Analyzing Solar Desalination With WaterTAP

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Why Solar Desalination?

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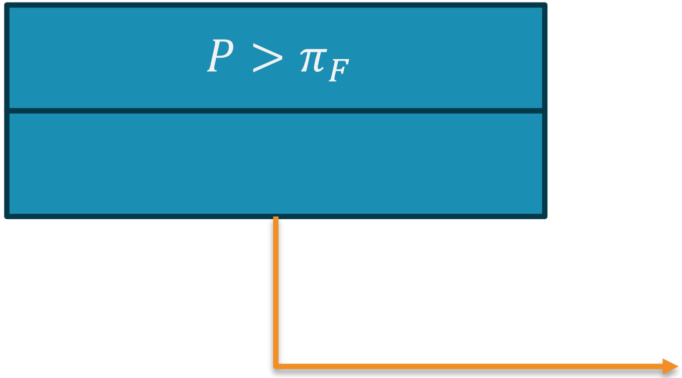
Managing highly saline streams with a high recovery ratio will require a thermal process.

Membrane Process



Highly Saline Brine

Technology	Max TDS (g/L)	Energy Consumption (kWh/m^3)
RO	<70	2-6
HPRO	~120	3-9
OARO COMRO CFRO	~140	6-19
FO	~200	0.8-13
MD	~350	39-67
MSF	--	18-29
MED	--	14-22

Panagopoulos, A. (2021). doi:10.1016/j.psep.2020.12.007

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Project Background

- **Objective:** build the ability to evaluate solar thermal desalination technologies for brines into WaterTAP
- **SETO Metrics**:
  - LCOH: $0.02/kWh$_{th}$
  - LCOW: $1.50/m^3
- Case study comparison against electrified alternatives
  - Produced water, brackish water

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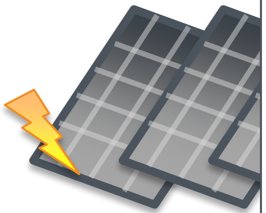
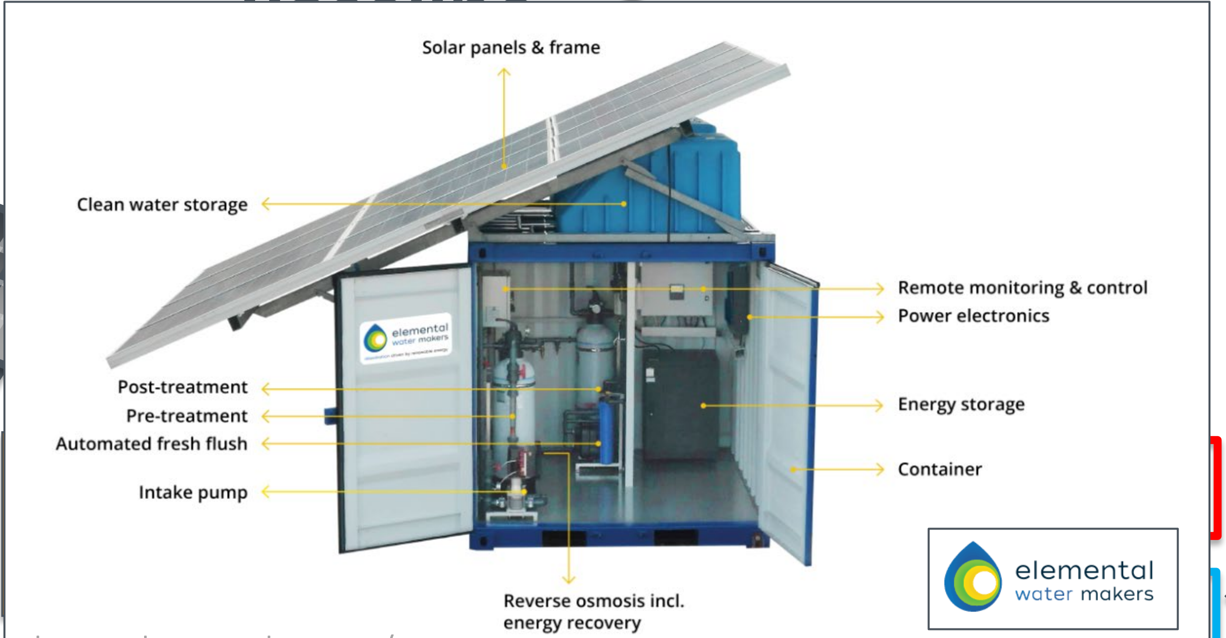
Project Background

Solar





elementalwatermakers.com/

Driven by electricity

Driven by heat

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Development Needs and Challenges

