University of New Mexico Seminar – February 11, 2026

2025

# New Water Sources for Controlled Environment Agriculture


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Clemson University, Clemson, SC

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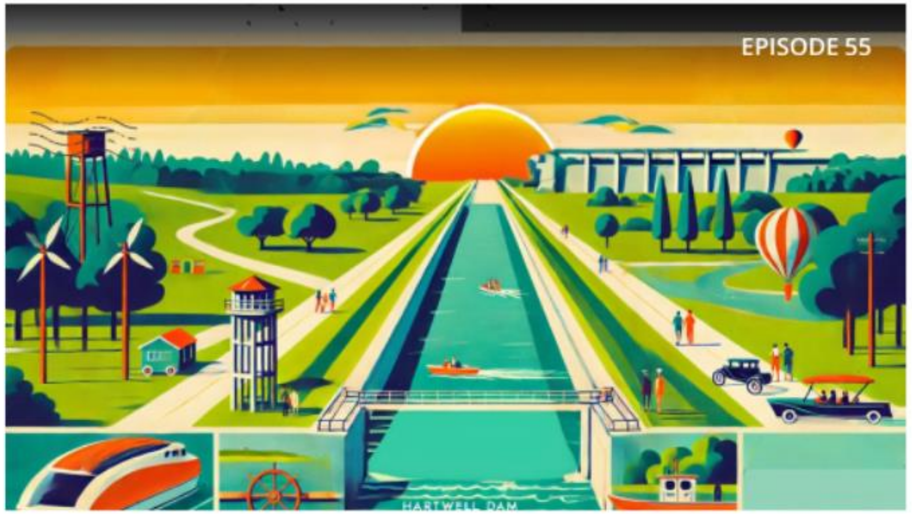
STORIES

## Clemson Under Siege: Ancient Relic Survives

September 1, 2024

In this series' third and final podcast episode, discover the untold story of Clemson College's existential battle against the Hartwell Dam project in 1956. Uncover how Plan X became the unexpected solution that saved Clemson's...

▶ PLAY EPISODE




STORIES

## Clemson Under Siege: The Unbuilt Canal

August 16, 2024

In 1956, Clemson College faced potential submersion as Hartwell Dam plans threatened to flood its campus. We continue to uncover the high-stakes battle between college officials and the federal government, revealing a forgotten alternative that...

▶ PLAY EPISODE

# Ladner Research Group

School of CIVIL AND ENVIRONMENTAL ENGINEERING AND EARTH SCIENCES

PI: David A. Ladner

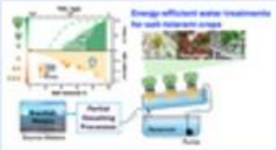
Department: Environmental Engineering and Earth Sciences

## RESEARCH GROUP FOCUS

- Partial desalination of saline and brackish waters using nanofiltration (NF) and electrodialysis (ED) technologies for salt-tolerant crop cultivation.
- Anaerobic membrane bioreactor-ultraviolet (AnMBR-UV) process tailored to the needs of crops in hydroponic controlled environment agriculture (CEA).

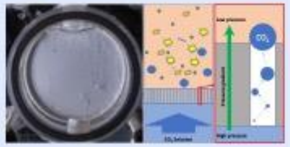
- Community water and wastewater treatment resilience and sustainability.
- Energy assessments for industrial processes.
- Ambient water quality and citizen science through Adopt-a-Stream.

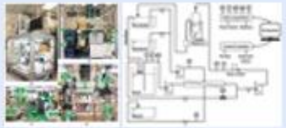
## RESEARCH HIGHLIGHTS



Partial Desalination: A new paradigm for cultivation of salt-tolerant food crops in controlled environment agriculture using brackish waters

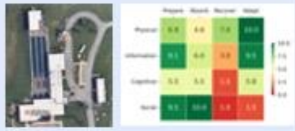
Supersaturated carbon-dioxide-enhanced backwash of ceramic microfiltration membranes





Automated testing apparatus for ceramic membrane filtration of high-strength industrial wastewater

Matrix-Based Resilience Assessment of Community Water Supplies



Energy and carbon footprint for animal rendering operations

## TAGS & COLLABORATIONS

- Membrane-based Water Treatment
- Surface and colloid science
- Fouling reduction
- Water Treatment Resiliency

### WE ARE INTERESTED IN COLLABORATORS WHO:

Work on infrastructure, social science, resilience, computational modeling, data science, etc. We need folks who can provide fundamental insight into what we do, as well as folks who can help us scale up and apply our work in the real world.

## LAB MEMBERS & CONTACT INFORMATION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Research Group Website https://davidladner.org


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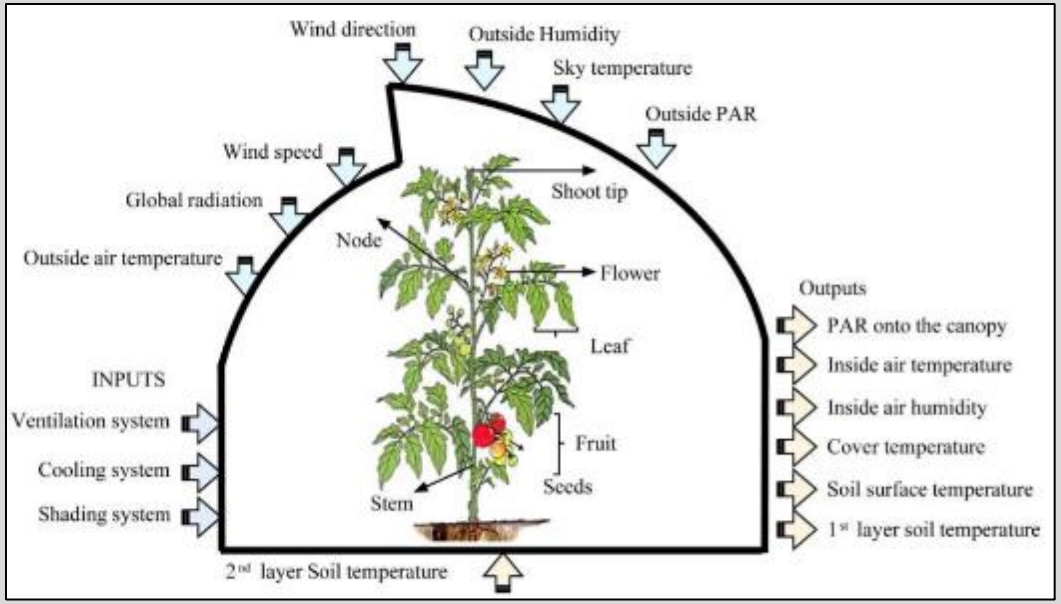
# Controlled Environment Agriculture (CEA)

- Greenhouses or modular containers
- Controlled water, light, temperature, & ventilation
- Soil-based or hydroponic
- Vertical farming = vertically stacked layers
- Rural, peri-urban, and urban CEA




Inputs and outputs of CEA (Shamshiri et al., 2018)

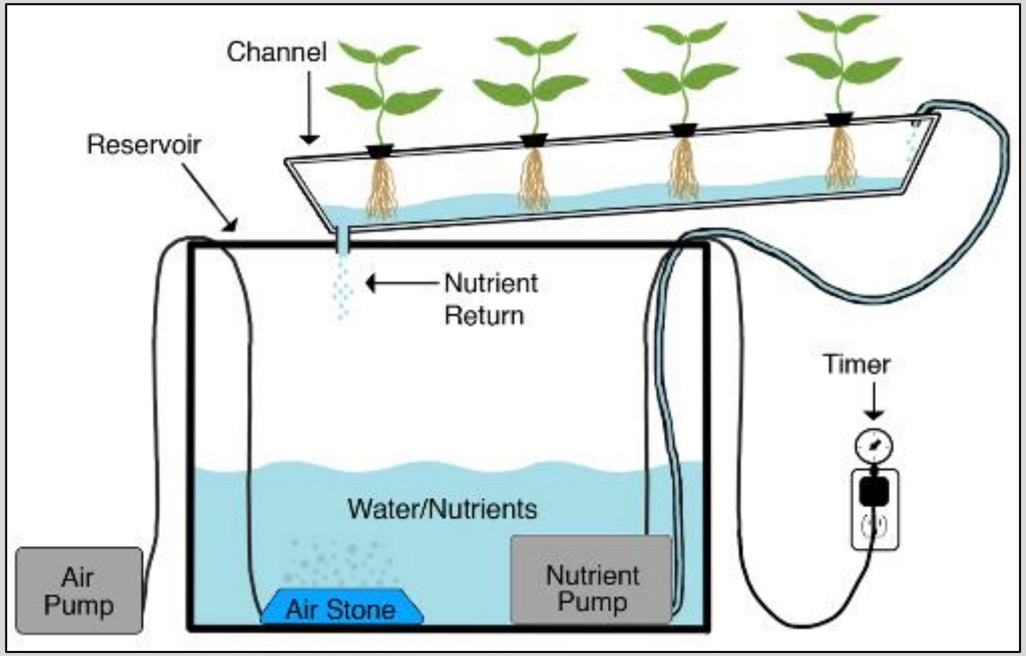
# Hydroponic CEA Platform

- High-value food crops that can be grown in hydroponic CEA
  - Leafy greens, tomatoes, cucumbers, beans, and strawberries
  - Water quality concerns:
    - Impacts of water quality on crop yield
    - Crop salt tolerance with saline/brackish water
    - Pathogens with reclaimed municipal wastewater
    - Plant bioaccumulation of metals etc. with urban stormwater

- Nutrient delivery
  - Nutrient Film Technique (NFT)
  - NFT solution recycling
    - Water and nutrient efficiency
    - Plant pathogen control

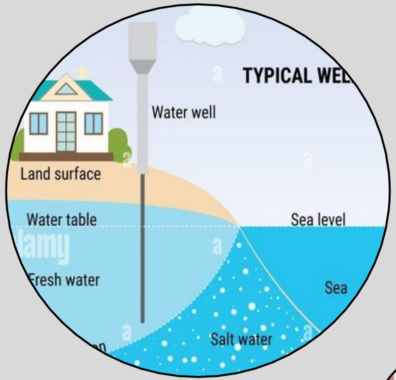
Leafy greens Tomatoes Cucumber

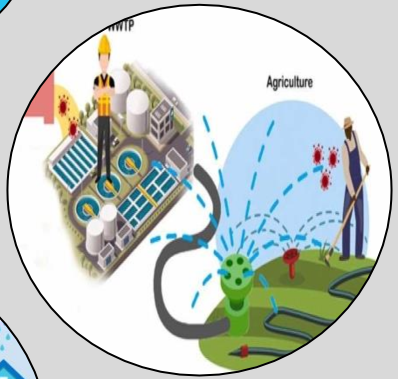
Beans Strawberries

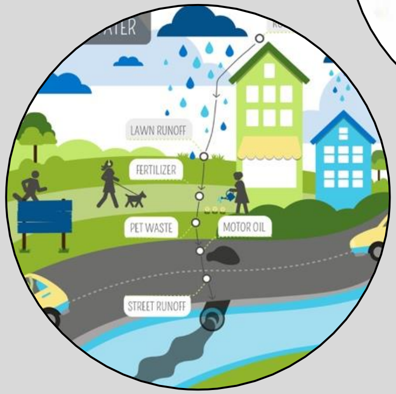



https://www.agritecture.com

# Water sources for agricultural irrigation

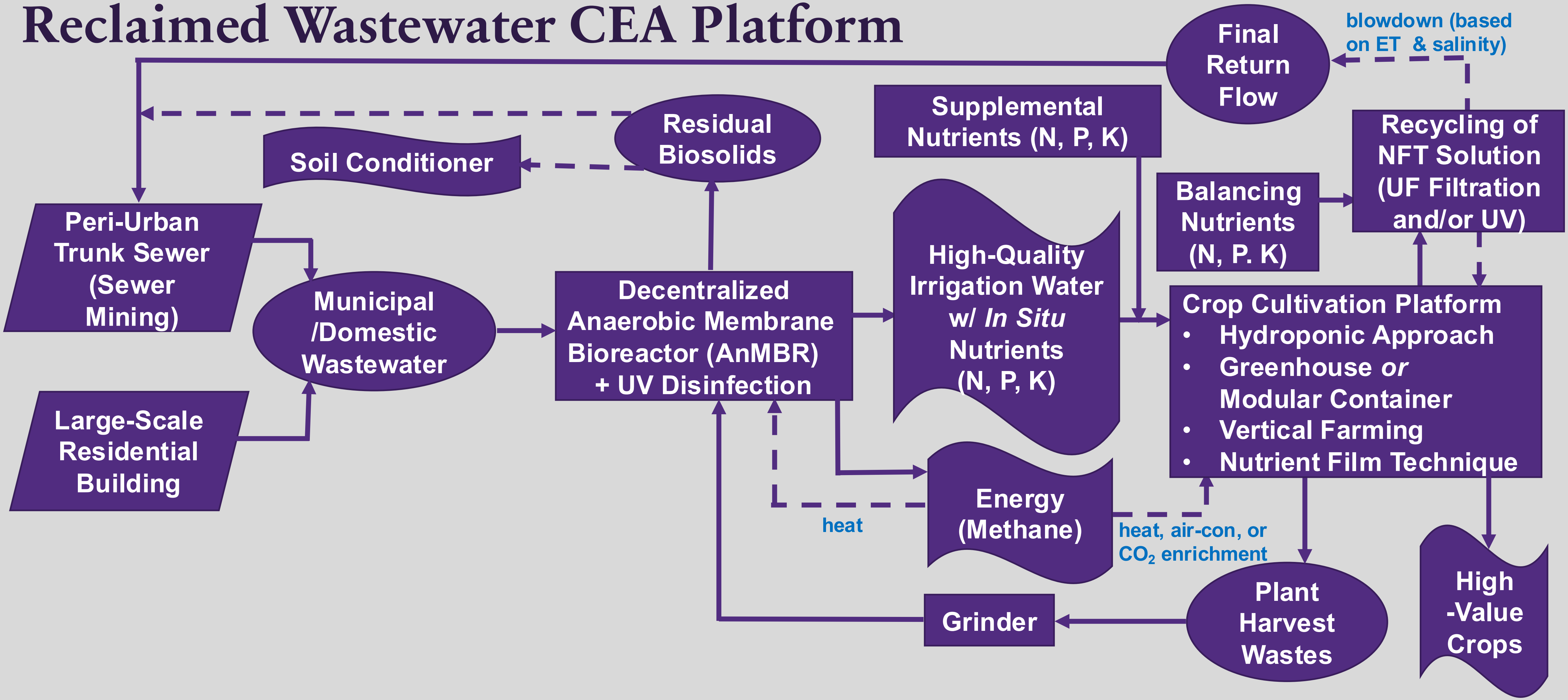


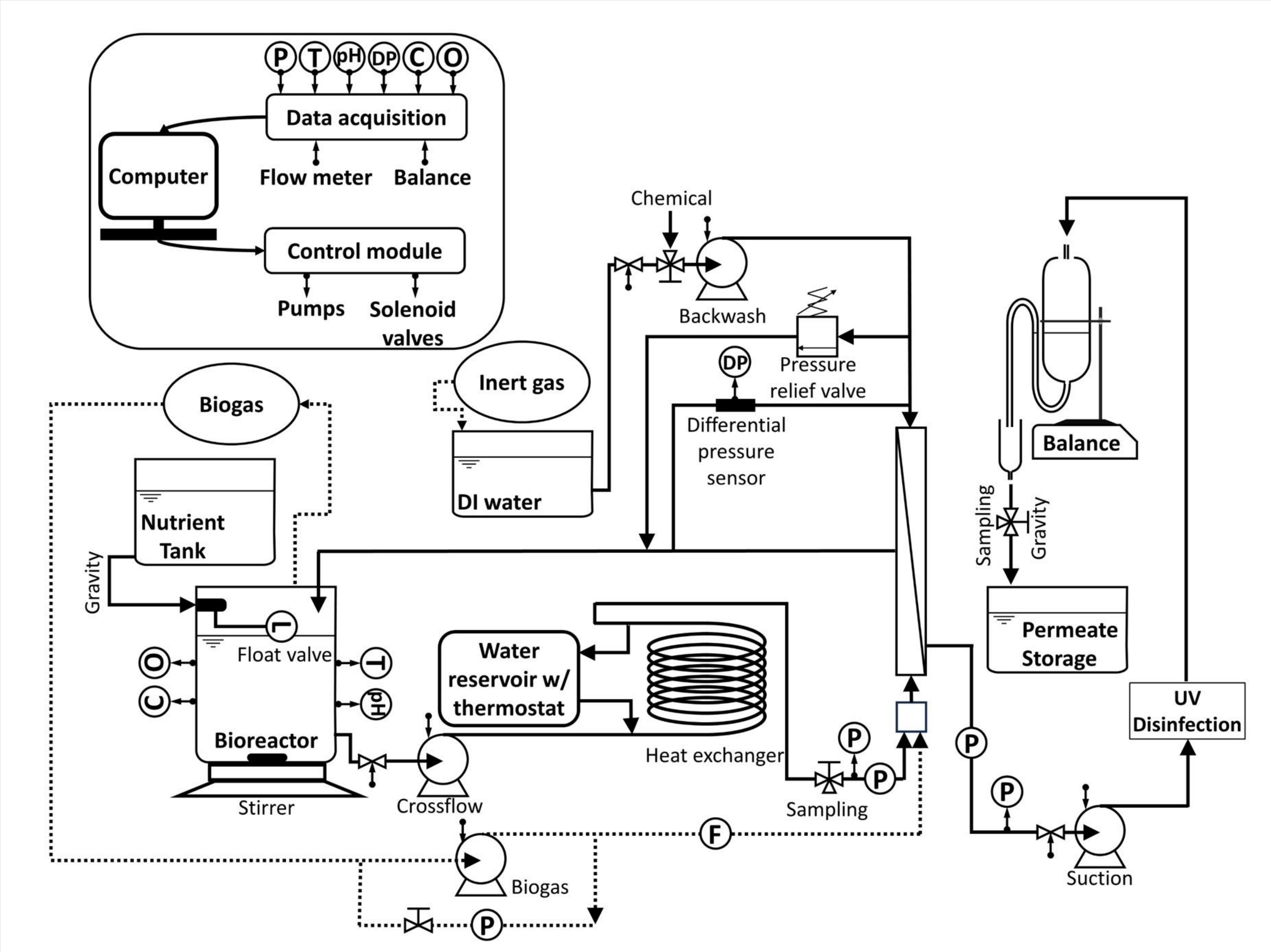

- Conventional sources
  - Freshwater from surface and groundwaters
  - Increasingly impacted by regional droughts
- Non-conventional (marginal quality) sources
  - Saline/brackish surface and groundwaters (rural)
    - Salinity
  - Reclaimed municipal wastewater (centralized and decentralized)
    - Human pathogens and chemical micropollutants, and plant pathogens
    - Attribute: presence of nutrients (P & N)
  - Urban stormwater (urban and peri-urban)
    - Heavy metals, hydrocarbons, pesticides, PFAS, microplastics

