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Produced/Brackish Water Treatment and Brine Valorization via Advanced Membrane Processes

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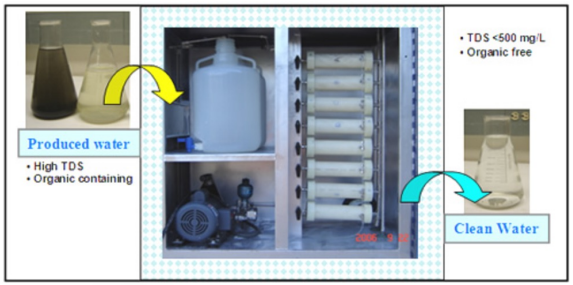
PRRC
a division of New Mexico Tech

Produced Water Treatment at PRRC/NMT

(1998 - current)



1998 — 2009 — 2013 — 2016 — 2018 — 2021 — 2023

Objective: to develop novel, portable, and scalable robust hollow fiber membrane-based separation processes that convert brackish water and produced water into a sustainable water resource.

Hollow fiber membranes

Water Treatment

- Ultrafiltration
- Microfiltration
- Membrane adsorption
- **Hybrid processes**

Desalination/ Brine Valorization

- Nanofiltration
- Reverse/Forward osmosis
- **Membrane distillation**
- **Hybrid processes**

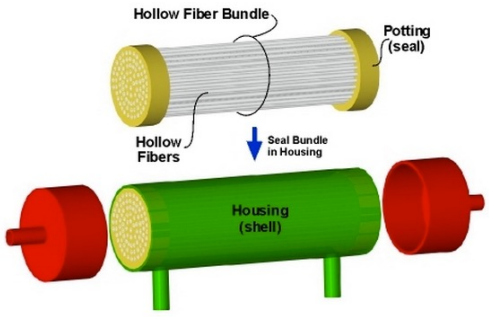
Compared to flat sheet membrane:

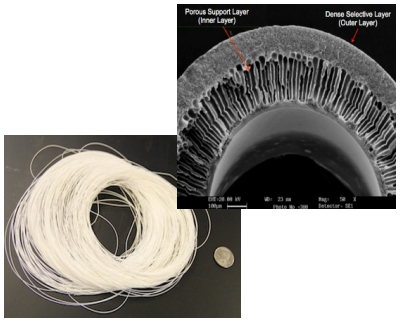
✓**higher productivity per unit volume** (high packing density and large surface area)

- For a 0.04 m^3 membrane device:
- HF membrane: 575 m^2 (90 mm in diameter);
- Spiral wound fiat-sheet membrane: 30 m^2;
- Tubular configuration: 5 m^2.

✓**self-supporting**

✓**small footprint, easy to scalable**

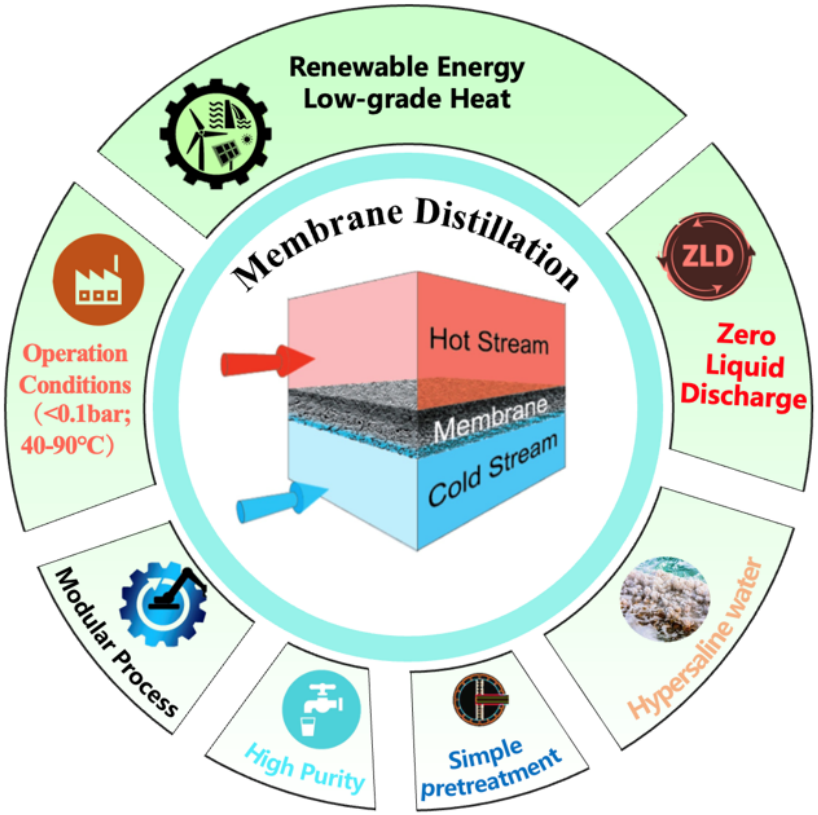




Hollow fiber membrane module*

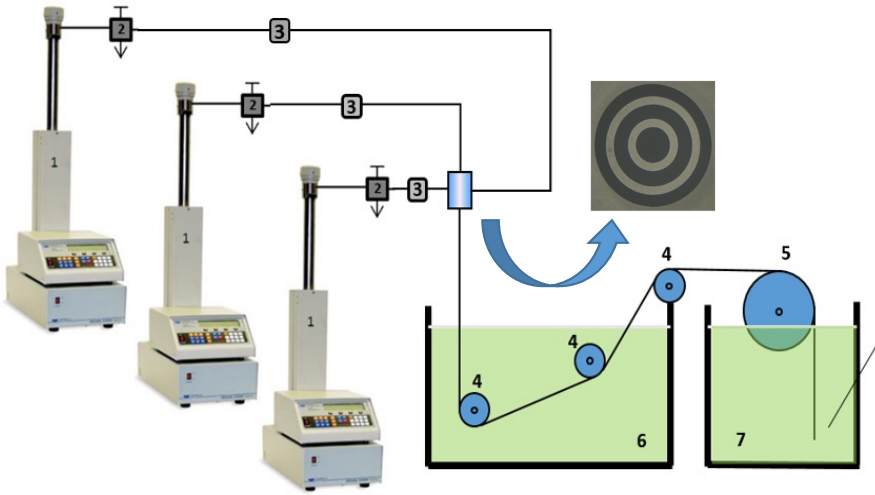
* https://www.permselect.com/membranes

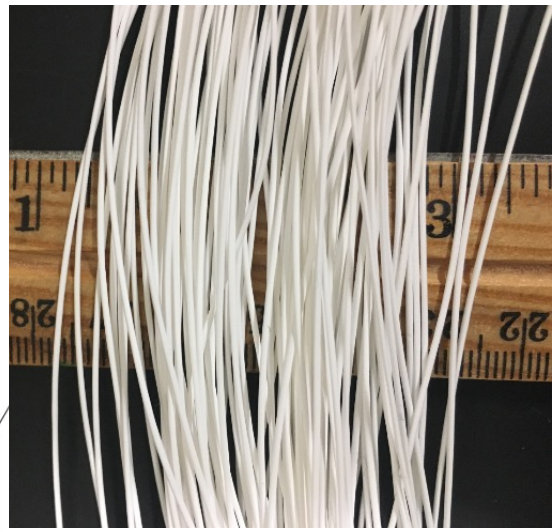
Direct Contact Membrane Distillation (DCMD)



- Very few full-scale MD tests have been reported in the world.
- Main challenges: (1) lack of commercially available membranes for particular use in DCMD; (2) energy consumption.