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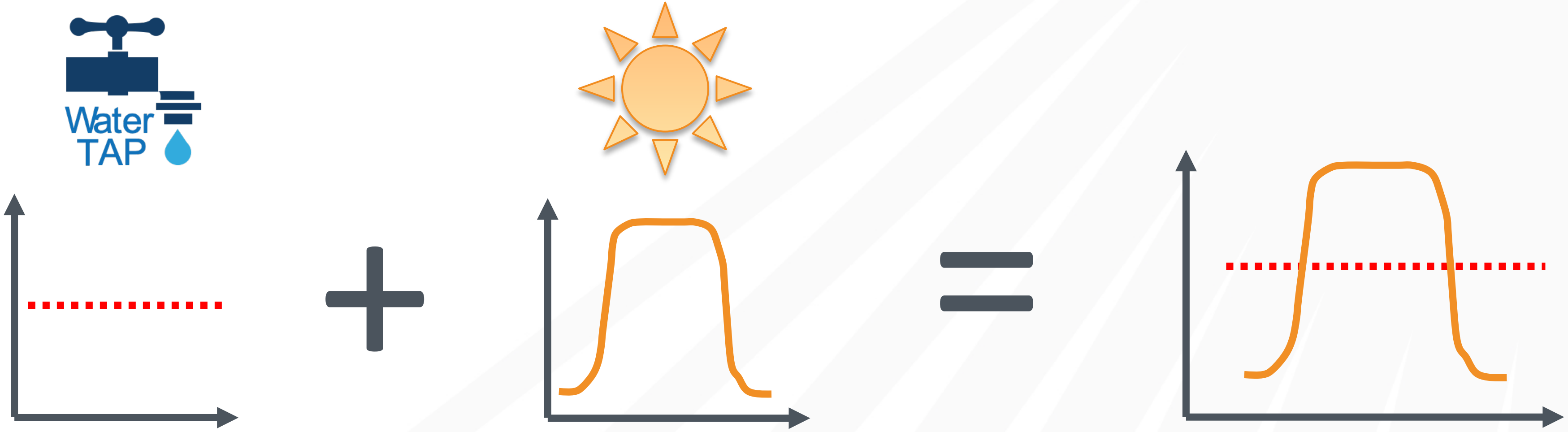

Maximizing resources

WaterTAP = $4M/year

WaterTAP-SETO = $300k/year

Analyzing nuances of time-dependent system without time dependent model is… challenging

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Analysis Goals

Given:

- Location
- Salinity
- Flow rate
- Technologies used

Subsystem	Design Variables	Operating Variables
Solar	X_1	Y_1
Treatment	X_2, X_3, X_4	Y_2, Y_3
Storage	X_5, X_6	Y_4

Low Level Optimization

- Fixed: Treatment, Solar, Storage
- Optimized: None (Simulation)

→

Mid Level Optimization

- Fixed: Treatment, Storage
- Optimized: Solar

→

High Level Optimization

- Fixed: None
- Optimized: Treatment, Solar, Storage

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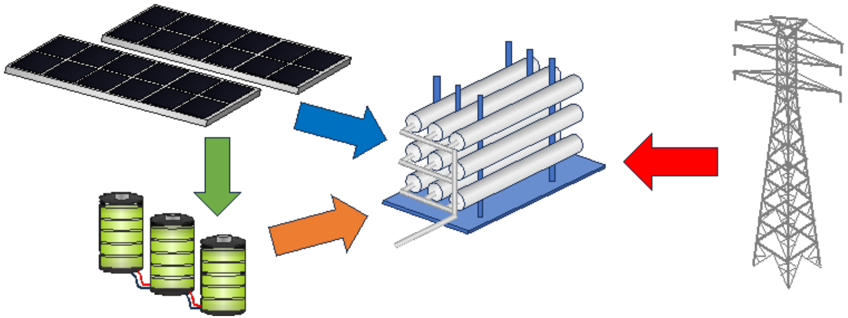
Analysis Goals



Subsystem	Design Variables	Operating Variables
PV	1 (size)	n/a
RO	2 (membrane area, width)	1 (pressure)
Storage (Battery)	1 (size)	2 (power in/out, state of charge)

Analysis A

- Fixed: PV, RO, Storage
- Optimized: None (Simulation)

Analysis B

- Fixed: PV, RO (design)
- Optimized: Storage, RO (op.)

Analysis C

- Fixed: no subsystem
- Optimized: PV, RO (design + op.), Storage

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Tiered Analysis Approach

Tier 1:
- Steady-state cost optimization of water treatment
- Parameter data from PySAM (net metering)

Q1 2023

Tier 2:
- Steady-state cost optimization of integrated system
- Steady-state surrogate from PySAM

Q4 2023

Tier 3:
- Pseudo steady-state optimization of integrated system
- Pseudo steady-state surrogate from PySAM

FY2024

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WaterTAP + PySAM

- **SAM = System Advisor Model**
- **Detailed performance and financial analysis for renewable energy systems**

```
>> pip install NREL-PySAM
```

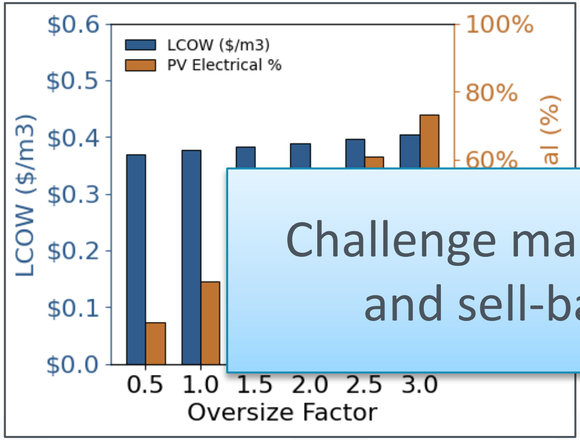
Renewable Energy Technologies:

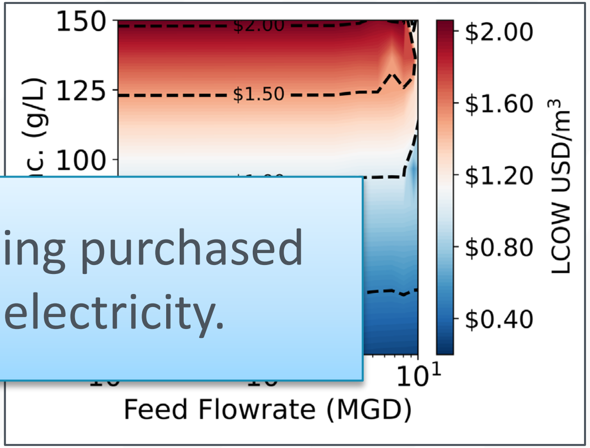
- PV
- Battery
- Conc. Solar Power
- Fuel Cell
- Wind
- Marine Energy
- Geothermal
- Biomass
- Solar Water Heating

Tier 1: WaterTAP + PySAM Simulation

WaterTAP + SAM Integration

- Simulation
- PySAM wrapper integrated as Unit Model
- PV peak generation = RO baseline demand
- WaterTAP wants to make massive solar plants





Challenge managing purchased and sell-back electricity.

