



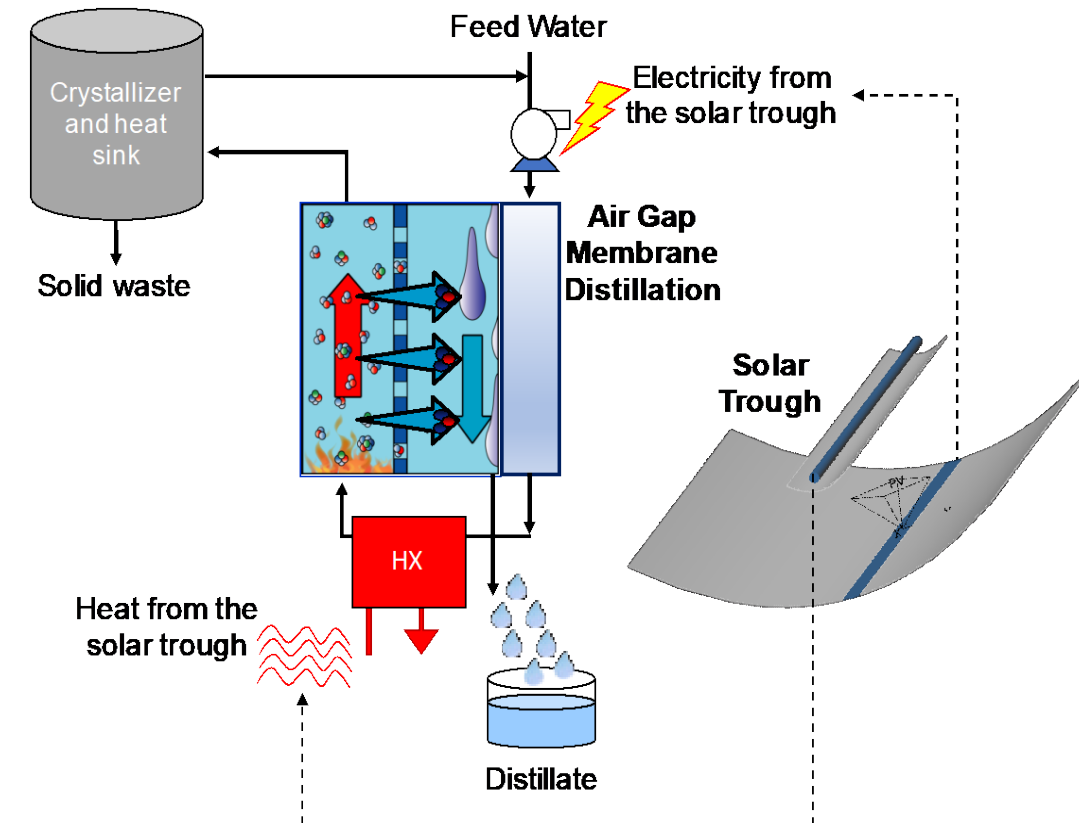
- Assistant Professor
- Education: PhD and MS, Colorado School of Mines
- Research areas: Novel engineered systems for resource recovery and reclamation of concentrate streams, environmental life-cycle assessment and techno-economic assessment, decision support tools



- Bridging ***energy and water*** research with a hybrid optical technology for inland concentrate management
- Addressing inland ***concentrate management*** for ***water reuse*** with a ***near zero-liquid discharge*** membrane-based system



- Hybrid membrane distillation crystallization (MDC) - hybrid solar heat/PV collector system
- Self-sustained, zero-liquid discharge (ZLD) technology for inland and off-grid applications



