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OLI Systems Response to RFI on Geothermal Power and Lithium Recovery

Please see attached document with a response from OLI Systems, Inc.

Additional submitted attachment is included below.

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STATE OF CALIFORNIA — NATURAL RESOURCES AGENCY Gavin Newsom, *Governor*

CALIFORNIA ENERGY COMMISSION

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Request for Information
Geothermal Power and Lithium Recovery
Docket # 23-ERDD-01
Due Date: September 15, 2023

The California Energy Commission (CEC) is releasing this Request for Information (RFI) to gather information on critical challenges and research needs for geothermal power production and lithium recovery from geothermal brine. Responses to this RFI may inform a future grant funding opportunity (up to $23M in grant funding) addressing the Electric Program Investment Charge (EPIC) 2021-2025 Investment Plan Topic 2 "Advancing Geothermal Energy and Mineral Recovery Technologies."

Stakeholders are encouraged to respond to the specific questions they feel most suit their knowledge and background.

Geothermal Power

1. What technical barriers have the largest impact on development of geothermal power plants that use hydrothermal resources in California? How could research and development (R&D) funding be most effectively applied to help increase deployments of new geothermal power plants that use hydrothermal resources in California? What high priority technical barriers have been the most underfunded, and why have they not been adequately addressed by competitive markets?

Brine Handling and Disposal: One of the biggest technical challenges in geothermal power is in brine handling. Changing process conditions leads to corrosion and scaling problems. These problems significantly impair energy recovery, equipment life, and reliability of the plant. Both corrosion and mineral can be managed through process optimization, material selection and chemical treatment.

Research to improve chemistry and process modeling software is an efficient approach to predict and prevent these flow assurance challenges. Accurate chemical process simulations effectively reduce operations costs, test the feasibility of process changes, provide a digital twin of current plant operations, and ultimately improve efficiency and reduce downtime. Specific monitoring examples include predicting the location and quantity of silica, carbonate, and sulfide scaling in steady-state operations and during process changes. Specific prevention examples include predicting the optimal amount of scale inhibitor pH control to add.

Commercially available (and used) software has been severely underfunded. Funding software that is already integrated into the geothermal industry is key to translating academic research into usable geothermal applications.

Environmental: Trace contaminants and greenhouse/acid gases are important environmental concerns that require additional treatment facilities and improved designs such as closed loop systems. Designing ancillary treatment systems coupled with complex chemistry as seen in geothermal brines adds significant complexity and cost. Process modeling and simulation continues to be underfunded and underused in this area and should be a requirement in assessing the economic feasibility of geothermal projects. More research into trace contaminants, potential for cycle-up, chemical behavior, and potential for environmental impact must be investigated and integrated with tools that are usable for commercial partners.

Reservoir Management: Research into enhanced geothermal systems should be explored as scaling and corrosion can play a large part in the success of EGS. Predicting the high temperature/pressure reaction between the injection water and the rock forming mineral are essential to anticipating produced brine compositions and fracture permeability. Research already completed by US DOE labs in high temperature/pressure geochemistry can be incorporated into thermodynamic software that has a sufficiently robust equation of state and activity model. Such a tool would be valuable to the reservoir geologist as they their injection process.

2. What novel technologies or techniques for cost-effectively managing silica in geothermal brine have been successfully demonstrated at a Technology Readiness Level (TRL) of 3, 4, or 5? What silica management technologies can be adapted from other industries and applied to geothermal brine?

   Electrolyte thermodynamic simulation of the production system is the most direct and efficient way to predict and manage silica scale. Mineral scale prediction software has been used for decades in oil and gas production to predict and prevent flow assurance problems caused by scale deposition.

3. What materials, technologies, or techniques to decrease corrosion or thermal stress-induced failures in existing geothermal plants and wells have been successfully demonstrated at a TRL of 3, 4, or 5? What technologies could be adapted from other industries for use in geothermal power plants and wells?

   Corrosion tests are time consuming and expensive. Add to this the various types of corrosion mechanisms and the different locations in a geothermal production process and the challenge becomes more of keeping up with current corrosion problems instead of staying ahead of any problems and working towards prevention. Investing in developing accurate corrosion prediction tools has the distinct advantage of reducing development costs and lowering maintenance costs. Corrosion prediction tools have been used in the oil and gas industry for decades and can be retrofitted to address key corrosion challenges caused by high salinity and high temperature. The benefit is faster development of mitigation strategies like pH control, cost effective material selection, corrosion inhibitor, or oxygen scavengers.

Lithium Recovery from Geothermal Brine

4. What are the greatest technical barriers to the commercialization of lithium recovery from geothermal brine? What technologies provide the greatest opportunities to facilitate the commercialization of lithium recovery from geothermal brine? What would be the most effective use of R&D funding to advance commercialization of lithium recovery from geothermal brine? What specific technologies or approaches are presenting a particular challenge, and what are some alternatives?

