Cornell Engineering

Civil and Environmental Engineering

CEE 4540

Sustainable municipal drinking water treatment

Topic: Desalination

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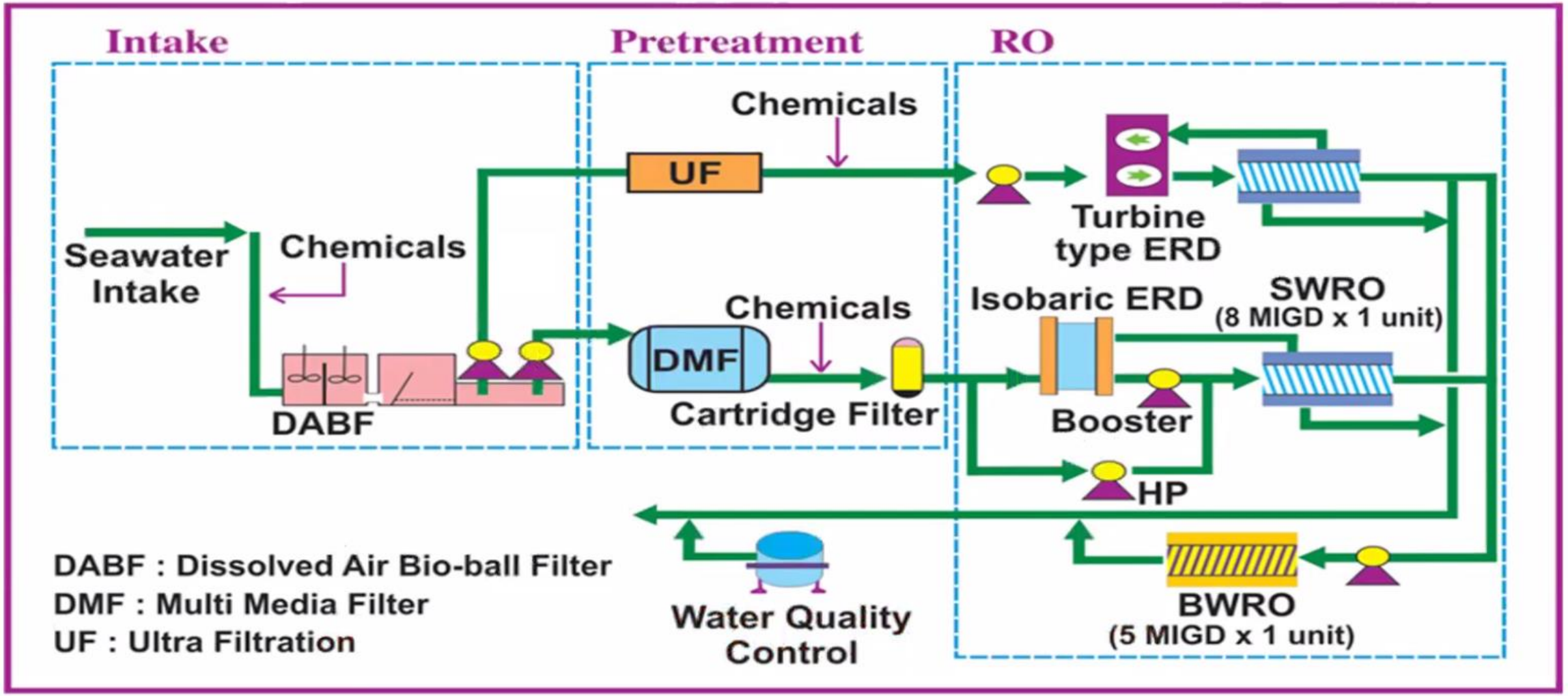
Class #17 10/29/2018 2:55 – 4:10pm

