Salton Sea Long-Range Plan

Appendix C: Water Use and Availability for Lithium Extraction

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SALTON SEA MANAGEMENT PROGRAM

CALIFORNIA NATURAL RESOURCES AGENCY

DEPARTMENT OF WATER RESOURCES · STATE OF CALIFORNIA

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

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Acronyms

CEC	California Energy Commission
DLE	direct extraction of lithium
GHG	greenhouse gas
Li	lithium
MW	megawatts
SSGF	Salton Sea Geothermal Field
SSMP	Salton Sea Management Program

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Appendix C: Water Use and Availability for Lithium Extraction

1.1. Introduction

The United States has a large, domestic source of lithium (Li) in geothermal brines at the Salton Sea Geothermal Field (SSGF) of southern California, where estimates of Li pass-through at existing geothermal plants exceed 24,000 metric tons per year, based on 2019 geothermal plant operations (~350 MW [megawatts] capacity) (Warren, 2021).

According to a recently updated geothermal conceptual model of the SSGF (Kaspereit et al., 2016), it has been estimated that the SSGF has a total reserve of 2,950 MW electricity generating capacity, a potential reserve of 2,000 metric kilotons of Li, with a potential annual production rate of ~600,000 tons per year of lithium carbonate equivalent (McKibben et al., 2020; Ventura et al., 2020). This is equivalent to ~7.2 billion US dollars in annual revenue based on a $12,000/ton price of Li carbonate.

The State of California has some of the most aggressive greenhouse gas (GHG) mitigation and renewable energy generation targets globally. Geothermal electric power production from the SSGF is one renewable energy source that will help California meet its legislated targets. Unlike wind or solar power, geothermal power has no intermittency issues and provides stable baseload capacity with minimum GHG emission. However, the upfront costs of developing geothermal power plants are high, with longer construction cycles when compared with wind and solar. These costs could partly be addressed through the production of Li from geothermal plants. The relatively high Li concentration in Salton Sea geothermal brines provides an opportunity for providing a secure, stable domestic supply of Li that could meet all US potential needs. Economically sustainable development of renewable geothermal energy can be performed by integrating geothermal development and Li production from geothermal brines together in the SSGF.

Extensive research and development over several decades have demonstrated the feasibility of extracting Li from geothermal brines in the SSGF (see Warren 2021 and references therein). Many techniques and process strategies have been proposed for the direct extraction of Li (DLE) from geothermal brines. These can be generally categorized into adsorption, ion exchange, and solvent extraction techniques. Of these technologies, the ones currently advancing to pilot- and near-commercial-scale demonstration involve adsorption/desorption and ion exchange techniques. Three planned and ongoing field projects for integrating geothermal and Li extraction are currently under development in the SSGF (BHER Minerals, 2020, Energy Source Minerals, 2021, Controlled Thermal Resources, 2020a, b). DLE technologies also present the opportunity to increase sustainability and reduce overall environmental impacts when compared to traditional evaporative pond and hard rock mining methods for producing Li.

This appendix provides a brief overview of the potential environmental impacts of integrated geothermal development and Li production in the Salton Sea region, in the context of restoration efforts that are being implemented as part of the Salton Sea Management Program (SSMP).

1.2. Potential Environmental Impacts

In general, the integrated geothermal development and Li production in the SSGF are expected to have low GHG emissions, and potential water quality impacts will be managed by reinjection of effluent brines and process wastewater into the source reservoir. Two key known environmental concerns are (1) induced seismicity due to continuous pumping and injection of a large amount of brine from/into the reservoir and (2) consumptive freshwater use associated with Li production processes in the arid Salton Sea area.