Initialize Standalone RO

↓

Size PV to Estimated RO Power Demand

↓

Add RO Costing

↓

Add PV Costing

↓

Simulate RO + PV

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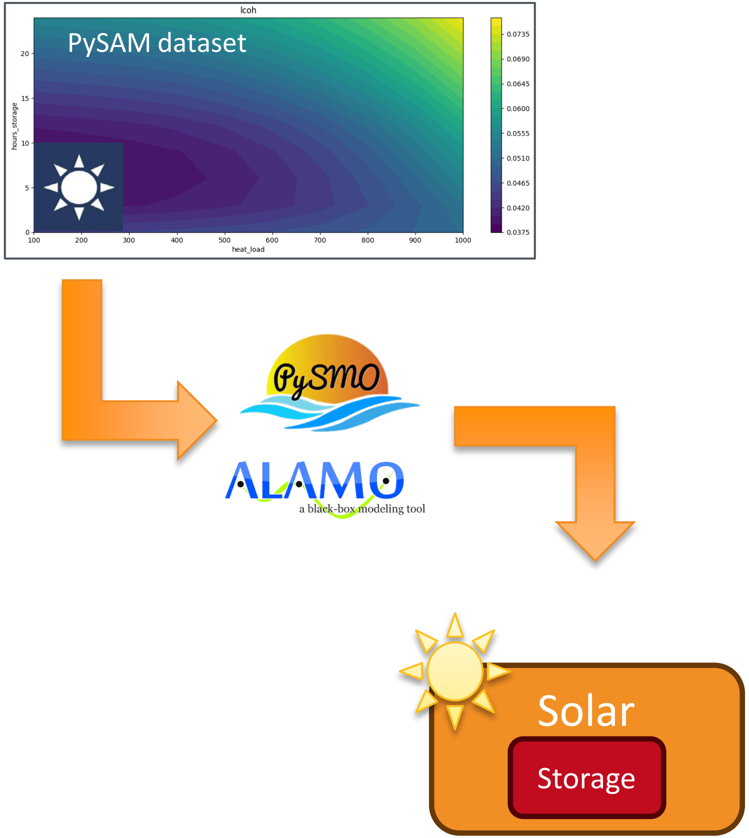
Building WaterTAP Surrogates with PySAM

Process:

1. Make simplifying assumptions
2. Determine valid input variable ranges
3. Run PySAM sweep across ranges
4. Use dataset to construct surrogate with PySMO (RBF)



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Building WaterTAP Surrogates with PySAM

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Simplifying Assumptions:

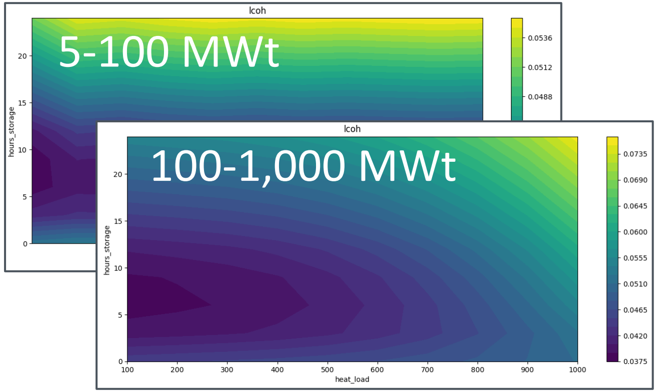
- One set of component designs
- Constant setpoint and return temp.
- Single location

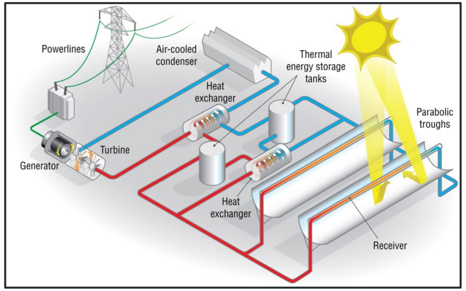
Inputs:

- Heat rate at design conditions
- Hours of thermal storage at design

Outputs:

