Low Cost Desalination Using Nanophotonics Enhanced Direct Solar Membrane Distillation (DE-EE0008397)

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Project Team

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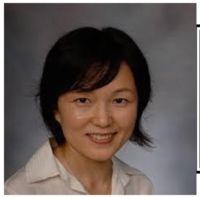

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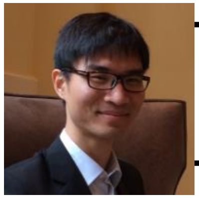
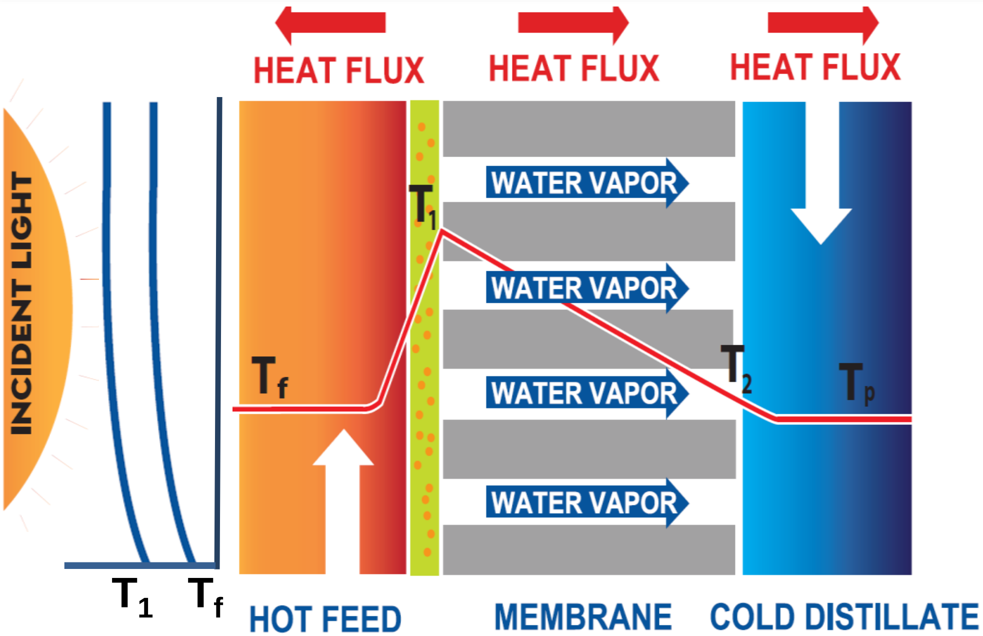
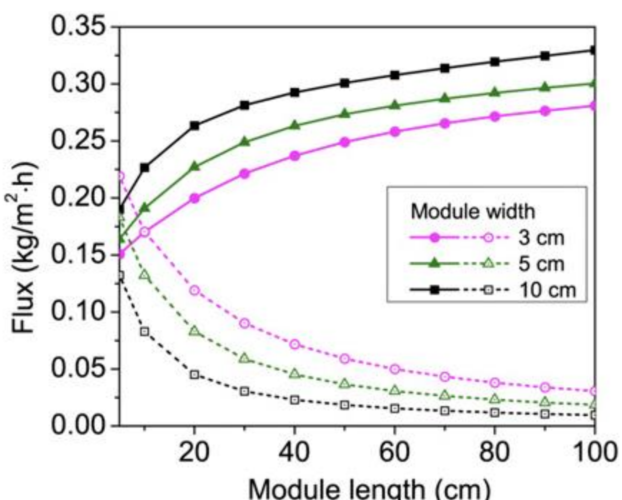


Project Manager
ES Engineering

PhD student
CMU

Nanophotonics Enhanced Direct Solar Membrane Distillation





Advantages

- Directly utilizes sunlight for desal
- Integrates solar collection and desalination
- Higher energy efficiency due to
  - Localized heating
  - Reversed temperature polarization
  - Low feed recirculation rate
- Scalability

Reduced capital and O&M costs compared to existing technologies

Project Objectives

Develop and **optimize** a pilot NESMD system, move the technology from TRL 3 to TRL 7, and **assess** its potential for low cost solar desalination

- **Develop** mathematical models at microscopic, reactor, and system levels
- **Design**, **build**, **test**, and **optimize** an integrated, NESMD pilot system
- Combine mathematical modeling and experiments in bench and pilot scale systems to **investigate** the effect of system scale, influent water quality, and environmental conditions (e.g., solar irradiance and ambient temperature);
- **Assess** the long-term system reliability and performance stability;
- **Develop** model framework for comprehensive cost and market analyses as well as system optimization for different source water and geographical locations

