020, p. 68). Maxwell and Mora argue that for the Chilean lithium industry to be a lithium market leader, reclassification of lithium from non-concessionable to concessionable is necessary (2020). However, Chile sees keeping lithium as
non-concessionable as an enabler for a mutually beneficial relationship between state and private companies (Gobierno de Chile, n.d.). This may be because the limited concession area keeps supply at a level that does not suppress the world price.

**Contracts.** In 2016 and 2018, with the approval of CCEN, CORFO renegotiated contracts with Albemarle and SQM, respectively, to increase annual production quotas (Maxwell & Mora, 2020, p. 68). The goal of recent negotiations between the government agency and mining companies was to increase captured rents from mining companies and community protections.

In the new contracts with SQM and Albemarle, CORFO establishes staggered, progressive, and marginal commission rates for lithium carbonate and hydroxide that depend on the sale price of lithium products. Over the last decade, Chile has captured 36 percent of economic rents from lithium, and after implementing the marginally progressive royalty scheme, it has been able to increase its capture of rents (Jorratt, 2022). Contracts with SQM and Albemarle are set to expire in 2030 and 2043, respectively (Gobierno de Chile, n.d.). Negotiations are planned to take place upon contract expiration.

<table>
<thead>
<tr>
<th>Price Range (USD/TON)</th>
<th>Lithium Carbonate (Albemarle and SQM)</th>
<th>Lithium Hydroxide (SQM)</th>
<th>Staggered, Progressive and Marginal Commission Rates (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 4,000</td>
<td>0 – 5,000</td>
<td>6.8</td>
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<tr>
<td>&gt; 4,000 – 5,000</td>
<td>5,000 – 6,000</td>
<td>8</td>
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<td>&gt; 5,000 – 6,000</td>
<td>6,000 – 7,000</td>
<td>10</td>
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<td>&gt; 6,000 – 7,000</td>
<td>7,000 – 10,000</td>
<td>17</td>
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<tr>
<td>&gt; 7,000 – 10,000</td>
<td>&gt; 10,000 – 12,000</td>
<td>25</td>
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<td>&gt; 10,000</td>
<td>&gt; 12,000</td>
<td>40</td>
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Source: Muñoz et al. (2023)
**SQM contract.** The 2018 contract renegotiation between CORFO and SQM stemmed from corruption-related issues and complaints about environmental damage (Mejia-Muñoz & Babidge, 2023, p. 1128). In the contract, SQM committed 1.7 percent of annual sales, equal to US $13,171,294, until 2030 when the contract expires. The contribution is divided as follows:

- 1 percent to Antofagasta Regional Government for public investment
- 3 percent to Antofagasta Regional Government for product development
- 2 percent to Municipality of San Pedro de Atacama
- 1 percent to Municipality of María Elena
- 1 percent to Municipality of Antofagasta

SQM also committed US $14 million per year to promote sustainable development and investment projects within the salar’s indigenous communities and US $10.8 million per year to research and development efforts (SQM, 2023).

The contribution of 1.7 percent of annual sales poses a risk for communities expecting to benefit, primarily due to the uncertainty of the lithium sale price and supply. For instance, if lithium sales are low in a given year, communities may receive a subpar monetary benefit. The uncertainty complicates the determination of whether SQM’s commitment is a fair deal for communities. It is also important to note that a commitment to “public investment” provides SQM leeway to use funds in a way that appears to benefit the local community but may actually serve SQM’s operations. For example, the construction of roads may seem like an investment in local infrastructure, but if the roads mainly serve to increase accessibility to lithium mines, mining companies become the main benefactors of funds intended to increase community well-being.
National Lithium Strategy. Seeing high demand for and prices of lithium as an opportunity for economic development in a lithium-rich Chile, current president Gabriel Boric aims to expand the lithium industry sustainably and with respect for community (e.g., indigenous) rights (Gobierno de Chile; n.d.). In April of 2023, Boric announced the launch of a new National Strategy for Lithium, which proposes the creation of a new national lithium company, Empresa Nacional del Litio (subject to the approval of Congress), that would partner with private companies at every point in the production process, from extraction to value addition. The plan emphasizes the importance of community engagement in the expansion of the lithium industry, in line with international agreements ratified in Chile (i.e., ILO Convention 169 (FPIC), Escazú Agreement). The national lithium strategy plans:

- To start a process of dialogue and participation with various stakeholders
- To create the National Lithium Company
- To create a Protected Salt Flats Network, and to ensure the use of technologies with low environmental impact in salt flats under exploitation
- To modernize the institutional framework
- To create a Public Technological and Research Institute of Lithium and Salt Flats
- To incorporate the State in the productive activity of the Salar de Atacama
- To prospect in other salt flats

The plan also entails granting exploration contracts to private companies and public-private partnerships, awarded through a transparent bid process. To partake in bidding, companies must disclose a local and supply chain value creation plan, environmental impact estimation, and reports of information collected, among other requirements (Gobierno de Chile, n.d.).
Socioecological Concerns

Social opposition. The 2018 contract renewal between CORFO and SQM, which increased the lithium production quota through 2025, faced social discontent, as observed during a 2019 demonstration in Santiago. Social movements at the local and national levels against the current Chilean model of lithium extraction and production are driven by concerns, including water-intensive brine extraction, misconduct of mining operations, corruption, and foreign investments in lithium. In recent years, social activism has grown from a local to a national scale (Liu & Agusdinata, 2020, p. 9).

Employment. In terms of employment opportunities, SQM and Albemarle must comply with local employment quotas. Those hired from local communities have historically made up a minority of the labor force in lithium operations and are typically offered low-skill, low-wage positions. Moreover, Liu and Agusdinata (2020) finds that when comparing the periods of 1997-2002 to 2012-2017, lithium mining increased labor influx by 2.3 times, but employed local labor declined from 52 percent to 18 percent. The issue with hiring non-local laborers is that they contribute only marginally to the local economy (p. 8). Local workers demand improvements to poor employment conditions and compliance with local employment quotas. Mining companies have laid off local employees, attributing layoffs to inability of workers to comply with safety standards, alcoholism, and unexcused absences (Gundermann & Göbel, 2018, p. 478).

Environmental impacts. Mining companies must submit Environmental Impact Statements, or in cases where the proposed project has one major impact, they must submit an Environmental Impact Assessment. A project may require an EIA when they may potentially involve health risks, adverse effects on renewable natural resources, resettlement, or significant impacts on communities, among other impacts (Fernández & Alba, 2023, p. 6). Environmental
and social impact studies in the Salar de Atacama are primarily conducted by mining companies. Companies claim that, according to their studies, there is no evidence of a causal relationship between brine pumping and hydrological imbalances. One environmental impact analysis conducted by a non-mining entity finds that lithium brine extraction from the Salar de Atacama has in recent years manifested in the form of loss of vegetation and fauna, decrease in water availability, and alterations to the balance of microbial communities, which poses threats to the food web (Garcés & Álvarez, 2020). According to the United Nations Conference on Trade and Development (2020), lithium and other mining activities consume 65 percent of water in the Salar de Atacama, leading to the depletion of groundwater, soil contamination, and causing displacement. Despite these findings, the limited scientific research conducted by non-mining entities makes it difficult to confidently refute claims made by mining companies about their lack of environmental impact. In spite of community skepticism about mining companies’ environmental studies, the Chilean government remains on the sidelines of the debate (van Pampus et al., 2023).

**Legal classification of water.** Brine is approximately 25 percent salt and 75 percent water by mass, but it is not considered water in Chile (Ejeian et al., 2021, p. 1). Instead, the Chilean mining law establishes brine from salares a mining resource, impeding the application of water extraction limits or regulations on brine (Jerez et al., 2021, p. 8). While mining operations must submit an Environmental Impact Statement, they do not have to request water rights since brine is not subject to the Water Code (Fernández & Alba, 2023, p. 11). The classification of brine as a mining resource is rationalized by the fact that it has no other function (e.g., for drinking or agriculture) due to its saltiness.
Freshwater usage calculations reflected in mining company reports only account for water from aquifers and streams used for industrial processing of brine, not the massive volumes of brine extracted to undergo evaporation (Jerez et al., 2021, p. 6). For example, SQM claims to extract 1700 liters per second (l/s) of brine and 240 l/s of water; Albemarle extracts 442 l/s of brine and 24 l/s of water (Bustos-Gallardo et al., 2021, p.186). According to Ingrid Garces, a professor at the University of Antofagasta, SQM and Albemarle report that they use more than 226 million liters of water daily (Chile Sustentable, 2019).

Despite high rates of brine extraction, the mining company SQM has conducted studies suggesting the limited connectivity between brine and less saline aquifers, allowing them to gain government approval to continue extraction under the premise that brine extraction does not affect water resources. The alleged separation allows mining companies to absolve themselves of accountability amid community opposition regarding the detrimental effects of brine extraction on the wetland ecosystem and local communities. In the midst of SQM’s legal troubles with the Chilean state upon discovery of environmental (and other) violations, the Superintendency of the Environment (SMA) discovered high uncertainty as to whether SQM’s premise is correct. Following this conclusion, renegotiations between SQM and SMA outlined a plan for SQM to reduce its water and brine quotas and to conduct improved modeling (Fernández & Alba, 2023). The SMA’s response to environmental violations demonstrates some level of competency in addressing environmental oversteps by mining companies. More broadly, this occurrence emphasizes the importance of the state monitoring (e.g., through the SMA) the environmental conditions of lithium mining regions.

Notably, Bustos-Gallardo et al. (2021) points to the flexibility of brine’s classification (brine or water) to the convenience of mining companies. When extracting brine, mining
companies do not classify brine as water. However, when lithium producers that choose to reinject brine do so, they classify brine as water to bypass regulation for underground chemical injection.

