DOCKETED	
Docket Number:	23-ERDD-01
Project Title:	Electric Program Investment Charge (EPIC)
TN #:	252018
Document Title:	Trevi Systems inc Comments
Description:	N/A
Filer:	System
Organization:	Trevi Systems inc
Submitter Role:	Public
Submission Date:	8/28/2023 10:21:30 PM
Docketed Date:	8/29/2023

Comment Received From: Trevi Systems inc
Submitted On: 8/28/2023
Docket Number: 23-ERDD-01

23-ERDD-01

Additional submitted attachment is included below.

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Electric Program Investment Charge (EPIC)

Geothermal Lithium

Geothermal Power

1. Technical barriers: Standardized corrosion/fouling resistant power plant design methodology and uniformity/standardization in the design approach is missing, leading to high construction risk and commensurate funding difficulties as every plant is a "full custom" design. A set of high-level design tools should be developed to evaluate different approaches to generating power and facilitate better TEA studies that are fundable. Furthermore, a standardize "geothermal brine" composition should be developed for use in early scale pilot testing before actual deep wells are drilled for pilot testing.
2. Novel technologies: Geothermal plants today seek to use a very high grade of heat (flash steam) for power production (>280^{o}C). Downstream from the primary (steam) turbine, a number of bottoming technologies could be funded to improve overall plant economics, including (i) higher performance Kalina cycle engines using mixed binary fluids, (TRL 5) or (ii) thermal desalination systems such as Forward osmosis and membrane distillation (TRL 5), especially in the Salton Sea area where they could beneficially desalinate the lake or local brackish aquifers to supply water for the extraction process and (iii) polymeric heat exchangers (TRL 4) to lower capital costs and reduce corrosion of exotic metal units due to salinity in the DLE process.
3. In the Oil and gas produced water fields, salinity is as high as geothermal brines, but temperatures are somewhat lower. New ceramic membranes (TRL5) exist that can operate at these high temperatures, but the components around them (seals specifically) have not been adapted to operate at the higher temperature. Water chemistry also requires precise pH control and onsite integrated acid/base generation from brines could be beneficial.

Lithium recovery

4. The greatest challenge lies in the pre-treatment of the brine to reduce metal silicate and calcite scaling of the downstream lithium extraction technology. All three downstream approaches, adsorbents, L/L extraction and electrochemical membranes suffer from these scaling issues. To make matters worse, the high temperatures present do not allow

these technologies to operate at much over 90°C at best, so research is urgently needed in (i) scaling control while cooling brines to allow extraction, (ii) recycling of regeneration chemicals (acids and bases), (iii) materials & components to facilitate operating in high brine environments (flow meters, conductivity sensors, heat exchangers).

5. Metal silicates and calcites scaling control needs a "low pollution" approach to be developed. Current methods are environmentally unfriendly and chemically intense. Two approaches that have demonstrated positive results in the lab are (i) new cationic silica scale inhibitors and (ii) high temperature NF ceramic membranes capable of operating at >150°C. These ceramic membranes have been tested and found to have >85% silica rejection at temperature, improving membrane flux and reducing silica scaling. The Silica scale inhibitors may be used with the NF membrane or at lower temperatures without. Both approaches have been bench tested at TRL 4 on synthetic silica rich brines, but not on actual geothermal waters.
6. There are many developing electrochemistry approaches that promise lower chemical consumption that resin adsorbents which require acid and base regeneration as well as frequent adsorbent replacement. One such approach is a novel Selective Electrodialysis Metathesis flow cell under test at Trevi to selectively extract lithium in the metathesis cell by using specially coated electrodes. The cell is under test at a TRL 3 level on synthetic brines and generates no chemical by products during the extraction or regeneration stage. The cell would have to be paired with a good pre-treatment to prevent the cell from fouling.
7. Early exploratory work at the Salton Sea by Trevi has shown high levels of gold in the brines. Although at high micro-gram levels, dollar for dollar the gold generates a greater profit than the lithium carbonate would. Crown ethers, and adsorbents are under investigation for low chemical consumption extraction, but the technology is still at a TRL 2 level. 6-12 months of R&D is needed prior to a pilot skid being tested.

Comprehensive Brine management

8. Minerals of interest include magnesium, lithium and gold at the Salton Sea. The magnesium would be extracted together with the calcium and silica in a pre-treatment step, followed by lithium and then gold. Power production would always precede the extraction stages, however a portion (up to 20%) of the power would need to be allocated to the extraction process to minimize chemical consumption. Examples include a near zero liquid discharge water reclamation process to provide water wash to the DLE process, as well potentially generating the acid and base chemicals onsite and neutralization thereof before re-injection. To manage costs, the power production would benefit from a standard approach for all plants, potentially under a PPP program between the State and plant operators. The extraction technologies need to access low-

cost pre-treatment approaches such as hot nano-filtration, selective electrochemical cells and careful end to end plant design to minimize waste streams.