# Reclaimed Wastewater CEA Platform




**Decentralized integrated hydroponic CEA/NFT platform: Novel Wastewater Reclamation Scheme**

# The AnMBR system realizes full automation and high-frequency data acquisition.




Bioreactor volume: ~9.6 L

Temp: 35 ° C

Typical HRT: 18 hr

Typical SRT: multiple months

Typical OLR: 4 g/L/day

Data acquisition: 4-5 Hz

P: pressure

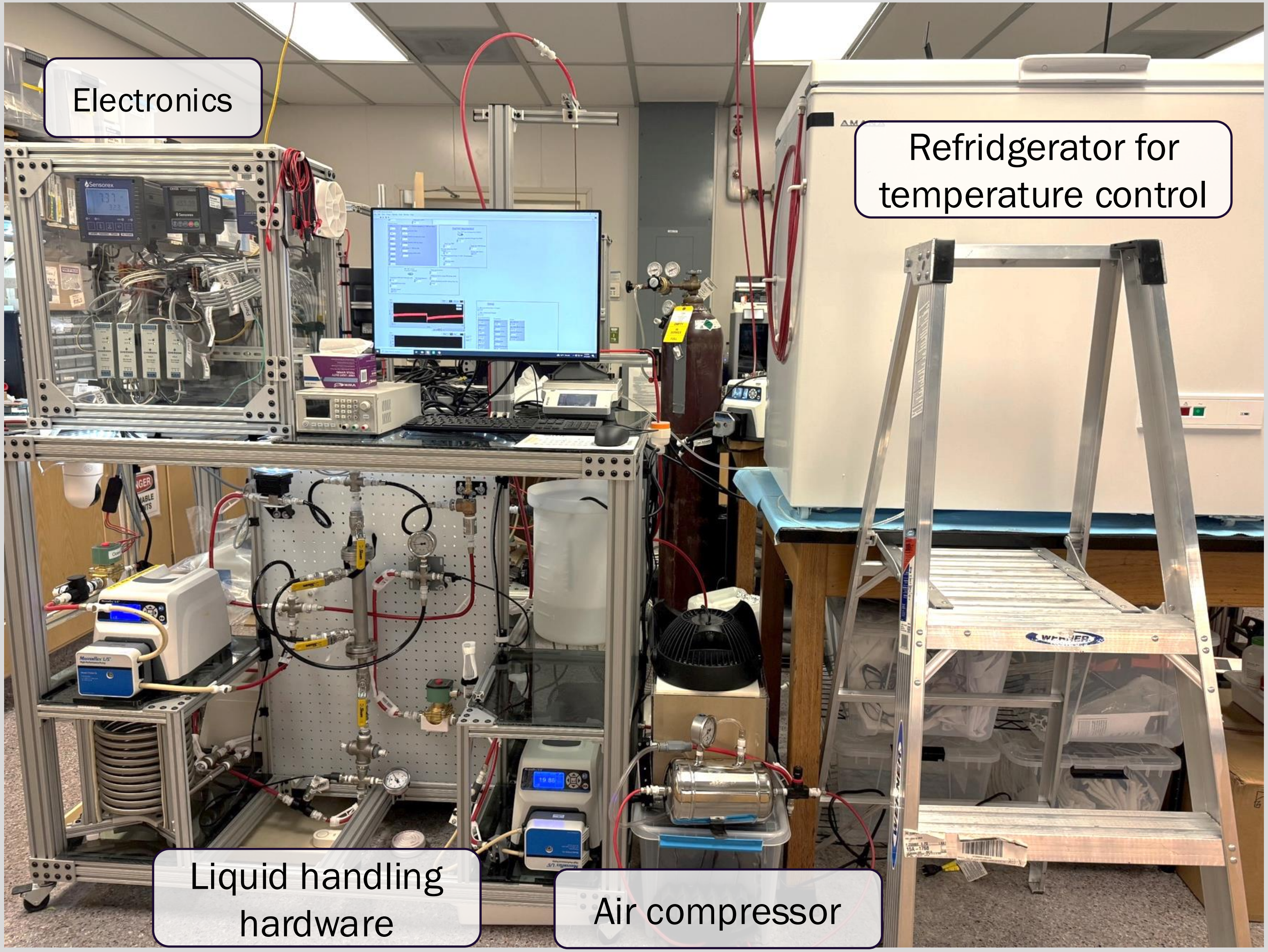
F: flowrate

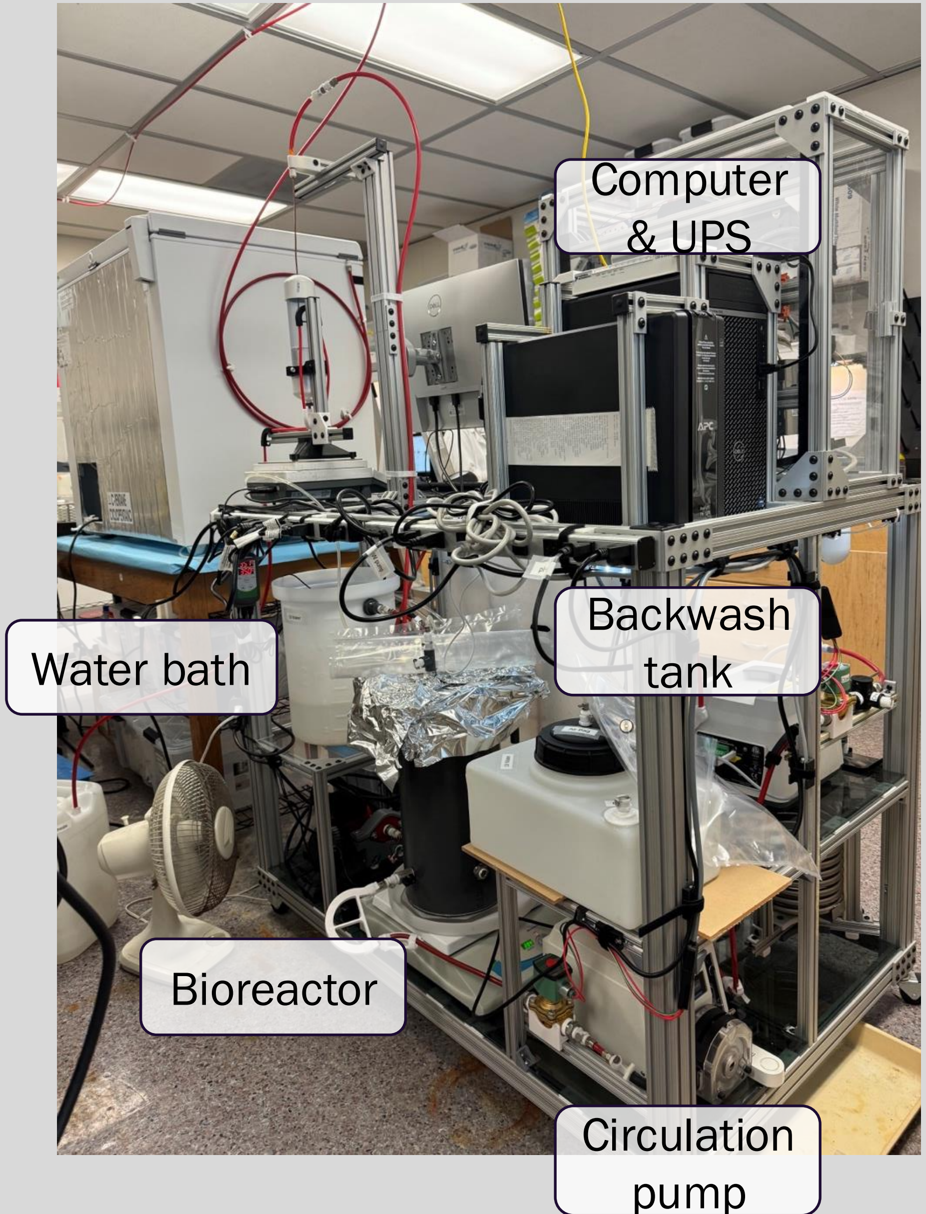
O: ORP

C: conductivity

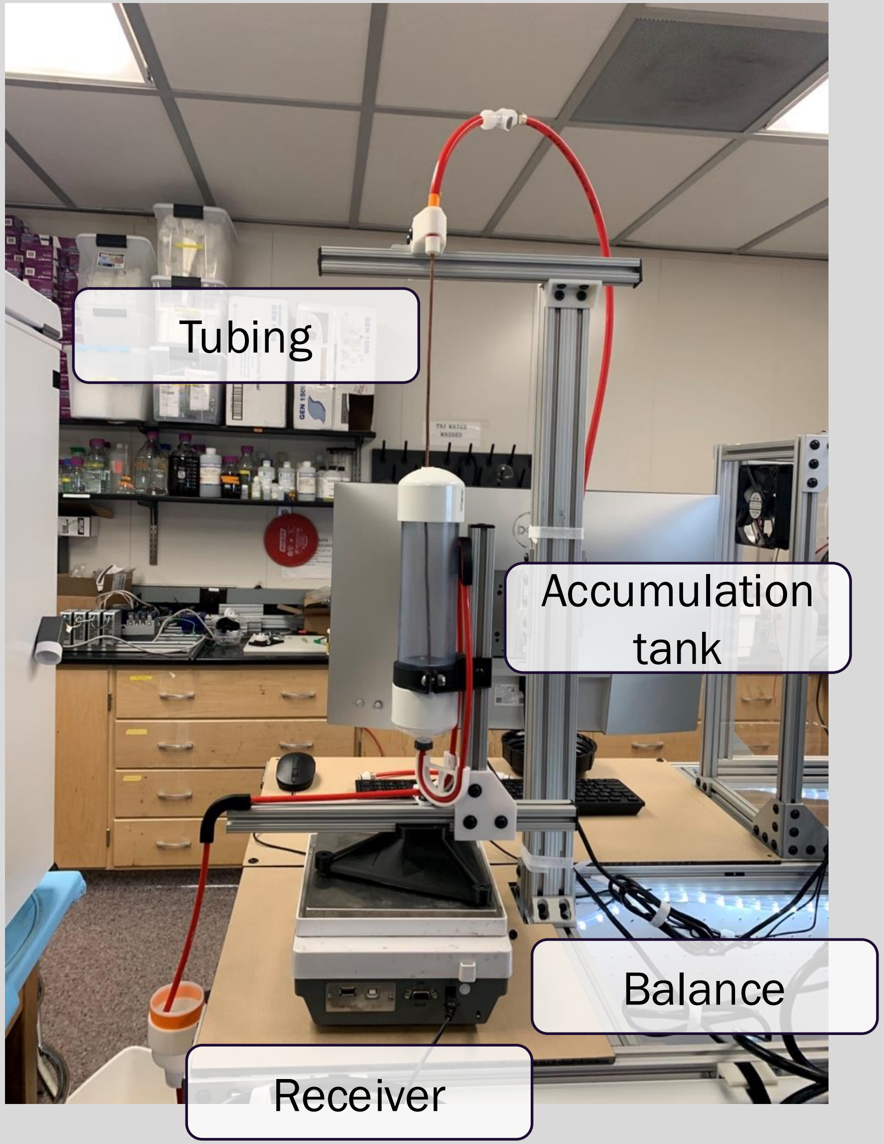
DP: differential pressure

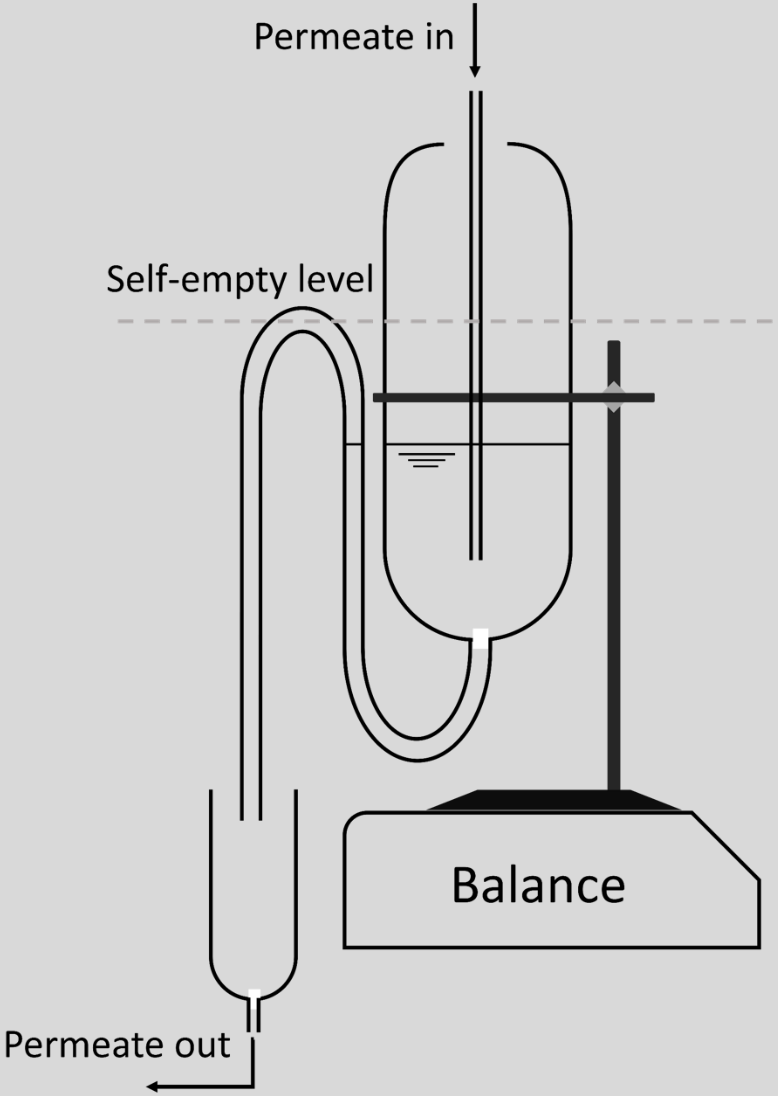
# An automated AnMBR was constructed for continuous operation with minimal operator time commitment.



# We built a flow meter using a balance and a “toilet” mechanism.

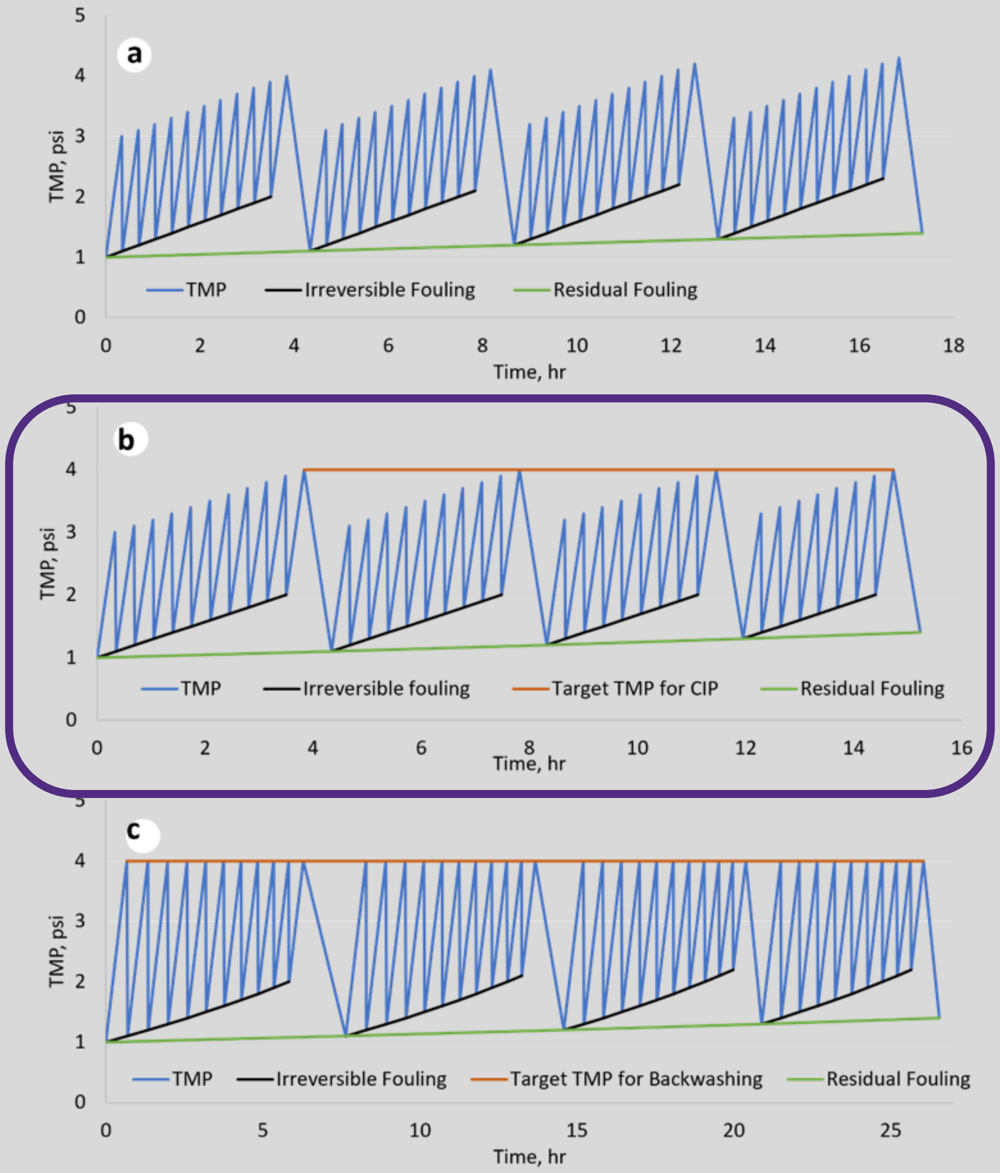


# Filtration, backwash, and cleaning conditions

- Filtration:
  - Duration: 30 minutes
  - Flux: 3.4-9.4 LMH
  - Crossflow velocity: 0.12 – 0.19 m/s
- Backwash
  - Trigger: every 30 minutes
  - Duration: 5 seconds
  - Strength: 169 LMH (limited by pump)
  - DI water
- Super backwash
  - Trigger: TMP > 5 psi
  - Duration: 30 seconds
  - Strength: 169 LMH
  - DI water

# The program was coded in LabVIEW for full automation.




- Cleaning strategies are the combinations of backwash and CEB triggers.
  - Backwash
    - Time
    - TMP
  - Chemical enhanced backwash
    - Time
    - TMP
    - Duration

- Filtration is controlled with the following criteria
  - Constant flux
  - Constant TMP
  - Constant pump speed

Qi, Weiming, & David A. Ladner. Journal of Environmental Engineering, 2023, 149(10): 04023063.

# We are augmenting the AnMBR with harvest waste for resource recovery.

# Harvest waste collection

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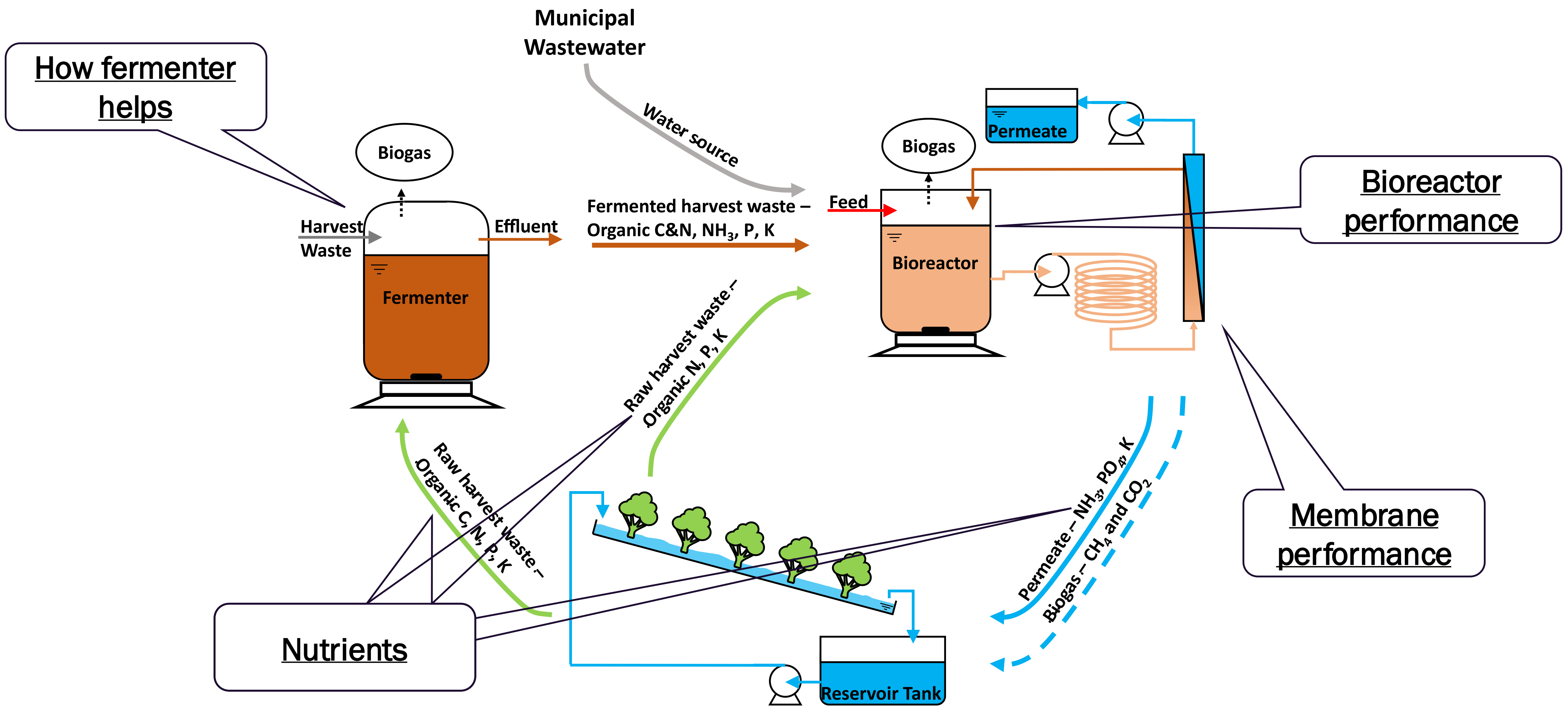
# Cotreatment of harvest waste and municipal wastewater



