DOCKETED	
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Project Title:	Geothermal Grant and Loan Program Workshops and Discussions
TN #:	232064
Document Title:	Presentations of California's Lithium Recovery Initiative - Symposium
Description:	February 12, 2020
Filer:	Elisabeth de Jong
Organization:	California Energy Commission
Submitter Role:	Commission Staff
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Docketed Date:	2/18/2020

California's Lithium Recovery Initiative Symposium

Schedule:

- 1:00 -1:30 Registration and Networking
- 1:30 -1:45 Welcome and Opening Remarks
- 1:45 - 2:15 Presentations: Innovation and Support
- 2:15 - 2:45 Presentations: Market Opportunity
- 2:45 - 3:00 Break
- 3:00 - 3:30 Panel: Supply
- 3:30 - 4:00 Panel: Demand
- 4:00 - 4:30 Panel: Execution and Regulation
- 4:30 - 5:00 Closing Remarks and Networking

Welcome and Opening Remarks

California's Lithium Recovery Initiative Symposium

- Chair David Hochschild, California Energy Commission
- Tyson Eckerle, Deputy Director, ZEV Market Development, Office of Business and Economic Development (GO-Biz)

Innovation and Support

California's Lithium Recovery Initiative Symposium

Elisabeth de Jong
February 12, 2020
Geothermal Grant and Loan Program
California Energy Commission

Geothermal Opportunities

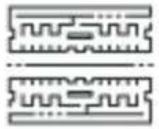
- Geothermal power plant development
- Mineral coproduction