- Annual energy produced/consumed





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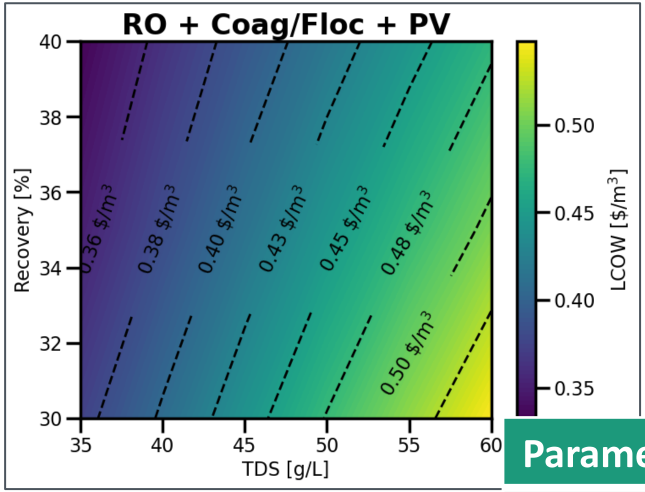
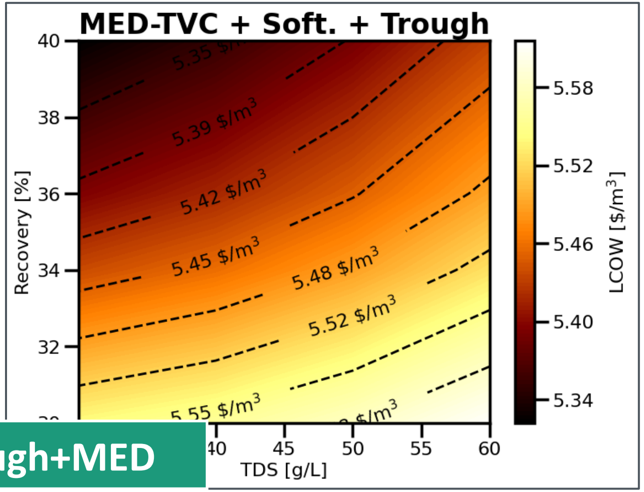
Building WaterTAP Surrogates with PySAM



Q = 10 MGD
TDS = 30-60 g/L
RR = 30-40%
7 hr storage
Tucson, AZ



Parameter	PV+RO	Trough+MED
LCOW ($/m³)	0.3-0.6	5.3-5.6
SEC (kWh/m³)	1.5-3.0	56.9-59.9
Capex ($MM)	7.1-12.8	76-101
Solar Size (MW)	1.1-2.9	52-67

