Latest Technologies in Water Desalination

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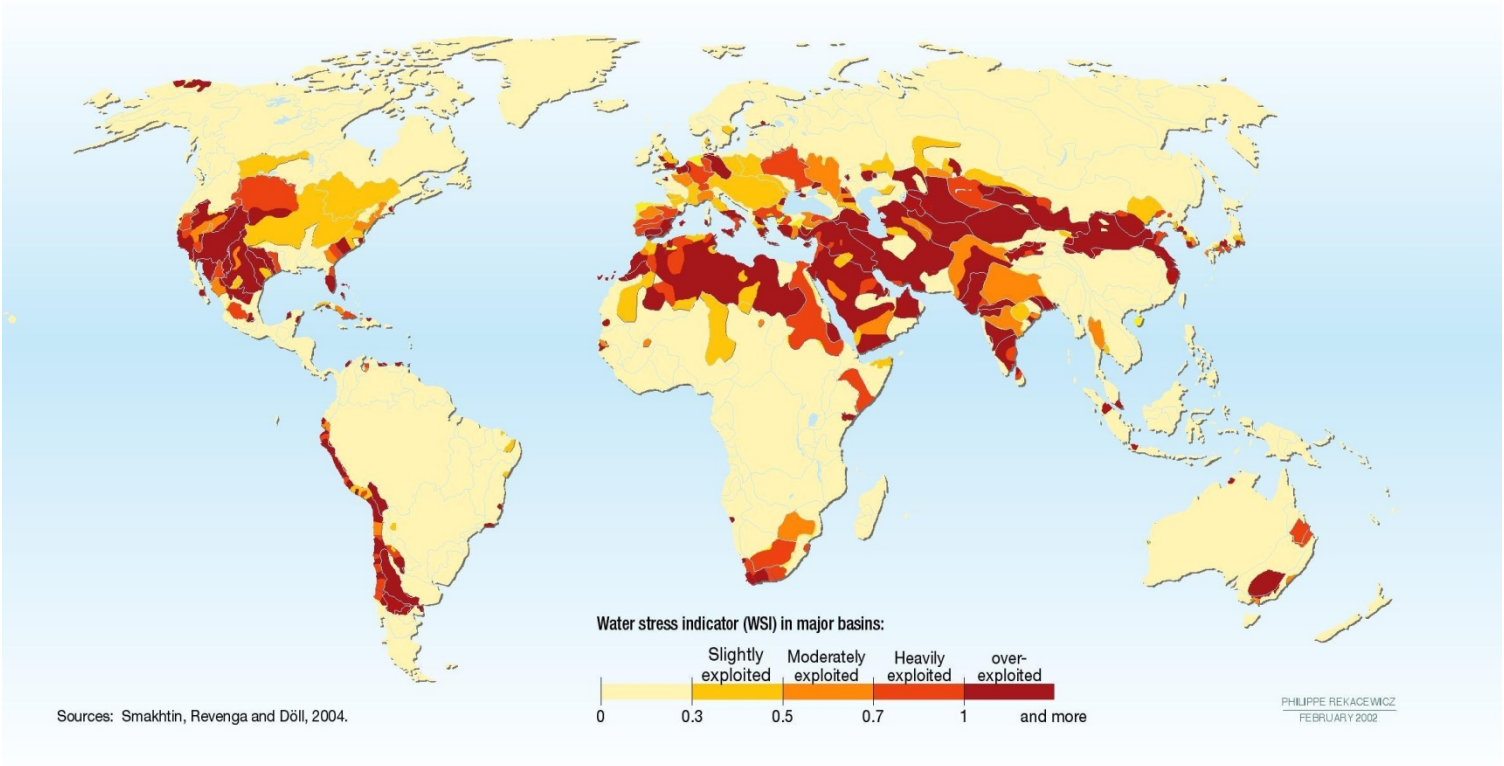
Outline

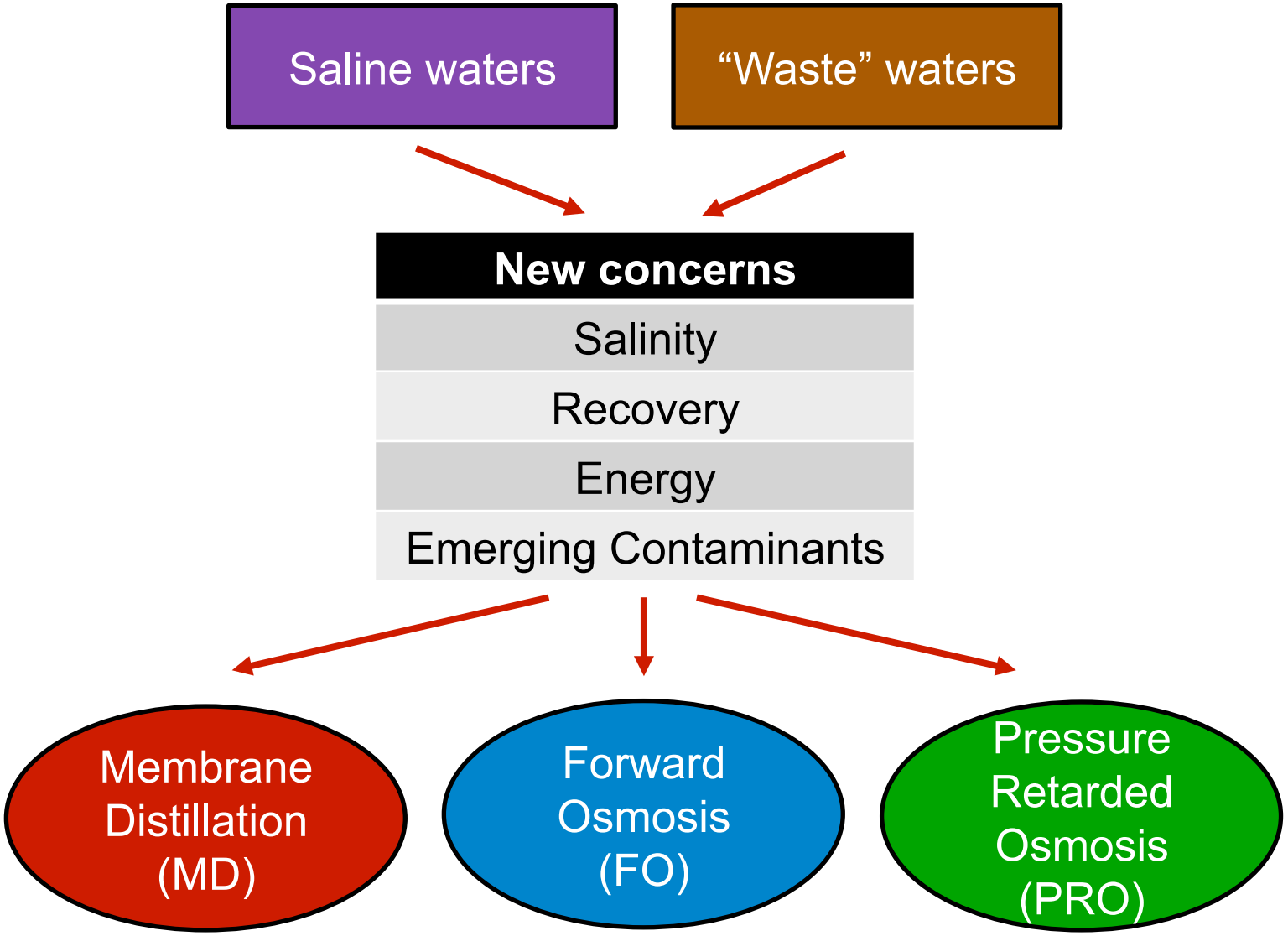
- Introduction
  - Fresh water scarcity
  - Alternate sources and new technologies
  - Desalination by reverse osmosis
- Emerging Technologies for Desalination Applications
  - Membrane Distillation
  - Forward Osmosis
  - Pressure Retarded Osmosis
- Final Remarks

Global Water Stress



Forcing water providers to rely more on alternative sources

Alternative Sources and New Technologies

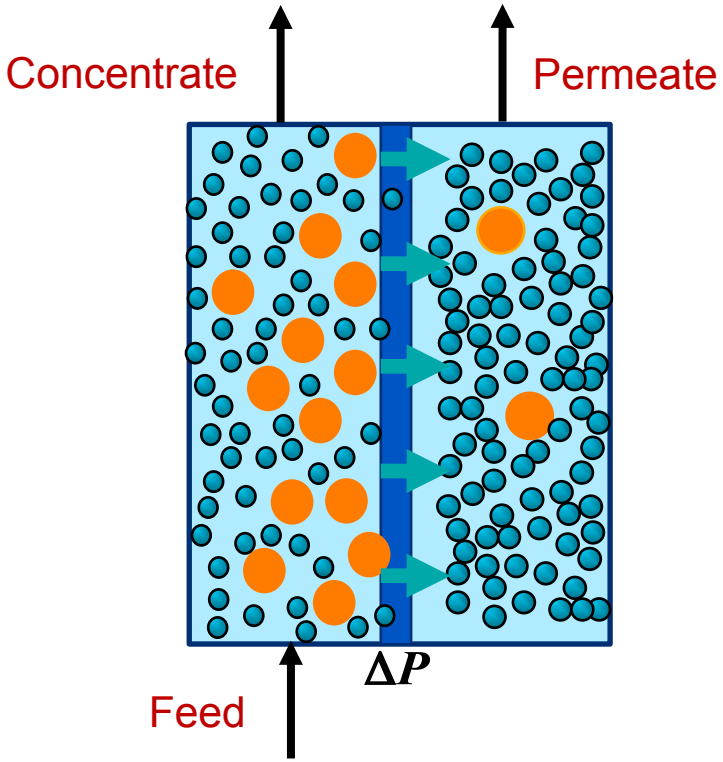


Desalination Applications and Salinity Levels

- Seawater desalination (35-41 g/L)
- In-land groundwater desalination (2-6 g/L)
  - RO brine (>40 g/L)
- Extreme salinity scenarios (>100 g/L)
  - Oil and gas applications
  - Mineral mining (water is by-product)

