Thesis Project Portfolio

Design of a Processing Plant for Direct Lithium Extraction from Geothermal Brines from the Salton Sea Region

(Technical Report)

Motivations and Implications of Electric Vehicle-Spurred Cobalt Mining in the Democratic Republic of Congo

(STS Research Paper)

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Executive Summary

Amid growing decarbonization efforts, the push toward vehicle electrification has intensified. Central to this transition are lithium-ion batteries (LIBs). Intuitively, the rapidly scaling LIB market has resulted in a dramatic expansion in the demand for and cost of minerals critical to the fabrication of LIBs, particularly, lithium and cobalt. As such, the consistent availability of these cathode materials is key to the successful deployment of electric and hybrid-electric vehicles. Furthermore, the soundness of cobalt and lithium extraction *processes* will dictate the broader sustainability and ethics of electric vehicles.

Traditional methods of lithium extraction are highly energy, land, and freshwater intensive. Furthermore, much of the lithium in the U.S. is imported, despite the country demonstrating high amounts of domestic lithium reserves. To decrease reliance on externally sourced and often harmful traditional extraction techniques, a new method of lithium sourcing, direct lithium extraction (DLE), is currently being developed. Team TELEPORT at the University of Virginia, consisting of Chemical Engineering Professors Geoff Geise, Gaurav "Gino" Giri, and Gary Koenig, have developed a novel sorbent, iron phosphate (FP), that selectively extracts lithium from geothermal brine containing several other competing ions. To assess process viability and direct further research efforts, this project needs to be modeled and analyzed on an industrial scale. Thus, in the enclosed technical work, we present a design of a processing plant for direct lithium extraction from geothermal brine in the Salton Sea region of California.

In this process, four major unit operations were designed to selectively obtain lithium ions from geothermal brine and generate lithium hydroxide monohydrate. These units consist of adsorption and regeneration, electrodialysis, a fuel cell, and crystallization. In adsorption and regeneration, lithium ions are extracted from geothermal brine, which is obtained from an existing geothermal power plant, and concentrated in a regenerated solution that is sent to

electrodialysis. Electrodialysis then uses an applied voltage to promote ionic transfer and form aqueous lithium hydroxide. Finally, aqueous lithium hydroxide is crystallized, filtered, and dried in the crystallization unit, which produces the final product: battery grade lithium hydroxide monohydrate.

This series of unit operations ultimately produces 10,625 tons of lithium hydroxide monohydrate annually, leading to a net present value of more than $2 billion USD over the plant lifetime and a 162% annual return on investment.

Generally considered the least plentiful and most expensive raw material used in LIBs, cobalt – a resource heavily concentrated in the Democratic Republic of Congo (DRC) – has risen to particularly high demand. While this growing demand has offered significant economic opportunity for the DRC, the intensity of the market paired with volatile governance and economic desperation has led to unlicensed, unregulated "artisanal mining", raising concerns over labor conditions and environmental impacts.

Using a Co-Production of Science and Social Order framework – an analytical method which emphasizes the inextricable relationship between social ordering and technological advancement – the interconnected nature of Congolese social structures and cobalt mines is investigated. The impact of public education, mining legislation, and economic standing on the development of artisanal mines is highlighted, and in turn, the reciprocal impact of Congolese cobalt mining on these aspects of society is revealed. This analysis provides information valuable to policymakers, industry stakeholders, and environmental/human rights advocates seeking a comprehensive understanding of the broader implications of the rapid EV market growth.

Electric vehicles (and thus necessarily Lithium-ion batteries) are often viewed as a "golden solution" to cutting fossil fuels out of one of the most carbon-intensive sectors: transportation. On the surface it seems simple. Remove the legacy fuels, remove the sustainability challenge. In reality, it is much more complex. Electric vehicles are lauded for their drastically reduced emissions, but if the components that make up these machines are irresponsibly or non-sustainably sourced, is the problem really being solved? To maximize the positive impact of EVs, it is insufficient to focus exclusively on EVs in operation. Instead, the full life cycle must be studied.

Together, these analyses bring attention to key challenges related to widescale EV deployment.