Research Needs & Challenges

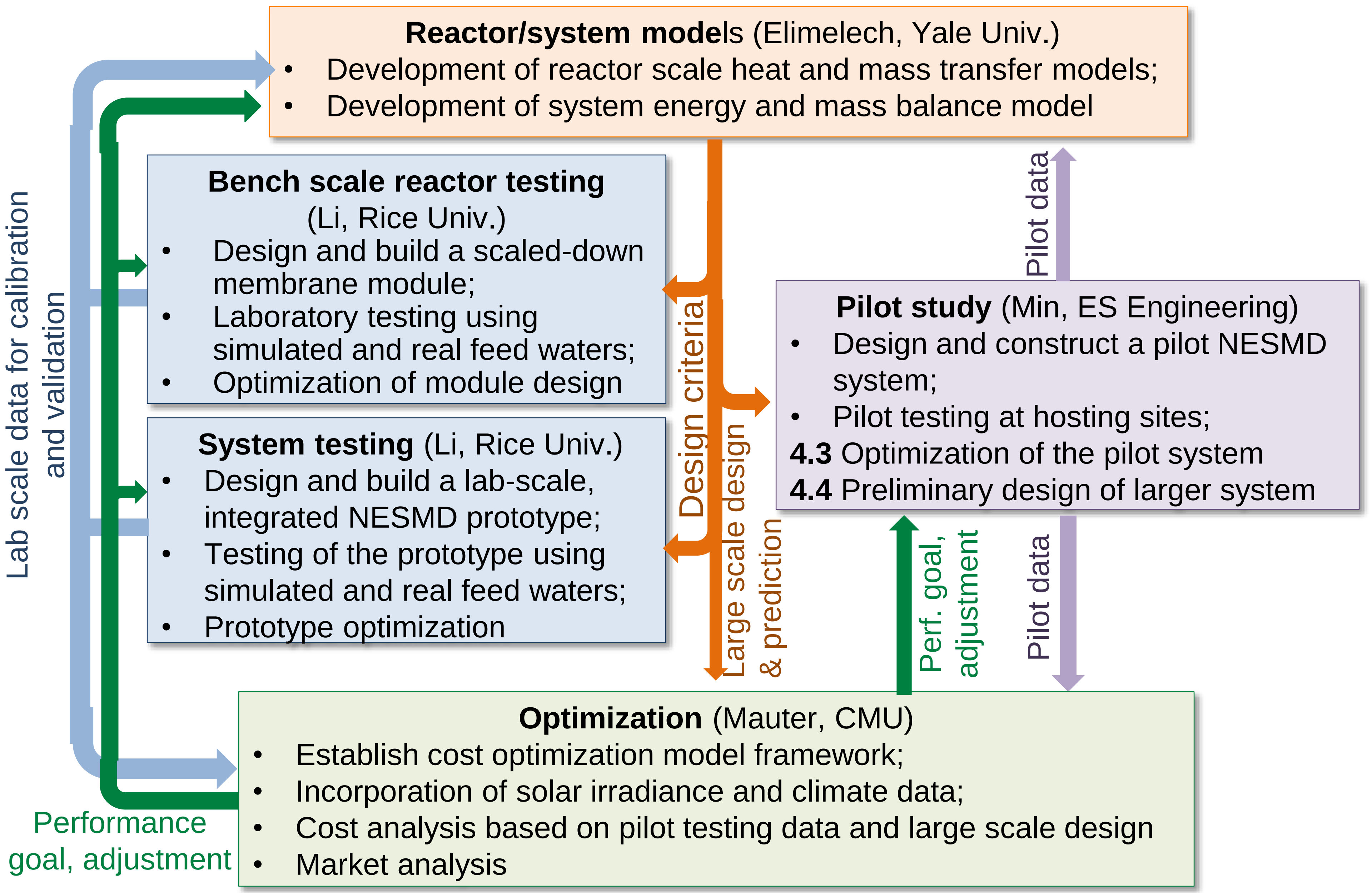
Research Needs

- ❑ Membrane module design
- ❑ Heat recovery/management
- ❑ System scale up
- ❑ Effect of environmental conditions

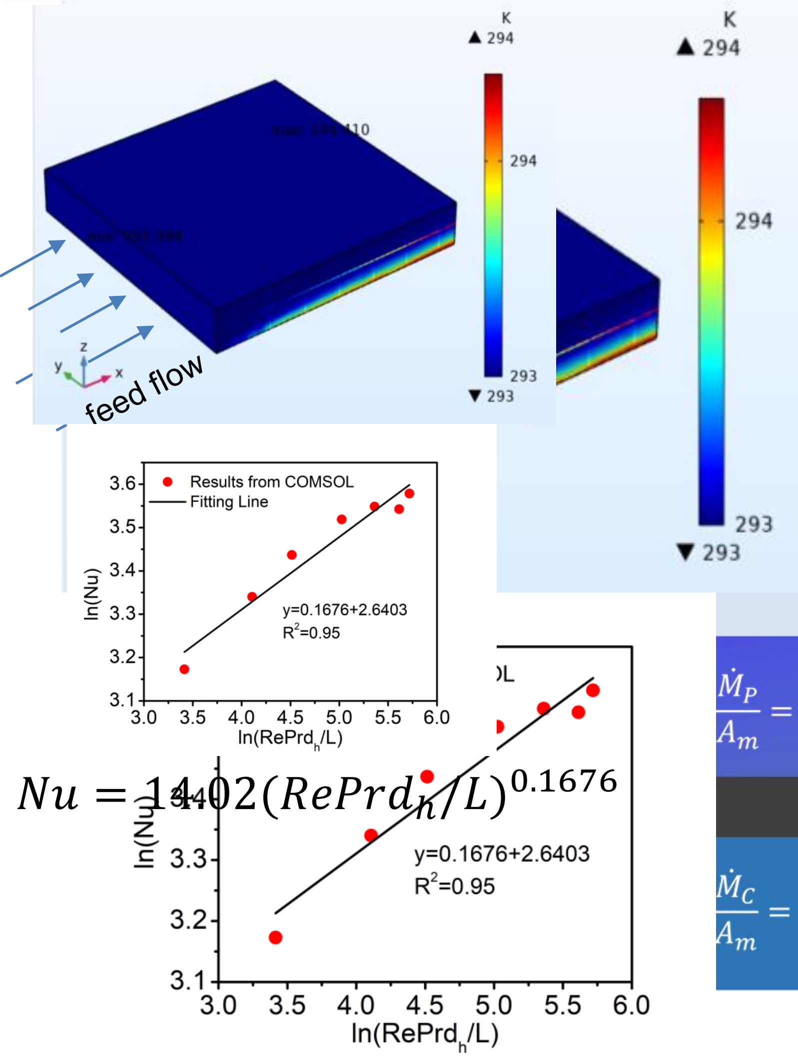
Technical Challenges

- ❑ Non-linear, coupled heat and mass transfer processes
- ❑ Non-steady state condition
- ❑ Complex, multi-objective optimization
- ❑ Membrane stability, fouling/scaling
- ❑ Scale up of membrane fabrication

