Hawaii Solar Desalination Project

Cost Effective Sea Water Desalination using Solar Thermal Energy Driven Forward Osmosis Process

March 18, 2019

Supported by funding from

SunShot U.S. Department of Energy

Team Members:

Natural Energy Laboratory of Hawaii Authority

Trevi Systems, Inc.

Cyanotech Corporation

Hawaii First Water, LLC

NELHA CSP Array at Keahole Point:
1,000 MicroCSP solar collectors
3.8 acres
2 MW thermal energy generation

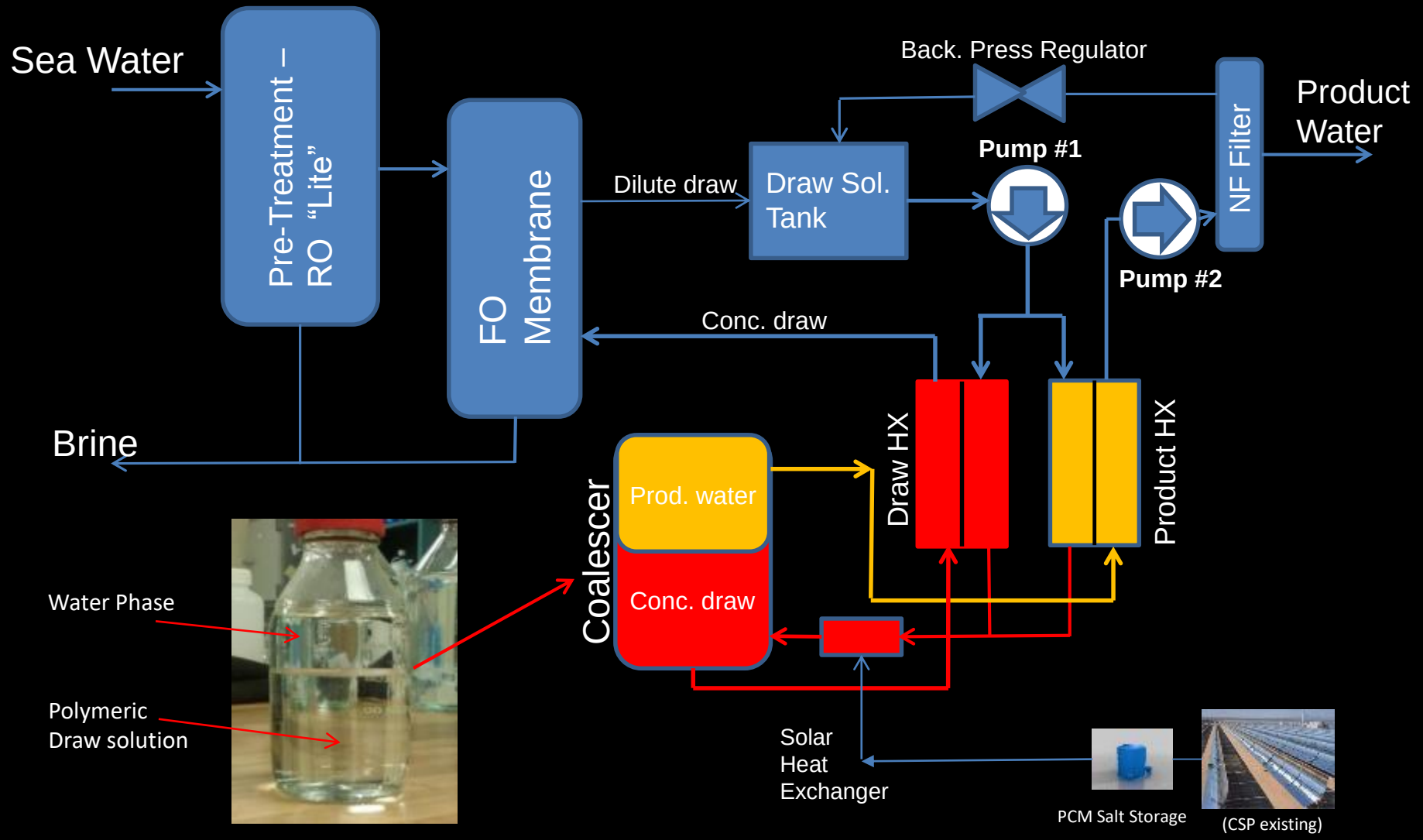
Project objectives

The project seeks to demonstrate a reduction of the levelized cost of water (LCOW) by 40% compared to current state-of-the-art.