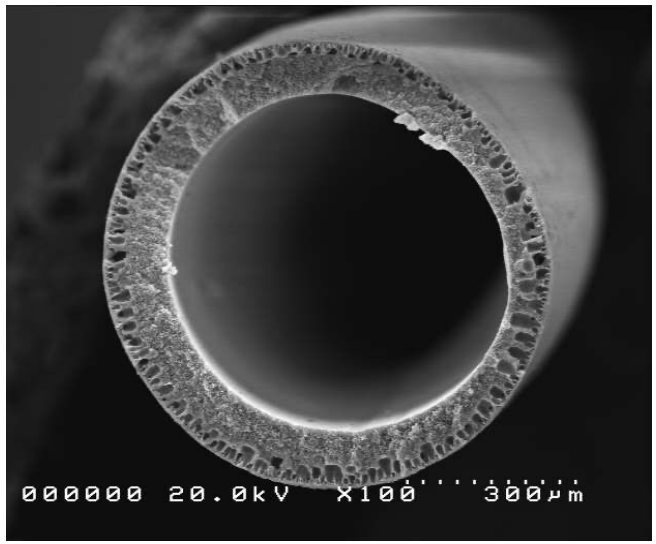
Hollow fiber membranes

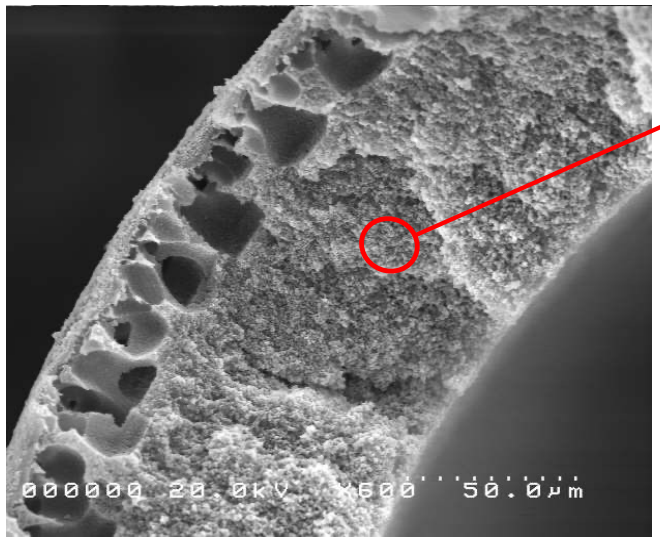


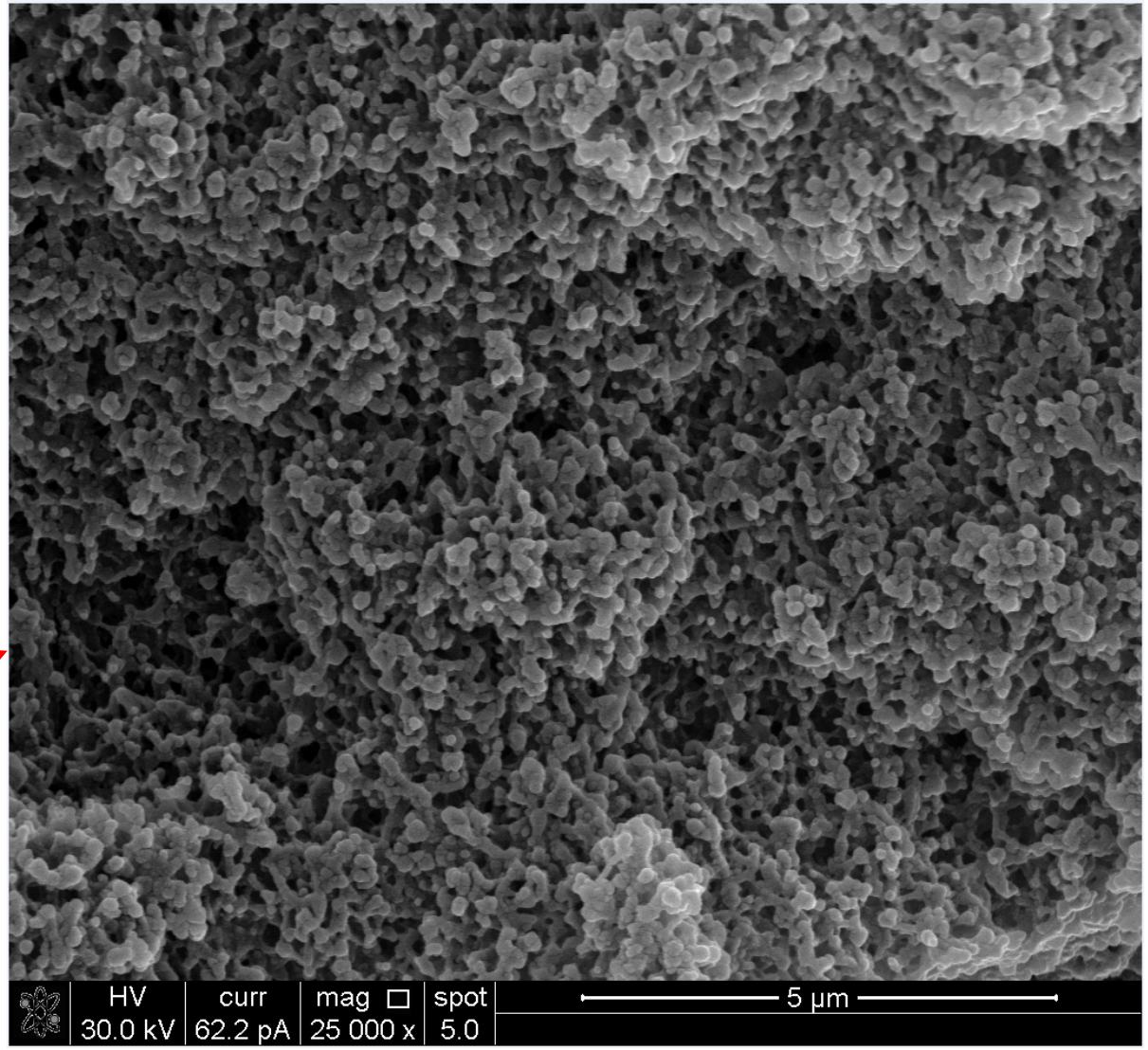


Properties of the fabricated Janus hollow fiber membrane.

