Economical re-use of produced water with batch desalting

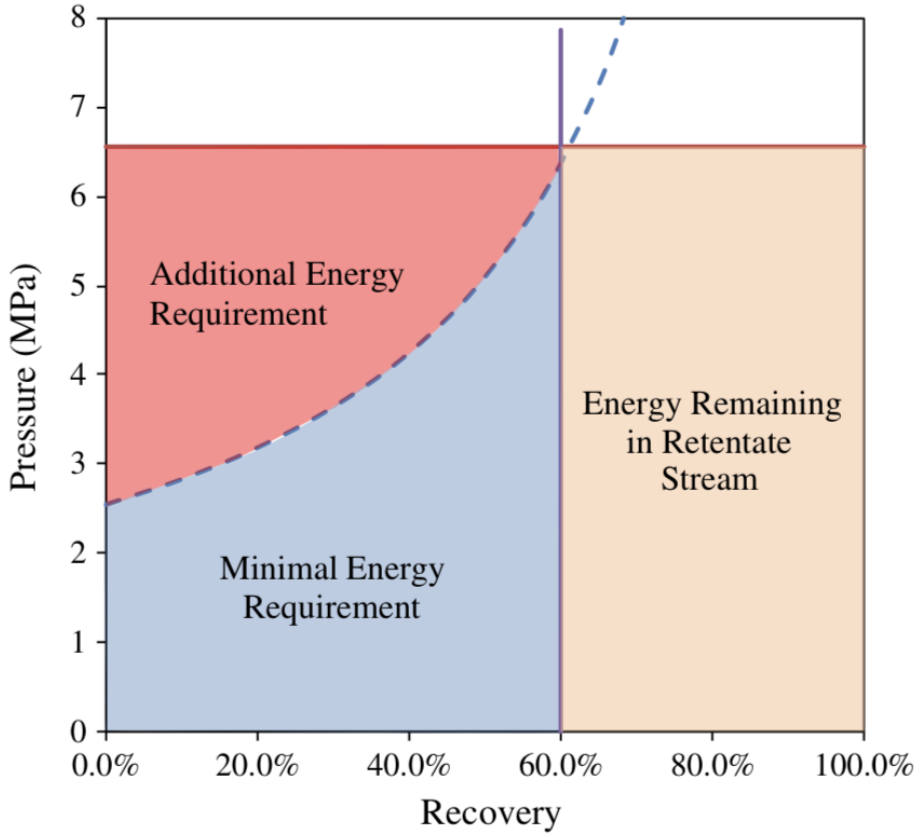
harmony
desalting

Conventional reverse osmosis (RO) is an energy hog.

1. Desalination is an inherently energy-intensive process. Higher pressures required as water recovery increases due to the "osmotic pressure curve."

2. Significant energy remains in pressurized brine/retentate stream. Recycled with energy recovery devices (ERDs) such as pressure exchangers and turbochargers.

3. Remaining energy is inherent to the configuration of conventional RO. One way to save this energy is with staged RO.



Liu et al., "Energy analysis and efficiency assessment of reverse osmosis desalination process" *Desalination* (2011)

