The Promise of Lithium Valley's Geothermal Lithium Resources

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LBNL

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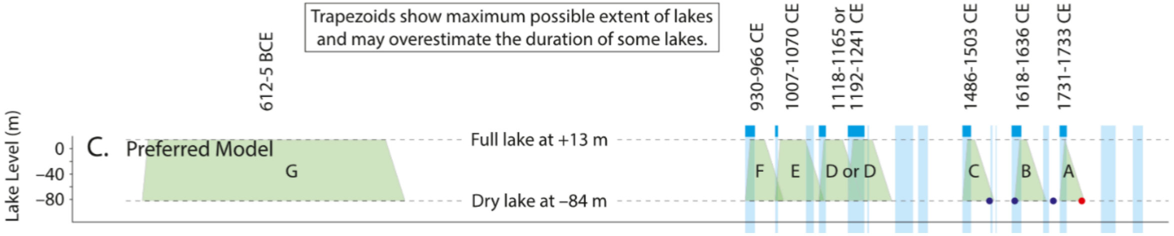
The Origin of Hot Brines Beneath the Salton Sea

Sources: University of Redlands, USGS NCT/CAL



Hundreds to thousands of ancient Salton Seas, collectively known as “Lake Cahuilla”, have formed and evaporated in the isolated northern Salton Trough rift since the late Pliocene. A lake has formed about every 200 years over the past several thousand years (Rockwell et al., 2022).

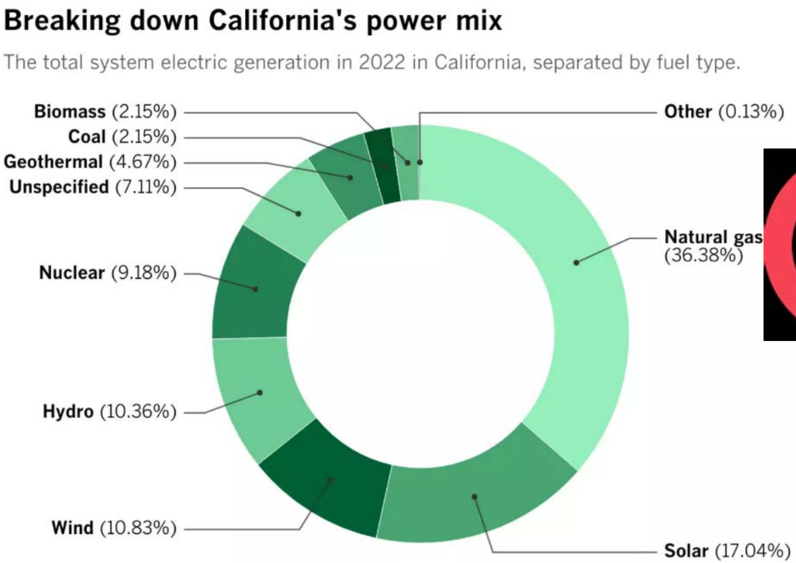
Some of these lakes were 3-4 times the area of the modern Salton Sea.

The lake has never been stable - it is always filling up or drying out. Repeated lake filling and its evaporation to residual salt over a long period of geologic time is responsible for the build-up of a large mass of Li-bearing brine at depth.

Igneous activity near the SE edge of the Sea has caused the brines to become hot and buoyant and rise to depths as shallow as 0.5 km below the ground surface, creating the geothermal resource that is being tapped for steam.