WaterTAP + Solar Energy

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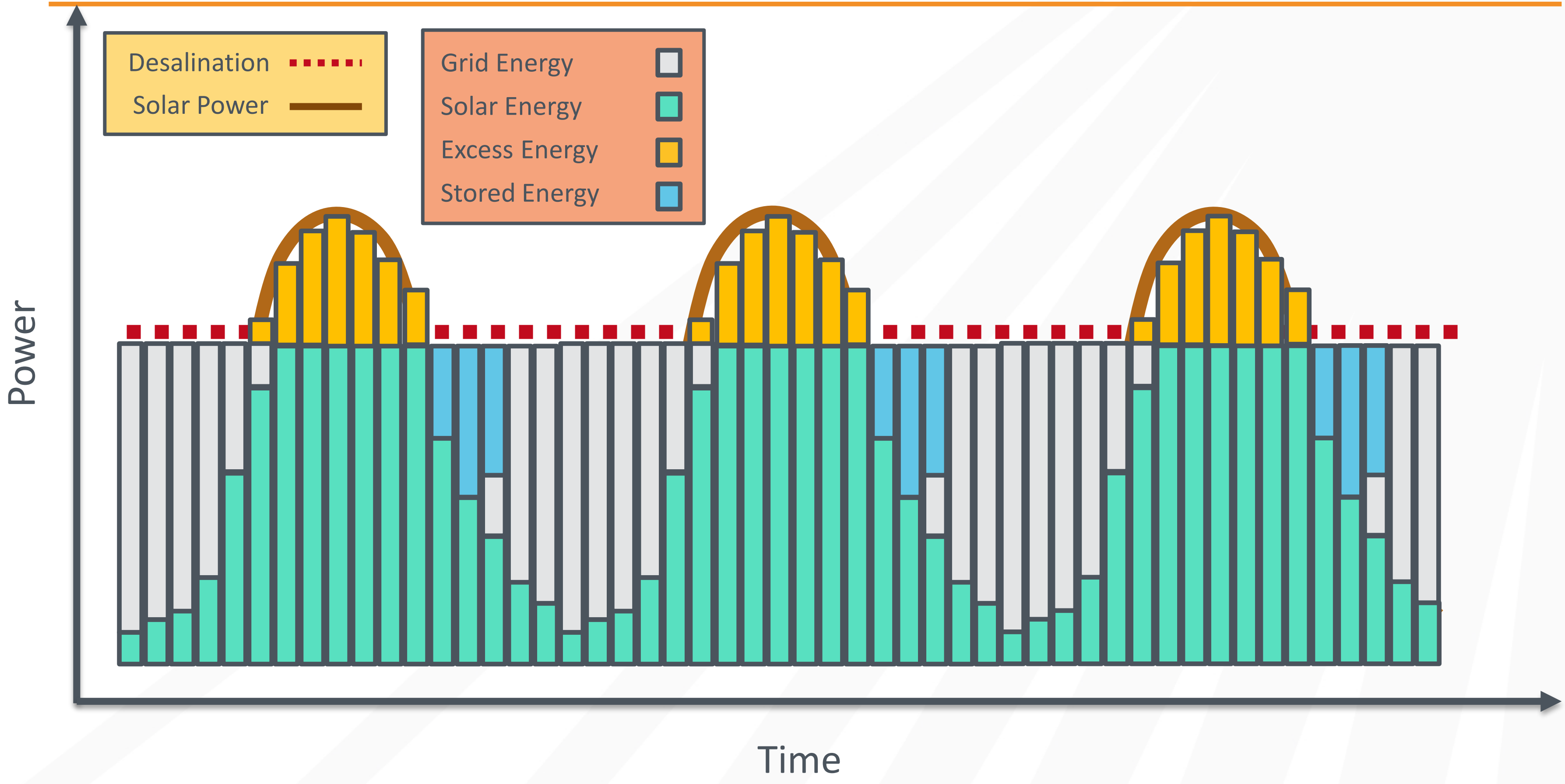
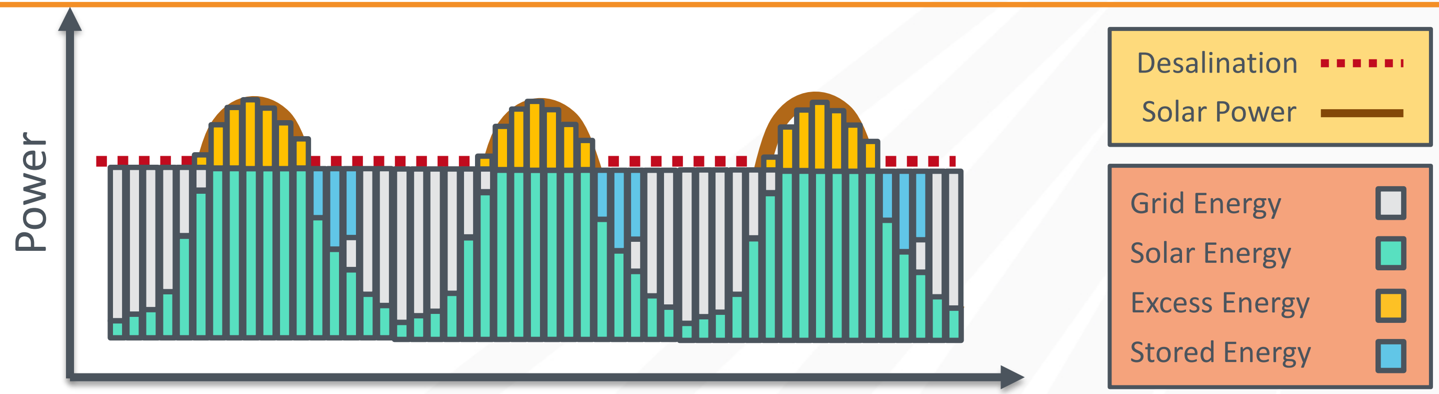
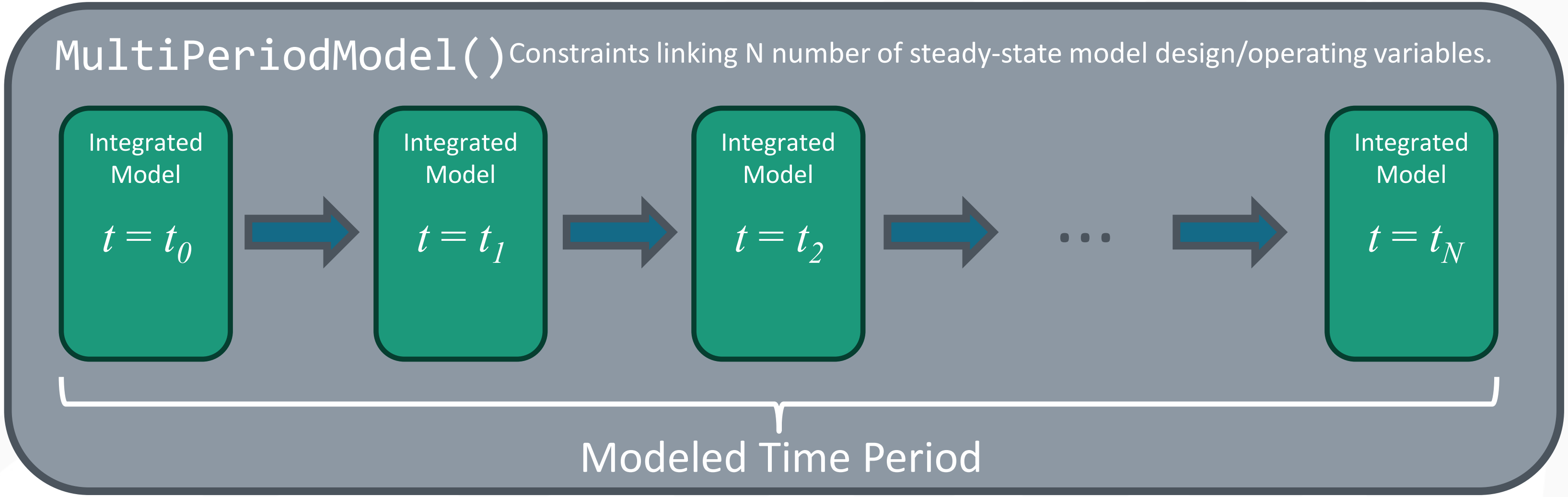


MultiPeriod Modeling





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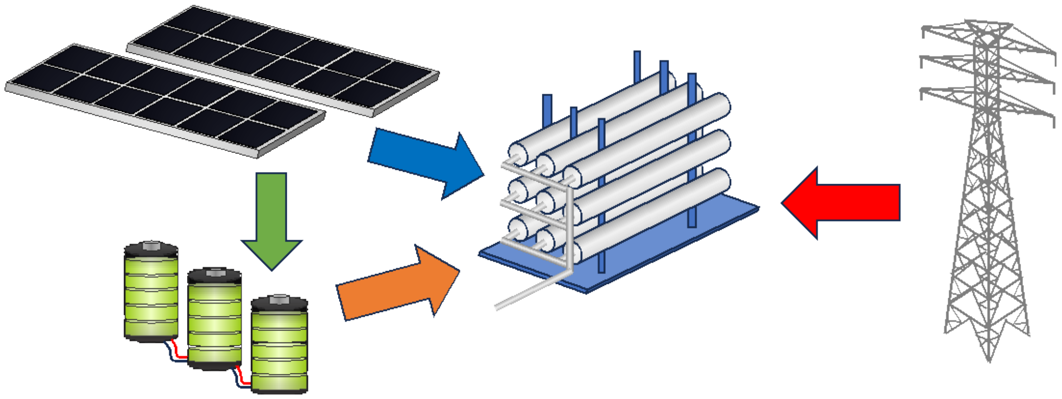
MultiPeriod PV + RO + Battery