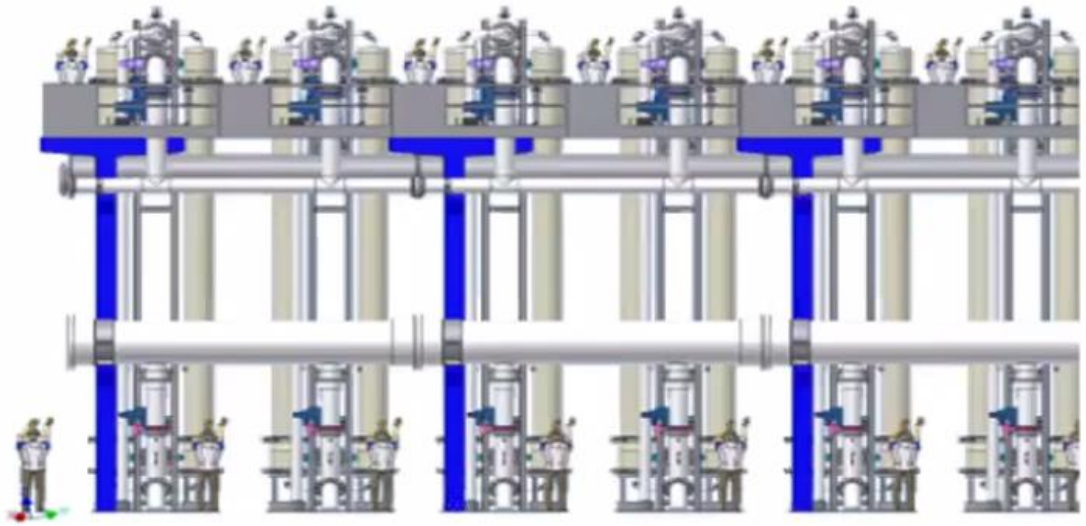
Typical RO Treatment Processes



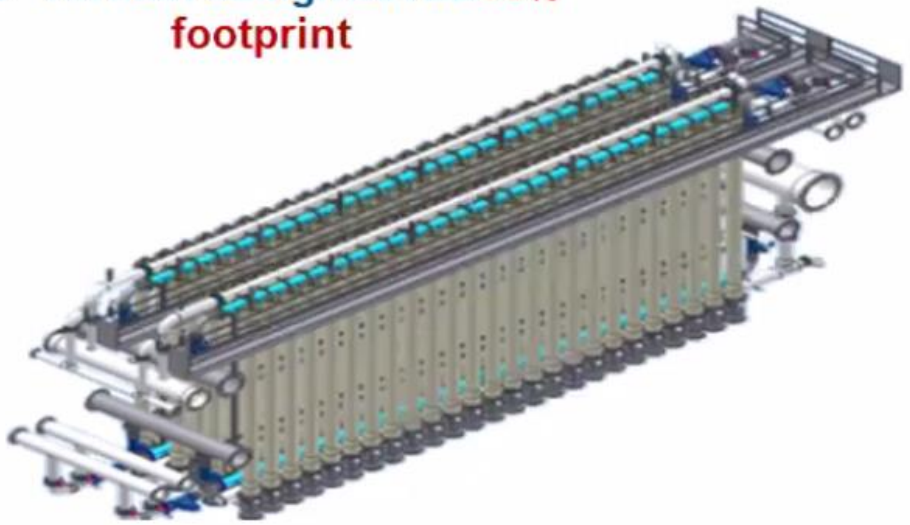
Advancements in SWRO: New RO Membranes & Modules

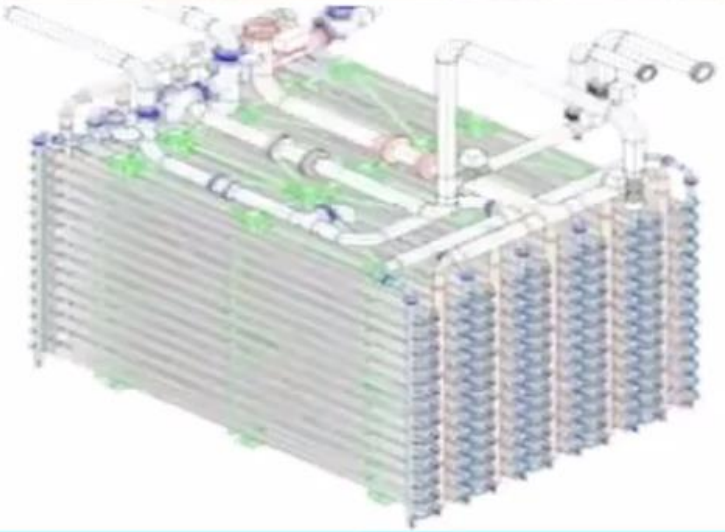
- LPRO & ULPRO Membranes
  - ~80 – 200 psi for Brackish Water
  - 600 – 900 psi for Seawater
- 16” Diameter RO Membrane Elements
  - Lower Capital Costs (One 16” element = 5.5 standard elements)
  - Smaller Equipment Footprint
  - Lower O&M Requirements