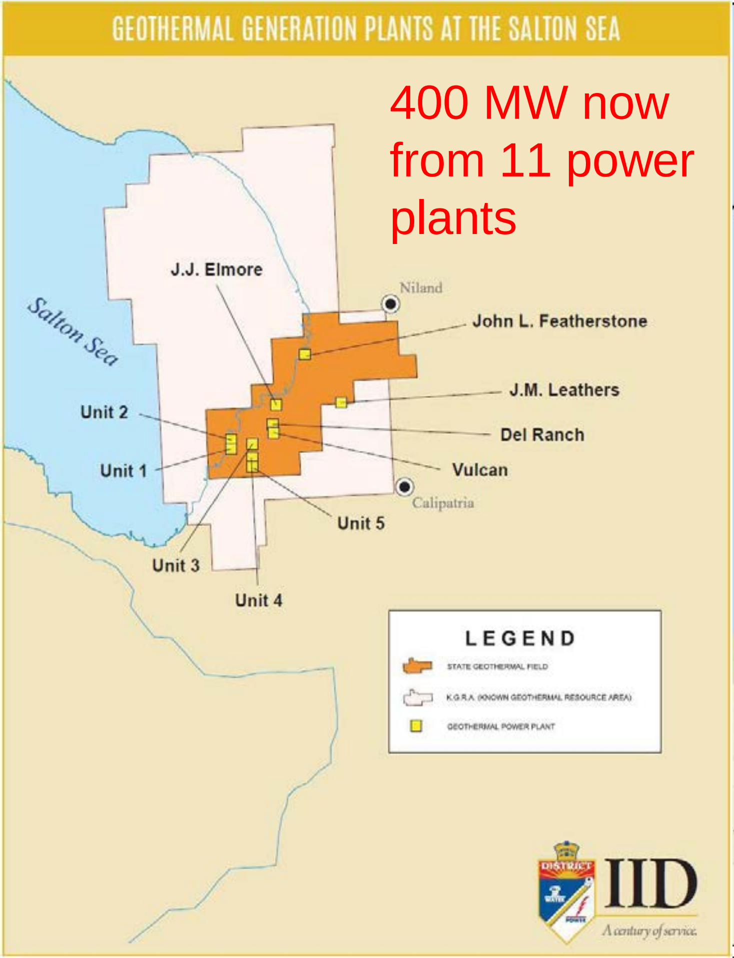
Salton Sea Geothermal Field expansion

- CPUC ordered ~1,000 MWe of additional renewable baseload (24/7) electricity for the state grid, to help meet 60% renewables portfolio by 2030 and 100% renewables portfolio by 2045 (S.B.s 350 and 100).
- Salton Sea geothermal field is the only major CA KGRA that can expand.
- Requires doubling or tripling the capacity of current field (~400 MWe): ultimately capable of producing as much as 3,000 MW