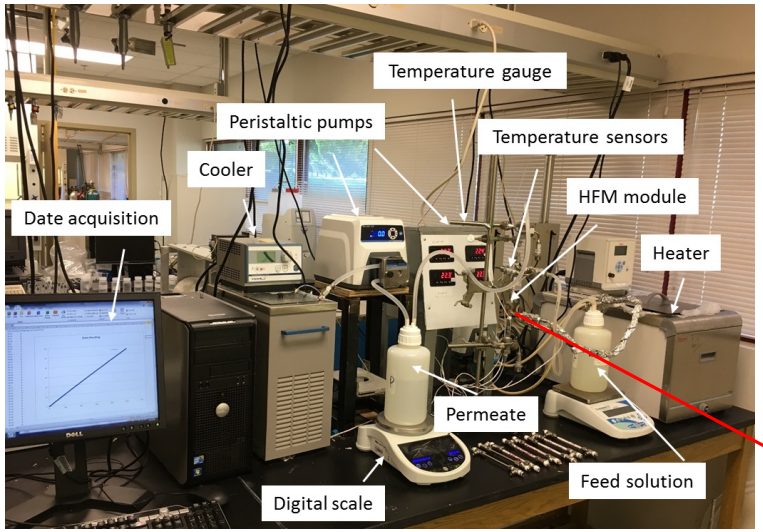
OD/ID/WT (μm)	Bulk Porosity (ε, %)	Effective surface porosity (ε_e, m^{-1})	Mean pore size (d_a, μm)	Bubble point pore size (d_m, μm)	LEP (bar)
1088/767/135	80.6±0.4	6471.3	0.27	0.40	1.95


000000 20.0kV X100 300µm

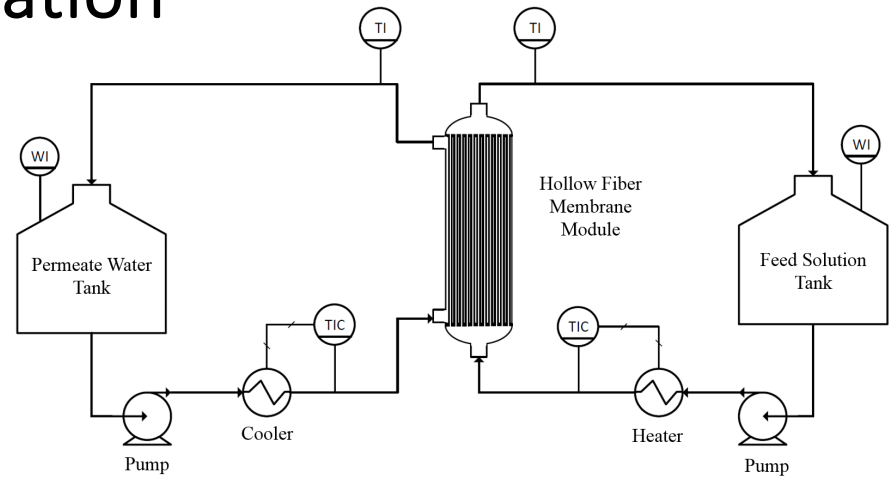

000000 20.0kV X500 50.0µm


HV
30.0 kV
curr
62.2 pA
mag
25 000 x
spot
5.0
5 µm

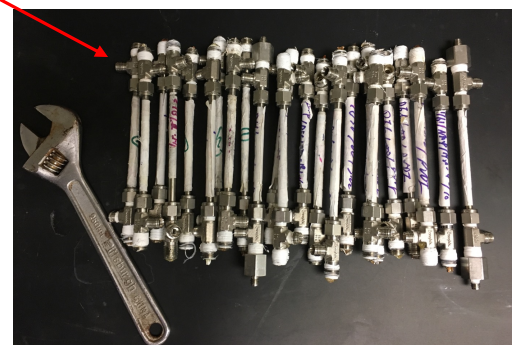
DCMD Process for PW Desalination



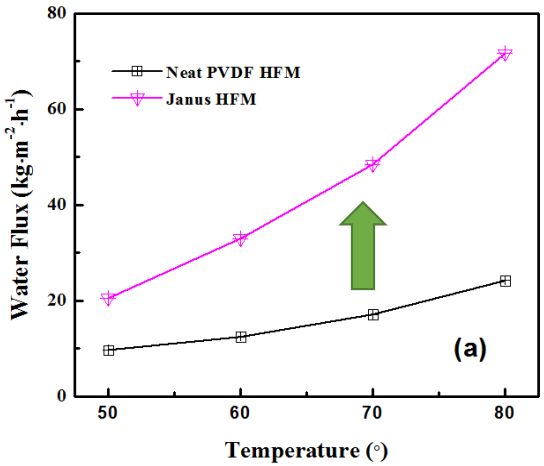
Apparatus of hollow fiber membrane-based DCMD process for high-salinity brines desalination.

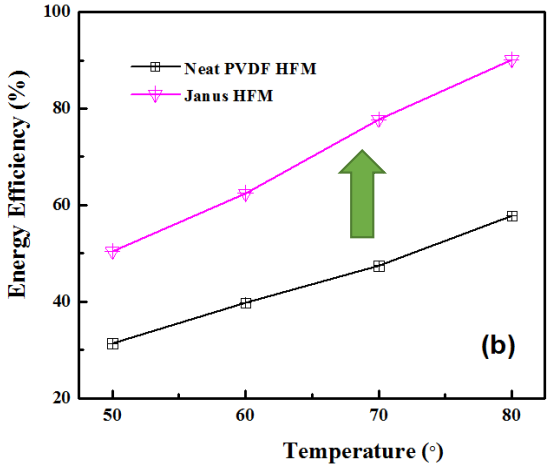


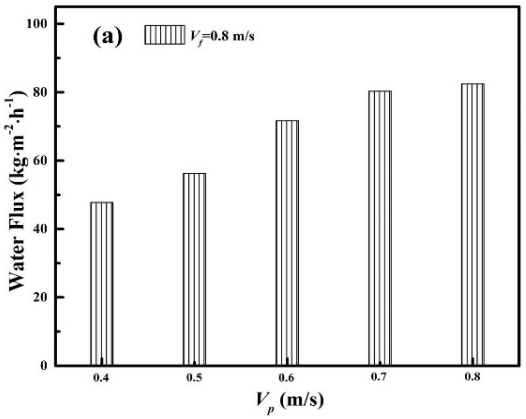
Membrane modules assembled for the DCMD experiments.