Dawn, Salton Sea Geothermal Field
Image Credit: Mike Krahmer

35 Critical Minerals - Lithium

Energy

HAFNIUM
RHENIUM
TANTALUM
URANIUM

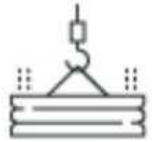


Technology

GERMANIUM
INDIUM
GALLIUM
RARE EARTHS

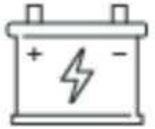
Industrial

BERYLLIUM
ZIRCONIUM
TUNGSTEN
ALUMINUM
PGMs
BARITE
FLUORSPAR
ARSENIC
SCANDIUM
STRONTIUM
TITANIUM
POTASH



Steel

MAGNESIUM
CHROMIUM
TIN
TELLURIUM
MANGANESE
VANDIUM
NIOBIUM



Batteries

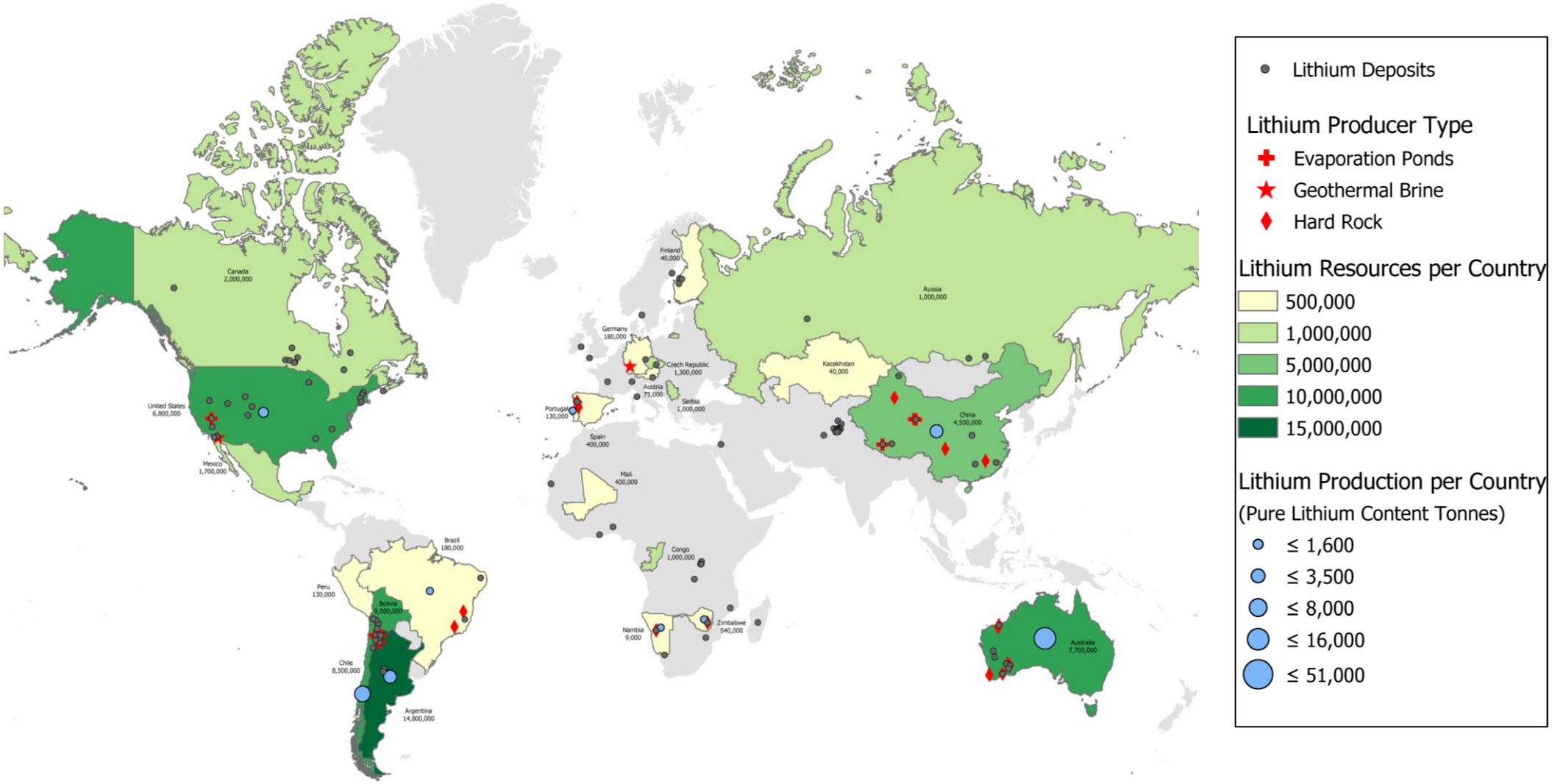
LITHIUM
COBALT
ANTIMONY
GRAPHITE

Research

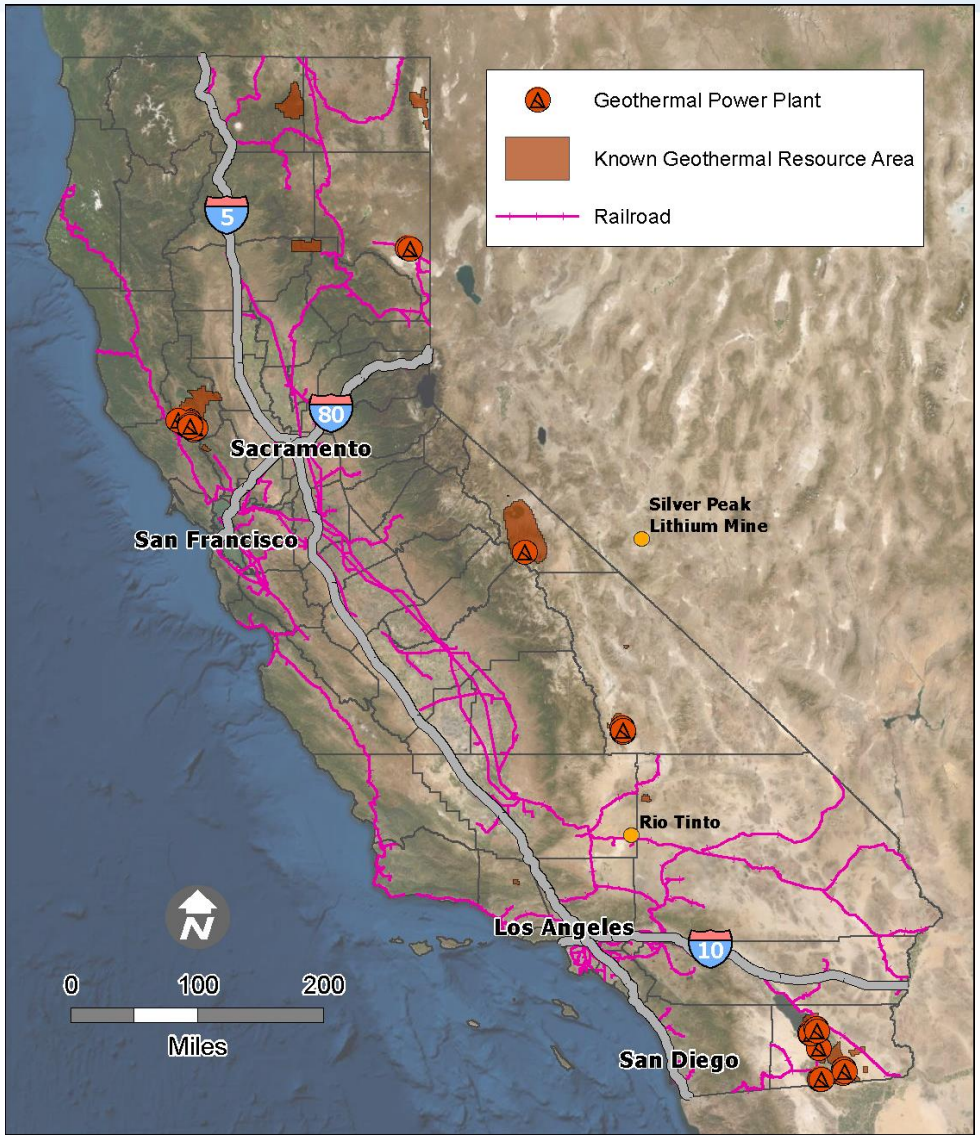
HELIUM
RUBIDIUM
CESIUM
BISMUTH

Image Credit: Visual Capitalist

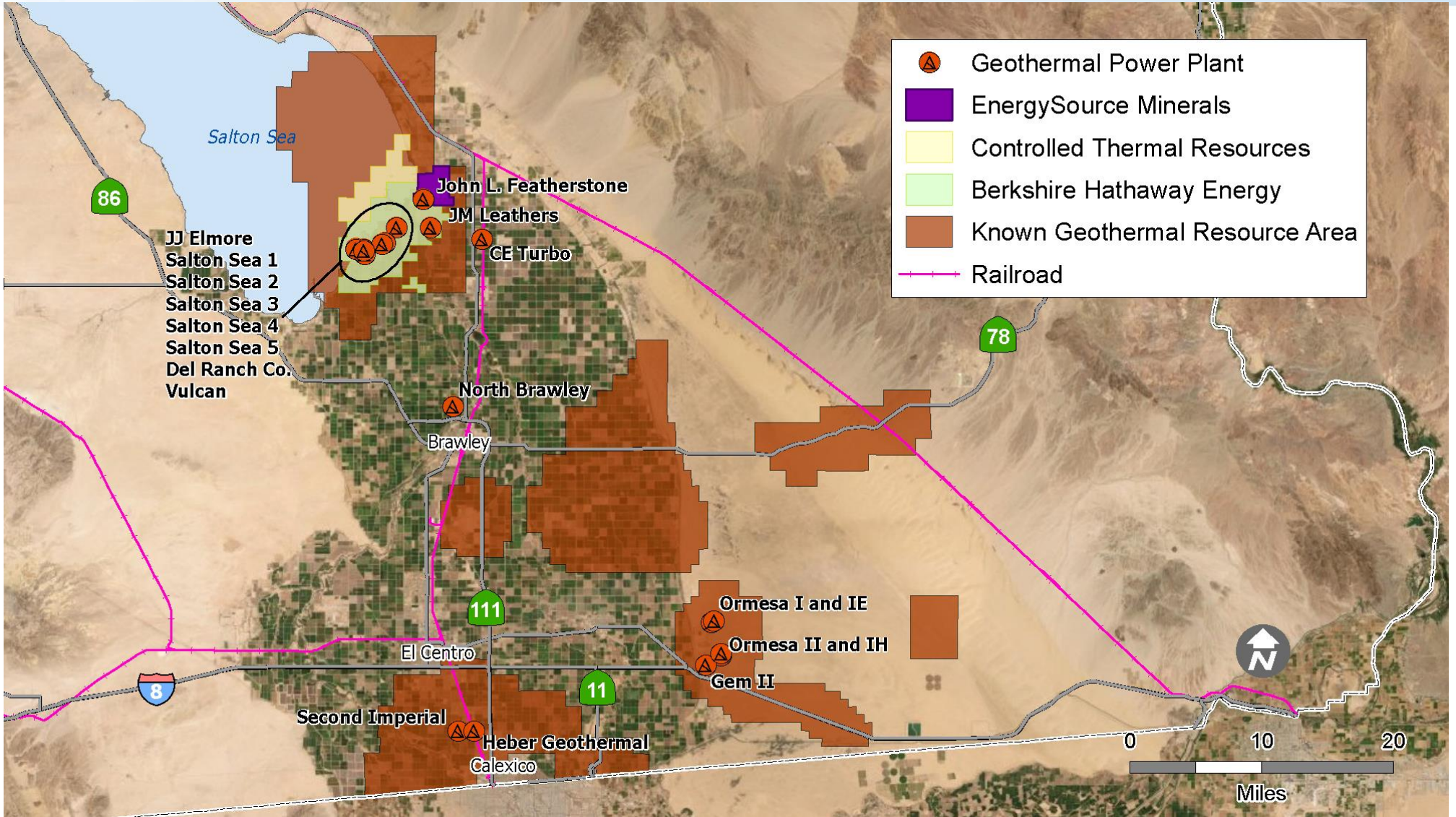
Lithium Worldwide



Lithium in California



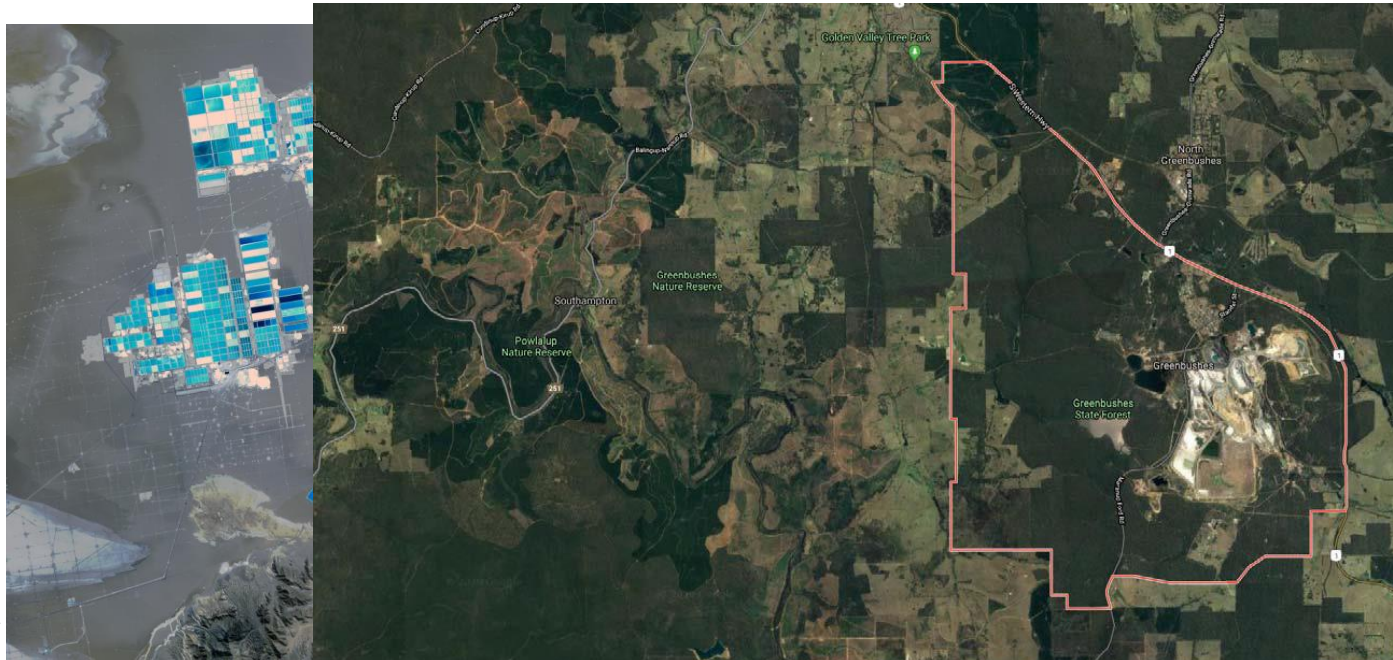
Lithium in Salton Sea Area



Benefits of CA-Sourced Lithium

- Supports Geothermal Development
- Smaller Footprint, Lower Water Intensity
- Integrated Renewable Generation
- Offers National Security in Lithium Supply
- Shorter Production Time
- Economic Development in Disadvantaged Communities

Geothermal Power Plant
Image Credit: Mike Krahmer



Evaporation Ponds
Salar de Atacama
Image Credit: NASA

California's Lithium Recovery Initiative

- CEC Support
  - Facilitated events on lithium recovery development
  - Funding from Geothermal Grant and Loan Program
  - Funding from Electric Program Investment Charge (EPIC)

Salton Sea Infrared Image Credit: Janet Harvey

Thank You!

Elisabeth de Jong
Elisabeth.deJong@energy.ca.gov
February 12, 2020
Geothermal Grant and Loan Program
California Energy Commission

Geothermal Research and Development

California's Lithium Recovery Initiative Symposium

Dr. Katharina Gerber
Energy Generation Research Office
Energy Research and Development Division

California's Leadership

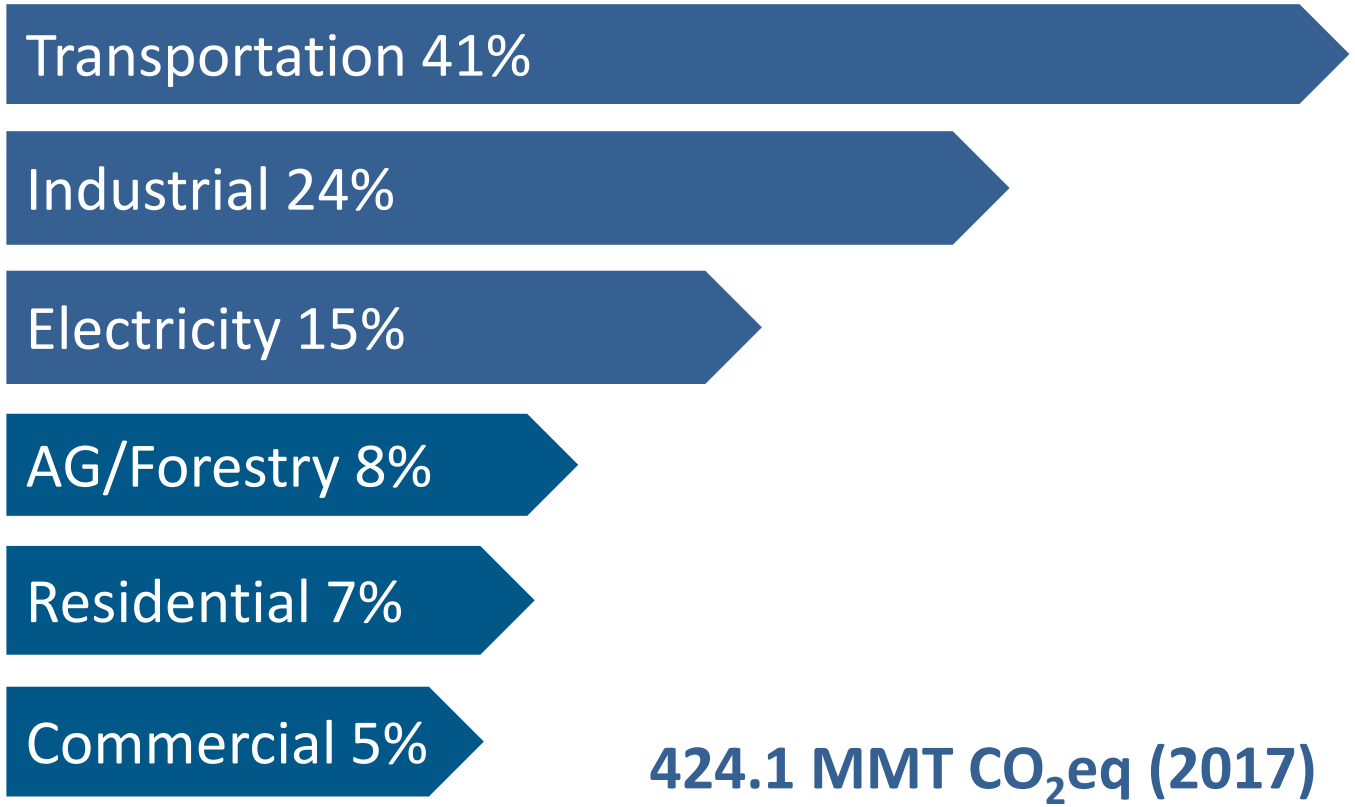
Greenhouse Gas Emissions Goals

(AB32, SB350, EO B-55-18):

- ✓ 1990 level by 2020
- ✓ 40% below 1990 levels by 2030
- ✓ 80% below 1990 levels by 2050
- ✓ Carbon Neutrality by 2045

Renewable and Clean Electricity Goal

- ✓ 100% clean energy by 2045 (SB 100)