Specifically, with key advances in the technology, Forward Osmosis will

- Lower the CAPEX for seawater desalination to $4.5M for 10,000 m3/day
  compare to $5.5M for RO; $7.3M for MED
- Reduce energy cost to $0.10/m3
  compare to $0.25/m3 for RO; $0.14/m3 for MED
- Increase seawater recovery to 50-60%
  compare to 40-48% for RO; 25-40% for MED)
- Achieve a Levelized Cost of Water of $0.52/m3
  compare to $0.79/m3 for RO; $0.92/m3 for MED

FO Desalination Components at NELHA



Masdar 2 container 50m3/day Pilot (Outside Dubai)

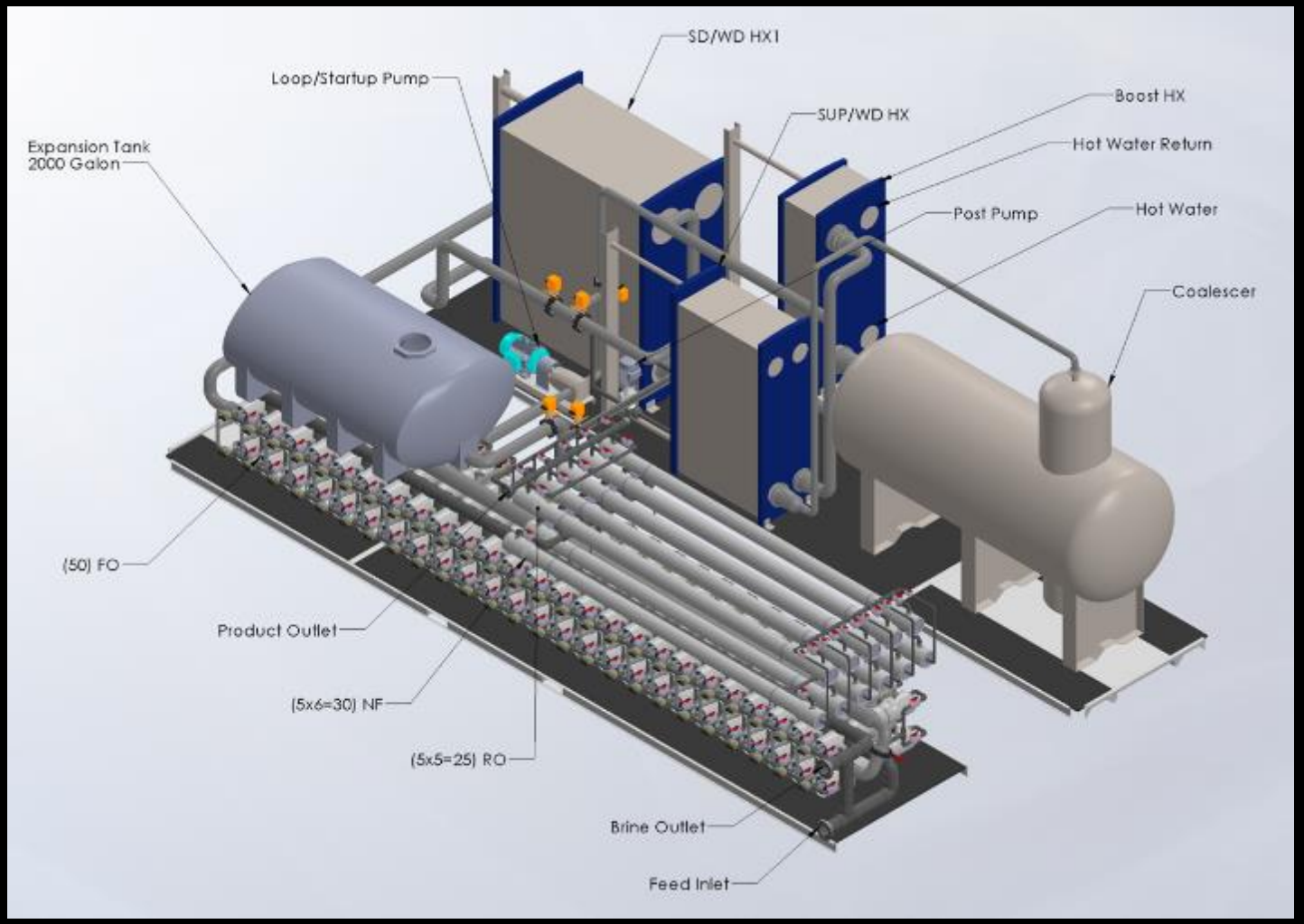
FO membranes, Pre-treatment and Heat recovery HX

