Geothermal updates for SSTF

Mike and Arun

American-Made Challenges

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Geothermal Lithium Extraction Prize

Develop solutions that de-risk and increase market viability for direct lithium extraction from geothermal brines.

Energy, Environment & Resources | Government

Stage:
Anticipated Phase 2: Open for submissions

Prize:
$4 Million Total Prize Pool

FOLLOW CHALLENGE

This challenge is closed

Overview | Guidelines | Timeline | Updates 13 | Forum 7 | Teams 194 | Entries | Resources | FAQ

AMERICAN-MADE

Geothermal Lithium Extraction Prize

PHASE 1: IDEA & CONCEPT

$600,000

UP TO **15** SEMIFINALISTS

PHASE 2: DESIGN & INVENT

$1.4 MILLION

UP TO **5** FINALISTS

PHASE 3: FABRICATE & TEST

$2 MILLION

UP TO **3** WINNERS

Last week, 15 team semifinalists out of 40 total teams were selected to advance to Phase 2 of the competition.

Most of the proposed methods involve membranes and electrochemical methods, which will be *very expensive*.

Ours involves cheap recyclable titania slag and diatomaceous earth.

https://www.youtube.com/watch?v=iJ7oRH6f6Dc

The Phase 1 semifinalists identified an impactful idea or solution to drive down costs of lithium extraction and, ultimately, help develop environmentally friendly, domestic sources of lithium. Each team will receive $40,000 and is eligible to move on to Phase 2.

The Phase 1 semifinalists are:

- **Boston University** – Pober-Strauss
- **George Washington University** – Ellexco
- **Massachusetts Institute of Technology** – Lithium from Home
- **Massachusetts Institute of Technology** – Nanoporous Graphene Membrane
- **Oregon State University** – Espiku
- **Rice University** – LiSED
- **Texas Tech University** – Tech Desal
- **University of Illinois Urbana-Champaign** – SelectPureLi
- **University of Massachusetts Dartmouth** – Lirix-nano Sengupta
- **University of Miami** – Miami Solution
- **University of Texas at Austin** – Freeman Lab
- **University of Utah** – University of Utah
- **University of Virginia** – Team TELEPORT
- **University of Wyoming** – Bruce Parkinson's Team
- **University of Wyoming** – Team Goldilocks

Phase 2 of the Lithium Prize, Design & Invent, kicks off this week. Over the coming months, semifinalist teams will advance their Phase 1 proposals to demonstrate their designs' abilities. Phase 2 finalists will then fabricate and test their designs for Phase 3.

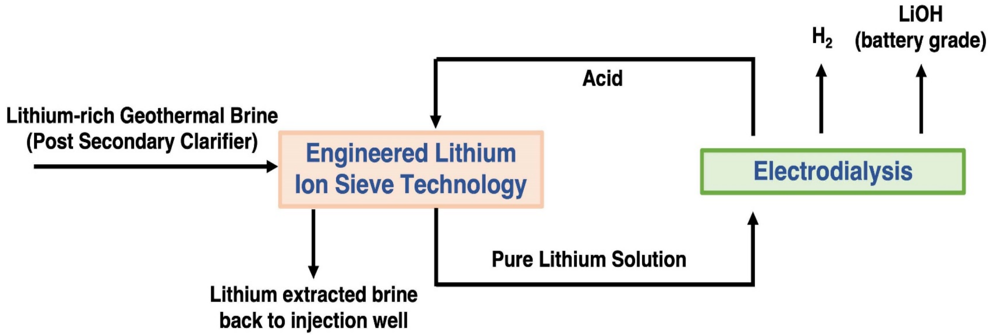
Engineered Lithium-Ion Sieve Technology (E-LIST) for Direct Lithium Extraction and Lithium Hydroxide Production

YORK SMITH / UNIVERSITY OF UTAH

Project Summary

We will demonstrate the use of Engineered Lithium-Ion Sieve Technology (E-LIST) as an innovative, multi-resource capable, and low-impact processing method.

