Undergraduate Thesis Prospectus

Process Advancements for Lithium Extraction and Purification from Geothermal Brine

(technical research project in Chemical Engineering)

The Fight for Water: How Indigenous Chileans and Lithium Corporations Compete

(sociotechnical research project)

by

Allison Sawyer

October 27, 2022

technical project collaborators:

Sarah Bhargava
Maurice Curran
Madaline Marland

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Allison Sawyer

Technical advisor: Eric Anderson, Department of Chemical Engineering

STS advisor: Peter Norton, Department of Engineering and Society

General Research Problem

How to transition toward recently developed energy technologies in North and South America?

According to Walton (2020), “the energy sector is a key contributor to climate change, accounting for two-thirds of global greenhouse gas emissions.” The fight against climate change requires participation from citizens, policymakers, and industries. Current technological research and advancement is electing solutions to enable the green energy transition, but societal change must drive implementation. North and South America are home to vast natural resources and can support the life cycle for technologies to mitigate climate change.

Process Advancements for Lithium Extraction and Purification from Geothermal Brine

How can Lithium Hydroxide be extracted from waste brine in geothermal energy plants?

Rapid clean energy scale-up will generate increased demand for critical minerals; thus, new and diverse supply sources are necessary to counter supply strains (International Energy Agency, 2022, p. 14). These strains arise particularly from rapid scaling problems (Olivetti et al., 2017, p. 229), high geographic reserve location and refining capability concentration (Sun et al., 2021, p. 12180), mining asset exposure to climate risk (Delevingne et al., 2020, p. 2-5), and long project development time (International Energy Agency, 2022, p. 12). Lithium is classified as a critical mineral “hav[ing] a supply chain that is vulnerable to disruption and serv[ing] an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economic or national security of the United States” (United States Geological Survey, 2022, p. 17). Current and pending mine projects have supply capability covering only half of projected 2030 lithium needs and “are not ready to support accelerated energy transitions” (International Energy Agency, 2022, p. 11). It is thus in the vested economic and security interests of the United States to jointly propel lithium extraction research and extraction process impact assessment (Hailes, 2022; Parker et al., 2022).

Primary lithium extraction pathways currently include extraction from hard rock pegmatites, extraction from sedimentary rock such as clays, or evaporation from arid basin brines (Blair et al., 2022, p. 4). Arid basin brine lithium sourcing faces particular criticism for its heavy water requirements within the internationally recognized wetlands of Chile, Argentina, and Bolivia; for its ecological disruption to migratory and native species; and for its exploitation of indigineous and local people's land (Blair et al., 2022, p. 4). Geothermal brine extraction has historically been hindered by severe scaling and equipment corrosion (Hoffmann, 1975, pp. 9-13); however, operations now produce electricity from the geothermal fluid heat (*Imperial Valley Geothermal Area*). This work will further evolving research which aims to extract target minerals before stream reinjection back into their source geothermal reservoirs (Warren, 2021).

The project focuses on extracting and purifying a lithium product, lithium hydroxide (LiOH), following pretreatment from geothermal brines. Figure 1 displays a block flow diagram detailing the lithium extraction process beginning after solids have been removed from the raw brine and the power cycle has been run. A pH balancing and filtration step removes contaminants to avoid precipitation on equipment. The lithium loading and extraction processes use two reactors with opposite chemisorption directions that form a regenerative absorption network.