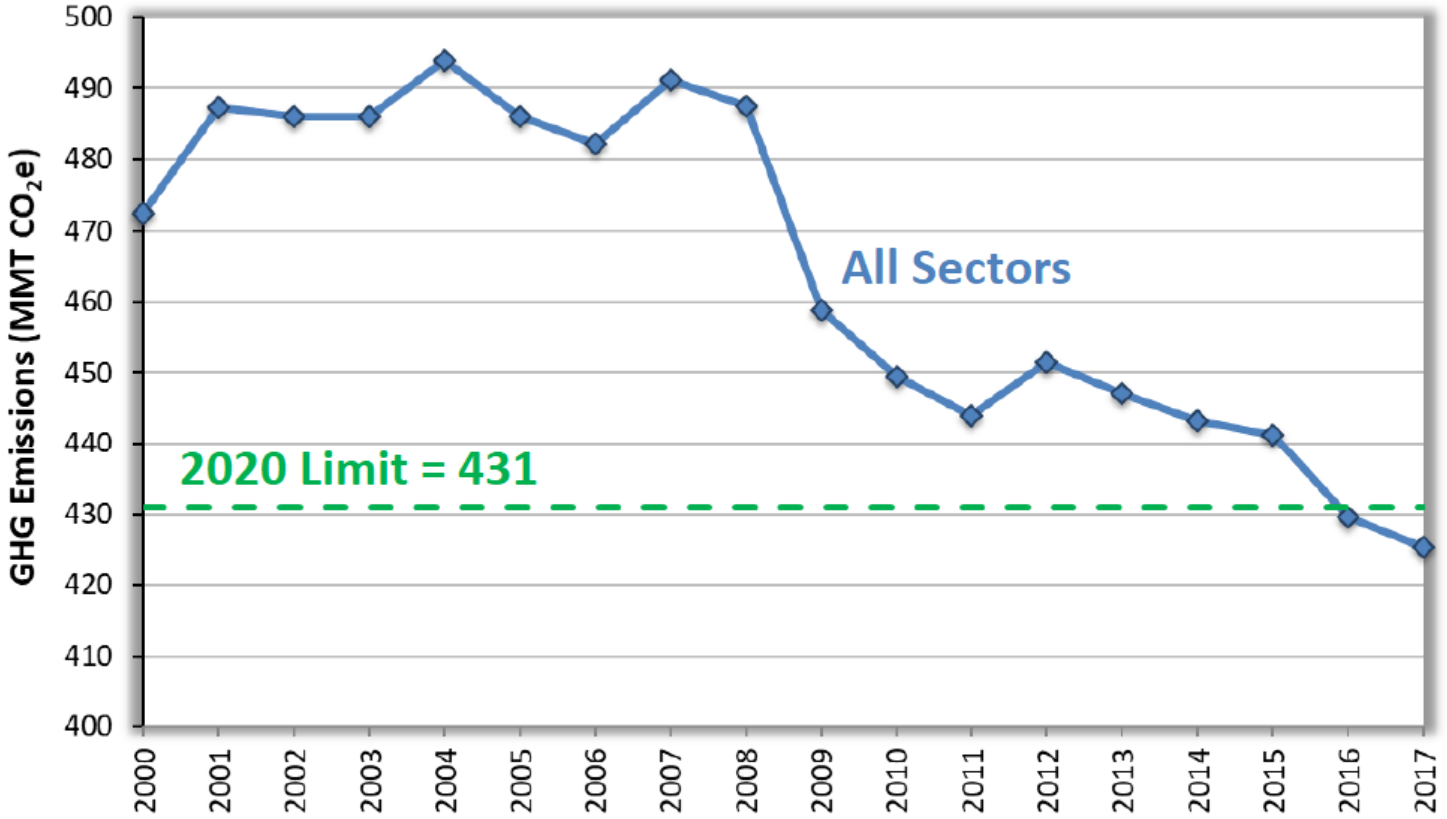


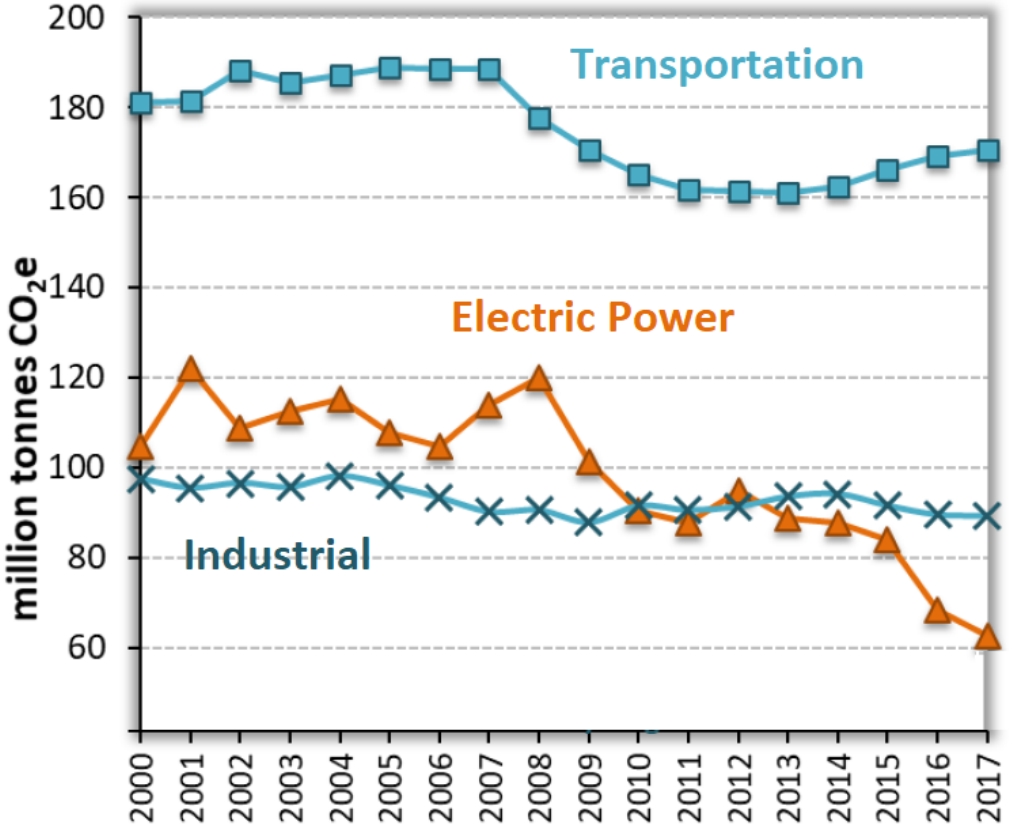
424.1 MMT CO_2eq (2017)

Source: CARB, Greenhouse Gas Emissions Inventory.

California's Leadership

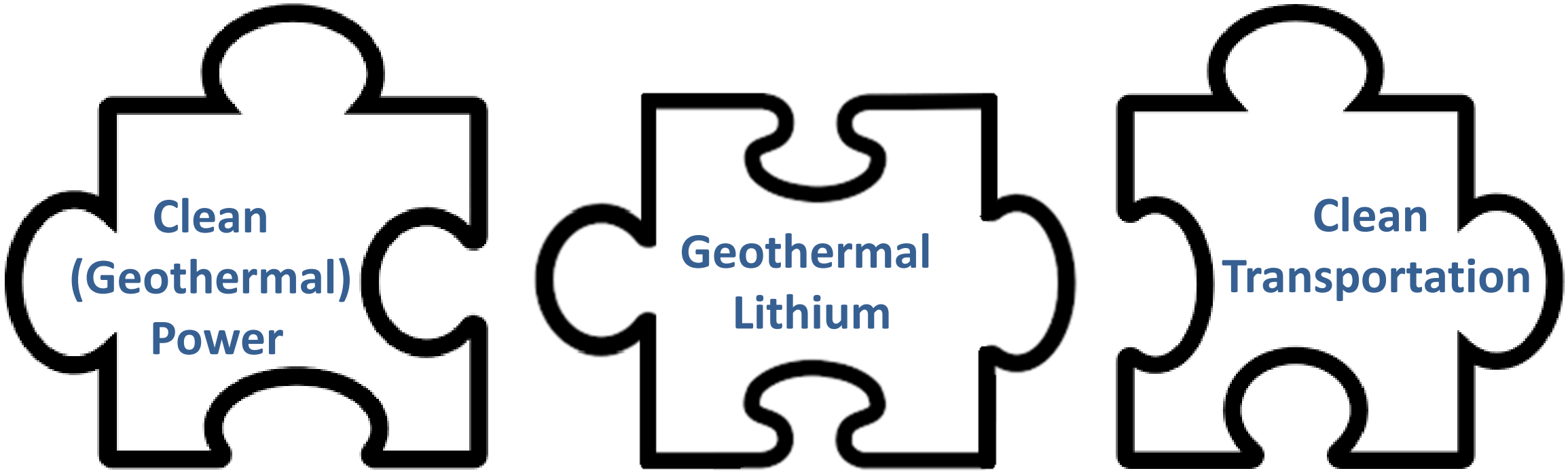
Greenhouse Gas Emissions Trends in California from 2000 to 2017





Source: CARB, Trends of Emissions and Other Indicators.

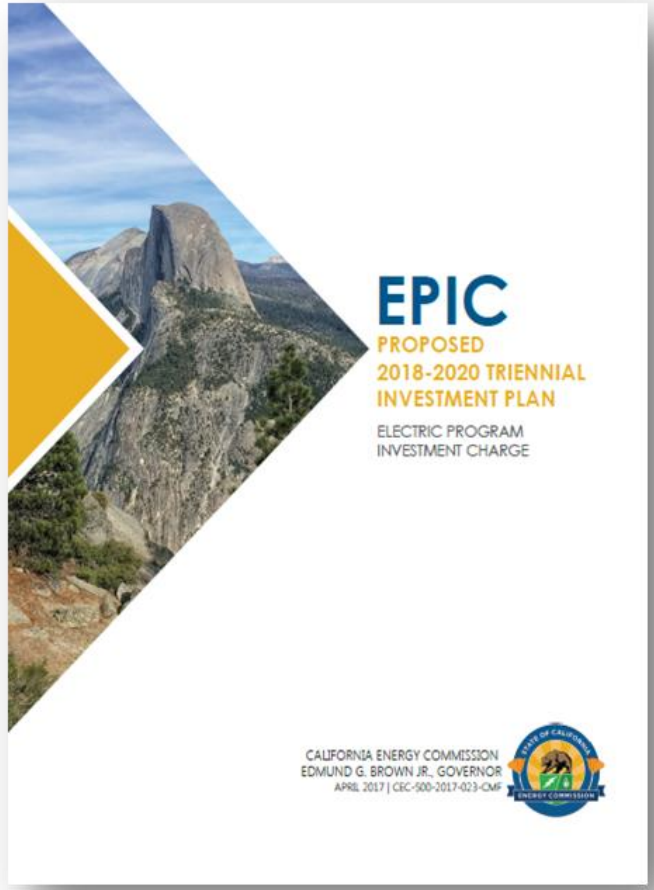
California's Lithium Valley Vision



California Energy Commission

The California Energy Commission is the state's primary energy policy and planning agency with seven core responsibilities:

- ✓ **Invest in energy innovation**
- ✓ Advance state energy policy
- ✓ Achieve energy efficiency
- ✓ Develop renewable energy
- ✓ Transform transportation
- ✓ Oversee energy infrastructure
- ✓ Prepare for energy emergencies

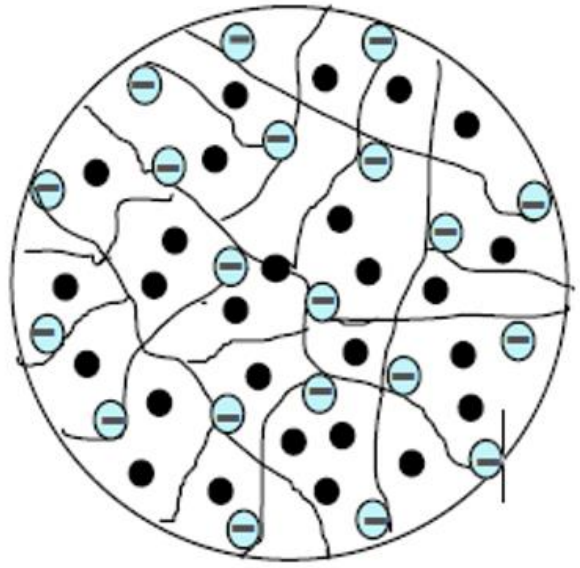


Geothermal Research Portfolio

- New geothermal projects face **technical** and **financial** hurdles.
- California Energy Commission provides the **largest** currently existing source of **funding for geothermal energy research** in the state.
- **EPIC provided $7 million** to geothermal research.

Project Highlight: Direct Lithium Extraction

- $873,387 of EPIC funds provided to SRI Intl.
- Innovative sorbent for lithium recovery from geothermal brine
- Direct production of lithium carbonate without intermediate lithium chloride
- No acidic waste
- Technology is patented and licensed to ExSorption, Inc.
- Plans to commercialize technology for lithium extraction from geothermal brines.



● Hydrous manganese oxide (HMO) nanoparticles

⊖ Li-Imprinted polymer site

Upcoming Lithium Recovery R&D

Recent **EPIC grant funding opportunity:**

- **$14 million** to geothermal research and demonstration projects
- **$10 out of $14 million** to projects advancing direct lithium extraction from geothermal brine
- Lithium recovery R&D aligns with the **"Geovision Roadmap"** by the U.S. Department of Energy

Imperial Valley Geothermal Field. (Source: Land Use Database)

Thank You!

Dr. Katharina Gerber
Energy Generation Research Office
EPIC Program
Katharina.Gerber@energy.ca.gov

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

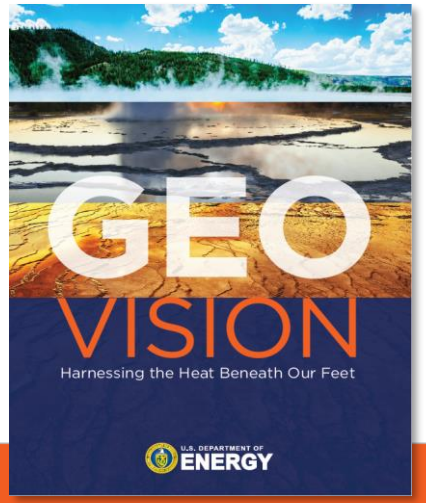
GTO Efforts in Geothermal Energy and Critical Materials

California Lithium Recovery Initiative Symposium

February 12, 2020

Sean Porse, Lead Analyst
Geothermal Technologies Office

GTO GeoVision and Mineral Recovery



KEY ACTION 3.3 – Quantify additional geothermal value streams

Additional geothermal value streams, such as tapping the desalination potential of geothermal energy and recovering dissolved solids from geothermal fluids, can help address the country's water and critical materials issues and create added revenue opportunities for geothermal operations.

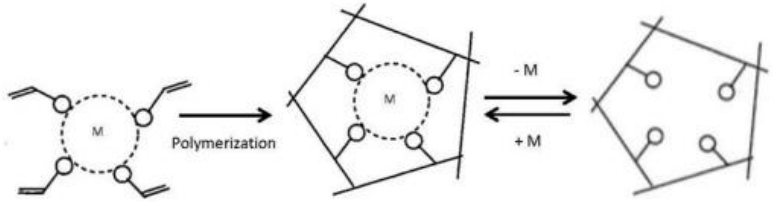
DELIVERABLE(S): Analyses of additional geothermal value streams, including new potential value streams.