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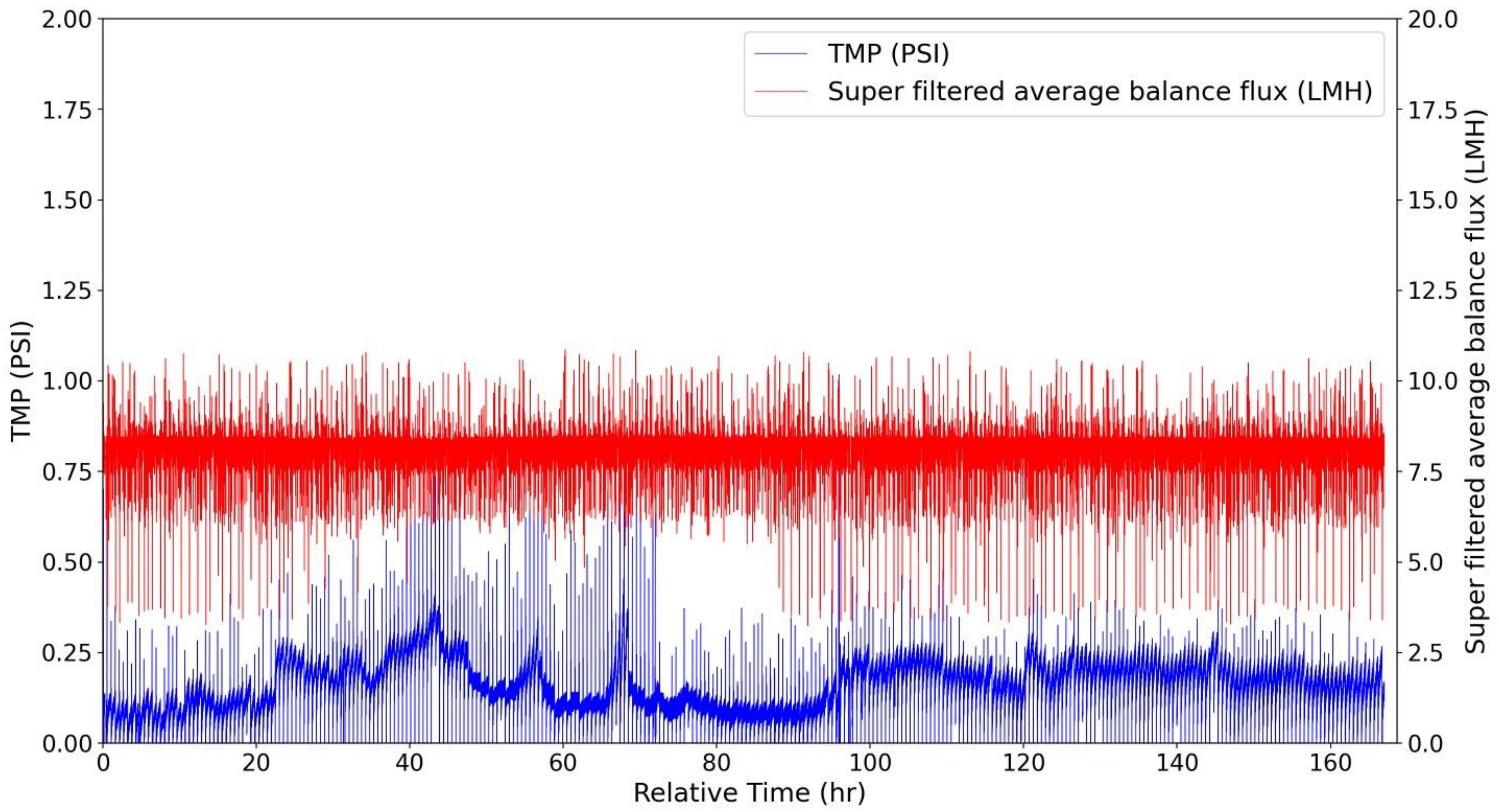
# Membrane performance - Raw data



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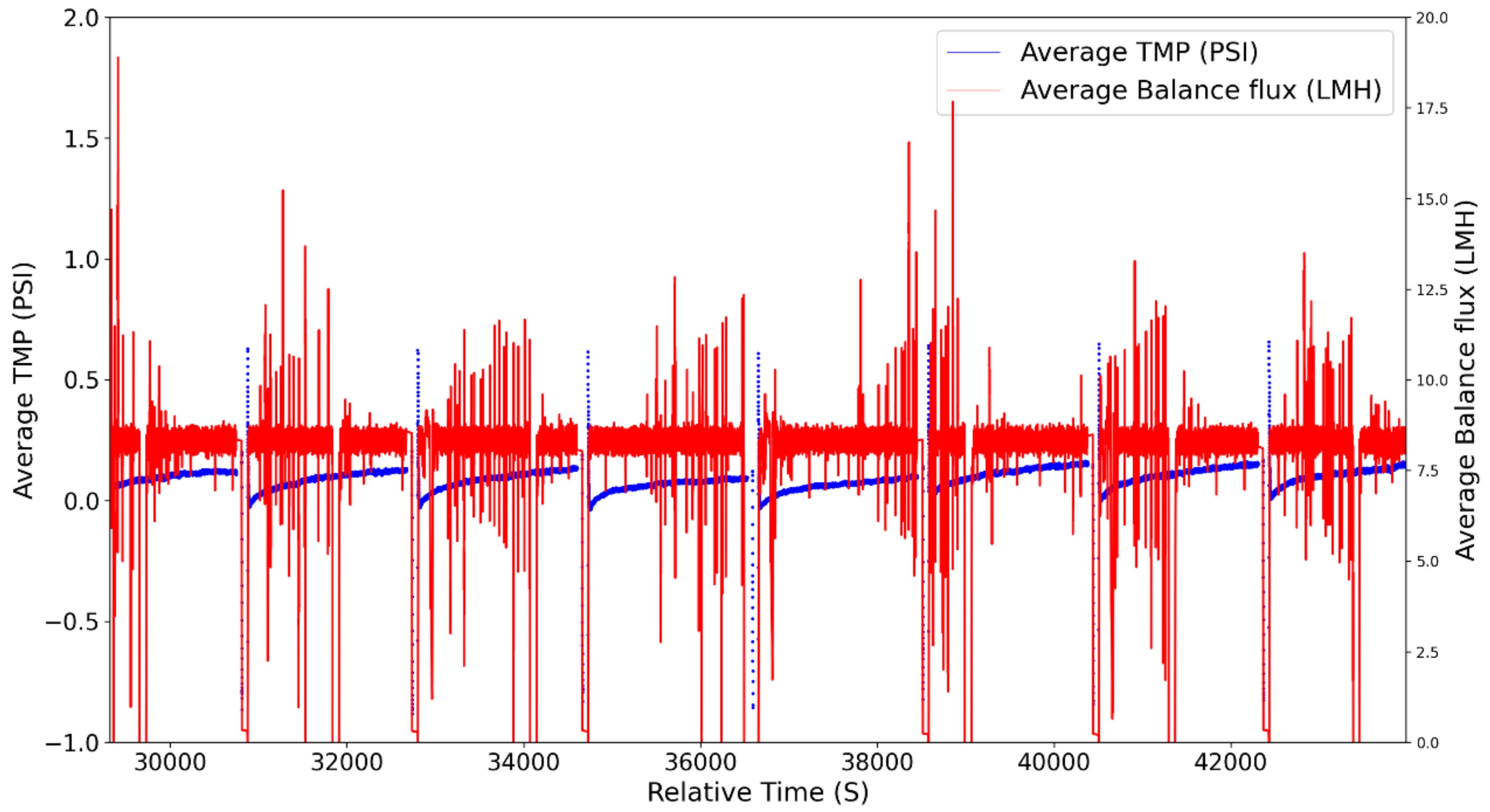
# Membrane performance – Raw data



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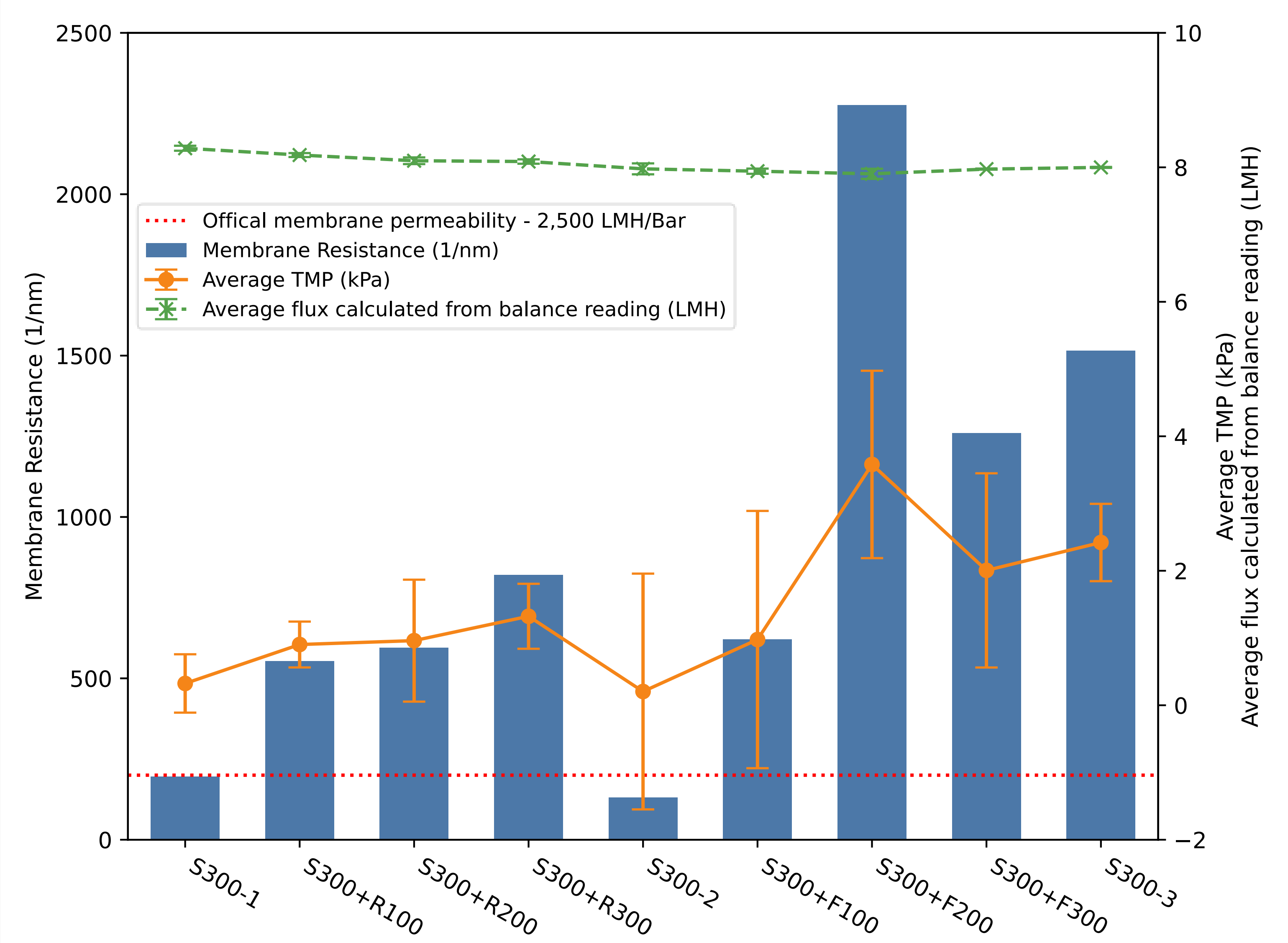
# Membrane performance - Resistance



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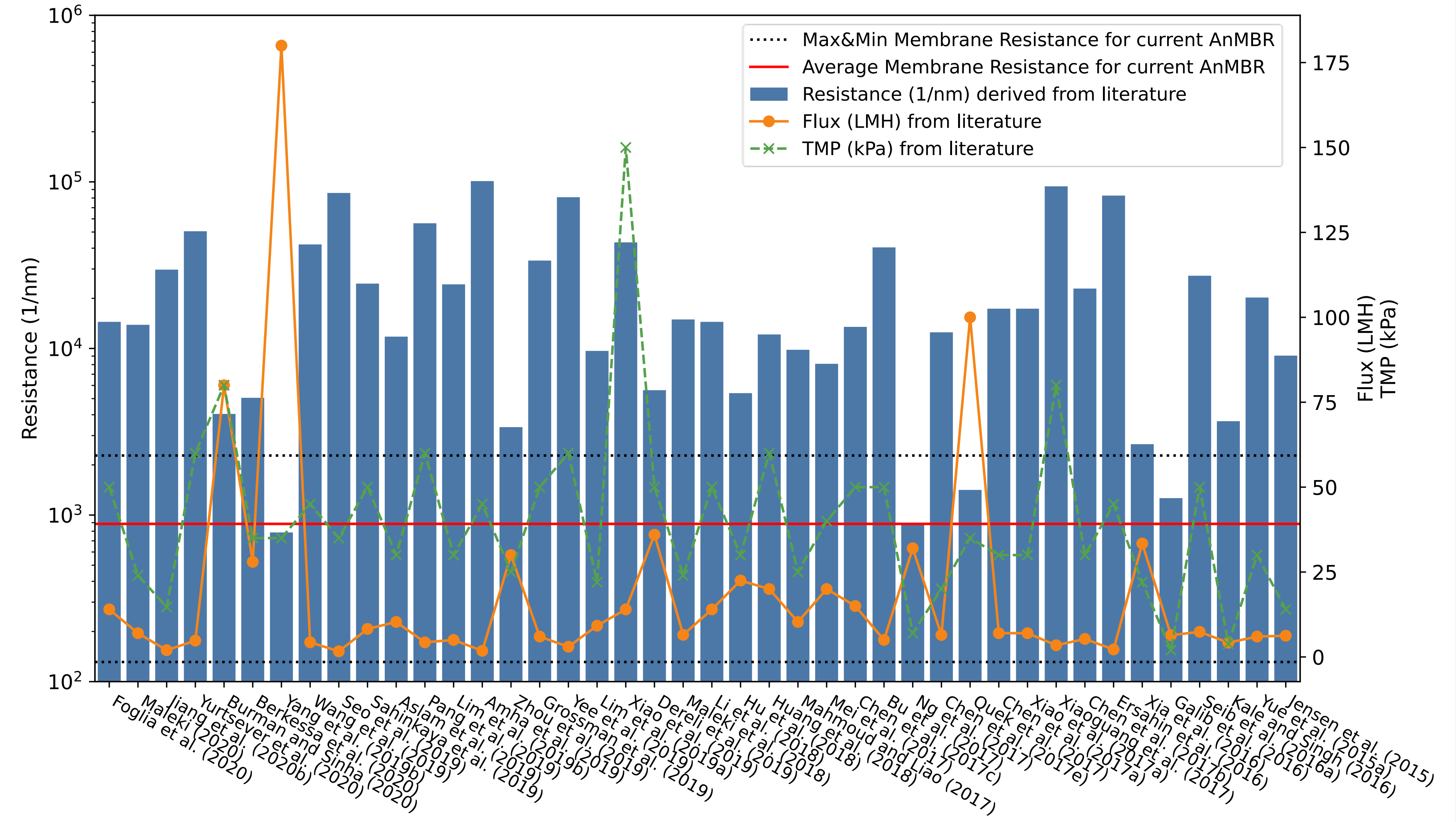
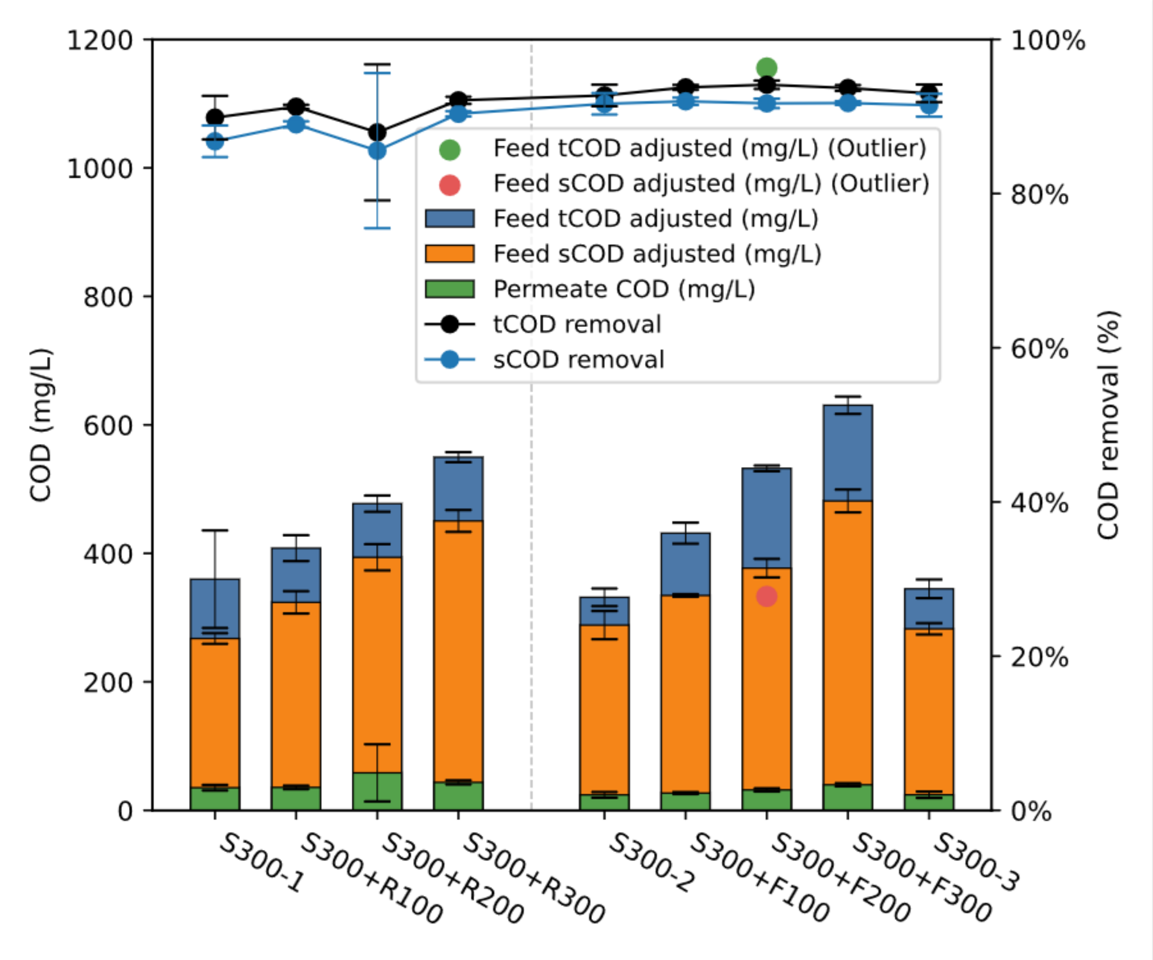
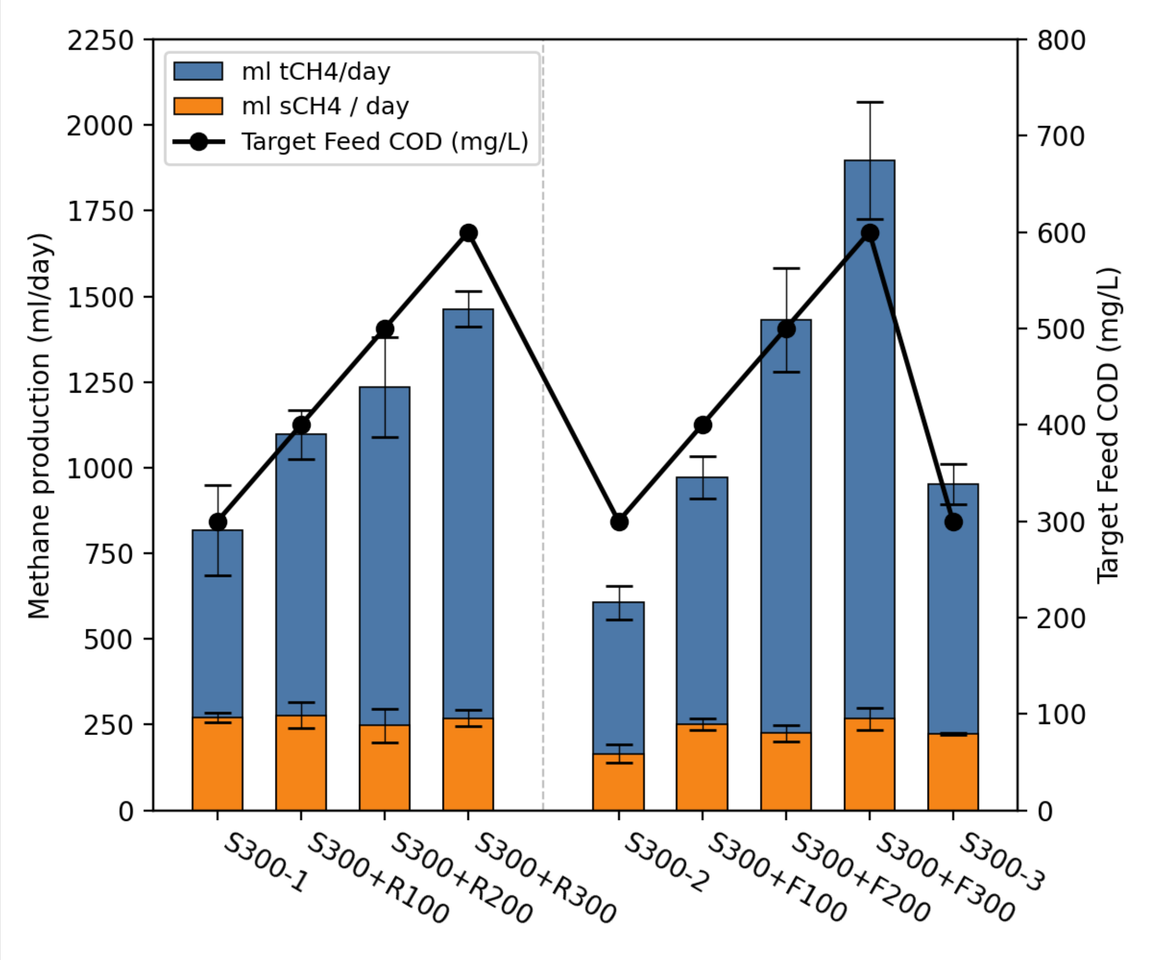
# Membrane performance - Resistance