A 2020 report by the Chilean Ministry of Mining discusses brine in the context of “brine-waters” (a type of hybrid) and the potential impact of brine extraction on water balances. However, the only clear call to action is the consideration of brine water in water balance research conducted by Chile’s General Water Department (Fernández & Alba, 2023). The legal classification of brine affects the socioenvironmental impacts of lithium extraction, indicating the need for further discussion in government-community circles about the classification of brine.

**Cultural significance of water.** From a commercial and colonial point of view, water is solely a resource for survival and commodity. For the Atacameño people, however, water forms an integral part of their Andean cosmovision, as well as social, political, and cultural organization within towns and communities. Moreover, they believe in the interconnectedness of all bodies of water in the salar (Jerez et al., 2021, p. 9; van Pampus et al., 2023, p. 3). The former view is enforced on indigenous communities in the Salar de Atacama, signaling the culturally insensitive nature of the classification of water as a mineral resource and its massive level of extraction.

**Community Participation.** An Environmental Impact Statement or an Environmental Impact Assessment is required for prospective mining operations. The former does not require community participation, though citizens can request a participatory process that is only approved if the government body evaluating environmental risks finds evidence of environmental burden. In the case of an Environmental Impact Assessment, community participation is mandatory. In accordance with the ILO Convention 169, consultation of
indigenous communities is required for companies submitting an Environmental Impact Assessment. It is important to note that consultation does not mean consent; even if communities oppose the approval of a project, the government may decide to approve a project (Mejia-Muñoz and Babidge, 2023, p. 1129). The state is not directly involved in the consultation process; private companies interact directly with communities in the region surrounding the Salar de Atacama (Petavratzi et al., 2022, p. 685).

**Albemarle-community agreement.** An example of community-mining company negotiations is that of the shared benefits agreement between the indigenous association, the Atacama Indigenous Councils (CPA), and Albemarle. The negotiation resulted from a mandatory community participation process upon submission of an Environmental Impact Assessment. Following negotiations, Albemarle was granted project approval in 2016. The agreement establishes a permanent working group, composed of equal representation from Albemarle and the CPA. The contract specifies the following contributions (O’Faircheallaigh & Babidge, 2023):

- An annual contribution of the equivalent of US $20,400 to the Andean boarding school
- 2016: payment of US $2,032,240 to three communities;
- If the environmental qualification resolution of the project (an RCA) is unfavorable, from 2017 onwards an annual contribution of US $2,075,760;
- If the RCA is favorable, payment in 2017 of 2.75 percent, and from 2018 of 3 percent, of the annual sales of lithium carbonate and potassium chloride produced based on the extraction of brine from the company's salt flat plant. The contribution is calculated annually on the basis of sales in the preceding calendar year;
- From 2018 onwards, a total annual contribution of US $76,400 to finance the granting of study scholarships;
From 2017 onwards an annual contribution of US $30,560 each to two Atacama associations for projects or activities.

Though the contract also addresses the protection of water resources, there are no specific stipulations for achieving broad environmental goals in the contract. In the agreement, the CPA urges the Chilean government to increase measures to protect indigenous communities. Compared to international standards, Albemarle’s commitments to the CPA are substantial (O’Faircheallaigh & Babidge, 2023).

The negotiations and agreement between Albemarle and the CPA can be considered a community development agreement (CDA), in which mining companies and communities negotiate to ensure direct benefits to communities impacted by mining operations, mitigate mining-related harm to communities, and prevent community-company conflicts. A common central component of CDAs in resource extraction is stipulations regarding the mitigation of environmental damages. While the Albemarle-CPA agreement sets forth financial compensation, it fails to hold Albemarle accountable for environmental impacts – a major concern of lithium mining, especially as it pertains to water usage. Thus, while the agreement forms the foundation of a CDA, it fails to address important considerations, increasing the risk of future conflict. It is worth mentioning that Albemarle’s inclination to negotiate with communities is likely a strategic move as it plans to expand its lithium production (Gundermann & Göbel, 2018, p. 484). CDAs will be further discussed in section 4.

**Intra-community conflict.** An estimated 11,000 people live on the eastern boarder of the salar, most of which are indigenous, depend on the water in the region (van Pampus et al., 2023, p. 3). The Atacameño/Lickanantay people are the eighteen indigenous communities (Río Grande, Machuca, Catarpe, Quitor, San Pedro de Atacama, Solcor, Larache, Yaye, Séquitor, Cúcuter,
Cuahutencos 46

Coyo, Toconao, Talabre, Camar, Socaire, Peine, Solor y Huatin) living within the Salar de Atacama. They are collectively represented—especially in political and cultural matters—by the CPA, though qualitative analyses demonstrate that there is growing uncertainty and distrust in the association (Blair et al., 2022; Fernández & Alba, 2023, p. 4; Lorca et al., 2022). Intra-community tensions arose because only those recognized as members of the CPA have participated in the negotiations with lithium mining companies, leading excluded communities to feel powerless. In addition, the CPA’s overemphasis on unification and consequent neglect of the differing community desires in negotiations, mining companies have begun to bypass the CPA and negotiate with specific mining-impacted communities. Amid conflicts, the state has taken a backseat, opening the door for companies to significantly influence the restructuring of social dynamics in the Salar de Atacama (Lorca et al., 2022). Companies have opted to fragment communities through the distribution of uneven benefits, which Lorca argues diminishes their ability to unite and resist mining operations (2022).

**Recommendations for Chilean Lithium Extraction**

**Increase enforcement of compliance with local employment quotas and provision of adequate work conditions. Invest in capacity building within local communities.** Though SQM and Albemarle have local employment quotas in place, concerns among local communities about the lack of access to well-paying jobs with adequate work conditions underscores the need for government action (e.g., by adequate state agency). Particularly, enforcement of local employment quotas and acceptable working conditions is necessary. It may be that shortage of specialized or high-skill employment opportunities for local communities stems from a need of adequate preparation for entering those positions. Chile may find it beneficial to invest in
capacity building and training of its labor force, particularly within communities near mining regions.

**Reclassify brine as water.** Brine’s classification as a mining resource impedes regulations that may diminish hydrological alterations, preventing water depletion – a key concern for local communities. Thus, reclassifying brine as a water resource would require that companies also request access to water rights and face more stringent conditions when extracting brine. Companies would potentially reconsider their rates of extraction in a way that would minimize environmental and social damage. Additionally, the reclassification of brine as water would respect the cosmovision of local indigenous communities.

**Increase state monitoring of environmental compliance.** SQM’s inaccurate reporting of its environmental impact, which was only discovered amid other legal troubles, suggests the need for increased state monitoring of environmental compliance. The SMA should conduct its own environmental impact assessments to ensure that company reporting is accurate and gain an increased understanding of the hydrological impacts of brine extraction in the Salar de Atacama.

**Increase community protection by improving the CDA model.** The Albemarle-CPA agreement is a step in the right direction for increasing community participation; however, it lacks adequate environmental mitigation measures. In consideration of intra-community conflicts related to exclusion from negotiations, mining companies need to ensure that they have adequately identified impacted communities and are compensating all impacted communities fairly. More detailed information on CDAs is discussed in section 4.

**Cautiously invest in expansion of lithium industry.** With favorable geological and climatic conditions that allow for low operation costs, Chile’s lithium industry has a clear
advantage both in the Lithium Triangle and internationally. However, in light of national-level concerns about lithium extraction, Chile needs to assure that it attends to socioenvironmental concerns both to protect the well-being of its people and minimize conflicts that may disrupt expansion of its lithium industry. Given the various risks of lithium extraction, further discussed in section 3, Chile needs to invest cautiously in its lithium industry. If Chile plays its cards right, it may be able to increase social well-being through lithium extraction.

Lithium Extraction in Argentina

Salares in Argentina

Salares in Argentina are in the Puna region of the Andean plateau. Current production of lithium – processed mostly into lithium carbonate – in Argentina comes from the provinces of Catamarca, Jujuy, and Salta (González & Snyder, 2020, p. 212; Gonzalez & Snyder, 2023, p. 53). Lithium extraction in Argentina commenced in 1998 in the Salar de Hombre Muerto in Catamarca. Lithium is currently extracted from the Salar de Olaroz in Jujuy and Salar de Hombre Muerto in Salta and Catamarca (Heredia et al., 2022; Oxford Analytica, 2021, p. 29390). Though there are 50 mining projects in pre-production stages (i.e., 42 percent in advanced exploration), only three are currently producing lithium. Australia-based Allkem extracts lithium in the Salar de Olaroz, operating its Olaroz project. Minera Exar, a joint venture between Lithium Americas Corp and China-based Ganfeng Lithium, also extracts in the Salar de Olaroz, operating its Cauchari-Olaroz project. US-based Livent extracts in the Salar de Hombre Muerto, operating its Fénix project (Ministerio de Economía Argentina, 2023). During 2001 to 2019, an average annual production growth of 13 percent was observed (Jorratt, 2022).

Despite its smaller surface size, Argentina’s Salar de Olaroz enjoys a mean lithium concentration that is competitive with Chile’s Salar de Atacama (see table below). The Salar de
Hombre Muerto experiences a mean lithium concentration that is approximately half of that of the Salar de Olaroz. Compared to Bolivia’s Salar de Uyuni, Argentina salares currently undergoing lithium extraction seen to have somewhat of an advantage (López Steinmetz et al., 2020).