IMPACT(S): Increased opportunities to realize additional revenue and value from geothermal technologies.

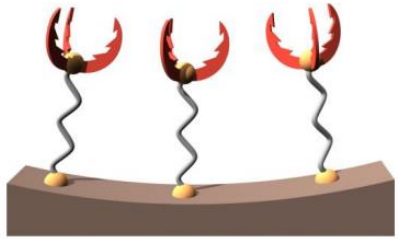
SUB-ACTION(S)	DELIVERABLE(S)	IMPACT(S)
SUB-ACTION 3.3.2: Analyze potential and develop advanced technologies for cost-effective and commercial-scale mineral recovery.	Economically feasible methods and processes to recover minerals from geothermal fluids at the commercial scale.	Ability to economically extract valuable and strategic materials from geothermal fluids. Cost-effective extraction of strategically important resources from geothermal brines.

Phase I GTO Mineral Recovery FOA Awards – 2014

Funded Organization	Nine awards $4 million	Funded Organization	
Southern Research	Geothermal Thermoelectric Generation (G TEG) with Integrated Temperature Driven Membrane Distillation and Novel Manganese Oxide for Lithium Extraction	Tussar	Environmentally Friendly Economical Sequestration of Rare Earth Metals from Geothermal Waters
SRI International	Selective Recovery of Metals from Geothermal Brine	LBNL	Engineering Thermophilic Microorganisms to Selectively Extract Strategic Minerals from Low Temperature Geothermal Brines
University of California, Davis	Maximizing REE Recovery in Geothermal Systems	PNNL	Magnetic Partitioning Nanofluid for Rare Earth Extraction from Geothermal Fluids
Carnegie Mellon University	Chelating Resins for Selective Separation and Recovery of Rare Earth Elements from Low Temperature Geothermal Water	PNNL	Evaluation of Advanced Sorbent Structures for Recovery of Rare Earths, Precious Metals and other Critical Materials from Geothermal Waters
		Simbol	Determination of Rare Earths in Geothermal Brines and Evaluation of Potential Extraction Techniques



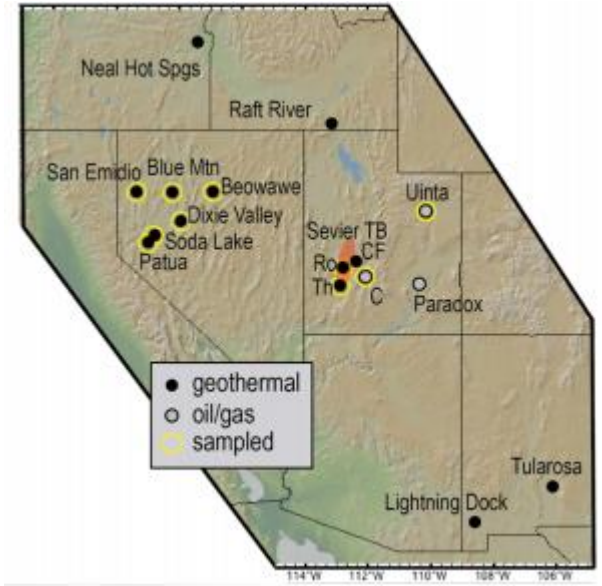
Metal ion imprinted polymers (SRI International)



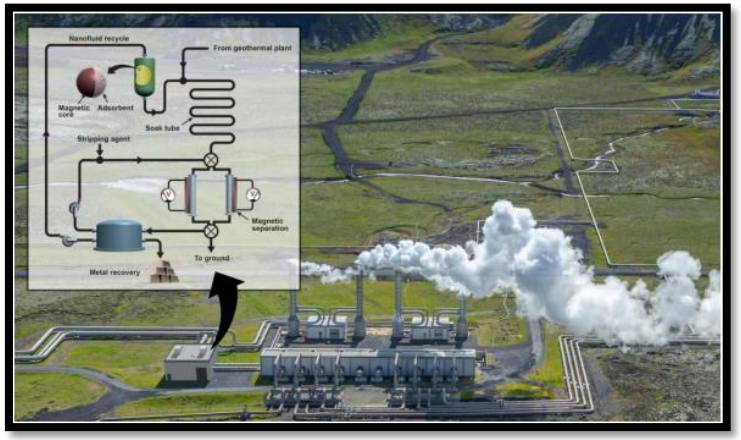
Solid-State Sorbent Technology (PNNL)

Phase II GTO Mineral Recovery FOA Awards – 2016

Funded Organization	Four awards $3.8 million
University of Wyoming	Investigating rare earth element concentration in US oil and gas (produced) and geothermal waters
EGI/University of Utah	Assessing and characterizing strategic/critical materials in US geothermal and hydrocarbon reservoirs
Lawrence Livermore National Laboratory	Bioengineering specialized microbes designed to extract rare earth metals from geothermal fluids
Pacific Northwest National Laboratory	Demonstrating magnetic nanofluid technology for REE extraction from geothermal brines



Western US geothermal fields surveyed and sampled (U of Utah)



Metal Organic Framework extraction example setup (PNNL)

Lithium Recovery from Geothermal Brines – DOE Retrospective

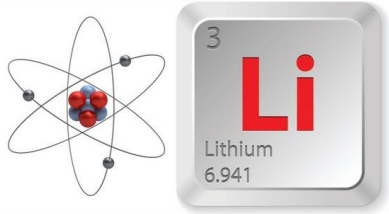
Key observations

- Natural brines are complex – they need to be evaluated in their entirety (simplified synthetic brines can produce misleading results in the lab)
- Multistep process likely needed to extract Li successfully (pretreatment of brines may be needed to remove Fe, SiO_2)
- Extraction system needs to be cognizant of reinjection requirements (brine needs to stay hot to avoid scaling)

Different Approaches

- Empirical (trial and error) methods for extraction
- Modification of other methods previously used for Li extraction (from salars)
- Chemical modeling (molecular dynamics simulations, coupled process reaction simulations) may help identify & screen possible methods/processes to more efficiently separate Li from brines

Current DOE Efforts – Critical Materials Supply Chain Nexus

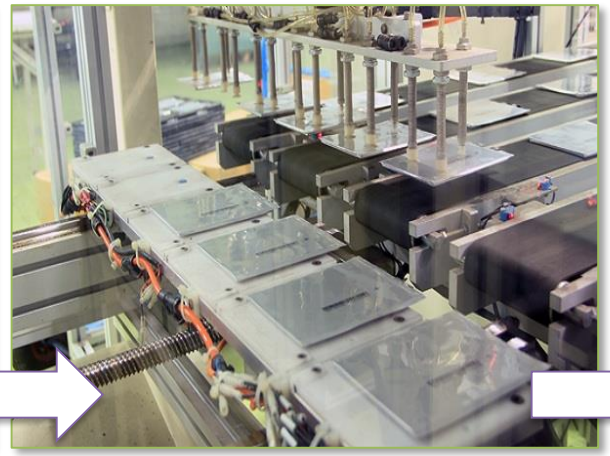


EERE seeks to demonstrate added value in regions where geothermal brines can deliver critical elements such as lithium.

Geothermal Technologies **SUPPLY**

Advanced Manufacturing **PROCESS**

Vehicle Technologies **MARKET**



Uniting GTO, AMO, and VTO creates clear-path integration from supply to manufacturing to end-market, with improved efficiencies and economics.

Current DOE Efforts –Critical Materials Supply Chain Nexus

Technology Benchmarking and Techno Economic Analysis (NREL)

- Reviewing prior GTO-funded, as well as available commercial operators data on mineral recovery performance
- Benchmark technologies – process steps, cost inputs, operational efficiencies
- Incorporate battery storage chemistry requirements into benchmarking considerations

Supply Chain and Lifecycle Analysis of U.S. Lithium Pathways (CMI)

- Mapping supply chains, trade flows, and global demand projections of Lithium
- Understand the minimum performance cost requirements

Battery Critical Materials Supply Chain Workshop (DOE)

- **Inform DOE cross-cutting R&D strategies** that strengthen battery critical materials supply chains
- Gather data and feedback on relevant performance metrics to support TEA
- Factors in determining success for validation projects

Questions?

The California Lithium Supply Chain Opportunity

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alexjadecove

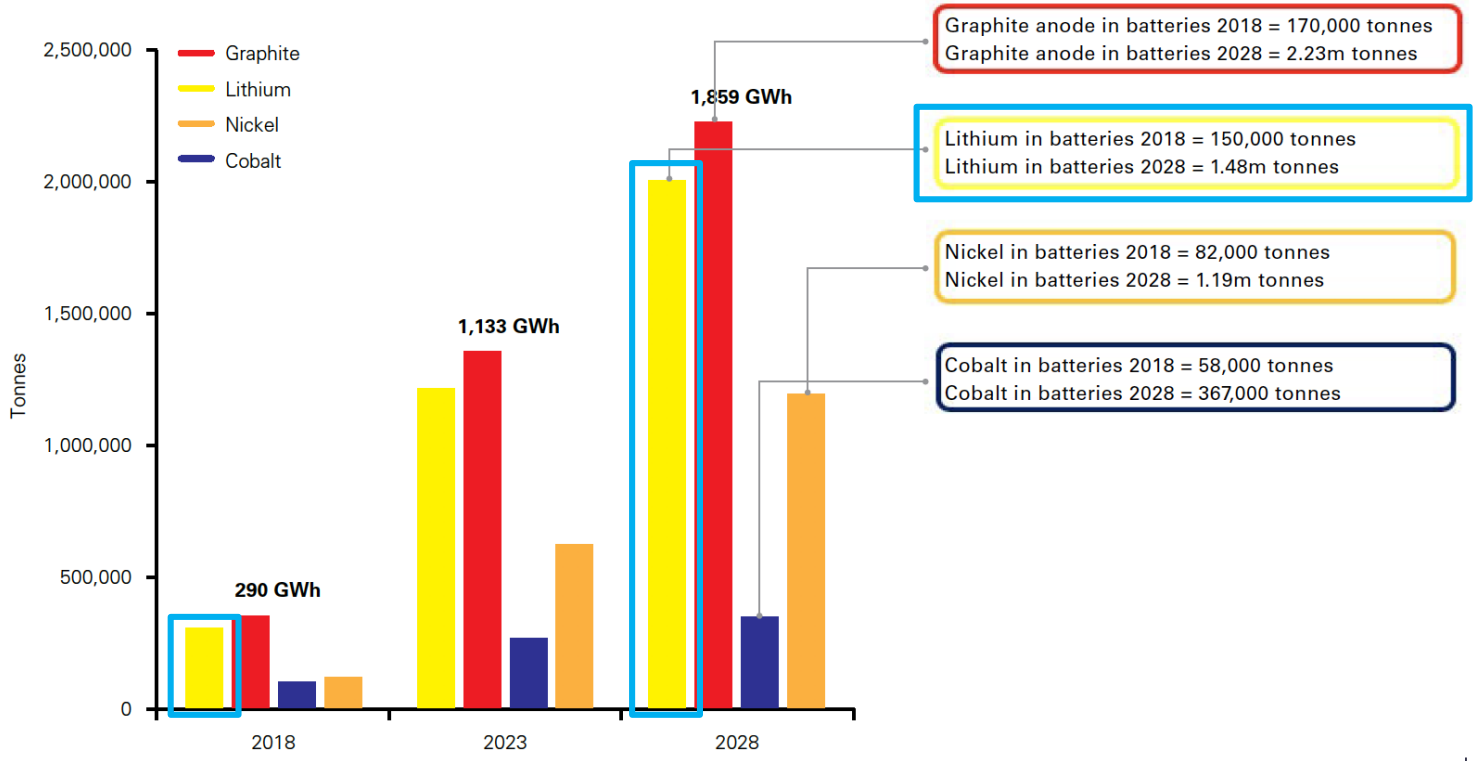
California's Lithium Recovery Initiative
Hosted by the California Energy Commission
Wednesday, 12 February, 2020
Stanford University

Lithium Ion Batteries and the Growing Lithium Market

Needed: Lithium Supply to Satisfy EV LIB Demand

The profound impact of the megafactories on raw material demand

Assuming a 100% utilisation rate, these are the numbers....