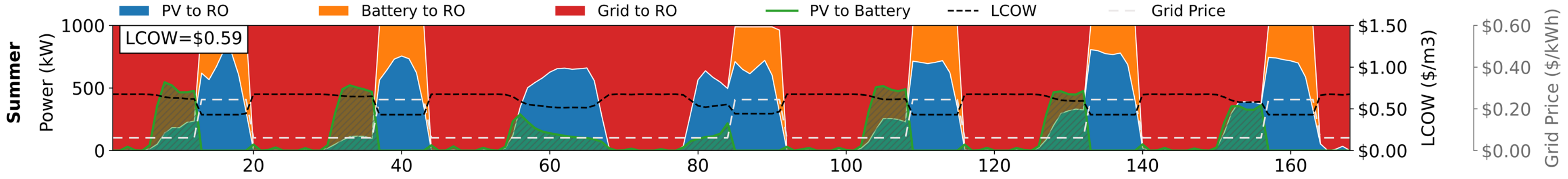
Key Features:

- Fixed RO operation
- Variable electricity pricing
- Seasonal PV sizing



Future work:

- Unfix and optimize PV system
- Part-load performance RO system



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MultiPeriod PV + RO + Battery

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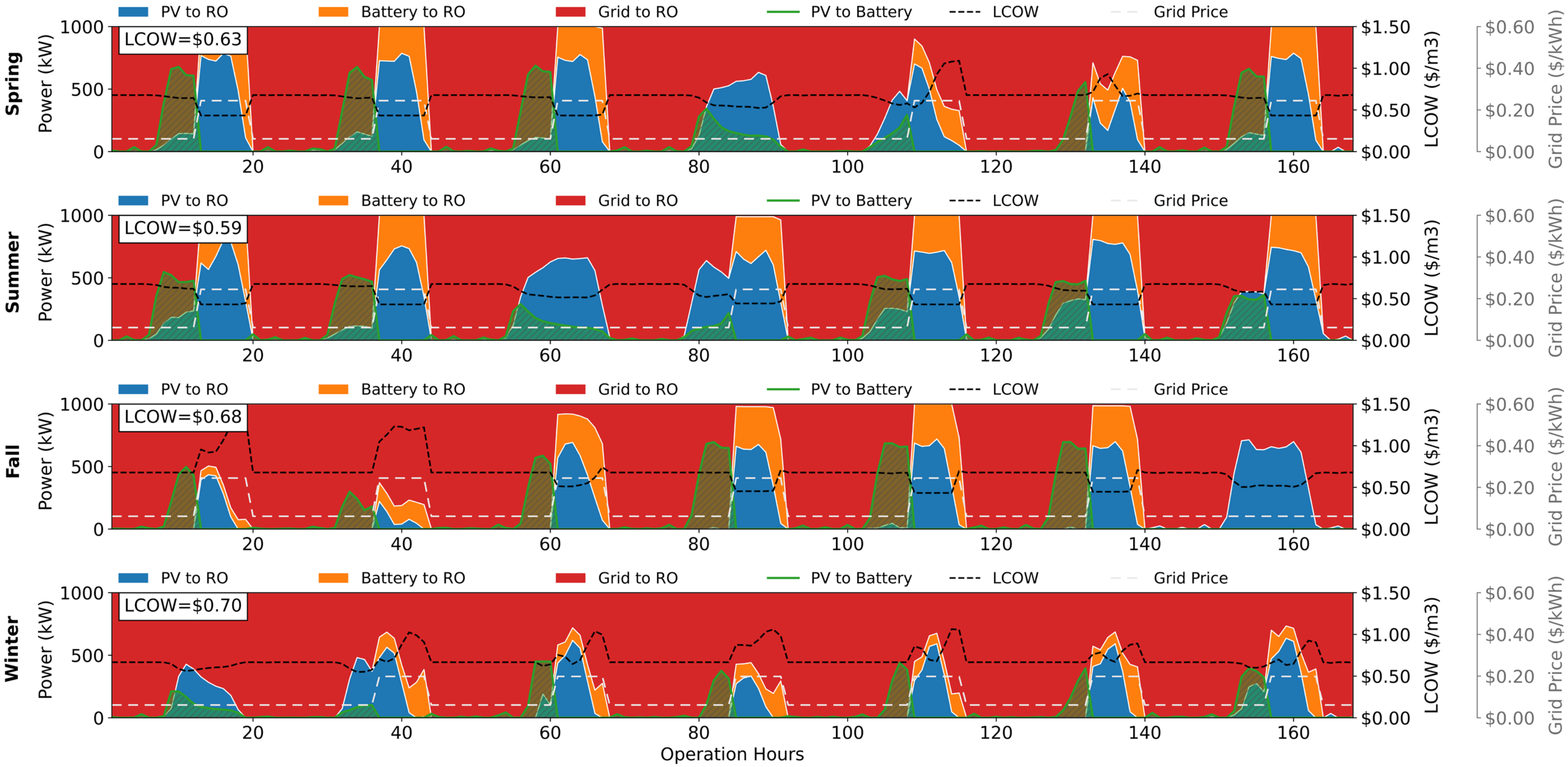