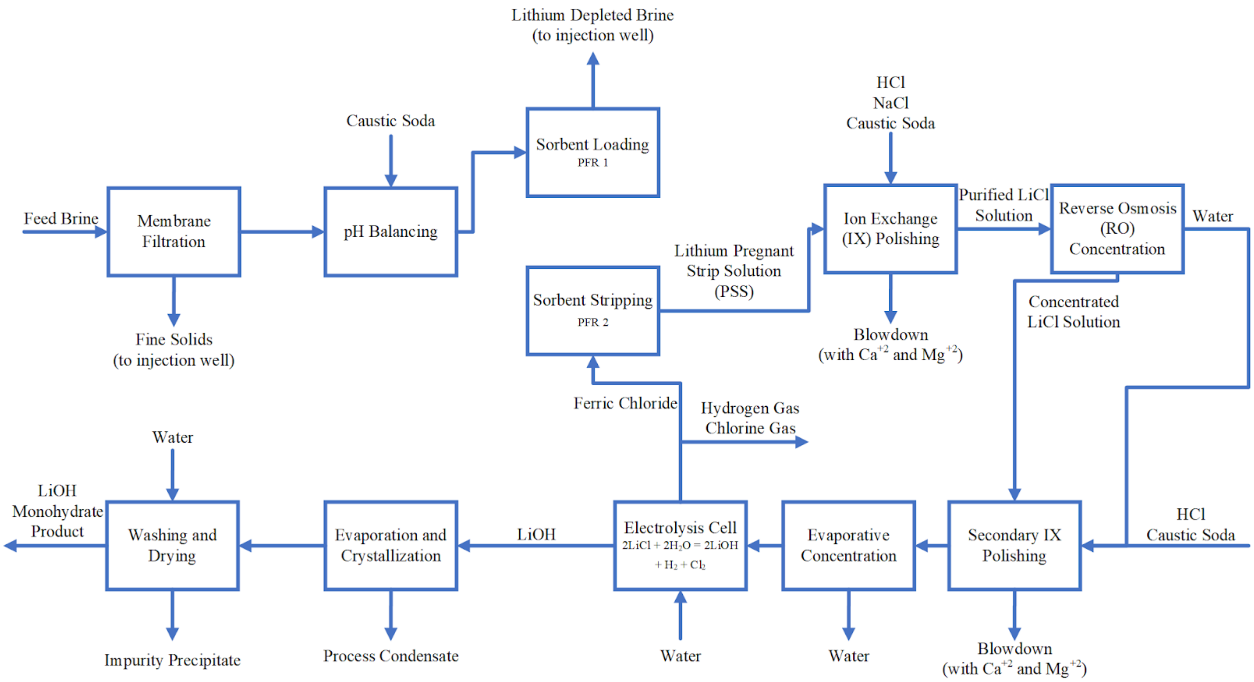

Figure 1. Block flow diagram of lithium extraction process

Two additional refining steps are executed to form a purer intermediate: Ion Exchange (IX) and Reverse Osmosis (RO). The IX process removes divalent ions such as calcium and magnesium. The reverse osmosis step pushes water through a membrane at high pressure to concentrate the mixture with the desired intermediate: lithium chloride (LiCl). The LiCl mixture then runs through secondary IX purification and evaporative concentration units to remove excess ions and water. The mixture is then processed in an electrochemical cell where lithium chloride is converted to lithium hydroxide. Once the LiOH is extracted from the cell, water is further evaporated and the LiOH is crystallized. Final processing steps include washing, drying, resizing and packaging to meet the high purity standards for use in batteries and other applications.

The team of four students will produce a design for a plant to produce LiOH from geothermal brines which will be carried out over two semesters. The team plans to model most of the process using Aspen Plus, a process modeling tool that predicts performances of specified processes through an iterative method given a process design and thermodynamic models. For processes that are not modelable on Aspen like electrolysis, the team will utilize Excel spreadsheets and/or MATLAB software to compute the necessary calculations manually. Under the assumption that the brine has a lithium composition of 287 ppm, the feed enters the process at 110°C and at a pressure of 1 atm. Within the packed-bed reactor, an assumed lithium to sodium molar selectivity of 100 to 1 describes the catalyst efficacy. The additional data will be obtained through sponsors, Professors Giri, Koenig and Geise, as well as geothermal brine reports. The team will divide the work based around our 10+ process units by splitting the total number of process units in half and pairing up to work on the designated units. Regarding main operating units such as plug flow reactors and the electrolysis cell, the team will collaborate to perform the necessary calculations.

The Fight for Water: How Indigenous Chileans and Lithium Corporations Compete

How do proponents and critics of lithium extraction in Chile advance their agendas?

Mining companies in Chile extract lithium by pumping brines from salt flats and separating water through evaporation (Greenfield, 2022). Evaporation is the most water-intensive extraction process and is disrupting scarce water allocation in the Atacama region. Local communities are confronting corporations but are met with promises of sustainability and economic growth.

Many Chileans are committed to preventing sacrifice zones in their country, an area where marginalized communities live in proximity to polluting industries (Lerner, 2011). This is an example of locally unwanted land use (LULU). Communities burdened with LULU are taken advantage of by corporations because they lack the economic and political power to avoid exploitation. To prevent destructive lithium extraction, Chileans engage in protests, file lawsuits and publicize their cause on social media.