Advancements in SWRO: 16” Vertical Membranes, Sorek



16” vertical design saves 30% footprint





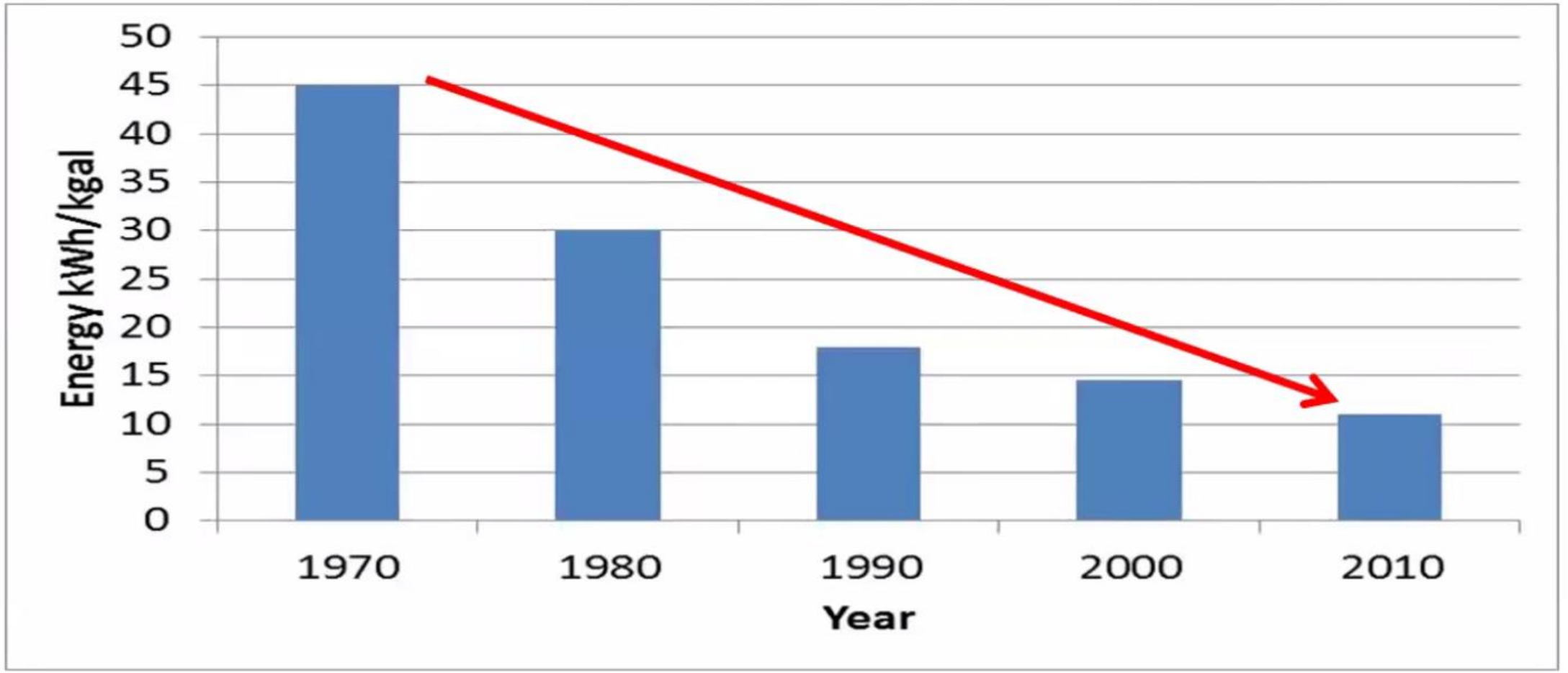
Standard 8” Horizontal design

AECOM Imagine it. Delivered.

Water/Energy Nexus: Energy Optimization

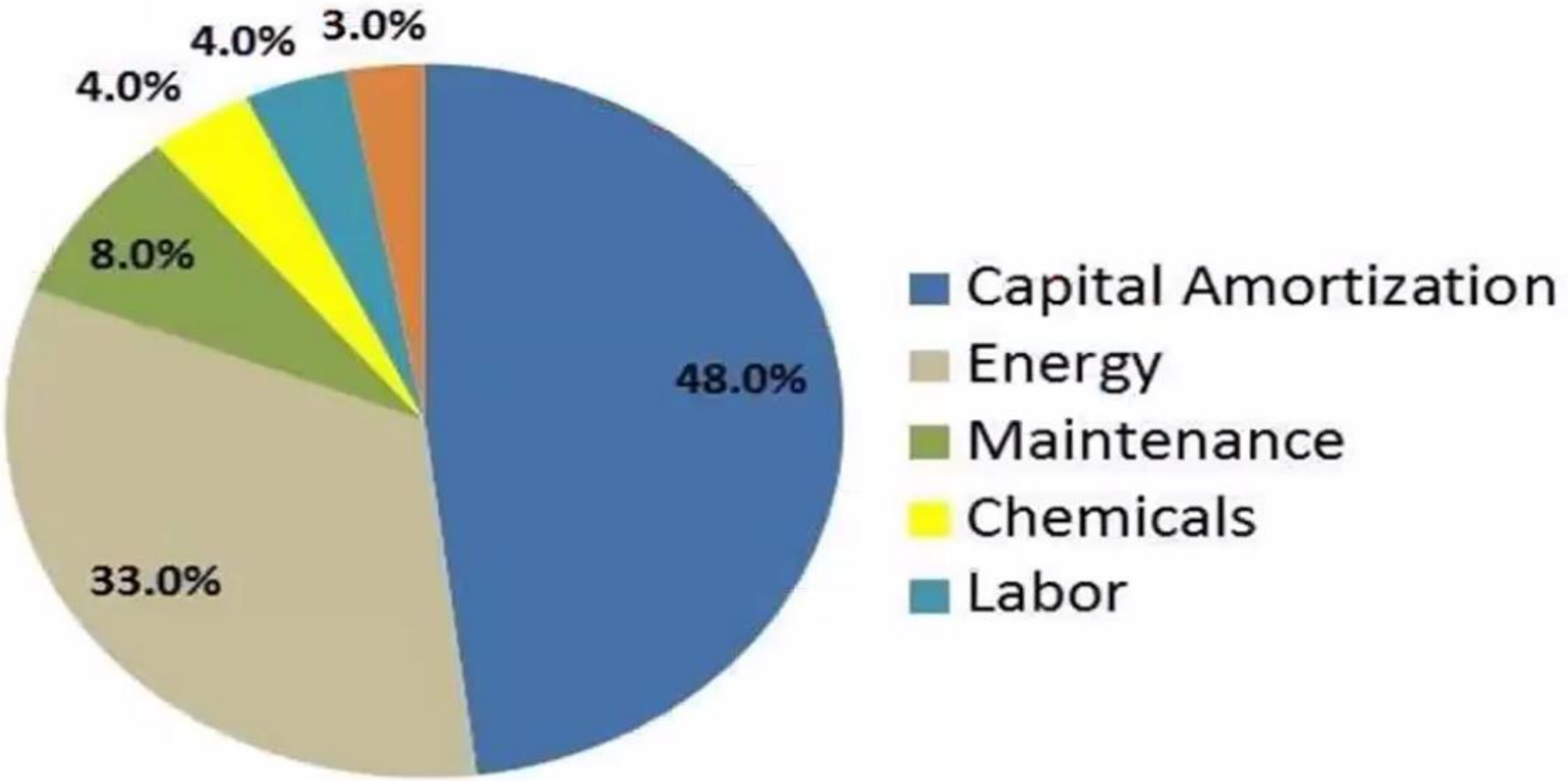
Minimizing Energy Consumption & Taping into Renewable Energy