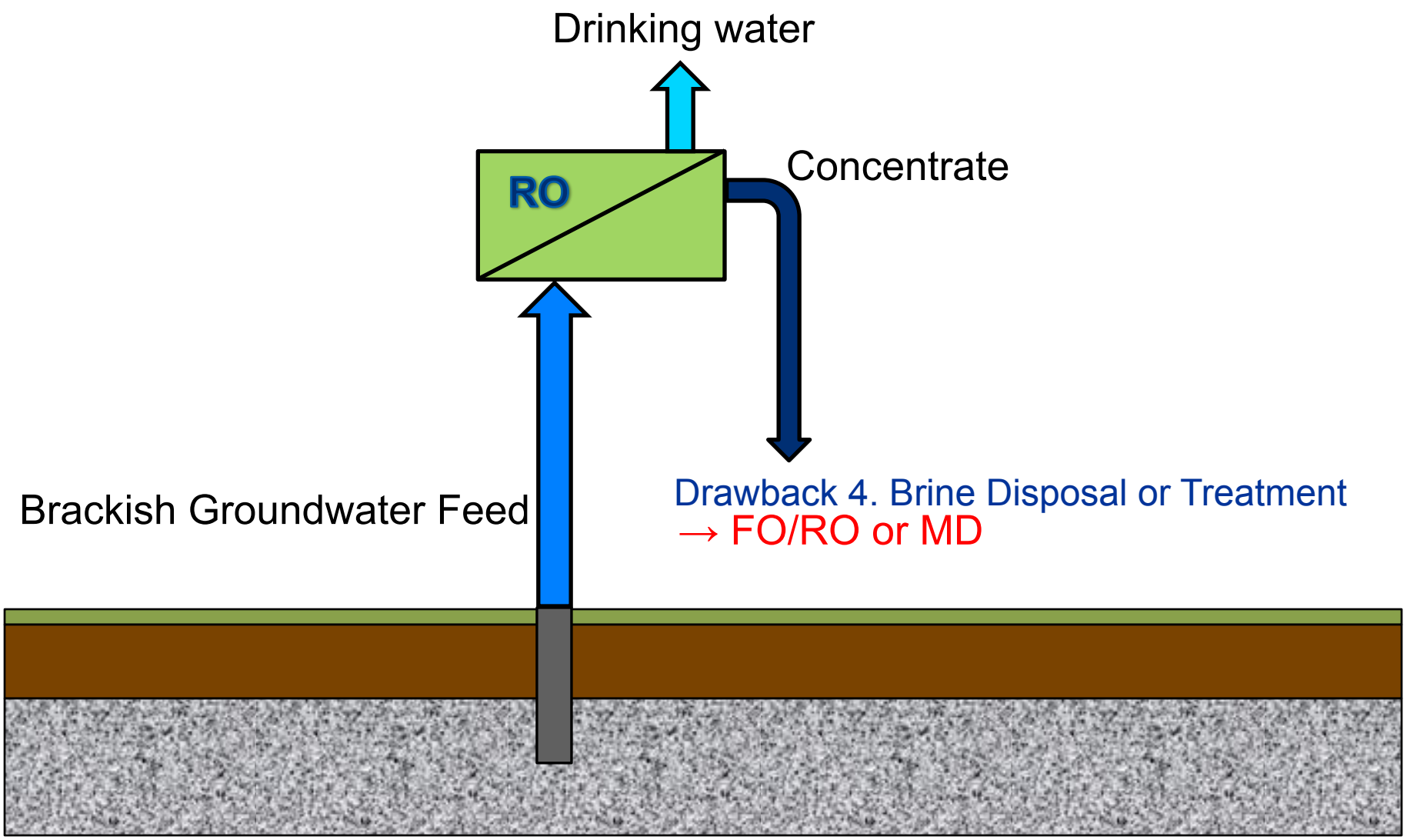
Current Leading Desalination Technology: Reverse Osmosis

Reverse Osmosis Separation

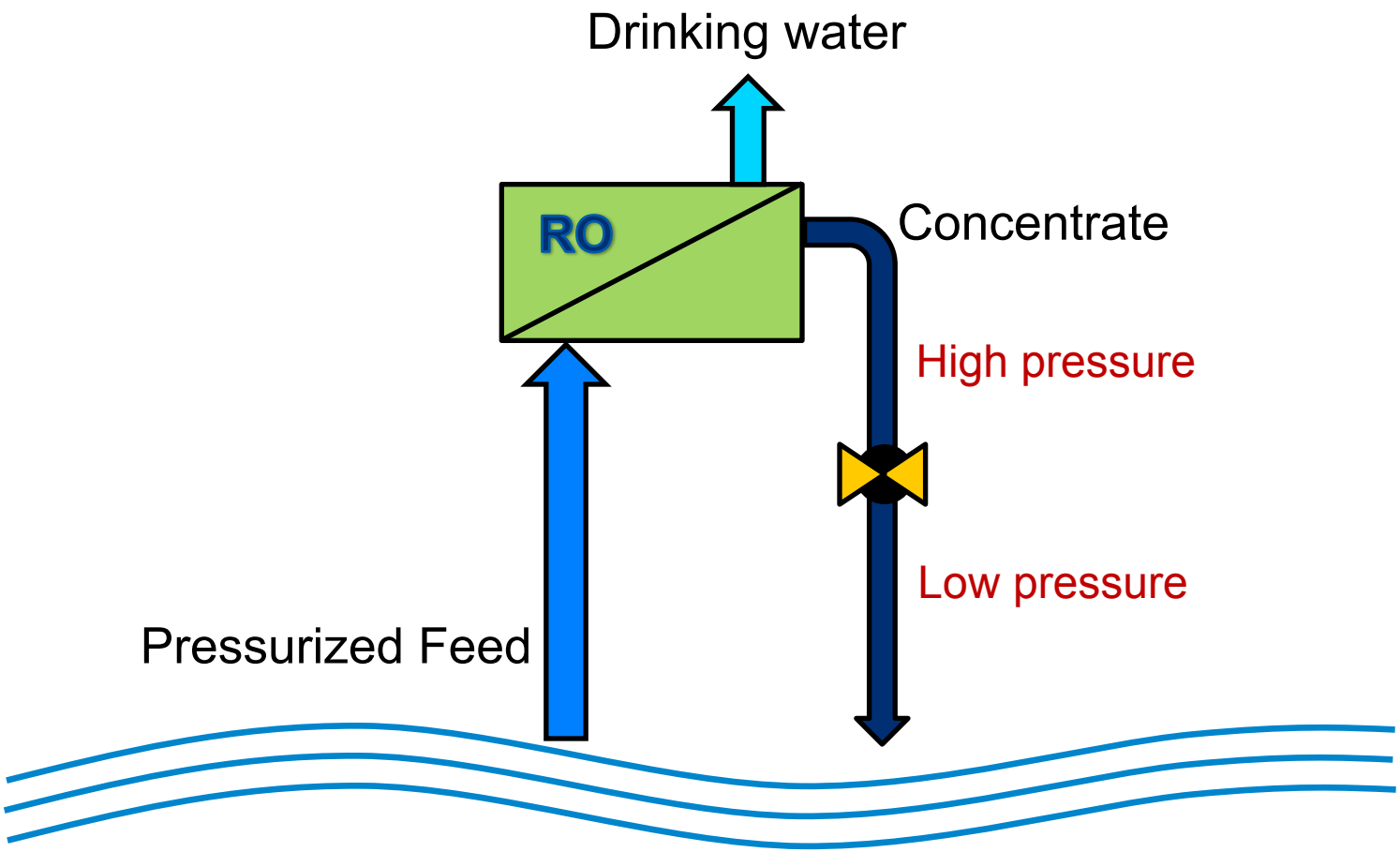


- Produces water with <500 mg/L salts
- Less energy intensive than distillation (~10x less)
- But… does have drawbacks
  1. passage of some contaminants → dual osmotic barrier (FO/RO) or MD
  2. reduced driving force at high salt concentrations → osmotic dilution or MD
  3. membrane fouling → FO as pretreatment for RO