Observatorio Plurinacional de Salares Andinos (OPSAL), an Andean organization representing indigenous communities, countered a press conference with a Tweet "water is worth more than lithium." They believe that extraction "is a threat to people who are denied their right to water and territory" (Ledger, 2022).

Atacama Indigenous Council, another group for native communities, filed a lawsuit blocking a multimillion-dollar extraction plan from mining company SQM. The Council won, but Chile's Supreme Court overturned the decision. Sergio Cubillos, the Council president, announced they "will make every effort to see SQM's [environmental permits] revoked." He states that damages from lithium extraction are "immeasurable" (Sherwood, 2020).

SQM, one of two lithium mining corporations in Chile, cites jobs opportunities and use of sustainable solar energy. They operate 3,000 hectares of solar evaporation ponds with 91.3% of their energy coming from solar power (SQM, 2022). In its Risk Management plans, SQM states that restrictions on water use from "prioritization of human consumption" might cause economic stress from water outsourcing.

Iquique Industrial Association (AII) represents companies in the mining town of Iquique, Chile, including SQM. Transportation, construction, and chemicals companies fill AII's director's board. The group cautions that increasing mining taxes will lower global investment due to economic burdens. AII declares they are "defending the motor for development" and performs community outreach warning that mining opposition hurts everyone (AII, 2022).

Turley et al. (2022) investigated cultural and ecological effects of mining in the Southwest USA, a more prosperous area than the Atacama region. They emphasize that critical resource geography must consider "power relations, values, and political economic dimensions of resource extraction and use." Policy, political opinion, and perceived acceptability of extraction play a large role in how and which communities are affected. Neo-extractivism, when governments allow environmental damage to finance social reform, discourages lithium extraction in developed areas and moves the burden to areas trapped in neocolonialism like Chile (IGI Global). The "just energy transition" must be prioritized by those advantaged by established global systems. Without their support, communities without political and discursive power will carry the unequal hardship of the industrialization required for the green energy transition.

León, Negredo, and Erviti (2022) examined perceptions of climate change publications on Twitter. Like the dangers of climate change, the risks of lithium extraction have often been discounted or neglected. Meaningfulness and personification can increase public engagement with publicity about climate change. Since many citizens do not have personal experiences with climate change, a negative second-hand experience must be constructed through images. This is best achieved with media depicting "real people" (non-staged participants that show emotion), telling a story, including a local connection, or showing impacts and actions by people who are directly affected. Chilean activist groups are increasing recognition for their fight in areas with power using social media, especially Twitter. In a Twitter campaign (fig. 2), a banner portrays a dead flamingo under the words "No Seremos Zona de Sacrificio" ("We are not a Sacrifice Zone") (OPSAL, 2022). This image tells the story of wetland destruction with a familiar animal. The strong language of "sacrifice" will resonate with those who are unaware of the group's agenda. Social media campaigns have been essential in promoting the values of lithium extraction critics by highlighting the "real people" behind their messages.