Historical Energy Consumption of Seawater Desalination



SWRO Cost Breakdown

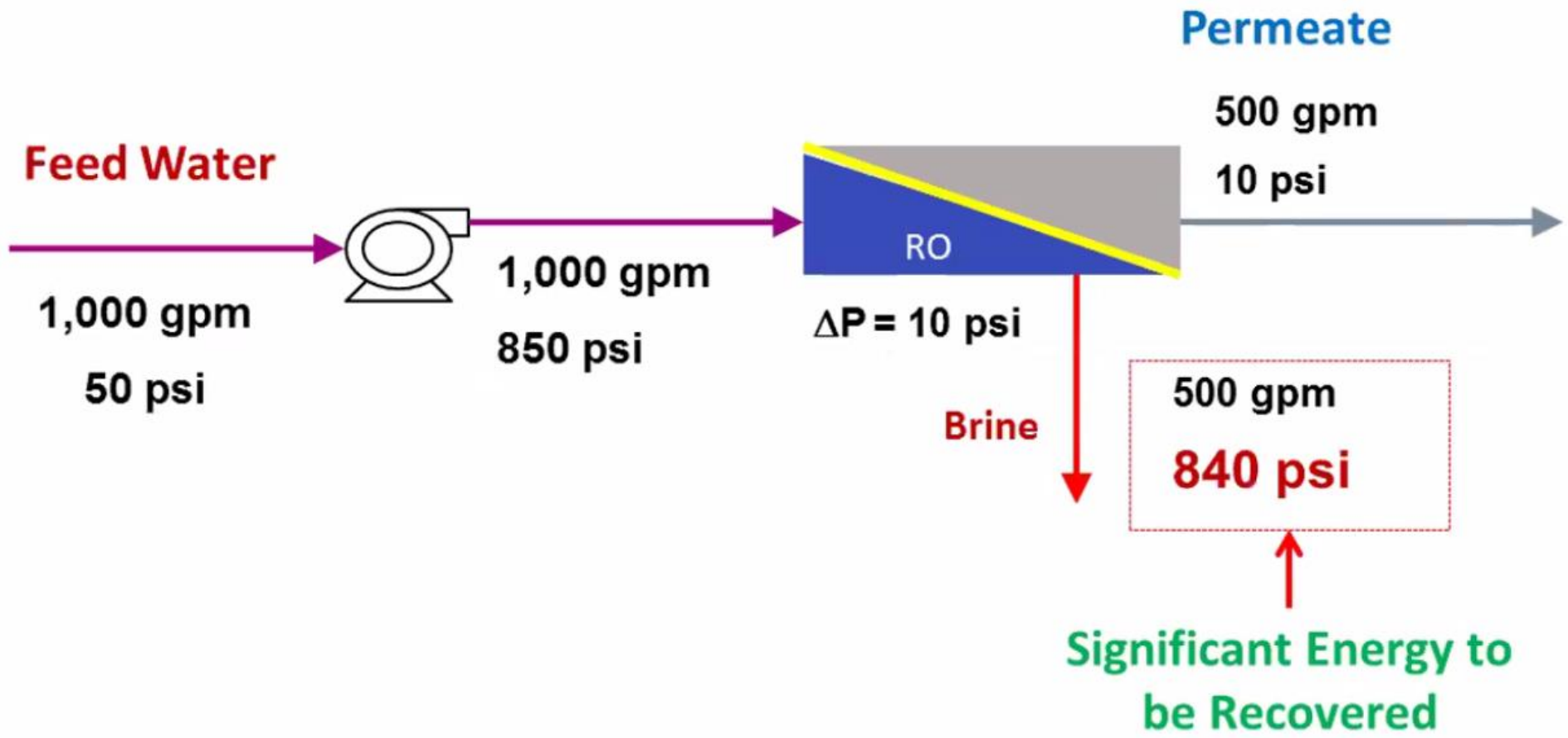
- Capital & Energy cost comprises > 80% of project cost



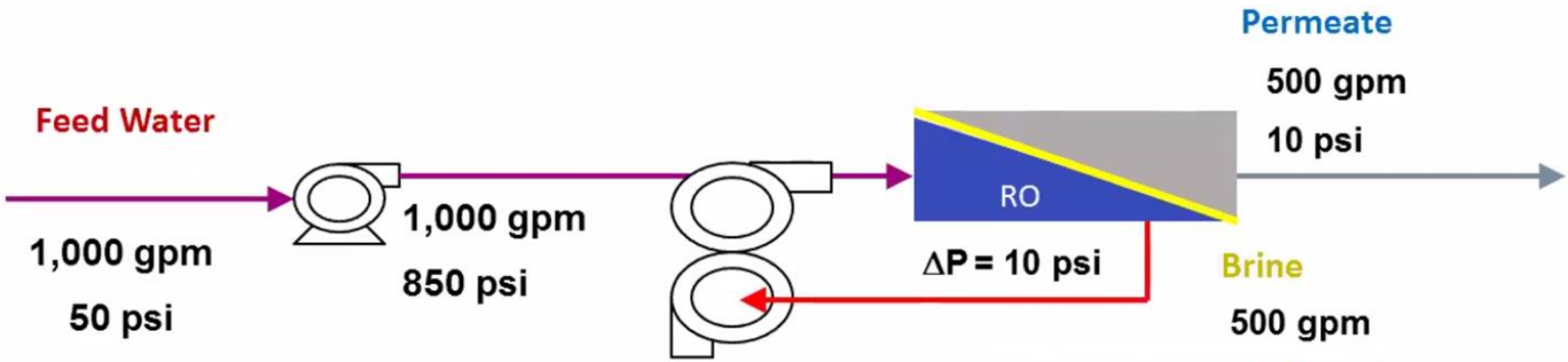
Factors Contributing to Lower RO Energy Consumption

- Better RO Membranes (Higher Permeability)
- High Efficiency Pumps
- High Efficiency Motors
- VFD (Variable frequency drive)
- Energy Recovery Devices (ERD)