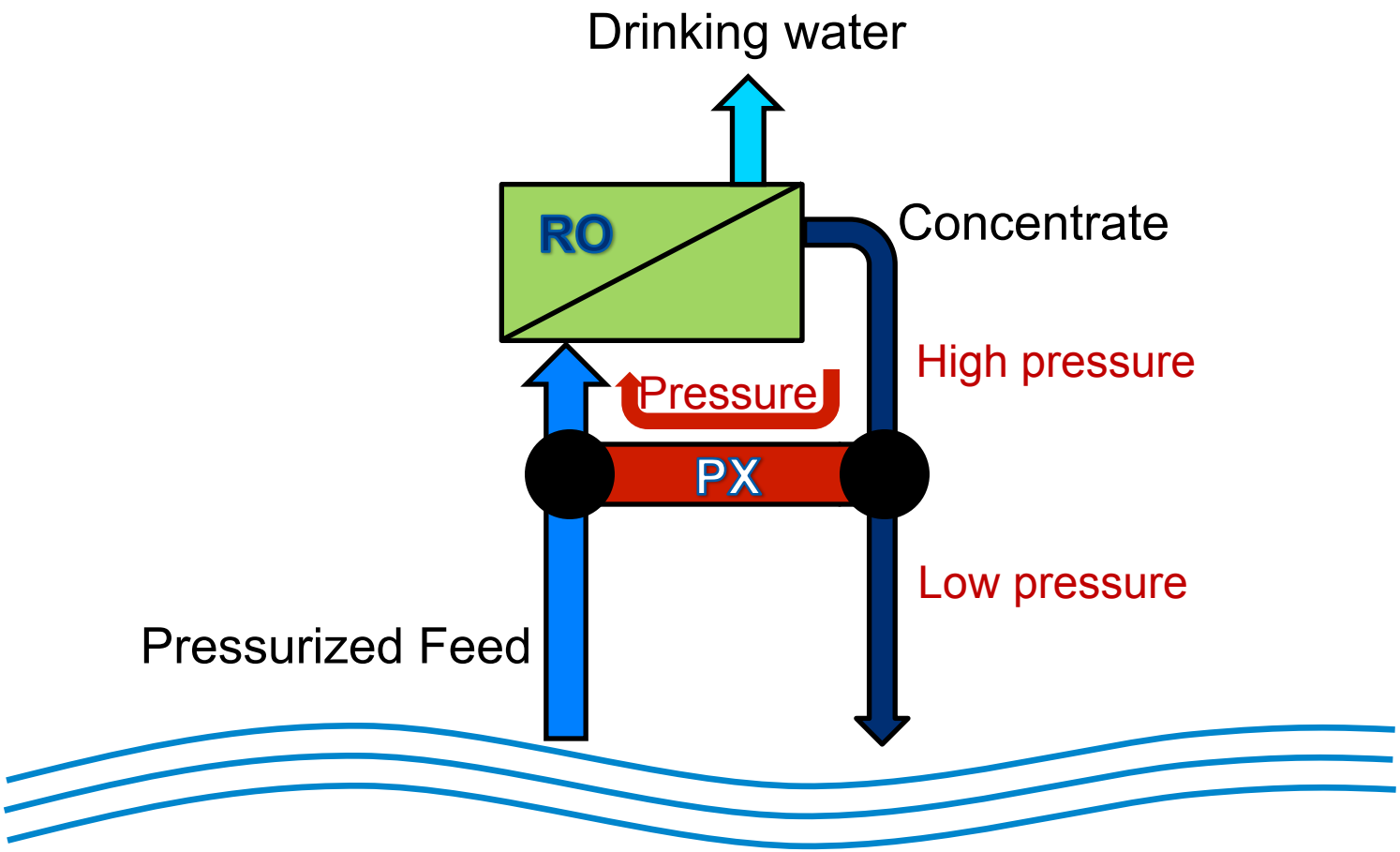
In-Land Desalination



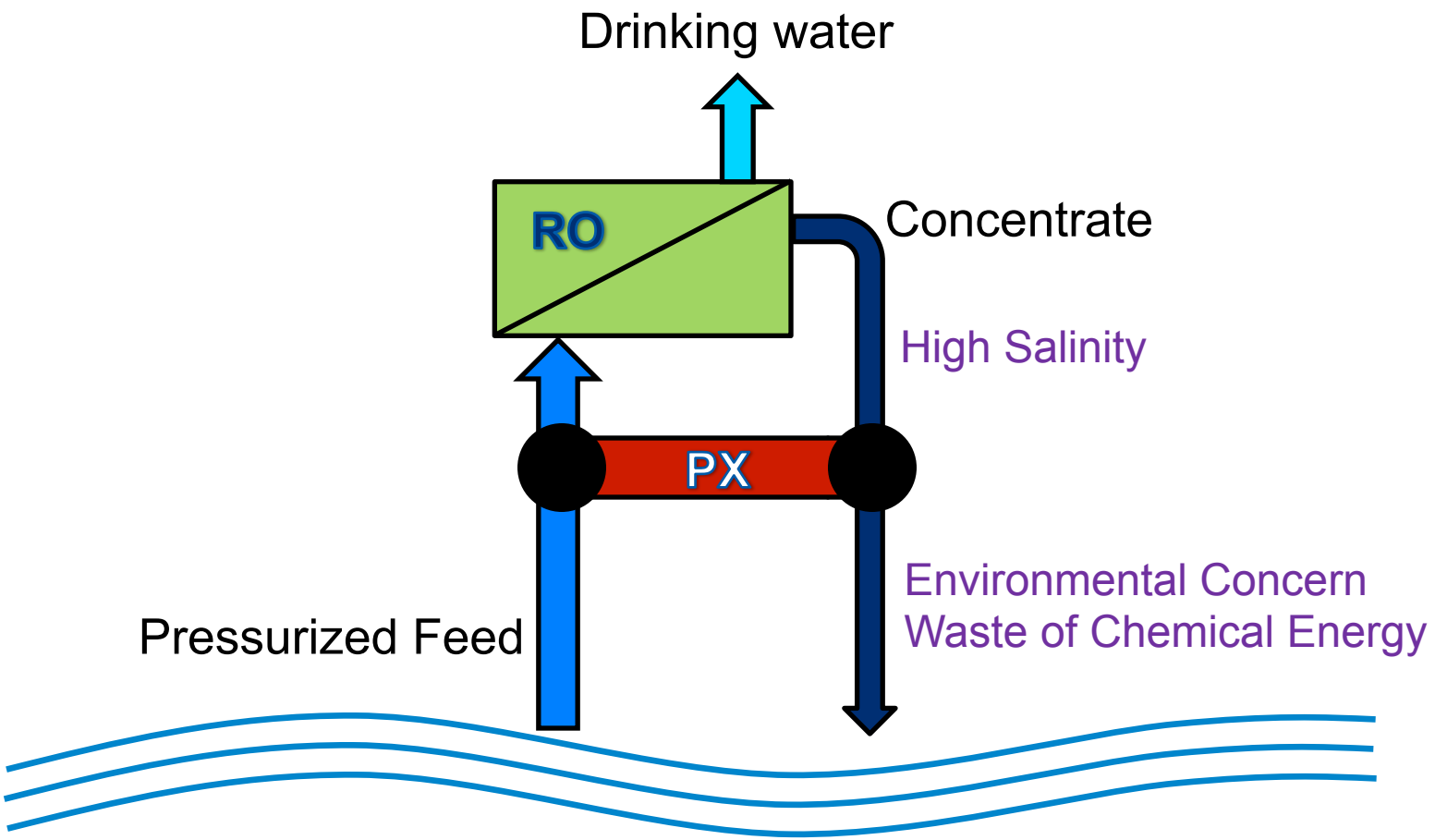
Seawater Desalination



Seawater Desalination



Seawater Desalination



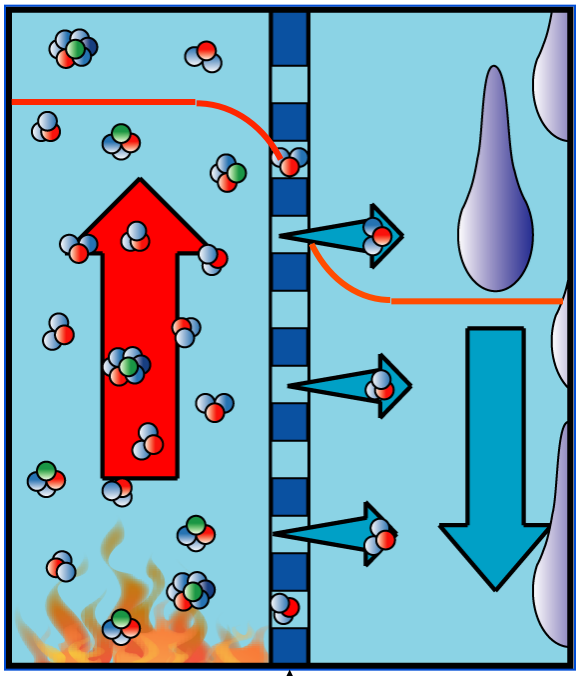
Emerging Technologies:

Membrane Distillation (MD)

Forward Osmosis (FO)

Pressure Retarded Osmosis (PRO)