Research Approach



Reactor Scale Model



$$Nu = 14.02(RePrd_h/L)^{0.1676}$$

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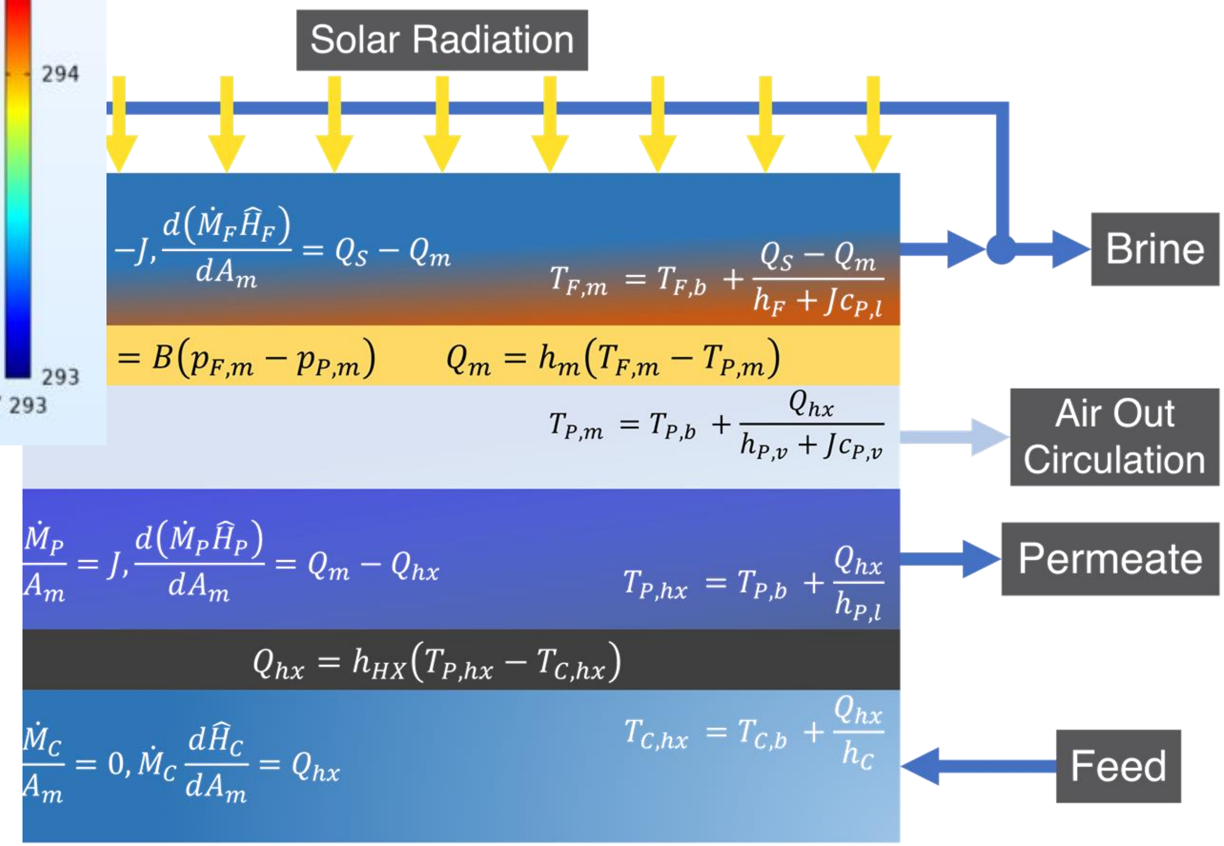
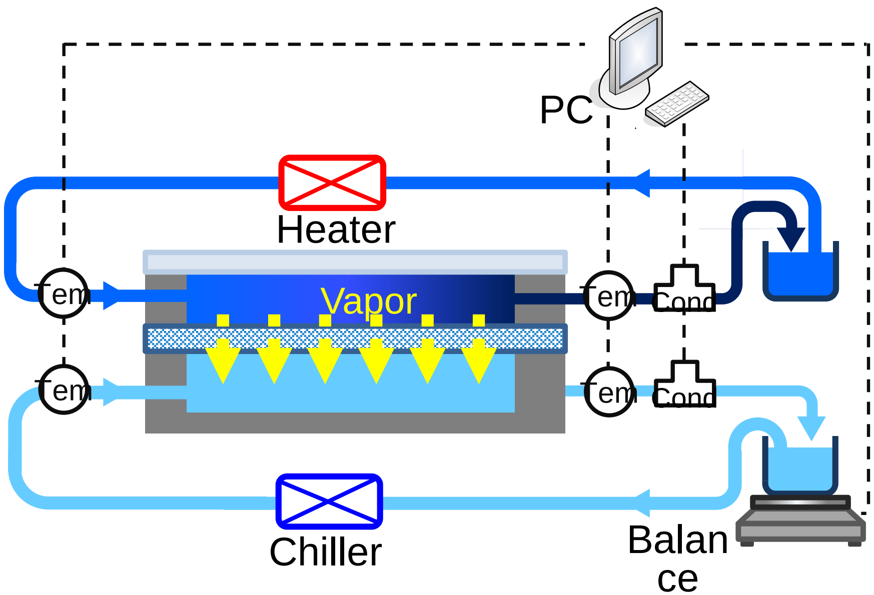
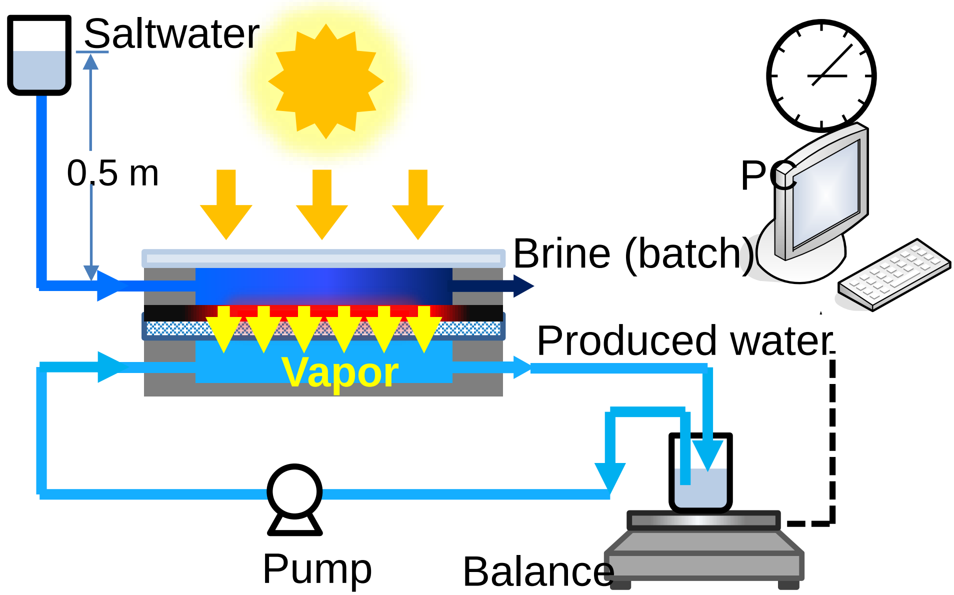
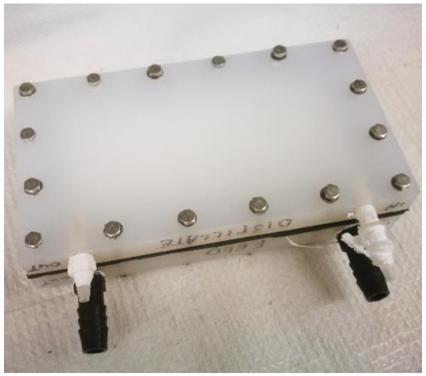
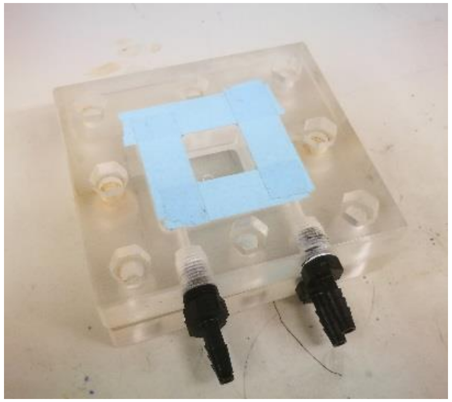


