# Environmental Impact Assessment of Lithium Recovery from Geothermal Brines in the SS-KGRA: An Overview

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## ABSTRACT

There is increasing interest in securing a reliable, domestic source of lithium in the United States to support an electrified grid and energy secure future. The Salton Sea Known Geothermal Resource Area (SS-KGRA) has garnered attention for this purpose due to the abundance of lithium in brines brought to the surface for geothermal energy production in this region. Geothermal production from this field is already expected to grow from the current 400 MWe to 920 MWe in the next 3-4 years with a potential total geothermal capacity in the region estimated at nearly 2,950 MWe. With this growth, there is potential for construction and operation of new direct lithium recovery and processing facilities to meet domestic demands for lithium. In this work, we estimate the potential impact of geothermal expansion and lithium extraction in the SS-KGRA on water use, direct air emissions from facilities, and solid waste production and management.

## 1. Introduction

Lithium is a vital resource for producing lithium-ion batteries that will facilitate renewable-based electricity and transportation grids in the United States. Currently, the U.S. relies heavily on importing lithium from resource-intensive processes (evaporation ponds) in Argentina and Chile, primarily (National Minerals Information Center, 2023). These regions are resource-limited, making it important to balance the resource-intense extraction and processing of lithium with the regional constraints of the source's geography. Lithium production in the U.S. has been occurring through a mining process in Nevada since the 1960s (Northey and Cama, 2023), but with the growing need for lithium to support electric vehicles (EVs) and decarbonization goals, the U.S. and state governments are investing heavily in a domestic supply chain for battery-grade lithium, most recently demonstrated by the Biden Administration's American Battery Materials Initiative included in the $2.8 billion Bipartisan Infrastructure Law (The White House, 2022).

The U.S. Geological Survey (USGS) has identified five areas in Imperial County that have geothermal resources, one of which is the Salton Sea Known Geothermal Resource Area (SS-KGRA). In the SS-KGRA, the geothermal brine that is being brought to the surface contains high concentrations of lithium (SWRCB, 2020), making it a potential target for sustainable and low-impact lithium production in the U.S..

Assessing the environmental impact of lithium production and increased geothermal production needed to meet lithium demand is critical for the SS-KGRA because the area is already experiencing significant impact from drought, declining water availability from the Colorado River, and consistently poor air quality. Further, reallocation of water in the region has led to decreasing water levels in the Salton Sea, causing the area to experience loss of biodiversity through the death of fish and birds and an increase in toxic dust from the drying sea bed, affecting nearby disadvantaged communities. It is vital that we evaluate the environmental implications of resource development and contextualize this impact with the environmental issues already present in the region.

Herein we provide a high-level summary of our efforts to assess the environmental impacts of expanded geothermal power production and lithium extraction in the SS-KGRA as well as engage with stakeholders in the local community to provide independent information about these potential projects.

## 2. Methods

### *2.1 Data Sources*

We used publicly available data sources to analyze potential implications of geothermal expansion and associated lithium production in the SS-KGRA. When possible, information about the onsite processes and associated water usage, emissions, chemical usage, and solid waste production was found in environmental impact reports (EIRs) for proposed lithium production facilities in the SS-KGRA (Chambers Group Inc., 2021; County of Imperial, 2022; Energy Source, 2012) as well as recently released environmental assessment documents (functionally equivalent to EIRs) (Black Rock Geothermal LLC, 2023; Elmore North Geothermal LLC, 2023; Morton Bay Geothermal LLC, 2023).

#### 2.1.1 Water

The information on water usage from the above reports was limited, and thus we also used historic and estimated water demand data for Imperial Valley renewable energy plants (GEI Consultants Inc., 2012). To understand the impact of water demand for geothermal and lithium production on the region, we also obtained data on Colorado River water allocations from the local water purveyor, Imperial Irrigation District (IID). We used the available data to evaluate how water will be used in the geothermal and lithium production processes as well as the impact that expanding this production would have on water allocations in the region.

