Lithium Resources Beneath The Salton Sea: Opportunities and Challenges

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What is Lithium and why is it so valuable?

Atomic number 3 on the periodic table of the elements: the lightest of the metals
Can store more energy per weight than other metals
So, lithium is ideal for powering mobile electrical devices
Smart phones, Laptops/Tablets, Earbuds/Airpods, Weedwhackers, Power drills, Electric vehicles

But, like, what is a battery even?
All batteries consist of four components: anode, cathode, electrolyte, and separator. As a battery is charged, ions flow from the cathode to the anode. When it’s discharged, the ions reverse course.

The components can come in a tightly wound cylinder steeped in liquid electrolyte. The amount and proportion of ingredients fluctuate with metals used.
Metals in battery cells for electric vehicles come from minerals and brines.

- ~ 6 kg of lithium (13.2 pounds)

Growth in demand = growth in price

This is the reason for all the sudden interest in the geothermal Li far beneath the Salton Sea!
The U.S. has a very fragile Lithium Supply Chain

This complex supply chain can be easily interrupted or broken by wars, embargoes, pandemics.

A domestic, more environmentally-friendly approach: Direct Lithium Extraction (DLE) at the Salton Sea Geothermal Field

Three operators generate ~400 MWe of electricity:

- Berkshire Hathaway Energy Renewables (BHER) (CalEnergy)
  10 power plants
- EnergySource Minerals (ESM) (Hudson Ranch/Featherstone)
  1 power plant
- Controlled Thermal Resources (CTR) (Hell’s Kitchen)
  Building new facilities
How much Li may be in the Salton Sea geothermal brines?

Brine Li concentration × reservoir porosity × reservoir volume

<table>
<thead>
<tr>
<th>Porosity</th>
<th>Reservoir brine volume (km³)</th>
<th>Li in reservoir brines (metric tons of Li metal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% 1990s</td>
<td>5.5 km³</td>
<td>1,000,000</td>
</tr>
<tr>
<td>“conservative” 2016</td>
<td>15.5 km³</td>
<td>3,000,000</td>
</tr>
<tr>
<td>20% 1990s</td>
<td>11 km³</td>
<td>2,000,000</td>
</tr>
<tr>
<td>“optimistic” 2016</td>
<td>33 km³</td>
<td>6,000,000</td>
</tr>
</tbody>
</table>

For comparison, Salar de Atacama in Chile contains 6 million metric tons of Li metal (Munk et al. 2016).

1 ton Li metal = 5.32 tons LCE = 6.05 tons LHME

How much of the dissolved Li might be recovered each year?
At current brine production rates, with 90% recovery efficiency for lithium:

115,200 tons LCE/yr @ 400 MWe

= **288 tons LCE/yr per MWe**

Announced expansion of the geothermal field over the next several years:

- BHER current = 345 MWe
- BHER additional = 395 MWe
- ESM current = 60 MWe
- CTR new Stage 1 = 50 MWe
- CTR new Stage 2 = 260 MWe

Total = 1,110 MWe x 288 tons LCE/MWe

= **320,000 metric tons LCE/yr 10M EVs/yr**

= 60% of global Li production in 2021 (532,000 metric tons of LCE)

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**How long might the Li production last?**

For a fixed rate of **320 kt/y** of LCE for the expanded geothermal field (1,110 MWe):

<table>
<thead>
<tr>
<th>“Reserves”</th>
<th>Annual depletion rate</th>
<th>Years of production</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Mt LCE (conservative)</td>
<td>6.4%</td>
<td>16 yrs</td>
</tr>
<tr>
<td>16 Mt LCE (half optimistic)</td>
<td>2.0%</td>
<td>50 yrs</td>
</tr>
<tr>
<td>32 Mt LCE (optimistic)</td>
<td>1.0%</td>
<td>100 yrs</td>
</tr>
</tbody>
</table>
BHER: April 2022 – commissioned a 1/10 scale Li extraction demonstration plant. Currently designing a second demonstration plant to convert extracted Li to marketable lithium carbonate.

ESM: will start construction on commercial scale 19,000 tpy lithium hydroxide plant next to 60 MWe Cyrq power plant 4Q22/1Q23.