Our new innovative processing approach will produce battery grade lithium hydroxide while simultaneously regenerating processing reagents.



New Innovative Processing Approach

- Electrochemical process to produce battery grade lithium hydroxide
- Low power consumption
- Reagent regeneration and recycling loop
- Hydrogen production is a by-product
    - Can be sold to improve economics

Project Impact

The study will establish a new paradigm in how lithium is extracted from resources enabling a wider range of lithium resources. The successful application of a selective hydrometallurgical purification and concentration technology specific to lithium would positively impact domestic resource efficiency.

The work aims to: i) recover lithium from resources with >90% purity, ii) reduce reagent consumption and waste generation by 25%, and iii) lower operating costs compared to conventional brine and mineral processing baseline processes.

Engineered Lithium-Ion Sieve Technology (E-LIST)

- Non-evaporative recovery process
    - Saves water
- High flexibility in brine chemistry
- Highly selective toward Li over other competing ions
- High cyclability/reusability
- Sorbent manufactured from waste materials
    - Inexpensive material cost

Key Personnel/Organizations

York Smith & John McLennan

University of Utah

Greeshma Gadikota

Cornell University

Michael A. McKibben

University of California, Riverside

BERKELEY LAB

EARTH & ENVIRONMENTAL SCIENCES

Improved quantification of Li resources for Lithium Valley – A research proposal

Pat Dobson, Will Stringfellow, Eric Sonnenthal, Jenn Stokes-Draut, Dev Millstein, Nic Spycher, Ram Kumar, Verónica Rodríguez Tribaldos, Nori Nakata, Avinash Nayak (LBNL), Mike McKibben, Maryjo Brounce, Jen Humphries (UC Riverside), Sabodh Garg (Geologica)

Basis of Lithium Valley – Recoverable geothermal Li

Abundant and sustainable Li source in geothermal brines from the Salton Sea geothermal field is needed for long-term economic production of Li.

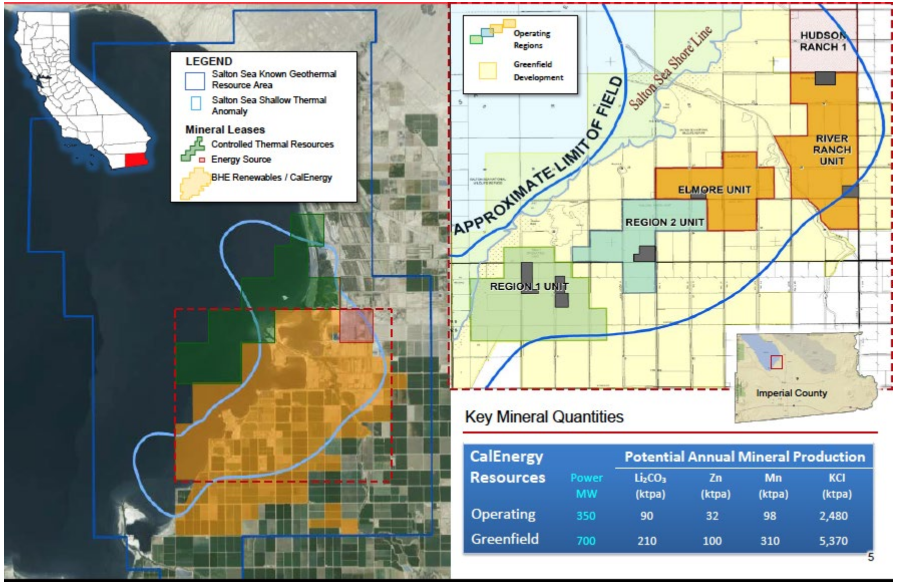
Key questions:

1. **How much Li is present** in the Salton Sea geothermal reservoir?
   - Li resource production estimates from brine production rates and Li contents
   - Reservoir total Li resource estimates from reservoir volume and Li contents
2. How much Li is **recoverable** (depends in part on extraction technology)?
3. How rapidly will the **Li concentration of the brine decrease** as Li is recovered and spent brine is reinjected (resource sustainability)?
4. Would Li in reservoir rocks “**recharge**” geothermal brines?
5. What are the **environmental impacts** associated with Li recovery from geothermal brines?