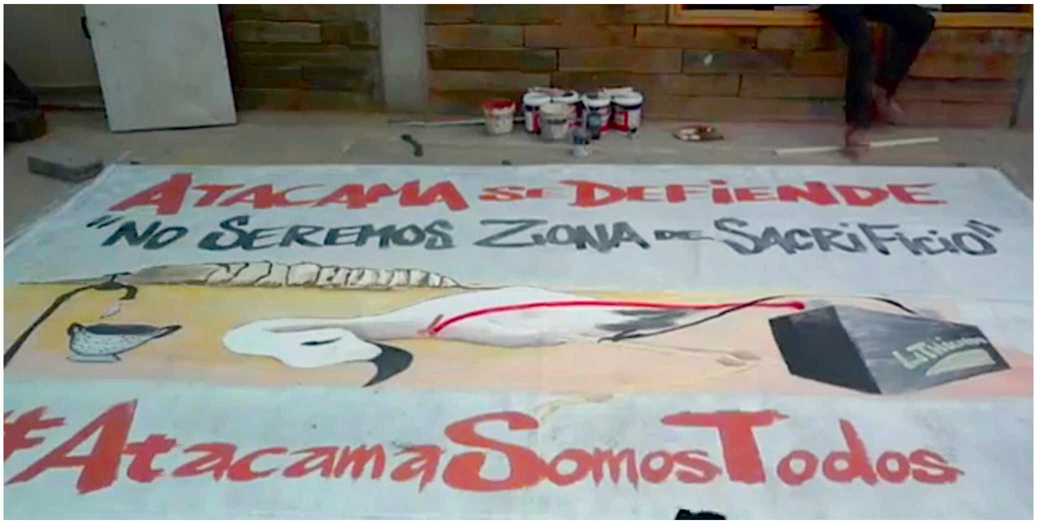

Figure 2. Banner from OPSAL's Twitter Profile (2022)

Political appearances of social movements between Latin American indigenous people and national governments have recently increased due to opportunities from the intersection of timing and allies. According to Puig (2010), "the presence and support of outsiders might be… an element of the social capital that was necessary for the empowerment of indigenous movements." The global attention, pushed forward by the Catholic Church and non-governmental organizations, has provided critical pressure to support local groups and their agendas. Ethnodevelopment, a social policy to promote cultural development of marginalized groups, has become valued by international organizations and anthropologists, though their motivations may be considered self-serving by some (Broadfield, 2017). International support can promote local change, yet interest from outside supporters can wane if relationships are neglected. This perpetuates the burden on local groups in maintaining global attention to reach their goals. Successful international partnerships depend on shared commitments and mutual trust. Puig (2010) warns that "the permeability of Latin American polyarchies" may be reaching a limit of responsiveness and new strategies should be explored by activists and their supporters.

References

AII. *Asociaciones de la Macrozona Norte Alertan Sobre Caída en la Inversión Si Se Aprueba el Royalty*. Asociación de Industriales. (2022, August 12). https://www.industriales.cl/web/index.php/n/item/1664-asociaciones-macrozona-aprueba-royalty.html

Bienvenido León, Samuel Negredo & María Carmen Erviti (2022) Social Engagement with climate change: principles for effective visual representation on social media, *Climate Policy* 22:8, 976-992, DOI: 10.1080/14693062.2022.2077292

Blair, J., Balcázar, R. M., Barandiarán, J., Maxwell, A. (2022). *Exhausted: How We Can Stop Lithium Mining from Depleting Water Resources, Draining Wetlands, and Harming Communities in South America*. California State Polytechnic Pomona, Natural Resources Defense Council, Inc., Observatorio Plurinacional de Salares Andinos, University of California Santa Barbara. https://www.nrdc.org/sites/default/files/exhausted-lithium-mining-south-america-report.pdf

Broadfield, K. (2017, October). Ethnodevelopment: Indigenous Development in indigenous hands (thesis). James Cook University. https://www.researchgate.net/publication/323253607_Ethnodevelopment_Indigenous_Development_in_Indigenous_Hands

Delevingne, L., Glazener, W., Grégoir, L., Henderson, K. (2020). *Climate risk and decarbonization: What every mining CEO needs to know*. McKinsey & Company. https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/Climate%20risk%20and%20decarbonization%20What%20every%20mining%20CEO%20needs%20to%20know/Climate-risk-and-decarbonization-What-every-mining-CEO-needs-to-know.pdf

Greenfield, N. (2022, August 26). *Lithium mining is Leaving Chile's Indigenous Communities High and Dry (Literally)*. NRDC. https://www.nrdc.org/stories/lithium-mining-leaving-chiles-indigenous-communities-high-and-dry-literally

Hailes, O. (2022). Lithium in international law: Trade, investment, and the pursuit of Supply Chain Justice. *Journal of International Economic Law*, *25*(1), 148–170. https://doi.org/10.1093/jiel/jgac002

Hoffmann, M. (1975). *Brine Chemistry - Scaling and Corrosion: Geothermal Research Study in the Salton Sea Region of California*. Environmental Quality Laboratory California Institute of Technology. https://www.osti.gov/servlets/purl/7364728-VQTguC/

IGI Global. (n.d.). *What is Neo-Extractivism.* https://www.igi-global.com/dictionary/might-the-keys-to-peace-open-the-doors-to-extractivism/52206#:~:text=The%20term%20refers%20specifically%20to,means%20of%20financing%20social%20reforms