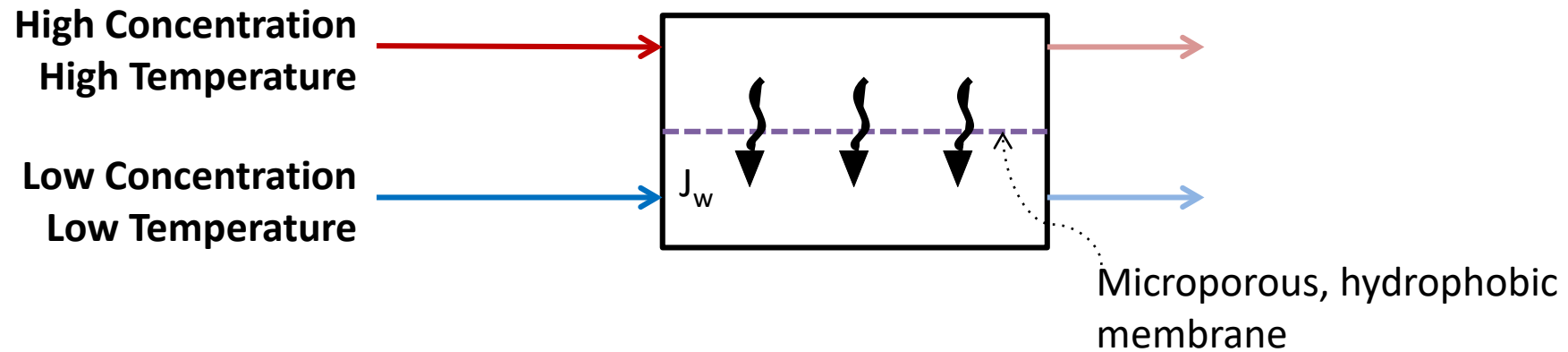
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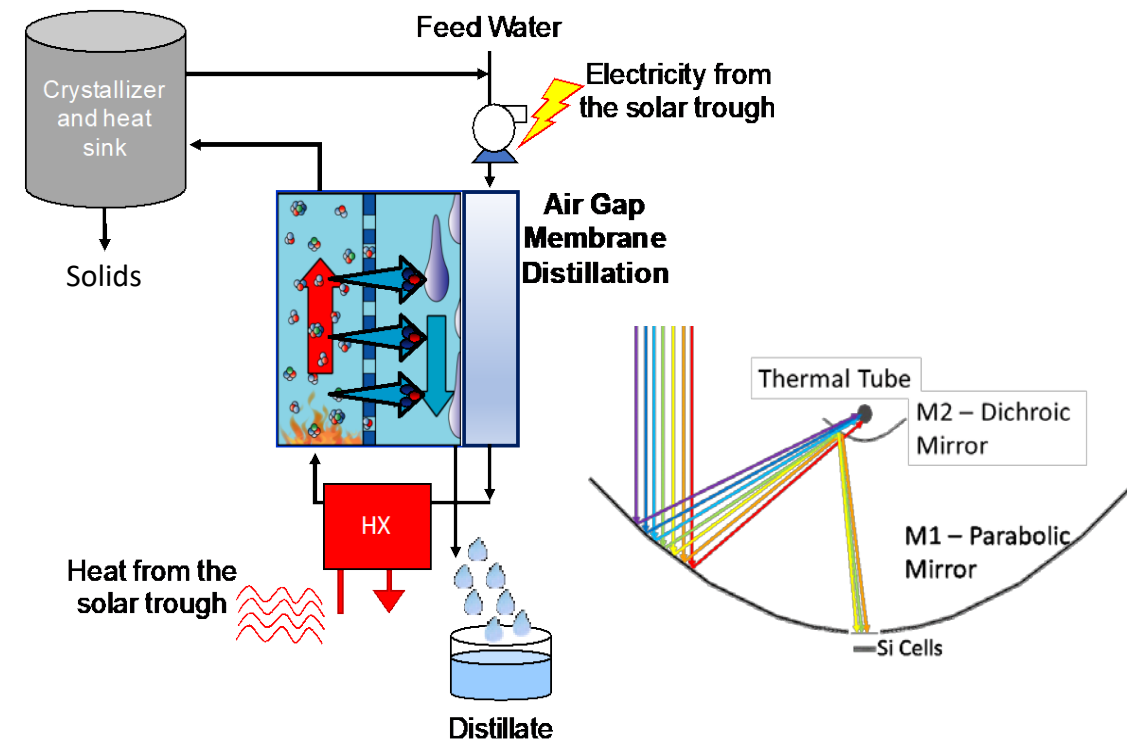
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$$\text{Water Flux } (J_w) = A_w(\Delta P_v^*) \text{ (simplistic!)}$$

Can utilize renewable energy and low-grade heat to simultaneously separate and concentrate mixed streams