Energy Recovery from RO Brine



Turbocharger: Mechanical Energy Recovery Device

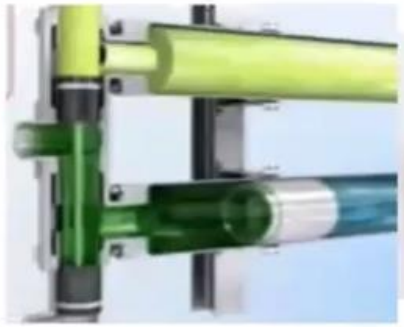


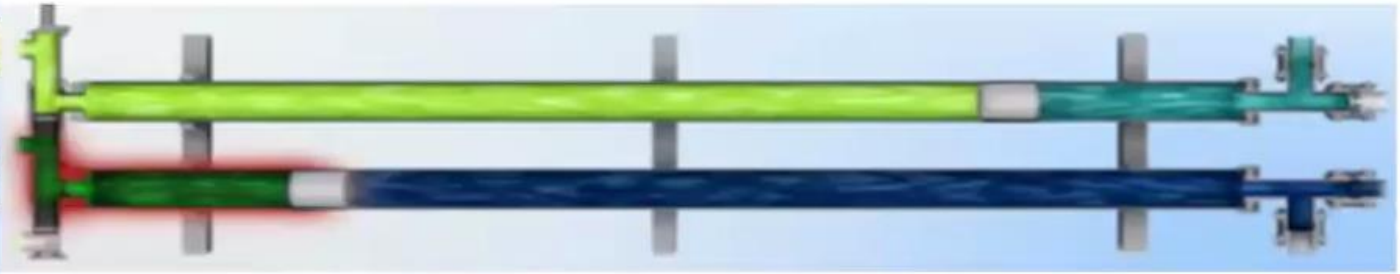
Hydraulic → Mechanical → Hydraulic

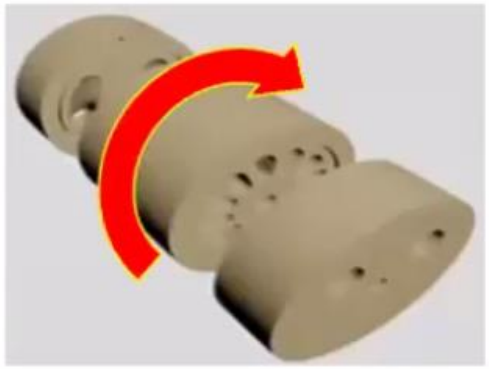
Energy Recovery Efficiency ~ 80%

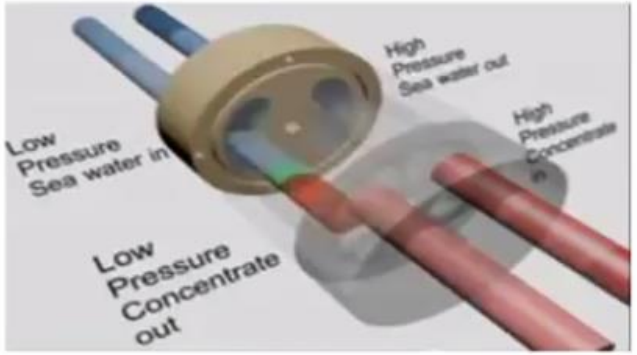
High Efficiency Energy Recovery

- **Isobaric devices (95-99%)**
  - **Piston style (DWEER by Flowserve)**
  - **Rotary pressure exchangers (PX by ERI)**