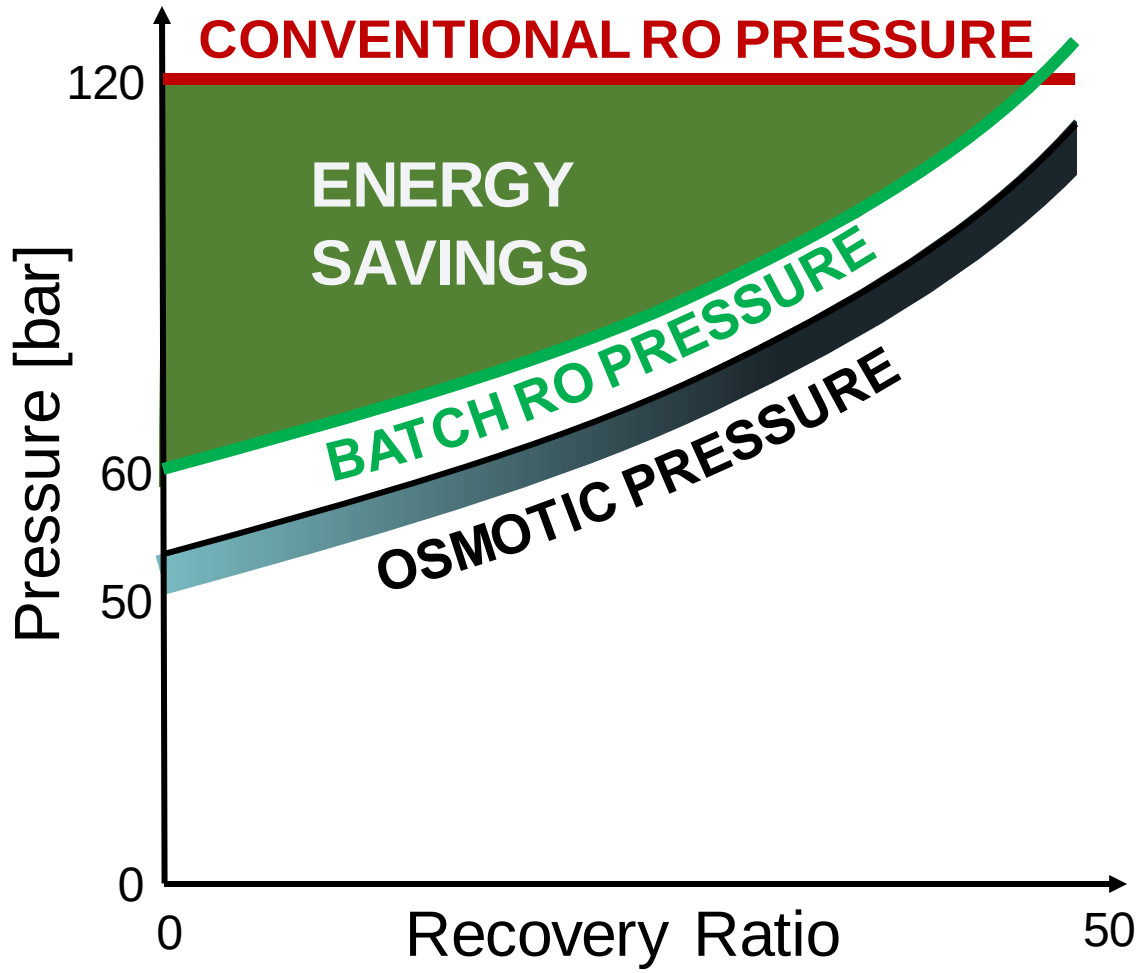
More water, less energy

Batch RO is the most efficient RO process

Conventional RO wastes energy by over-pressurizing the system.

Our Batch RO process saves this energy

by tracking osmotic pressure over time, like an "infinite-stage" RO system.



More water, less maintenance

Reliable performance for remote locations

Smaller & cheaper pumps

The high-pressure pump only drives product flow and is protected from corrosion

Superior membrane performance

Smart operation gets the most out of your membranes -- without ruining them!

No energy recovery devices (ERDs)