# Bioreactor performance



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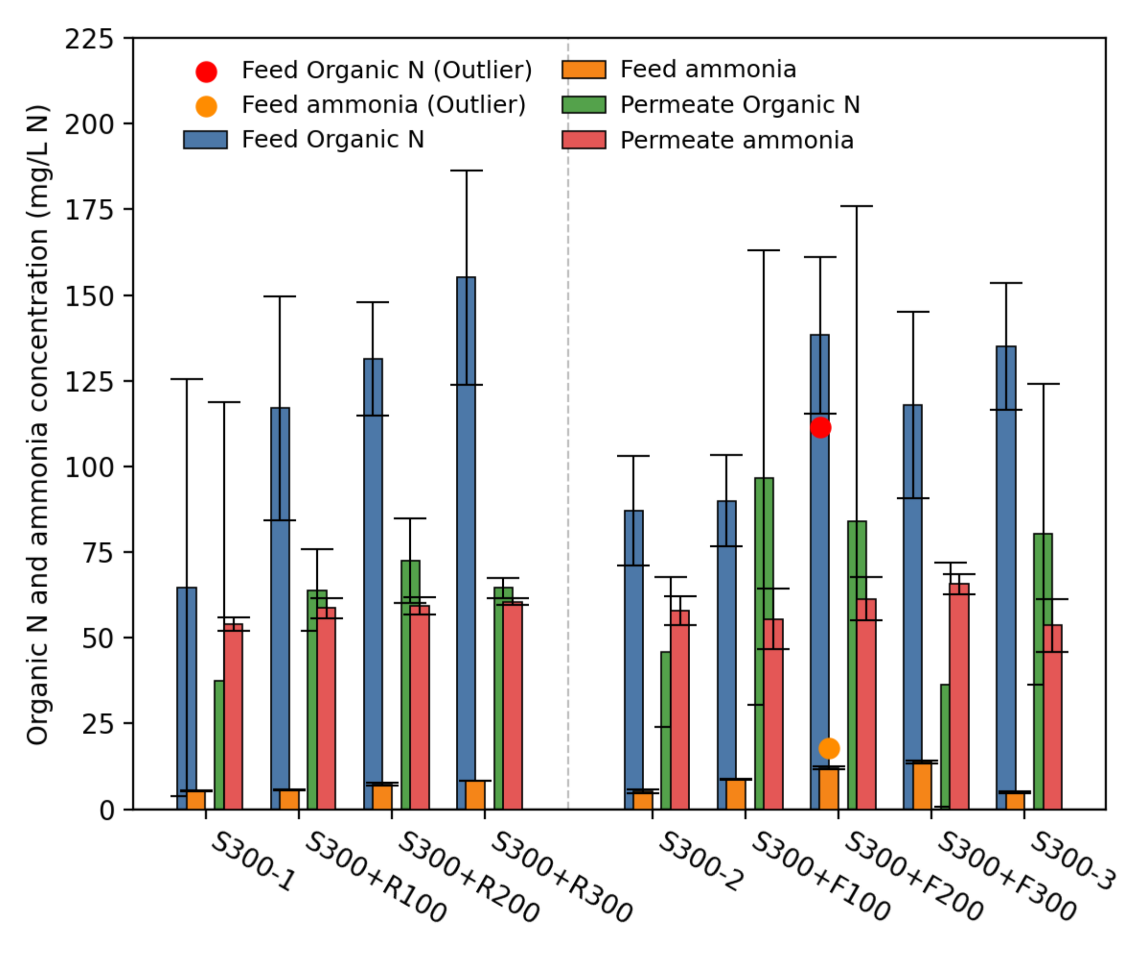
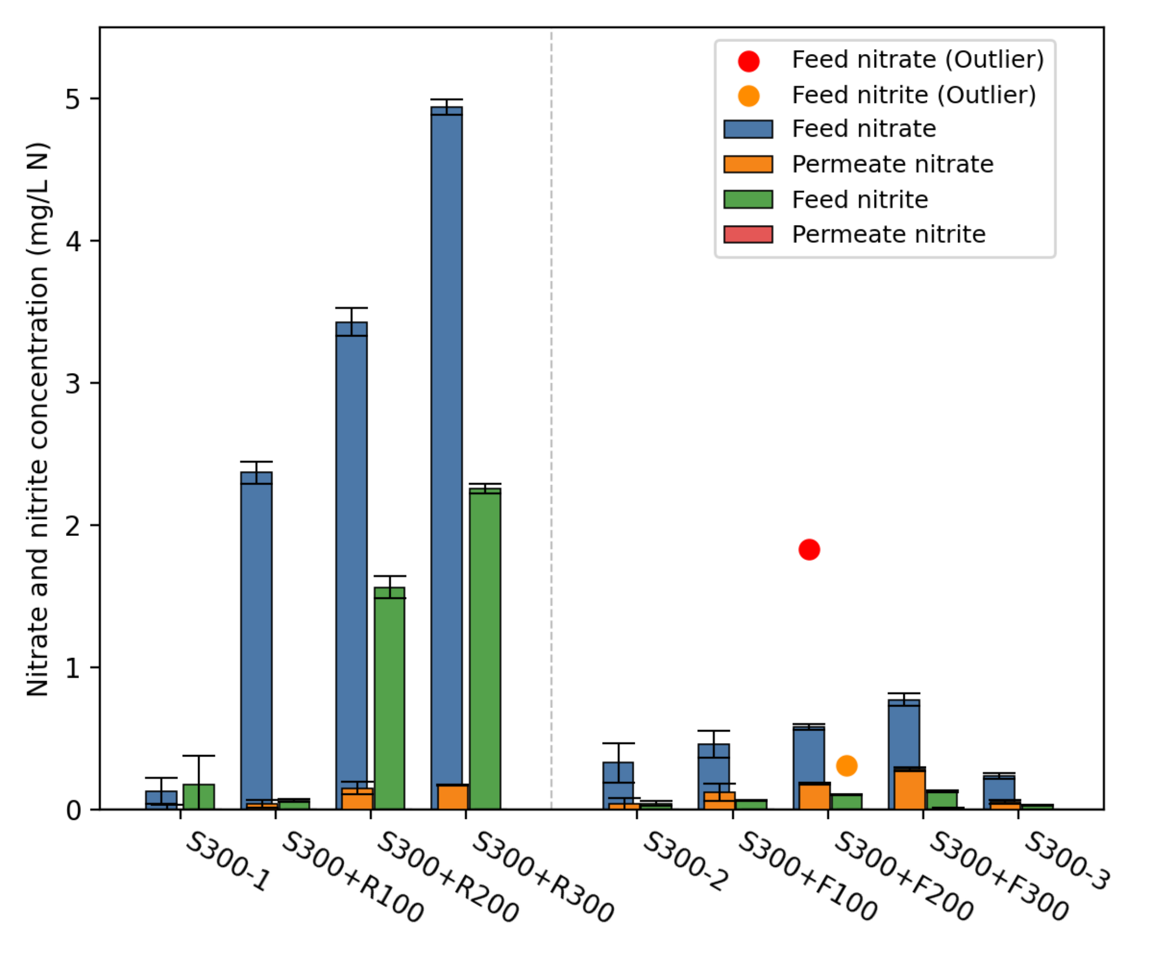
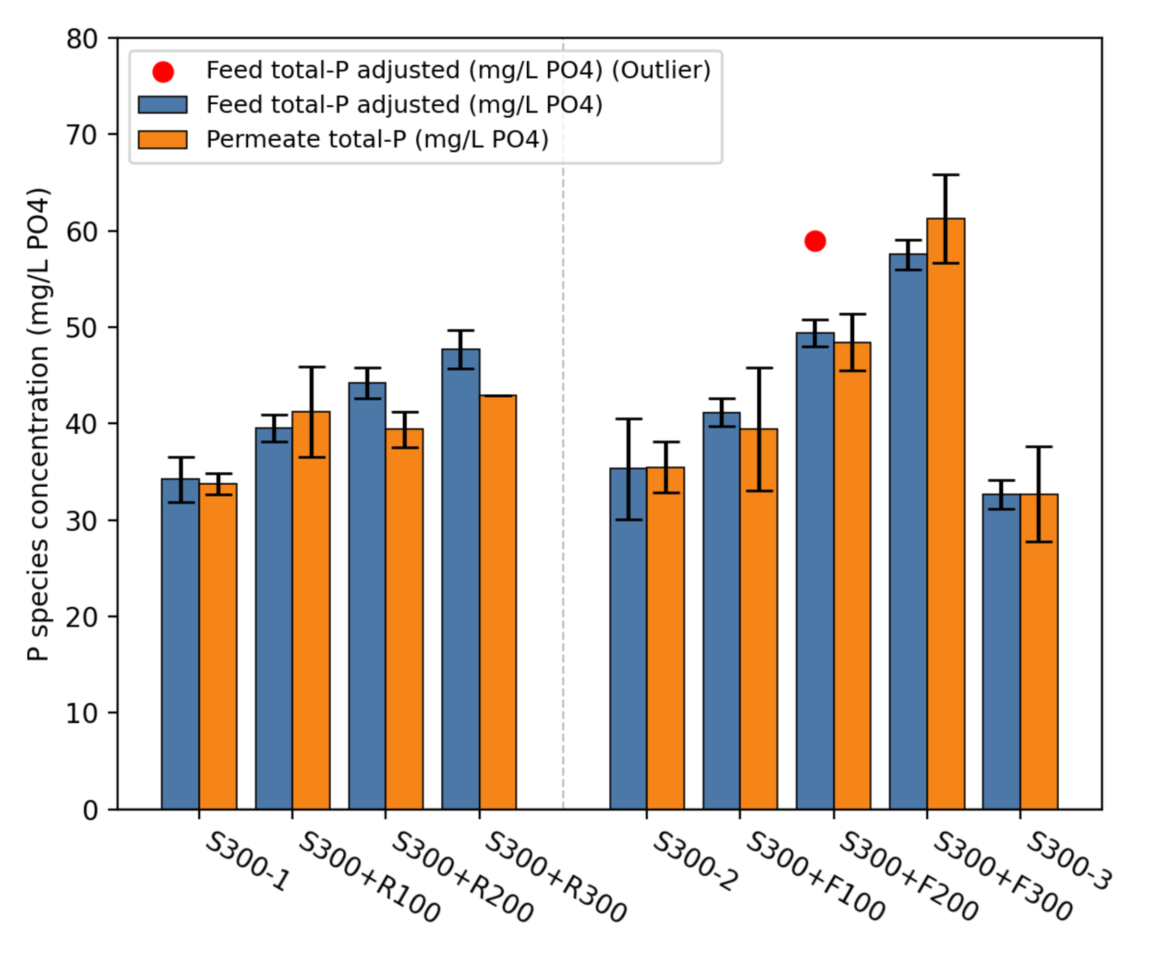
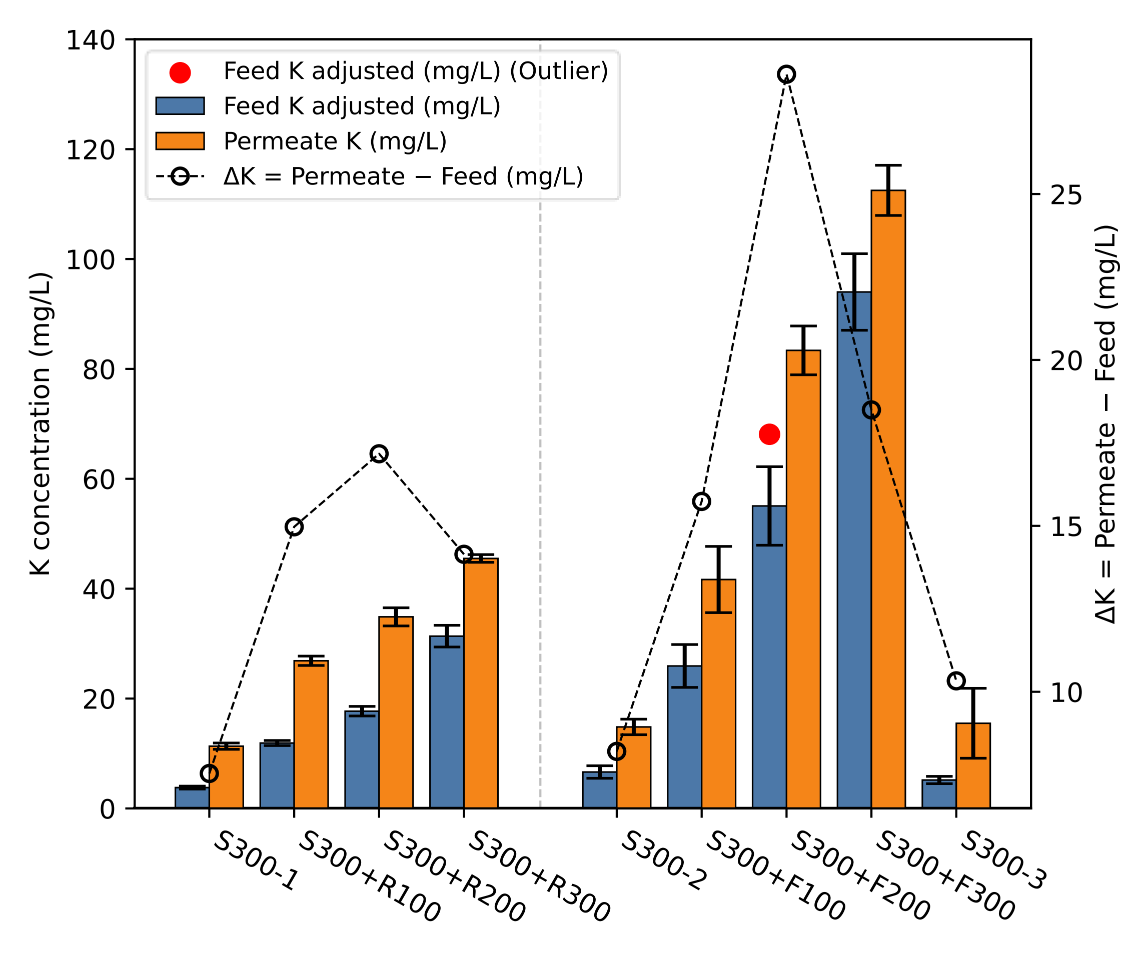
# Nutrients - N



# Nutrients – P and K



4201 2nd Street Southwest, Albuquerque, NM

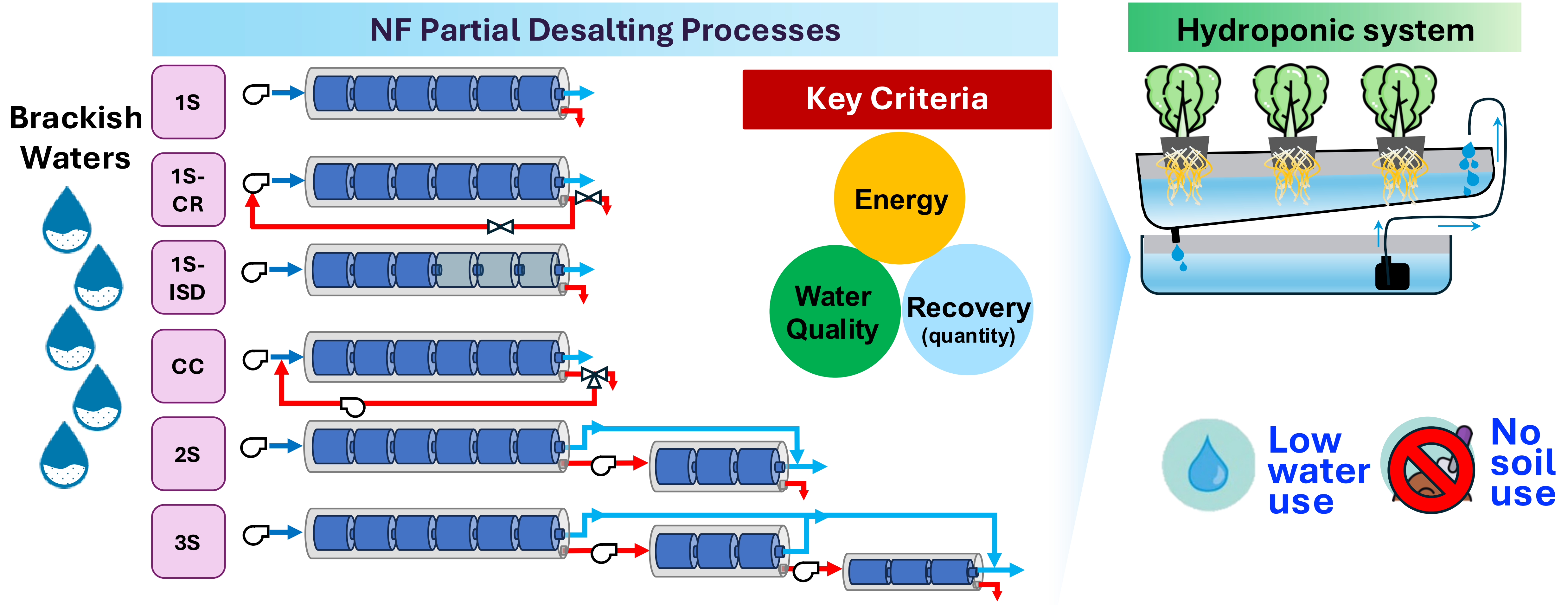
# Partial Desalination Using Reverse Osmosis and Nanofiltration for Salt-Tolerant Hydroponic Crops

Jing-Hua Tzeng, David A. Ladner, W. Shane Walker, Clinton Williams, Geethakrishna Puligundla, R. Karthikeyan, & Gary Amy

Department of
ENVIRONMENTAL ENGINEERING
AND EARTH SCIENCES
Clemson University

# Goal

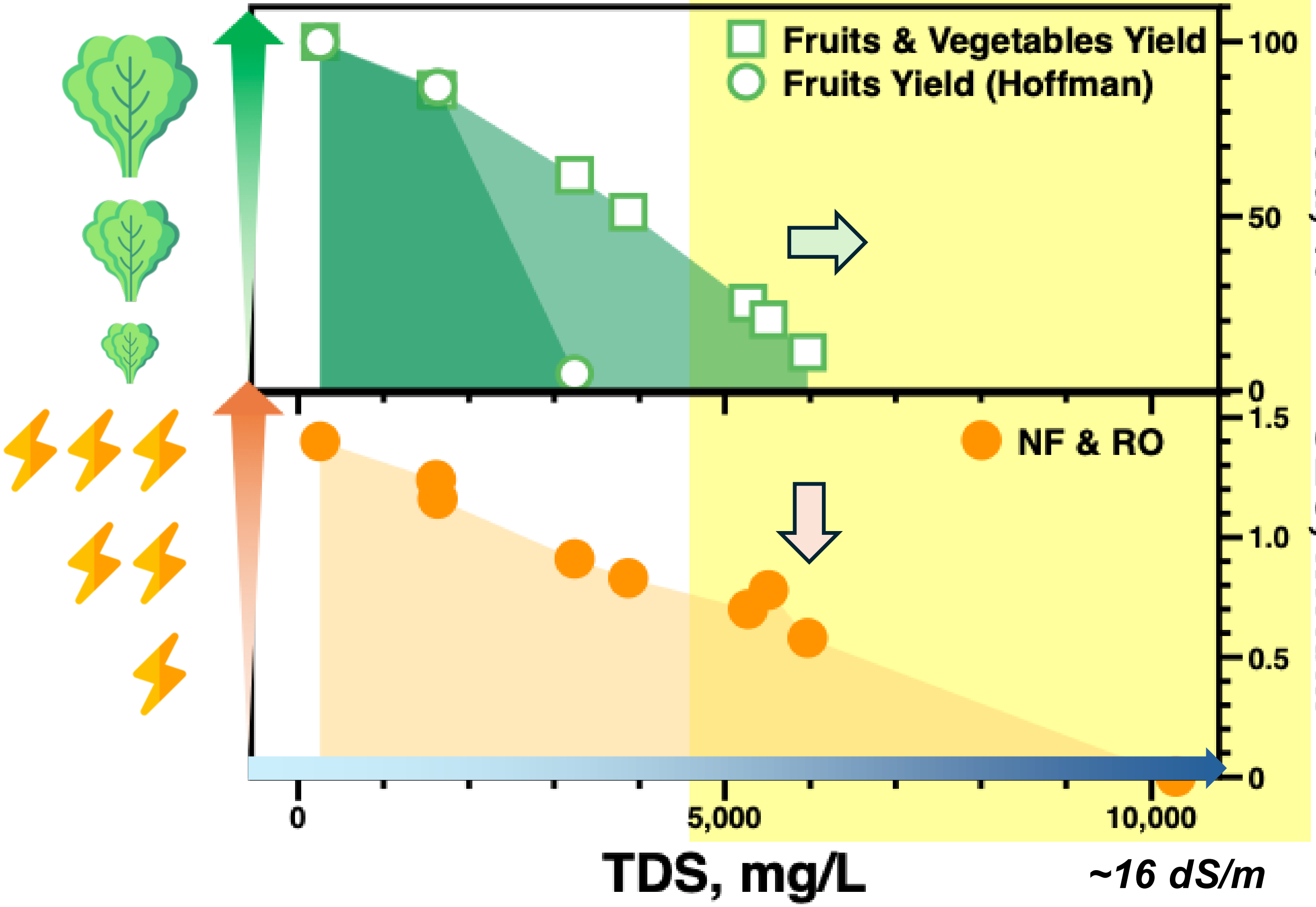
- To develop a new paradigm of desalination for the agriculture sector, **partial desalination (focus on NF innovations)** whereby tailored water quality is produced in accordance with the salinity tolerance of target crops.