<table>
<thead>
<tr>
<th>Salar</th>
<th>Surface (km²)</th>
<th>Altitude (m a.s.l.)</th>
<th>Mean [Li] (mg L⁻¹)</th>
<th>Mean [Li/Mg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uyuni</td>
<td>10,580</td>
<td>3,970</td>
<td>316⁻⁵⁻⁶⁰²ᵇ</td>
<td>0.07ᵃ⁻⁰.⁰⁹ᵇ</td>
</tr>
<tr>
<td>Atacama</td>
<td>3,000</td>
<td>2,305</td>
<td>1,400</td>
<td>0.16</td>
</tr>
<tr>
<td>Jama</td>
<td>25</td>
<td>4,080</td>
<td>82</td>
<td>0.42</td>
</tr>
<tr>
<td>Olaroz</td>
<td>130</td>
<td>3,903</td>
<td>1,014</td>
<td>0.89</td>
</tr>
<tr>
<td>Cauchari</td>
<td>80</td>
<td>3,903</td>
<td>860</td>
<td>0.86</td>
</tr>
<tr>
<td>Salinas Grandes</td>
<td>280</td>
<td>3,410</td>
<td>332</td>
<td>0.5</td>
</tr>
<tr>
<td>Guayatayoc</td>
<td>140</td>
<td>3,400</td>
<td>96</td>
<td>0.92</td>
</tr>
<tr>
<td>Centenario</td>
<td>7</td>
<td>3,816</td>
<td>141</td>
<td>0.2</td>
</tr>
<tr>
<td>Diablillos</td>
<td>4</td>
<td>4,032</td>
<td>180</td>
<td>0.26</td>
</tr>
<tr>
<td>Hombre Muerto</td>
<td>300</td>
<td>3,970</td>
<td>570⁻⁵⁻¹⁻⁵²⁰ᵈ</td>
<td>0.92⁻⁰.⁸⁸ᶜ</td>
</tr>
<tr>
<td>Incahuasi</td>
<td>18</td>
<td>3,269</td>
<td>95</td>
<td>0.01</td>
</tr>
<tr>
<td>Pastos Grandes</td>
<td>27</td>
<td>3,780</td>
<td>483</td>
<td>0.19</td>
</tr>
<tr>
<td>Pozuelos</td>
<td>75</td>
<td>3,663</td>
<td>401</td>
<td>0.43</td>
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<td>Ratones</td>
<td>3</td>
<td>3,822</td>
<td>158</td>
<td>1.24</td>
</tr>
<tr>
<td>Antofalla-Botijuelas</td>
<td>655</td>
<td>3,330</td>
<td>209</td>
<td>0.64</td>
</tr>
<tr>
<td>Arizaro</td>
<td>1,708</td>
<td>3,474</td>
<td>191</td>
<td>0.16</td>
</tr>
<tr>
<td>Pocitos-Quirón</td>
<td>450</td>
<td>3,663</td>
<td>57</td>
<td>0.17</td>
</tr>
<tr>
<td>Rincón</td>
<td>250</td>
<td>3,725</td>
<td>281⁻⁴⁻⁰⁰ᵉ</td>
<td>0.24</td>
</tr>
<tr>
<td>Río Grande</td>
<td>56</td>
<td>3,668</td>
<td>396</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Source: López Steinmetz et al. (2020)⁵

⁵ See text Table 2
Management of Lithium Extraction in Argentina

Argentina has no federal-level regulatory framework for lithium. Decisions occur at the provincial level since provinces are the “original owners” of natural resources within their territorial boundaries (Gonzalez & Snyder, 2023, 56; Heredia et al., 2022, p. 142). The legal owners of lithium, as with other minerals, can transfer ownership, which awards concession rights (Oxford Analytica, 2021, p. 29390). Even after concessions are awarded, the province remains the original owner of the resource (Ministério de Desarrollo Productivo Argentina, 2022). Concessions allow entities (including private individuals or companies) to explore and develop lithium deposits.

The 1994 constitutional reform awards provincial governments the right to regulate mining, which includes issuing and revoking mining permits and enforcing compliance with mining laws. They can also levy royalties and other contributions for mining activity. Provincial governments receive these mining revenues (Ministério de Desarrollo Productivo Argentina, 2022; Gonzalez & Snyder, 2023; Oxford Analytica, 2021, p. 29391). Mining operations must comply with federal and provincial mining rules. Specifically, at the federal level, they must comply with Argentine Mining Code, which establishes minimum environmental protection requirements (e.g., mining, taxes, issues that involve multiple provinces). Since provinces can establish supplementary environmental protection laws, mining operations must also comply with the provincial mining rules applicable to the province they are operating in (Oxford Analytica, 2021, p. 29391). Mining laws may differ across provinces. Concessions do not have an expiration, nor do they have annual extraction quotas (Silva, 2023). Upon obtaining a concession, an entity must pay an annual fee and make investment commitments, keep the mine active, and abide by Mining Code conditions (Ministério de Desarrollo Productivo Argentina,
The decentralized structure, requiring mining companies to abide by both federal and provincial regulations and policies, makes way for a complex and convoluted governance system (Petavratzi et al., 2022, p. 690).

**Annual fees and royalties.** The Mining Administration of each province oversees concessions for lithium mining, which are awarded for a surface of up to 100 hectares. In addition to the annual fee paid to the national government, mining companies must also pay annual royalty of up to three percent of the whole extracted resources to the province where they hold a concession (López Steinmetz & Fong, 2019, p. 4). Royalties collected by the national government are funneled into the national budget; provincial royalties are funneled into the corresponding provincial government’s budget. In the last 10 years, Argentina has been able to capture 28 percent of economic rents from lithium extraction done by private companies – eight percentage points lower than Chile (Jorratt, 2022).

**Incentives for foreign investment.** Unlike Chile and Bolivia, Argentina does not classify lithium a strategic resource (Petavratzi et al., 2022, p. 687). As a result, the concession-seeking process is easier to navigate in Argentina. It is important to note that some provinces have designated lithium a strategic resource. Furthermore, Argentina provides miners incentives for extraction: miners pay a royalty of three percent, the tax rate remains fixed for 30 years, no annual extraction quotas, concessions with no expiration (Silva, 2023). Jorratt (2022) finds that private companies have been refunded amounts generally higher than the royalty. Also, the royalty is lower than the Free on Board value of exports. Argentina’s emphasis on drawing in foreign investment has materialized in the form of new plans for salar development. Elon Musk, who aligns with President Milei’s free-market beliefs, has demonstrated interest in Argentina salares (Debre, 2024). The Argentine government notes that in 2023, Australian and Asian
companies took the lead in terms of salar investment announcements (Ministério de Economía Argentina, 2023).

Argentina provides more incentives for foreign investment than its Lithium Triangle counterparts, seemingly at its own expense in terms of its capture of resource rents. The high incentives for foreign investment may be an attempt to compensate for poor local infrastructure, high inflation, and political instability. To illustrate the latter, civil unrest in response to President Javier Milei’s devaluation of the Argentine peso by more than 50 percent and plans for austerity measures (Nicas & Herrera, 2024). Investors may be willing to overlook those risks in light of strong incentives for lithium extraction investments.

**Provincial differences.** The provinces of Salta and Catamarca choose to have little oversight in mining activities, while Jujuy is more active in extraction and processing as a minority shareholder in lithium mining projects through the state-owned enterprise Jujuy Energía y Minería Sociedad del Estado (JEMSE). JEMSE is a public-private partnership. Jujuy declared lithium a strategic resource in 2016 (Gonzalez & Snyder, 2020, p. 216).

**Environmental regulations.** Argentina’s Mining Code requires that parties interested in exploring or extracting lithium (or any mineral) must submit an Environmental Impact Assessment to the provincial authority. Approved assessments are followed by an Environmental Impact Statement issued by the provincial enforcement authority, granting individuals or entities the ability to explore or extract. The statement is valid for two years and contains conditions and requirements that must be fulfilled to keep the permit. After two years have passed, entities must submit an updated Environmental Impact Statement (Ministério de Desarrollo Productivo Argentina, 2022).
**Water law.** Per mining code and water laws, brine in Argentina is considered both a mineral and water resource, meaning that mining companies must obtain both a mining and water concession. Provinces may have additional regulations for brine that companies may have to comply with. In the case of Jujuy, water concessions are at odds with mining concessions, requiring urgent revision of water (or mining) laws (López Steinmetz & Fong, 2019). For mining companies having to comply with federal, provincial, mining, and water laws, navigation of Argentina’s lithium governance is complex.

**Socioecological Concerns**

**Demographics.** As of 2022, 40 percent of Argentines live in poverty (Rodriguez Chamussy, 2023). The lithium-extracting provinces of Jujuy, Salta, and Catamarca have relatively high poverty rates (Dorn, 2021, p. 76). Thus, equitable and strategic investment in lithium extraction may serve as a poverty alleviation mechanism for Argentina, especially communities near extraction sites.

**Employment.** The Argentine government finds that as of December 2022, lithium mining provided 2,531 jobs (26 percent female), representing a 57 percent year-on-year increase (Ministério de Economía Argentina, 2023, p. 27). Despite reports by the Argentine government about the positive employment outcomes, the accuracy of employment data is questionable, given discrepancies between company and government employment information, with the latter reporting higher values. Specific to company employment data, skepticism about methodology raises concerns about the validity of the data. For instance, there are concerns that to satisfy provincial employment quotas, companies ask employees to falsely register themselves as belonging to a specific region. Provincial employment quotas required of companies operating in Salta and Catamarca, but not Jujuy (Lender 2023, 92-97).
While lithium production proponents, especially mining companies and political elites, promise increasing social well-being via various mechanisms, including employment generation (at a local, regional, and national scale), studies conducted by non-governmental or mining entities suggest that lithium mining in Argentina has yet to fulfill that promise. Lende (2023) finds that in lithium-producing provinces, the lithium industry accounts for about half of foreign trade yet makes up about one to two percent of formal labor opportunities. Workers of the lithium industry in Argentina also experience high levels of exploitation and precarity, with a labor intensity ten times lower than the average for the Argentine economy. Escosteguy et al. (2023) supports this, finding that salar workers have claimed workers' rights violations, citing extreme working conditions and unpaid overtime hours.