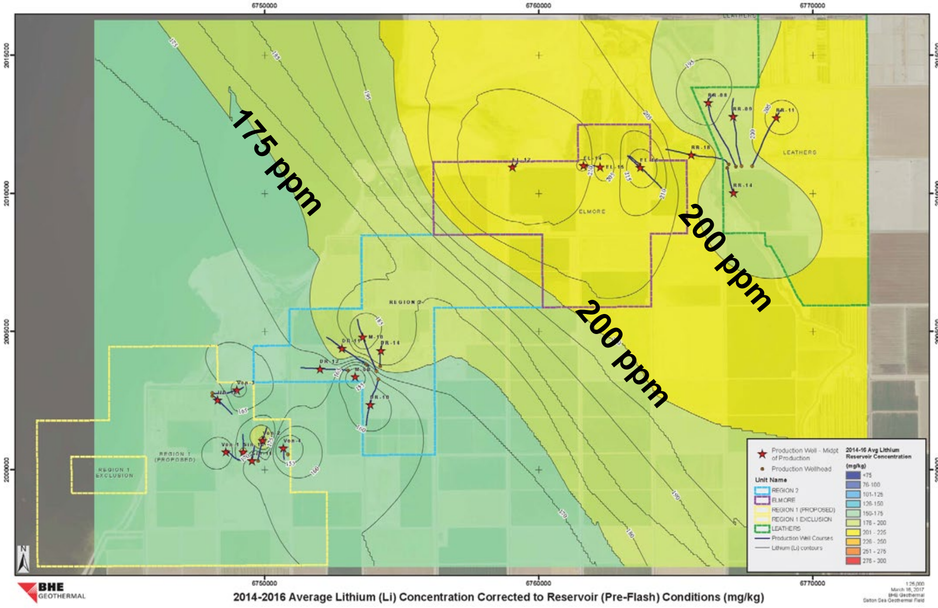
Li Resource Estimates - BHE

Leases and current production

Spatial variation in Li content in brine



CalEnergy Resources	Power MW	Potential Annual Mineral Production Li_2CO_3 (ktpa)	Zn (ktpa)	Mn (ktpa)	KCl (ktpa)
Operating	350	90	32	98	2,480
Greenfield	700	210	100	310	5,370



Besseling, 2018

Proposed Research Activities

Task 1. Develop better constraints on **Li brine variability and distribution** within Salton Sea resource to improve estimates (and uncertainty) of **expected Li contents** in brine produced from existing and new wells.

Drs. Dobson, Stringfellow, and McKibben will compile existing data concerning **water chemistry of Salton Sea geothermal fluids** along with supporting geological and geophysical measurements. Sources of data will include journal articles, government reports, and **privately held data from industry partners**, such as Berkshire Hathaway Energy (we have letter of support). Data will be imported into **statistical software (e.g., JMP/SAS) and geospatial software (e.g., ArcGIS)** for analysis. **Data quality will be evaluated** for criteria including completeness and ion balance. Chemical data will be evaluated using **spatial and statistical methods**, including tests for variance, multivariate techniques, two-dimensional geospatial analysis, and three-dimensional grid analysis. Determining variance in data will be used to guide modeling and to establish constraints and “error bars” on resource estimates.

Proposed Research Activities

Task 2: Evaluate **correlation between dissolved Li values with chlorinity and temperature** (e.g. a 3-D plot of log Li molality vs log Cl molality vs 1/T); such a regression algorithm could be coupled with a reservoir salinity-temperature model to **predict Li concentrations** throughout the reservoir.