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MultiPeriod Thermal Desalination

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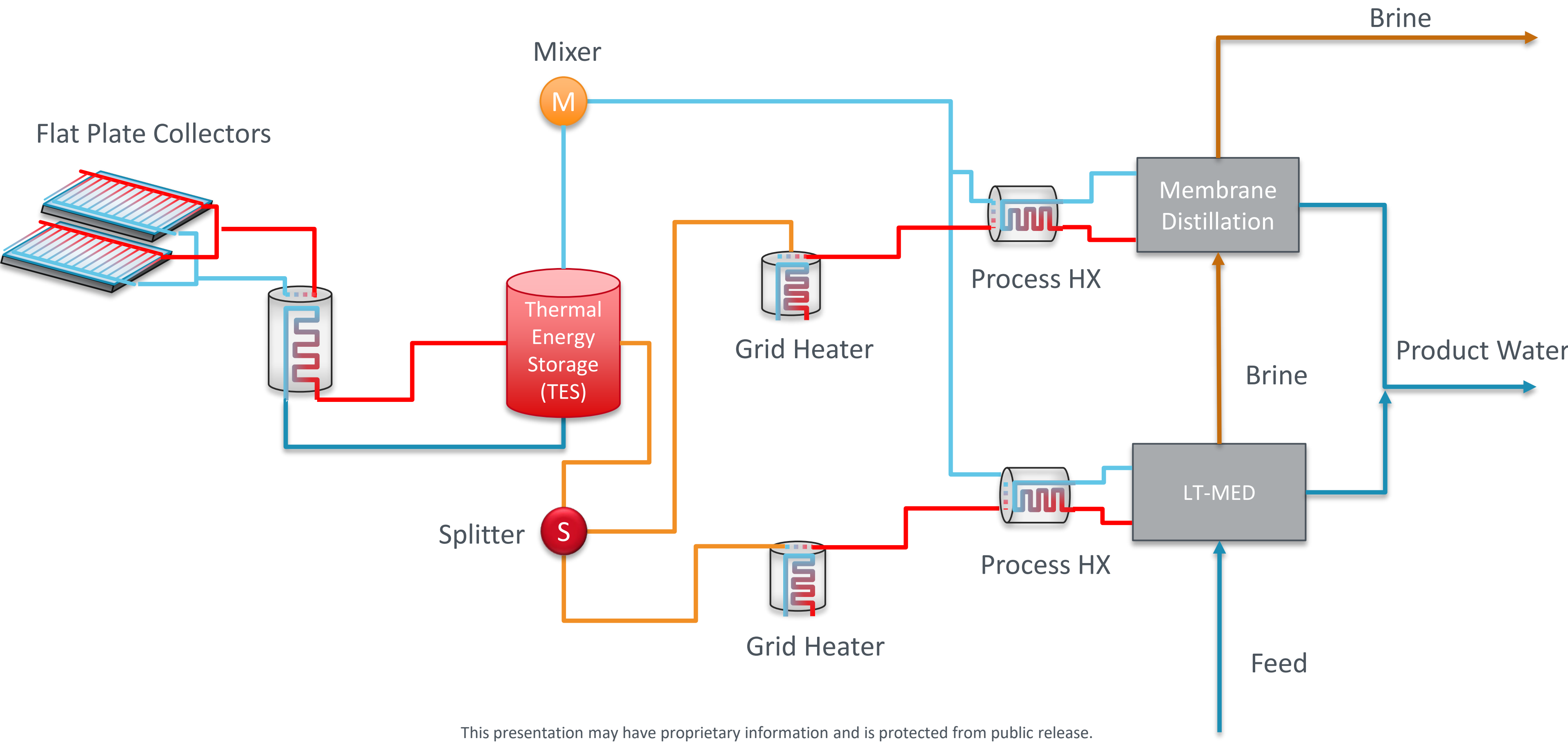

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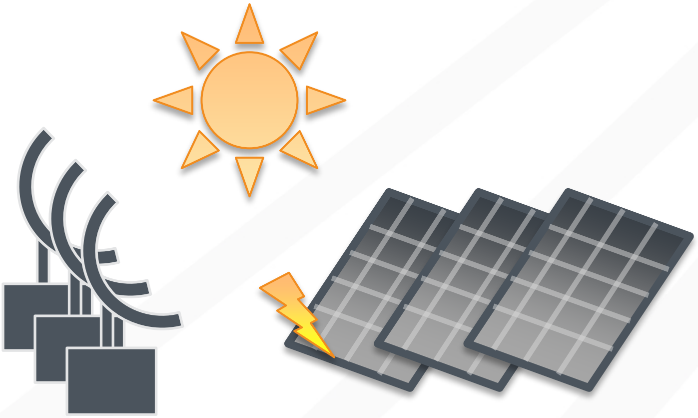
Current Status

Renewable Energy Models

Solar Energy:

- ✓ PV (Surrogate)
- ✓ Trough (Surrogate)
- ✓ Flat Plate Collector (Surrogate)
- ✓ Flat Plate Collector (Physical)