INDUCED SEISMICITY An environmental impact concern of future integrated geothermal development and Li production at the SSGF is the potential for induced seismicity due to the increased pumping and re-injection of geothermal brines, a well-known phenomenon associated with large-scale subsurface fluid extraction and injection operations. This concern is of particular interest at the SSGF since it is located within a tectonically active region of many active regional faults, including the San Andreas Fault nearby. According to the seismic monitoring data (Brodsky and Lajoie, 2013; Trugman et al, 2016), the seismic rate in the area was initially low during the period of low-level geothermal operations before 1986. As the operations expanded, so did the seismicity. The seismic rate increased during the mid-1980s to early 1990s, during which most geothermal development activities occurred in the SSGF. After that, the rate of seismicity remained relatively stable despite continuous (however, at a lower rate) geothermal development in the area.

Based on the mapped seismicity events from 1981 to 2012, Brodsky and Lajoie (2013) concluded that the SSGF seismicity is dominated by small earthquakes, and the magnitude distribution follows the Gutenberg-Richter relationship: the number of earthquakes of magnitude greater or equal to M is proportional to $\sim 10^{-0.99M}$. The largest recorded magnitude earthquake in the SSGF is 5.1, which occurred in August 2005. According to Brodsky and Lajoie's (2013) analysis, the risk of triggering a damaging earthquake due to geothermal development in the Salton Sea is relatively low.

Historically, the geothermal brines have been produced from the reservoir at a temperature of ~450 – 480 °F, and the effluent brines were re-injected back into the reservoir at a temperature of 205-230 °F. When coupled with Li extraction from brines, the injected brines might be cooler than the current normal power plant reinjection temperature. It is unclear from publicly available data what the temperature range of injectate would likely be after the removal of Li. The cooler injectate might promote seismic activities within the reservoir. Reservoir modeling considering the thermoelastic effects could clarify the importance of the impacts on reservoir stress state and fault slip potential due to the injection of cooler brines.

CONSUMPTIVE FRESHWATER USE Operations of geothermal power plants in the SSGF require limited freshwater use. Most of the freshwater is obtained from Imperial Irrigation District (IID) canal water and used primarily for preparing diluted acidic solutions for controlling silica scale buildups, supplemental cooling tower makeup water, conditioning/treating brines during power generation cycles, and diluting brines prior to reinjection and portable usage (CEC, 2003; CEQA Report-Hell's Kitchen PowerCo 1 and LithiumCo 1 Project, 2022; CEQA Report- Energy Source Mineral ATLIS Project, 2021). While the exact amount of freshwater used for normal geothermal power plant operations in the SSGF is not available from public sources, based on very limited information in permit applications and environmental documents (CEC, 2003; CEQA Report-Hell's Kitchen PowerCo 1 and LithiumCo 1 Project, 2022), the estimated freshwater use is in the range of ~1.58 to 4 acre-feet per year per MW generating capacity. Under the current geothermal generating capacity of ~350MW, the annual freshwater use for Salton Sea geothermal power plant operations is approximately in the range of 550 to 1,400 acre-feet per year. At roughly double the generation capacity (700 MW), the freshwater use would be ~1,110 to 2,800 acre-feet per year.

Despite the extensive literature on various direct Li extraction technologies, there is limited information available in the public domain on freshwater use associated with the various sorbent and ion-exchanger-based Li extraction processes that have been proposed in the SSGF (Harrison, 2014; Ventura et al., 2018; Ventura et al., 2020), largely due to the proprietary nature of these various extraction technologies. Freshwater is primarily used for cooling water makeup to cool down brines to desired optimal temperatures, makeup solutions for pre-treating/conditioning brines for controlling mineral precipitation (e.g., silica, iron, etc.), to prepare various process waters, including acidic and alkaline solutions of desired chemical compositions and pH values for use at all stages of Li extraction, purification, concentration, and conversion processes, and to make up solutions for regenerating sorbents or ion-exchangers and solutions to extract sorbed Li and other metals (e.g., zinc, manganese, etc.) wash water. For example, Harrison (2014) noted that about 6 to 9 L of wash water per kg Li_2CO_3 must wash Li_2CO_3 precipitates prior to downstream concentration and purification stages. Ventura et al. (2020) reported using CO_2-loaded, deionized water for extracting sorbed Li and regenerating their proprietary sorbents/ion exchangers, without any information on how much deionized water was needed for their process.

