DESIGN OF LITHIUM EXTRACTION PROCESS FROM GEOTHERMAL POWER PLANT

ANALYSIS OF THE GEOTHERMAL POWER PLANT FAILURE IN COOPER BASIN, AUSTRALIA

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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.

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Introduction

The international agreement to mitigate climate change has been the primary driving force to conversion into greener energy. This includes less dependency on fossil fuels for electricity and fuels for the residential and transportation sector. The geothermal power plant, combined with the method of lithium extraction, serve as both a greener energy alternative with profitability and supply for increasing global demand for lithium due to the electrification of vehicles.

Normally, extracted geothermal brines are injected back into the ground after heat or electricity has been generated by the geothermal power plant. However, since geothermal power plants are usually less economically competitive compared to hydrocarbon-based power plants, several methods are being investigated to increase the profitability of the plant. One way to add more value to these geothermal brines is a series of unit operations including adsorption, electrolysis, and crystallization column will aim to extract lithium in the forms of lithium hydroxide along with side products such as rubidium or cesium for additional profit. Selective lithium extraction is characterized by a reduction-oxidation (redox) reaction developed by professors Gaurav Giri, Gary Koenig, and Geoff Geise.

I will also look at a failed case of a geothermal power plant in Cooper Basin, Australia. The lead operator for the project pointed to economic profitability and the geographical location of the plant as its reason for failure. However, this investigation will be focused on investigating the effect of change in administration and policy shift in Australia as well as analyzing current public perceptions of geothermal energy and its indirect consequences on public opinion to the success of the geothermal plant.

To address climate change problem, in-depth analysis of previously failed geothermal plant and future projection of geothermal design must be studied. Leaving this analysis of social aspects to the implementation of geothermal technologies will prevent a more efficient approach to addressing carbon emissions. However, relying solely on social analysis will provide no technical advancement to solve fossil fuel dependency. Below, I will use actor-network theory to effectively look at how technical portions and societal/political aspects of technology collectively define the development of geothermal power plants. New design of geothermal power plant will try to tackle challenge of lithium scarcity and analysis of project in Cooper Basin willl include economic, political, societal, and geographical contribution to failure.

Technical Project Proposal

With technological advancements in electric vehicles and batteries, global demand for high-energy density materials, such as lithium, has increased significantly. It is estimated that rising demand will push production of lithium from 447 thousand tons of lithium carbonate equivalent in 2018 to over 2 million tons by 2050 (Stringfellow & Dobson, 2021).

Currently, the United States relies on lithium imported from Chile and Argentina, where an energy intensive and environmentally damaging process known as evaporative extraction is utilized (Warren, 2021). Geothermal brines from the Salton Sea in California contain a significant amount of lithium along with trace quantities of other valuable elements, such as rubidium and cesium. Directly adsorbing lithium from Salton Sea brines offers an attractive, environmentally conscious alternative to meet increasing lithium demands. With eleven geothermal wells drawing from the Salton Sea in California, lithium extraction holds the potential to produce $5 billion annually (Jones et al., 2022).

For this project, we propose a plant design to extract lithium and other valuable metals from an existing 6000 gal/min well located in the Salton Sea (Ventura et al., 2020). A single well has the potential to produce 2500 mt/yr of lithium. The plant can be separated into three distinct sections: pre-treatment, lithium extraction, and alternative products capture. Pretreatment of the feed involves the removal of silicates from brine by introducing calcium hydroxide to precipitate iron silicates, which are then physically filtered from the solution (Koenig, personal communication, 2022). Once silicates are removed, the stream is passed through a boiler, where the hot brine is used to produce high pressure vapor for geothermal power plants.