CTR: will start construction of commercial scale 50 MWe power plant with 20,000 tpy lithium hydroxide facility in 2023.
CTR: also plans to add additional Li extraction stages plus battery manufacturing and recycling to its Li campus:

![CTR Concept Image](image)

**Water use estimates for geothermal Li extraction**

ESM EIR 2021: 3,456 AFY of IID canal water for scaled-up extraction operations = 62,600 gallons of water per metric ton of Lithium Carbonate. BHER has said it will use 50,000 gallons of water per metric ton of Lithium Carbonate, one tenth of the water needed in South American salar operations.

Potential water sources for geothermal Li extraction:
- IID canal water (but competes with ag, municipal)
- Brackish (non-potable) shallow groundwater (non-IID) - desalinated
- Imported municipal grey water (e.g., The Geysers geothermal field)
- Steam condensate (self-generated by the geothermal operators)
CO₂ emissions from Salton Sea geothermal power plants are published online at CARB web site: https://ww2.arb.ca.gov/mrr-data

Annual emissions data for 2019:

<table>
<thead>
<tr>
<th>ARB ID</th>
<th>Facility Name</th>
<th>Report Year</th>
<th>Total CO₂e (metric tons CO₂e)</th>
<th>AEI</th>
<th>Excess CO₂e (metric tons CO₂e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100902</td>
<td>CalEnergy Operating Corporation - J J Elsinor - Geothermal</td>
<td>2010</td>
<td>7,716</td>
<td>No</td>
<td>7,716</td>
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<tr>
<td>100708</td>
<td>CalEnergy Operating Corporation - J M Leathers - Geothermal</td>
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<tr>
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<td>CalEnergy Operating Corporation - Region 1 - Geothermal</td>
<td>2013</td>
<td>70,992</td>
<td>No</td>
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<tr>
<td>100715</td>
<td>CalEnergy Operating Corporation - Region 2 - Geothermal</td>
<td>2010</td>
<td>35,500</td>
<td>No</td>
<td>35,500</td>
</tr>
<tr>
<td>104540</td>
<td>Hudlon Ranch Power Plant - Geothermal</td>
<td>2010</td>
<td>24,800</td>
<td>No</td>
<td>0</td>
</tr>
</tbody>
</table>

160,644 metric tons/yr for all Salton Sea power plants = avg of 14,604 tons/yr per geothermal power plant

Compare with:

- Chevron’s Oil Refinery, El Segundo: 3,000,000 tons/yr
- CalPortland Cement plant, Oro Grande: 1,374,930 tons/yr
- Spreckels Sugar Co. plant, Brawley: 91,113 tons/yr
- U.S. Gypsum Co. plant, Plaster City: 69,943 tons/yr
- IID Gas Turbine plant, Niland: 57,533 tons/yr

Does geothermal Li extraction itself add any emissions?

Only from the added electrical energy used, when adding a Li filter to the existing power plant.

Most geothermal power plants generate their own electrical power to use, called the "parasitic power" load, typically 10-20% of the total power produced.

If some of this power can be used for Li extraction, it actually reduces CO₂ emissions that would otherwise be generated by using electricity generated elsewhere from fossil fuels – a carbon credit.

Grant et al., 2020
Conclusions

- Geothermal Li extraction is the least destructive method of Li production and can help secure a stable supply chain for growing U.S. lithium needs.
- Infrastructure costs are minimized at the Salton Sea field because the bulk of the brine production and reinjection facilities already exist as geothermal power plants.
- The Salton Sea geothermal field’s reservoir brines may contain up to 32 million metric tons of LCE, making it one of the largest Li deposits in the world.
- Up to 115,000 metric tons/yr of LCE could be produced from the current power plants, if Li extraction methods being piloted now are highly effective and can be scaled up to commercial production. Enough Li for 4 million electric cars per year.
- Expansion of the field over the next decade could generate over 320,000 metric tons/yr of LCE. Enough for 10 million electric cars per year.
- Lithium recovery may not add any new CO₂ emissions, but water use should be very carefully assessed. Many alternatives to IID canal water exist, including municipal grey water, solar-desalinated brackish groundwater, and self-generated steam condensate.