A few permit applications and environmental documents filed for developing integrated geothermal power and Li extraction field projects in the SSGF listed freshwater use for plant operations and targeted Li production (CEC, 2003; CEQA Report-Hell's Kitchen PowerCo 1 and LithiumCo 1 Project, 2022; CEQA Report-Energy Source Mineral ATLIS Project, 2021). Water use for Li extraction associated with these projects, per unit of Li production, is summarized below:

- BHER Minerals Demonstration Project, funded by the California Energy Commission (CEC)
  - Technology: Ion exchanger
  - Targeted water use: 0.154 acre-feet/ton Li_2CO_3
- Energy Source Minerals (project ATLiS)
  - Technology: Adsorption-desorption
  - ~20,000 tons/year LiOH equivalent
  - ~0.18 acre-feet/ton Li_2CO_3
  - ~3,400 acre-feet annual water use
- Control Thermal Resources: Hell's Kitchen Project
  - Technology: Ion-exchanger
  - ~17,000 tons/year Li_2CO_3 equivalent
  - ~0.382 acre-feet /ton Li_2CO_3

The environmental documents cited above provide reasonable estimates of overall water use associated with Li production, as shown in Table 1 (using upper and lower bounds of unit water use rates from the above numbers). If Li extraction were coupled with current levels of geothermal generation (350 MW), the water use would be in the range of 13,938 – 34,574 acre-feet per year. The numbers would increase proportionally at higher levels of geothermal generation and Li production, as shown in Table 1.

Table 1. Estimated annual freshwater use for Li production in the Salton Sea Geothermal Field.

Generating Capacity (MW)	Projected Li Annual Production Potential (metric tons**)	Projected annual freshwater use on full scale of Li production. (acre-feet per year)
350*	17,000	13,938 – 34,574
700	40,000	32,796 – 81,351
1,000	60,000	48,960 – 121,445

* 350MW is the current geothermal power generation in Salton Sea Geothermal Field
** To convert from lithium to lithium carbonate, multiply by 5.324, thus 17,000 tons of Li corresponds to 90,508 tons of lithium carbonate

1.3. Conclusions

In general, the integrated geothermal development and Li production in the SSGF will have limited direct discharges. All effluent brines and wastewater from production cycles will be reinjected back into the deep reservoir, therefore the risk of water pollution is low. The plant operations emit little GHG and pose a negligible impact on air quality. After the construction of the plants, the increased land coverage by buildings and paved ground surface could help reduce dust emissions. Potential environmental impacts of specific geothermal and lithium projects will be evaluated in individual environmental compliance documents and are not part of the scope of this Long-Range Plan.

Based on the past nearly four-decade history of geothermal power plant development and seismicity mapping records in the area, the risk of damaging earthquakes triggered by the continuous development of geothermal power in the Salton Sea Reservoir Field is likely to be low. However, the added cooling of geothermal brines during Li production processes prior to reinjection will induce added changes in the stress state to the deep reservoir around injection wells. The temperature of the injectate after the removal of Li from brines is unclear. The largest earthquake observed in the SSGF was M5.1, which occurred in August 2005. Therefore, precautions need to be taken in designing and constructing buildings and berms in the area to avoid potential liquefaction events associated with earthquakes triggered by pumping and injection operations.

At the current geothermal power generating capacity of 350MW in the SSGF, annual production of 17,000 metric tons of Li could be reached by processing effluent geothermal brines after power generation. At this annual Li production rate, about 13,938 to 34,574 acre-feet of fresh water per year are needed during various stages of Li extraction, purification, concentration, and conversion processes. All currently proposed field Li production projects in the Salton Sea are planning to purchase fresh water from IID canal water for irrigation. The water is expected to be used entirely consumptively in that it is either evaporated or injected into deep formations and is not returned to the near-surface environment. The amount of water needed for Li extraction, over and above that needed for geothermal production, is not insignificant, particularly within the arid Salton Sea area, and needs to be considered in the overall water balance for restoration project planning.

1.4. References

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