Evaporative Processes in WaterTAP

Elmira Shamlou[a,b], Carson Tucker[c]

[a]National Energy Technology Laboratory (NETL), [b]NETL Support Contractor, [c]Department of Mechanical Engineering, Stanford University

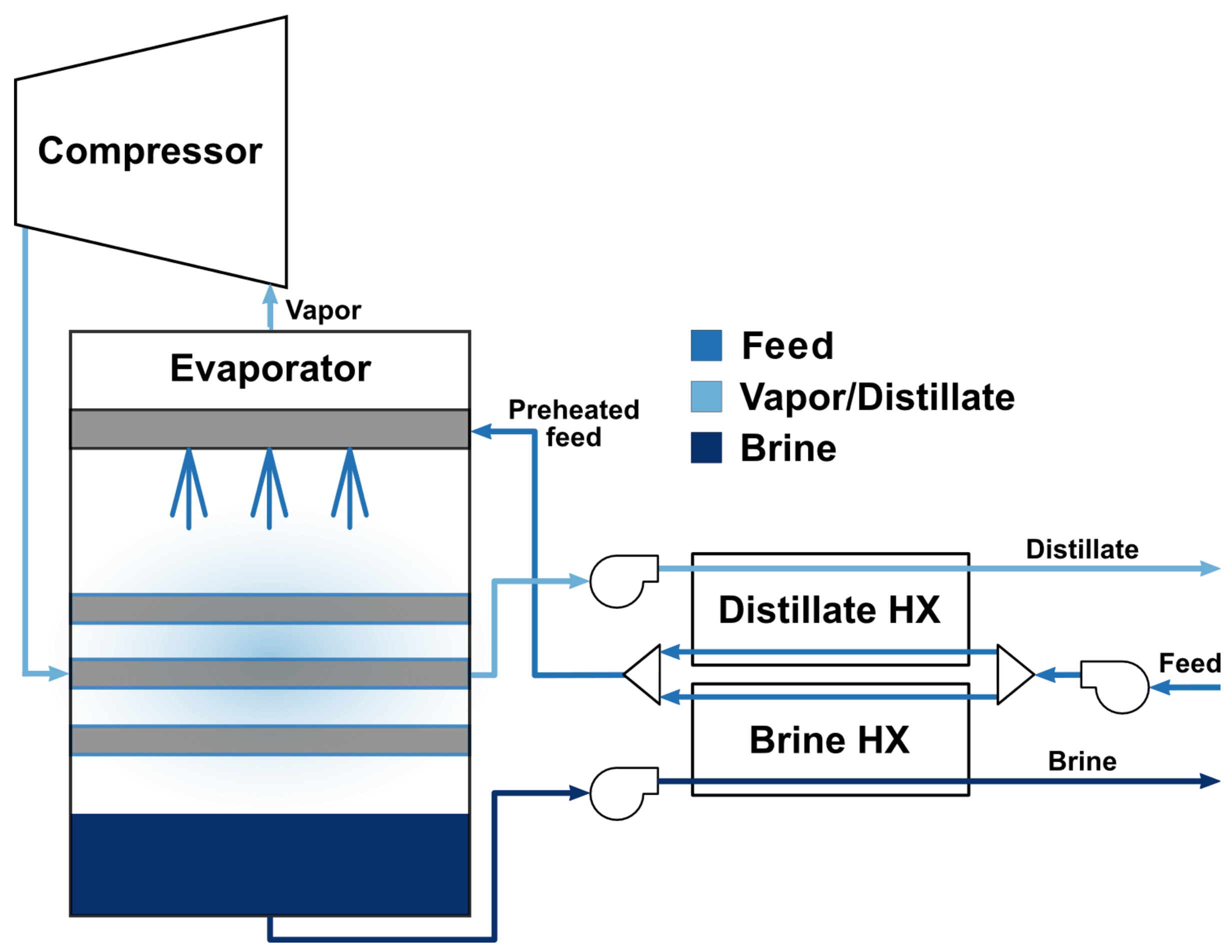
Mechanical Vapor Compression

Motivation: mechanical vapor compression (MVC) is an efficient and electrified thermal desalination process that can achieve high water recoveries

Unit models: preheater heat exchangers, evaporator, compressor, and condenser

Key properties: vapor depression/boiling point elevation in evaporator, vapor properties for the compressor and condenser