(Tzeng et al., Desalination 613 (2025) 119072)

# *Crop* Yield, *Water* Quality (TDS) & *Energy* Consumption of Different Desalting Scenarios

**Save the freshwater for drinking water purposes**




***Food***

Specific ***Energy*** Consumption (SEC)

***Water***

Diluted Seawater (**SW**) @10,000 mg/L simulate a coastal groundwater aquifer

(Data source: Tzeng et al., (2025), Maas and Hoffman (1977), Wallender and Tanji (2011), and International Water Management Institute (IWMI, 2004).

# Desalting processes

Department of ENVIRONMENTAL ENGINEERING AND EARTH SCIENCES
USDA Agricultural Research Service U.S. DEPARTMENT OF AGRICULTURE

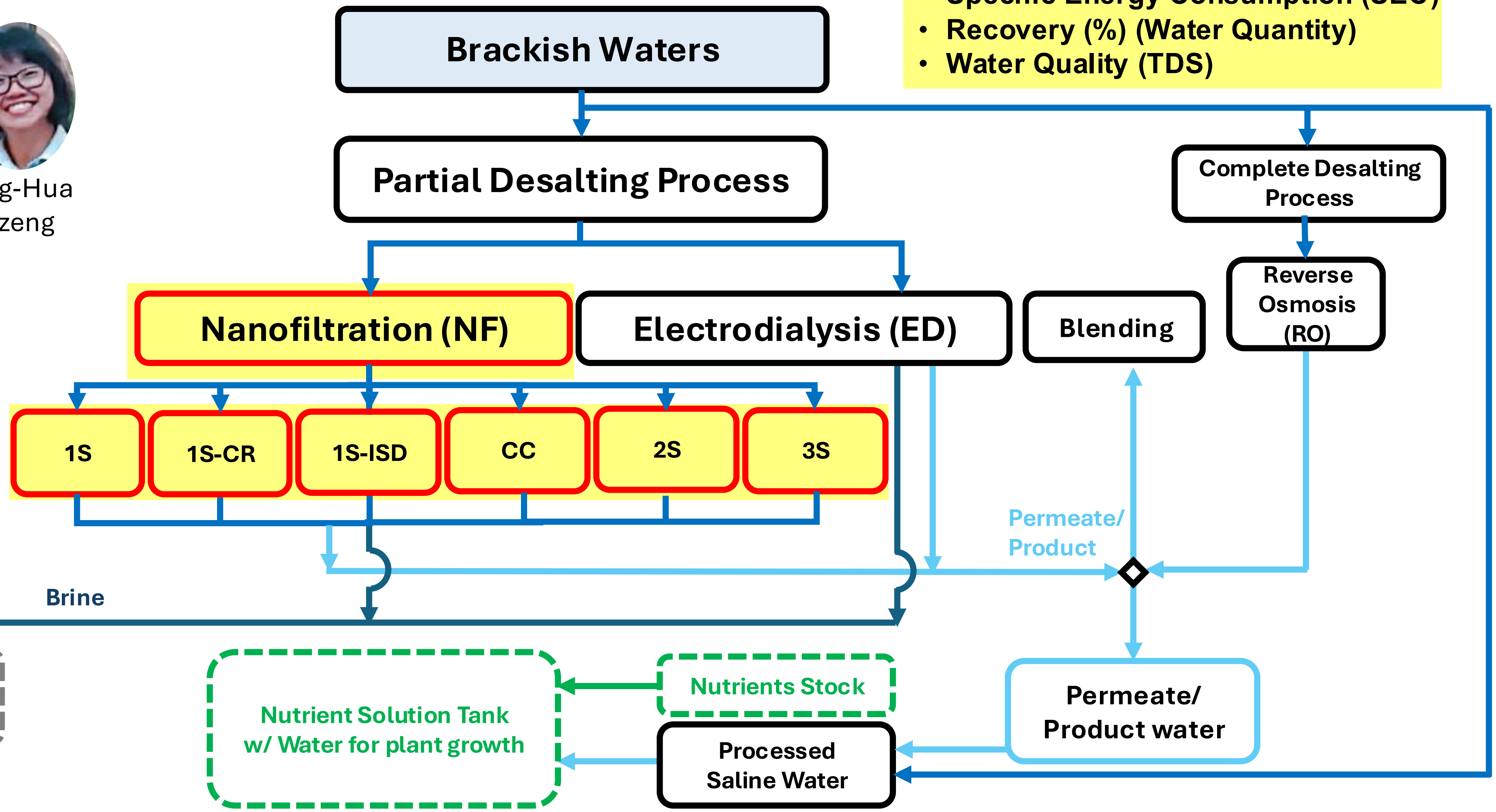
Gary Amy
David Ladner
Clinton Williams
Jing-Hua Tzeng

**Evaluation Criteria:**
- Specific Energy Consumption (SEC)
- Recovery (%) (Water Quantity)
- Water Quality (TDS)

## Water Quantity:

Feed water (100%)
– Recovery %
(= Product/Feed)

= Brine %




Brine Management

# Nanofiltration (NF) Modeling

## Input

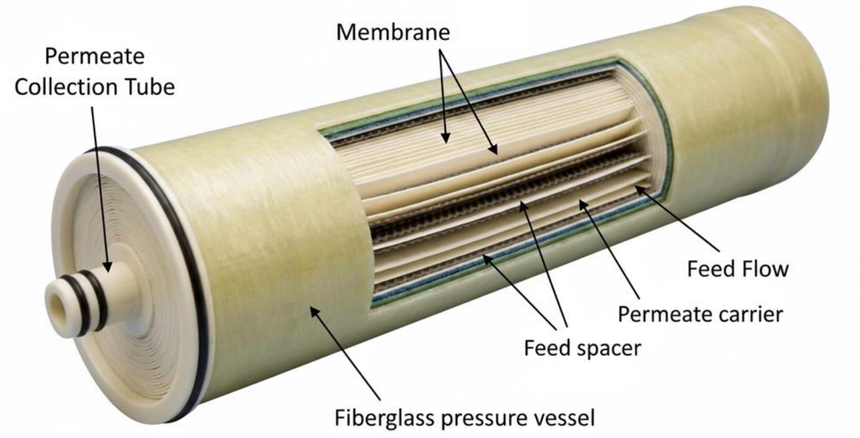
1. Feed Flowrate: 2.1 $m^3/h$
2. Feed TDS: 10,000 mg/L
3. Variable:
   - # of Stage: 1, 2, 3
   - # of pressure vessels (PV): 1 per stage
   - # of elements per PV:
     - 6 at 1st stage,
     - 2 to 4 at 2nd stage;
     - 3 at 3rd stage (2.5-inch element)
4. Feed pressure (1st stage): 10-40 bar
5. Boost pressure (2nd and 3rd stages): 20-40 bar
6. Concentrate recycle
7. Internally staged design (ISD)
8. Closed circuit
9. Membrane type: NF90, NF200, BW30

## WAVE

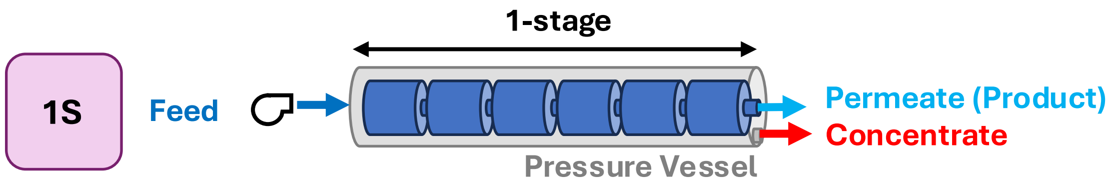
DuPont

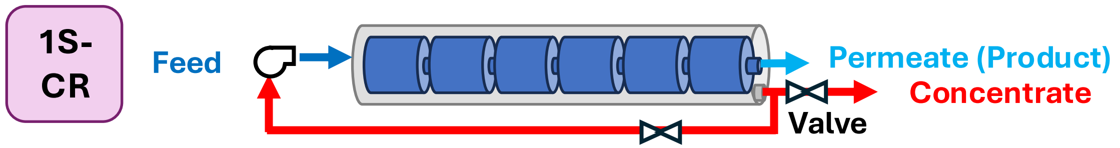
## Output

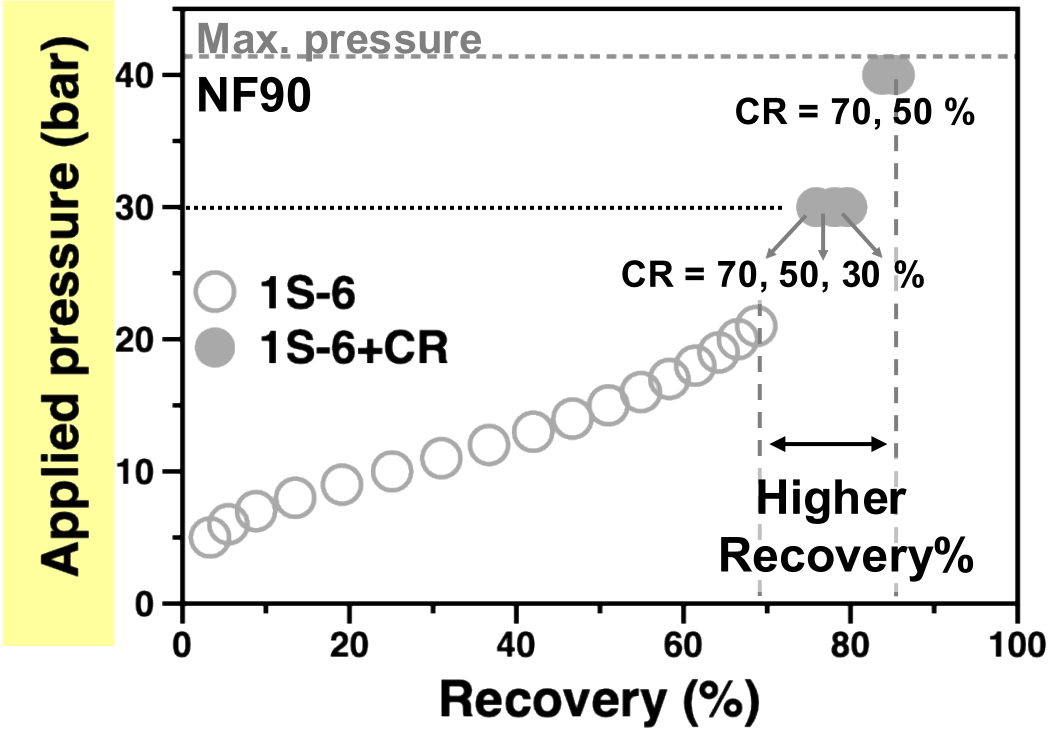
1. Flowrate ($m^3/h$): Feed, Conc., Permeate
2. Perm Flux (LMH)
3. Recovery (%)
4. Feed pressure (bar)
5. Water quality:
   - TDS (mg/L): Feed, Conc., Perm.
   - Ion concentration: Feed, Conc. Perm.
   - pH
6. Utility & Chemical cost
   - SEC ($kWh/m^3$)

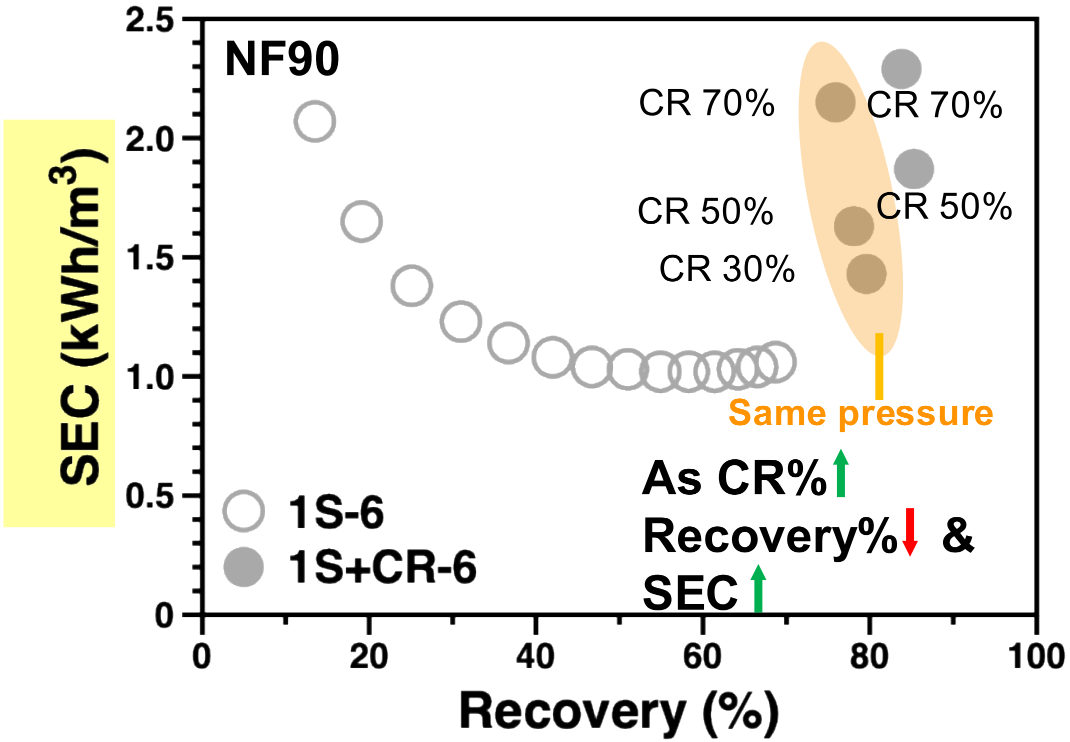


# 1S vs. 1S-CR


1S
1-stage
Feed
Permeate (Product)
Concentrate
Pressure Vessel

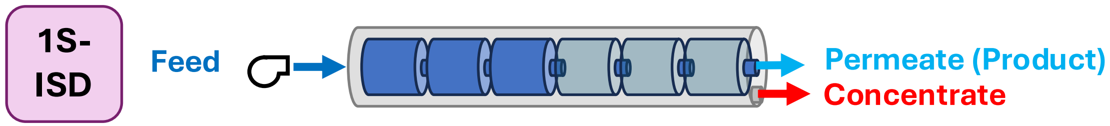

1S-CR
Feed
Permeate (Product)
Concentrate
Valve

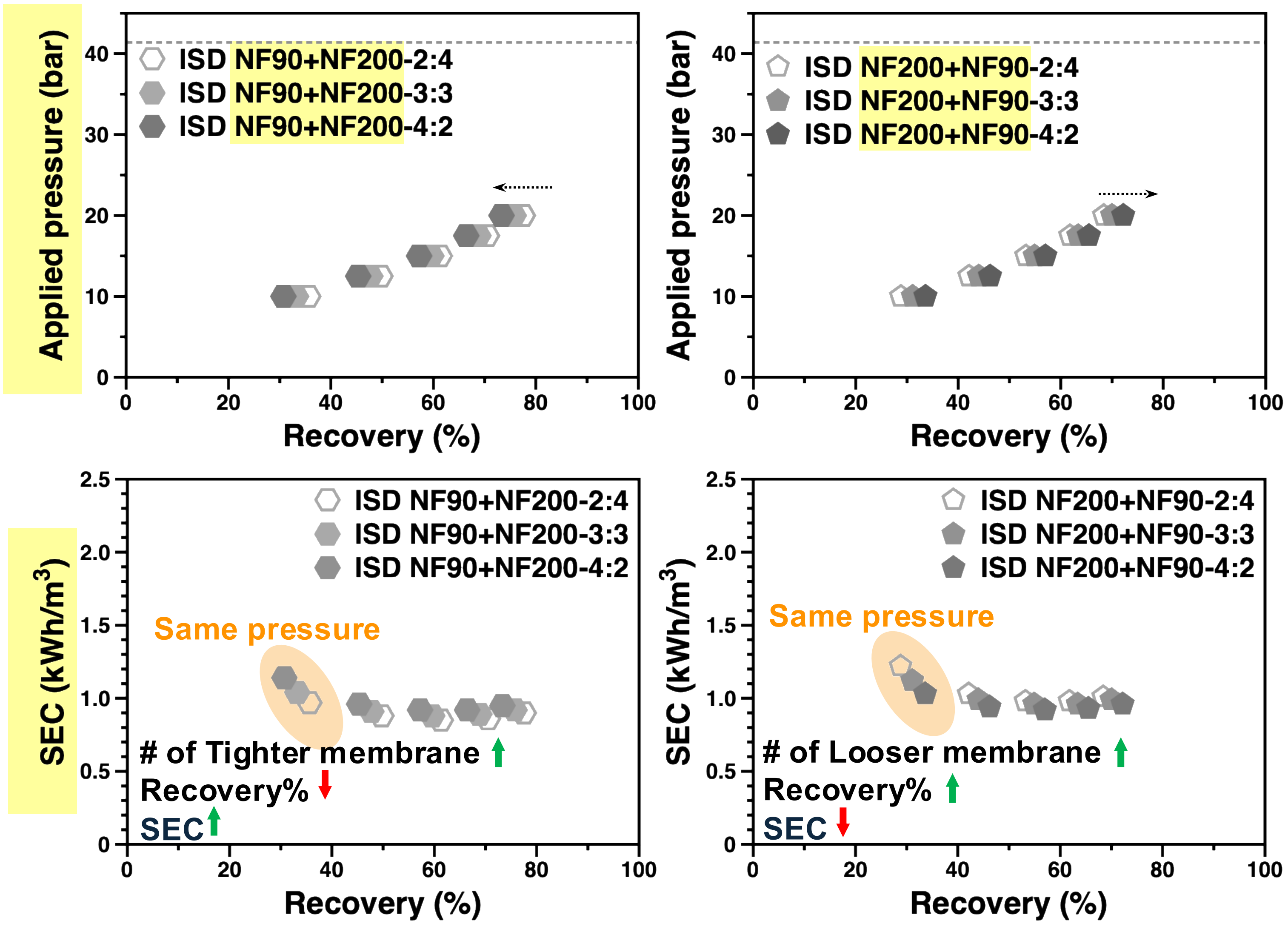

Applied pressure (bar)
Max. pressure
NF90
CR = 70, 50 %
CR = 70, 50, 30 %
1S-6
1S-6+CR
Higher Recovery%
Recovery (%)
0
10
20
30
40
0
20
40
60
80
100