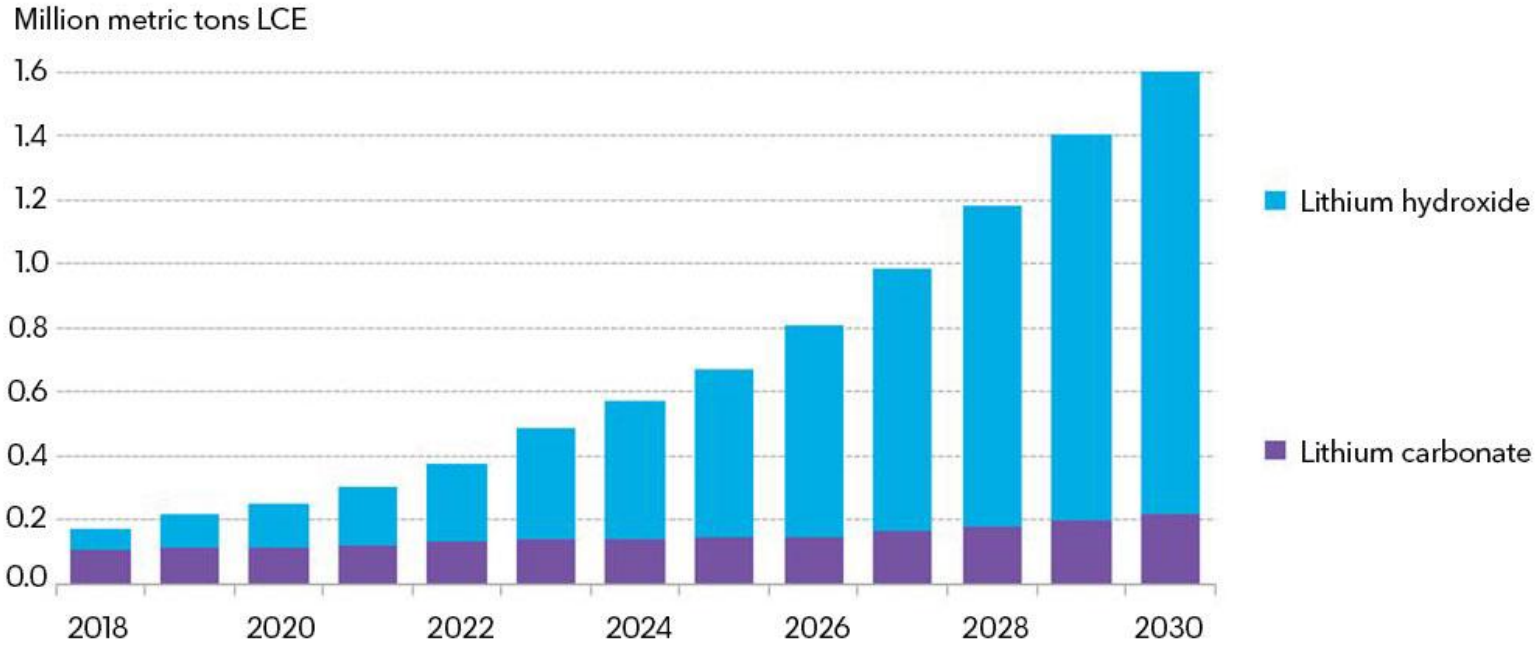
Source: Benchmark Mineral Intelligence

"That's 68 new 25,000 tLCE/year extraction projects by 2030 to meet new demand"
– Rodney Hooper

We will need more lithium chemicals.

Needed: Lithium Supply to Satisfy EV LIB Demand

Figure 2: Lithium hydroxide versus carbonate – what do batteries need?



Source: BloombergNEF.

Note: Inclusive of lithium-ion batteries used in passenger EVs, e-buses, e-trucks, consumer electronics and stationary storage. Demand expressed in year of metal demand, which occurs approximately one year before year of battery demand.

We may especially need more $LiOH \cdot H_2O$ compared to Li_2CO_3 for new cathode chemistries.

Needed: Lithium Supply to Satisfy EV LIB Demand

Livent

LITHIUM HYDROXIDE MONOHYDRATE, BATTERY GRADE **CAS No. 1310-66-3**

QS-PDS-1021 Revision 03

Formula $LiOH \cdot H_2O$

Appearance White crystals

Application High purity product suitable for use in production of cathode materials for lithium ion batteries, low noise lubricating greases and other fine chemical formulations

Product Specifications

	Guaranteed	
LiOH, wt%	56.5	min
CO_2, wt%	0.35	max
Cl, wt%	0.0020	max
SO_4, wt%	0.010	max
Ca, wppm	15	max
Fe, wppm	5	max
Na, wppm	20	max
Al, wppm	10	max
Cr, wppm	5	max
Cu, wppm	5	max
K, wppm	10	max
Ni, wppm	10	max
Si, wppm	30	max
Zn, wppm	10	max
Heavy metals as Pb	10	max
Acid Insolubles, wt%	0.010	max

Other Data Bulk density Loose 0.9 g/cm³, Tap 1.0 g/cm³

Physical Properties

Molecular weight	41.96
Density @ 20°C	1.51 g/cm³
Standard heat of formation	-188.9 kcal/mole
Standard heat of fusion	-0.867 kcal/mole
Specific heat @ 25°C	0.453 cal/g/°C
Loses water of hydration	100 -110°C

Water Solubility

Temperature (°C)	Weight percent LiOH in saturated solution*
0	10.7
20	10.9
100	14.8

* The solid phase in equilibrium with saturated solution is the monohydrate, $LiOH \cdot H_2O$.

GanfengLithium 赣锋锂业

Jiangxi Ganfeng Lithium Co., Ltd

Tel: +86-790-6411121; Fax: +86-790-6411121; Http://www.ganfenglithium.com

Lithium Hydroxide, Battery Grade

CAS No.: 1310-66-3

Formula: $LiOH \cdot H_2O$

Appearance: White powder

Specifications:

Item	Standard（wt%）	Typical（wt%）
LiOH	≥56.5	56.5
CO_2	≤0.500	0.300
Na	≤0.002	0.0015
K	≤0.001	0.0005
Mg	≤0.001	0.0002
Ca	≤0.0015	0.0010
Al	≤0.001	0.0002
Fe	≤0.0005	0.0003
Ni	≤0.001	0.0003
Cu	≤0.0005	0.0002
Pb	≤0.0005	0.0002
SO_4^{2-}	≤0.010	0.0020
Cl	≤0.002	0.0012
Mn	≤0.0005	0.0003
Si	≤0.003	0.0015
Zn	≤0.001	0.0002
Insoluble in acid	≤0.010	0.005
Note: This product can be made to agreed upon customer specifications.		

We will need higher purity lithium chemicals than have been produced historically.

Needed: Lithium Supply to Satisfy EV LIB Demand

OROCOBRE

ASX / TSX ANNOUNCEMENT

22 June 2017

Severe Weather Affects Operations

Orocobre Limited (ORE:ASX, ORL:TSX) (**Orocobre** or the **Company**) wishes to provide advice about recent severe weather in the Puna Region of Argentina and Chile and its impact on operations and logistics at the Olaroz Lithium Facility and Borax Argentina.

Severe snowfall at Paso de Jama in Chile, which has now reopened

Milder conditions further east at Olaroz

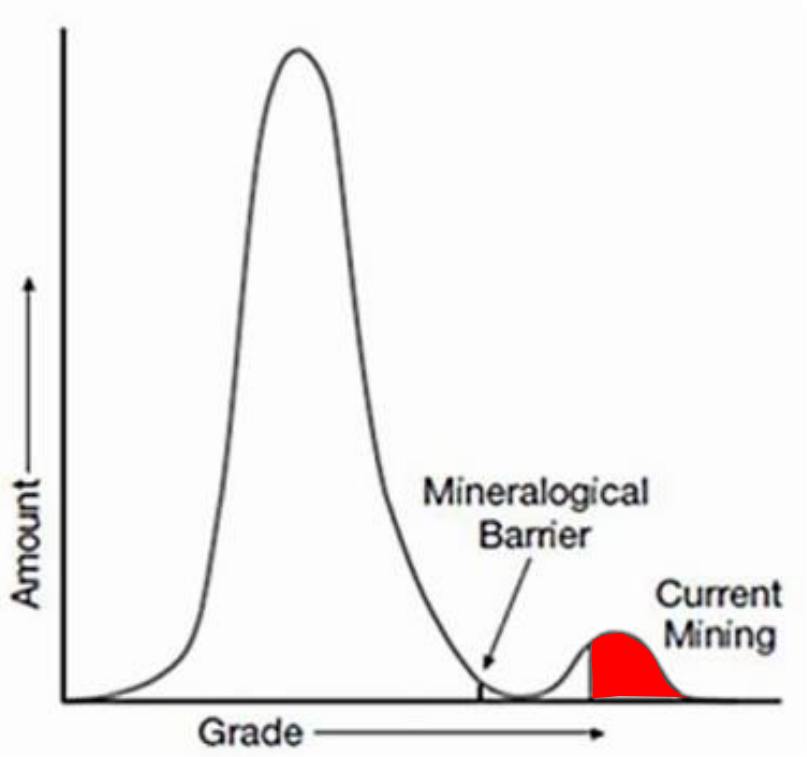
We will need more reliable forms of lithium production that don't depend on weather & location to function.

Where Lithium Chemicals for Batteries Come From: Present and Future

Types of Lithium Resources

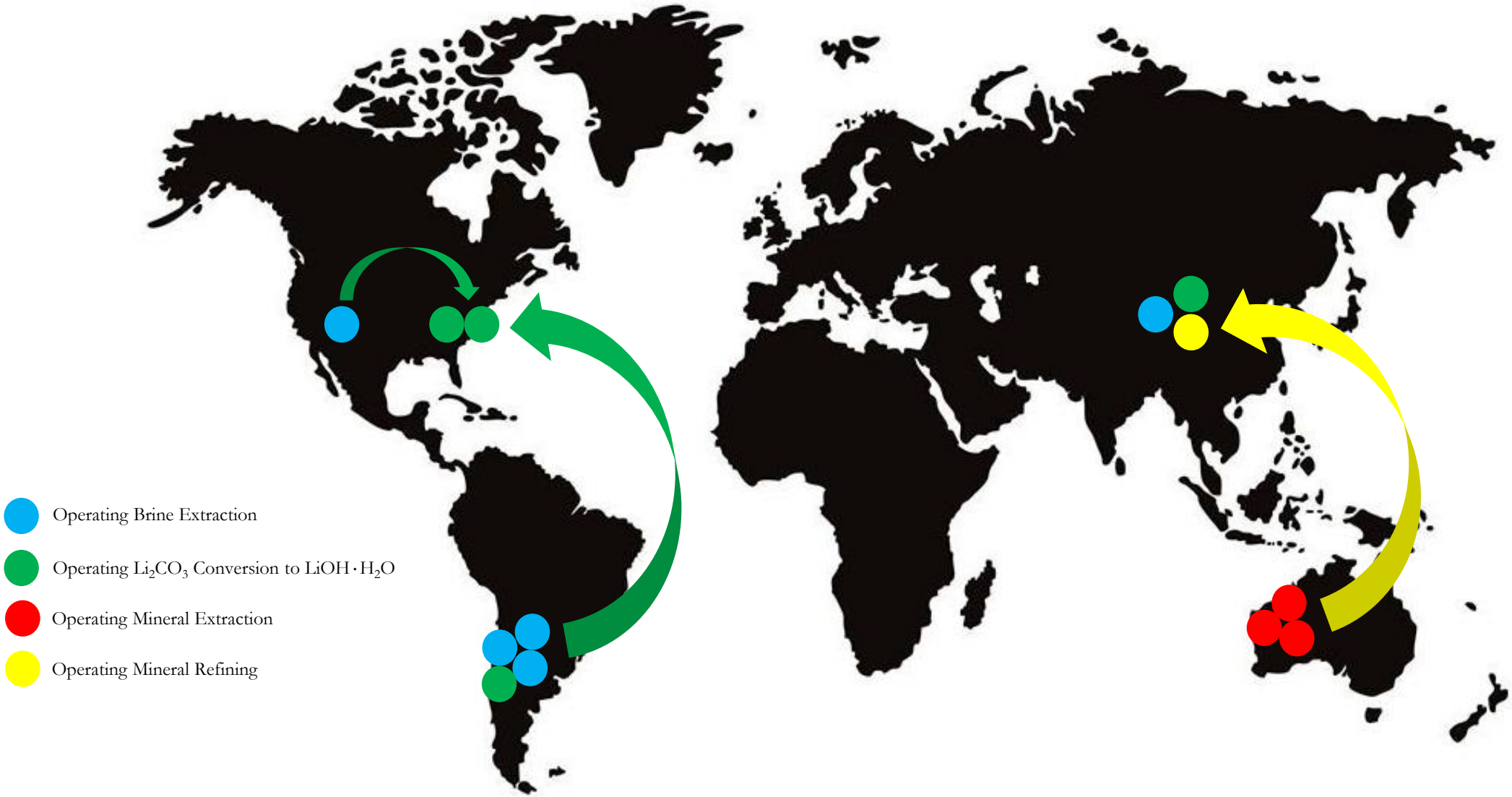
Pegmatites	Sedimentary Deposits	Brines
Spodumene Lepidolite Petalite Zinnwaldite Amblygonite Eucryptite Zabuyelite	Hectorite Montmorillonite Jadarite Searlesite *Combinations & Others*	Salars Oilfield/Continental Geothermal Ocean
		