CEO J Webley, CSO G Carmignani and Field Te.ch at Masdar

Biological Fouling at Masdar Trial

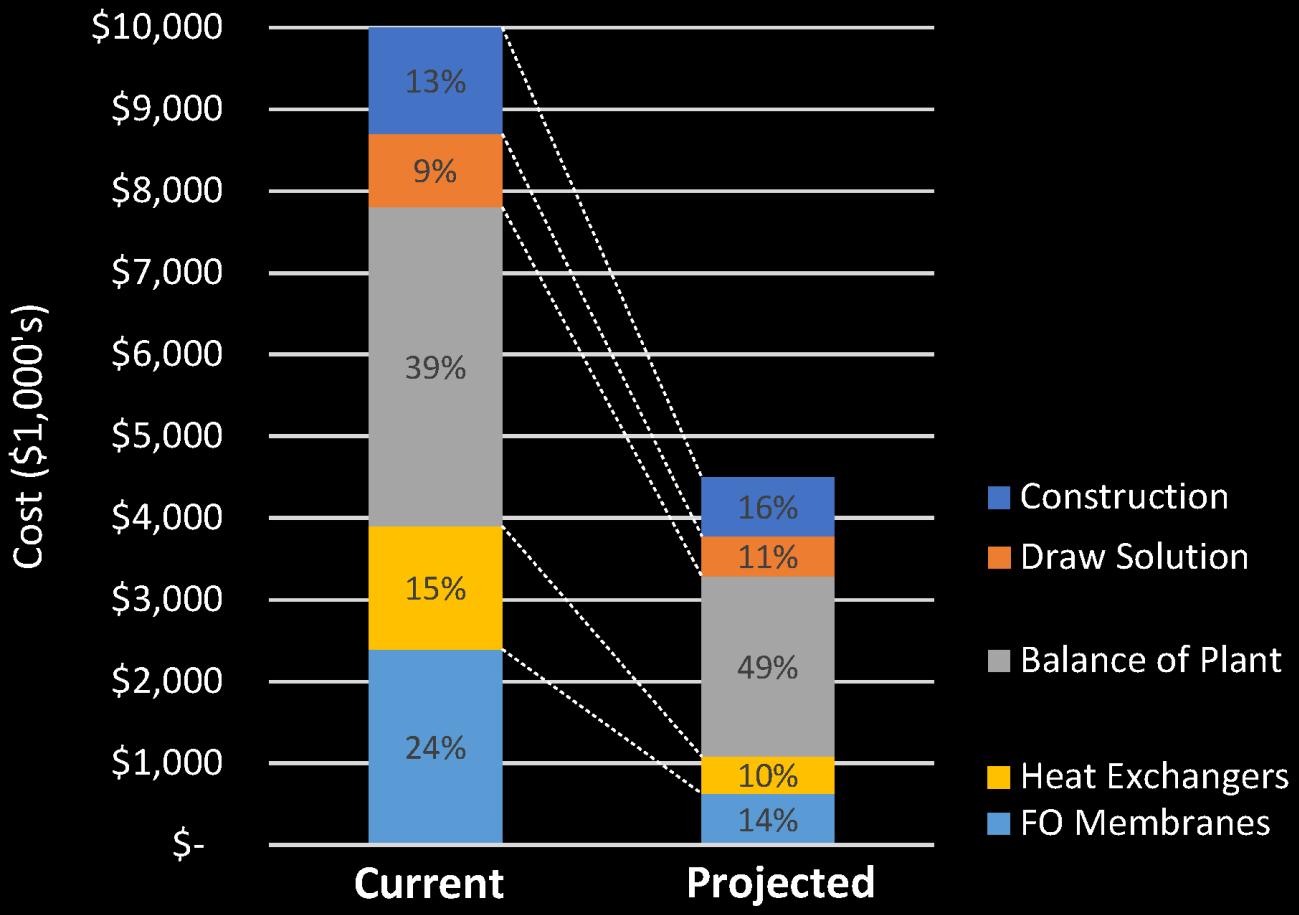
Coalescer and loop pump

500m3/day (2*40ft shipping container)
3D CAD skid design (excluding pre-treat)



Capital intensive elements are FO membranes and heat recovery heat exchangers. Standard plate and frame heat exchangers shown to scale.

CAPEX Reductions to Meet LCOW Target



- Cost of energy – Targets of 1kWh$_e$ and 30kWh$_t$ have been demonstrated at smaller scale and will improve with scale-up.
- Capital Cost – Target of reducing FO membrane and heat exchanger relative cost from 39% to 24%.
- Remaining Balance of Plant costs and construction costs are amenable to market based price reductions as they are mature (low tech) components.