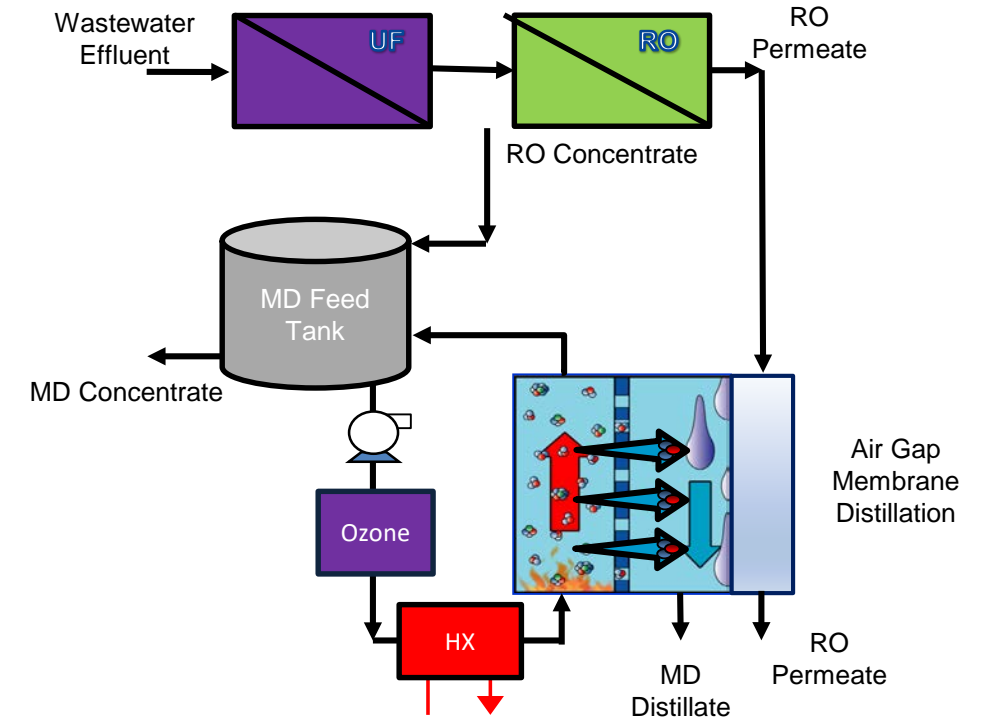
- MD recovers high-quality distillate water and concentrates the brine to supersaturation
- Crystallizer unit precipitates crystalline solids, recovering possible valuable minerals and achieving near ZLD, and mitigating membrane scaling
- Novel flexible dichroic mirror technology tunes the heat-to-electricity ratio for geographic and seasonal variations to achieve the greatest overall desalination efficiency in high-salinity off-grid applications where ZLD is critical



- 1) Show that coupled MD with crystallizer unit can **mitigate membrane scaling and fouling** and recover valuable mineral by-products
- 2) Integrate MDC with hybrid CSP-PV to **improve energy efficiency** in desalination
- 3) Demonstrate hybrid CSP/PV platform developed for FOCUS can be adapted to **solar desalination**
- 4) Experimental and modeling optimization of system-level performance by **maximizing solar energy resource utilization and water recovery** for the hybrid CSP/PV-ZLD system
- 5) Demonstrate a **cost-effective solution for concentrate management for inland desalination**

Location, Latitude	Average daily DNI, KWh/m ² /day	Estimated LCOH as preselection guideline – best case scenario
Tucson, N 32.2 deg.	7.4	\$0.017/kWh(th)
Albuquerque, N 35.11 deg.	6.8	\$0.019/kWh(th)
Los Angeles, N 34.05 deg.	5.0	\$0.025/kWh(th)
Atlanta, N 33.75 deg.	4.0	\$0.032/kWh(th)
Pittsburgh (NETL), N 40.29 deg.	4.7	\$0.028/kWh(th)

Enhancing recovery of reverse osmosis (RO) concentrate while **addressing concentrate management** from water reuse with an integrated ozone-membrane distillation (MD) for near zero-liquid discharge (ZLD)