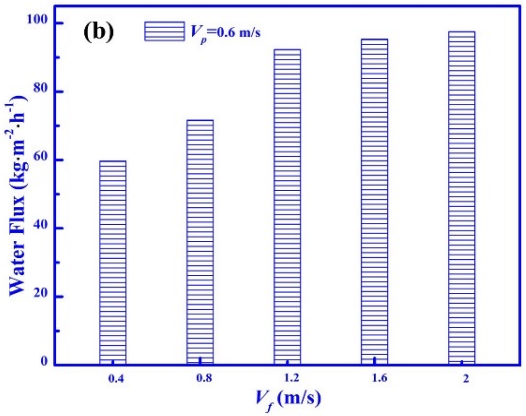


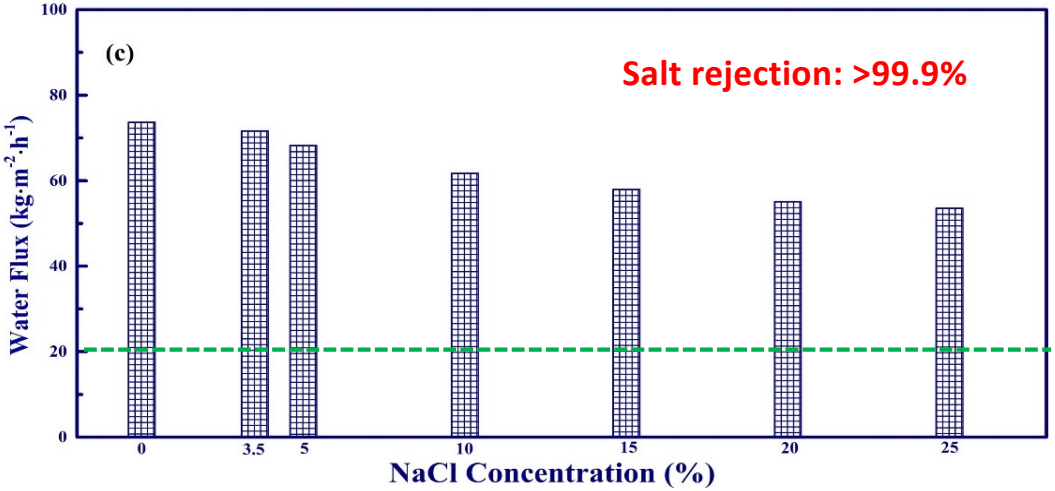
Desalination Performance Evaluation



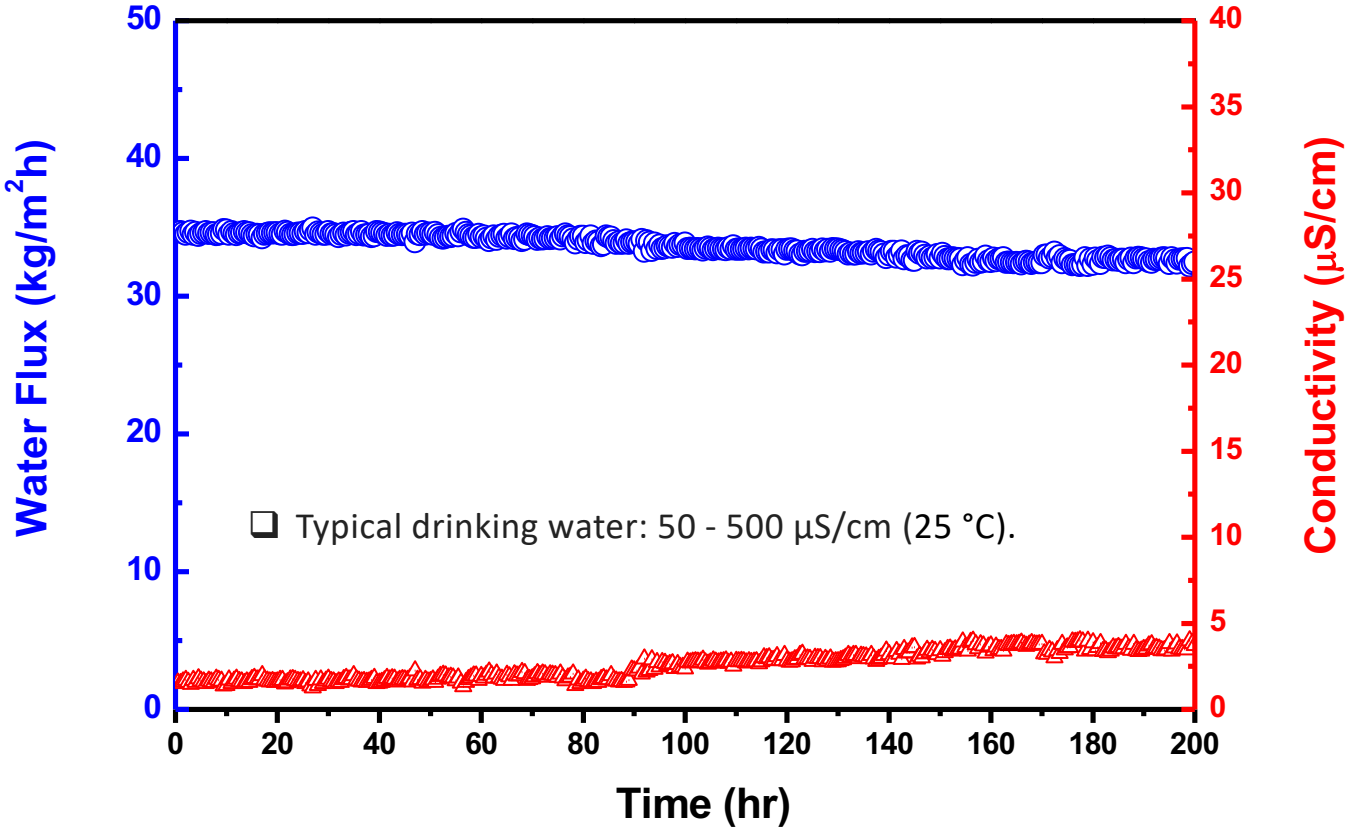








Long-term desalination performance evaluation

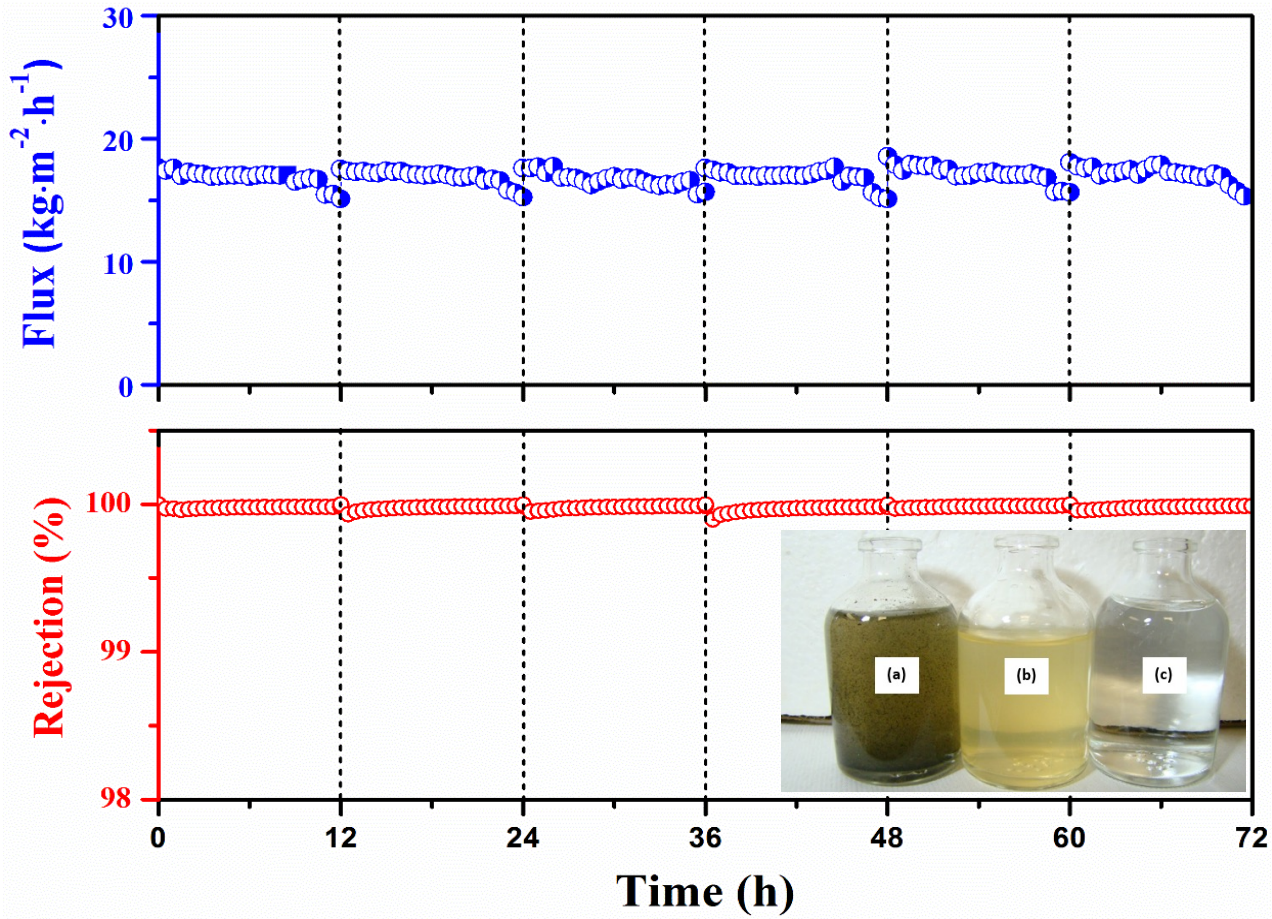


SW: TDS=35,000 mg/L

- **Operating conditions:**

  T-feed: 60°C;
  T-permeate: 20°C;
  ν-feed: 0.8 m/s
  ν -permeate: 0.6 m/s

- No significant scaling and wetting during a continuous 200 hours of DCMD operation.