Direct Contact Membrane Distillation



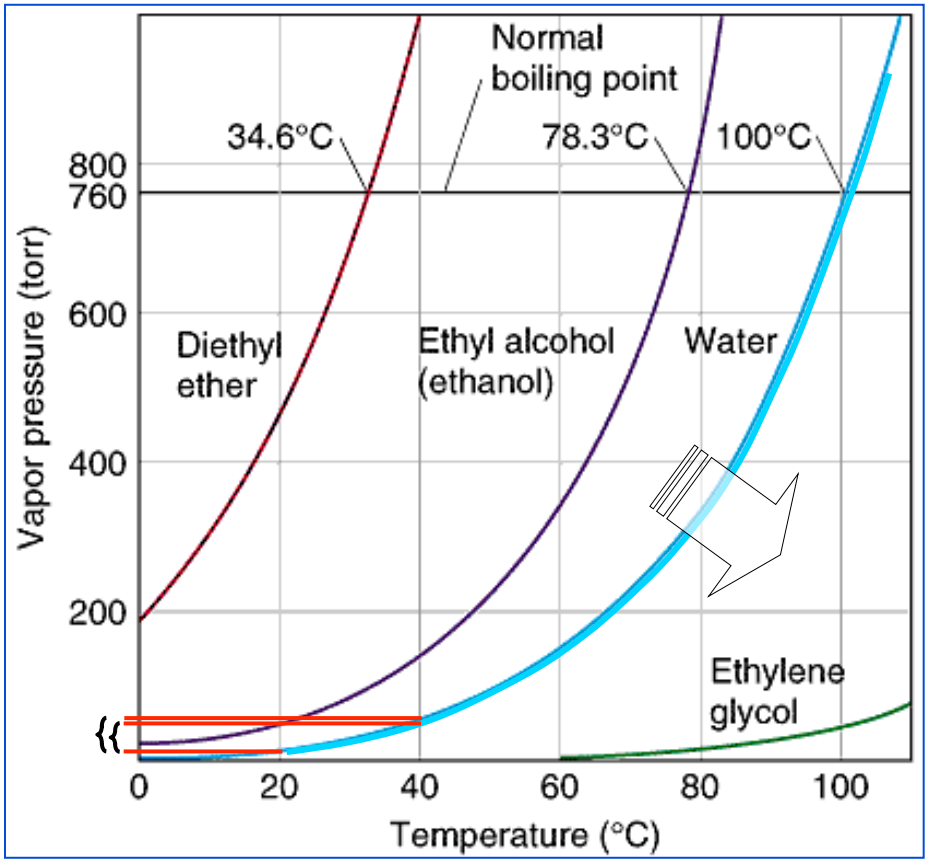
Heated Feed Stream

Cooler Distillate Stream

Hydrophobic, Microporous Membrane

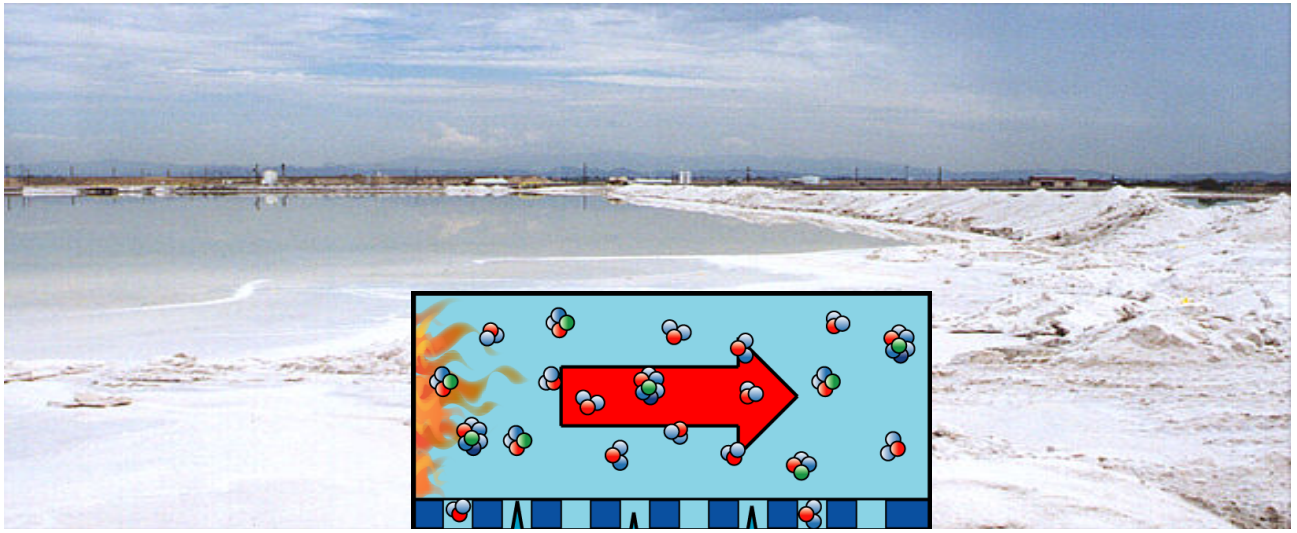
Driving force: vapor pressure gradient

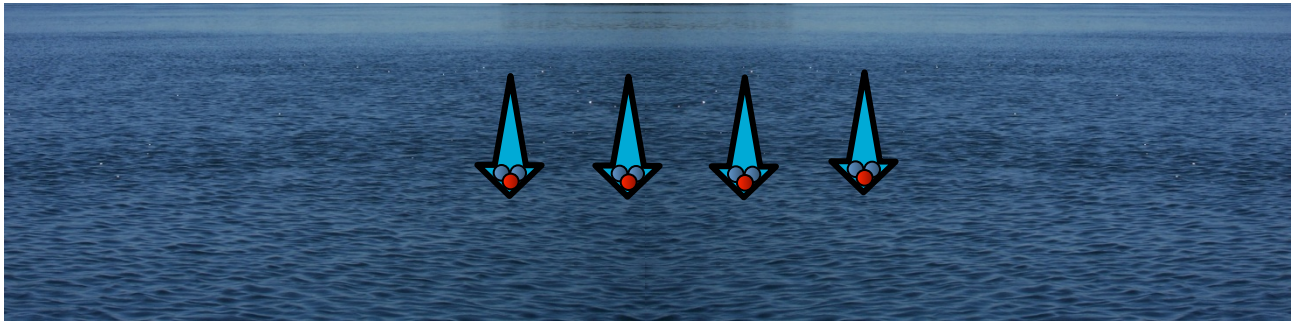
Driving Force in MD



Addresses RO Drawback 1: Reduced Driving Force at High Salt Concentration

Industrial Mineral Harvesting
Great Salt Lake, Utah



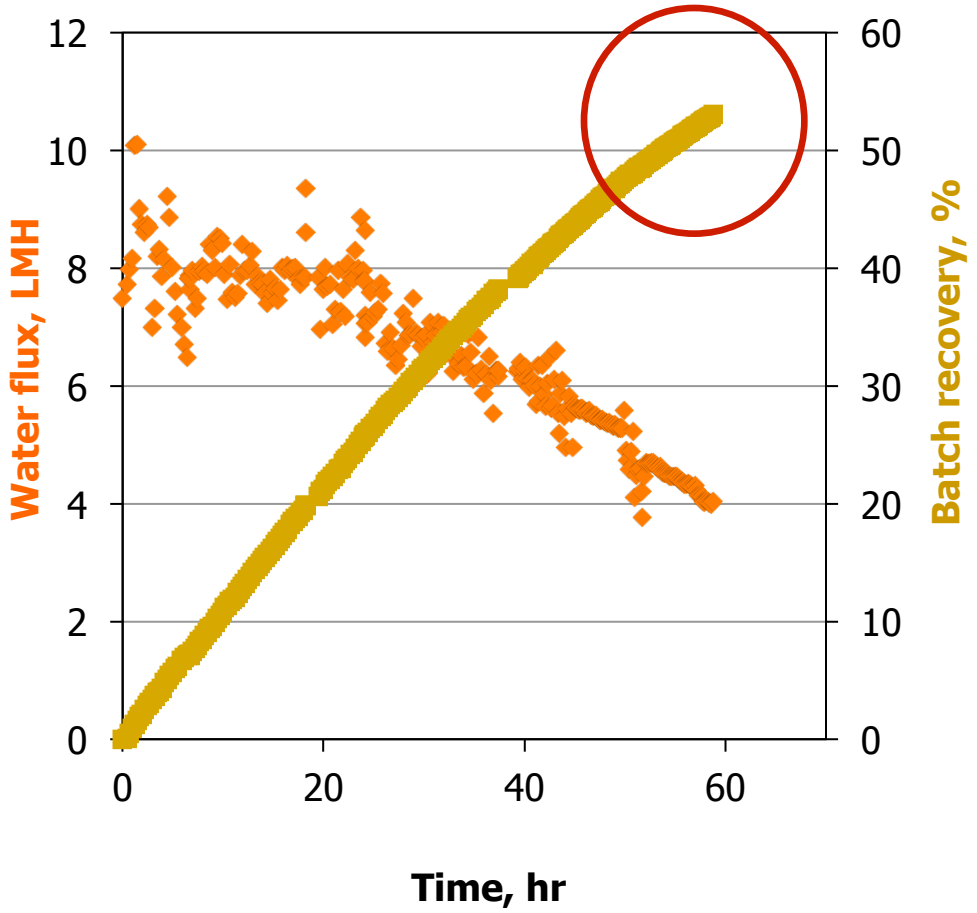


Tzahi Cath's Lab at Colorado School of Mines

Desalination of Hypersaline Lake Water

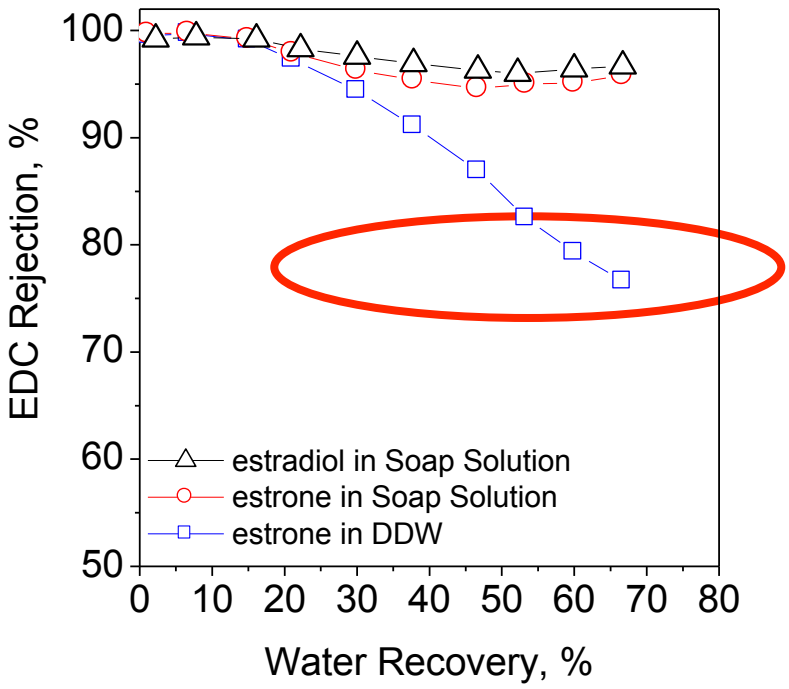
Constituent	g/L
Cl	83
SO_4	10
Ca	0.3
K	3
Li	0.03
Mg	6
Na	47
TDS	149 g/L

> 300 g/L

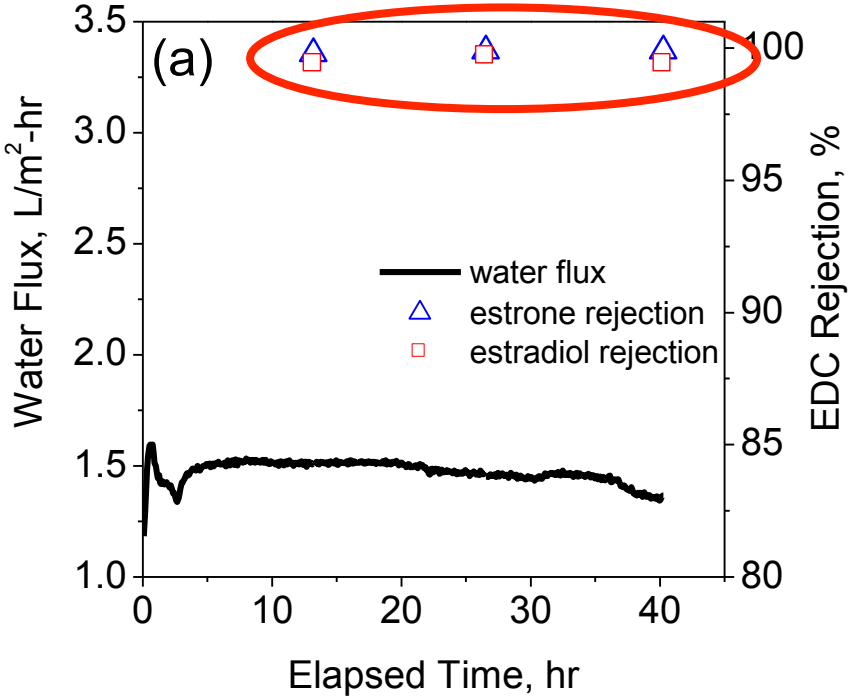


Removal of Emerging Contaminants

Osmotic Processes



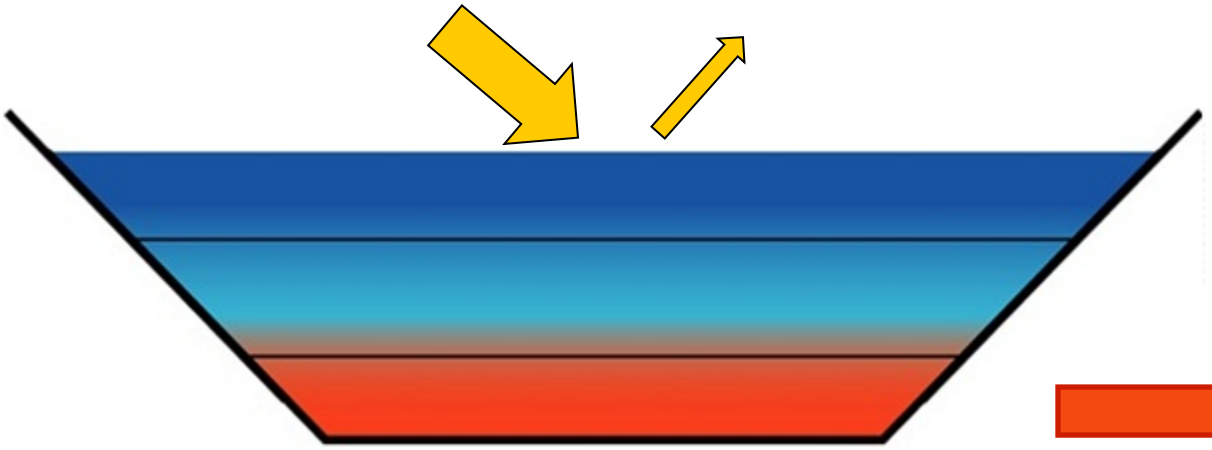
Membrane Distillation



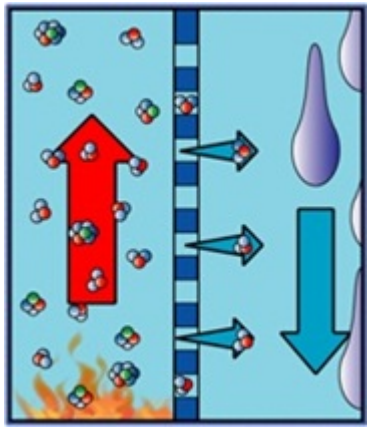
Addresses RO Drawback 3: Passage of Some Contaminants

