Electrochemical Desalination

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Water Technologies

The Challenge

- In August, 2007, the Singapore Environment & Water Industry Development Council (EWI) offered a Challenge
- They sought ideas to produce drinking water from seawater at an energy value of 1.5 kWh/m^3 or less
- Siemens Water Technologies R&D was announced the sole winner in June, 2008 from 35 proposal submissions
- The Siemens Project officially commenced on 01 October 2008
- The project is to culminate with 50 m^3/d Demonstration Plant in Singapore, treating actual seawater, by October, 2011 2010

The Pursuit of 1.5 kWh/m³

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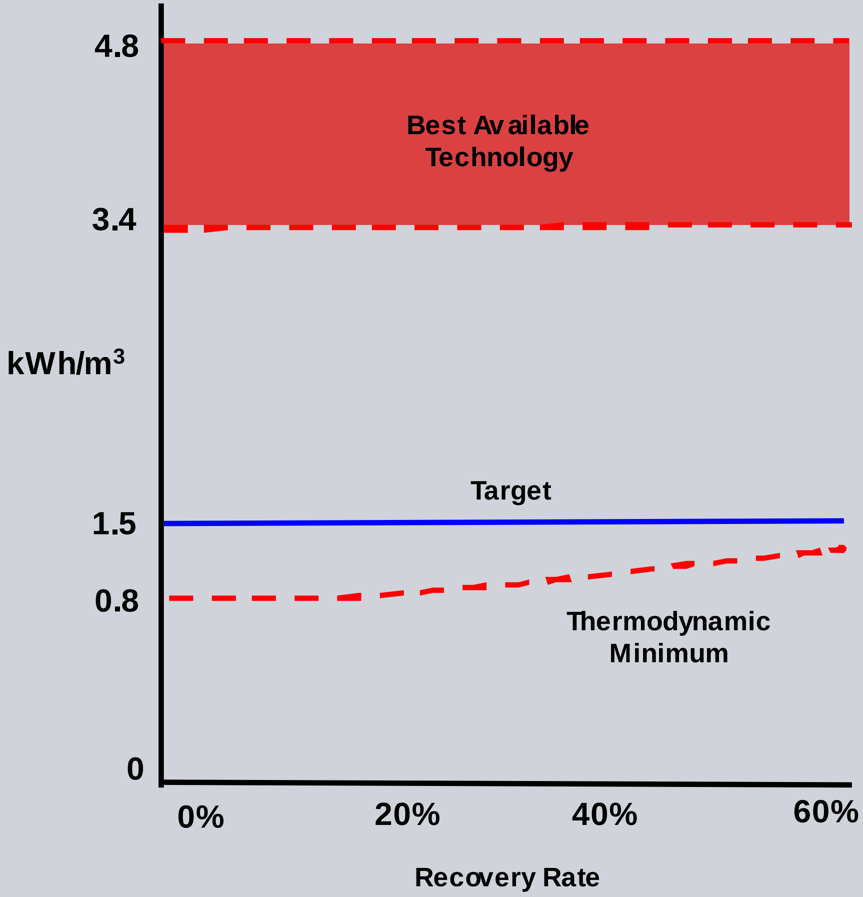
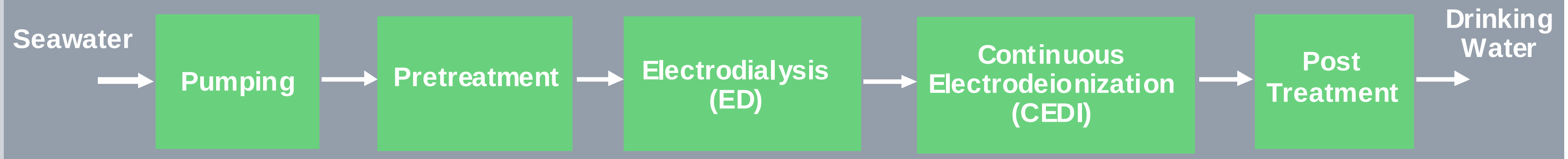


- Minimum energy to desalt 35,000 ppm Total Dissolved Solids (TDS) to drinking water standards is ~ 1.0 kWh/m3
- This value assumes 35% recovery at 25 degrees Celsius
- The working range to optimize inefficiencies is, therefore, only 0.5 kWh/m³
- The challenge of achieving an energy value target of 1.5 kWh/m³ is enormous