Drs. Stringfellow, Spycher, Dobson, and McKibben will assess **regression models** of relationships between chemical and physical parameters such as dissolved **Li values, chlorinity, and temperature**, with the goal of developing an algorithm that can accurately predict dissolved lithium values Exploratory statistical analysis, including multivariate techniques such as **principal component analysis (PCA) and canonical analysis**, will be conducted to discover potentially predictive or causative relationships between geophysical, geological, and geochemical outcomes (e.g., lithium concentration and distribution) These potentially causative or predictive relationships will be further explored using reactive transport modeling (Task 5).

Proposed Research Activities

Task 3: Develop better constrained estimates of resource extent, thickness, and porosity to improve **reservoir volume estimates** and their uncertainty

Our team will compile available geologic and geophysical data to **define the extent of the Salton Sea geothermal reservoir**, and will use **reservoir porosity and permeability data** from the literature to provide additional constraints on the character of the reservoir. This information will be used to help construct the numerical models in Tasks 4 & 5.

Proposed Research Activities

Task 4: Create simplified reservoir models to estimate **production declines in Li** brine contents caused by reinjection of Li-depleted brines back into reservoir (dilution effects)

Using data from Task 3, Dr. Garg (Geologica) will construct **simplified reservoir models** to: 1) Estimate production declines in lithium (Li) brine contents caused by reinjection of Li-depleted brines into the reservoir (**dilution effects**), and 2) Evaluate potential for additional **Li contributions from reservoir rocks** to geothermal brine over time (in conjunction with Task 5). Geologica's STAR geothermal reservoir simulator incorporates a 3-phase (liquid brine, vapor phase, solid precipitate) brine equation-of-state for fluid properties and provides for the description of the motion of "**dilute tracers**". The simplified reservoir models will include (1) removal of Li from reservoir brines along with the brine, (2) injection of Li-depleted brine into the reservoir, and (3) possible addition of Li to reservoir brines from the surrounding rocks. STAR does not incorporate chemical reactions; reactive transport reservoir models will be developed outside the STAR framework (as part of Task 5) to evaluate potential for additional Li contributions from reservoir rocks.

Proposed Research Activities

Task 5: Develop initial reactive transport reservoir models to evaluate potential for additional **Li contributions from reservoir rocks** to geothermal brine over time

This task will build upon Tasks 1 – 4. The initial work will **characterize the reservoir mineralogy**, with a focus on which mineral phases host lithium. Dr. Brounce, Ms. Humphries and Dr. McKibben (UCR) will use **SEM/EDS elemental mapping** on polished sections of drill core and cuttings samples to identify mineral and rock phases that contain lithium. **Elemental maps** will be combined with backscatter electron images that together will readily distinguish the major phases from one another for all phases ≥5 microns in grain size. This geochemical characterization will then be incorporated into **reactive transport models** using TOUGHREACT v4 by Drs. Sonnenthal, Spycher, and Kumar to evaluate the **quantity and rate of resupply of lithium** to accessible geothermal fluids. The model will integrate the magmatic-hydrothermal system with the rock mass and surficial deposits so that the full Li resource can be considered. Additional constraints will be incorporated using **Li isotopes** which can be used to constrain the reactions of feldspars to clays over a wide temperature range (Wanner et al., 2014).

Proposed Research Activities

Task 6: Evaluate the potential **amount of water needed** for lithium extraction

Fresh water is used to **wash and regenerate the ion-exchange media** used to capture Li from the brine. Although there is no reason to initially assume that this will create a ‘large’ demand for additional fresh water usage, there is a need to understand water use in the context of **limited water availability** in arid regions. In this task, Drs. Stokes-Draut and Stringfellow will assess the **magnitude of water demand** relative to the **context of local limitations and regional industrial and municipal water consumption**. Comparison of **water consumption based on reported values for Li extraction processes** will be made to **ion-exchange** as applied on **oil and gas fields and in mineral extraction and purification**. Because overall water use and consumption may increase if Li extraction spurs expanded geothermal power development, we will also examine **water use and consumption by geothermal power plants** and produce estimates of upper and lower limits for water demand as a function of expanded geothermal power production in the region. We will specifically examine **water planning documents** for the region to understand how the potential additional demands of Li extraction and the increased development of geothermal power may fit into and/or be constrained by the region’s fresh water balance.