Membrane Distillation with Solar Energy

Salinity Gradient
Solar Pond



Membrane
Distillation



Solar Thermal, Geothermal

Waste Heat

Stand-alone energy collection/storage and water desalination

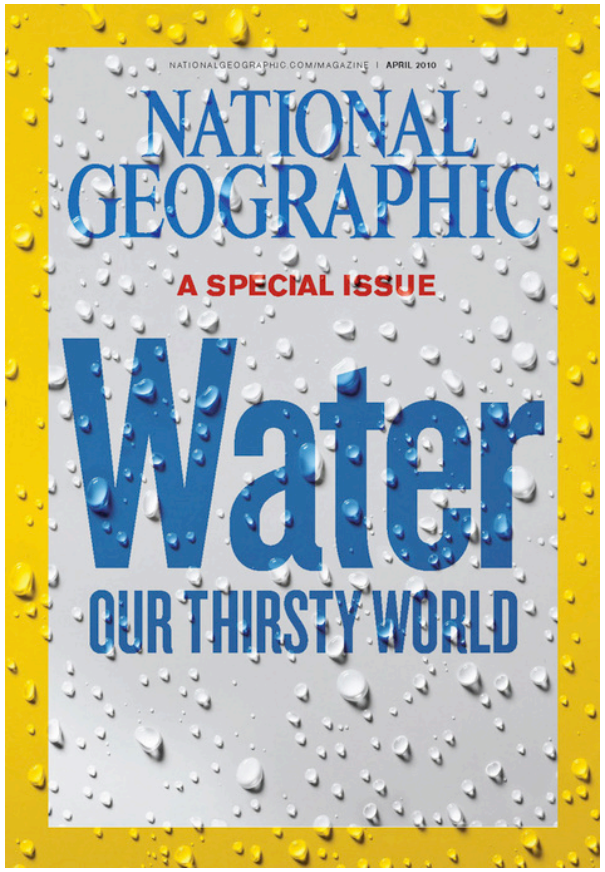
Emerging Technologies:

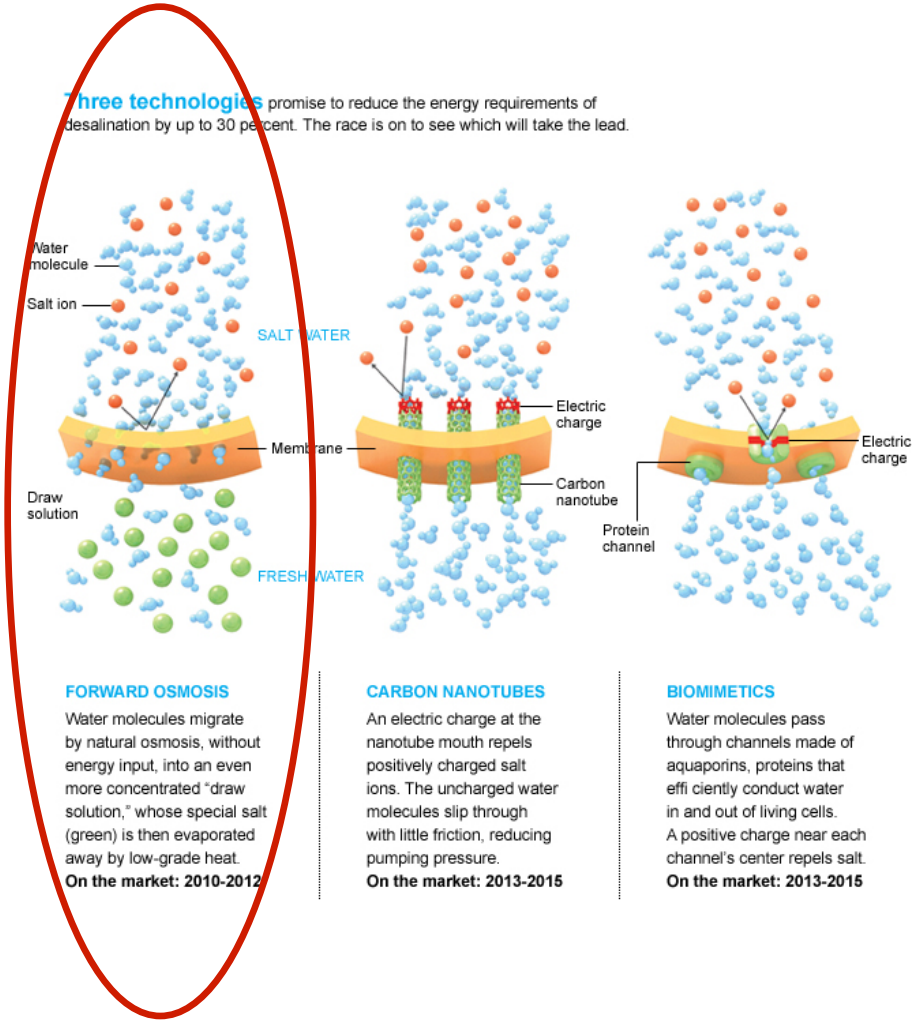
Membrane Distillation (MD)

Forward Osmosis (FO)

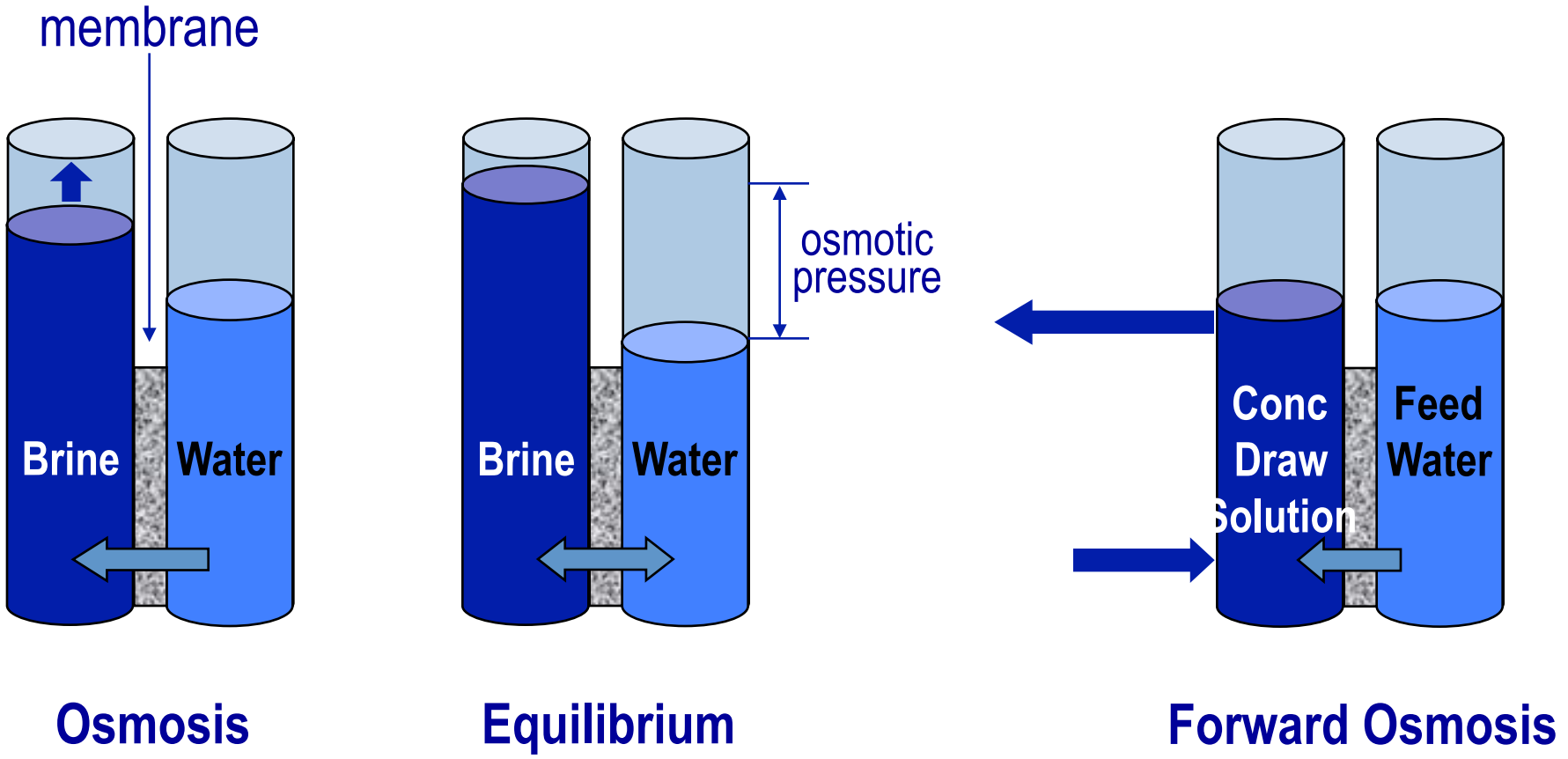
Pressure Retarded Osmosis (PRO)