The greatest technical barriers to the commercialization of lithium recovery from geothermal brines are 1) finding low-cost extraction process that maximizes lithium recovery while minimizing contaminant concentration, 2) minimizing water demand in water-stressed locations like Salton sea, and 3) minimizing the environmental impacts of the extraction operation.

Designing the extraction plant using process modeling software reduces enormously the cost of commercializing the plant. Geothermal brines are high ionic strength, high temperature, and have complex compositions. Relying on experiments and pilot plants to build a demonstration or commercial plant is costly and time consuming. The more effective approach by far, is to use electrolyte thermodynamic models that accurately predict plant operations. These models are validated against peer-reviewed experimental data and tuned to the extraction media or kinetics observed in the laboratory. When equipped properly, these tools can cut the laboratory and engineering time and cost by an order of magnitude or more.

Investing in a commercially available model that can accurately predict the chemical behavior of geothermal brines while also accounting for the novel process units is where future investment should be. Lithium extraction media and membranes are evolving quickly and have proprietary tag. It is worthwhile to invest in a tool that can incorporate new extraction and separation materials so that these novel capabilities can be applied within days to weeks of their discovery and testing. Comprehensive process models that have such capabilities would improve technical evaluations, scale-up, commercialization, and operations at a lower cost with reduced lab and field tests.

5. What brine pretreatment issues have been especially challenging to overcome? What technologies or techniques have been successfully tested at a TRL of 3, 4, or 5?
   The key challenges are mineral scaling and corrosion. As brines cool and drop in pressure, silica and carbonate scaling risk become a challenge. Oxygen ingress in a high chloride brine increases localized corrosion (i.e., pitting and crevice corrosion) risk.

   Since pH modification is required for effective DLE processing, we conclude that pH, and carbonate treatment with precipitation / filtration effectively removes transition and post-transition metals. This sludge contains iron, nickel, manganese, lead, copper, and zinc. If sulfuric acid is used in the process, then sulfate pre-treatment can eliminate barium scale buildup. These methods were tested in TRL 3 within the BHERM LHD design and pilot plant work.

6. What technologies or processes can reduce waste products from the lithium recovery process (such as by decreasing mass or by recovering additional co-products in the lithium recovery process)? What TRL are these technologies?
   A recent Salton Sean project PoC design required approximately 1 gpm canal water to process every 4 gpm of Salton sea brine. This is achieved by maximizing water reuse.

7. What co-products are the most feasible to recover? What technologies or processes are available to produce them? What TRL are these technologies? Is any R&D needed prior to conducting a pilot demonstration?
   For Salton Sea brines, the high value coproducts are the metals: Cu, Pb, Zn, and Mn. These can be separated by chemical precipitation/filtration.

Comprehensive Brine Management

8. Could a comprehensive new approach to brine management (i.e., one which involves the complete process from start to finish) simultaneously address issues that affect geothermal power production and lithium recovery (such as corrosivity, scaling, and constituents that interfere with the recovery of marketable minerals) while leveraging opportunities to recover profitable co-products? How could a comprehensive approach be implemented in a cost-effective manner?

   Electrolyte-based process simulation software is the most effective, new brine management approach. Such a tool can predict the mass, energy, and chemistry balance of the process plant, effectively combining TRL's #1 through #4 in a single step. Furthermore, comprehensive electrolyte thermodynamic software predicts mineral scaling and corrosion, and therefore materials selection can be done concurrently with the plant design. Lastly, the same comprehensive software should incorporate rate- and mass transfer-limiting processes like lithium uptake by the DLE media. Incorporating these non-equilibrium steps enable the plant designer to create a closest-approach simulation design of the actual plant.

How to Provide Information

Respondents to this RFI should not include any proprietary or confidential information. Comments must be submitted by 5:00 p.m. on September 15, 2023, using the e-commenting feature to submit to Docket 23-ERDD-01.

To use the e-commenting system, respondents will be asked for a full name, email address, comment title, and either a comment or an attached document (.doc, .docx, or .pdf format). After a challenge-response test is used by the system to ensure that responses are generated by a human user and not a computer, click on the "Agree & Submit Your Comment" button to submit the information to the CEC's Docket Unit.

Written comments, attachments, and associated contact information included within the documents and attachments will become part of the viewable public record and searchable on the internet.

Interested stakeholders are encouraged to use the electronic filing system described above to submit information. If you are unable to submit electronically, a paper copy of your information may be sent to:

California Energy Commission
Docket Unit, MS-4
Re: Docket No. 23-ERDD-01
715 P Street
Sacramento, CA 95814-5512

Alternatively, you may email responses to docket@energy.ca.gov with the subject line "23-ERDD-01: RFI Geothermal Lithium".