SEC (kWh/m³)
NF90
CR 70%
CR 70%
CR 50%
CR 50%
CR 30%
Same pressure
As CR%
Recovery% &
SEC
1S-6
1S+CR-6
Recovery (%)
0
0.5
1.0
1.5
2.0
2.5
0
20
40
60
80
100

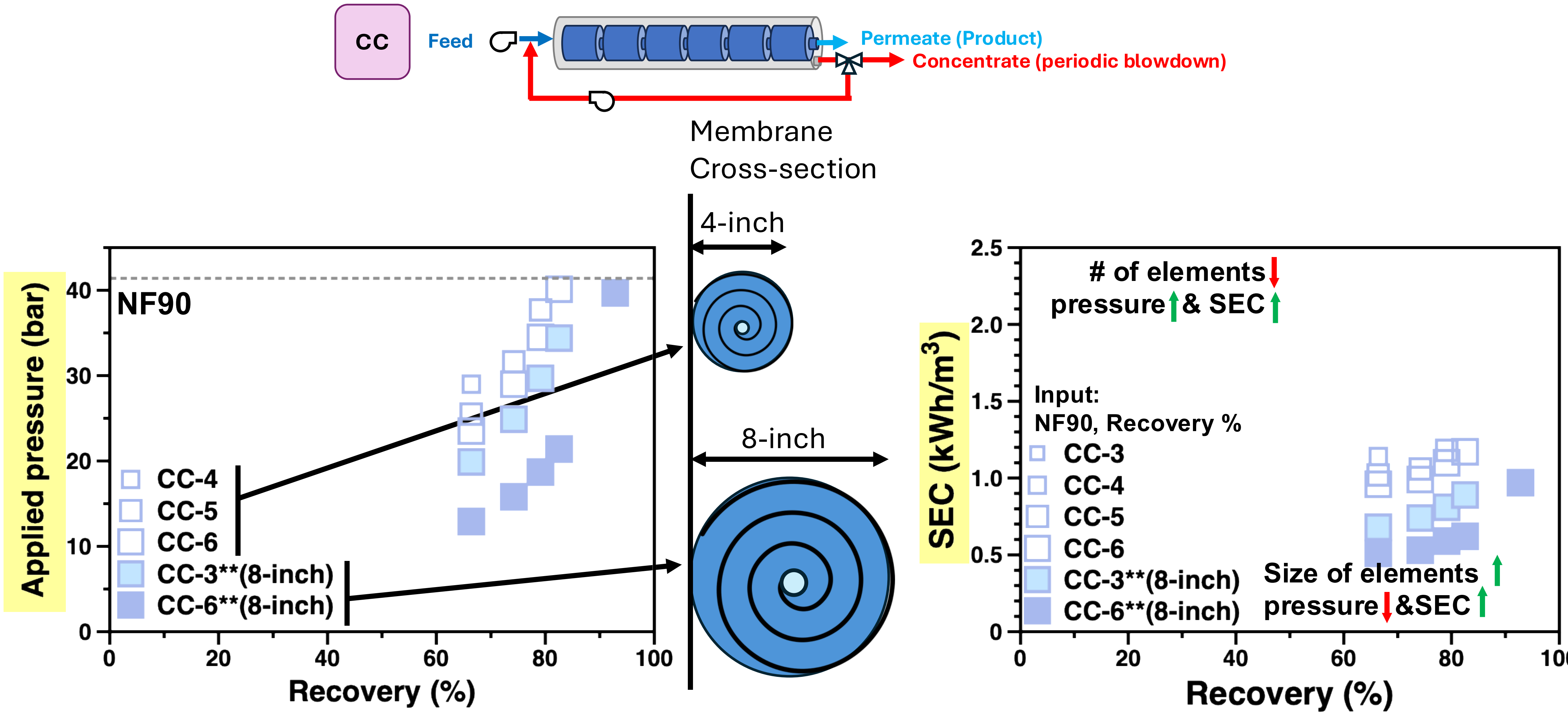
# 1S-ISD (Internally Staged Design)



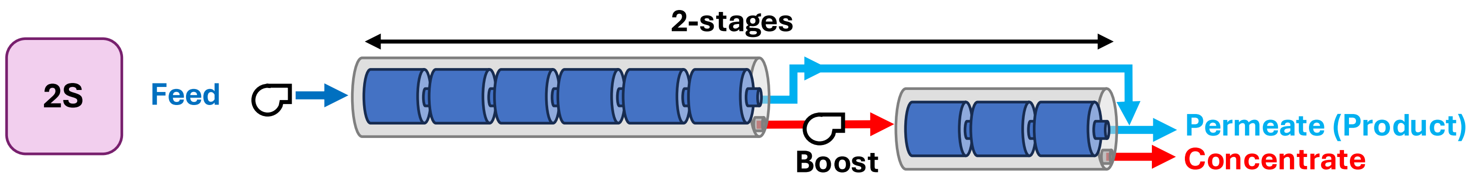


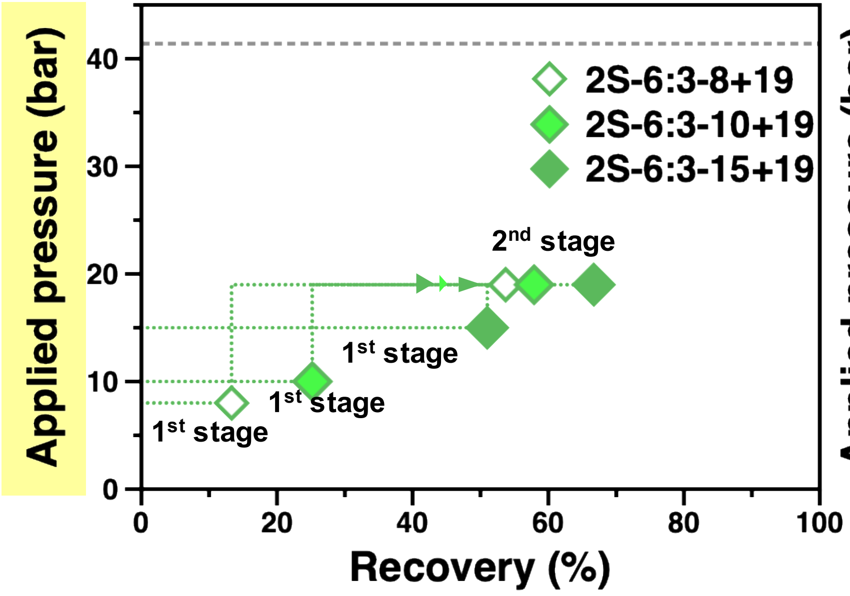



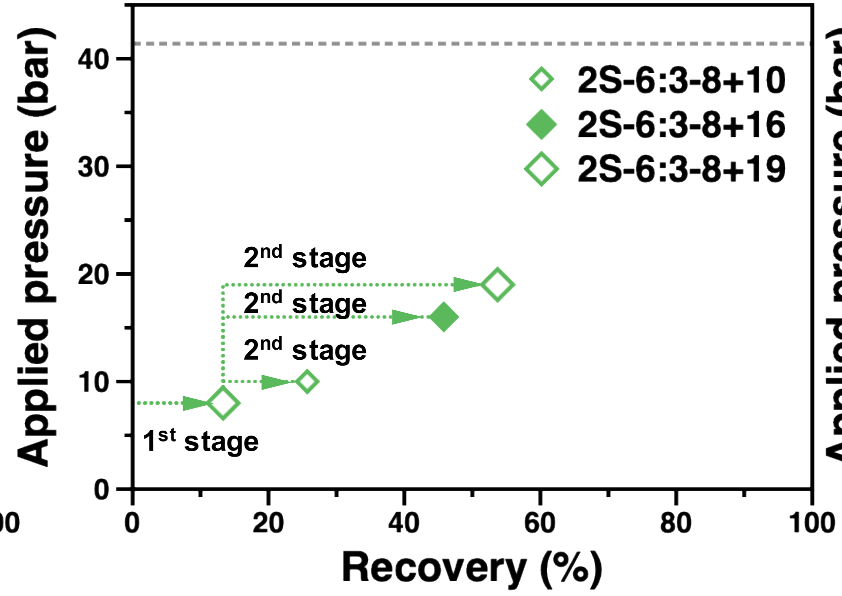
# CC (Closed Circuit)