Emerging Technology: Forward Osmosis



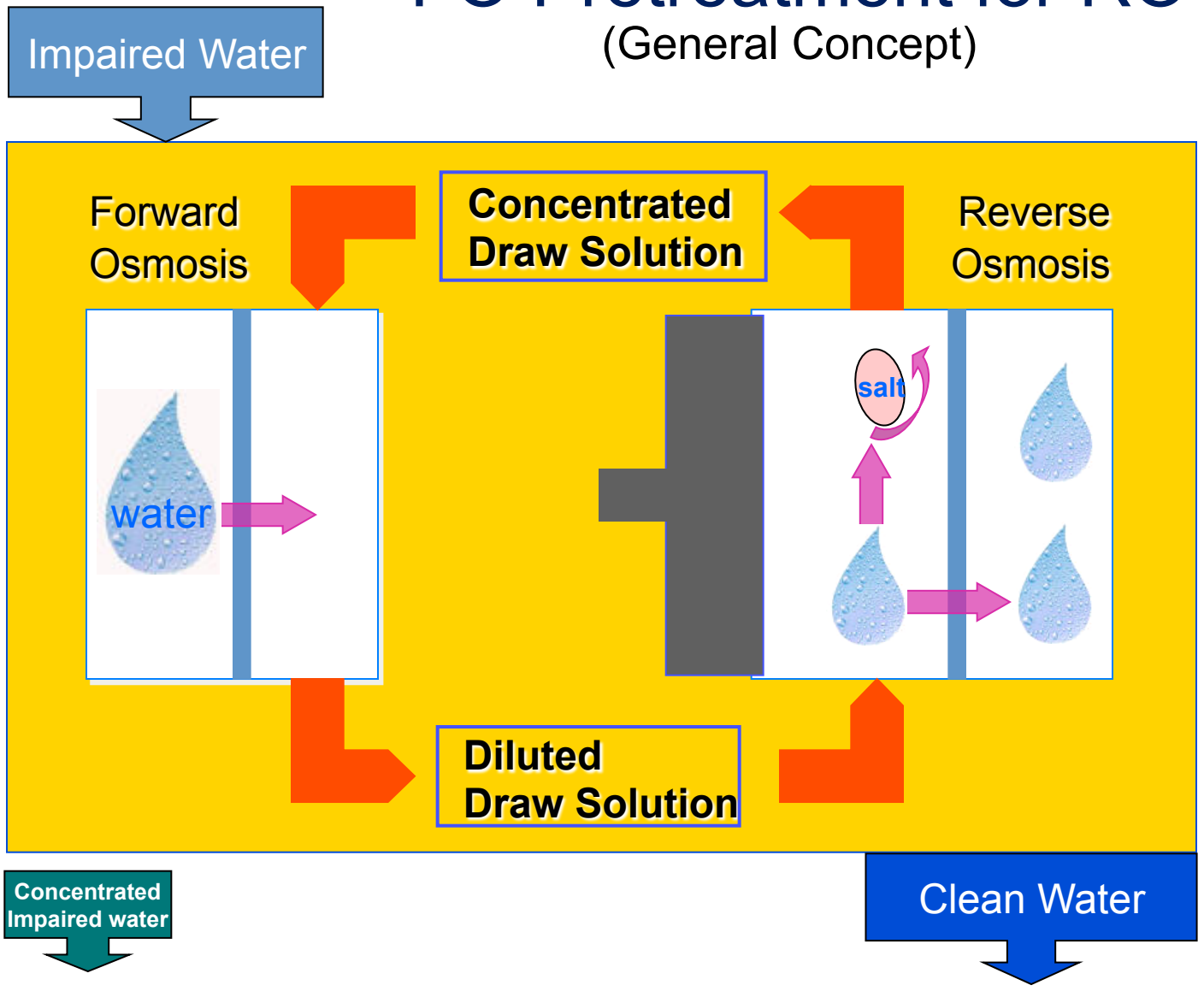


Osmosis and Forward Osmosis



FO Pretreatment for RO

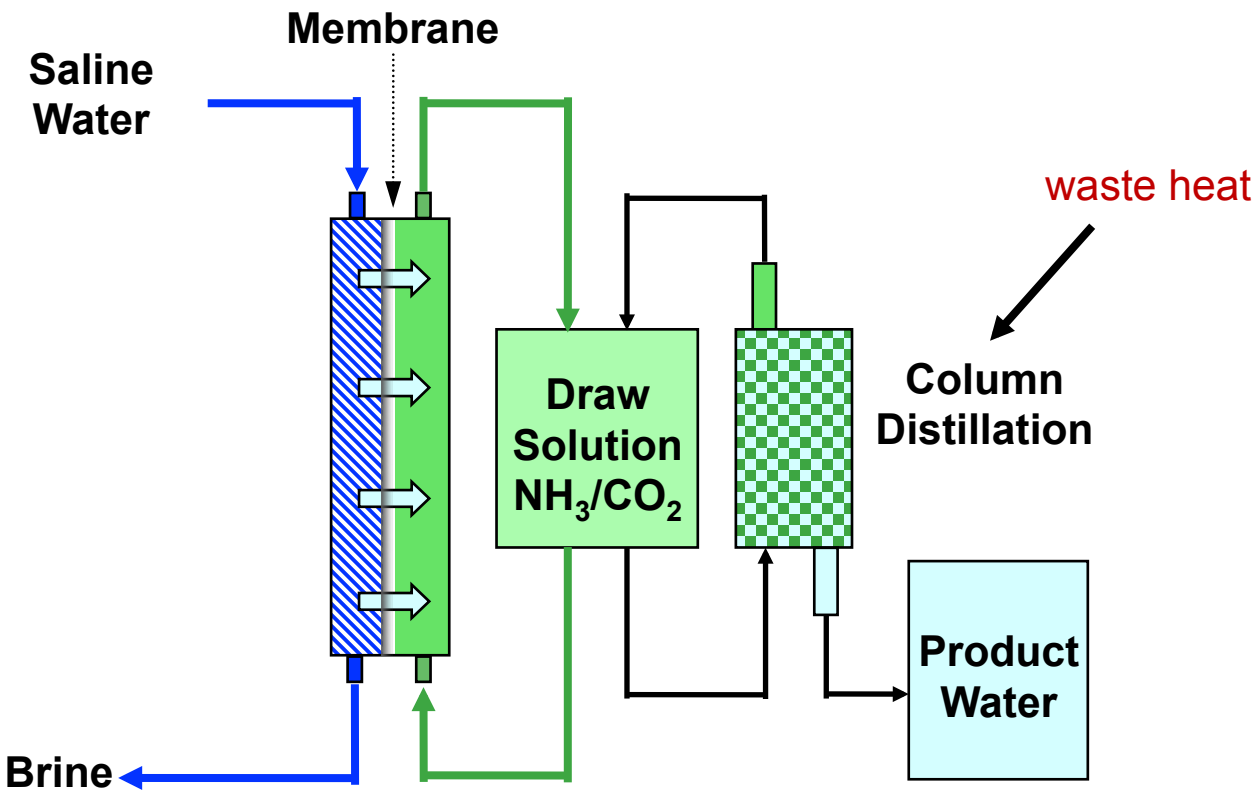
(General Concept)



Addresses RO Drawback 3: Membrane Fouling

Addresses RO Drawback 3: Passage of Some Contaminants

Ammonia-Carbonate FO Process



Has potential to require less energy than FO/RO

Meny Elimelech's Lab at Yale University

Emerging Technologies:

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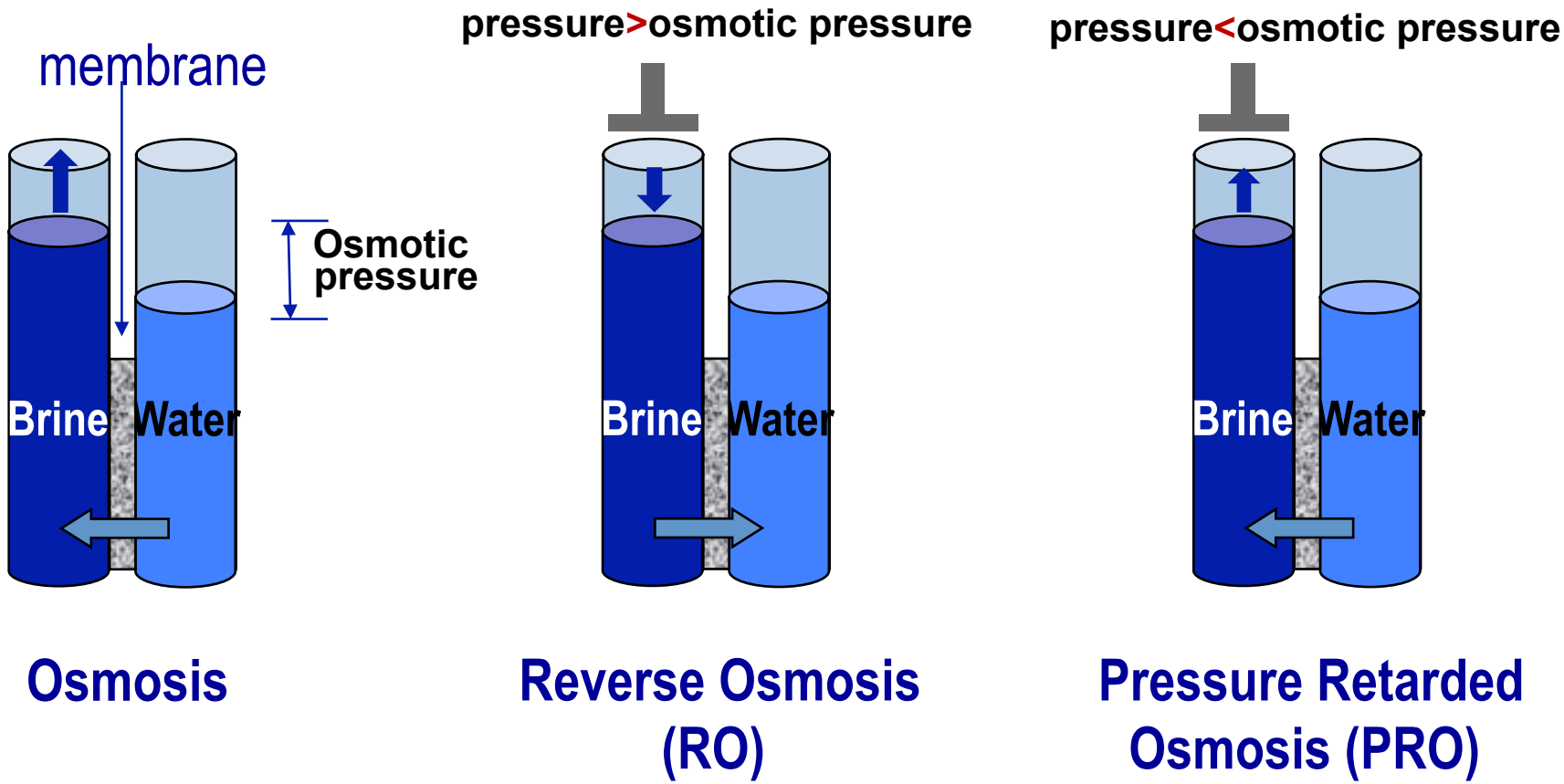
Pressure Retarded Osmosis (PRO)

What is Pressure-Retarded Osmosis?

- An osmotically driven membrane process similar to RO and FO



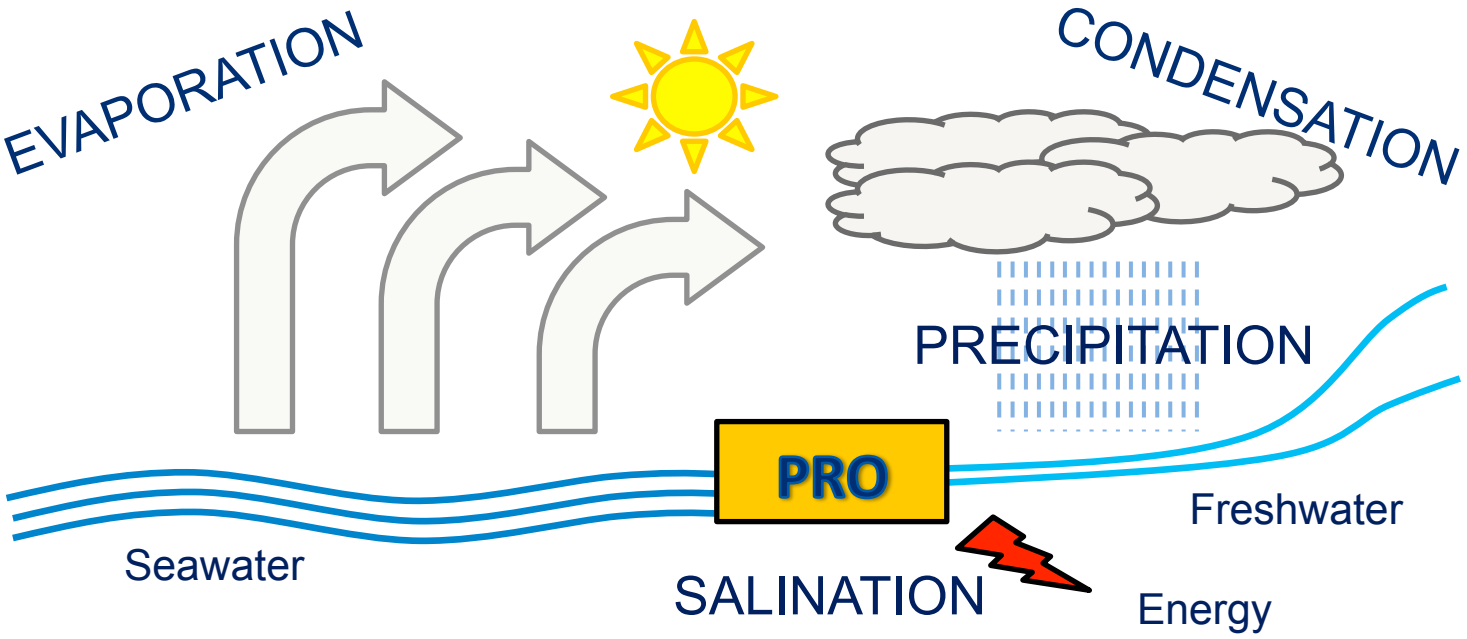
Osmosis

Reverse Osmosis (RO)

Pressure Retarded Osmosis (PRO)

What is Pressure-Retarded Osmosis?