Source: Jade Cove Partners

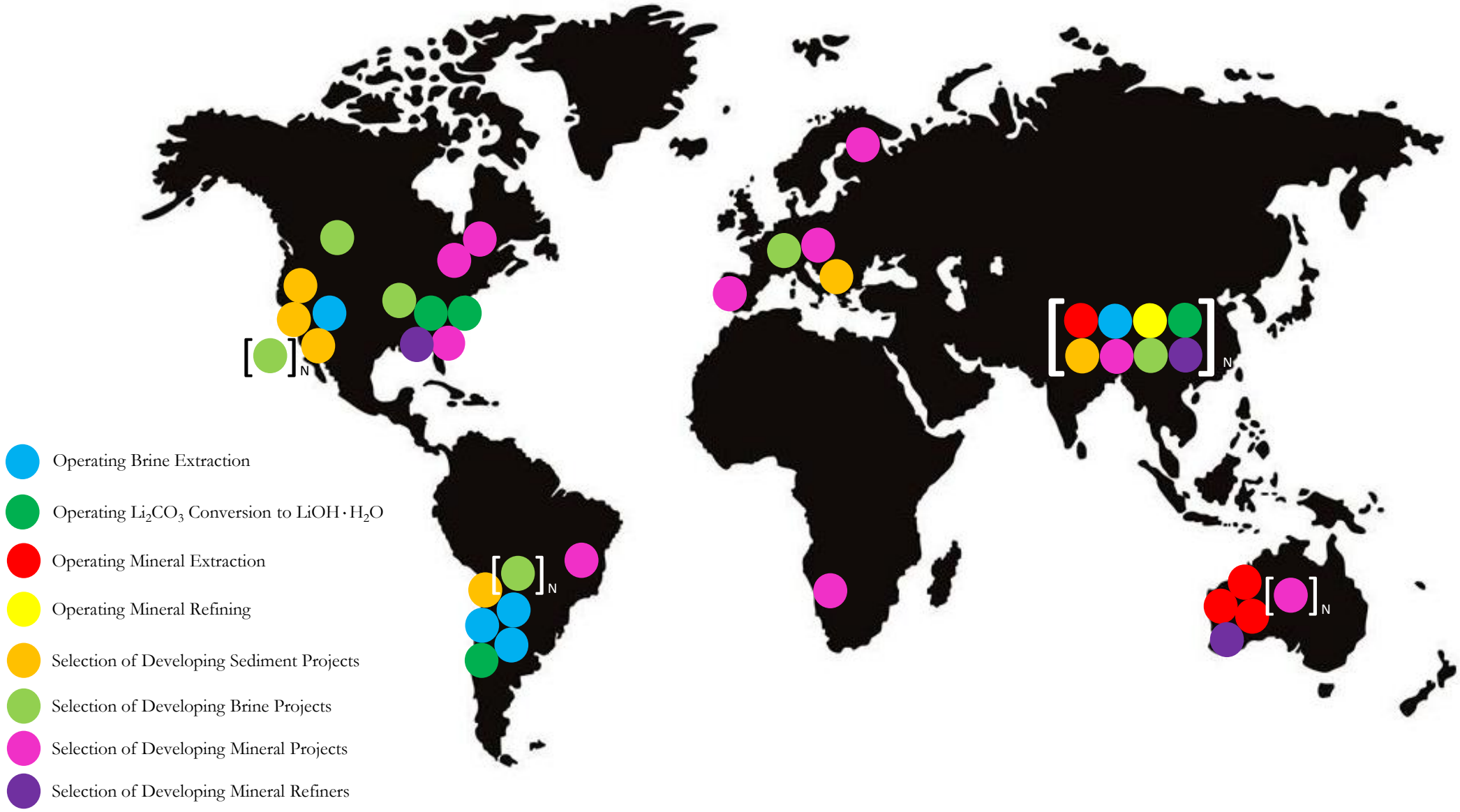


Source: Bradshaw

Today's Two Main Commercial $LiOH \cdot H_2O$ Supply Chains

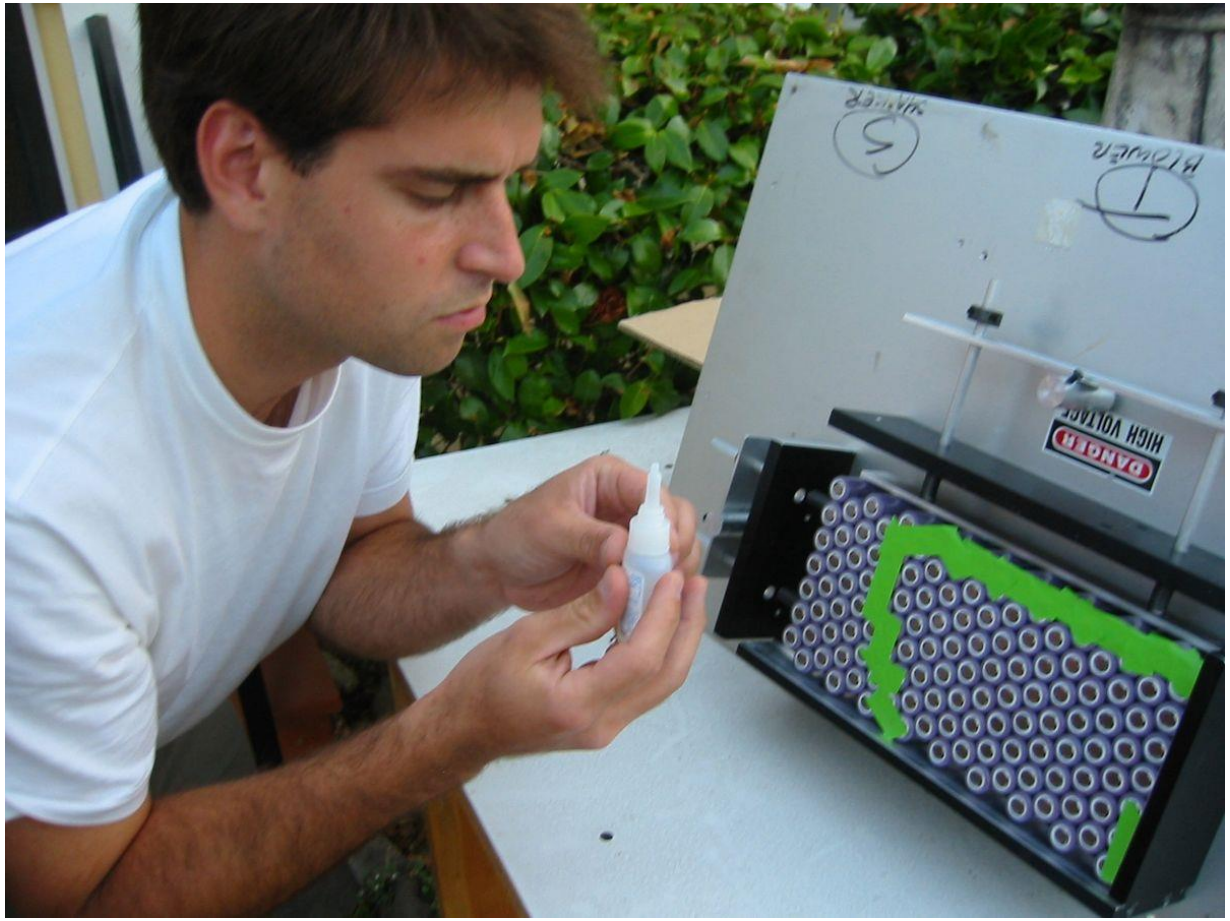


Tomorrow's Possible $LiOH \cdot H_2O$ Supply Chains



The California Lithium Supply Chain Opportunity

Californians: The OG Lithium Industry Mavericks & Perennial Do-Good-Go-Getter Smart (and Creative?) People



2003

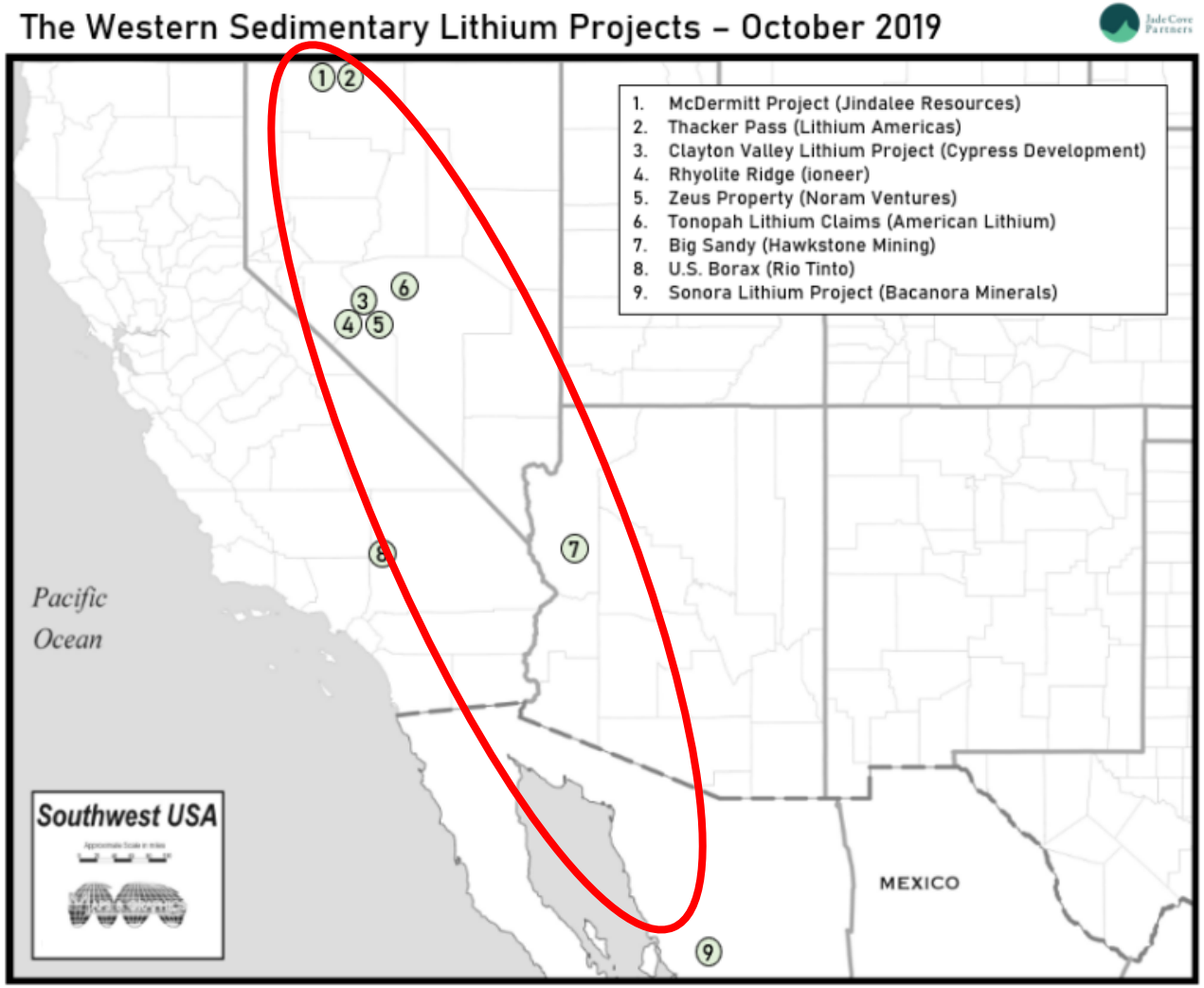
2020

Californian Opportunities for Vertical Integration

Pegmatites	Sedimentary Deposits	Brines
Spodumene Lepidolite Petalite Zinnwaldite Amblygonite Eucryptite Zabuyelite	Hectorite Montmorillonite Jadarite Searlesite *Combinations & Others*	Salars Oilfield/Continental Geothermal Ocean
		