### 2.1.2 Air Quality

Emissions data for carbon dioxide as well as toxins and criteria pollutants emitted on a facility basis were collected from California Air Resources Board (CARB) reporting. These were compared to estimates of air emissions from point, nonpoint, on-road, nonroad, and "event" sources from the National Emissions Inventory (NEI). The US EPA also provides a comprehensive data set for environmental characteristics of electric power generation in the U.S. through the Emissions and Generation Resources Integrated Database (eGRID), where all geothermal emissions are estimated (US EPA, 2020). Net generation for energy sources at the facility level each year from the U.S. Energy Information Administration (EIA) was used to develop emission rates of pollutants for geothermal energy production and lithium extraction, including particulate matter (PM), carbon dioxide, ammonia, hydrogen sulfide, and benzene.

### 2.1.3 Solid Waste

Data on solid waste from reactor-clarifiers and brine ponds located at the geothermal power plants was obtained from the California State Water Resources Control Board (SWRCB) through GeoTracker (SWRCB, 2023). Information on regional landfills, including the quantities of waste accepted and the permitted capacities of these landfills, was obtained from the California Department of Resources Recycling and Recovery (CalRecycle) through the Solid Waste Information System (SWIS) (CalRecycle, 2023). Information on manifested solid waste was obtained from the California Department of Toxic Substances Control (DTSC) through the Hazardous Waste Tracking System (HWTS) (DTSC, 2023). Further, we used data from the California Geologic Energy Management Division (CalGEM) to develop mass balances around injection and production wells to better understand solid waste production (CalGEM, 2023). As mentioned above, we also used facility energy generation data from EIA to develop rates of solids production at each facility that were relative to their geothermal energy production (U.S. EIA, 2023).

## *2.2 Geothermal Expansion and Lithium Production Scenarios*

We considered three scenarios for geothermal expansion in the SS-KGRA:

- existing or allocated demand, which represents the 400 MW (net) of existing geothermal power production in the region;
- projected short-term (3 – 4 year) increased geothermal capacity, which represents an additional 520 MW of planned expansion (920 MW in total); and
- maximum possible capacity, which represents an additional 2030 MW capacity from the projected scenario to meet the estimated maximum geothermal capacity in the region of 2950 MW (Kaspereit et al., 2016).

For each scenario, we projected the amount of potential lithium production. To do so, rates of projected lithium carbonate equivalent (LCE) production in metric tons per MW were determined for facilities that provided projected water use for LCE production. Low, mid, and high estimates correlate to production processes at Simbol/Hudson Ranch (Energy Source, 2012), Hell's Kitchen (County of Imperial, 2022), and ATLiS/Hudson Ranch I (Chambers Group Inc., 2021), respectively. Based on these production rates, the calculated lithium production for each geothermal expansion scenario are summarized in Table 1. These calculations assume all of the produced brine passes through the lithium production process.

**Table 1. Summary of projected lithium capacity for geothermal expansion scenarios.**

| | Total Capacity (MWe) | Calculated Li production (million metric tons LCE/yr) | | |
|---|---|---|---|---|
| | | Low | Mid | High |
| Current Geothermal Production | 400 | 0.13 | 0.15 | 0.15 |
| Projected (3-4 year) Capacity | 920 | 0.29 | 0.34 | 0.35 |
| Maximum Possible Capacity | 2950 | 0.95 | 1.09 | 1.12 |

### *2.3 Community Outreach*

Our team held community outreach events in the Imperial Valley to communicate our findings to local stakeholders through community forums and presentations to local community college students. In community forums, we used pre- and post-presentation surveys to evaluate public perception of geothermal energy and lithium production. For community college presentations we evaluated participant knowledge of geothermal and lithium processes and resources using pre- and post-evaluation through an online polling system. We also responded to questions relating to concerns associated with lithium extraction from geothermal brines that were raised by community members.

## 3. Results and Discussion

### *3.1 Water*

Through this analysis we calculated the potential implications of water consumption by expanded geothermal and associated lithium production on IID water allocations in the county (Table 2). The cuts to Colorado River water allocations reflect two future scenarios: a continuation of the 10% cut that IID committed to in May 2023 and the adoption of a 40% cut that the Bureau of Reclamation suggested may be needed in coming years to keep the river basin functioning.