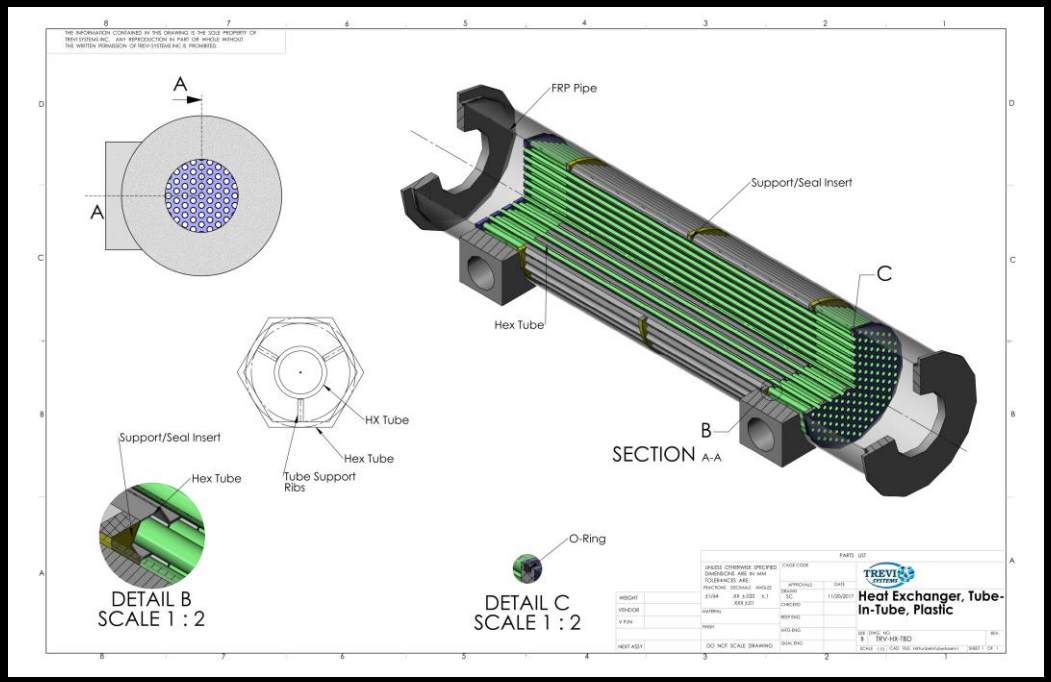
Risk: Membrane Cost Reduction

- Two factors driving the cost of FO membranes are (1) Hollow fiber membrane element manufacturing costs and (2) pressure vessel costs.
    - There is no intrinsic reason that an FO membrane element should be more expensive than an RO element. Higher costs today are due to development costs still being amortized.
    - To drive costs down, a competitive landscape with several manufacturers is required.
- Trevi is in negotiation with three suppliers of Hollow fiber elements, two in Japan and one in the USA, that have committed to producing the membranes. Trevi has entered a JDA with one supplier to accelerate the production. All three have given commitments that they can supply volume in the timeframe desired.
- As a back-up, if these three vendors do not meet the timeframes needed, Trevi is currently spinning its own membrane.

Plastic (pipe) housing prototype 4” element with traditional high pressure FRP 8” behind. Cost reduction of the pressure vessel follows the same path as existing UF membrane housings.

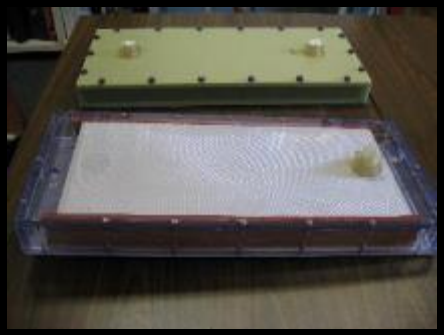
Trevi FO hollow fibers being evaluated for flux and rejection. Trevi is currently spinning one 4” element per day, ramping to one 8” by September. 60-80 elements needed for 500m3/day system.

Risk: Plastic Heat Exchanger Fabrication



3D CAD of proposed tube-in-tube design

- The unique phase change characteristics of its draw solution require a non-traditional heat exchanger design.
- This requires a tube-in-tube design, similar in performance to a plate and frame but optimized for the phase change induced viscosity changes, and is also different from a tube-in-shell, due to the tight pinch required (<2^{o}C).
- We have prototyped the design and proven the concept at small scale.
- We believe the risk is low in scaling up the design as the structure is self supporting.



Trevi's Plastic Plate and Frame heat exchangers

- We can revert to the more traditional stainless- steel plate and frame design if the tube-in-tube does not perform well.
- Performance is similar but costs are higher.

Trevi developed Spiral Wound plastic HX

Summary of Outcomes

- On-sun demonstration system at scale
- Hardware Innovations
  - Low pressure-drop polymeric heat exchangers
  - Commercially produced FO filters at viable cost-point
  - NF membranes capable of operating at higher temperatures
- System Optimization
- Advance technology from TRL 4 to 7

Questions and Answers

Hawaii First Water