Furthermore, a qualitative study focusing on the main concerns shared by community members in the areas around the Salar de Olaroz and Fénix in Argentina indicates community dissatisfaction with employment opportunities related to lithium mining, namely about the limited employment opportunities for local communities. The analysis finds that the workforce is comprised of non-local workers and even when local community members are offered employment at lithium production facilities (usually only workers from areas adjacent to extraction sites), it is usually only low-skill employment opportunities during the construction stage of a project (Escosteguy et al., 2023, p. 229). That is, lithium facilities at the Salar de Olaroz and Fénix are mainly dependent on outside (non-local) labor, especially for high-skill jobs.

**Violations of Free, Prior, and Informed Consent.** Argentine law promises indigenous communities a free, prior, and informed consent process (FPIC) prior to mining activity in accordance with various regulations, including the ILO Convention 169 (Escosteguy et al.,
Provinces are responsible for ensuring that adequate consultation processes take place. Without FPIC, mining companies cannot commence operations. Despite the legal framework in place intended to protect local and indigenous communities, there has been a clear implementation gap.

In 2010, in early stages of salar exploration, 33 indigenous communities from Salinas Grandes and Laguna de Guayatoayoc (in the provinces of Jujuy and Salta) created a protocol—Kachi Yupi—to ensure that indigenous communities are given a true FPIC process in the provincial governments’ assessments of potential mining activities (Kachi Yupi – Huellas de la Sal, 2015; Kingsbury, 2023, p. 594). One main point of emphasis in the protocol (completed in 2015) is the demand for a culturally sensitive and symmetrical negotiated extraction, in which there is “mutual respect between the parties” and “full and effective participation” (Kachi Yupi – Huellas de la Sal, 2015). The pro-business governor of the Jujuy province, Gerardo Morales, however, rejected the proposed FPIC protocol.

In 2019, an occurrence of unnegotiated extraction by the Canadian mining company A.I.S. led the 33 communities to protest in Jujuy. The government ignored community discontent, instead issuing a tender for new lithium projects in Salinas Grandes and Laguna de Guayatayoc in 2019 (Gonzalez & Snyder, 2023, p. 60). The Argentine state-run company, JEMSE, issued a tender for seven areas as recently as November 2022, which communities only found out about through the newspaper, signaling the persistent disregard of FPIC rights and consideration of socioecological impacts (Jujuy Dice, 2023). Large mobilization against lithium extraction in the region has persisted, taking the form of blockades, creating alternative reports, lawsuits, protests, and more. Mining operations were halted. In response, in 2023, the Ministry of Production and the Mining Environmental Management Unit met with one municipality to
discuss community concerns. However, other communities protested, claiming that the detrimental impacts of water are felt regionally, not just at a municipal level (Jujuy Al Momento, 2024).

In 2020, communities living near the Fénix project in the Salar de Hombre Muerto protested due to a violation of their right to FPIC. An aqueduct to redirect water for lithium extraction was built without prior consultation with local communities (Escosteguy et al., 2023, p. 230). In addition, communities report occurrences of intrusion into communities’ land for lithium extraction purposes near the Fénix project (Clavijo et al., 2022, p. 300).

**FPIC compliance.** Though many lithium projects in Argentina have violated community rights to some degree, the negotiations between communities in the Olaroz-Cauchari region and Orocobre demonstrate a relatively better case of community-mining company relations. Orocobre made case-by-case agreements with indigenous communities in the area, promising employment, annual payments, a new school, and internet access. Despite short-term benefits, communities in the area have started to experience displacement due to water shortages (Gonzalez & Snyder, 2023, p. 61).

**Environmental (and other) impacts.** A qualitative analysis of the socio-environmental impacts of lithium extraction finds the prevalence of injustices at Salar de Fénix and Salar de Olaroz, namely unemployment issues, water scarcity, air pollution, and lack of access to basic services. Community members do not believe that the benefits outweigh the damages of lithium extraction (Escosteguy et al., 2023, p. 229). The analysis does also note, however, that some positive aspects of lithium mining were highlighted, especially in Jujuy. Communities living near the Fénix project in the Salar de Hombre Muerto blame the aqueduct for the drying up of the river that sustained the community (Clavijo et al., 2022, p. 300).
Recommendations for Argentine Lithium Extraction

**Increase capture of economic rents.** Argentina’s current royalty scheme prevents a greater capture of resource rents (Jorratt, 2022). Though this is intended to increase the attractiveness of Argentine salares in the eyes of foreign investors, Argentina may be missing out on an opportunity to increase the benefits it receives from lithium mining. In the worst-case scenario, Argentina may be losing by engaging private companies under its current royalty requirements, undermining the goal of increasing social well-being through lithium extraction.

**Increase enforcement of compliance with local employment quotas and provision of adequate work conditions. Invest in capacity building within local communities.** Communities near extraction sites lack access to well-paying jobs with adequate work conditions provided by the lithium industry. To increase local employment opportunities, the state needs to monitor and enforce compliance with provincial employment quotas given skepticism around the validity of mining companies’ employment data. The lack of high-skill job opportunities at lithium plants may be due to a lack of expertise or appropriate knowledge within the local workforce. Argentina may find it beneficial to provide its workforce, especially that of regions near lithium extraction sites, with capacity building and training. Additionally, the state needs to better enforce work condition requirements (e.g., adequate pay, a safe work environment), and, as deemed necessary, increase regulations pertaining to working conditions at lithium facilities.

**Provide indigenous communities a true FPIC process. Consult all affected communities.** Argentina has the legal framework for protection of local indigenous communities, though mining companies have repeatedly violated FPIC rights without repercussions. It is imperative that Argentina respects the rights of local communities. Section 4 of this thesis will recommend a potential framework for ensuring a true FPIC process.
Additionally, when consulting communities, state officials should include all affected communities – contrary to what was done in Jujuy in 2023 when only one municipality was consulted.

**Address inconsistencies between mining and water laws.** Due to the convoluted nature of compliance with multiple laws for lithium extraction (i.e., federal, provincial, mining, and water laws), inconsistencies have resulted between the laws. Particularly, Jujuy needs to address inconsistencies between water and mining concessions.

**Section 3: Opportunities and Risks**

In addition to the country-specific lithium opportunities and risks, the Lithium Triangle countries must consider the broader dynamics of the global lithium market. This section will first discuss the opportunities of lithium extraction, followed by the associated risks. The section will conclude with an assessment of which Lithium Triangle players are best equipped to mitigate the risks of extraction given the current state of their lithium industry and trajectory.

**Opportunities**

**Growing Lithium Demand**

Growing attention to electrification in efforts to tackle climate change has sparked interest in raw materials that are expected to be critical for energy transition infrastructure. Lithium is one of them. From 1994 to 2015, lithium consumption grew four times, reaching 31 kilotons in 2015 (Sun et al., 2018, p. 2827). The U.S. Geological Survey (2024) finds that worldwide lithium production in 2023 increased by 23 percent from 146,000 tons to 180,000 tons. On the demand side, consumption increased by 27 percent from approximately 142,000 tons in 2022 to 180,000 tons in 2023 due to strong battery demand.
Batteries are the driving force for lithium demand acceleration, as illustrated by the breakdown of global lithium end uses:

- Batteries: 87 percent
- Ceramics and glass: four percent
- Lubricating greases: two percent
- Continuous casting mold flux powders: one percent
- Medical: one percent

Batteries have driven the increase in lithium consumption due to the surge of electric vehicles (EVs) and portable electronic devices, and to an extent, that of electric tools and grid storage applications as well (U.S. Geological Survey, 2024). Thus, analyzing future lithium demand will largely depend on the growth of the lithium-ion (LIB) market. It seems likely that EV market will continue experiencing growth as EVs are currently the best candidate for achieving climate mitigation goals in transportation (Greim et al., 2020).

**Long-term projections.** The future relevance of lithium, and consequently, that of brine extraction from the Lithium Triangle, is contingent on its future demand. Projections for lithium range, partly due to differences in projections for the growth of electric vehicles and assumptions about lithium recycling. A 2023 report by the Chilean Copper Commission (Cochilco) forecasts that lithium consumption will increase from 508 kilotons of lithium carbonate equivalent (LCE) in 2021 to 3,829 kilotons LCE in 2035 – a compound annual growth rate of 15.5 percent. The forecast factors in the predicted growth of the EV market, along with other smaller lithium-demanding markets. Another paper forecasts that demand for lithium will reach 400 kilotons of

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6 LCE is used to better compare various types of lithium products with different densities (Lithium products: Different types of lithium).
lithium per year by 2050 and 857 kilotons of lithium per year by 2200, though the paper notes the large difference between various lithium forecasts (Mohr et al., 2012). Ambrose & Kendall (2020) project demand to reach between 4.4 Mt to 7.5 Mt LCE/year by 2100. In more relative terms, Maisel et al. (2023) finds that to meet the future demand for lithium by 2040, lithium production must increase by six times its current amount. Forecasts assume that lithium, especially in lithium-ion batteries, remains an essential part of the EV, though there is some uncertainty around this assumption. It is important to note that the extent of decarbonization efforts on behalf of government policies will influence future demand for lithium as well.

**Supply Shortage**

There is some concern about the possibility of a lithium supply shortage due to heightened demand. Cochilco forecasts a lithium supply shortage by 2030, which is predicted to worsen to an undersupply of 726 kilotons of lithium by 2035 (Comisión Chilena del Cobre, 2023). Ambrose and Kendall (2020) find that the current levels of lithium produced from brines will likely be able to meet demand up to 2035. After 2050, production from low-grade lithium brines (e.g., China and the US) will be necessary to keep up with demand. Another study also finds that for lithium supply to successfully meet demand in the long term (up to 2100), efficient recycling systems, lower lithium intensity electric vehicles, and vehicle-to-grid integration is necessary (Greim et al., 2020, 6). Calvo and Valero (2022) indicate that the resources to demand ratio for lithium in 2018 was 709 and is predicted to plummet to 66 in 2050, making lithium a high-risk mineral.

A lithium supply shortage is a major concern for climate change mitigation efforts relying on lithium for EVs. However, this shortage poses an opportunity for the Lithium Triangle, given that low supply and high demand yield high prices. Alternatively, concerns about
lithium supply may propel efforts to find mineral alternatives to lithium, a risk which will be discussed further in the risks section.