**Table 2. Water allocations to sectors within Imperial County in million acre-feet per year (MAFY), and the projected changes as a result of geothermal expansion and lithium production.**

| Scenarios | | | Sector Allocation (MAFY) | | | | |
|---|---|---|---|---|---|---|---|
| Year | Geothermal Expansion | Colorado River Cut (%) | Agriculture | Municipal | Renewables | Other | Lithium |
| 2010 | - | - | 2.5 | 0.034 | 0.032 | 0.027 | - |
| 2022 | - | - | 2.2 | 0.042 | 0.072 | 0.028 | 0.003 |
| 2050 | Planned | 10 | 2.1 | 0.073 | 0.087 | 0.028 | 0.064 |
| 2050 | Planned | 40 | 1.3 | 0.073 | 0.087 | 0.028 | 0.064 |
| 2050 | Max Capacity | 10 | 1.8 | 0.073 | 0.135 | 0.028 | 0.257 |
| 2050 | Max Capacity | 40 | 1.1 | 0.073 | 0.135 | 0.028 | 0.257 |

Regionally, the water demand for currently proposed (planned) geothermal production and lithium extraction facilities is modest (3% of historical supply) and will not have a significant impact on water available to agriculture, the dominant industry in the region. The megadrought in the Colorado River basin is constraining water resources in the region, which will significantly reduce agricultural water. As a result of these concurrent forces, any increase in water demand in the region should be carefully evaluated and delicately communicated.

It is also important to note that water demand for lithium extraction is appreciable, representing an additional 3.5 – 4 times the freshwater requirements of geothermal energy production alone from a given volume of brine based on published estimates for facilities planned in the SS-KGRA. However, this amount of water use is significantly less than that required per ton of LCE for conventional approaches to lithium removal from salar brines in Nevada and South America.

### *3.2 Air Quality*

To determine the contribution of SS-KGRA geothermal energy production to noncondensable gas and particulate matter emissions, the total emissions reported to CARB for a given facility for each pollutant type were scaled by the net energy production at that facility. Table 3 summarizes the carbon dioxide emissions rates for geothermal production compared to other sources of energy production.

**Table 3. Emission rates for carbon dioxide from geothermal plants in the SS-KGRA compared to other sources of energy production.**

| Energy Type | Category | Emission Rate (g/kWh) | Source Facility | Data Source |
|---|---|---|---|---|
| Natural Gas | - | 400 | - | eGRID (US EPA 2020) |
| Oil | - | 800 | - | eGRID (US EPA 2020) |
| Coal | - | 1000 | - | eGRID (US EPA 2020) |
| Geothermal | Low estimate | 55 | Hudson Ranch | CARB GHG Mandatory Reporting 2020; EAI Net Generation 2020 |
| | Central estimate | 59 | Average | |
| | High estimate | 65 | Ormat Nevada (Brawley and GEM 2&3) | |

For comparison, we also calculated the expected carbon dioxide emissions for lithium production to be around 92 g/kWh. This was based on a production rate in the SS-KGRA of 288 tons lithium carbonate equivalent (LCE)/yr per MWe at 90% recovery efficiency (McKibben et al., 2023), and IEA calculations that $CO_2$ emissions from lithium carbonate production from brine occur at a rate of 2.8 $tCO_2$ per metric ton LCE equivalent. It is important to note that the use of lithium hydroxide monohydrate (LHM) instead of lithium carbonate results in higher $CO_2$ intensity (~5 $tCO_2$ per metric ton of technical grade LHM from Chilean salar brines) (Grant et al., 2020).

Current geothermal electricity production in the SS-KGRA produces very low emissions of carbon dioxide relative to generation based on natural gas, coal, and oil. Further, current geothermal electricity production produces relatively low emissions of particulate matter, hydrogen sulfide, ammonia, and benzene. However, some limited data suggests that $H_2S$ and ammonia emission rates deserve further study.