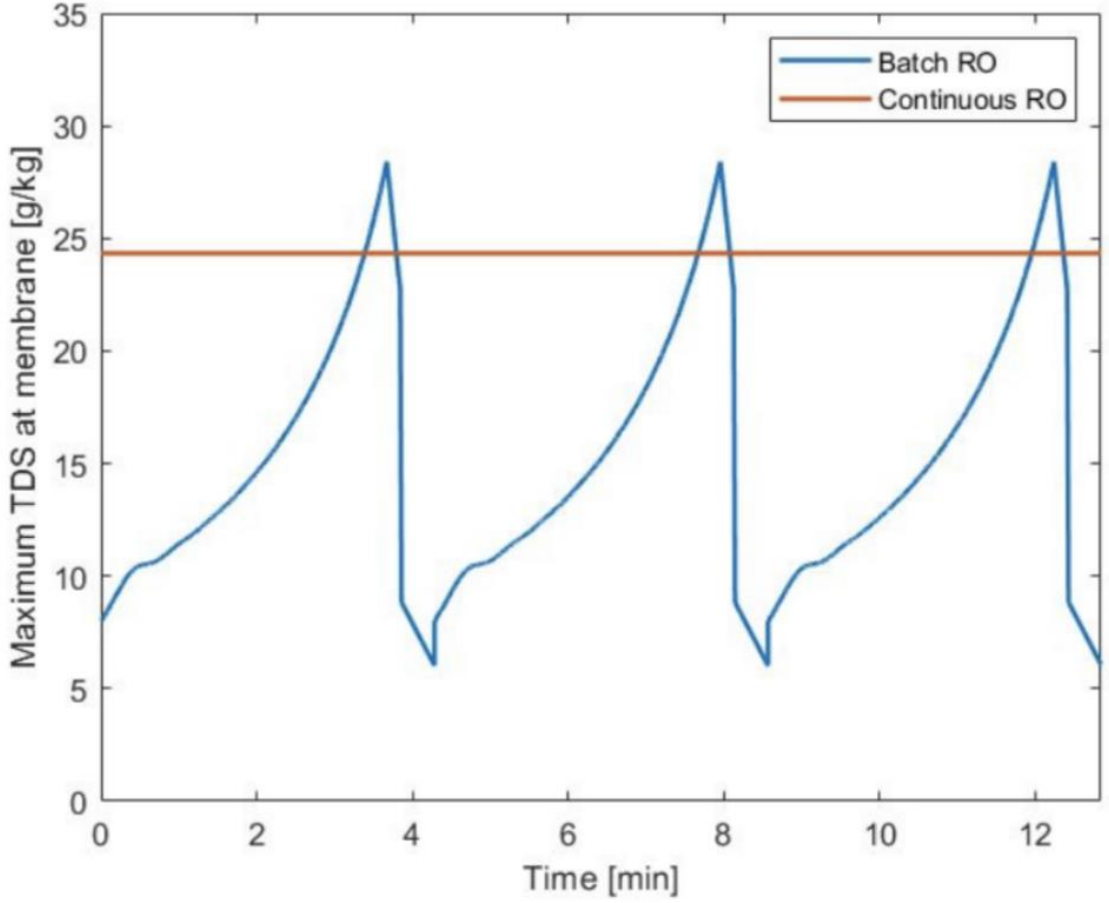
Complex devices are replaced by a reliable bladder: simple and cheap

More water, less waste

Minimize discharge w/o scaling due to rapid salinity cycling

In continuous RO, the last element is prone to scaling because it is constantly exposed to the maximum concentration.

In batch RO, the membrane is only exposed to the highest concentration for a minute at a time. We design cycles to be too short for potential scalants to nucleate.



Bench-top studies
0.25 m^3/day (0.05 gpm)
290 psi (20 bar)

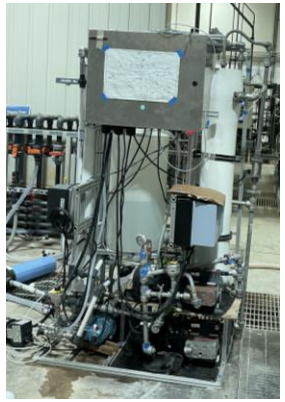
2017-2021

- Proof of concept
- Characterized losses
- Backwash prediction

Field pilot
11 m^3/day (2 gpm)
500 psi (34 bar)

2022-2023

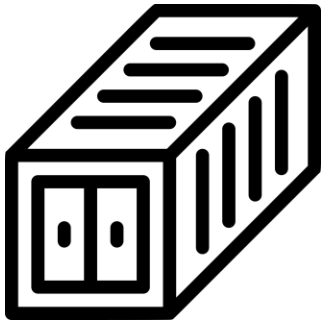
- **Won the More Water Less Concentrate challenge (treating BWRO brine)**
- >9 months of scale-free operation in Yuma, AZ.