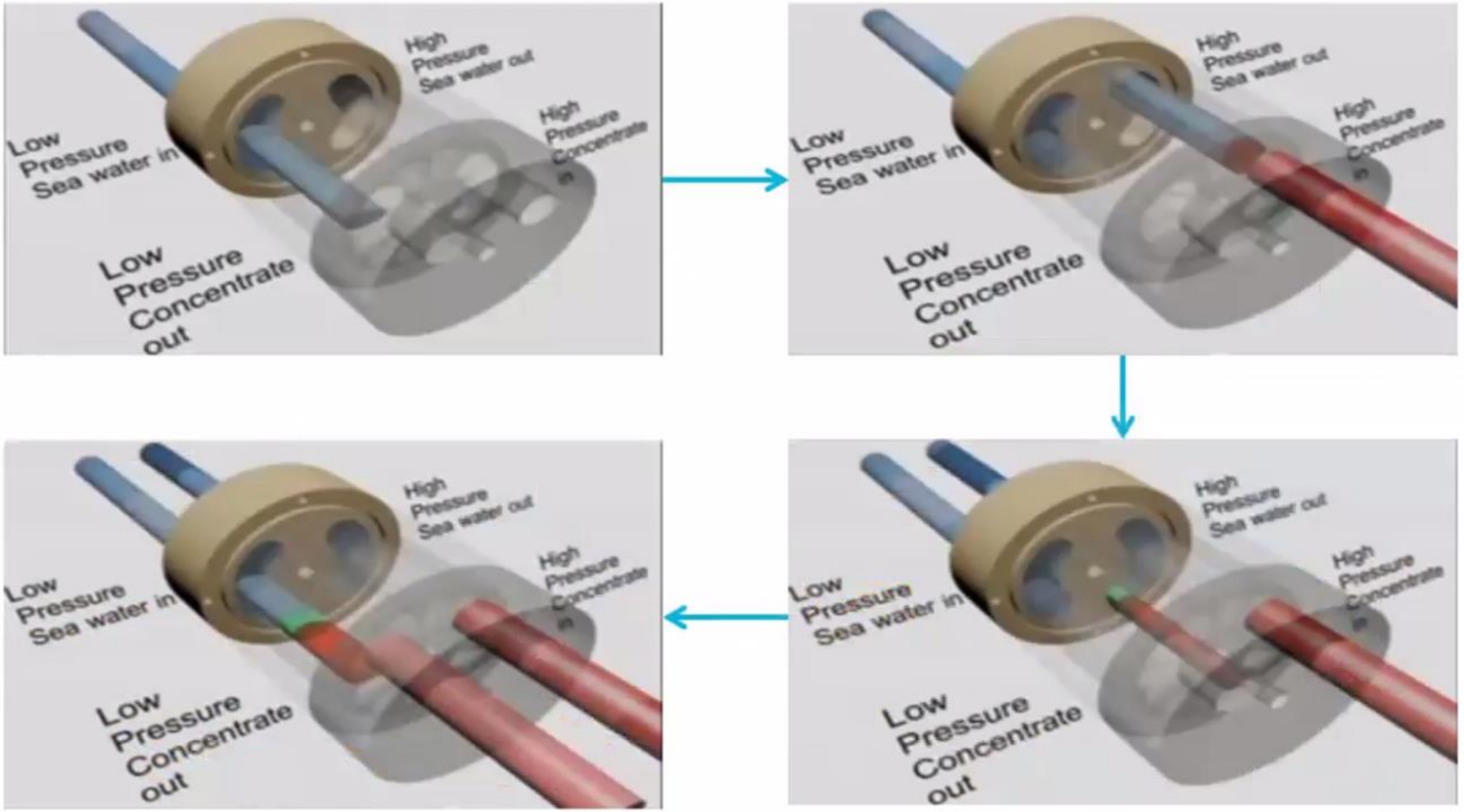








Mechanism of ERI Isobaric ERD



Renewable Energy for Desalination

Solar PV

Wind

Ocean

Hydro

Solar Thermal

Biomass

Geothermal

Hydrogen

The Perth Plant (Australia)

- Wind-Powered Desalination Facility at Kwinana
  - 34.3 MGD (144 MLD) seawater desalination facility
  - 48 wind turbines (80 MW) generate more energy (270 GWh/yr) than the desalination plant needs (180 GWh/yr)
  - Connected to gas fired power grid to supplement in low-wind conditions, but “return” power over time

World's Largest EDR Plant (Barcelona)

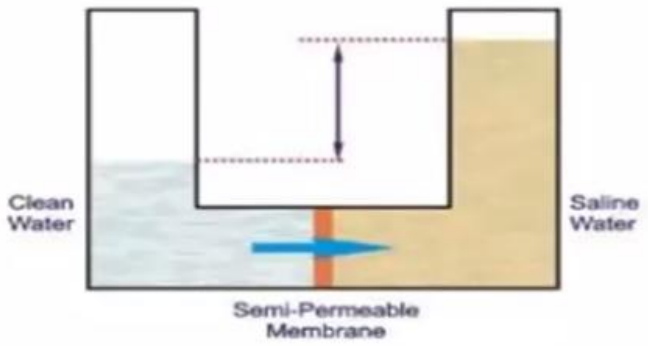
- Treating surface water under wastewater influence
- 58 MGD (230 MLD; 2.54 m3/sec)
- 210 MW/day (29% for pretreatment; 71% for EDR)
- 3.6 MW Solar Farm

AECOM Imagine it. Delivered.

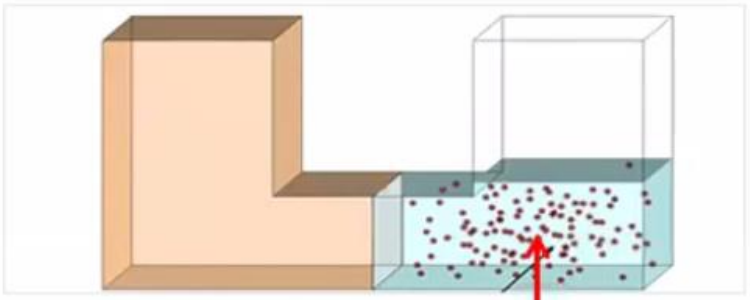
Emerging Desalination Technologies

Emerging Technology: Forward Osmosis

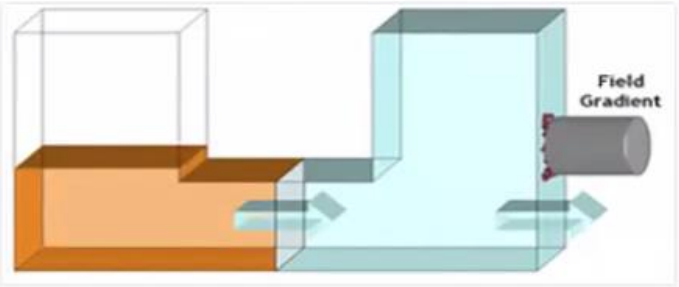
- Use osmotic agents in the Draw Solution
- No feed pressure required, Low Fouling
- FO membranes now available
- Can be used to treat VERY nasty and challenging water
- Draw agent recovery