**Cost Advantage of Brine**

The Lithium Triangle has a unit production cost advantage over other countries, including Australia and China, primarily due to the difference in the type of lithium deposit. Lithium brine deposits have a lower average production cost compared to pegmatite resources. Even when looking specifically at China’s lithium brine deposits, its average production costs were higher compared to other countries, especially Chile and Argentina (Ambrose & Kendall, 2020, p. 84). Bolivia may not be able to reap the benefits of this cost advantage due to its low lithium concentration brine.

**Risks**

**Socioecological Concerns**

Lithium extraction’s socioecological impacts, discussed in the previous section, are a primary concern of extraction. Risks include water depletion, pollution, limited employment opportunities, negative health impacts (human and ecosystem health), among more. Lithium extraction without adequate mitigation will disadvantage local communities, defeating the purpose of extraction as a means of improving social well-being in the Lithium Triangle.

**International Competition**

The economic success of the Lithium Triangle hinges on the South American countries’ abilities to mitigate risks, including competition. In 2023, Australia led in global lithium production (47 percent), followed by Chile (24 percent), China (18 percent), and Argentina (5 percent). Hence, the Lithium Triangle’s main competitors are Australia and China, though more
countries are trying to penetrate the lithium market due to the acceleration of lithium demand. The list of market players in lithium extraction confirms this. Brine-based lithium sources were in various stages of development or exploration in Argentina, Bolivia, Canada, Chile, China, and the United States. Mineral-based lithium sources were in various stages of development or exploration in Australia, Austria, Brazil, Canada, China, Congo (Kinshasa), Czechia, Ethiopia, France, Finland, Germany, Ghana, India, Iran, Kazakhstan, Mali, Namibia, Nigeria, Peru, Portugal, Russia, Rwanda, Serbia, Spain, Thailand, Turkey, the United States, and Zimbabwe (U.S. Geological Survey, 2024). Competition poses a threat for the Lithium Triangle: an increase in supply will decrease the lithium price. Lithium Triangle countries run the risk of developing a lithium market that may become unprofitable or dominated in the long term by other global agents.

**Australia.** In 1995, Australian lithium accounted for 23 percent of global production; it is now 47 percent (Maxwell & Mora, 2020, 58). Australia holds the world’s largest spodumene (lithium hard rock) reserves. Spodumene’s high lithium content makes it the top contender among other lithium hard rock sources. As of 2023, Australia has seven mineral operations (U.S. Geological Survey, 2024). A report by the Argentine government attributes Australia’s success to its resources, infrastructure, and mining culture (González & Méndez Silvana, 2020, p. 7). In 2022, Australia exported 98 percent of its spodumene to China but, as of 2023, has shifted plans to focus on both mining and refining lithium domestically due to geopolitical tensions (Australian Government Department of Industry, Science, and resources, 2023; Frost & Abbott, 2023). This means that the Lithium Triangle’s emerging downstream segments (as all three countries are planning for) will be competing with those of Australia.
**China.** China’s lithium resources consist mostly of hard rock and continental brine deposits, following the Lithium Triangle in terms of concentration of salares. However, comparing conditions which determine the relative success of lithium production – flow gradient\(^7\), adequate quantity of material needed for building impermeable walls and floors for the ponds, low rainfall, high solar radiation and temperatures – the Lithium Triangle’s conditions are generally more favorable compared to Chinese counterparts (Kesler et al., 2012). This may not be the case for all brine comparisons between the two regions given the range of brine characteristics in both regions, but there is a general sense that the Lithium Triangle (particularly Argentina and Chile) enjoys geological and climatic conditions that give its industry an advantage over China.

China’s current lithium production focuses on hard rock deposits, rather than brine (Zheng et. Al, 2023, p. 564). Most Chinese brines in the Qinghai-Tibet plateau have high magnesium to lithium ratios, limiting China’s ability to scale up lithium production from brine extraction. China is trying to overcome this challenge by finding adequate technologies for the efficient separation of magnesium from lithium. These technologies aim to produce lithium products with high recovery rates and purity, a more challenging task when using brine with a low lithium concentration, though most projects remain at a small scale. Further research and development are necessary for China to overcome this geological challenge (Song et al., 2017). If China continues to improve its ability to extract from its low-grade lithium brines, China may be able to overcome the climatic and brine composition advantage of the Lithium Triangle’s salares. Given China’s resources, if it achieved this goal, it may result in the rapid growth of its brine extraction.

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\(^7\) The flow gradient determines how liquids, including brine, will move across the land.
Hard rock lithium extracted in the city of Yichun accounts for 40 percent of China domestic reserves, accounting for 10 percent of global lithium supply. However, China is also a lithium importer: China imports 57 percent and 23 percent of its lithium from Australia and Chile/Argentina, respectively (Yuan et al., 2023, p. 19). Notably, while China may be a competitor in terms of lithium production, it is also a key trading partner for Lithium Triangle countries. In Bolivia, China has been involved in construction of infrastructure. In Argentina, China is increasing its reach in lithium projects, while also importing Argentine lithium. In Chile, China is not involved in lithium extraction, though it also imports Chilean lithium. There are growing interdependencies between Lithium Triangle countries and China (Sanchez-Lopez, 2023).

Given China’s role as the main player in the lithium market, especially in lithium-ion battery manufacturing, it determines the spot price of lithium carbonate equivalent within the global market (International Energy Agency, 2023; Sanchez-Lopez, 2023). A deacceleration of economic growth in China, particularly within the EV market, poses high risk for Lithium Triangle countries due to China’s key position within the lithium industry.
Lithium-ion battery manufacturing capacity, 2022-2030

Source: International Energy Agency (2023)

Large-scale DLE technology. If DLE technologies develop to the extent of achieving scalability, countries with access to them will be able to produce lithium products more efficiently, giving them an advantage over countries using traditional evaporitic technology. This quest is particularly important for countries worried about the environmental impacts of lithium extraction and those unable to use the evaporitic method given brine limitations. For instance, countries with brines experiencing high levels of magnesium and low lithium concentrations would benefit. If the Lithium Triangle countries implemented effective DLE technologies that permitted large-scale production, they would benefit from reduced environmental impacts and faster production timelines. However, if other countries, especially China, achieved large-scale production using DLE technology, the Lithium Triangle would face strong competition. It is important to emphasize that given unique brine characteristics, the same DLE technology will not work everywhere.

Supply shortage: potential buffer? The lithium market is dynamic. In the last few years, new producers have entered the market, increasing the risk of driving down the lithium price. If competition increases substantially, the lithium price may fall to a point that makes extraction unprofitable – a significant loss for the Lithium Triangle countries, which are investing large sums of money into developing their industries. However, a possible supply shortage – a reoccurring concern in several lithium demand forecasts, though with high uncertainty – may mean that increasing competition will not necessarily make lithium extraction unworthwhile for the Lithium Triangle countries. For example, even in the case of a fall of the lithium price in 2023, most cost-effective lithium producers were able to continue producing
profitably (Australian Government Department of Industry, Science, and Resources, 2023, p.139). Also, as mentioned previously, studies forecasting a lithium supply shortage suggest that lower grade and currently undeveloped lithium mines will need to be exploited and further developed to keep up with lithium demand, suggesting that the Lithium Triangle will remain a relevant lithium supplier.

**Future Lithium Hydroxide Demand Exceeding Lithium Carbonate Demand**

The Lithium Triangle produces lithium mainly in the form of lithium carbonate. Though lithium carbonate currently dominates the lithium market and expects to see a continued increase in demand over the next decade, lithium hydroxide is forecasted to outcompete lithium carbonate by 2035. This is a result of battery producers’ growing preference for lithium-hydroxide-intensive batteries (i.e., nickel-lithium, cobalt, and manganese batteries) due to their high energy density (Comisión Chilena del Cobre, 2023). Lithium carbonate requires additional processing for its conversion to lithium hydroxide, meaning that a future dominated by lithium hydroxide strips the Lithium Triangle of its lithium production cost advantage (especially pertinent for Chile and Argentina).

The growth of lithium hydroxide, however, does not mean that the demand for lithium carbonate will cease to exist. Lithium carbonate is also projected to see continued growth, though at a slower pace relative to lithium hydroxide (Comisión Chilena del Cobre, 2023). Considering that several projections of lithium supply and demand forecast a lithium supply shortage, battery producers will see a need to purchase lithium, whether in the form of lithium carbonate or hydroxide. In the case of lithium supply shortage, lithium produced in the Lithium Triangle will remain relevant, especially since about half of the world’s lithium resources are found in the region. Technological developments that can facilitate the conversion from lithium carbonate to
hydroxide may arise in the next decade and allow lithium carbonate to better compete with lithium hydroxide. Additionally, potential future developments in battery technologies may also impact the demand for both lithium carbonate and hydroxide.

**Projection for lithium hydroxide and carbonate demand 2020-2035**

*Source: Comisión Chilena del Cobre (2023)*

**Price Volatility**

The lithium market is volatile. After an all-time high in 2022 and early 2023, lithium prices fell significantly due short-term lithium oversupply, the expiration of China’s EV subsidies, and EV sales falling below expected values (U.S. Geological Survey, 2024). Lithium hydroxide prices, for example, dropped from an average price of US $62,279 per ton in 2022 to US $25,327 per ton in October 2023 (Australian Government Department of Industry, Science, and Resources, 2023, p. 139). Spot market prices for lithium carbonate reached a high of $80,909 per ton of lithium carbonate in January 2023 and fell to $14,676 per ton in January 2024 (Dirección Nacional de Promoción y Economía Minera, 2024). The annual average U.S. lithium carbonate price for fixed contracts experienced the same trend, decreasing 32 percent from the 2022 value (U.S. Geological Survey, 2024). Despite the fall in prices, most lithium producers,
excluding high-cost producers including lepidolite miners in China, were able to continue producing lithium profitably (Australian Government Department of Industry, Science, and Resources, 2023, p. 139). Cochilco forecasts a continued decline in lithium carbonate and hydroxide prices in the short term (up to 2027) (Comisión Chilena del Cobre, 2023, p. 32).