Source: Jade Cove Partners

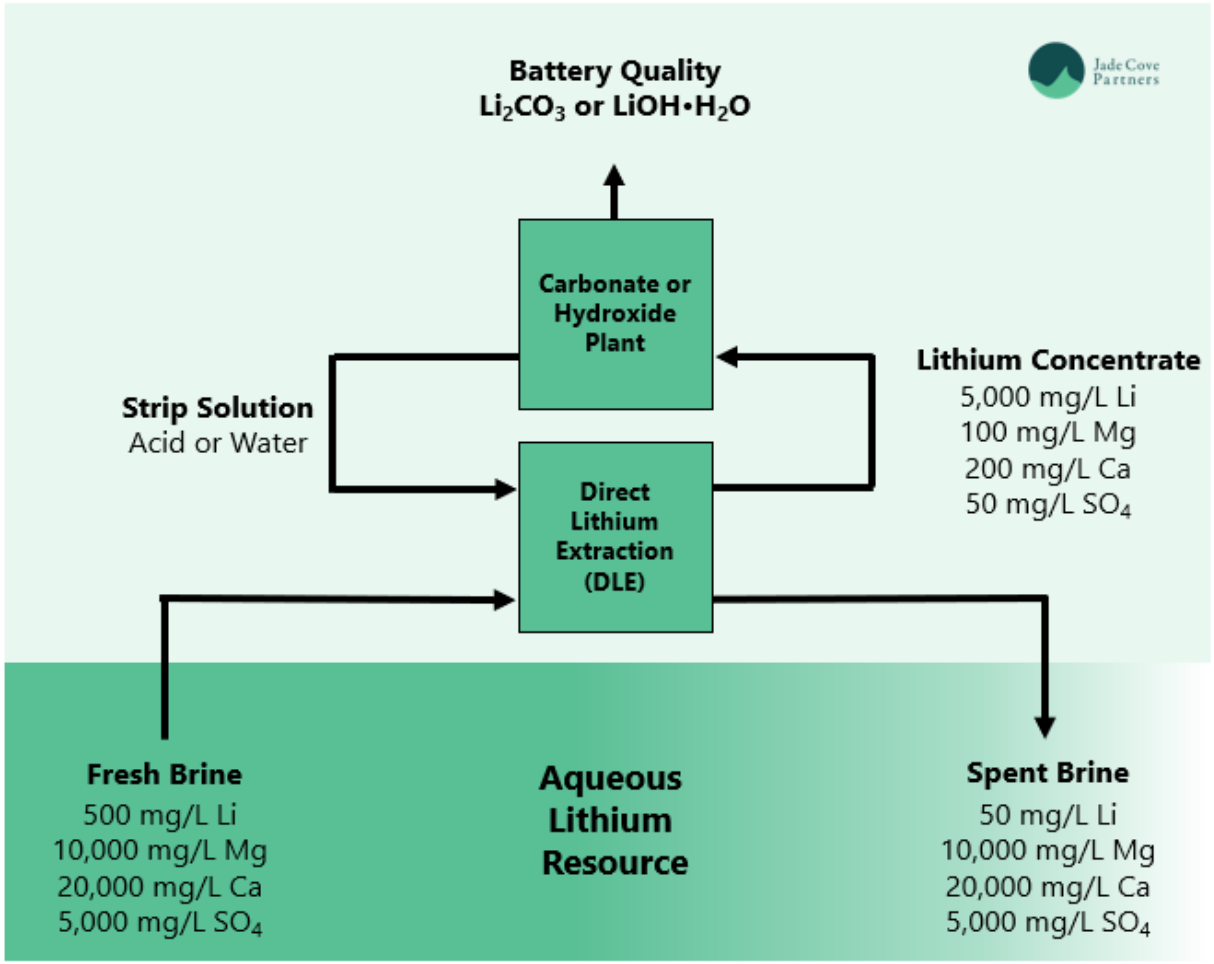
Project Characteristic	South American Salar-Type Brines	Australian Spodumene & Chinese Conversion	Geothermal Lithium
Carbon Intensity of Heat & Power Consumption	Burn natural gas or diesel	Burn natural gas or coal	Free zero-carbon heat from brine
Proximity to Battery Manufacturing	No local cathode manufacturing	Interjurisdictional risk	Close proximity to future battery manufacturers
Waste Management	Evaporate water in desert or reinject brine to dilute resource	Production of tailings	Spent brine reinjected by design
Jurisdiction	Argentina, Chile, and Bolivia notorious for sovereign risk	Dependence on Chinese converters	USA & Germany pose zero sovereign risk



Source: Jade Cove Partners

DLE: Enabling Class of Technology for Salton Sea Lithium

Direct Lithium Extraction (DLE) Overview



Hypothetical Performance

1. Extraction rate and efficiency **does not depend on rain** or wind speed,
2. The need for complex & expensive evaporation ponds is eliminated and either **lithium carbonate or hydroxide** can be produced,
3. Up to **90% lithium** extraction compared to 40% for evaporation pond systems,
4. Lithium is extracted in hours instead of days,
5. Production of a high concentration and purity lithium concentrate which can be **easily processed** into battery quality lithium chemical products,
6. The concentration of Mg, Ca, and SO_4 in the brine does not matter,
7. **OPEX typically $3-5,000/t$Li_2CO_3$**, much cheaper than Australian spodumene,
8. Minimal footprint required for processing compared to evaporation ponds so salars remain in their undisturbed natural state with **no disturbance to animals and plants**,
9. Water consumption is reduced by 50x compared to evaporation ponds,
10. **Jade Cove is tracking 40 different groups who are developing DLE processes** which could be applied to recovering lithium from different types of aqueous solutions including brines, leachates, and battery recycling wastewaters.

Things for California to Think About

Transportation does not have a major CO_2 or cost impact on lithium chemicals

Chemical processing is much more significant and that should be our focus

Lithium supply close to the Nevada Gigafactory doesn't really matter unless cathode materials are made there

Tesla is working on this across the Bay but their cathode is still made in Asia

We should be proud of producing large quantities of chemicals using renewable energy in the US or Europe

NIMBYism against industrial activity could harm the long term prosperity of developed countries

The CEC should do more to help geothermal lithium developers in the Salton Sea

- *Build connections with potential off-takers & development partners*
- *Help facilitate investment from state government or quasi-state government (e.g. CalPERS?)*
- *Socialize a better understanding of the size of the lithium resource according to 43-101 guidelines*
- *Concentrate funds on the best projects that are most likely to succeed*

Battery manufacturing is complex and Imperial Valley may not be the best place to do it

Might be different reasons why it is a good or bad place to build a cathode/battery manufacturing plant

California is already leading the decarbonization revolution and we should all be proud of that

Let's work together to get projects built in the 2020s!

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California's Lithium Recovery Initiative
Hosted by the California Energy Commission
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Stanford University


ENERGYSOURCE
MINERALS

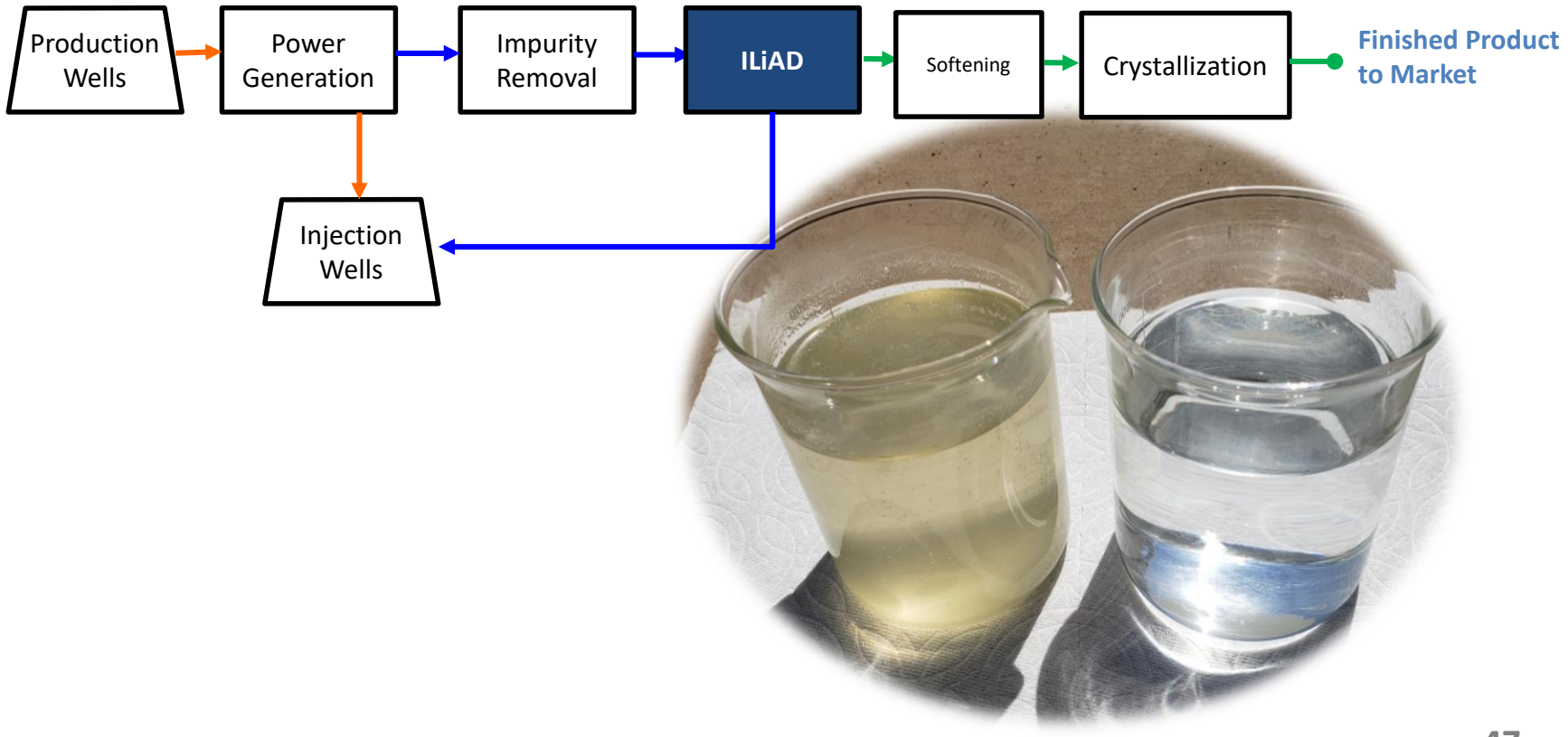
ENERGYSOURCE MINERALS - INTRODUCTION

- ES Minerals' mission is to transform the way lithium is extracted, to be low-cost, low-carbon, safe and efficient.
- How? Through ES Minerals' **I**ntegrated **Li**thium **A**dsorption **D**esorption ("**ILiAD**") platform technology.
- Demonstrated to be the key that unlocks Salton Sea lithium development.
- Further, it's a technology that can be **deployed globally**, disrupting current industry practices, with a **smaller environmental and cost footprint** compared to competing lithium separation techniques.

ILiAD: Robust Technology For All Brine Applications

- ILiAD technology can be the heart of any lithium processing flowsheet.
- ILiAD can be deployed on salar brines, geothermal brines, and petro-brine resources; can be coupled to and significantly reduces the size of almost any downstream process; and is scalable allowing deployment in modular phases.

Geothermal Block Flow



ILiAD: Technology Benchmarking

- ILiAD delivers numerous advantages over alternative approaches, such as fixed bed ion exchange (IX), fixed bed adsorption-desorption (AD), metal organic framework, and/or membrane technology:
    - **Lower CapEx** vs fixed bed IX/AD: smaller vessels / single valve / smaller adsorbent inventory with continuous system.
    - **Lower OpEx:** water as the "reagent" vs IX which requires acid (typically HCl), low energy use, low maintenance costs, lower water requirements.
    - **Better performance:** higher temperature stability (geothermal), longer life, and no attrition observed.
    - **Productivity.** ILiAD-based system is capable of extracting >90% of the lithium out of brines, doubling the value/output of any brine resource.
    - **Risk.** All evaporation pond operations have histories of delayed start-ups, cost overruns, long residence and process times, product quality challenges and challenged output expansion attempts. Operational output is beholden to seasonal and climate risks.

