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Additional submitted attachment is included below.

CONTROLLED THERMAL RESOURCES

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23-ERDD-01

Electric Project Investment Change (EPIC)

Request for Information – Geothermal Lithium

Thank-you for your request for information regarding the production of lithium from geothermal resources. Please find below our responses.

Geothermal Power

1. What technical barriers have the largest impact on development of geothermal power plants that use hydrothermal resources in California?

The high cost of early-stage drilling of resource delineation wells and associated challenges with federal, state and local permitting has long been realized as the greatest technical barrier. At the Salton Sea, the challenge of brine conditioning adds to these impediments.

Early studies required to determine the feasibility and design of a geothermal development, including geoscience and geotechnical surface investigations, are often delayed due to permitting restrictions. Research to develop less invasive and lower impact methods, including drone or satellite data acquisition, would streamline project development.

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?

Develop less invasive and lower cost methods for delineation and assessment of geothermal resources that eliminate the need for costly exploration drilling in the early stages of development. Studies have shown that small-diameter slim hole drilling is not an effective exploration tool in many geothermal fields because flow test data does not allow definitive measurement of critical resource parameters (Kaspereit and Osborn, GRC Transactions, 2017). Instead, perhaps, micro-scale tools deployed in a slim hole or microbore might conduct these measurements under conditions that provide a unique solution.

What high priority technical barriers have been the most underfunded, and why have they not been adequately addressed by competitive markets?

Decline

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?

Silica management techniques demonstrated at the Salton Sea have predominantly involved precipitation via alkalization (Schultze and Bauer, GRC Transactions, 1982), precipitation via seeding (Featherstone et al., 1979), or inhibiting precipitation via acidification (Gallup, 1996). These technologies have been demonstrated at TRL 7-9. Research funding to identify more elegant techniques, such as sequestration and selective filtration without stoichiometric reagent addition and bulk precipitation, might integrate better with extraction of critical minerals.

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What silica management technologies can be adapted from other industries and applied to geothermal brine?

Unknown at this time as most geothermal applications have adapted silica management technologies that allow satisfactory economics for their applications. Perhaps funding national lab work can provide new techniques that provide better economics.

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?

Various metallurgies have been demonstrated at TRL 6-9 at the Salton Sea, including carbon steel, titanium Grade B and Grade 29, Hastalloy C-276, Alloy 625, Super Duplex 2507, and other nickel alloys, various chrome alloys, etc. Carbon steel cladded with these alloys has also been demonstrated. Cement-lined steel pipe reached TRL 9 but has since been discontinued due to poor longevity. In current applications, carbon steel internally clad with corrosion-resistant alloys or synthetic materials are being tested in field trials at TRL 6-7. CEC funding should encourage development and deployment of additive manufacturing applications, which have the potential to produce corrosion resistant materials faster, at lower cost and with higher reliability.

What technologies could be adapted from other industries for use in geothermal power plants and wells?

This question might best be addressed by CEC funding of just such a study by a national laboratory with broad connections to other industries – a focused search for solutions applicable to the geothermal industry from other hydrometallurgical industries and processes. Regarding wells, for example, technical advances from oil and gas applications may be suitable for geothermal applications.

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?

Selctively extracting lithium ions while in the presence of other cations such as sodium, potassium, calcium, etc. The challenge therefore is producing a lithium solution that is free of other materials that may interfere with the subsequent conversion to battery-grade lithium compounds. The three basic technologies that have demonstrated technical effectiveness extracting lithium from geothermal brines are solvent extraction, ion exchange, and adsorbent extraction. The basic issue is economic efficiency or acceptability. The better the overall economics, the higher the probability for funding, and therefore construction of a commercial facility.

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?

Geothermal brines typically contain a myriad of other cations (elements) beyond the material of choice such as lithium. The challenge is preparing the brine for the extraction efficiency & purity that is necessary for an adequate overall economic outcome for a commercial facility. Our work in this area is proprietary.

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?

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Mineral extraction typically involves filtration of extracted product slurries to remove entrained water. Studies to improve filtration efficacy would decrease product weight and conserve valuable water resources. Research currently being conducted by Controlled Thermal Resources in association with Pacific Northwest National Laboratory is addressing one approach to this issue.

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?

The feasibility of mineral extraction is dependent on market conditions. In the 1990s, when zinc extraction by ion exchange was demonstrated at TRL 9, manganese was the most attractive Salton Sea mineral extraction target. Changes in market conditions have currently made lithium more attractive. Rather than focusing on one mineral, research funding might better be applied holistically to extract a broad array of minerals such that technologies are advanced and made ready for changing market conditions.

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?

Controlled Thermal Resources is developing the Hell's Kitchen project using this new approach to brine management, with a cost-effective and integrated mineral extraction and electric power generation process that optimizes resource utilization and minimizes water consumption. The mineral extraction technologies currently being implemented are applicable to other valuable and critical minerals. Research to apply these technologies in parallel and serial, while minimizing water and reagent consumption and waste generation, offer the promise of harvesting a large part of the periodic table from the Salton Sea brine.

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