Market fluctuations and uncertainty about future prices can be attributed to the rapid growth of the electric vehicle market and increase in producers in recent years. The recent volatility of lithium prices attests to the high risk and uncertainty of lithium production. Another consideration to keep in mind is that low prices are not the only concern; high prices pose another, albeit different in nature, challenge. An increase in prices may mean that other types of deposits become profitable, weakening the Lithium Triangle’s competitive advantage (Dorn & Peyré, 2020, p. 73).

Spot prices for lithium carbonate (in US $ per ton of lithium carbonate) from January 2020 values to July 2024 projections

Source: Australian Government Department of Industry, Science, and Resources (2023)
Lithium Substitutes

The lithium boom is driven by technologies that call for lithium, particularly EV batteries and to a lesser extent, grid storage batteries. Continued demand for lithium depends on lithium’s applicability in relevant technologies. Therefore, a diminished demand for primary lithium sources (i.e., extracted rather than recycled) and the development of new technologies that do not require lithium pose a risk to lithium demand. This would be bad news for the Lithium Triangle.

Recycling. Lithium-ion batteries (LIBs) are the most prevalent type of lithium battery, though environmental, health, and lithium supply shortage concerns have propelled development in lithium recycling (Fan et al., 2020). This thesis will not delve into the discussion of risks of lithium-ion batteries, though the prospect of recycling may impact the demand for raw lithium and consequently, the relevance of lithium extraction in the Lithium Triangle.

The general range for the current rates of LIBs recycled globally is between five to eight percent (Graham et al., 2021; Mao et al., 2022, p. 2732). Current recycling technologies face several barriers, including logistical issues (e.g., collection and transportation of batteries to recycling facilities and lack of battery standardization), lack of infrastructure (i.e., economic recycling facilities and processes), and lack of economic policy-established incentives (Gaines et al., 2018; Qiao et al., 2021, p. 9). Additionally, long battery service lives (and non-battery end uses for lithium) mean that recycling will not provide a substantial short-term supply of lithium (Olivetti et al., 2017).

Despite presently low rates of battery recycling, alleviation of barriers has the potential to increase rates of battery recycling and lithium recovery rates. If advancements in lithium battery recycling permit reaching sufficiently high quality and profitability, a closed-loop system in which battery manufacturers need less raw lithium is possible. Substantial policy support and
technological advancements are necessary to drive the cost of lithium recycling down and increase its prevalence. Governments have begun to show initiative. For example, in 2023, the European Union announced targets for mandatory minimum levels of recycled lithium content (six percent for several types of batteries), including EV and industrial batteries (European Union, 2023).

Possible lithium recovery rates from batteries vary, though an optimistic scenario predicts a lithium recovery rate of up to 80 percent. A scenario in which stars align for the future of battery recycling would decrease the annual demand for primary lithium by 11 percent by 2050 and 28 percent by 2100 (Ambrose & Kendall, 2020, p. 87). An optimistic future for lithium recycling would come to the benefit of countries like China, which imports much of its raw lithium, and to the disadvantage of the Lithium Triangle countries (Qiao et al., 2021). A less optimistic scenario, as predicted in Zeng & Singh (2014), expects a recovery rate for lithium in cathode materials of 51 percent. Also, it is uncertain if the lithium recovered will reach high enough purity levels to be used in new lithium-ion batteries. If not, a closed-loop system cannot be achieved (Qiao et al., 2021, p. 9). Clearly, there are several factors influencing the success of battery recycling, generating high uncertainty about the future role of recycling in lithium demand, and consequently, its impact on the Lithium Triangle.

**Other minerals.** Concerns about lithium supply risks have spurred research focused on finding alternative materials for lithium-ion batteries, especially focusing on abundant elements that are able to produce cost-efficient batteries (Nayak et al., 2018). The U.S. Geological Survey (2024) notes that calcium, magnesium, mercury, and zinc are potential lithium substitutes as anode material in primary batteries. Specific to electric vehicles, notable non-lithium-ion batteries include lead-acid, nickel-cadmium, nickel-metal-hydride, zinc-bromine, sodium
chloride and nickel, and sodium sulfur batteries. Compared to these, lithium-ion batteries are the most widely adopted in electric vehicles given their superior performance in most categories, including specific energy, energy density, high voltage, and high life cycles (Sanguesa et al., 2021, 384). Lithium’s light weight makes it an ideal raw material for battery storage, especially in comparison to other tested alternatives, including lead acid and sodium/nickel chloride batteries (Speirs et al., 2014, p.188). Despite lithium’s lead in current battery technologies, there are other alternatives to lithium-ion batteries in the early research and development stage, some of which still require lithium, while others do not. Sodium-ion batteries may become a threat to the lithium-ion large-scale storage market share if they are able to overcome challenges relating to high costs and competition with existing stationary battery technology preventing their commercialization (Chayambuka et al., 2020). This is less of a concern as battery demand is mainly driven by electric vehicles, not large-scale energy storage. Nonetheless, if developing battery technologies (especially for EVs), such as graphene and magnesium-ion batteries, overcome current technological challenges may diminish the current expected demand for lithium – a threat to the extraction of lithium in the Lithium Triangle. There is high uncertainty about the future of battery technologies, though lithium appears to have characteristics that make it a competitive material.

Substitution timeline. Despite progress in technologies with the potential to replace lithium, it is unlikely that these developments greatly affect lithium demand before 2030-2035; some sources predict timelines after 2035 (Graham et al., 2021; Herrington, 2021, p. 457). Even if recycling trends upward as expected, in an optimistic scenario, recycling can only meet 30 to 40 percent of lithium demand, indicating the continued need for a raw source of lithium (Herrington, 2021, p. 457). Moreover, Heredia et al. (2022) notes that although battery
technologies are evolving, mineral industry insiders tend to believe that lithium will be present regardless of the technology (p. 140). Thus, there is some level of security, at least in the short to medium term (2030-2035), that lithium will play a critical role in climate change mitigation.

**Climate Change**

Climate change, a global threat, poses economic risks for lithium extraction via the evaporitic process, which is climate and weather dependent. Increased droughts, for example, will exacerbate hydraulic stress in the area, detrimental to local communities and the productivity of brine extraction which depends on underground freshwater aquifers. The evaporitic process also depends on low rainfall – a condition which allows for faster rates of evaporation. A change to these conditions economically threatens lithium extraction requiring evaporation ponds, while also putting residents of regions in the Lithium Triangle at risk.

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**Who can mitigate risks?**

Argentina follows Chile in lithium production, though notably after 2012, Argentina started taking Chilean market share (Maxwell & Mora, 2020, p. 59). Nevertheless, on several recent accounts, lithium mining activity has commenced in Argentine provinces without prior
consultation of local and indigenous communities. Despite community opposition, minimal government response has been observed. With a pro-business president in office, attention to indigenous rights may not be a top priority, unless it significantly interferes with lithium operations (i.e., mobilizations impede operations). Thus far, there has been little indication that social concerns are a top priority for Argentina. Rather, one clear priority for Argentina is attracting foreign investment, though it seems to be doing so at the expense of effectively capturing the economic rents of lithium. Investors may be wary of investing in a country with high inflation and political instability but may be convinced by strong lithium investment incentives. From this analysis, without urgent attention to social concerns and royalty scheme, Argentina may be developing its lithium industry at the expense of social well-being.

Utilizing a resource nationalist lithium strategy, Bolivia has not been able to make significant progress in its lithium industry. Bolivia needs to assess whether its vertically integrated lithium model is economical, especially considering the country’s limited resources. Compared to Chile and Argentina, Bolivia seems to be at a disadvantage given its low-grade brine and poor infrastructure, though it may benefit from a possible lithium supply shortage that will likely require the extraction of lower grade lithium deposits. The Bolivian government discloses minimal environmental information, keeping the Bolivian people, especially mining-impacted communities, uninformed. Moreover, the country’s current resource distribution framework poses a high risk of future social conflict if not addressed given existing rural-urban community tensions. Up to now, Bolivia has seen substantial challenges in developing its lithium industry and attending to social concerns. It also does not seem to have clear mechanisms or strategies in place to address these issues. Therefore, Bolivia will need to make important reassessments to proceed successfully in extracting lithium.
Of the three countries, Chile currently seems the best equipped to continue leading the Lithium Triangle’s lithium production. For one, Chile has the legal frameworks and institutions in place to address socioecological issues. It has demonstrated the ability to address instances of company misbehavior, showing greater responsiveness to community concerns relative to Argentina and Bolivia. Nonetheless, several socioenvironmental concerns remain unaddressed. Given social opposition to lithium extraction at both the local and national level, Chile needs to address these concerns both for the sake of protecting its people as well as its mining operations. Chile’s lithium concessions are also relatively more sophisticated in that they include progressive and marginally staggered commission rates based on the value of lithium extracted, allowing Chile to better capture lithium resource rents. Though there are several risks associated with lithium extraction, Chile seems to have a politically stable environment (perhaps with the exception of ongoing constitutional reform) and economic state relative to Latin American counterparts, arguably, making it the most capable of bearing the risks of lithium extraction. So long as Chile addresses social concerns and can distribute resource wealth equitably, Chile may want to cautiously ride the lithium wave. Nonetheless, the evolving nature of the lithium industry makes it difficult to predict with certainty which countries will take the lead in the long term.

Section 4: Recommendations

Each country faces its own set of challenges in lithium extraction, for which specific recommendations have been provided. Comparing the circumstances in the Lithium Triangle countries makes it clear that the three nations experience common challenges. This section provides recommendations for shared concerns with the Lithium Triangle.
Recommendation 1: Improve community participation through fair Community Development Agreements (CDAs) between mining companies and communities.