Additional configurations: multi-stage, brine recirculation



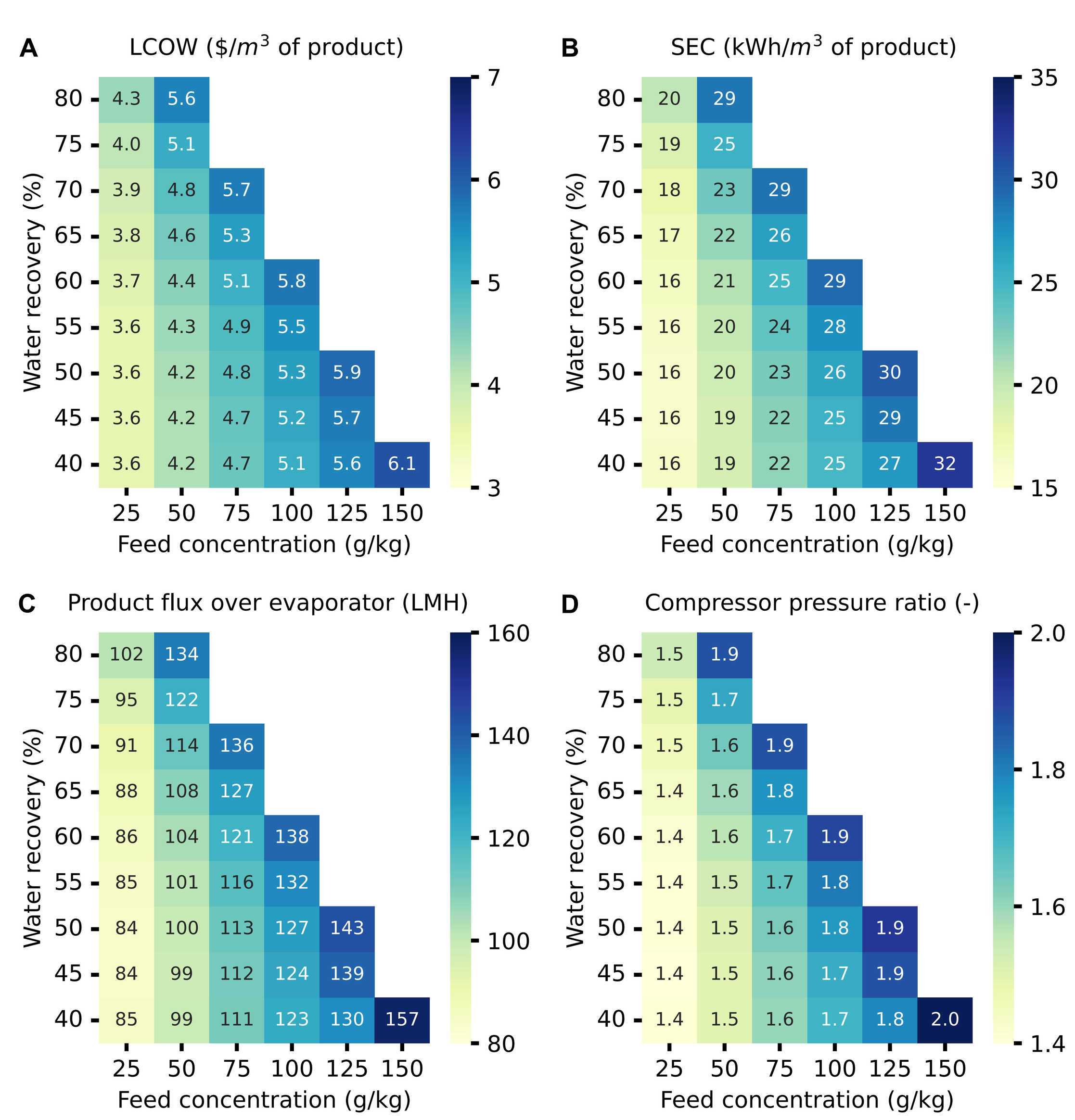
Cost-optimization of MVC treating seawater

Costing: evaporator material factor is a linear function of the brine salinity to reflect increased cost of corrosion and scaling resistant materials