PW: TDS=155,000 mg/L
NPOC=57.6 mg/L

- **Operating conditions:**

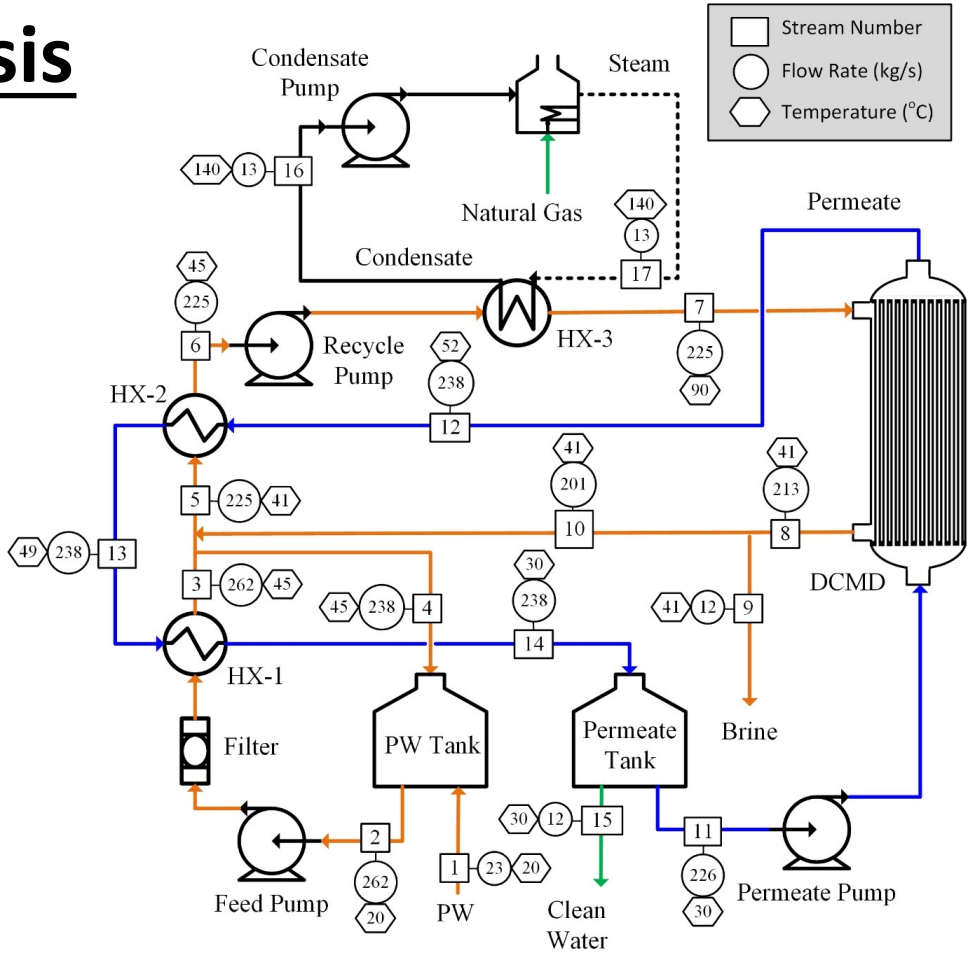
  T-Feed: 60°C;
  T-Permeate: 20°C;
  v-feed: 0.4 m/s
  v -permeate: 0.4 m/s

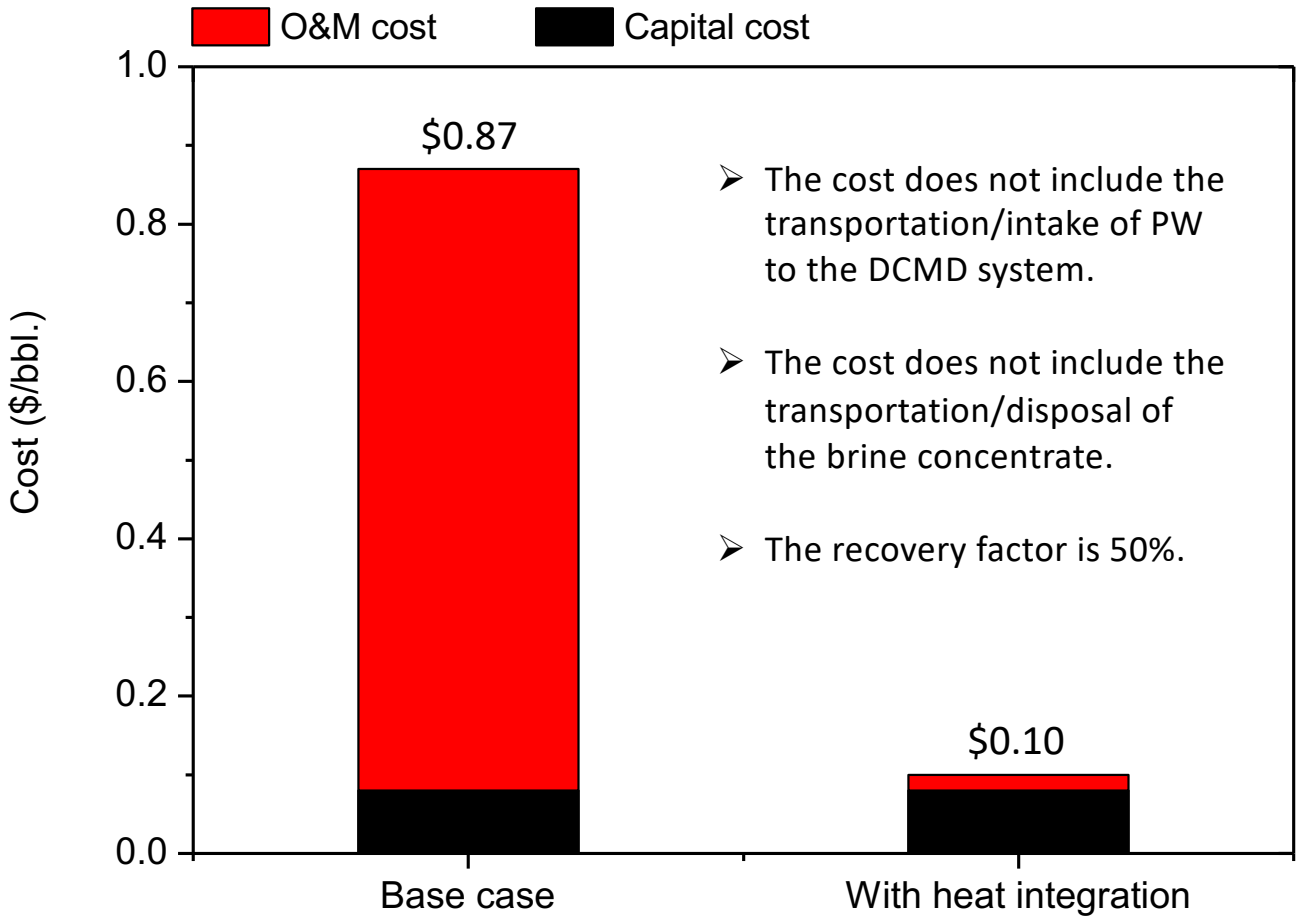
- Due to the complicate composition of PW, membrane regeneration was preformed for 30 mins every 12 hours.
- No membrane wetting, the salt rejection remains higher than 99.99%.
- Water samples: (a) actual oilfield produced water; (b) pre-treated with a 50 µm filter; (c) product water.