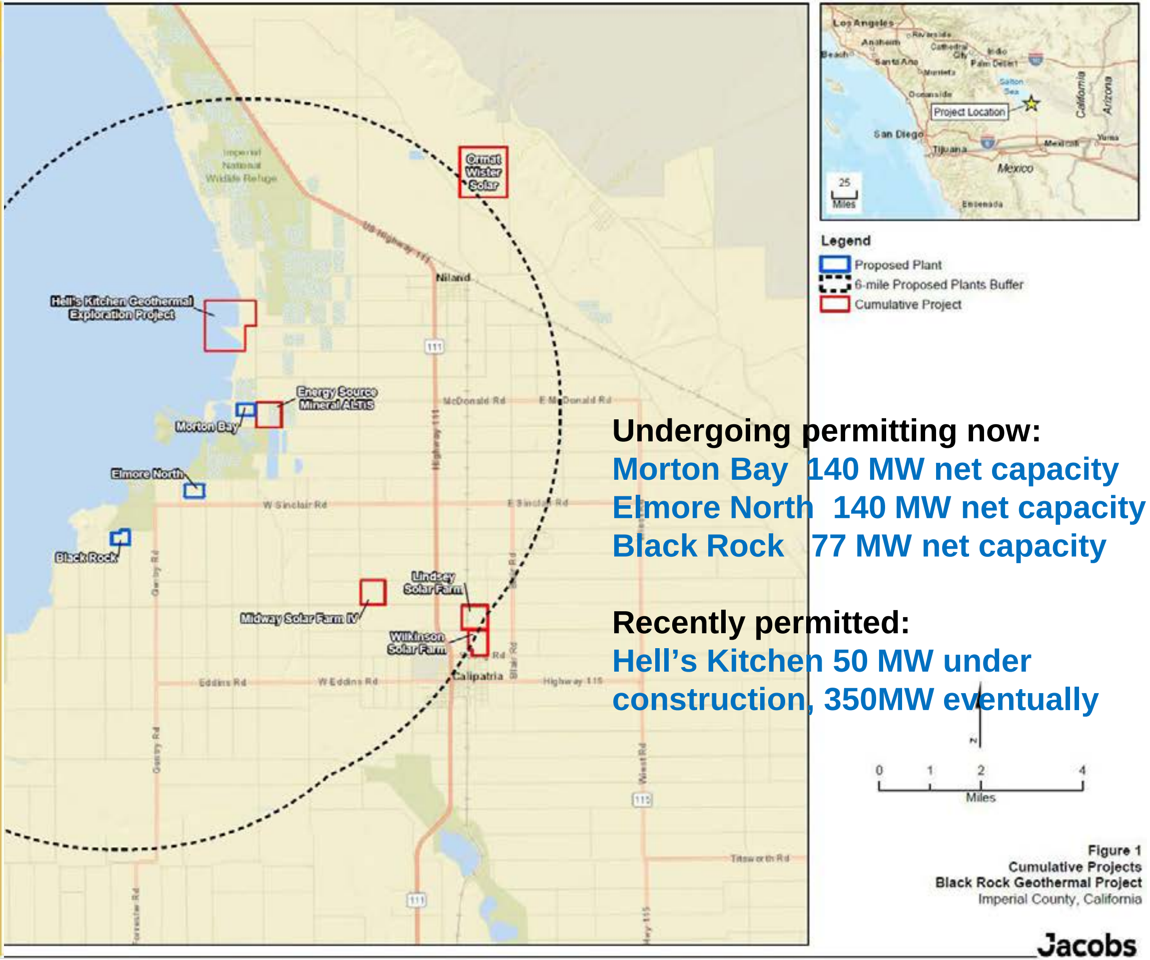


CEC/SD U-T

Current and Future Power Plants: it may take a decade to get fully built out



400 MW now from 11 power plants



Undergoing permitting now:
Morton Bay 140 MW net capacity
Elmore North 140 MW net capacity
Black Rock 77 MW net capacity

Recently permitted:
Hell's Kitchen 50 MW under construction, 350MW eventually

IID 2018 CEC/BHER 2023

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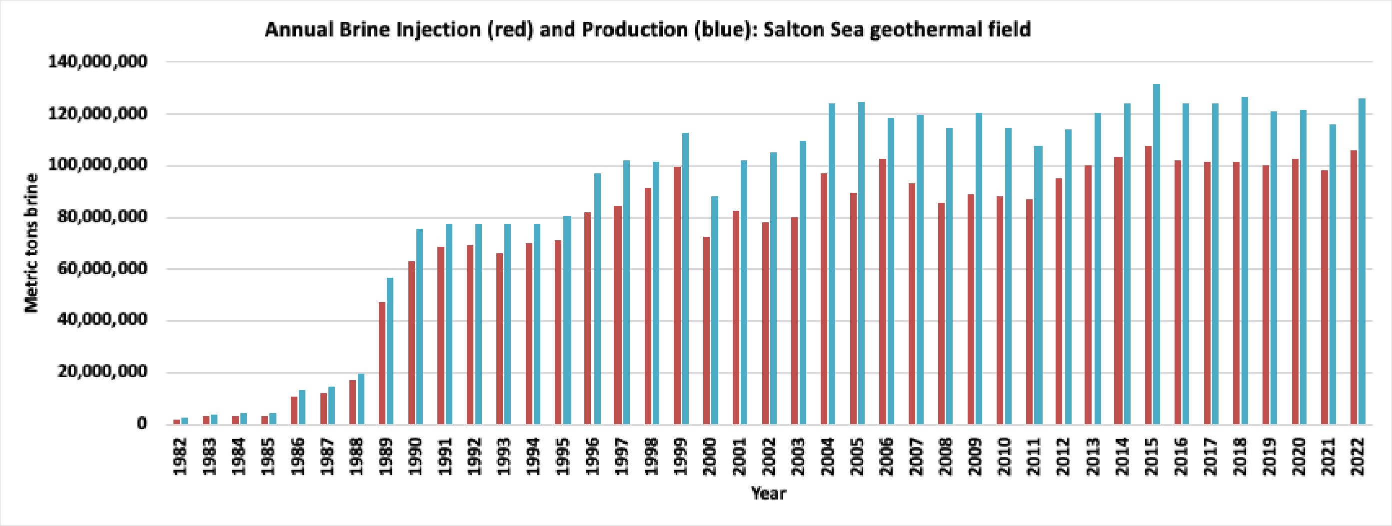
How much of the dissolved Li in the brine might be recovered each year?

