Thesis Project Portfolio

Design of a Processing Plant for the Extraction of Lithium from Geothermal Brines in the Salton Sea, California

(Technical Report)

Case Studies of Lithium-Ion Battery Disposal Methods

(STS Research Paper)

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Bachelor of Science, School of Engineering

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Prospectus

Executive Summary

Electric cars are a key way that the world will be able to move the transportation sector towards clean energy. For the United States, European Union and China, their transportation sector's carbon dioxide emissions account for at least a quarter of total emissions per country. By incentivizing electric cars through government policies, over a third of global transportation emissions can be decreased. In order to make this happen however, there must be enough lithium-ion batteries (LIBs) available to power these electric vehicles. Raw materials necessary for the production of these batteries, such as lithium, are limited in supply and have already tripled in price because of increased demand. This trend will only continue because as soon as 2035, 50% of all global passenger-vehicle sales will be electric. Demand for LIBs will also increase because batteries only have a lifetime of around eight years, leading to a large volume of LIBs requiring disposal. The supply chain management of the manufacturing of LIBs and then disposal at their end-of-life will require private companies and governments to figure out sustainable practices that best support the transition to electric vehicles.

The United States relies heavily on imports of lithium from Chile and Argentina and with the increase in LIBs required to power electric vehicles, the current lithium supply cannot meet the demand. The technical report explores a process that generates clean energy and extracts large, untapped amounts of lithium found in underground pools in the Salton Sea in California. Geothermal brine from these aquifers already is pumped it to the surface for use in geothermal power plants and the lithium extraction process proposed can be retrofitted on to this existing infrastructure. Designs discussed in the report are based on the work of chemical engineering professors Geoffery Geise, Gaurav Giri and Gary Koenig along with industry partner PowerTech water as a part of their submission for the Department of Energy American-Made Geothermal

Lithium Extraction Prize. Lithium is extracted with a novel redox intercalation process alongside electrolysis to continuously regenerate the deintercalation material required. The process has an input of 6,000 gallons per minute of geothermal brine and produces a net power output of 25.5 MW and 7,701 tonnes per year of $LiOH•H_2O$, producing $474 million annually. Although economics seem favorable with an internal rate of return of 175%, this process is a no go decision because of the high cost of calcium citrate needed and other unknowns with the process.

Shown through policy, China, the European Union (EU) and the United States (US) all have very different approaches for how to handle the end-of-life pathways of LIBs. The STS paper discusses these countries as case studies in order to conclude how they are progressing towards a circular economy: a zero-waste model where resources are conserved, reused and remanufactured. The circular economy model is highly motivated by the need to retain the limited stock of lithium used within LIBs—as prices for the precious mineral increase—and lessen the environmental impact from improper disposal methods. China is farthest along in its policies for LIB recycling and has an established business sector and plans in place to collect data on each step of the recycling process to improve. The EU has the framework for successful LIB recycling policy because of its past success with lead-acid battery recycling. Finally, the US has taken steps to invest in LIB recycling research and states have taken initiative to establish policy although federal policy is lacking. New policies need to have the flexibility to encompass new technology but also must continue to support the move towards a circular economy in these countries.

Through the technical report and the STS paper, this document discusses both a technical solution to limited lithium supply and policy analysis for the current state of governments' approaches to LIB disposal. The design process of the technical report was a comprehensive way to learn about the chemical engineering design process and to understand the difficulties of designing a process with novel technology. This was a fruitful project because of the understanding of design that our team now has but also limited because of the many assumptions that had to be made that would not be made in the field with the proper data. More work can be done once the lithium extraction process is more understood and all materials required for this technology are well documented. The STS paper was a useful perspective for the state of the world's policies and unveiled the pressing need to pass policies before there are an overwhelming number of LIBs waiting to be disposed. From case study synthesis, it was interesting to learn where different countries stood in their policies and how that directly impacted how far they have progressed in establishing a circular economy in the private sector. As policies continue to be passed, more work could be done to analyze which is the strongest in prioritizing the environment and the reuse of materials in a circular fashion. LIB production and disposal are crucial to the success of electric vehicles and the technologies and policies discussed are essential to mitigating climate change.