Refinement
16 m^3/day (3 gpm)
500 psi (34 bar)

2023

- Improved bladder, frame, and controls
- Second field pilot (direct potable reuse)



Containerized deployment
55 m^3/day (10 gpm)
900 psi (60 bar)

2024-2025

- Further iteration
- 8” RO element
- >100,000 ppm brine with batch NF

MIT

MORE WATER LESS CONCENTRATE

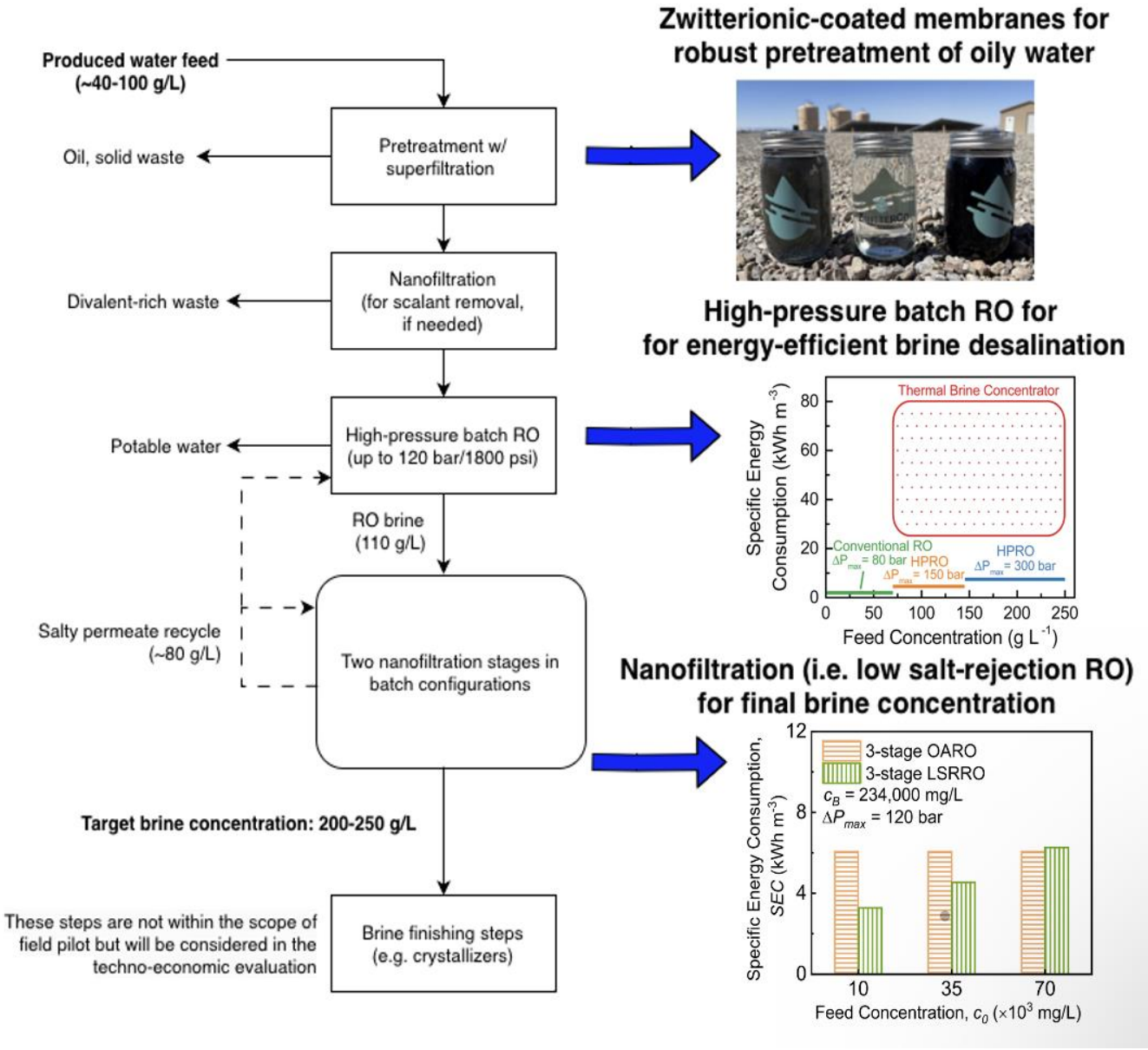
Canada

MASSACHUSETTS CLEAN ENERGY CENTER

BUREAU OF RECLAMATION

Proposed treatment train for produced water treatment

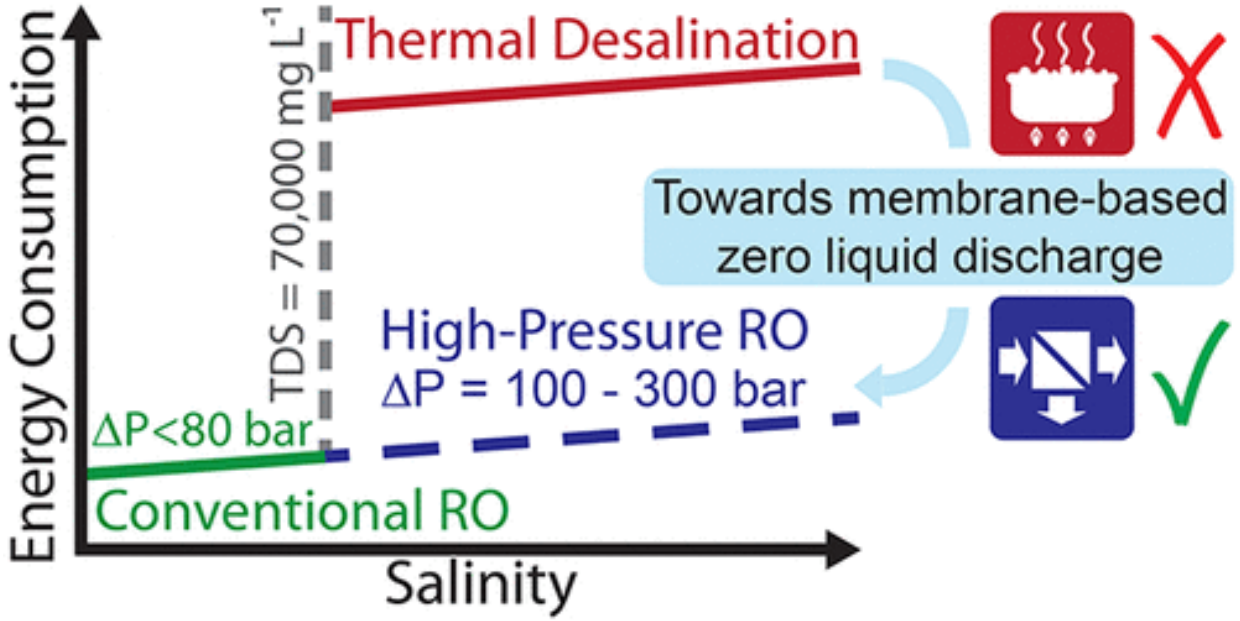
R&D needed to achieve this.



Minimal liquid discharge
with new high-pressure RO elements (120 bar/1800 psi)