Each Lithium Triangle country is experiencing conflicts between communities and lithium mining entities – an issue which will only worsen if mitigation steps are not taken soon. The three Lithium Triangle countries have the legal frameworks in place for community participation in the assessment of potential mining activities. For instance, the three countries award indigenous people the right to free, prior, and informed consent of projects impacting their territories and livelihoods, recognized by the United Nations Declaration on the Rights of Indigenous Peoples and the International Labour Organization Convention 169 (United Nations, 2016). In practice, however, the participatory process can be exclusionary and does not always lead to changes that alleviate community concerns in so far as participation is relegated to a legal formality, rather than an attempt to empower and protect local communities. Local communities have observed this issue materialize in the form of water scarcity issues. In the face of injustices related to lithium production, improvements to the community participation process are necessary to improve social well-being in mining regions.

Improving community participation and negotiations is also in the best interest of mining companies. Considering plans to grow the lithium industry in all the Lithium Triangle countries, attention to community concerns can facilitate smoother business operations for mining companies. In the case of Bolivia, for example, social opposition to a partnership between YLB and a German company led to the revocation of the partnership contract. In the case of Salinas Grandes and Laguna de Guayatoayoc in Argentina, following violations of FPIC, resolute mobilizations against lithium mining led to the halt of mining operations in 2021 (González & Snyder, 2023, p. 60). Both cases demonstrate how the lack of regard for community concerns
can hinder business operations, highlighting how a fair negotiation process between mining companies and communities can be mutually beneficial.

Community development agreements (CDAs) may provide a solution that allows communities and mining companies to negotiate the terms of extraction, ensuring the communities can benefit from extraction and are compensated for any damages to the community (e.g., environmental damages) (Puschner, 2024; Nikolaou, 2019). CDAs allow communities to directly negotiate with mining companies, increasing the chance that community concerns are properly presented and addressed, which may be more difficult to ensure if government bodies were to negotiate on behalf of communities. The process of creating a CDA involves determining project-affected communities, planning out negotiation logistics, negotiations, and ensuring compliance via monitoring done by a working group made up of key stakeholders (i.e., community leaders, company representatives, government representatives, NGO representatives, etc.) (Nikolaou, 2019). CDA negotiations between communities and mining companies may involve establishing agreements regarding financial compensation and distribution logistics, development of social programs, employment opportunities, mitigation of environmental damages, and processes for ensuring compliance, among other topics. External advisors (e.g., World Bank or NGOs) may be involved in the CDA process, which can decrease the risk of bias in negotiations, monitoring, etc. Government officials should be involved, but only in a facilitative role. Nikolau (2019) finds that CDA case studies demonstrate the importance of effective communication about the terms and limitations of the agreement to affected communities, which should be the responsibility of mining companies, governments, and external advisers. This can serve as a mechanism to decrease conflict.
Following the formation of an agreement, if a community is discontented due to a change in mining operations (e.g., an unforeseen event) or deliberate reneging by the mining company, they may choose to take action. For instance, they may file a complaint to an environmental authority or bring the matter directly to the mining company. In some cases, a CDA may be frozen after a disagreement. As Puschner (2024) puts it, “agreements do not mean consent” and the agreement provides only fragile stability (5).

When utilized correctly, CDAs may provide communities with a tool to protect themselves and benefit in the face of resource extraction. Mining company operations also benefit. The development of CDAs in lithium extraction regions in Argentina, Bolivia, and Chile may be a promising tool to decrease community-mining company conflicts by mitigating environmental damages (especially related to water usage) and compensate communities. Given prior challenges in adhering to true FPIC in the Lithium Triangle, a CDA process may provide a framework by which companies can uphold the legally defined rights of local and indigenous communities. In Chile, Albemarle and a group of impacted communities have taken part in a benefit sharing agreement – a CDA – though there are various shortcomings that must be addressed to increase the effectiveness of the agreement and maximize social outcomes.

It is important to note that the term “community” in community development agreement implies that there is a collective and uniform party negotiating with mining companies. However, as discussed earlier, communities often have various beliefs about and perceptions of extraction. Some may be opposed to mining completely, while others may be more than willing to negotiate with companies. There is also a range of beliefs in between. This makes negotiations difficult and potentially misrepresentative of the community, especially if there are beliefs that are
disproportionately represented in the negotiating body. Hence, it is imperative that the group participating in negotiations is truly representative of the community’s range of beliefs.

A CDA process also involves determining the composition of the negotiating body representing the community, requiring in-depth studies identifying who is affected, the extraction-related impacts, and community dynamics. The analyses may reveal that a community negotiating body falls into one of two scenarios. The first involves cases where there is one clear intact community with leadership who will engage in negotiations with mining companies. Presumably, community leaders have a commitment to the well-being of the group. The second case is one in which there are multiple communities involved. In this case, it is imperative that the pre-negotiation community studies accurately identify communities affected by mining operations. Once project-impacted communities have been identified, a referendum should be utilized to determine what the negotiating body for the group of communities should look like and what proportion of the population needs to agree with signing a CDA.

**CDA risks**

CDAs pose several risks to be wary of. Puschner (2024) critiques the use of CDAs, noting that they “strengthen the indigenous position only insofar as the indigenous are willing to enter into dialog and further negotiations” (p. 5). There is a risk that a CDA may be used as a method by which corporate extractivism strengthens its grip on communities, increasing dependency on resource extractivism, while the state takes a passive role. However, it may also be that by participating in a fair CDA, communities can increase their access to resources, potentially leaving them better off. It is important to emphasize that this is contingent on CDA stipulations that truly protect and benefit communities. The risk that mining companies may unfairly use a CDA to their advantage – a CDA in which communities do not benefit, while the
mining company gains community approval of business operations – can be mitigated, such as with the oversight of external advisors or a facilitative body.

CDAs may also create or deepen intra-community tensions in circumstances when not all community members agree with signing a CDA or when communities that are affected by mining operations are excluded from participating in negotiations. Mining companies, ideally with help from external advisers, should make sure that the identification of impacted communities is as accurate as possible prior to starting the negotiation process.

Another potential issue that may arise is that of community leaders agreeing to terms during the negotiation process out of self-interest, rather than with the community well-being in mind. Exacerbation of intra-community tensions may arise.

Another critique of community participation in a CDA is that they alter indigenous cultures by imposing mercantile conceptions of land that may differ from their cosmovision. In the context of salares, indigenous Atacameño people, for example, see water (which includes brine for them) as life, sacred, and integral to their way of life – a conception that is far different from mining companies’ view of salares, brine, and freshwater as mere mining resources (Jerez et al., 2021, p. 9). By participating in a CDA, the Atacameño people in Chile would be accepting the latter conception. Considering the importance of salares and water for the Atacameño people, signing a CDA carries the potential risk of regrettable cultural alterations in the future. In exchange, if mining companies comply with their part of the agreement, the Atacameños would receive promised benefits (e.g., increased resources), which they may deem as valuable. Given the trade-off at hand, indigenous people must carefully weight their options when considering the prospect of a CDA.
Recommendation 2: The state should conduct its own environmental assessments and monitoring and set limits on brine extraction rates.

Substantial weight is placed on environmental impact assessments in the approval of lithium mining projects. To ensure that decisions made about prospective lithium operations are adequately informed, the state (or potentially outsourcing to an external advisor, such as in the case of Bolivia) should also conduct its own studies on the impact of mining operations. As seen in the case with SQM in Chile, following community complaints about SQM’s impacts, the state conducted a study that found discrepancies in SQM’s reported environmental impact. Strong monitoring can serve as a method to deter companies from overexploiting lithium brine. Limits on rates of brine extraction should be considered as a solution to water scarcity issues, which will be exacerbated by climate change.

Recommendation 3: Brine should be considered a water resource due to connectivity between aquifers.

In Chile, brine is not considered water, influencing rates of brine extraction. Argentine mining code and water laws define brine as both a mineral and water resource, respectively, meaning that mining companies must obtain both a mining and water concession (López Steinmetz & Fong, 2019). In addition to this, provinces may have specific regulations for brine. In the case of Jujuy, water concessions are at odds with mining concessions, which need urgent revisions. Legislation in the Lithium Triangle Countries has not been updated to account for complexities induced by a relatively recent acceleration of lithium demand. This calls for urgent reassessment, especially due to major water shortage concerns in a highly arid region. The reclassification of brine as water would help increase regulation of brine extraction.

Recommendation 4: Increase access to and transparency of environmental information.
The three Lithium Triangle Countries ratified the Escazu Agreement, a regional agreement on access to information, public participation (in decision-making), and justice in environmental matters in Latin America and the Caribbean (United Nations, 2018). The three countries also award indigenous people FPIC rights, which includes giving indigenous people the right to express themselves freely and in a fully informed manner (International Labour Organization, n.d. – a). Despite having legal frameworks in place to safeguard the rights of local communities within lithium mining regions, violations of these rights are evident across the three countries to some degree (Clavijo et al., 2022).

In terms of transparency as it relates to environmental information, the limited accessibility of information is a common theme. For instance, communities have complained about the difficulty in being able to understand heavily technical and dense Environmental Impact Assessments in Chile. Instances of flaws in applying the FPIC doctrine, such as due to a lack of information, have led communities to file appeals for environmental damage (Clavijo et al., 2022, p. 302). It is important to note that despite flaws in the consultation process, broadly speaking, Chile has safety guards and tools in place (i.e., National Environmental Information System that makes environmental information available, environmental courts, Territory Dialogue Agency) that give it a strong foundation to increase (environmental) transparency more easily (Clavijo et al., 2022, p. 307). In Argentina, the lack of an integrated information system makes it difficult to access environmental reports. Moreover, various agencies managing environmental information increase the difficulty of accessing information (Clavijo et al., 2022, p. 303). Provincial governments, responsible for attending to local mining activities, have not been effective in making environmental information easily accessible; there are several bureaucratic barriers to accessing information. However, in 2021, Jujuy established the country’s
first environmental court, a potential sign of hope for the future of transparency in lithium-producing provinces.