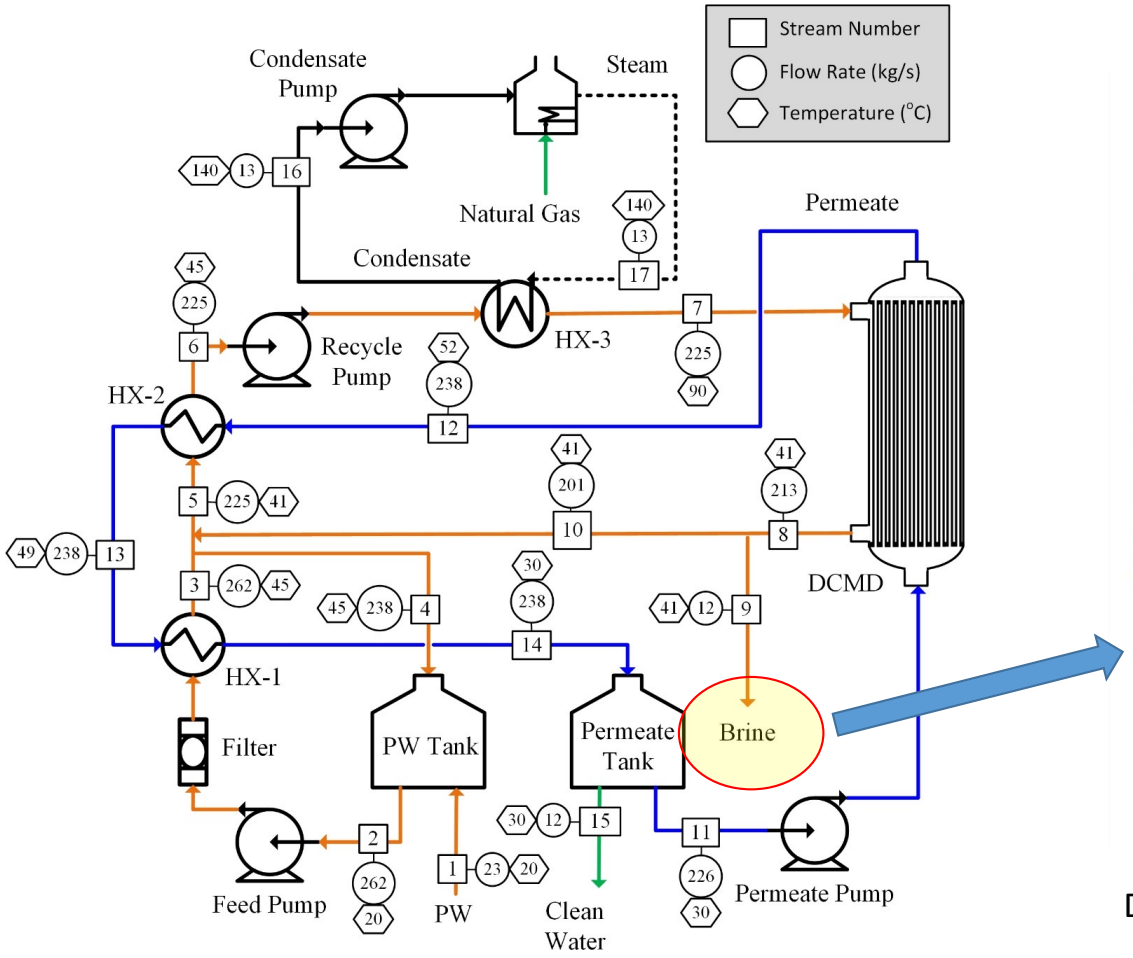
Tech-economic analysis

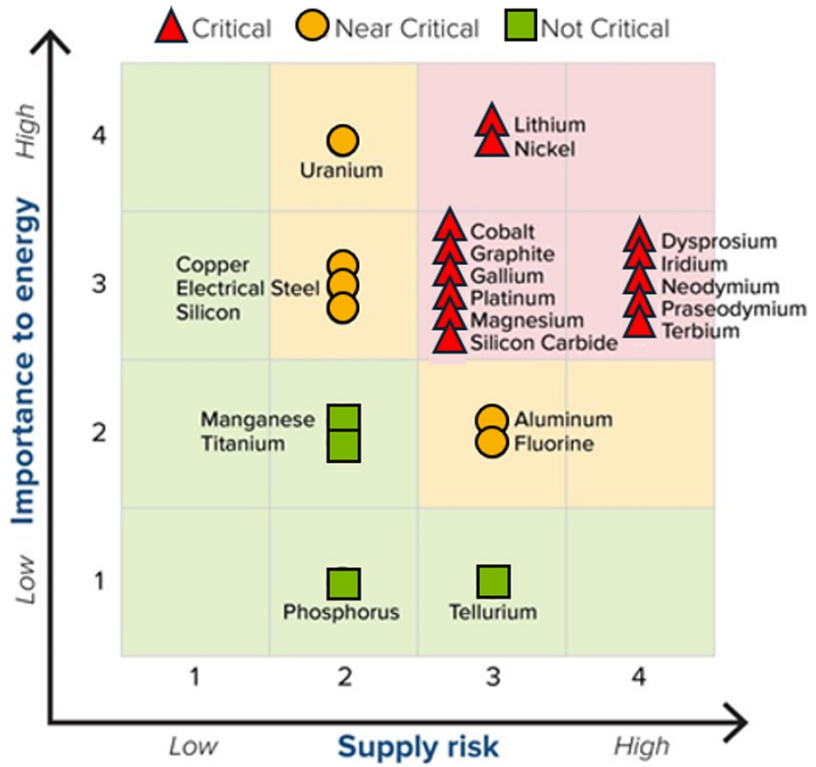
- Assumptions:

- ✓ Plant capacity: 500,000 GPD;
- ✓ Plant lifetime: 30 Years;
- ✓ Plant availability: 90%; **100,000 mg/L**
- ✓ PW - initial TDS:;
- ✓ PW – concentrated brine: **200,000 mg/L**;
- ✓ PW - recovered: **<500 ppm**;
- ✓ Water recovery: **50%**;
- ✓ Membrane cost: $20/m^2;
- ✓ Membrane replacement: 20%/year;
- ✓ Pretreatment: $80/m^3/day;
- ✓ Electricity cost: $0.069/kwh;
- ✓ Steam price: $0.008/kg




O&M cost
Capital cost
Cost ($/bbl.)
1.0
0.8
0.6
0.4
0.2
0.0
$0.87
$0.10
Base case
With heat integration
The cost does not include the transportation/intake of PW to the DCMD system.
The cost does not include the transportation/disposal of the brine concentrate.
The recovery factor is 50%.