Osmosis

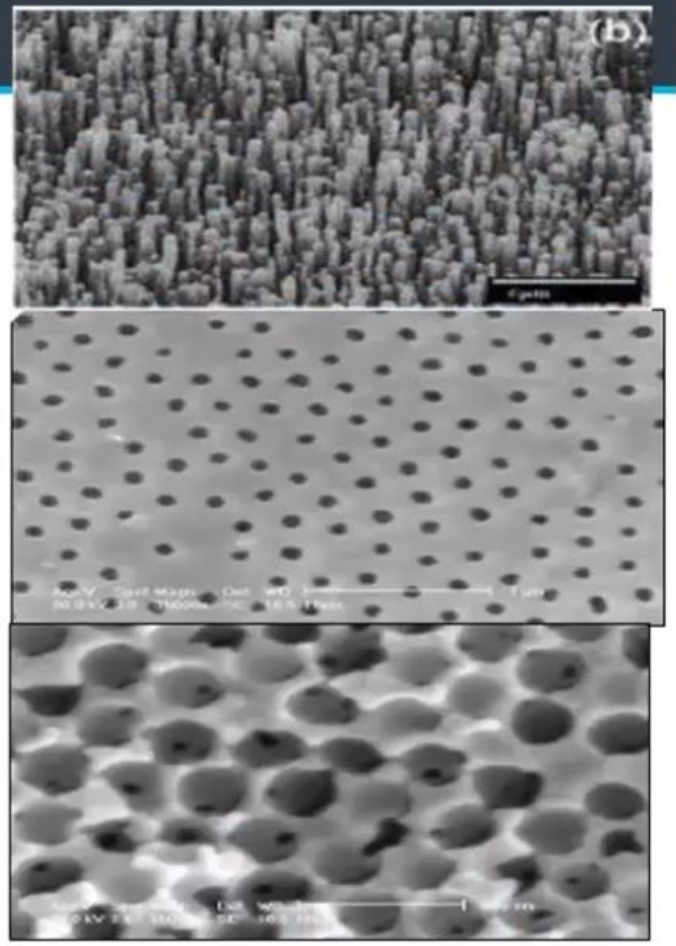


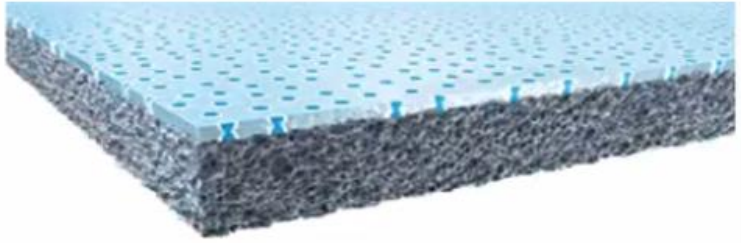
Draw Solution
(High Osmotic Pressure)



Emerging Technologies

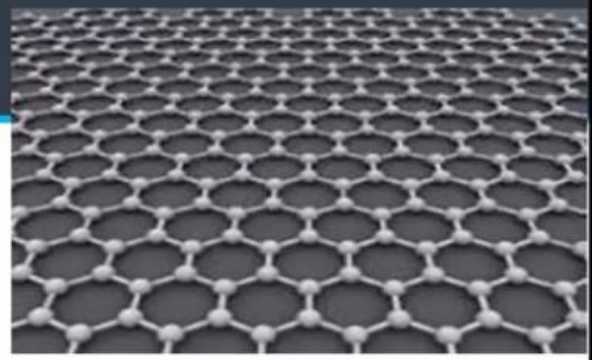
- Nano-Structured Membranes
  - Carbon Nanotubes
  - Inorganic/Organic Nanocomposites
- High Production (Flux) RO
  - Smooth membrane surface via surface modification
- Chlorine Resistance RO
  - Free Cl tolerance > 1 mg/L
- Biomimetic Membranes (Aquaporin)
- Membrane Distillation

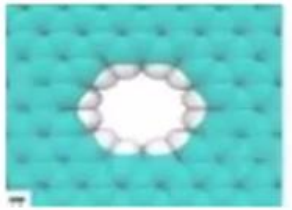


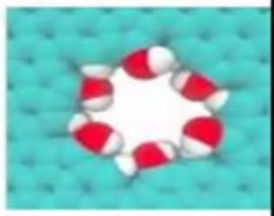


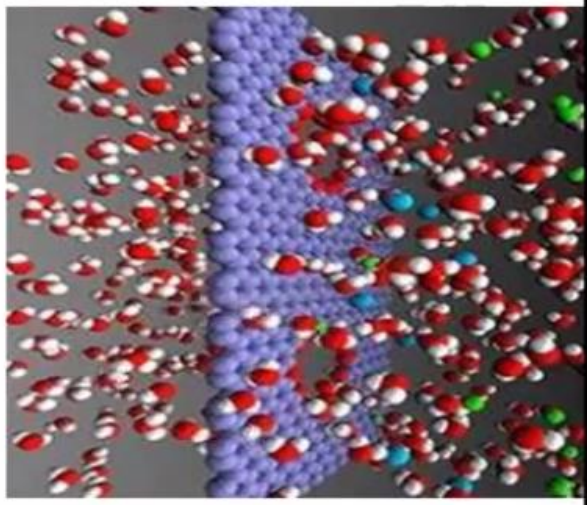
Graphene

- Nanoporous material (1.5 – 62 A^2)
- 1-atom thick of layered graphite
- Can “design” specific pore sizes
- Fast water convection, instead of slow diffusion
- Improve permeability by 100 -1,000 X
- Fouling resistant
- Chlorine tolerant
- Closer to mass production