Proposed Research Activities

Task 7: Evaluate the **use of chemicals** needed for lithium extraction

Acids and other chemicals are used in geothermal Li extraction processes. **HCl** is **used to extract lithium (as lithium chloride) from molecular sieve ion-exchange sorbents and regenerate the ion-exchange media**. Other chemicals that may be used in a geothermal lithium extraction process include **anti-scaling compounds, strong bases, lime, and reducing agents**. Dr. Stringfellow will calculate a preliminary **estimate of potential chemical use** that may be expected as lithium extraction processes are applied in the region. Information about potential chemical use for geothermal lithium extraction will be gathered from technical publications on lithium extraction processes, including patents and industrial reports. In addition, **chemical use by the geothermal power industry** and for ion-exchange processes by other industries will be examined.

Proposed Research Activities

Task 8: Evaluate **pollutant emissions and air quality** associated with **lithium extraction** and potential expansion of **geothermal production**

Imperial County has **high levels of particulate matter** compared to most other counties in California, which has led to increased rates of childhood asthma and other health burdens. Given this context, it is important to understand any **potential new air emissions from geothermal power expansion and Li extraction**. **Geothermal emissions** typically derive primarily from **CO_2 and H_2S** in the produced geothermal fluid or steam. During the flashing process, these compounds are released to the air. H_2S can form $PM_{2.5}$ which causes health impacts in an exposed population. H_2S can potentially be removed from geothermal emissions through treatment technology. Though it is possible to also remove CO_2 emissions from the air emissions stream, it is currently expensive to capture CO_2. Dr. Millstein will evaluate currently **available data on emission rates and pollution control equipment** from existing geothermal operations within the Li Valley region. His analysis will also explore **potential emissions associated with the lithium extraction process** itself by a review of emissions from similar ion-exchange processes as well as based on data and reports of existing Li extraction processes.

Proposed Research Activities

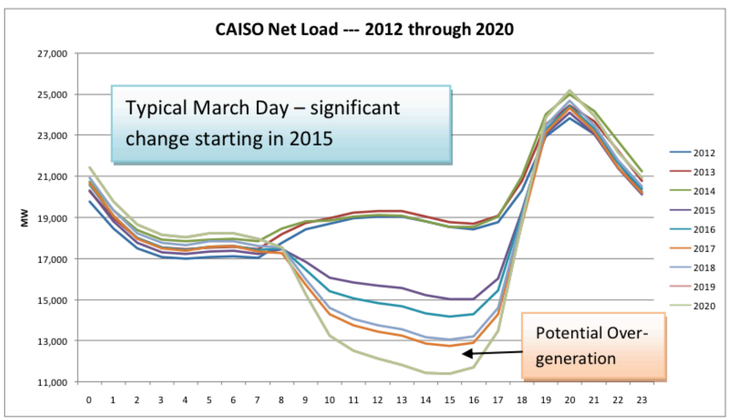
Task 9: Conduct **risk assessment** of **induced seismicity** associated with **Li extraction** and potential **expansion of geothermal production**