$2.2M **annual savings**

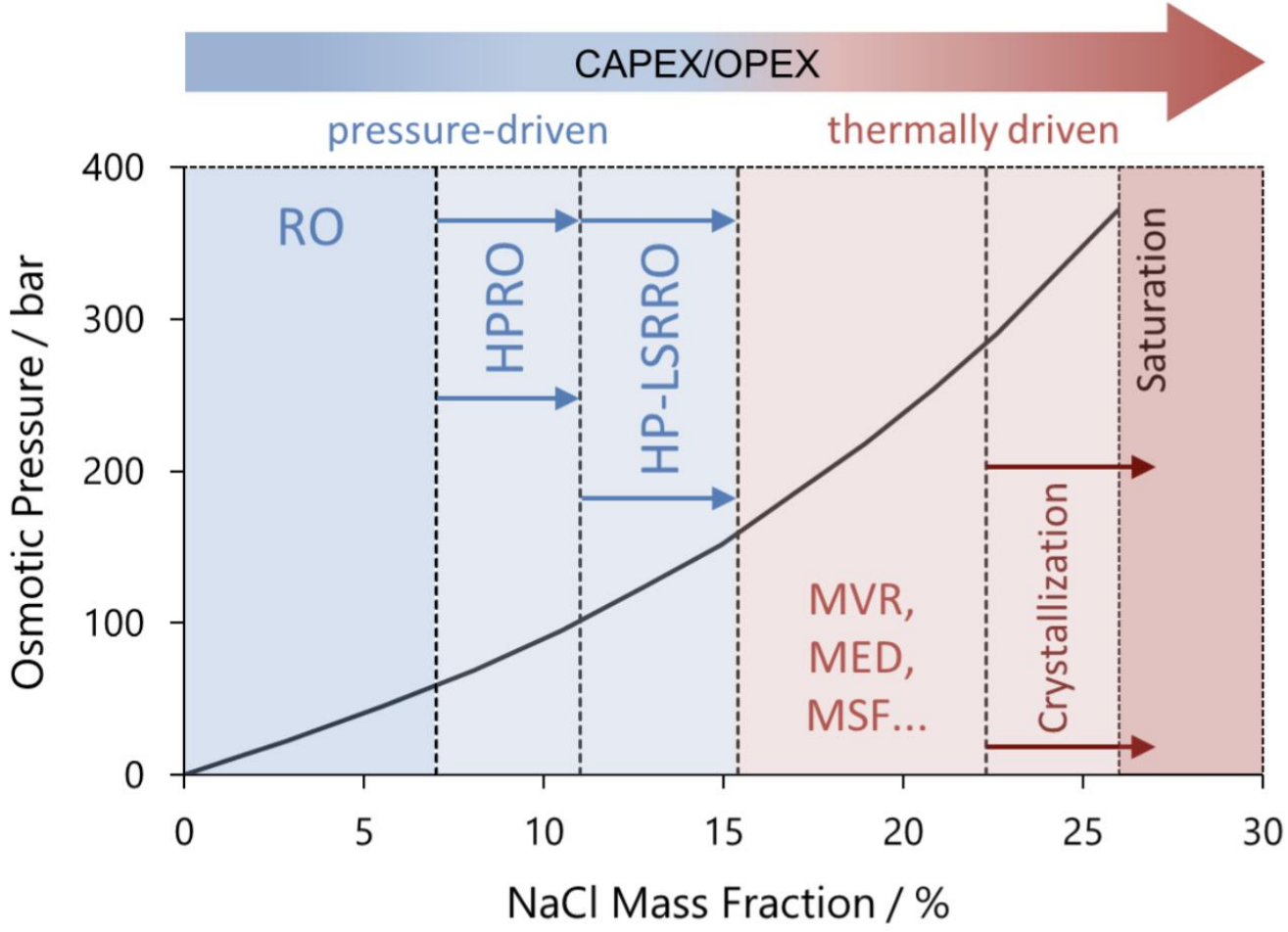
versus mechanical vapor recompression
(1000 m^3/day or 180 gpm system)



Davenport et al., "High-pressure RO for energy-efficient hypersaline brine desalination," *Environmental Science & Technology* (2018)
Wenzlick et al., "Techno-economic analysis of converting oil & gas produced water into valuable resources," *Desalination* (2020)

Pushing the limits of membrane brine concentration using nanofiltration (i.e. low salt rejection RO)

- **More practical than OARO**
  - Uses proven NF elements
- **Batch processing for scaling resistance**
  - Minimize or eliminate the need for antiscalant



Kleffner et al., "High-pressure membrane processes with energy recovery: new perspectives for efficient brine concentration" *IDA World Congress, Sydney, Australia* (2022)

harmony
desalting

more water,

less energy/waste/space/chemicals/maintenance/etc...

Questions?

Contact: water@harmonydesal.com