Bench-scale Experimental System

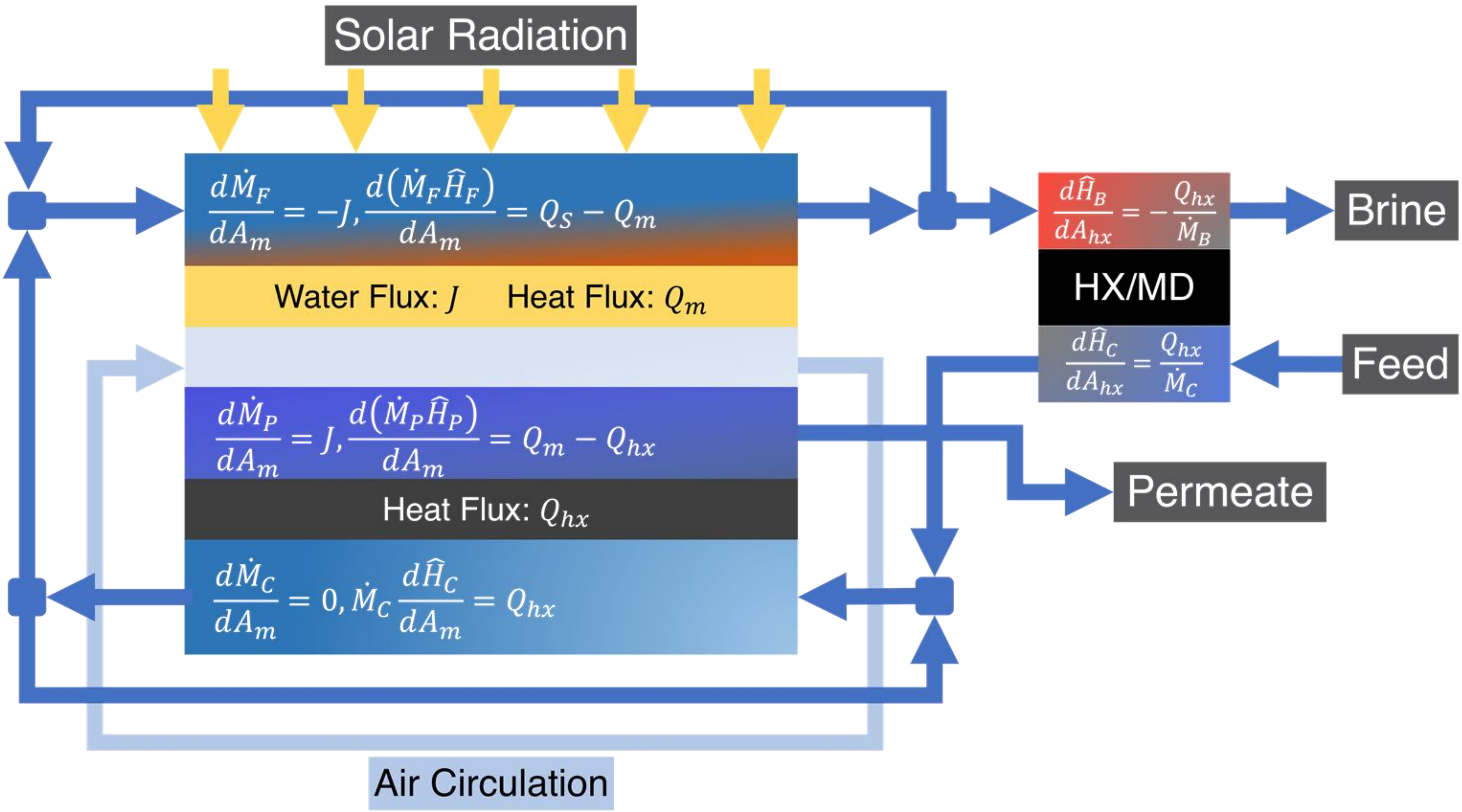