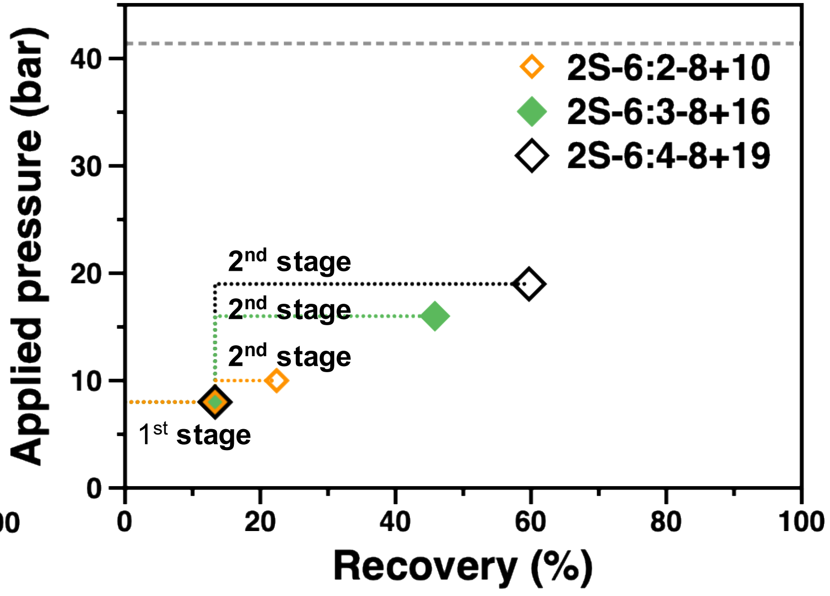


# 2S with various numbers of elements

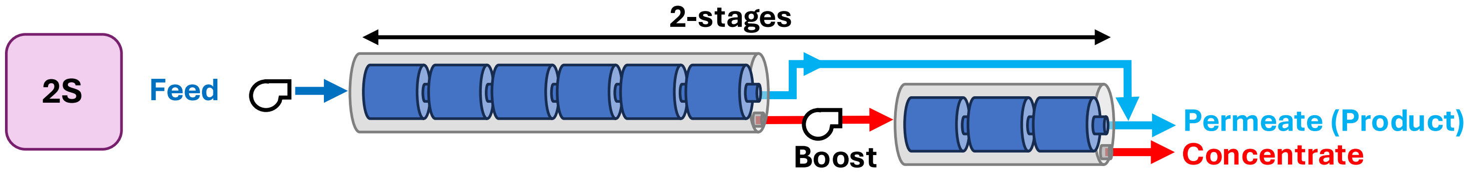


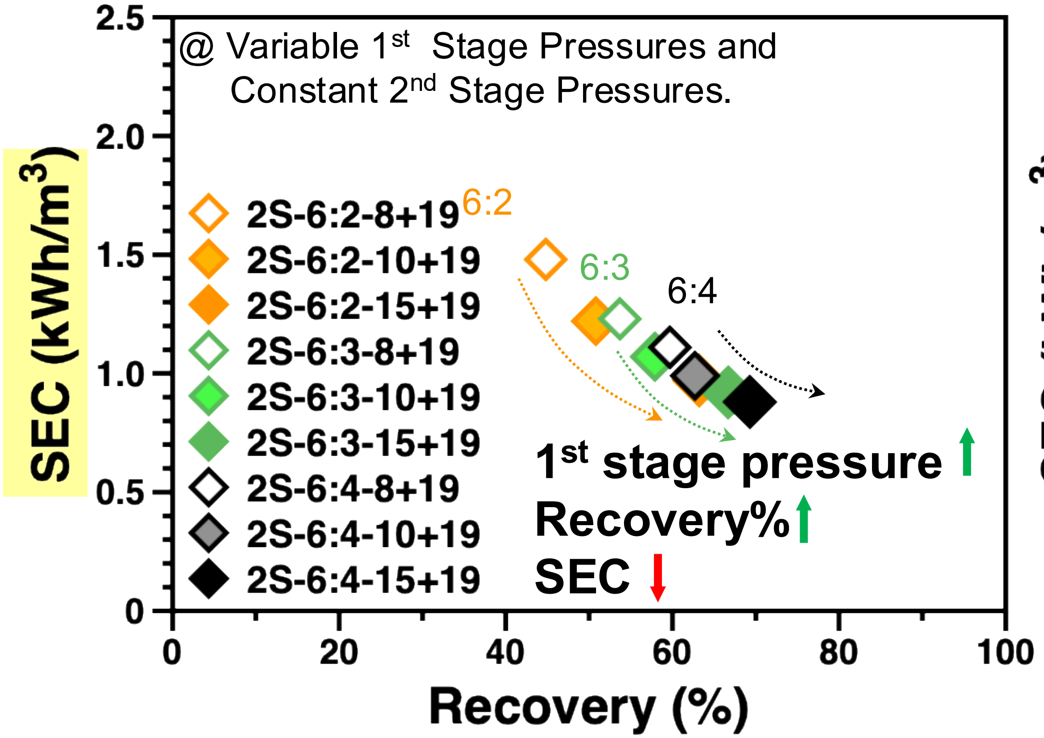



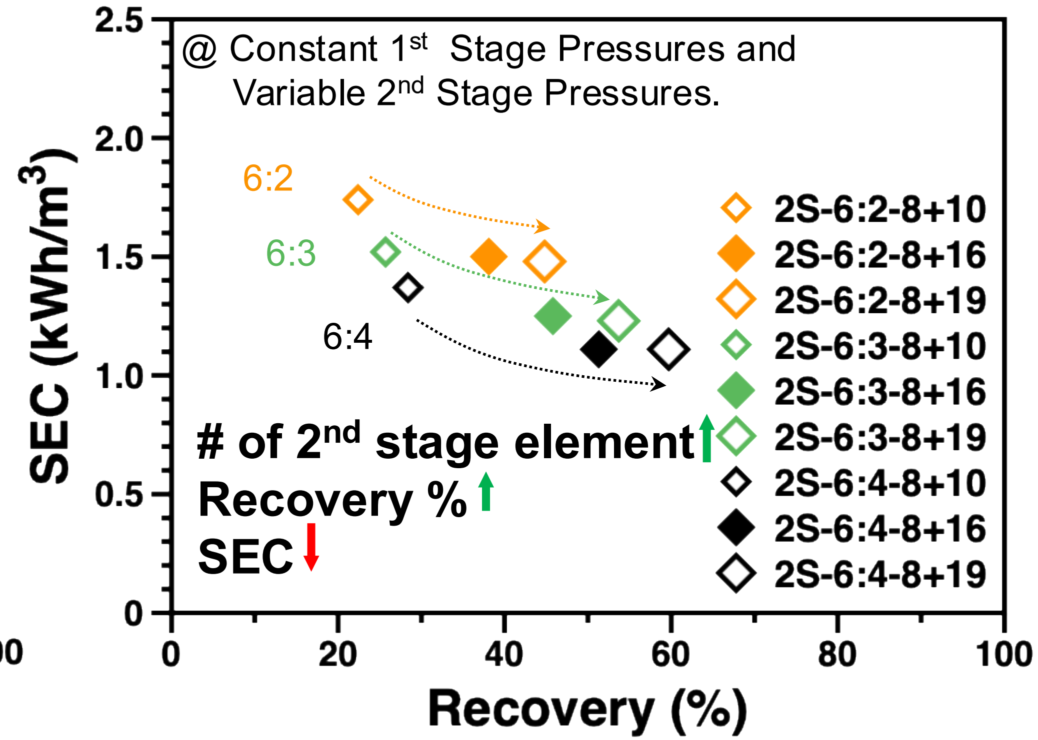



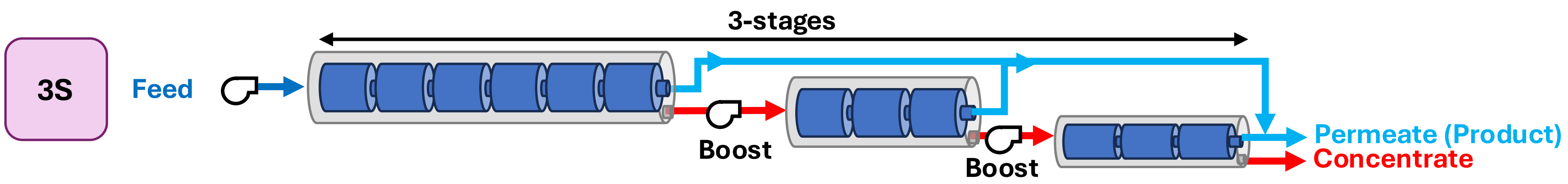
# 2S with various numbers of elements

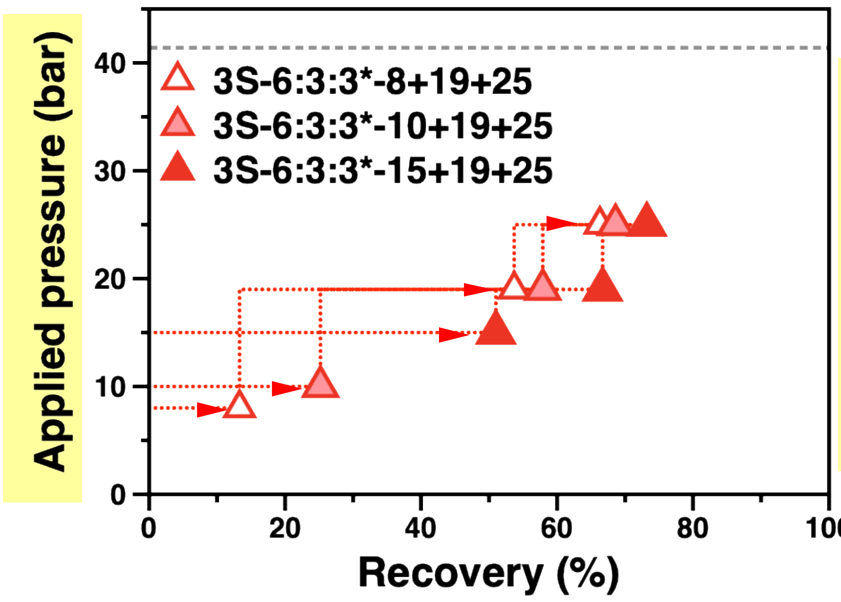


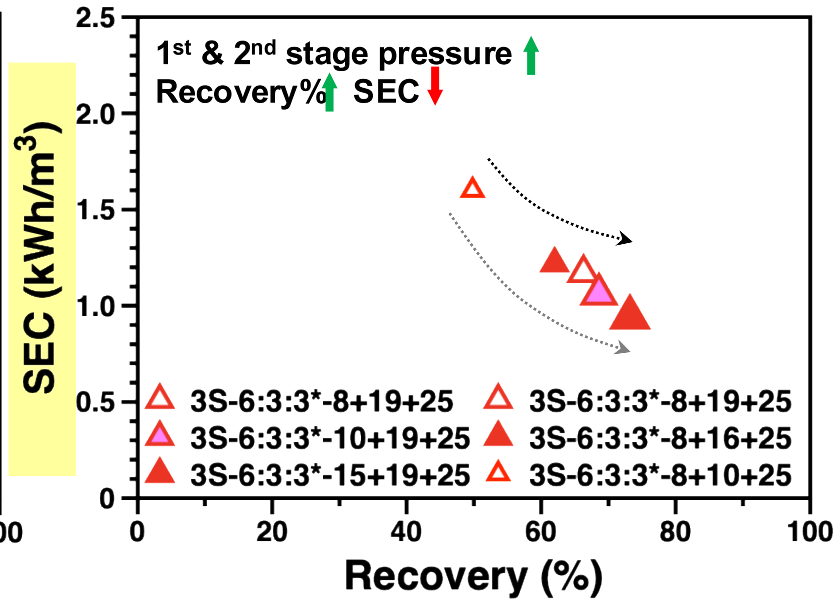



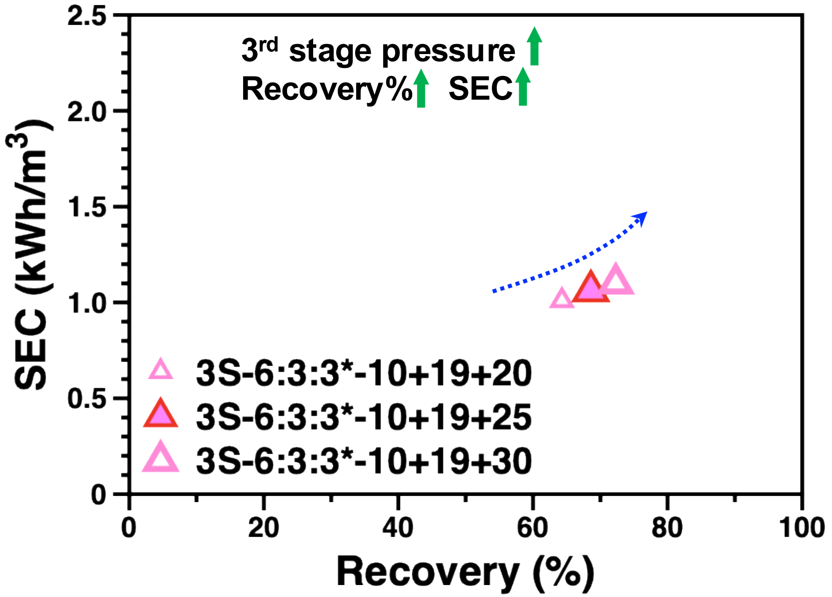



# 3S


3-stages
3S
Feed
Boost
Boost
Permeate (Product)
Concentrate

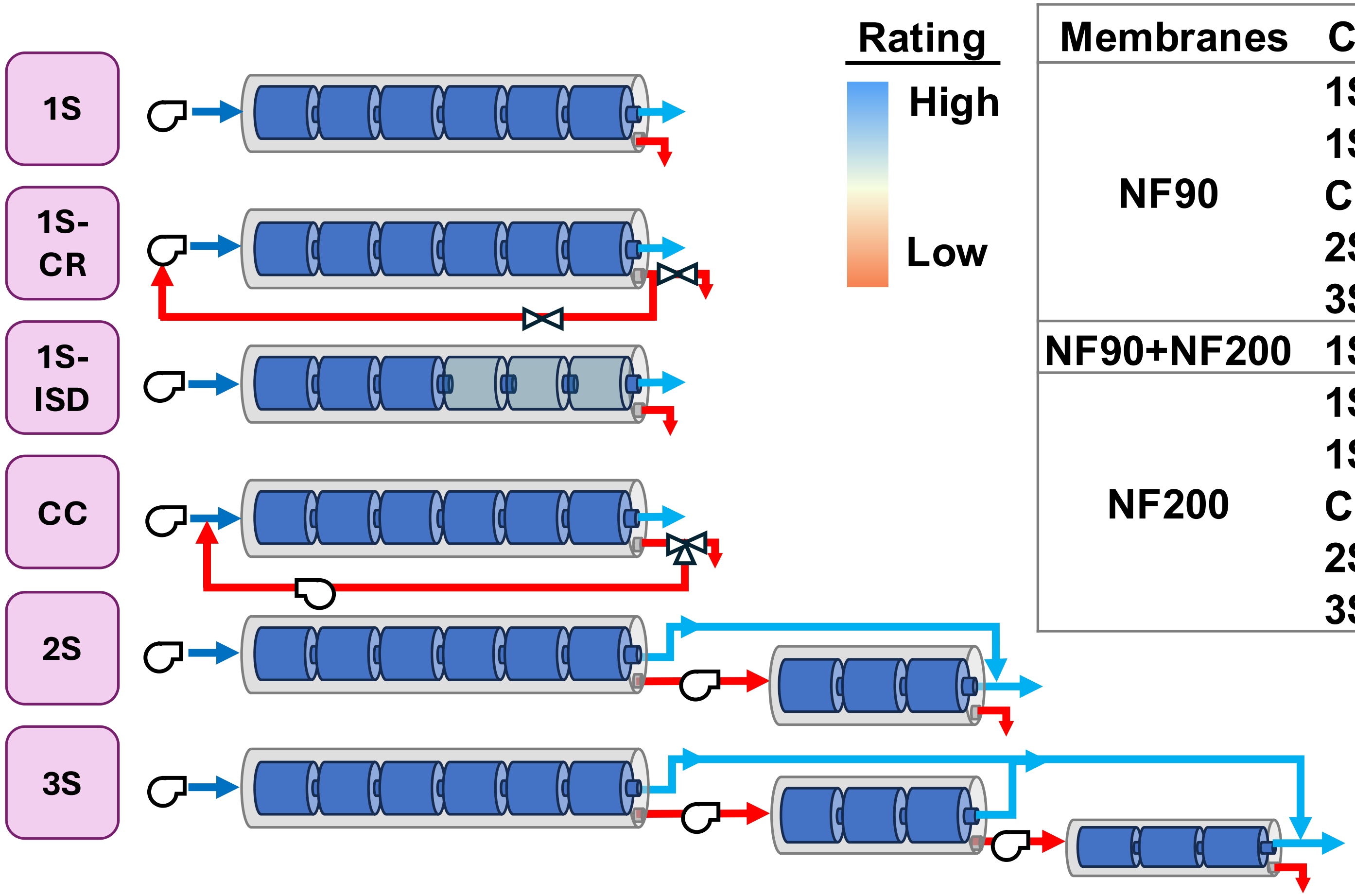

Applied pressure (bar)
Recovery (%)
3S-6:3:3*-8+19+25
3S-6:3:3*-10+19+25
3S-6:3:3*-15+19+25


SEC (kWh/m3)
Recovery (%)
1st & 2nd stage pressure
Recovery% SEC
3S-6:3:3*-8+19+25
3S-6:3:3*-10+19+25
3S-6:3:3*-15+19+25
3S-6:3:3*-8+19+25
3S-6:3:3*-8+16+25
3S-6:3:3*-8+10+25


SEC (kWh/m3)
Recovery (%)
3rd stage pressure
Recovery% SEC
3S-6:3:3*-10+19+20
3S-6:3:3*-10+19+25
3S-6:3:3*-10+19+30

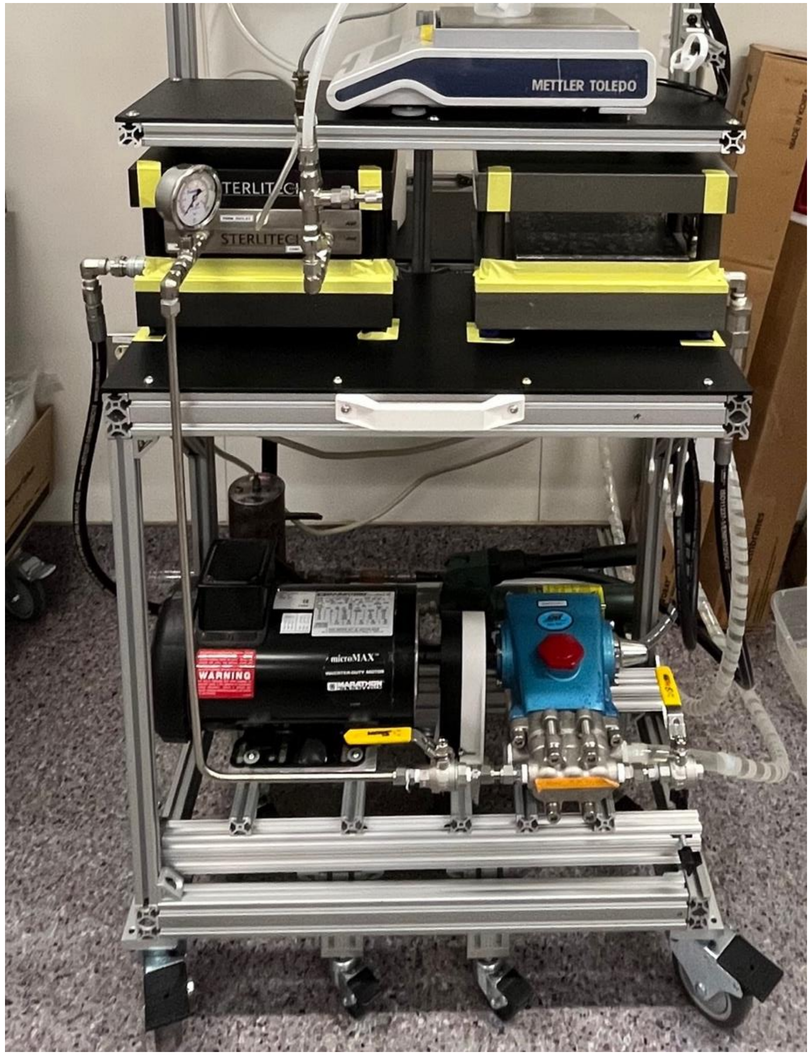

EXIT
NATIONAL CHAMPIONSHIP
SEMIFINALS

# General Rating of NF Processes based on the parameter chosen




| Membranes | Configurations | TDS | Recovery | SEC |
|---|---|---|---|---|
| NF90 | 1S | | | |
| | 1S-CR | | | |
| | CC | | | |
| | 2S | | | |
| | 3S | | | |
| NF90+NF200 | 1S-ISD | | | |
| NF200 | 1S | | | |
| | 1S-CR | | | |
| | CC | | | |
| | 2S | | | |
| | 3S | | | |

# Bench-Scale Nanofiltration Experiments

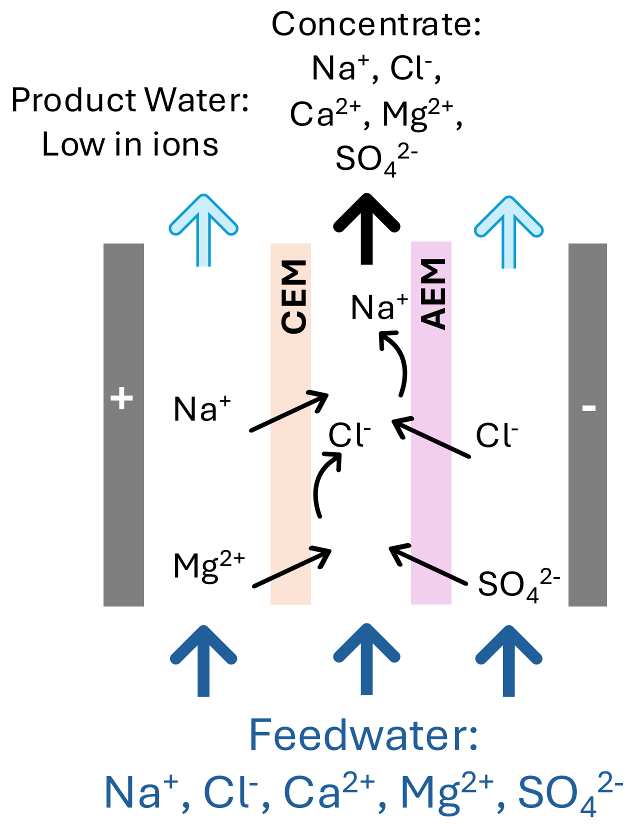



- Membrane properties:
  - Surface charge
  - Pore size
  - Molecular weight cutoff (MWCO)
- Operating Conditions:
  - Applied pressure
  - Flux
  - Recovery

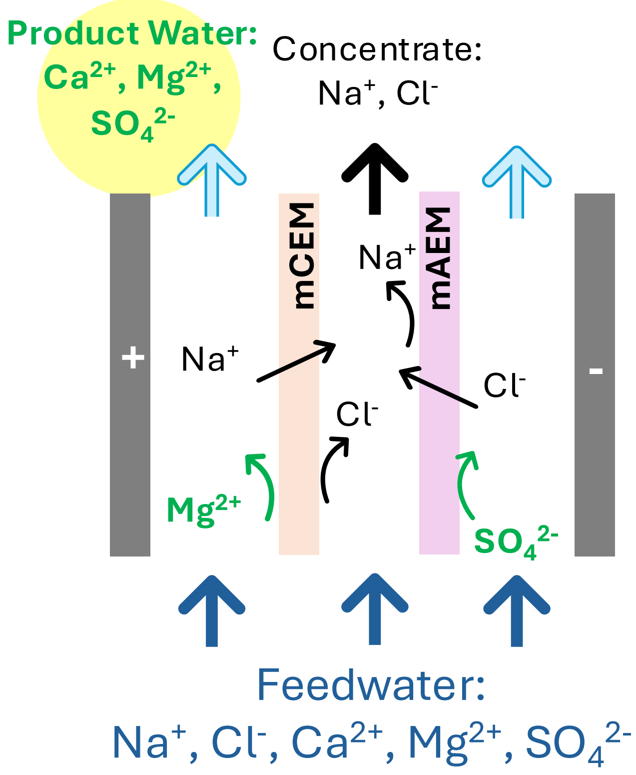
# Bench-Scale Electrodialysis Experiments

## Ion Exchange Membranes

### *Conventional*




### *Monovalent selective*




# Acknowledgments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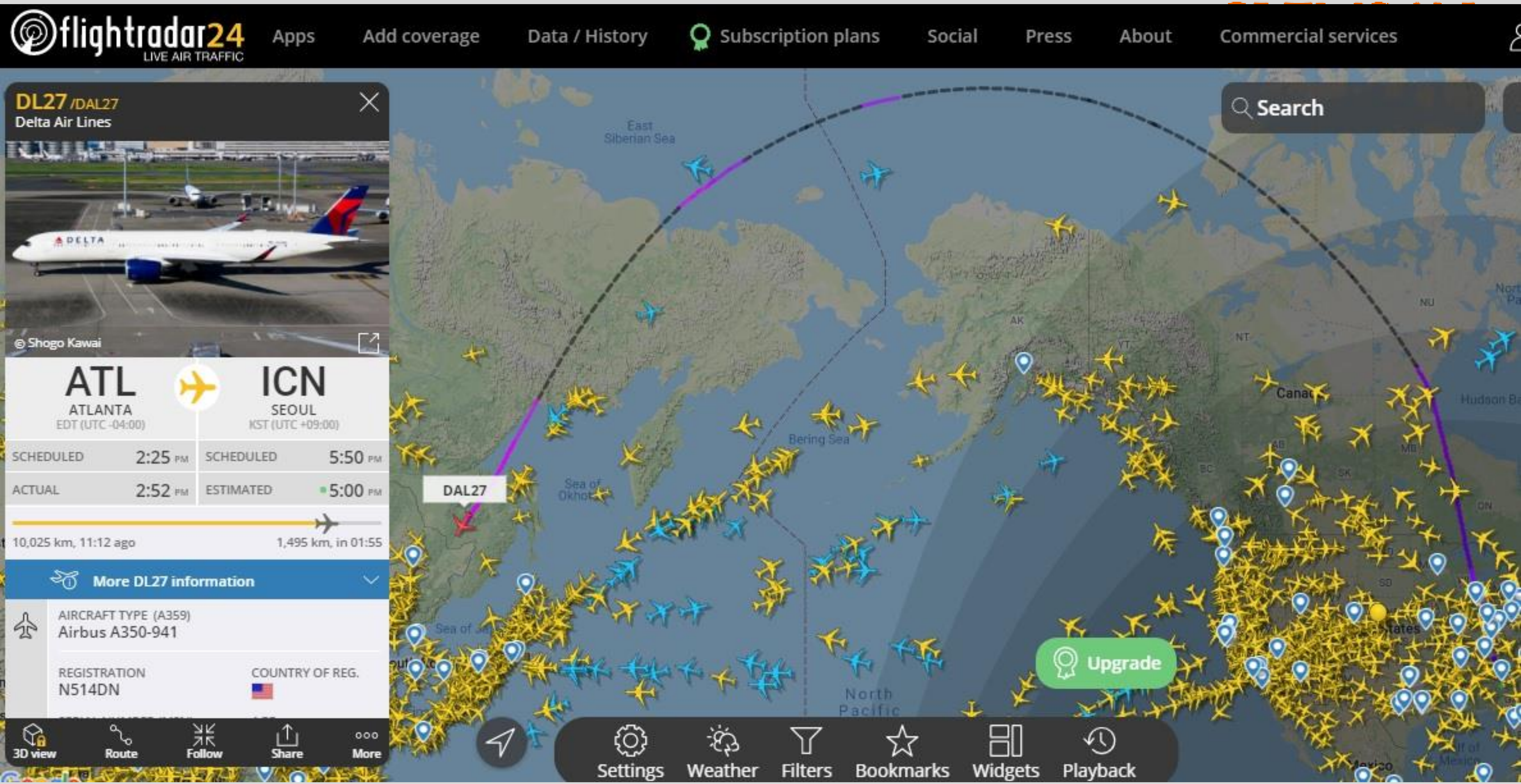
- **Co-authors:** W. Shane Walker, Robert Huehmer
- **Ladner Research Group members**: Weiming Qi, Geethakrishna Puligundla, Riley Schrader, Anna Reynolds, Zachary Padgett, Spencer Jackson, Jackson Sholl, Olivia Mucci, Timothy Ziegler
- **Rich Lab**: Daekyun Kim, Rodney Morgan, Kelli McCourt
- **USDA NIFA SAS Award # 2023-69012-39038**: Controlled Environment Agriculture Platform for Cultivation of Salt-Tolerant Crops with Integrated Saline Water Irrigation and Salinity Management.

flightradar24
LIVE AIR TRAFFIC
Apps
Add coverage
Data / History
Subscription plans
Social
Press
About
Commercial services
Search
DL27 /DAL27
Delta Air Lines
© Shogo Kawai
ATL
ATLANTA
EDT (UTC -04:00)
ICN
SEOUL
KST (UTC +09:00)
SCHEDULED 2:25 PM
SCHEDULED 5:50 PM
ACTUAL 2:52 PM
ESTIMATED 5:00 PM
10,025 km, 11:12 ago
1,495 km, in 01:55
More DL27 information
AIRCRAFT TYPE (A359)
Airbus A350-941
REGISTRATION
N514DN
COUNTRY OF REG.
3D view
Route
Follow
Share
More
DAL27
East Siberian Sea
Sea of Okhotsk
Bering Sea
North Pacific
Upgrade
Settings
Weather
Filters
Bookmarks
Widgets
Playback