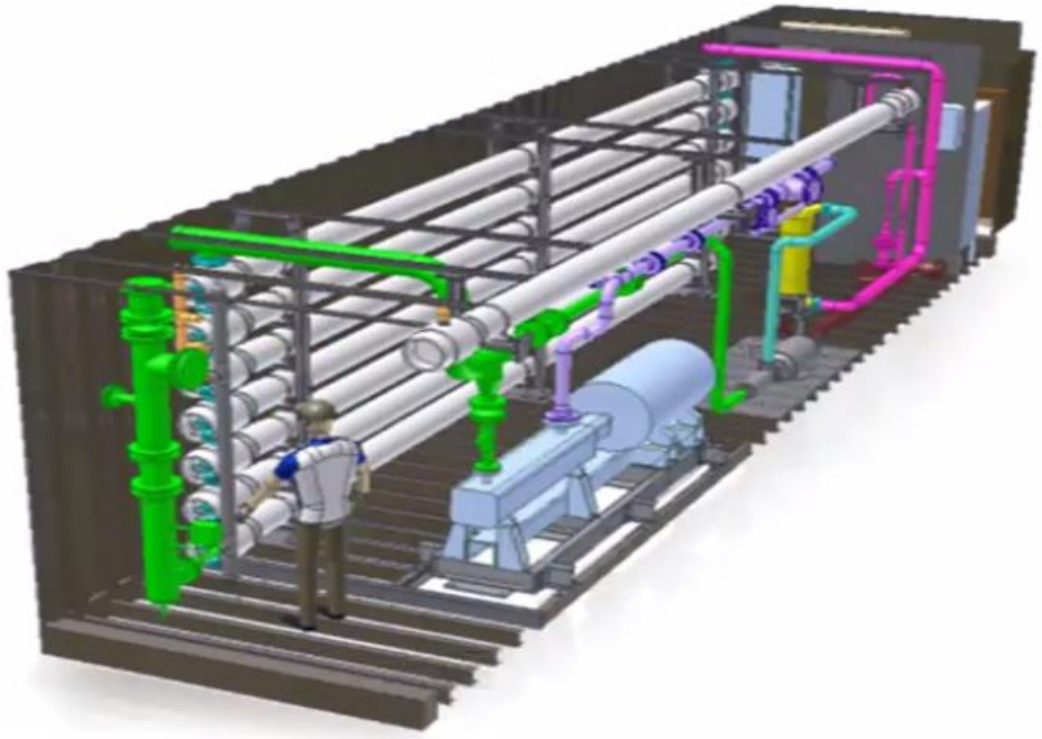


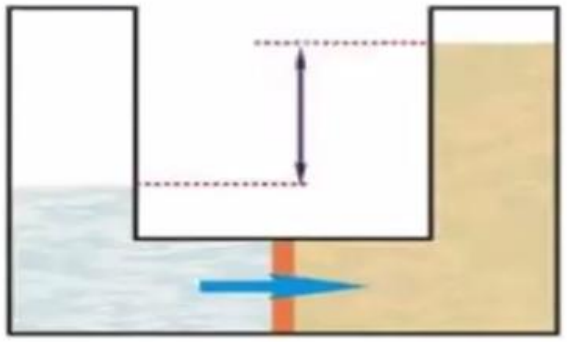
Innovative Chemical-Free Approach

- Utilizing biological filtration without coagulant addition
  - Control biological fouling by limiting AOC/BDOC
- Direct Osmosis Cleaning (DOC)

DOC Provides Quick "Backwash" to RO

- Use permeate stored in the DOC vessel to increase pressure on the RO permeate side to same as that in the feed
- Natural osmotic pressure will draw water from the permeate side to the feed side, and hence "backwash"
- Typically twice a day and each lasts ~ 12 sec

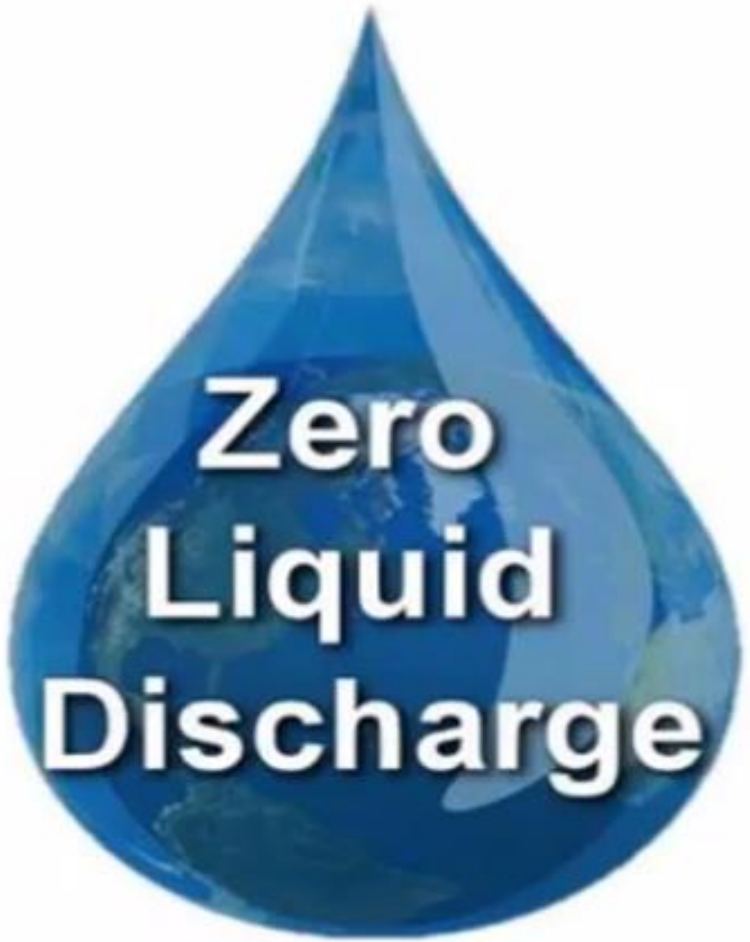




Permeate
Low TDS

Seawater
High TDS

Zero Liquid Discharge (ZLD)



ZLD