Input parameters: evaporator and preheater overall heat transfer coefficients, compressor and pump efficiencies, maximum evaporator temperature (75°C shown)

Decision variables: preheater areas, evaporator area, evaporator temperature and pressure, compressor pressure ratio

Results: LCOW, SEC, product flux per evaporator area, and pressure ratio



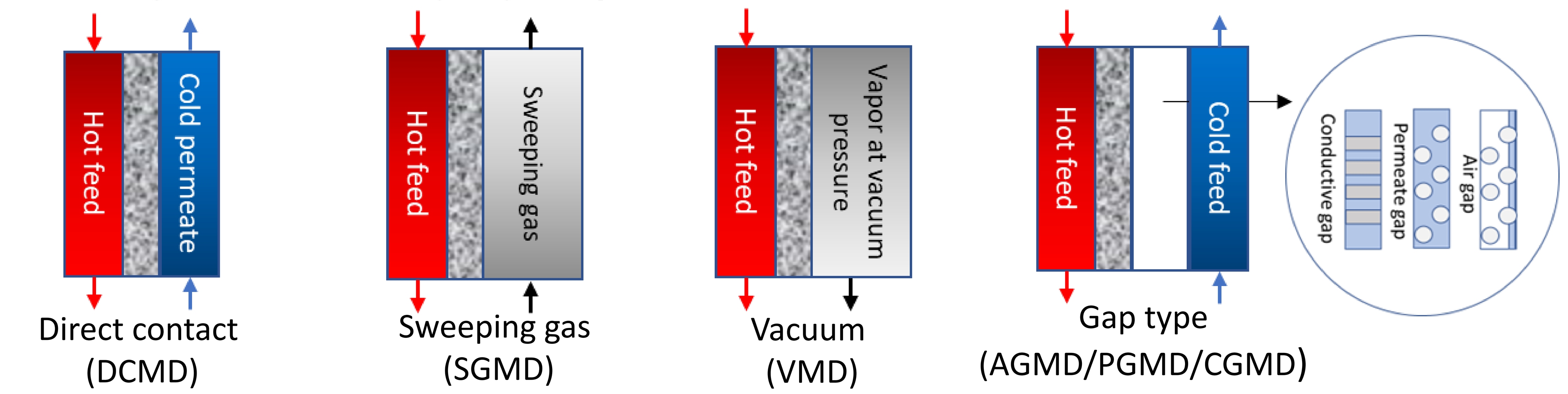
Contact: Elmira Shamlou, elmira.shamlou@netl.doe.gov

Acknowledgment: This material is based upon work supported by the National Alliance for Water Innovation (NAWI), funded by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), Industrial Efficiency & Decarbonization Office, under Funding Opportunity Announcement Number DE-FOA-0001905.

Membrane Distillation

Process overview: Membrane Distillation (MD) leverages the temperature gradient-induced vapor pressure differential across a hydrophobic membrane.

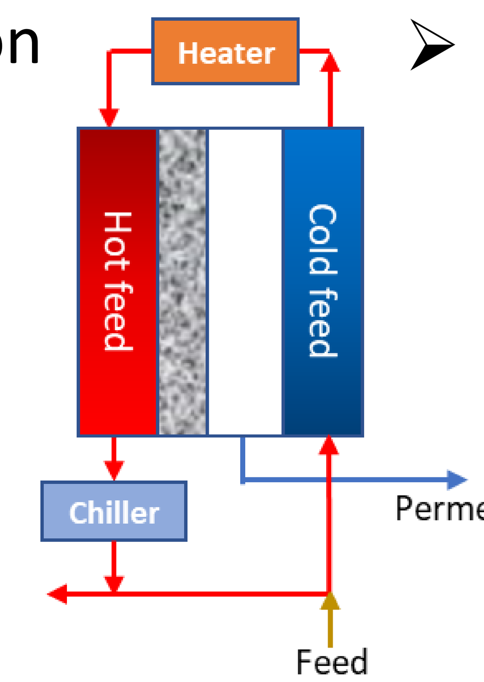
MD configurations vary by vapor collection and condensation method:



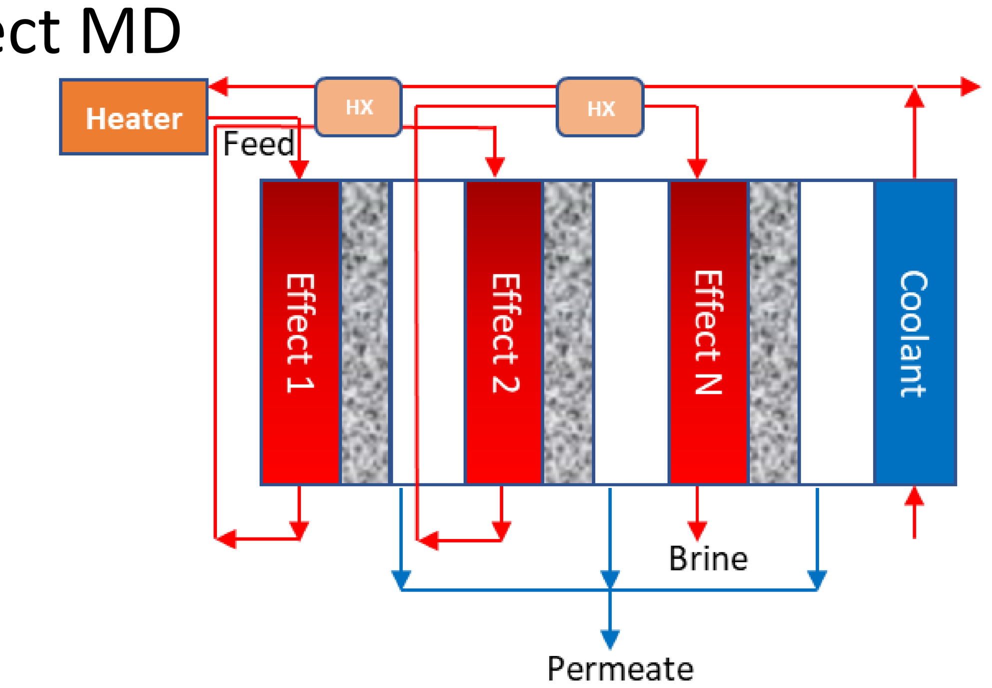
Membrane Distillation Operation Modes

Single pass recovery in MD is typically low. Methods to enhance Recovery:

- Brine recirculation



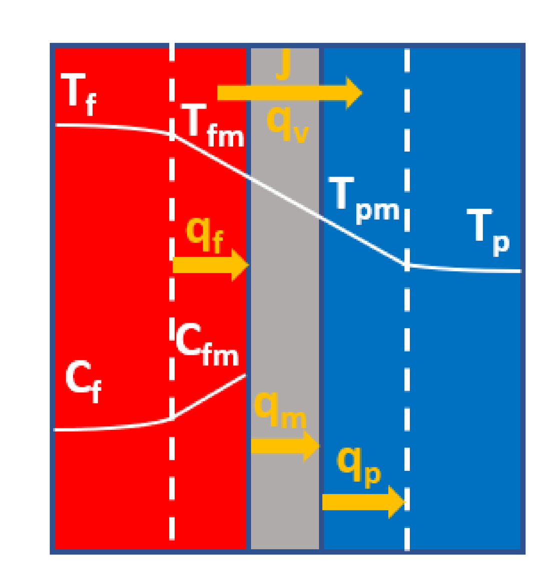
- Multi-effect MD



*The single-pass DCMD model is currently available in WaterTAP, with other configurations and operation modes still in development.

Membrane Distillation Modeling Approach

- 0-D: Module behavior via inlet-outlet properties
- 1-D: Finite difference discretization-lengthwise
- Boundary layer modeling:
  - Concentration and temperature polarization
- Core mass/energy balance equations:
  - Vapor flux $J = B(P_f - P_p)$ and $q_v = h_{fg}J$
  - Conductive heat $q_m = \frac{k}{\delta}(T_{fm} - T_{pm})$
  - Convective heat $q_f = h_f(T_f - T_{fm})$ and $q_p = h_p(T_{pm} - T_p)$



NATIONAL ENERGY TECHNOLOGY LABORATORY | BERKELEY LAB | OAK RIDGE National Laboratory | NREL NATIONAL RENEWABLE ENERGY LABORATORY | West Virginia University | Stanford | NAWI | U.S. DEPARTMENT OF ENERGY