International Energy Agency. (2022). *The Role of Critical Minerals in Clean Energy Transitions*. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf

Ledger, G. (2022, September 28). *Declaración ante El VI Foro del Litio 2022: El Agua Vale Más Que El Litio*. Salares Andinos. https://salares.org/2022/09/28/declaracion-ante-el-vi-foro-del-litio-2022el-agua-vale-mas-que-el-litio/

Lerner, S. (2011, June). *Sacrifice zones: The front lines of toxic chemical exposure in the United States*. Environmental Health Perspectives. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3114843/

OPSAL. [@OPSAL_]. (2022, Octover 24). Observatorio Plurinacional de Salares Andinos. *En este #DíaDelCambioClimático las y los invitamos a participar entre este 26 y 30 de octubre en el #GEFF2022 #GLOBALEXTRACTIONACTION, festival internacional donde podrás ver gratis el documental "El #agua vale más que el #litio" Más info en https://vimeo.com/ondemand/waterisworthmorethanlith* [Tweet]. Twitter. https://twitter.com/OPSAL_/status/1584553210269749248?cxt=HHwWgMCqnfuvu_0rAAAA

Olivetti, E. A., Ceder, G., Gaustad, G. G., & Fu, X. (2017). Lithium-ion battery supply chain considerations: Analysis of potential bottlenecks in critical metals. *Joule*, *1*(2), 229–243. https://doi.org/10.1016/j.joule.2017.08.019

Parker, S., Franklin, B., Williams, A., Cohen, B. S., Clifford, M., Rohde, M. (2022). *Potential Lithium Extraction in the United States: Environmental, Economic, and Policy Implications*. The Nature Conservancy. https://www.scienceforconservation.org/assets/downloads/Lithium_Report_FINAL.pdf

Puig, S. M. i. (2010). The Emergence of Indigenous Movements in Latin America and Their Impact on the Latin American Political Scene: Interpretive Tools at the Local and Global Levels. *Latin American Perspectives*, *37*(6), 74–92. http://www.jstor.org/stable/25750421

Sherwood, D. (2020, August 14). *Indigenous groups in Chile's Atacama Push to Shut Down Top Lithium Miner SQM*. Reuters. https://www.reuters.com/article/us-chile-lithium-sqm/indigenous-groups-in-chiles-atacama-push-to-shut-down-top-lithium-miner-sqm-idUSKCN25A2PB

Sun, X., Liu, Z., Zhao, F., & Hao, H. (2021). Global competition in the lithium-ion battery supply chain: A novel perspective for criticality analysis. *Environmental Science & Technology*, *55*(18), 12180–12190. https://doi.org/10.1021/acs.est.1c03376

SQM (2022). Sustainability Report 2021. SQMLithium.com. https://www.sqm.com/sustentabilidad/reporte-de-sustentabilidad/.

Turley, B., Cantor, A., Berry, K., Knuth, S., Mulvaney, D., Vineyard, N. (2022, April 11) *Emergent landscapes of renewable energy storage: Considering just transitions in the Western United States.* Energy Research & Social Science, Volume 90, 102583, ISSN 2214-6296, https://doi.org/10.1016/j.erss.2022.102583.

United States Department of Energy. (2022, July 13). *DOE announces finalists of Geothermal Lithium Extraction Prize*. https://www.energy.gov/eere/articles/doe-announces-finalists-geothermal-lithium-extraction-prize

United States Geological Survey. (2022). *Mineral Commodity Summaries 2022*. https://pubs.usgs.gov/periodicals/mcs2022/mcs2022.pdf

U.S. Department of Energy Geothermal Technologies Office. (n.d.). *Imperial Valley Geothermal Area*. https://www.energy.gov/eere/geothermal/imperial-valley-geothermal-area

Ventura, S., Bhamidi, S., Hornbostel, M., Nagar, A. (2020). *Selective Recovery of Lithium from Geothermal Brines*. California Energy Commission. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-020.pdf

Walton, M. (2020, March 23). *If the energy sector is to tackle climate change, it must also think about water – analysis*. IEA. https://www.iea.org/commentaries/if-the-energy-sector-is-to-tackle-climate-change-it-must-also-think-about-water

Warren, Ian. (2021). *Techno-Economic Analysis of Lithium Extraction from Geothermal Brines*. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy21osti/79178.pdf