Bolivia has minimal environmental transparency: only Environmental Impact Statements are made accessible to the public. Though Bolivia has a National Environmental Information System, important documents, including environmental impact assessment studies and environmental monitoring reports are not yet accessible on the system (Clavijo et al., 2022, p. 305). In addition to this, the lack of information about President Luis Arce’s plans for the future of the lithium industry in Bolivia creates conditions of high uncertainty and stress for the Bolivian people.

Each country must work to increase the transparency of environmental information – an important tool in detecting injustices and addressing, such as by increasing symmetrical negotiations between communities and mining companies. Though private companies in Argentina and Chile release their own reports as a form of Corporate Social Responsibility measures, this information is carefully regulated and sifted. Governments have a responsibility to increase transparency of information. There is power in information, particularly for vulnerable communities.

**Recommendation 5: Increase collection of economic rents as determined by concessions.**

A report by the United Nations Economic Commission for Latin America and the Caribbean on the economic rents captured by the three Lithium Triangle countries finds that in the last 10 years, Argentina has been able to capture 28 percent of economic rents from lithium extraction done by private companies; Chile captured 36 percent. The report also provides the results of an additional simulation of a lithium extraction project to determine the percentage of
resource rents captured in each country under their existing tax regimes. The simulation assumes that private mining companies undervalue the price of lithium by 20 percent – a pattern seen among mining companies – and concludes that Argentina captures 30 percent of economics rents, Chile captures 48 percent, and Bolivia captures 41 percent (Jorratt, 2022). Comparing Chile and Argentina, which allow private mining companies to engage in lithium extraction, Chile’s tax regime has been able to capture more than Argentina.

For lithium projects to be worthwhile for the Lithium Triangle, each country must maximize the economic (resource) rents captured. Profits made by mining companies should come from processing and selling, not by the resources (lithium) owned by the country. An open and fair auction process is also pivotal.

As previously discussed, Argentina’s emphasis on attracting foreign investment is reflected in the incentives it gives foreign private companies. Argentina must ensure that it is maximizing its capture of the resource rents from lithium extraction. This does not seem to currently be the case given that as a result of reimbursements, private companies have been refunded amounts generally higher than the royalty (three percent of the pithead value). The royalty is also lower than the Free on Board value of exports (Jorratt, 2022, p. 55). Thus, it seems worthwhile for Argentina to reassess its tax regime. It may choose to follow Chile in applying ad valorem progressive marginal royalties, though there are also other taxation frameworks that it may choose to implement, so long as it can strategically and effectively increase the economic rents it captures.

Although Chile is capturing greater resource rents than Argentina, it may also want to reassess its tax regime to ensure that it is maximizing its capture of resource rents.
Recommendation 6: Maximize the transfer of expertise and local employment opportunities.

While partnerships with foreign companies can be beneficial for Lithium Triangle countries trying to strengthen their lithium industry, to minimize dependencies on foreign countries, the three countries should ensure that enough attention and funds are allocated to capacity building and transfer of expertise. This may also help stimulate employment opportunities at the local level. Additionally, creating regulation or enforcing existing requirements for local employment quotas is crucial to ensuring that the economic benefits of extraction are contributing sufficiently to the local economy. Adequate work conditions in mining facilities should also be enforced.

Recommendation 7: Increase research and development.

Current lithium extraction methods primarily depend on the evaporitic process, which requires the extraction of massive volumes of brine to produce lithium, risking seepage from freshwater aquifers into the brine. As a result, there is a high risk of brine dilution as well as contamination of freshwater resources. There is hope that direct lithium extraction techniques may be the solution to the environmental concerns, particularly by decreasing amounts of residue and freshwater usage. Not all current DLE techniques have achieved improved sustainability; in fact, some use more water than the evaporitic process. Even for relatively more successful small scale DLE technologies, challenges in applying these technologies at a large scale exist (Vera et al., 2023). Nonetheless, there is hope that with more research and development, DLE technologies can serve as a more sustainable form of lithium mining, while increasing efficiency by bypassing long wait periods of brine evaporation ponds. If successfully done, DLE
technology can help in mitigating the various socioecological risks in the Lithium Triangle. Continued investment in research and development of DLE technologies is required.

**Recommendation 8: Caution against overinvestment in light of risk.**

There are many uncertainties in the lithium industry, ranging from the future relevance of lithium to its future profitability given increasing competition. Currently, lithium research remains in its early stages, causing forecasts to have moderate to high uncertainty. Moreover, relatively limited research on the various aspects of lithium extraction and its impacts has been conducted in some regions, especially Bolivia and Argentina. Thus, it is in the best interest of the Lithium Triangle countries to cautiously invest in their lithium industries to decrease dependency on a risky source of revenue. Shall future research on lithium provide greater security about the prospect of lithium investments, countries can at that point reassess their investment portfolio and potentially increase lithium investments if deemed appropriate.

Recommendations provided here address key concerns, though they are not comprehensive. Further work, especially informed by more research in currently research-scarce regions, may be helpful in further determining what improvements are needed to maximize the benefits and minimize the risks of extraction in the Lithium Triangle.

**Section 5: Conclusion**

**Extraction in the Lithium Triangle**

Lithium is a critical mineral in a rapidly electrifying world due to its use in batteries that power energy transition technologies (i.e., electric vehicles, stationary storage for renewable energy plants, etc.). Though risks of mineral substitutes and increasing international competition create some uncertainty about the future relevance and profitability of lithium extraction, these
threats seem unlikely to hinder lithium demand in the medium term; that is, not before 2035. Growing decarbonization efforts, especially in vehicle transportation, have accelerated the demand for lithium batteries, projected to continue increasing. Thus, lithium is likely to continue as a relevant mineral in the next decade (and with some uncertainty, in the long term), posing a potential for the Lithium Triangle to seize the economic opportunity by growing their lithium industries.

On the surface, lithium seems to be a promising tool that society can leverage to liberate itself from the grip of fossil fuels, leading some to believe that lithium is a more ethical and sustainable alternative. In possession of over half of the world’s lithium resources, Argentina, Bolivia, and Chile, play an essential role in advancing climate change mitigation efforts. As seen in other cases of green extractivism, however, lithium extraction comes with a cost to the environment and local communities. Thus, Lithium Triangle governments must balance the opportunities and risks of lithium extraction. Unfortunately, thus far, the mitigation of socioecological risks of lithium extraction in Argentina, Bolivia, and Chile has been inefficient. Local communities, a significant portion of which are indigenous, are concerned about excessive water usage (leading to water scarcity), pollution, harm to wetland ecosystems, and poor employment opportunities, among other concerns. An important point related to indigenous communities to remember, however, is that though a significant portion of communities have apprehensions about lithium extraction, there are also community members that may see negotiations with lithium mining companies as an opportunity to increase community resources (Puschner, 2024). Local and indigenous communities do not have a homogenous perception of lithium mining, which can make the community participation process and representation in negotiations a complicated task.
Recommendations

1. Improve community participation through fair Community Development Agreements (CDAs) between mining companies and communities.
2. The state should conduct its own environmental assessments and monitoring and set limits on brine extraction rates.
3. Brine should be considered a water resource due to connectivity between aquifers.
4. Increase access to and transparency of environmental information.
5. Increase collection of economic rents as determined by concessions.
6. Maximize the transfer of expertise and local employment opportunities.
7. Increase research and development.
8. Caution against overinvestment in light of risk.

Insights

*Differences in brine concentration*

As demonstrated in this thesis, each country faces different challenges in trying to strike a balance between opportunities and risks, influenced by varying brine compositions, governance frameworks, and attention to mitigating socioecological risks.

For one, the climatic conditions and lithium concentration in brine varies from salar to salar, influencing the technologies required for lithium extraction and costs of production. Chile and Argentina enjoy a relatively high lithium concentration brine. Bolivia’s Salar de Uyuni, on the other hand, faces a lower lithium concentration and rainier weather patterns, increasing the cost of production. This means that what works in one region will not necessarily be applicable elsewhere. More broadly, the complexity and distinctiveness of salares make lithium a mineral with more nuanced considerations.
Differences in governance

In terms of governance, Chile and Bolivia have a centralized form of governance, while Argentina’s is decentralized. In Chile, CORFO regulates lithium mining operations by private companies. In Bolivia, YLB – the state-owned enterprise – extracts lithium and only allows the involvement of private companies in downstream processes in the form of public-private partnerships where the state is a majority stakeholder. While a decentralized model may be theorized as having the potential to be more responsive to local concerns, that has not been the case seen with Argentina’s provincial governments responsible for awarding concessions and regulating lithium mining. Argentine communities near extraction sites seem to have little government support. All three countries have plans to expand their lithium industries, though their governance structures greatly influence their strategies. The added layer of political motivations behind certain decisions related to lithium extraction was briefly discussed in this thesis but also significantly contributes to the future of lithium in each country.

Chile’s Potential

In light of its established industry, relative political stability, and financial and institutional resources, Chile seems to be the most likely of the three Lithium Triangle countries to strike a balance between the risks and opportunities of lithium.

Final Considerations

Lithium is not the panacea for a sustainable and ethical electrical future it is sometimes painted to be. Case studies of lithium extraction in the three countries have proven that there are social concerns necessitating attention if lithium production is truly going to be a method of increasing social well-being in the Lithium Triangle. Without attention to addressing these concerns, how “clean” can a lithium-powered energy transition really be for the countries of the
Lithium Triangle? Will lithium be yet another example of wealthy developed nations benefiting off the resources of developing nations at the expense of vulnerable communities? It is up to Argentina, Bolivia, Chile, and private (domestic and foreign) companies to answer those questions.
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