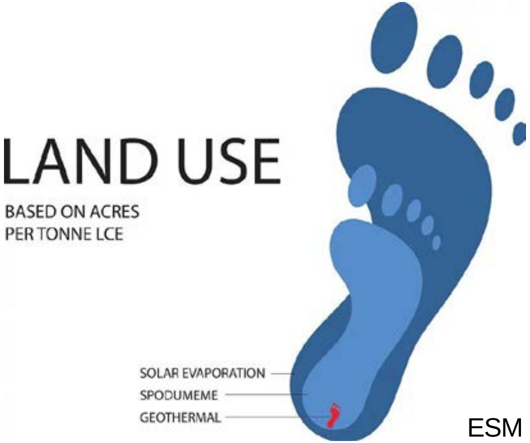
- Annual Li production = mass of brine × Li conc. × recovery efficiency for the current 400 MWe capacity
- Using 20-year avg. of brine production (120,000,000 metric t/y), 200 ppm Li, and a recovery factor of 90%, 21,600 metric tons/y Li metal (**115,000 metric tons/y LCE**) could be recovered **now** (**3.6 M EVs/y**).
- If field doubles its current capacity to 800 MWe, production could reach **230,000 mt/y LCE** (**7.2 M EVs/y**).
- Tripling of capacity to 1200 MWe would generate **345,000 mt/y LCE (10.8 M EVs/y).**
- For comparison, global Li production in 2022 was **680,000 mt/y LCE**.

Salton Sea Geothermal Field production and injection data from CA Dept. of Conservation



Dobson et al., 2023

Geothermal brine DLE: smallest footprint: closed-loop process, no evaporation ponds, no open pits, blasting, smelters. No significant CO_2 footprint from a long global supply chain.

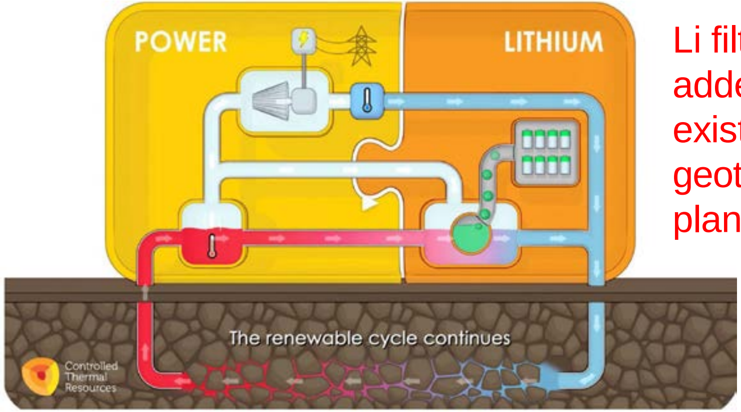


ESM

Chilean salar brine:
3,100 acres

Australian hard rock:
465 acres

Geothermal lithium:
50 acres



Li filter added to existing geothermal plant

CTR

Li extraction efficiency:

Evaporation ponds 40-50%

DLE >90%

DLE can be self-powered with renewable geothermal electricity

Steam condensate from geothermal power can supply some fresh water

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Direct Lithium Extraction (DLE):
Aluminate (clay-like) adsorbents used with fluidized bed reactors (giant blenders or food processors)

CTR

BHER

ESM

Currently used in: Argentina, Rhine Valley EU

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Demonstration and Optimization Plant Delivers 95-97% Lithium Recovery

- In September 2022, CTR commenced operation of an onsite Demonstration and Optimization Facility to identify optimum operating conditions for the brine conditioning and DLE process circuits utilizing live geothermal brine from its Stage 1 production wells
- Operation of the brine conditioning system successfully produced Silica and major transition metals from the brine while producing stable, high-quality feed for Direct Lithium Extraction
- CTR selected DLE adsorption technology developed by Koch Technology Solutions based on superior performance in operating temperature, filtration requirements, and reagent usage, to deliver better overall capital and operating costs
  - ✓ **Temperature** - operation at higher temperature requires less upstream brine cooling
  - ✓ **Filtration** - higher tolerance for suspended solids requires less filtration
  - ✓ **Reagents** - elution with water instead of hydrochloric acid substantially reduces reagents consumption
- The facility includes operation of a **1/15th-scale DLE circuit**, well within normal scale up parameters for this technology
- DLE results of **95-97% lithium recovery** were confirmed. DLE operation demonstrated high lithium loading on the sorbent with good selectivity relative to other major cations, including Na, K, Ca and Mg
- CTR's Optimization Plant operated from September 2022 until April 2024