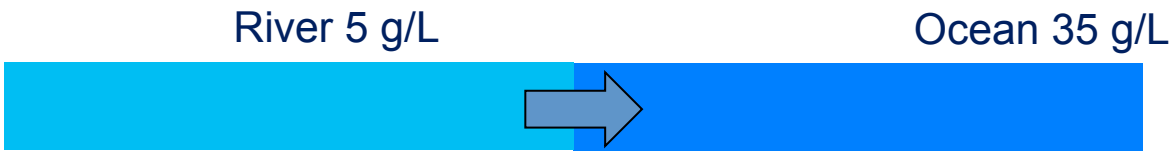
- An osmotically driven membrane process similar to RO and FO
- A source of renewable and sustainable energy



global energy production from mixing in estuaries: 2,000 TWh/y
current global energy production from all renewable sources: 10,000 TWh/y

What is Pressure-Retarded Osmosis?

- An osmotically driven membrane process similar to RO and FO
- A source of renewable and sustainable energy
- A process of capturing the energy released from the mixing of freshwater with saltwater



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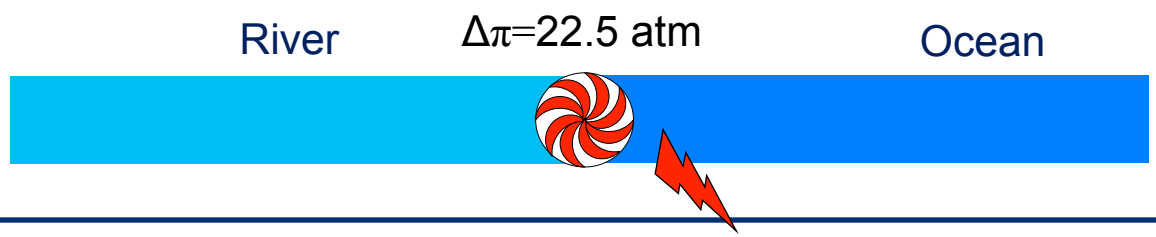

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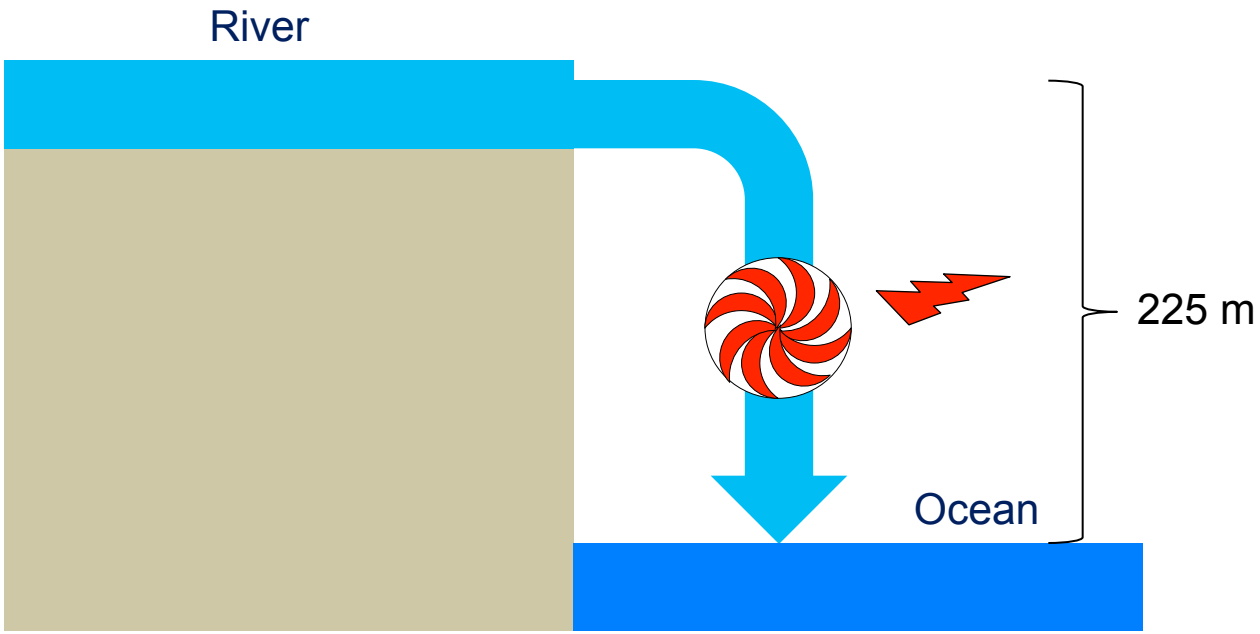
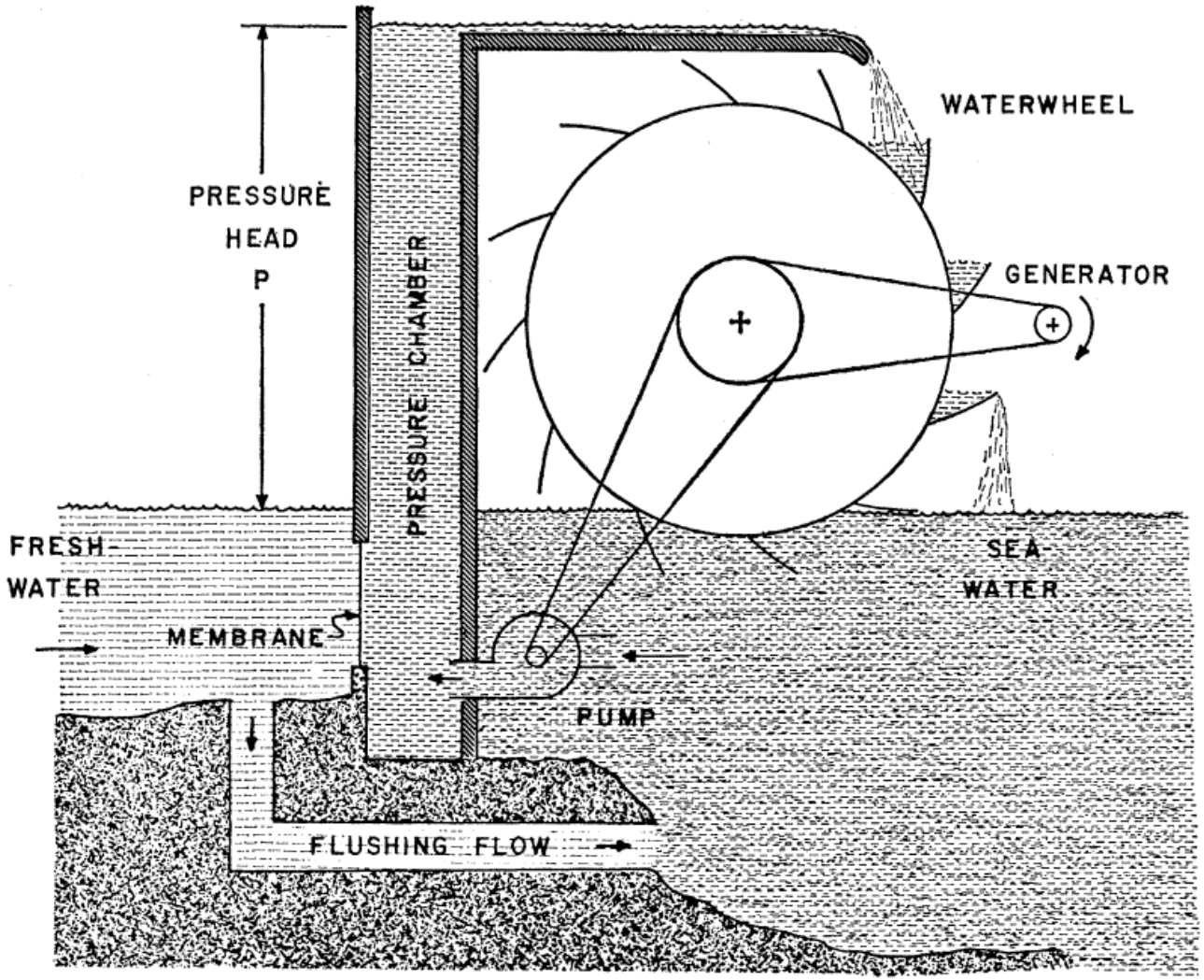