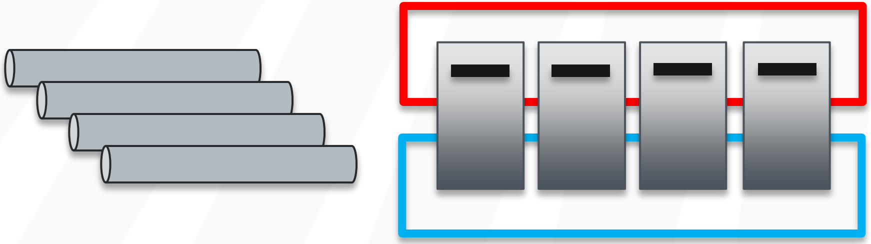
Water Treatment Models

Desalination:

- ✓ LT-MED
- ✓ MED-TVC
- ✓ VAGMD
- ✓ Solar Still

Pre-Treatment:

- ✓ Electrocoagulation
- ✓ Chemical Softening
- ✓ Air Stripping



Additional Outputs

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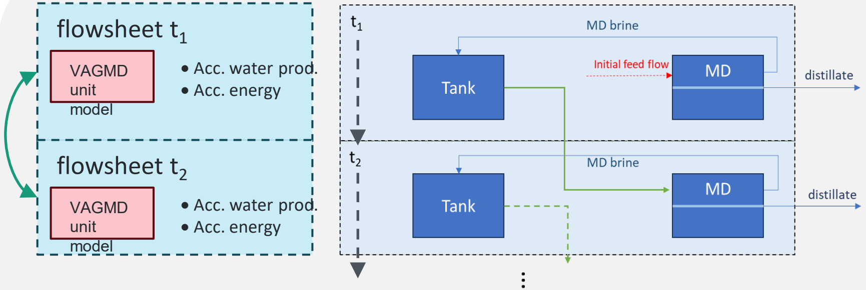
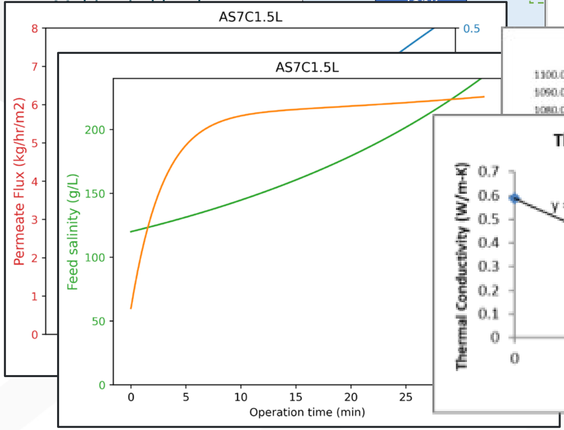
VAGMD Multiperiod

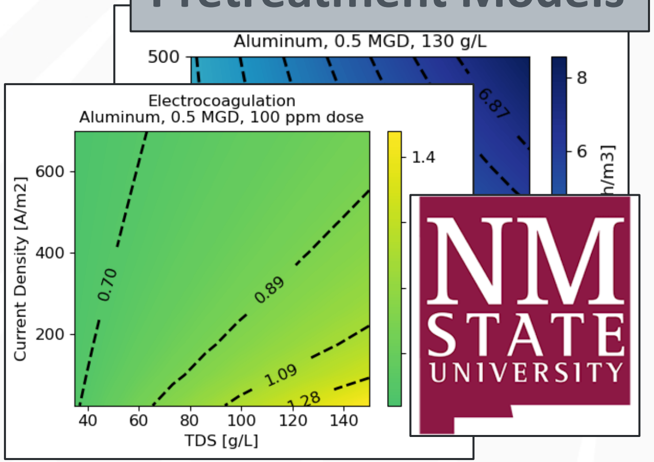


Link variable pairs:

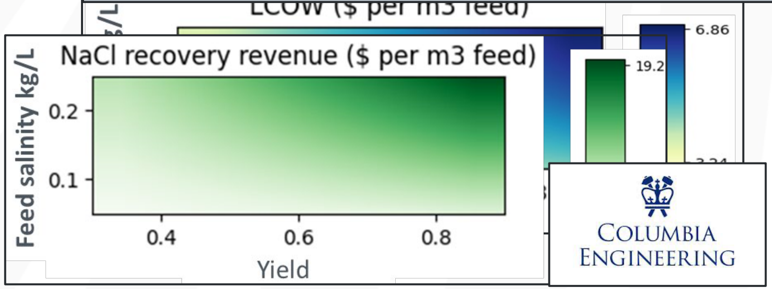
- Unit model variables



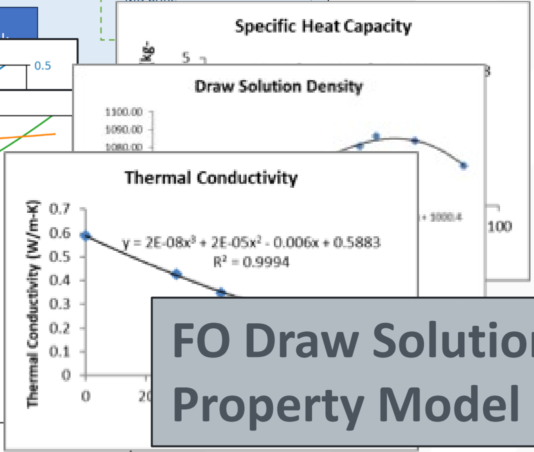
Pretreatment Models



Multi-Component Crystallizer



FO Draw Solution Property Model



WaterTAP-REFLO

WaterTAP-REFLO

WaterTAP with

Renewable
Energy and
Flexible
Load
Optimization

Acknowledgements

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