Lithium is one of many metals in the Salton Sea geothermal brines that are strategic (critical)

Field:	Salton Sea
Well:	S2–14[b]
Temperature (°C)[g]	330
Depth (m)[h]	2500–3220
Constituent	
Na	54,800
Ca	28,500
K	17,700
Fe	1,710
Mn	1,500
SiO_2[i]	>588
Zn	507
Sr	421
B	271
Ba	≈210
Li	209
Mg	49
Pb	102
Cu	7
Cd	2
NH_4	330
Cl	157,500
Br	111
CO_2[i]	1,580
HCO_3	NA
H_2S	10
SO_4	53
TDS	26.5%

McKibben & Hardie 1997

Commodity	Main use	Import reliance	Import sources
Li 200 ppm	Batteries	>90%	Argentina, Chile, China
Mn 1500 ppm	Steel-making	100%	S. Africa, Australia, Gabon, Georgia
Zn 500 ppm	Galvanizing	76% (refined)	China, Peru, Australia
K 18000 ppm	Fertilizer	93%	Canada, Russia, Belarus
Sr 400 ppm	Magnets	100%	Mexico, Germany, China
Rb 90 ppm	Quantum computers	100%	Canada, China

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Lithium Valley EV battery production and domestic supply chain job scenarios from Benner et al. (2024)

TABLE 3.

Estimates of potential lithium recovery from current and future geothermal facilities

	Scenario	Li (MT per year)	Process efficiency (%)	Recoverable Li (MT/year)	Battery Production (GWh/year)	Potential EV production
Current power production	GT1	24000[72]	90%[73]	21600	222	2.9 million
Doubled power production	GT2	48360[74]	90%	43524	447	5.1 million

Jobs estimates of 2 different lithium recovery scenarios

current doubled

Product	Sample facilities	Jobs/GWh	Total GT1	Total GT2	Percentage of Total Jobs
LCE	ESM, BHER, CTR	4	931	1891	0.67%
CAM	BASF Japan, Umicore (Ontario), Redwood Materials (South Carolina)	8	1765	3583	1.26%
Cell + Pack	Panasonic (Nevada and Kansas), SK (Tennessee and Kentucky)	115	25294	51357	18.13%
EV	Tesla (Fremont), Ford (Blue Oval Tennessee), Rivian (California)	507	111514	226420	79.94%
Total		634	139503	283251	100%

Can add recycling jobs to these Numbers !!!

Occupations developed within Lithium Valley battery supply chain

TABLE 2.

Sample occupations in the battery value chain.[70]

Segment	Occ. Type	Occupation title	Annual mean wage in CA (Q1 2023)	Typical education needed for entry
Mineral extraction and refining	Blue-Collar	Chemical technician	$56,834	Associate's Degree
		Chemical plant and system operator	$93,562	High school diploma or equivalent
		Occupational health and safety technician	$99,991	High school diploma or equivalent
Battery manufacturing	Blue-Collar	Electrical, electronic, and electromechanical assemblers	$48,719	High school diploma or equivalent
		Maintenance workers, machinery	$63,425	High school diploma or equivalent
		Industrial machinery mechanic	$70,596	High school diploma or equivalent
	Professional	Software developers	$189,587	Bachelor's degree
		Electrical engineers	$156,741	Bachelor's degree
		Electronics engineers	$143,938	Bachelor's degree
		Chemical engineer	$122,432	Bachelor's degree
		Industrial engineer	$121,881	Bachelor's degree
Other jobs needed for Lithium Valley	Professional	Environmental scientists and specialists, including health	$105,079	Bachelor's degree

Links

2023 LBNL-UCR-UCD-MIT-Yale-Auckland assessment of Li resources in Salton Sea Geothermal Field: https://escholarship.org/uc/item/4x8868mf

2024 UCSC-UCB-UCD-New Energy Nexus report on building a Lithium Valley supply chain: https://transform.ucsc.edu/powering-prosperity-building-an-inclusive-lithium-supply-chain-in-californias-salton-sea-region/