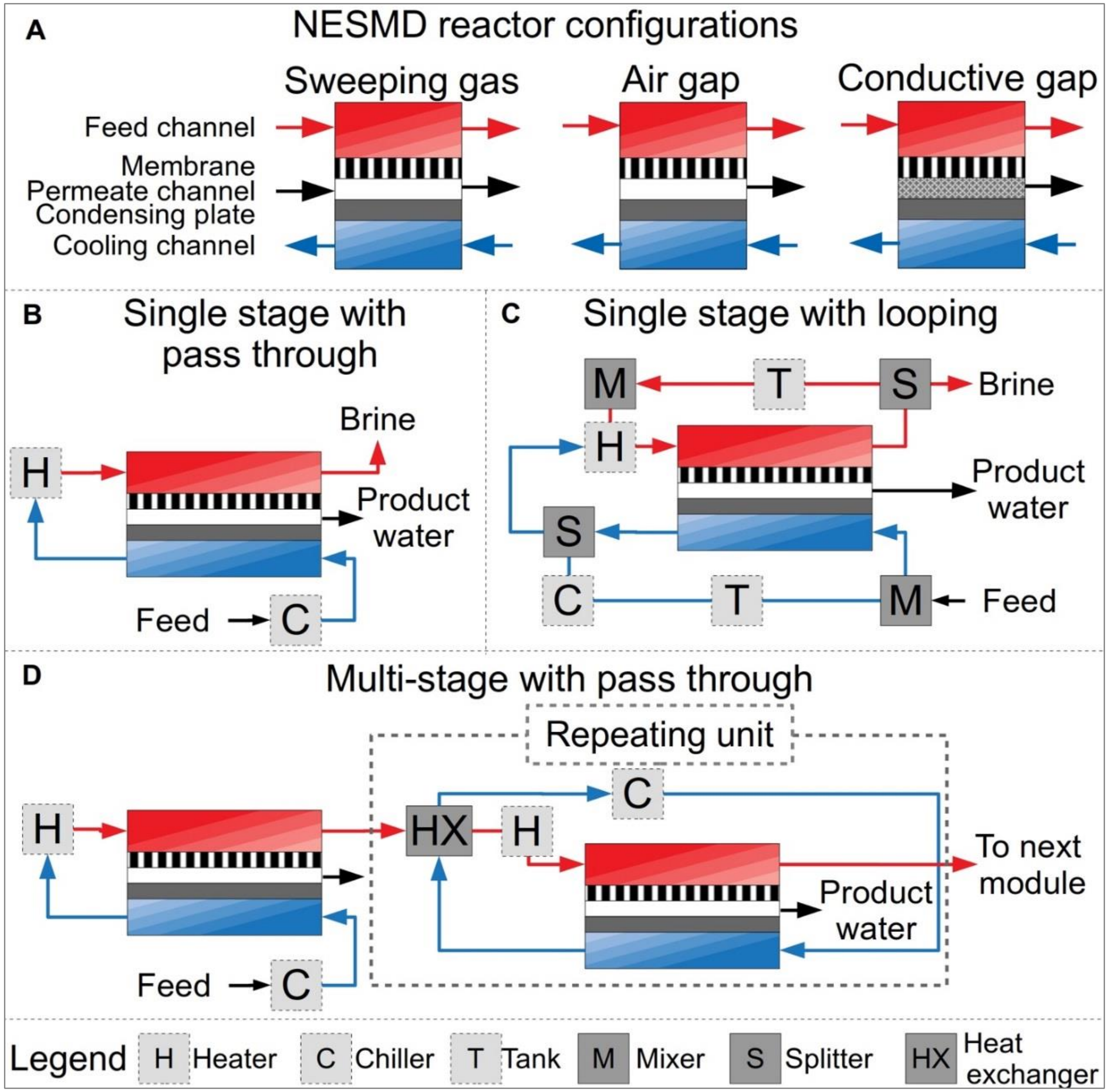




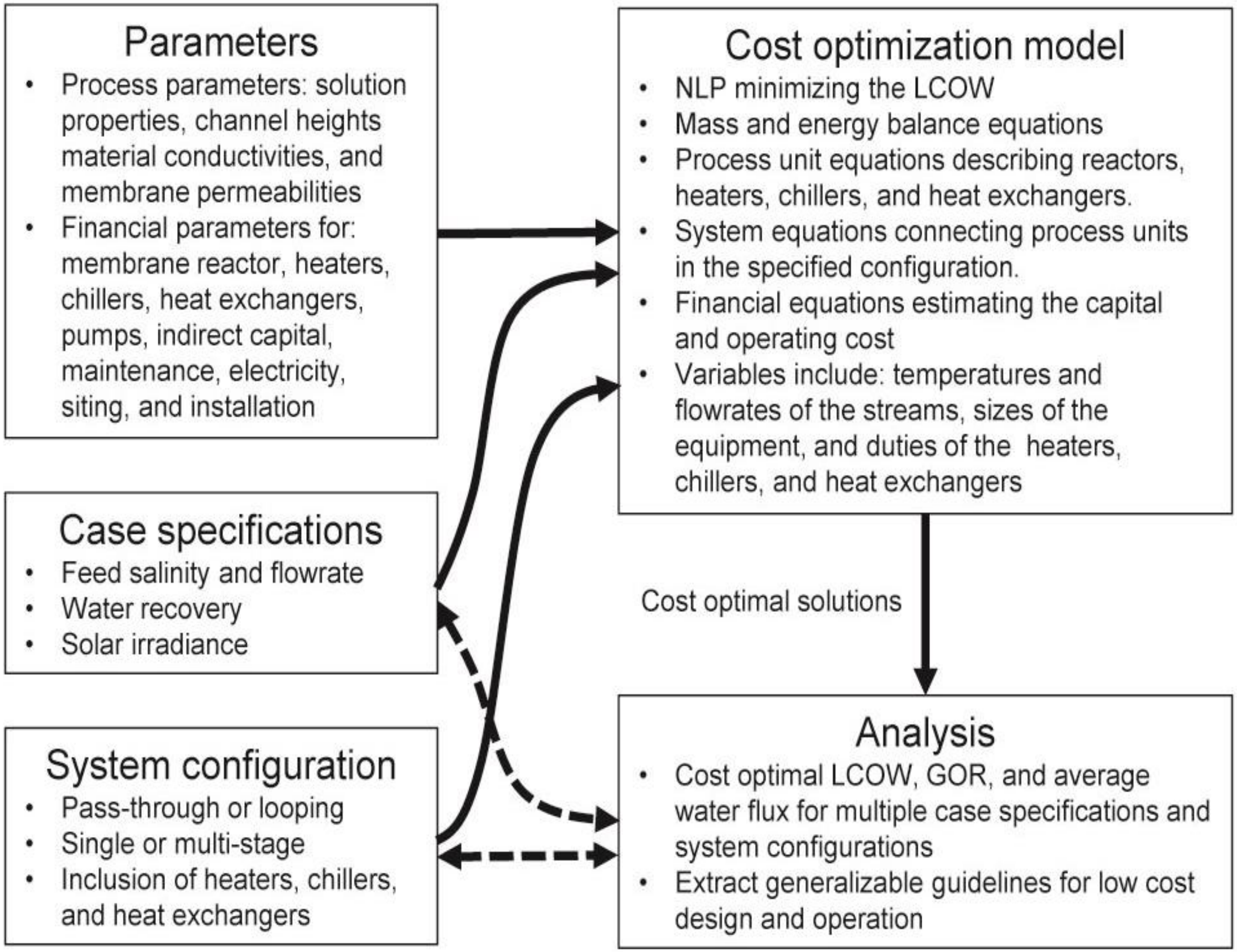
System Scale Model