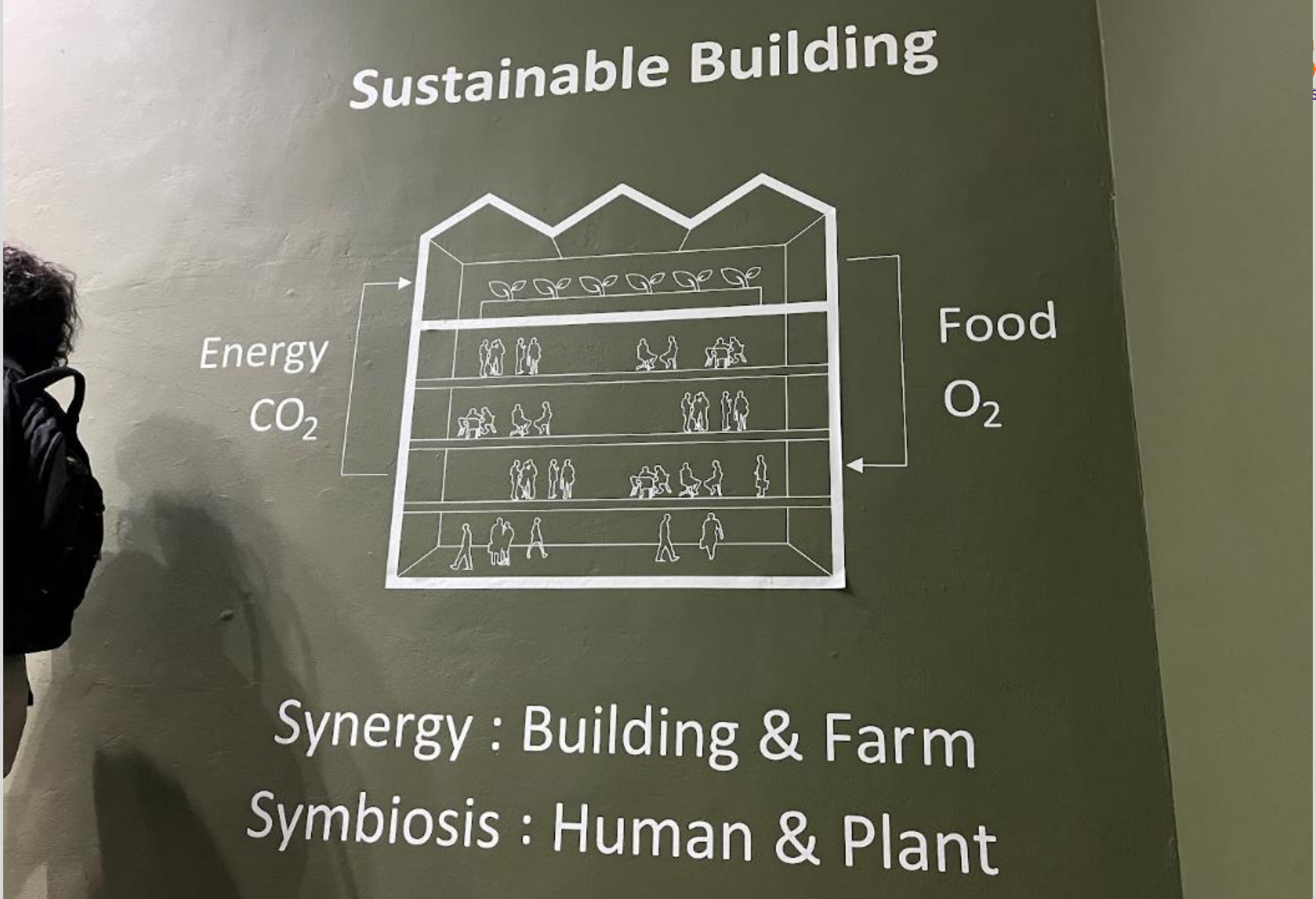

N
SEOUL TOWER

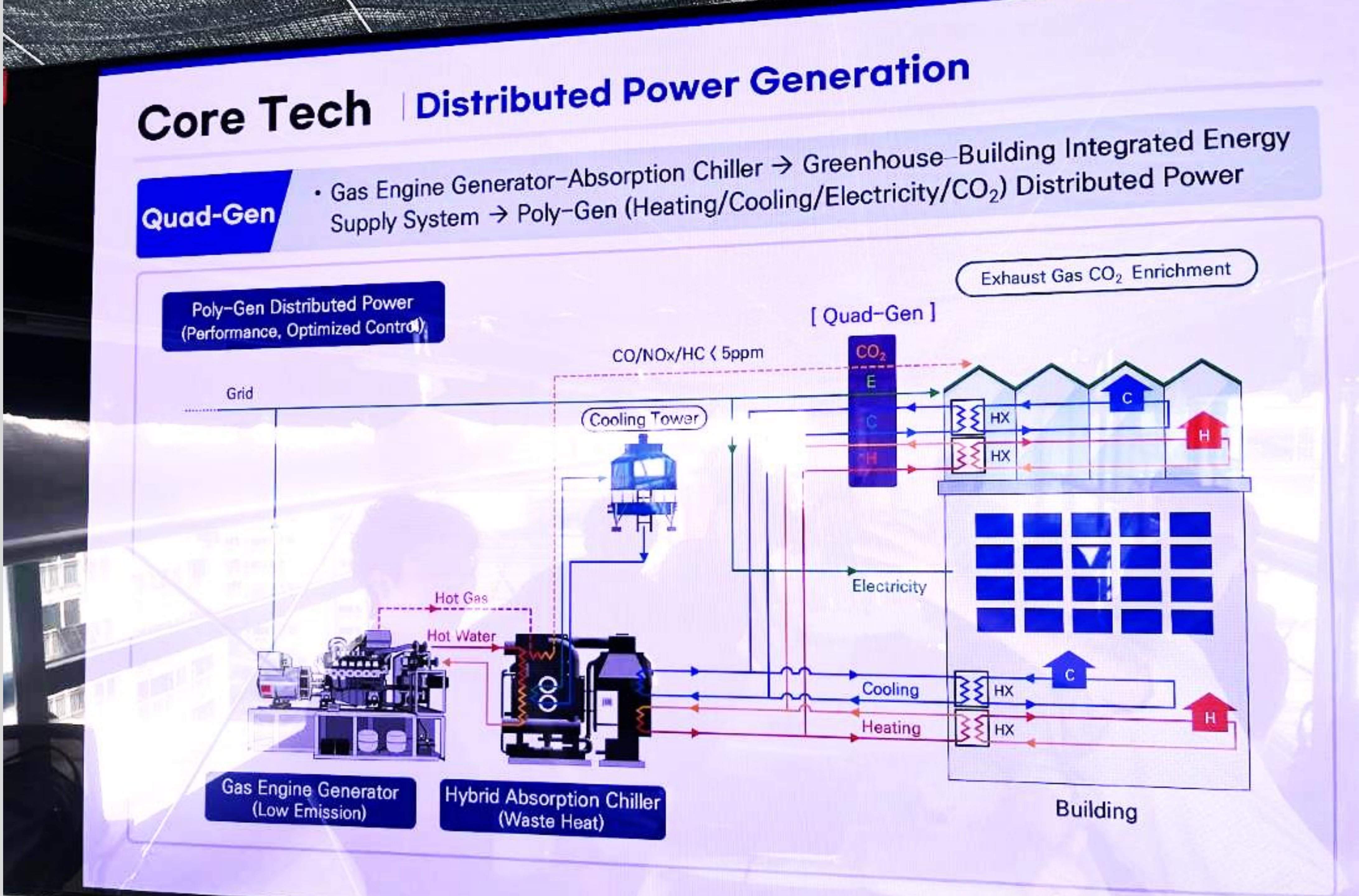

2275-4324


주민편의시설
사이언스놀이터
에너지가든
산책로
부출입구
(주민편의시설)
관리동
주민편의시설
주차장 (41대)
블루플라자
국기게양대
주출입구
그린플라자
관리동
주차장 (63대)
유지관리차량
출입구
풋살경기장
테니스장
농구장
진입광장
장래확장부지
산책로
(기존) 송도하수처리수 재이용시설
진입로

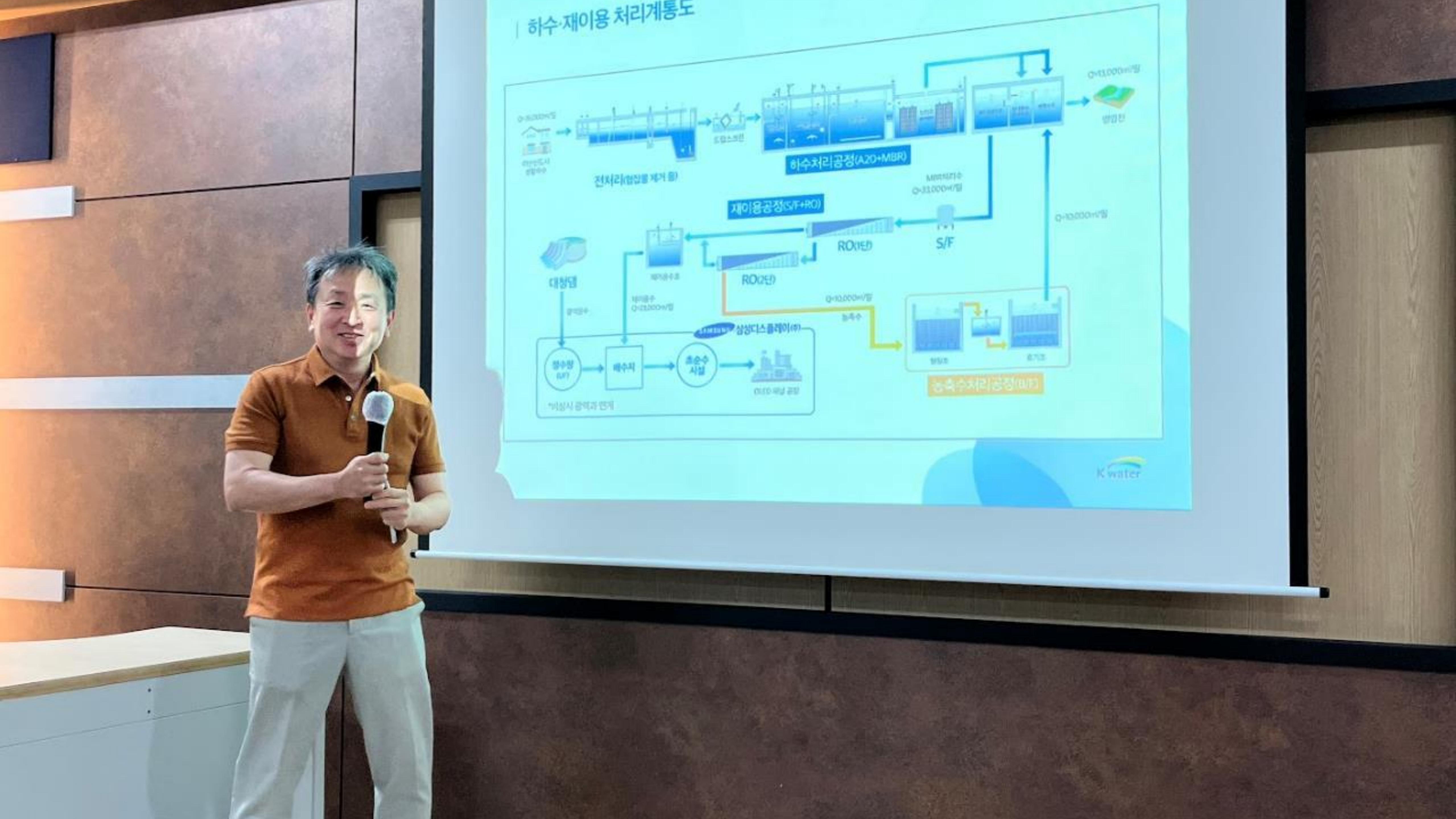

OZONE CONTROL PANEL
오존
MSDS


층집
店在二樓
世光
FASTFIVE
Peace
노래방
박가
GYM


Sustainable Building
Energy
$CO_2$
Food
$O_2$
Synergy : Building & Farm
Symbiosis : Human & Plant

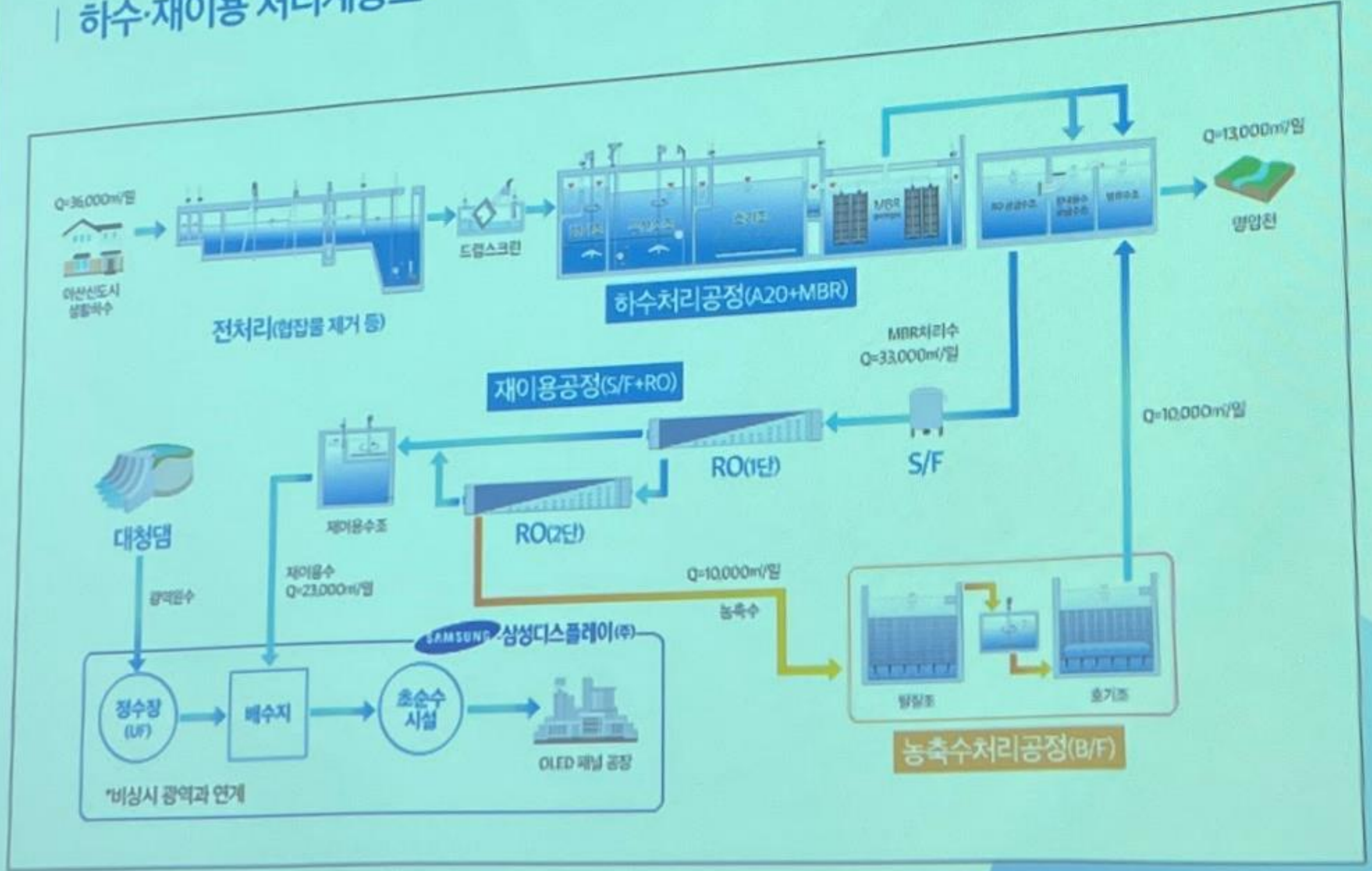

Core Tech
Distributed Power Generation
Quad-Gen
• Gas Engine Generator-Absorption Chiller → Greenhouse-Building Integrated Energy Supply System → Poly-Gen (Heating/Cooling/Electricity/CO2) Distributed Power
Poly-Gen Distributed Power
(Performance, Optimized Control)
Exhaust Gas CO2 Enrichment
[ Quad-Gen ]
CO/NOx/HC < 5ppm
CO2
E
C
H
Grid
Cooling Tower
HX
HX
C
H
Electricity
Hot Gas
Hot Water
Cooling
Heating
HX
HX
C
H
Gas Engine Generator
(Low Emission)
Hybrid Absorption Chiller
(Waste Heat)
Building


Seoul Metro
Farm8
팜에이트(주)
The Nearest Farm Where You Are
당신이 사는 곳에서 가장 가까운 농장



하수·재이용 처리계통도
전처리
하수처리공정(A2O+MBR)
재이용공정(S/F+RO)
RO(1단)
RO(2단)
S/F
대청댐
삼성디스플레이(주)
배수지
초순수 시설
K water

# 하수·재이용 처리계통도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아산신도시
생활하수
전처리(협잡물 제거 등)
드럼스크린
하수처리공정(A20+MBR)
MBR
Q=13,000㎥/일
MBR처리수
Q=33,000㎥/일
재이용공정(S/F+RO)
RO(1단)
S/F
RO(2단)
재이용수조
Q=10,000㎥/일
대청댐
광역원수
재이용수
Q=23,000㎥/일
Q=10,000㎥/일
농축수
삼성디스플레이(주)
정수장
(UF)
배수지
초순수
시설
OLED 패널 공장
*비상시 광역과 연계
탈질조
호기조
농축수처리공정(B/F)

# 하수처리 및 재이용수 수질

✓ 現 재이용수 생산량 : 하수유입량의 70% (23,000㎥/일)

- 하수처리수질 (2023년)

| 구분 | BOD mg/L | TOC mg/L | SS mg/L | T-N mg/L | T-P mg/L |
|---|---|---|---|---|---|
| 법정수질 | <10 | <25 | <10 | <20 | <2 |
| 설계유입 | 197 | COD 201 | 207 | 35.6 | 5.5 |
| 유입수질 (설계대비) | 254.6 (129%) | 84.7 | 250.7 (121%) | 62.5 (176%) | 6.8 (125%) |
| 방류수질 | 1.1 | 10.1 | 1.0 | 8.0 | 0.6 |
| 처리효율 | 99.4% | 88.1% | 99.6% | 87.3% | 91.8% |

- 재이용수질

| 구분 | TOC mg/L | Turbidity NTU | TDS mg/L | SDI %/min | $Ca_2^+ + Mg_2^+$ mg/L | Conductivity ㎲/㎝ |
|---|---|---|---|---|---|---|
| 보증수질 | <3 | <1 | <100 | <3 | <50 | <160 |
| 공급수질 | 0.05 | 0.05 | 13 | 0.8 | 1.2 | 20 |

# Acknowledgements




U.S. National Science Foundation

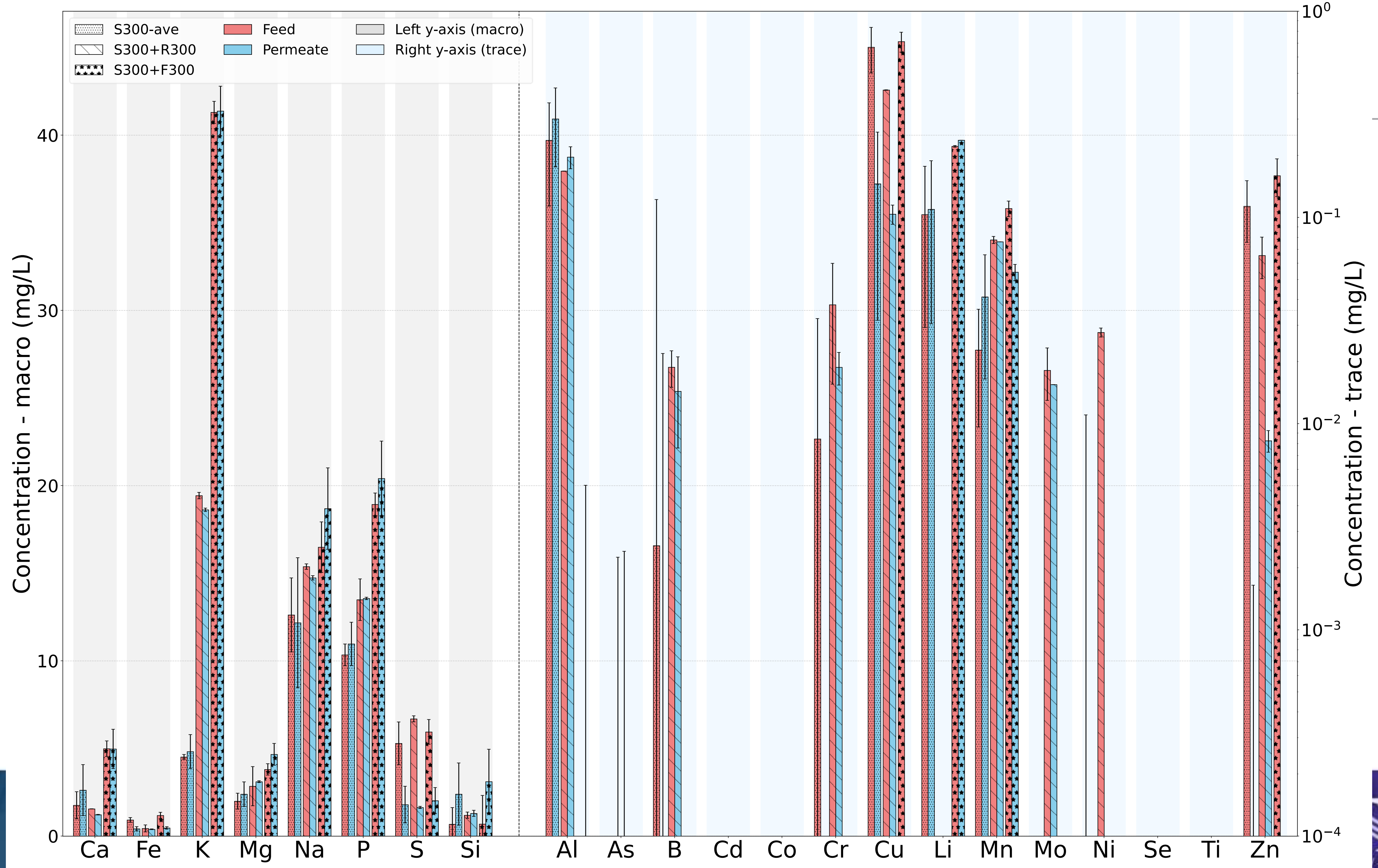
Award #2230696

CLEMSON UNIVERSITY



Univ

MS N
E R S I T Y



S300-ave
S300+R300
S300+F300
Feed
Permeate
Left y-axis (macro)
Right y-axis (trace)
Concentration - macro (mg/L)
Concentration - trace (mg/L)
0
10
20
30
40
$10^{-4}$
$10^{-3}$
$10^{-2}$
$10^{-1}$
$10^{0}$
Ca
Fe
K
Mg
Na
P
S
Si
Al
As
B
Cd
Co
Cr
Cu
Li
Mn
Mo
Ni
Se
Ti
Zn