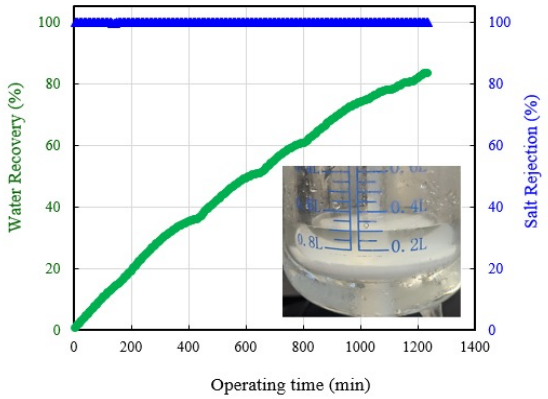


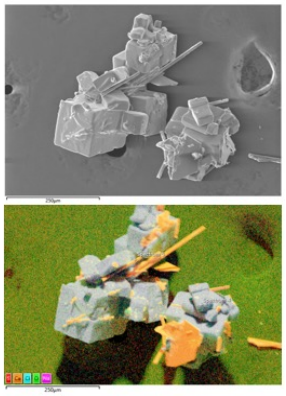


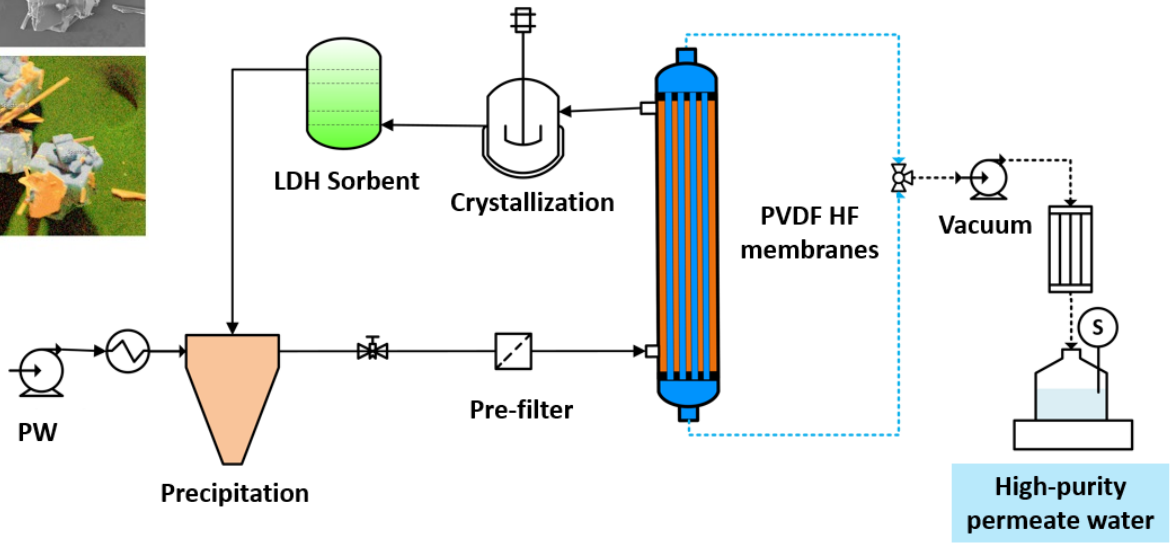
DOE list of the most important critical materials with respect to energy and supply chain risk.

Simultaneous clean water and high-purity lithium recovery

(Funded by the **Bureau of Reclamation** and **Department of Energy**)