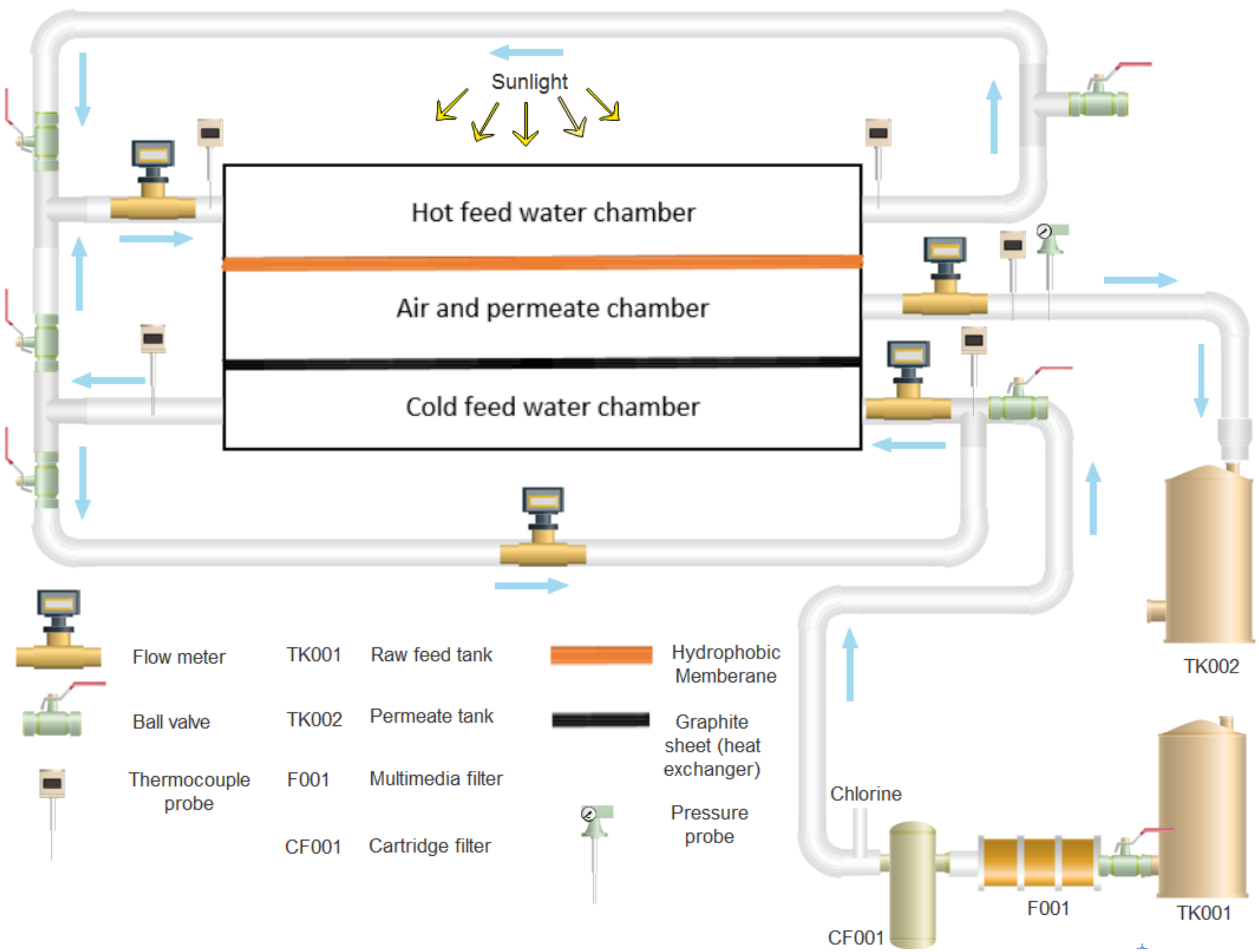
Reactor/system Configurations Considered