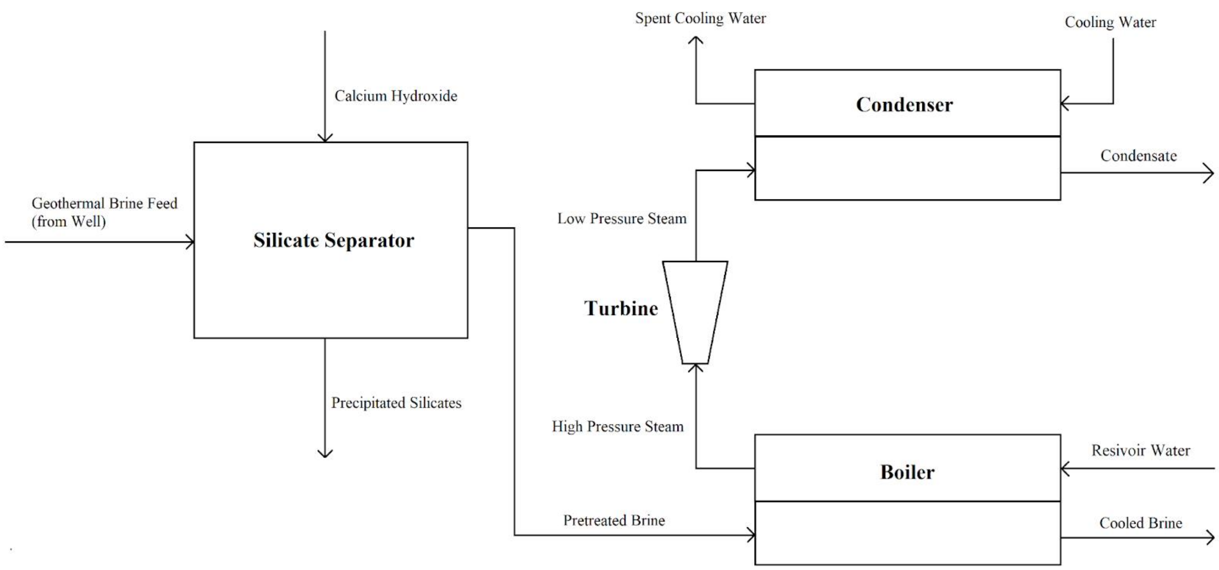

Figure 1. Processed Flow Diagram of Brine Pretreatment Process

After passing through the power plant, cooled brine is processed using a series of packed bed reactors containing iron (III) phosphate, which selectively adsorbs lithium through a reduction-oxidation (redox) reaction (Geise, personal communication, 2022). The spent brine is then sent away for further product extraction. After reaching sorption capacity, iron (III) chloride is then fed to the reactor, which reacts with the lithium iron (II) phosphate to regenerate iron (III) phosphate and lithium chloride. The packed bed reactors are operated such that half are in adsorption mode and half are in regeneration mode to ensure the process is continuous.

Lithium rich brine is then sent to an electrolysis unit, which selectively isolates lithium ions from chloride and iron ions via a redox reaction. Chloride ions from brine (Cl^-) are oxidized at the anode to form chlorine gas (Cl_2), while water is reduced at the cathode to form hydroxide ions (OH^-). Lithium ions pass from the anode to the cathode to form lithium hydroxide monohydrate ($LiOH \cdot H_2O$), which is sent to a crystallization unit for further purification. Oxygen (O_2) and hydrogen (H_2) gas are produced as side products as well as iron (III) chloride, which can be reused in the reactor.

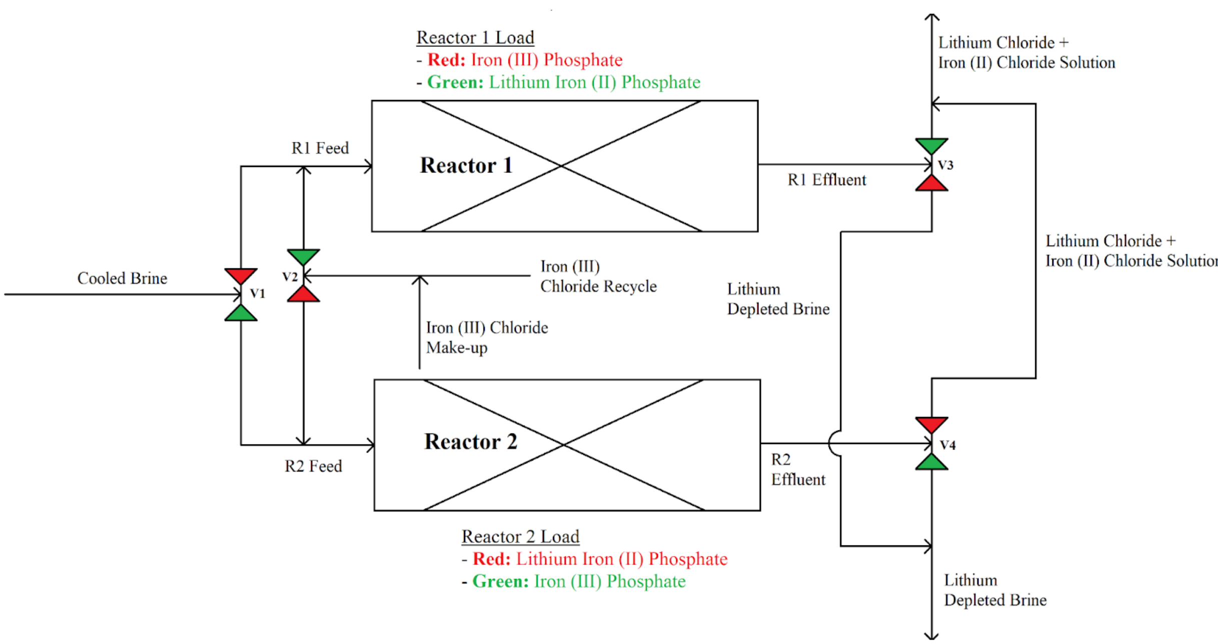

Figure 2. Processed Flow Diagram of Lithium Adsorption/Regeneration Process

Additional product capture involves the extraction of alkali metals from spent brines. While only present in small concentrations, rubidium (32 ppm) and cesium (6 ppm) have high market values (Warren, 2021). Rubidium and cesium can be selectively separated from other minerals via an ion exchange process using zeolite-based sorbents (Neupane & Wendt, 2017). A similar operation structure to the lithium extraction process could be implemented to extract rubidium and cesium products.