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NM STATE UNIVERSITY

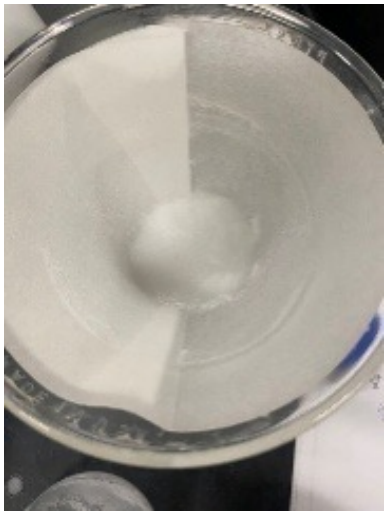
Sandia National Laboratories

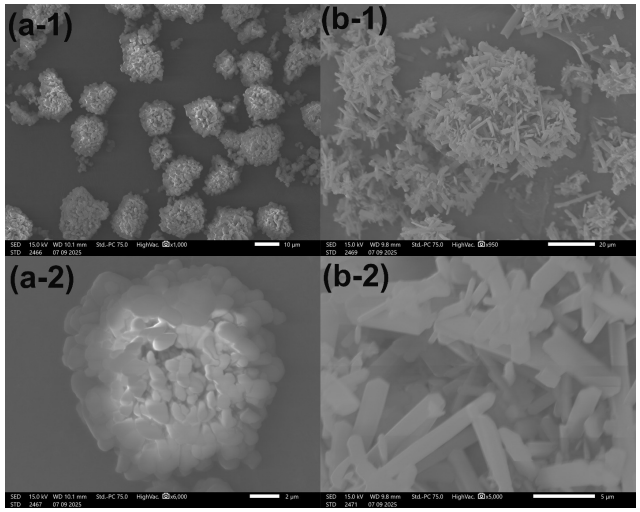
Los Alamos NATIONAL LABORATORY

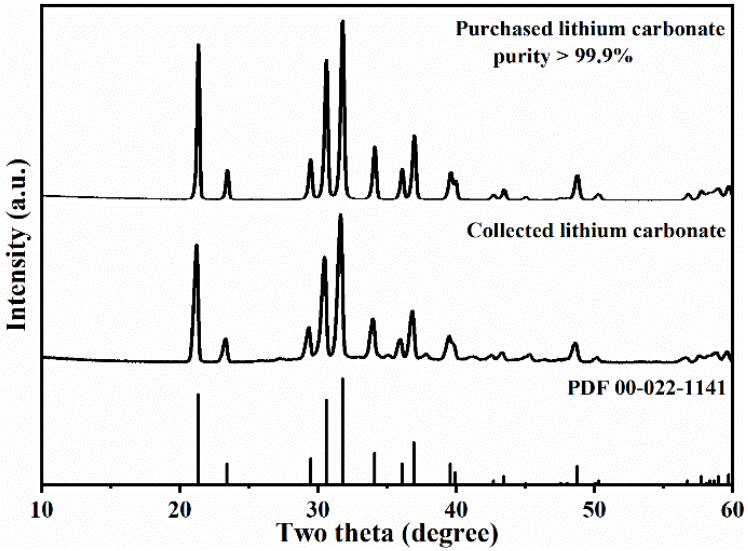
UNIVERSITY OF WYOMING

Simultaneous clean water and high-purity lithium recovery

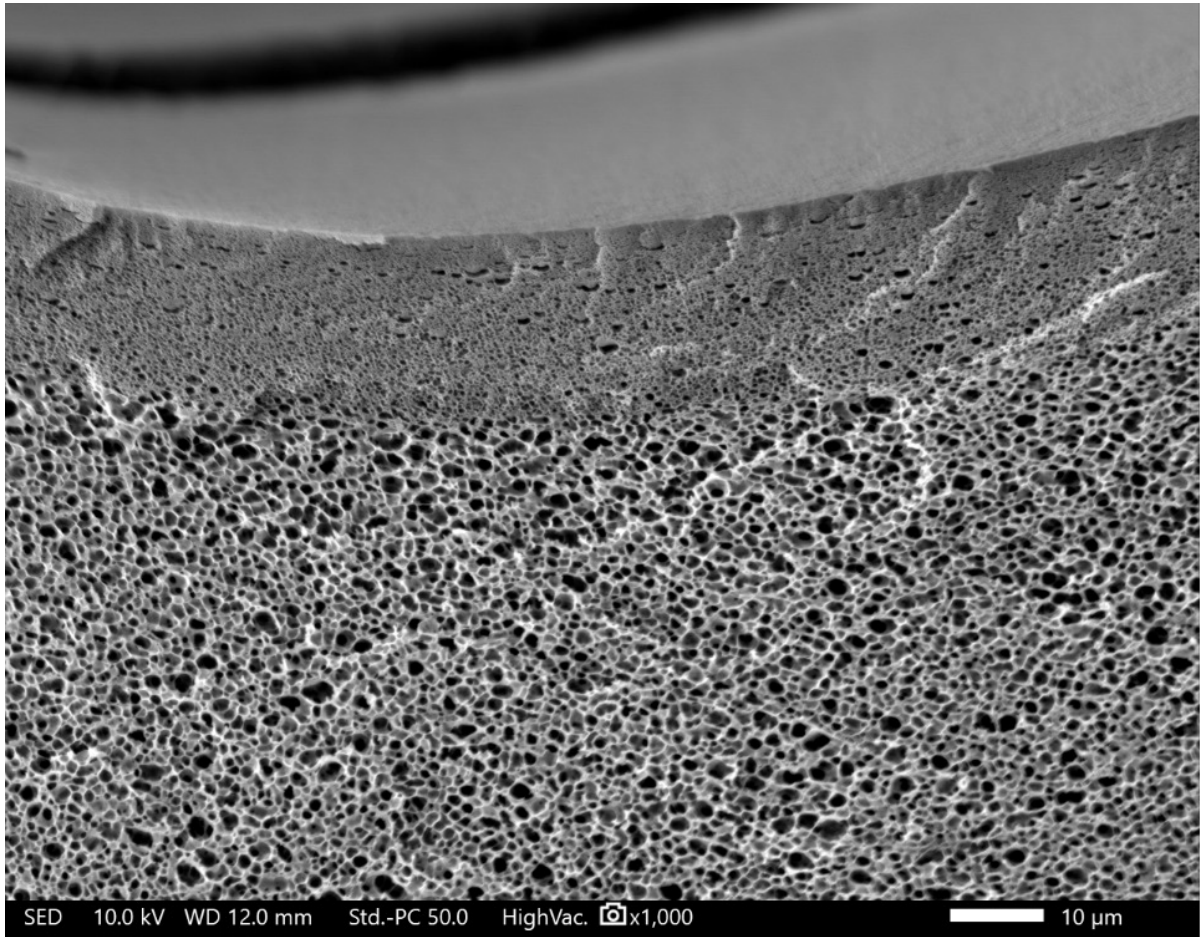
Lithium is recovered as >99.9% Li_2CO_3.

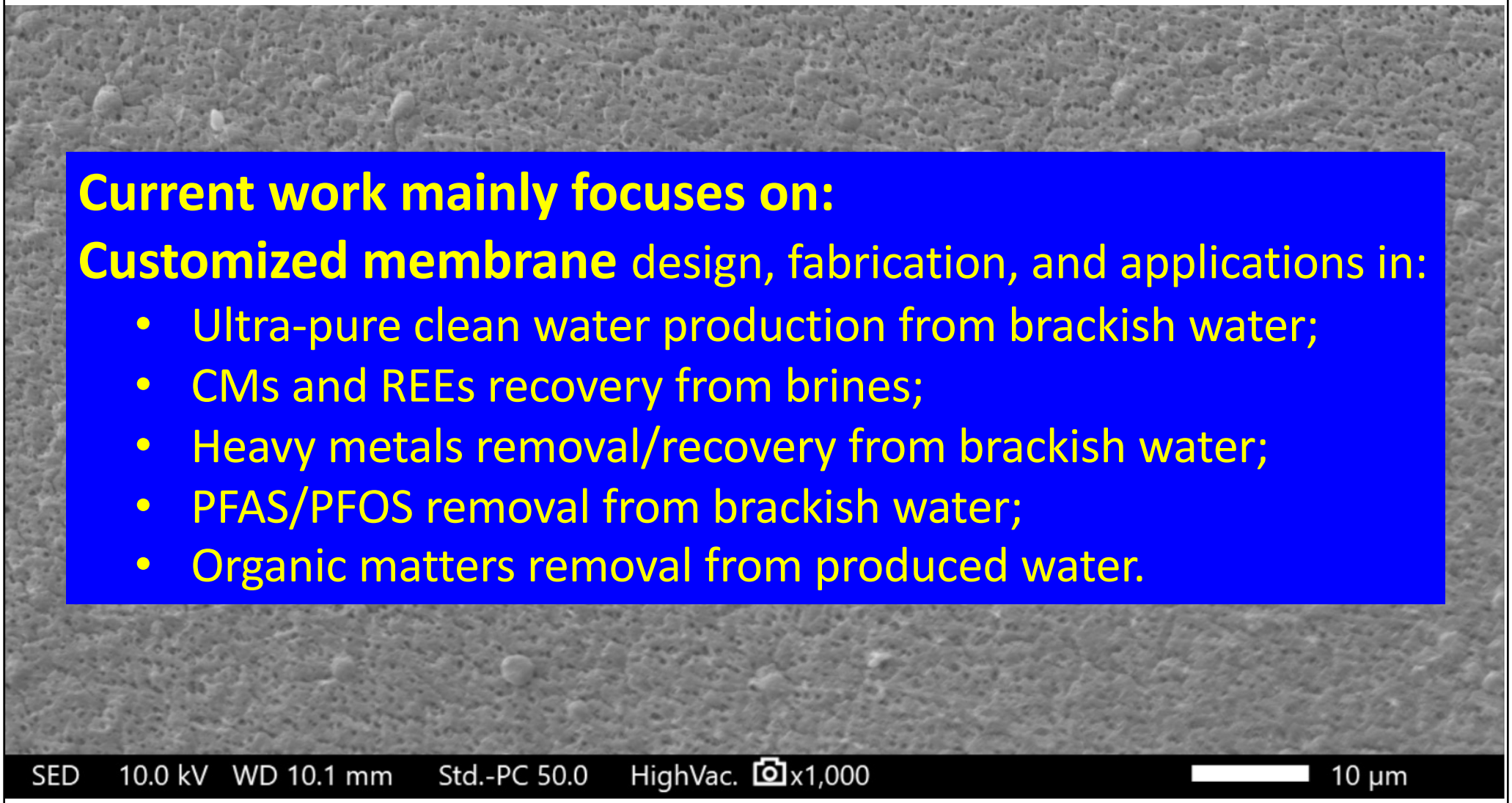






More Future Work…




Current work mainly focuses on:
Customized membrane design, fabrication, and applications in:
• Ultra-pure clean water production from brackish water;
• CMs and REEs recovery from brines;
• Heavy metals removal/recovery from brackish water;
• PFAS/PFOS removal from brackish water;
• Organic matters removal from produced water.
SED 10.0 kV WD 10.1 mm Std.-PC 50.0 HighVac. x1,000 10 µm

Acknowledgement

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U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

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