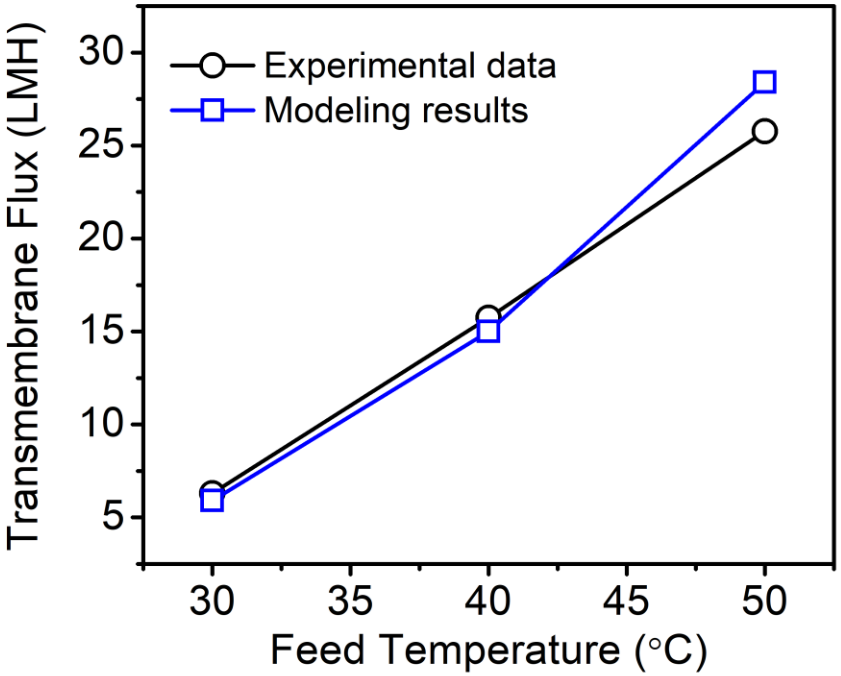
Cost Optimization Model Framework



Scaled-down Module Design



Preliminary Results: Reactor Model



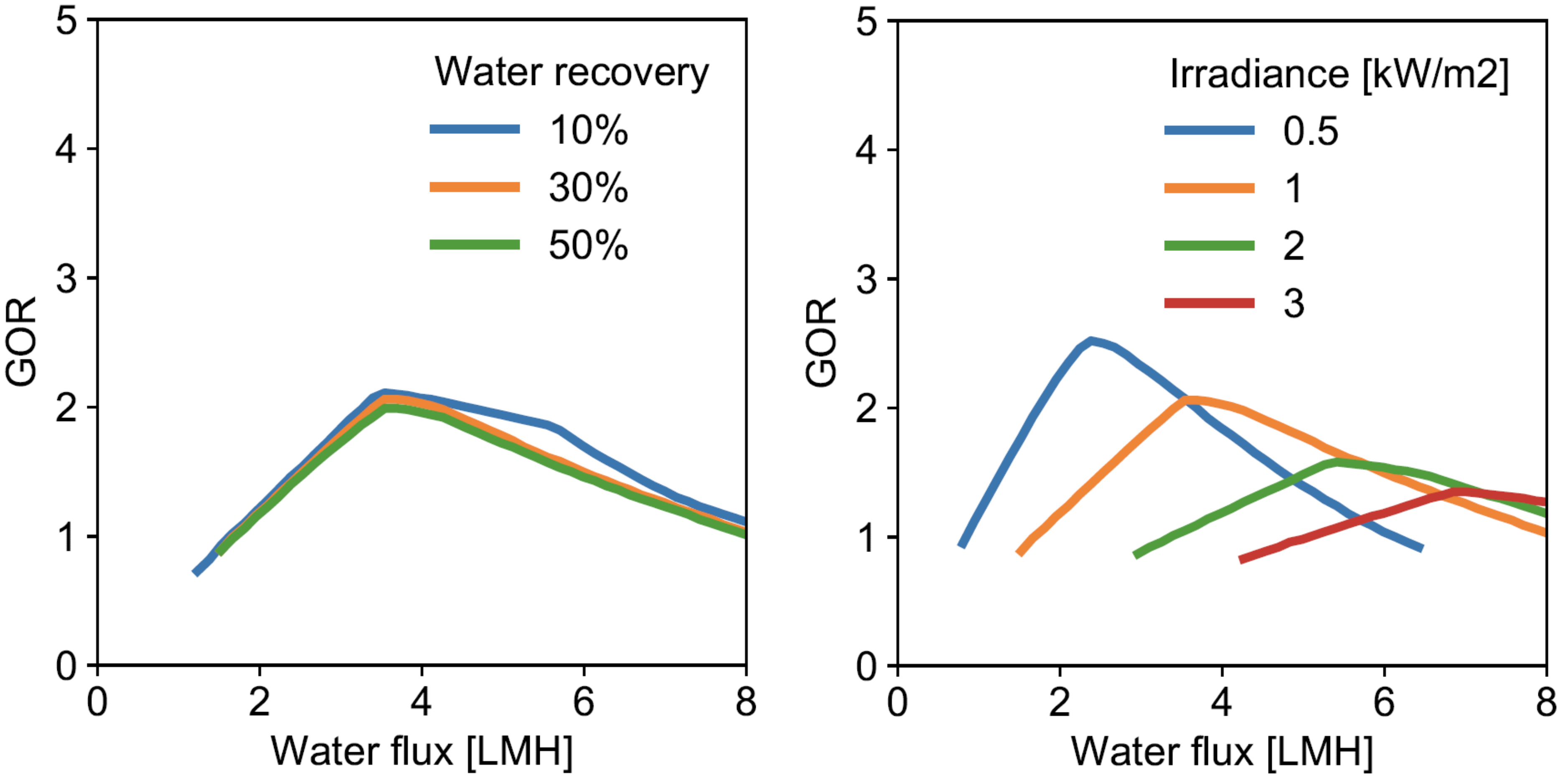
Experimental measurements

$T_{feed,in}$(°C)	$T_{feed,out}$(°C)	$T_{perm,in}$(°C)	$T_{perm,out}$(°C)
30.18	27.62	20.1	21.62
39.96	34.99	20	22.34
49.89	41.73	19.75	25.12

Model prediction

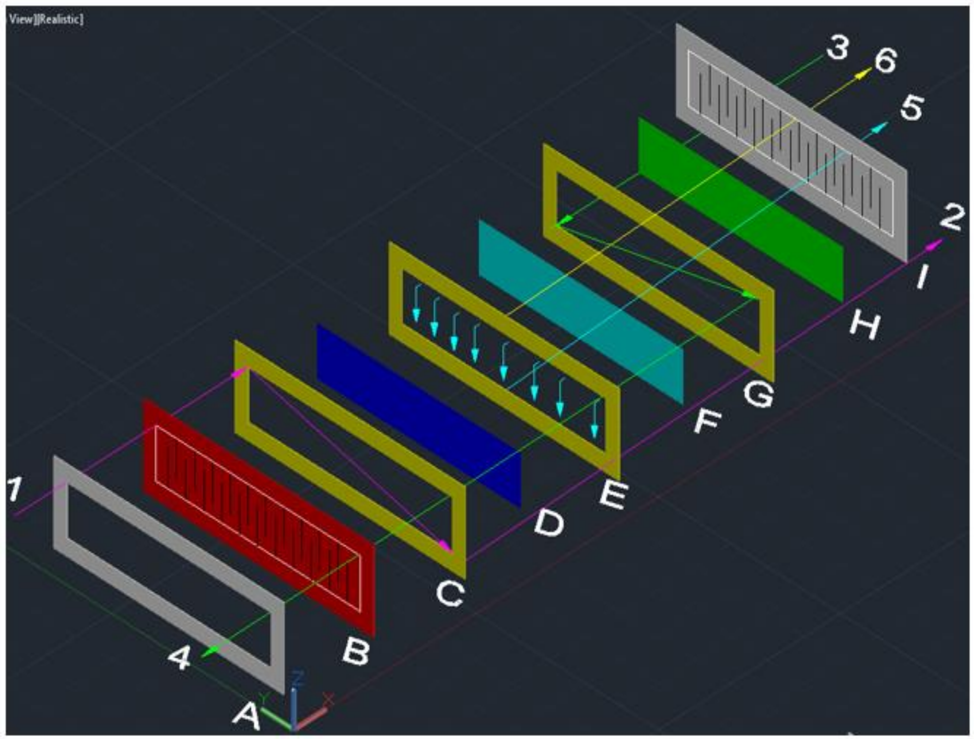
$T_{feed,in}$(°C)	$T_{feed,out}$(°C)	$T_{perm,in}$(°C)	$T_{perm,out}$(°C)
30	27.4	20	21.06
40	34.68	20	22.37
50	41.78	20	24.1