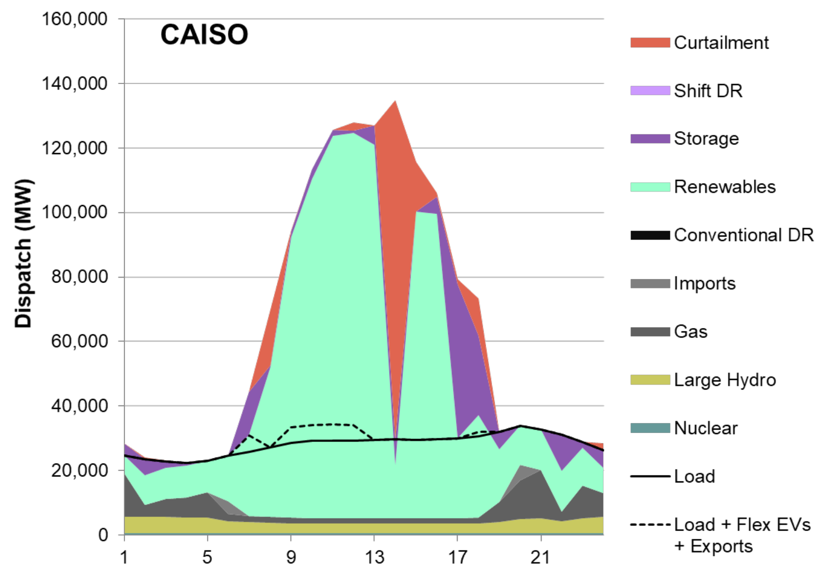
Extracting Li from Salton Sea geothermal fluids could lead **more geothermal deployment, wells and subsurface injection and production**. **Induced seismicity** has at the Salton Sea geothermal field has been **correlated with the net volume of produced fluids**. Drs. Nakata, Rodríguez-Tribaldos, and Nayak will use available long-term observations of seismicity to model the relationship between fluid injection/production and induced seismicity. Using estimated amounts of lithium that could potentially be extracted and possible scenarios of fluid production and re-injection volume at various locations, we will **predict induced earthquake rates and ranges of magnitude**. New instrumentation, such as **dark fiber sensing**, can potentially dramatically increase the sensitivity of monitoring seismicity and obtaining detailed structural information for the subsurface. We will develop and test an **initial predictive model for induced seismicity** at the Salton Sea geothermal field that can be used to estimate possible maximum magnitude of earthquakes due to the lithium extraction and evaluate the **potential for triggered earthquakes** in this seismically active region.

UCR College of Engineering- Center for Environmental Research & Technology

Renewable Energy and Storage Needs

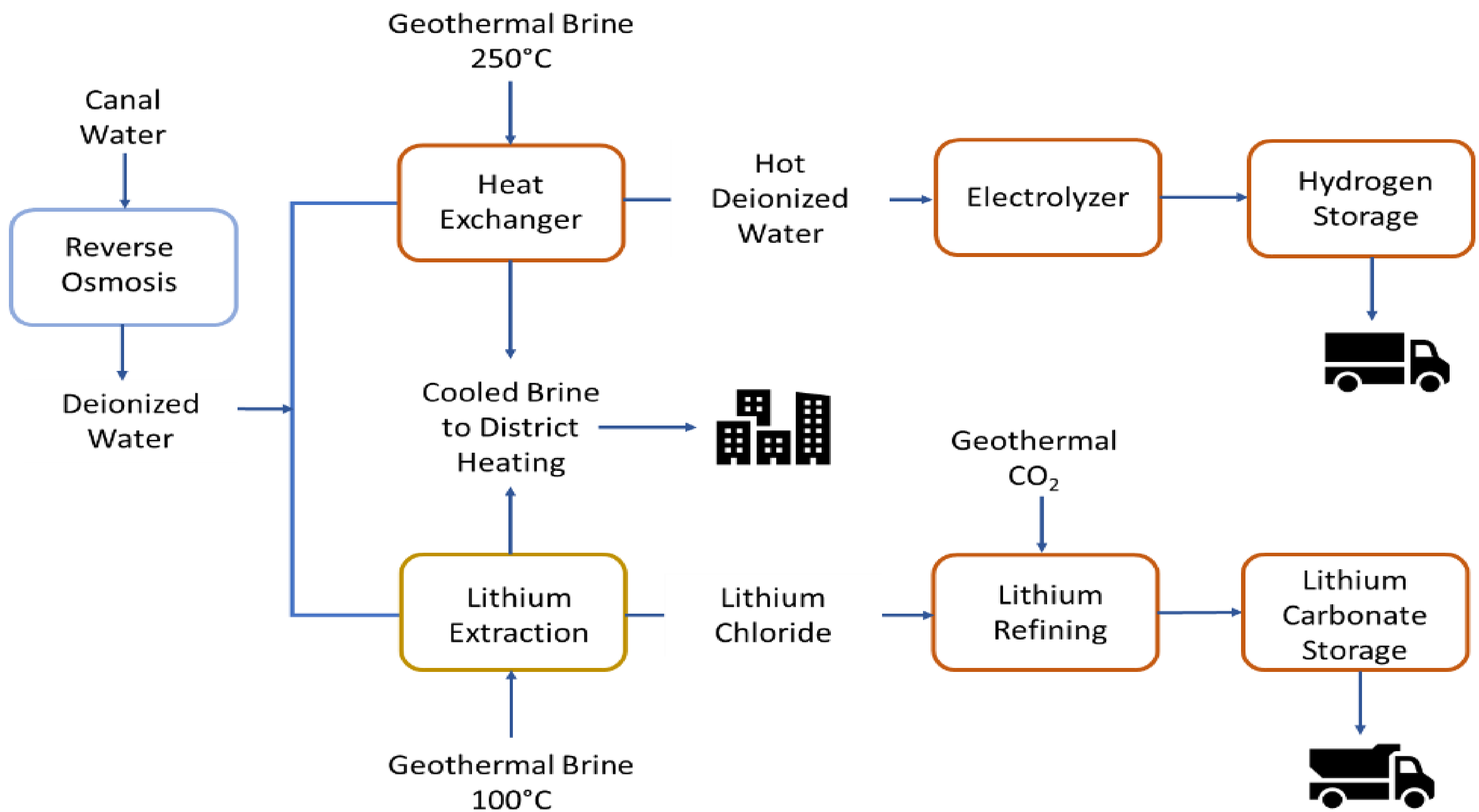
- Critical need for energy storage over the next decades
- Batteries – short term energy storage
- Hydrogen (power to gas) – mid to long term energy storage medium; and sustainable transportation fuel