For proprietary adsorption and electrolysis unit operations, experimental design data will be sourced from professors Gaurav Giri, Gary Koenig, and Geoff Geise. Additional information regarding other components of the process, such as other alkali metals capture, will be acquired through peer reviewed journals. Data will be consolidated into a thermodynamic model using Aspen Plus design software with the Electrolyte-Nonrandom Two-Liquid equations activity model (ELECNRTL) which has shown to be successful in simulating high temperature and pressure brines in previous literature (Ye et al., 2019). Over the course of two semesters in CHE 4474 and CHE 4476, this project will be completed as a team of five members. Work will be divided equally where each member will focus on a specific unit operation's design and economic analysis; a project management tool, such as a Gantt chart, will be used to assess group progress.

STS Project Proposal

With the Paris Agreement signed in 2016 aimed to reduce global carbon emissions and decrease the global temperature by 2 degrees Celsius, efforts to reduce carbon emissions for power plants have been discussed (Unfccc.int., n.d.). In July 2010, Geodynamics Limited initiated a project to demonstrate a new technology called Enhanced Geothermal Systems (EGS), which differs from the conventional geothermal power plant utilizing volcanic geology (Mills, 2014). EGS is a type of geothermal energy extraction technology that utilizes heat from hot granite rocks to generate electricity or produce heat. The project was referred to as Habanero Geothermal Project (HGP) and consisted of the extraction of heat or production of electricity from Habanero to provide to residents near Cooper Basin. The 1MWe Habanero pilot plant operated for 160 days in 2013 at 19 kg/s and 215 degrees Celsius production wellhead temperature (Mills, 2014). However, the project closed on 10 December 2015 because Geodynamics Limited had concluded that the cost of production for energy in the current market and the remoteness of the plant site was uneconomical for full-scale production of geothermal energy. The sites have since been plugged and remediated and Geodynamics Limited has moved away from exploring geothermal energy but other green energy initiatives.

While these economic and geographical factors were major determinants for project closure to Geodynamics Limited, limiting the cause of project closure to just the cost of operation, infrastructure, and transportation undermines the role played by political and social factors. The Federal and State policies of Australia had shifted its focus away from low-emission fuel supply and reduced research funding for geothermal energy, which resulted in fewer programs looking at the challenges of power generation in geothermal (Huttrer, 2021). Also, overlooking political factors could underestimate the contribution of government subsidies to the economics of HGP since many other green energy alternatives take account of subsidies when determining profitability. The geographical aspects could be tied to societal perception of geothermal energy since it is widely considered a dangerous energy source with the potential of causing earthquakes; therefore, the source of energy had to be placed away from communities, which would increase the transportation cost of providing electricity to communities. Considering the relationship between economic, political, geographic, and societal factors, attributing the cause of failure to just economics and geographic reason would prevent one from making a comprehensive argument.

Drawing on Actor-Network Theory (ANT), I will argue that it was the Australian government's change of focus on energy along with the public perception of geothermal energy as a dangerous source that added complication to the already-existing profitability of EGS and remoteness of the site, which led to the ultimate failure of a geothermal power plant in Cooper Basin. The Actor-Network Theory approach accomplishes this goal by employing recruitment of human and non-human actors to study the activity of network builders. Applying this concept, I will highlight the role of network builder, Geodynamic Limited, in the recruitment of actors and how those technical, social, natural, economic, and conceptual actors interacted to operate the geothermal power plant and led the program to failure. To analyze this program, I will use evidence from public reports by the Australian government, analysis reports by Geodynamics, and press releases.

Conclusion

The deliverable for the problem discussed in the previous technical section will consist of a full power plant design with pretreatment, power generation, adsorption, electrolysis, and crystallization to extract lithium and other valuable minerals like rubidium and cesium. The STS portion of the deliverable will aim to go beyond economic and geographical factors to what caused the project to fail from the perspective of a political and societal standpoint. The analysis will be done through the application of actor-network theory to consider the interaction between technical, economic, natural, social, and conceptual factors. The comprehensive research will give insight into the future of geothermal power plants and their feasibility while understanding why some previous geothermal plants have been unsuccessful. This will allow future development of geothermal power plants to be implemented not only with innovative technologies but also take careful consideration of social and political factors that could impact its commissioning stage and implementation stage.

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