Preliminary Results: Optimization Model



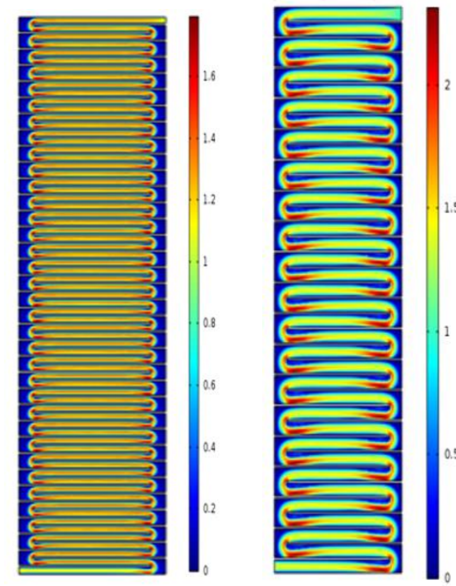
Preliminary Results: Reactor Design

A and I	Acrylic closing plates (thickness 12.7 mm)
B	Irradiation acrylic glass (thickness 3mm)
C,E, and G	Silicon rubber frames
D	Hydrophobic membrane
F and H	Plastic net spacer
1	Inlet hot feed water
2	Outlet hot feed water
3	Inlet cold feed water
4 = 1	Outlet cold feed water, which is the inlet of feed water
5	Distillate
6	Venting line

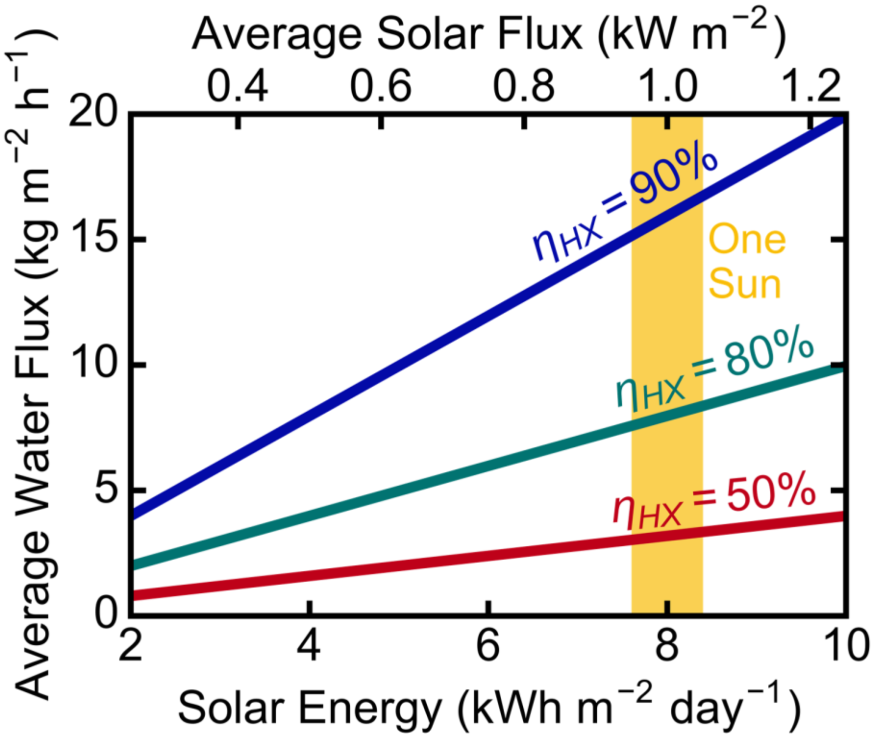


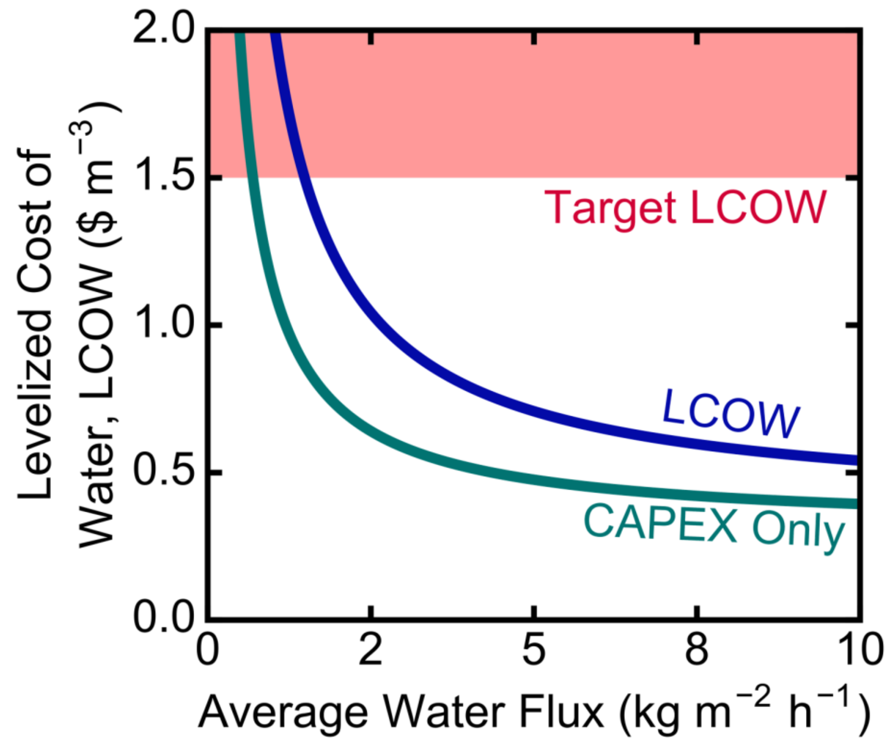
9.9 mm

21.108 mm



Feasibility to Meet LCOW





Average Water Flux:

$$\bar{J} = \frac{Q_S}{(1 - \eta_{HX})\Delta^v H}$$

where Q_S denotes the solar flux, η_{HX} is the heat exchange efficiency, and $\Delta^v H$ is the enthalpy of vaporization of water.

System Size:

$$System\ Size = \frac{Target\ Capacity}{\bar{J}_{day}}$$

where $\bar{J}_{day}$ is the average water flux per day assuming a daily solar irradiation time of $8\ \mathrm{h\ day^{-1}}$.

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