Integrating Nuclear with ZLD Seawater Desalination and Mining

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ABSTRACT:

This project performs a feasibility study and cost-benefit analysis of an integrated energy system consisting of a nuclear power plant with zero-liquid-discharge (ZLD) production of power, distillate, and mined commodities. This work paves the way for addressing freshwater scarcity while simultaneously producing electric power and economically mining high-value minerals. Seawater contains a wide variety of minerals including Rb, Li, Mg, K, Na, Ca, Br, and U, many of which may be at or close to economically feasible extraction at current prices. However, it is also recognized that extraction of multiple minerals simultaneously will improve economic feasibility and that higher concentration brine streams improve the economics of extraction. Desalination is a means of addressing water scarcity, although discharge of concentrated brine presents environmental concerns. ZLD can mitigate this at increased cost and energy consumption, but integration with nuclear enables a multi-stage process combining thermal and electrical technologies. The high brine concentrations in ZLD presents an exciting opportunity for added value by way of mineral extraction.

OBJECTIVES:

Objective 1: Specify the desalination and mining system including methods for clean water production, seawater concentration and mineral extraction. Mass flows, temperatures and energy & chemical balances will be derived using steady-state models leveraging Modelica and the WaterTAP toolkits.

Objective 2: Heat and electricity extraction from the power cycle will be optimized to balance energy consumption with water production and purity. Siting aspects will also be investigated, including configuration of the joint facility and possible location options.

Objective 3: A pilot experimental study will be performed to validate/demonstrate the ZLD system for seawater mining.

TASKS:

Task 1 involves system process design and performance, wherein the capabilities of the power cycle are balanced with the requirements for heat and power in the downstream ZLD system. Task 2 involves desalination system specification. The specific arrangement of extraction processes is defined. Task 3 executes an experimental demonstration of the core ZLD processes that enable mineral extraction and distillate recovery. Task 4 includes technoeconomic analysis & optimization of the system. Finally, Task 5 considers siting and plant layout issues.

DELIVERABLES AND OUTCOMES:

We will deliver: (1) an assessment framework and downselection to a set of candidate mineral commodities based on technoeconomic viability; (2) ZLD power, water, & mining system design using an integrated nuclear heat and electricity source; (3) a cost/benefit analysis including optimization of system configuration according to relative capital costs, and (4) experimental demonstration of key desalination and mining processes using UW experimental facilities.