80% RPS by 2045; 17 MMtCO2e GHG – V3

GeoFlex Concept



Shnell et al 2016, Proceedings, 41st Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California

UCR Lithium Valley Strategy

- Accelerate development of the nascent lithium recovery industry and associated sustainable energy generation.
- UCR's long-term goal is to help develop an eco-manufacturing hub around the SSGF's geothermal and lithium resources in an environmentally friendly, equitable manner that benefits the region.
- Strategically aligned with the OASIS Initiative: creation of a lithium battery supply chain as part of this effort is a key objective of OASIS.

Timeline

- Analytical and testing support – immediate (3-6 months)
- Li extraction R&D – near (6-24 months)
- Battery testing R&D and demos – mid term (12-36 months)
- Hydrogen production, storage & distribution – long term (12-48 months)
- Environmental justice and public health – parallel
- Policy analysis and support – near to long term

Current Activities

- Writing a white paper/proposal on the different requirements for distribution with stakeholders
  - Legislators, Li valley commission, Industry, potential partners
  - CA will invest $110 million in green H2 production (https://www.hydrogenfuelnews.com/green-hydrogen-funding/8545283/)
- Proposals: UC National Lab Fee Research Program to develop microgrids with hydrogen production/storage capabilities; NSF NRT program
- Organizing a conference around the Li Valley efforts (OASIS, SSTF, CE-CERT, SPP, Geochemistry faculty)
- Ongoing projects: Li extraction pilot demo (Berkshire/CEC), Evaluating pipeline H2 injection (CPUC), Developing ZEV infrastructure blueprint (CEC), ZEV truck deployment (CARB, Volvo)

Next Steps

- Identify and communicate with potential partners
  - Ongoing conversations with CalEnergy, EnergySource
  - Identifying and communicating with UCR faculty working on relevant areas
  - Identifying priority technology partners: battery makers, customers, electrolyser manufacturers, hydrogen integration stakeholders
  - Utilities
  - Academic/research partners: LBNL, others
- Workforce training – conversations with Imperial County workforce development agency, Imperial Valley College, SDSU
- Develop and pursue long term research & development strategy
- Seed funding opportunities