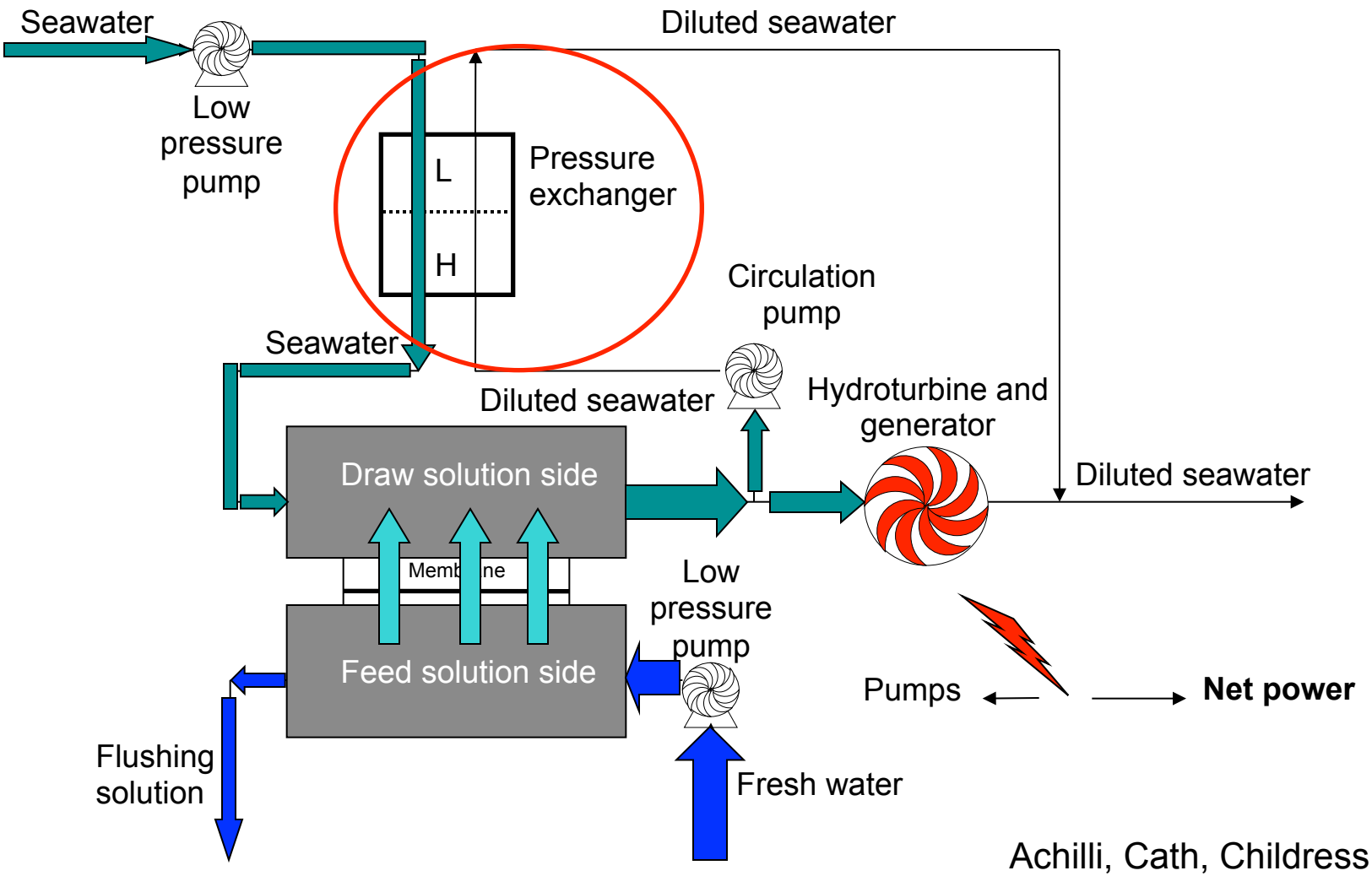
Power Generation with PRO

chemical potential transformed to hydraulic potential



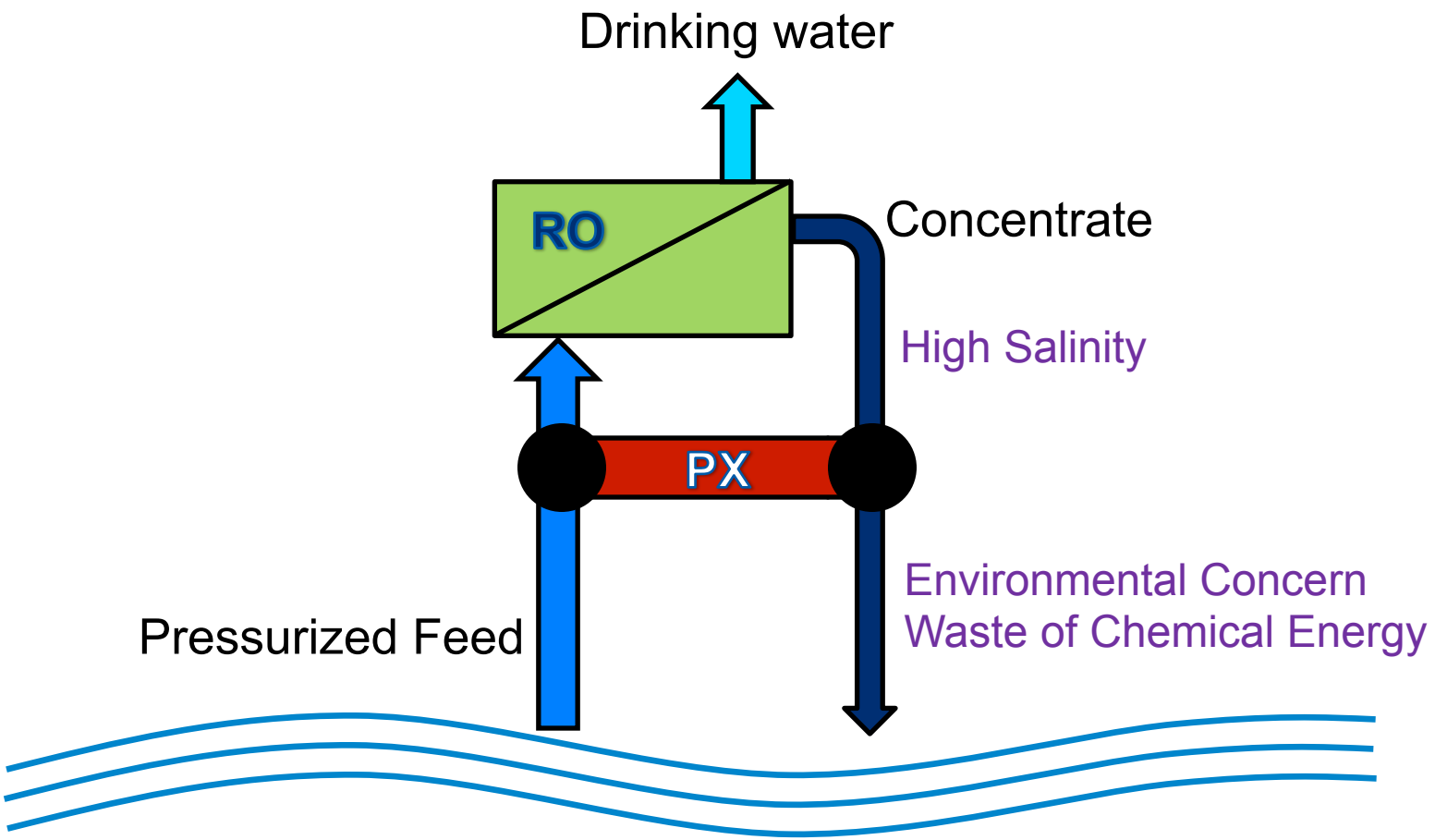
Norman, 1974

PRO System

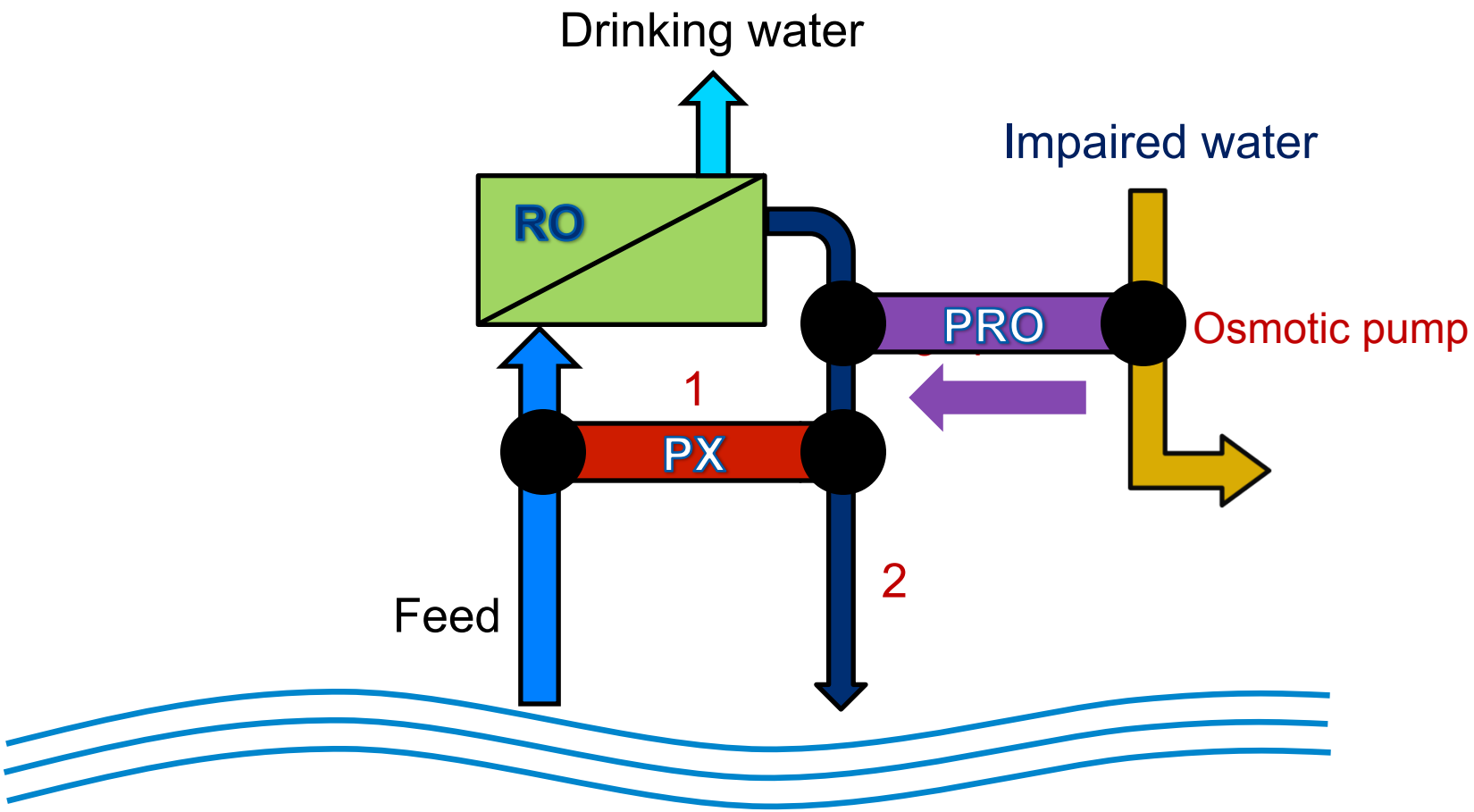


Achilli, Cath, Childress, 2009
Adapted from Loeb, 2002

Seawater Desalination



Proposed Energy Recovery in Seawater Desalination



1- Energy generation
2 - Concentrate dilution

Final Remarks

- There is no single best method for desalination
  - Water source and energy availability
  - Treatment needs
  - Sustainability considerations
- The needs for all processes are similar:
  - Commercial competition for membranes
  - New membrane modules / packing
  - Cost models
- MD, FO, and PRO have implications for wastewater reuse

Acknowledgements

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