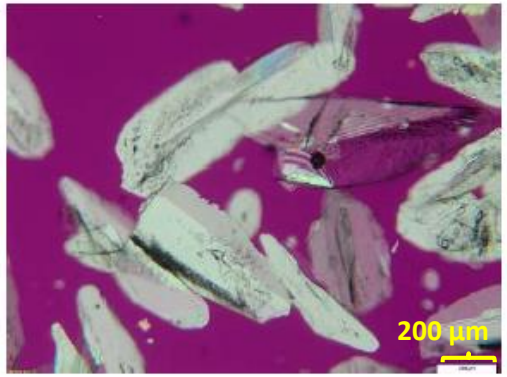
INTRODUCING PROJECT ATLiS

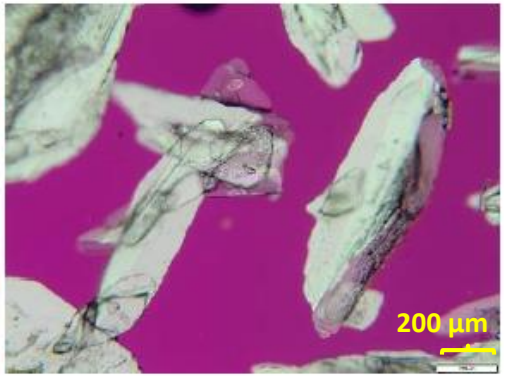
- The Project is located in Southern California, USA on the Salton Sea Geothermal Field.
- The nameplate capacity is **19,250 tonnes** per annum of Lithium Hydroxide monohydrate (LiOH).*
- The brine resource has been flowing at commercial quantities for over 7 years (7,000 gpm / 1,574 m^3/hr) demonstrating viability. $100M well field in operation since 2012.
- Feasibility Study completed in 2019; shows good economic viability and small environmental footprint.
- Option to produce battery grade lithium carbonate or lithium hydroxide.
- Q1 2021 – forecast start of construction.
- Q1 2023 – forecast start of operations.

* *- represents 15% of current Salton Sea brine flows*

PROJECT ATLiS: CONFIRMATION OF BATTERY GRADE PRODUCT

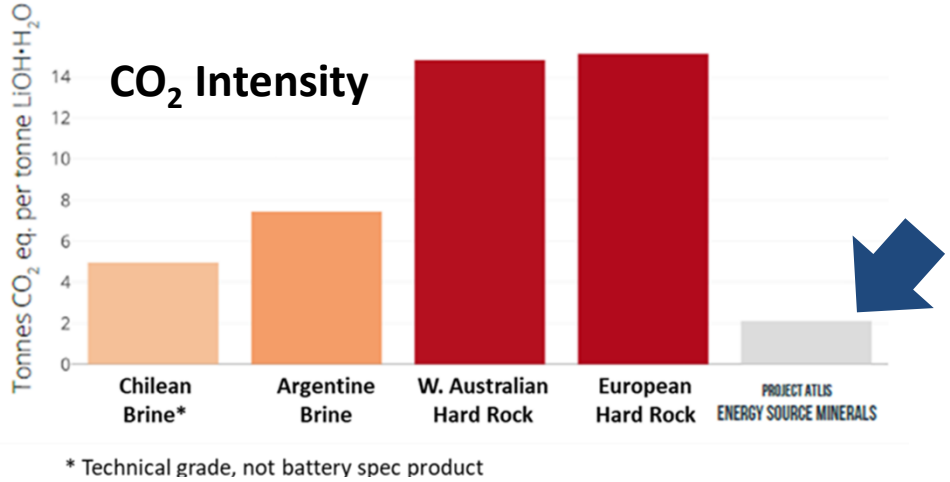
- Concentration and crystallization pilot work conducted by Veolia at their Plainfield, IL test facilities.
- Battery spec lithium carbonate material was produced in early 2019.
- Confirmation of battery spec lithium hydroxide material completed in December 2019 utilizing proposed flow sheet.



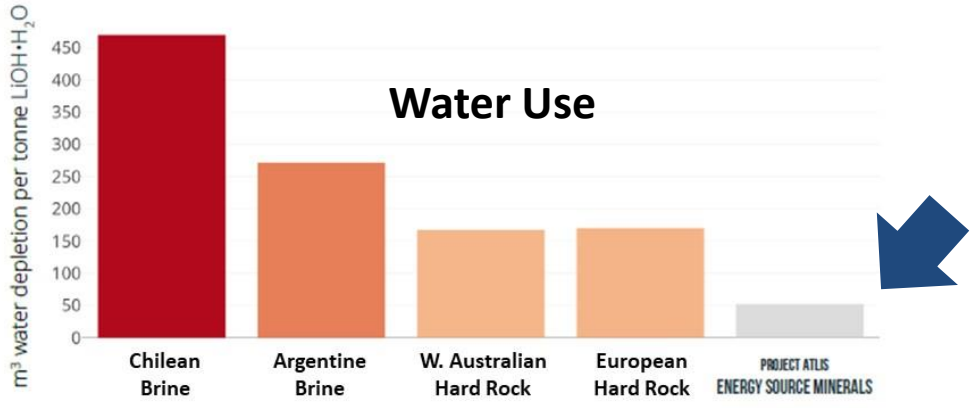


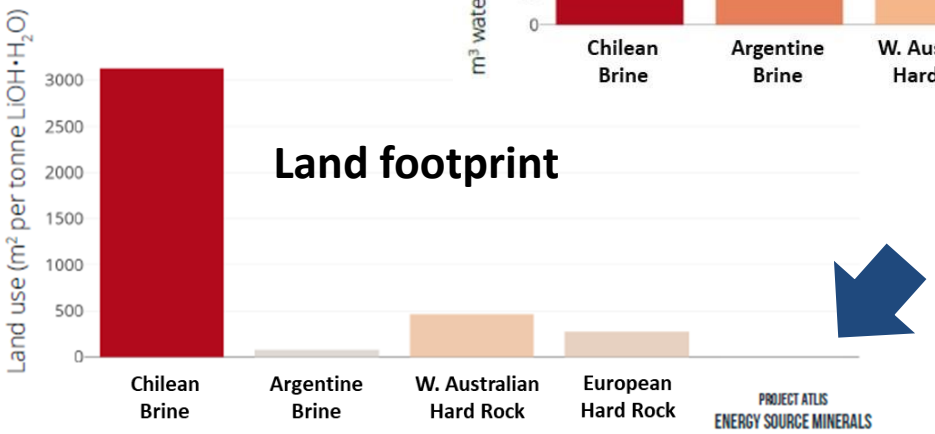
Environmental Stewardship

- ES Minerals' process leads in every environmental metric.
- CO_2 emissions are the lowest of any lithium resource type.
- Water depletion is lowest.
- Land use is smallest.



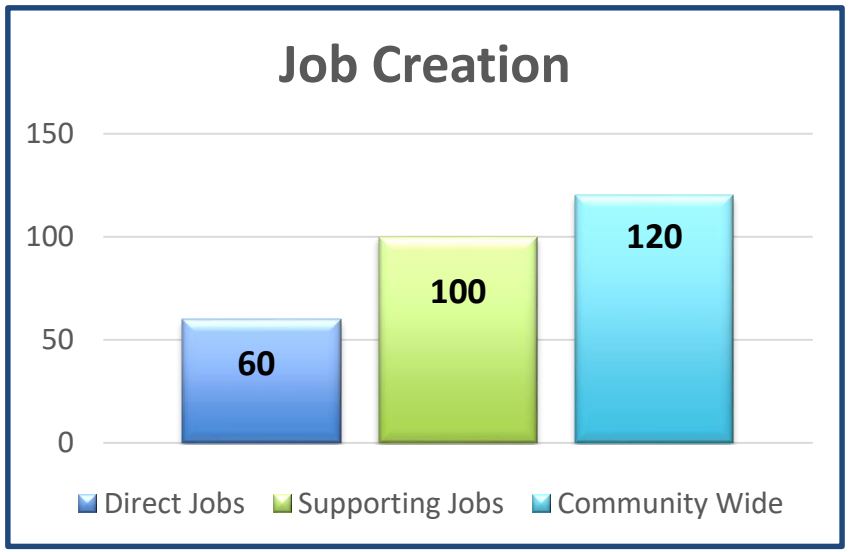
* Technical grade, not battery spec product

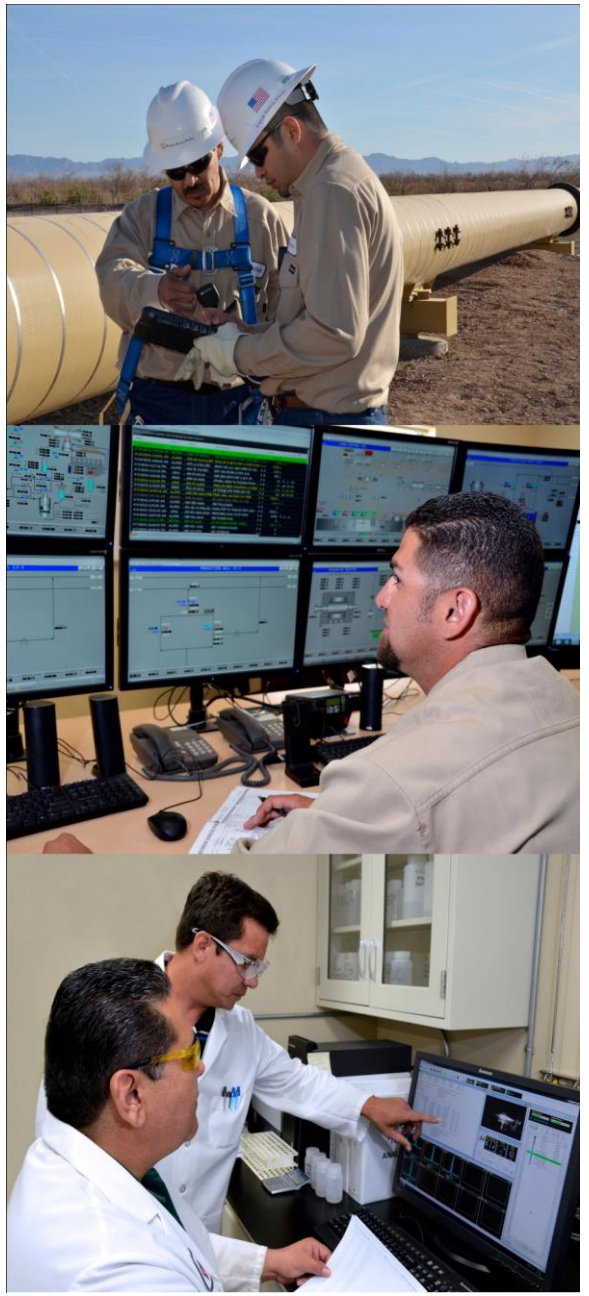




Community Benefits

- Significant creation of direct, maintenance and service support, and tertiary jobs.
- Direct economic activity of approximately $70,000,000/yr.
- Large capital investment provides substantial and sustainable property tax stream.





CHALLENGES

- We anticipate being the first geothermal brine resource to operate at commercial scale, this has presented some unique hurdles, real and perceived.

RISK	MITIGANT
Technology (general)	Use commercially proven techniques and or equipment
Direct Lithium Extraction	Avoid TRL <7; implemented known technology with efficient hardware
CAPEX and OPEX Exposure	Significant Early Engineering / Pilot Demonstration
Product Quality	Preferred Partners and Guaranty

THANK YOU

Questions?

15 Minute Break

Panel Discussion: Supply

Panel Moderator: Danny Kennedy, New Energy Nexus

- Derek Benson, EnergySource Minerals
- Richard Cohen, Rio Tinto
- Rod Colwell, Controlled Thermal Resources
- Jonathan Weisgall, Berkshire Hathaway Energy

Panel Discussion: Demand

Panel Moderator: Tyson Eckerle, GO-Biz

- Julie Blunden, EVGo
- Sarah Busch, California Energy Storage Alliance
- David Deak, Marbex LLC
- Stella Li, BYD Motors LLC

Panel Discussion: Execution and Regulation

Panel Moderator: Commissioner Karen Douglas, California Energy Commission

- Tim Kelley, Imperial Valley EDC
- Jim Minnick, Imperial County Planning and Development
- Jim Scrivner, BLM

Thank you!

California's Lithium Recovery Initiative Symposium