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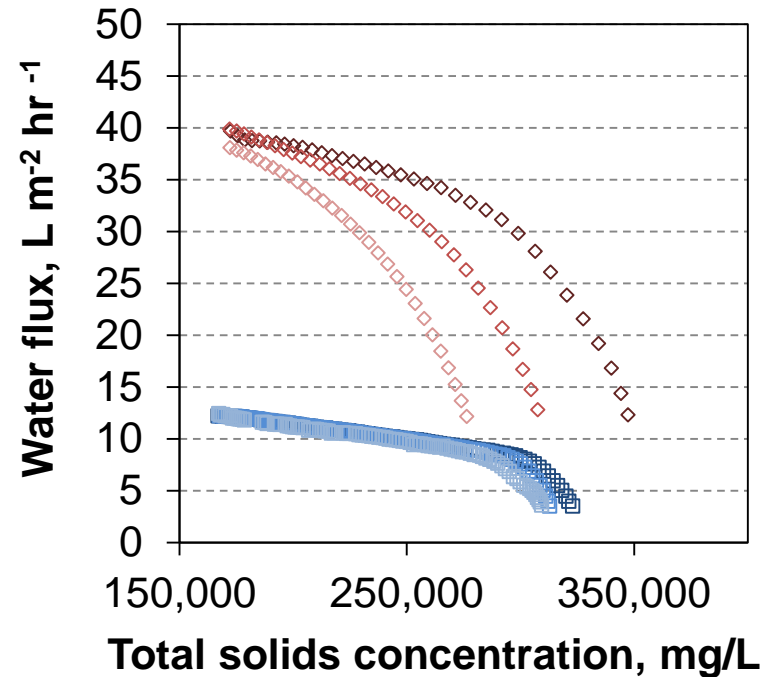
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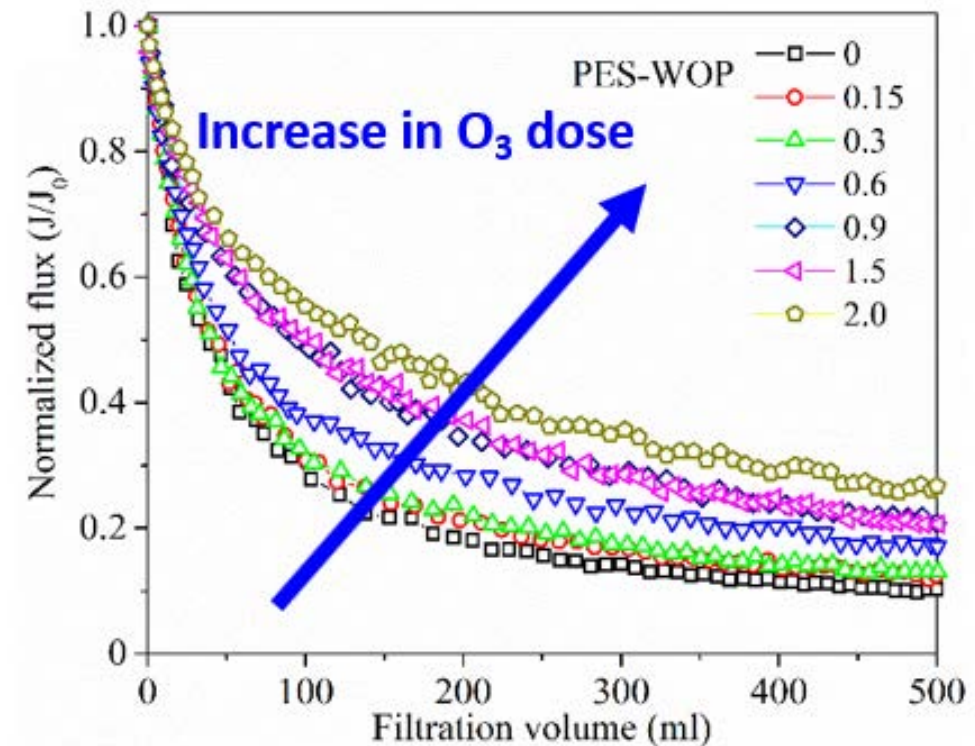


- MD can recover high salinity waters to near supersaturation
- Performance of concentrating saline waters with organic matter is unknown



- | | |
|-----------------|-----------------|
| □ 50/30 - Run 1 | ◇ 70/30 - Run 1 |
| □ 50/30 - Run 2 | ◇ 70/30 - Run 2 |
| □ 50/30 - Run 3 | ◇ 70/30 - Run 3 |

- Pre-ozonation of wastewater effluent is effective in reducing organic fouling in ultrafiltration
- Applying low doses of ozone could reduce organic fouling in MD and maintain hydrophobicity of membrane



- 1) Realize ozone-MD as an **effective and economic technology** to enhance water recovery in RO-based water reuse systems
- 2) Develop novel MDC components and **system configurations to improve energy efficiency**
- 3) **Mitigate membrane fouling and scaling** through integration with ozonation and investigate a unique closed-loop batch mode MD configuration to control the kinetics of scale formation
- 4) Design and test a novel **pilot-scale closed-circuit ozone-MD system that maximizes water recovery** from a UF/RO system while **minimizing energy consumption**