### *3.3 Solid Waste*

Geothermal power plants in the Salton Sea geothermal field currently produce an average of 80,000 metric tons of solid waste per annum (all plants), representing approximately 30 kg of solid waste per MWh of electrical production. Most of the solid waste generated at the geothermal power plants originates from the reactor-clarifiers, is non-hazardous, and primarily contains iron silicate. This waste stream is dewatered in filter presses and disposed of in Class II and Class III landfills. Solid waste is also generated through plant maintenance and other activities at the power plants. Currently, approximately one-fifth to one-third of geothermal power plant solid wastes in the SS-KGRA contains sufficient levels of hazardous materials to require management as hazardous wastes under California regulations.

The production of geothermal solid wastes is expected to increase proportionally with the planned increase in geothermal power production within the field. It is estimated that regional landfill capacity (currently undergoing expansion) is adequate for management of the expected solid waste production under the short-term (3 – 4 year) scenario. If ultimate production of geothermal capacity is pursued in the future, additional study of regional landfill capacity will be needed.

Lithium chloride production from geothermal brine requires that the brine be treated for additional removal of silica and metals—beyond what is currently done for geothermal power production—prior to the lithium extraction process. The amount of solid waste that will be produced as part of direct lithium extraction is dependent on the processes applied and whether the solids produced can be monetized. Some of the solids produced during pretreatment contain manganese and other potentially valuable metals. One company in the region estimates that they will produce 7.2 tons of iron-silicate solids per ton of lithium carbonate equivalent (LCE) as well as 3.7 - 4.2 tons of (potentially marketable) metal hydroxides per ton of LCE produced (Chambers Group Inc., 2021). Based on our independent mass balance calculations, we expect slightly lower solid waste production although the difference may be the result of other elements (e.g., calcium and magnesium) that will precipitate and form solid streams during brine pre-treatment. Based on our mass balance calculations, less than 1% of the brine total dissolved solids (TDS) are currently being removed in geothermal power production. This current removal of solids includes approximately 70% of the brine silica. Future lithium extraction processes will likely require 90% removal of brine silica as well as 90% removal of iron, manganese, zinc, and potentially other elements (Stringfellow & Dobson, 2021). Pre-treatment of brine prior to the lithium extraction processes will increase solids production accordingly.

### *3.4 Community Outreach*

The communities surrounding the SS-KGRA are highly engaged and seem interested in learning more about the impacts of geothermal expansion and lithium production. The high-priority questions identified from the community that are within the scope of this work are: (1) How much lithium is there and how long will the resource last? (2) How much water will it take to produce this resource? (3) What are the resulting impacts on air emissions and waste streams? and (4) Will geothermal/lithium extraction impact the San Andreas fault? Community members also expressed a desire for more information about how the process works and the status of development for each company.

We believe that community engagement should be sustained as the projects move forward through in-person and virtual events that are tailored for specific audiences, providing clear and concise printed and online materials. Events should be structured to dedicate equal time to listening and sharing information, and all information should be available in English and Spanish.

## 4. Conclusions

Our analysis has indicated that direct emissions of air pollutants (such as $PM_{10}$, $H_2S$, and $NH_3$) from facilities should have minimal impact on local air quality. Further, the required operational water for these facilities is minor compared to other current water uses in the region (e.g., agriculture), but new demands may face more scrutiny if supplies from the Colorado River are further constrained in response to ongoing drought. Solid wastes, including iron-silicate solids, are produced as part of geothermal power production in the SS-KGRA, so solid waste production will increase as power production is increased. Commercial lithium production from geothermal brines is also expected to result in increased solid waste production.

Furthermore, this analysis indicates that current projections for geothermal expansion and the supported lithium production is expected to have a minor impact on the region's environment. For water, even a minor increase in demand will be challenging to meet whereas with air emissions, it is crucial to keep emission rates low enough to ensure minor impact. Changes in solid waste production resulting from expanded geothermal power production and lithium extraction processes should be periodically reviewed as should availability of regional landfill capacity. Overall, it would be important for new development in the region to consider potential impacts and mitigation strategies.

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