Process Schematic

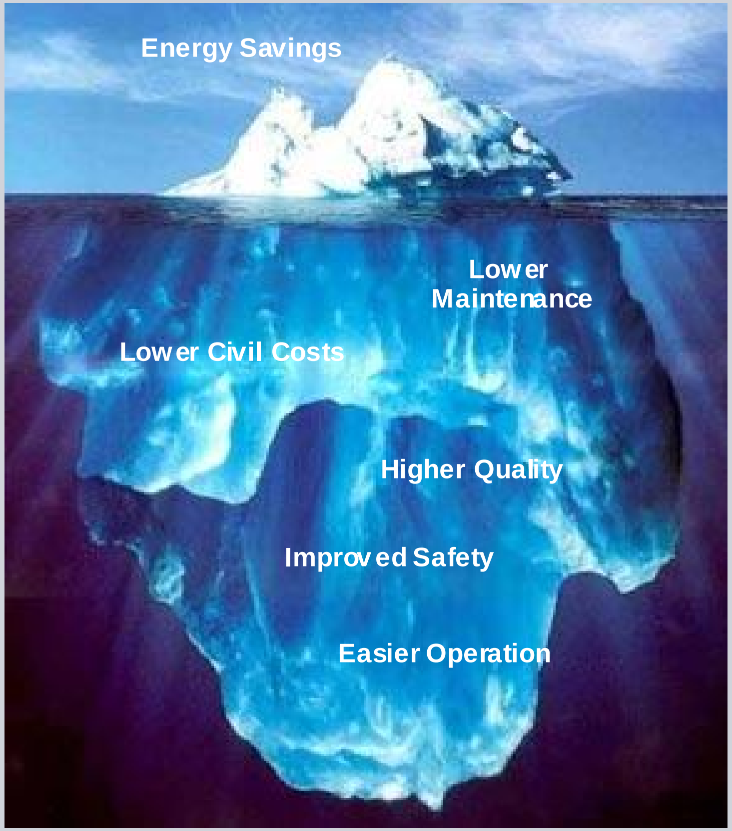


Value Proposition

- Low pressure pumps, piping, valves, fittings, etc.
- Low vibration, low noise levels
- Less Pretreatment, Less Post-treatment
- Less corrosion concerns with non-metal piping
- Chlorine tolerant components
- Improved finished water quality
- Improved safety (elimination of high pressure)

What does this mean for the customers?

Siemens Value Proposition



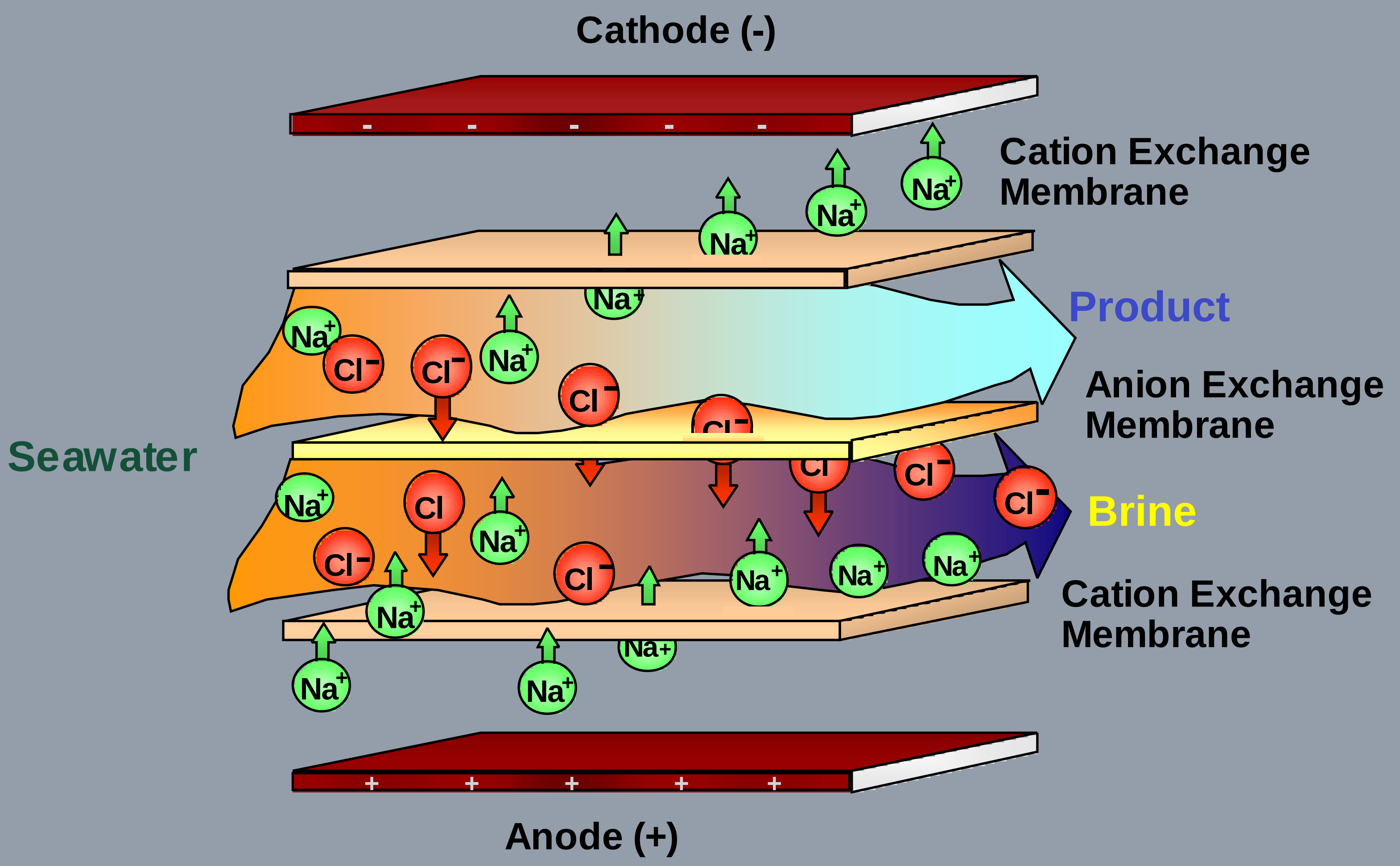
The Customer's Challenges of Desalination

- Energy costs have only been the "tip of the iceburg" of conditions limiting desalination
- Customers also have significant concerns on operating costs, consistency of performance and high water pressure work environment.

New desal technology will be "best available"

- Lowest total cost of ownership
- Ability to desalinate under residential water pressures (40 psi)
- Reduction in maintenance,
- Lower construction and civil.
- Improvement in Health & Safety work conditions

Electrochemical Desalination
The Technology: ED, CEDI



ED Testing Results; Predictive Model

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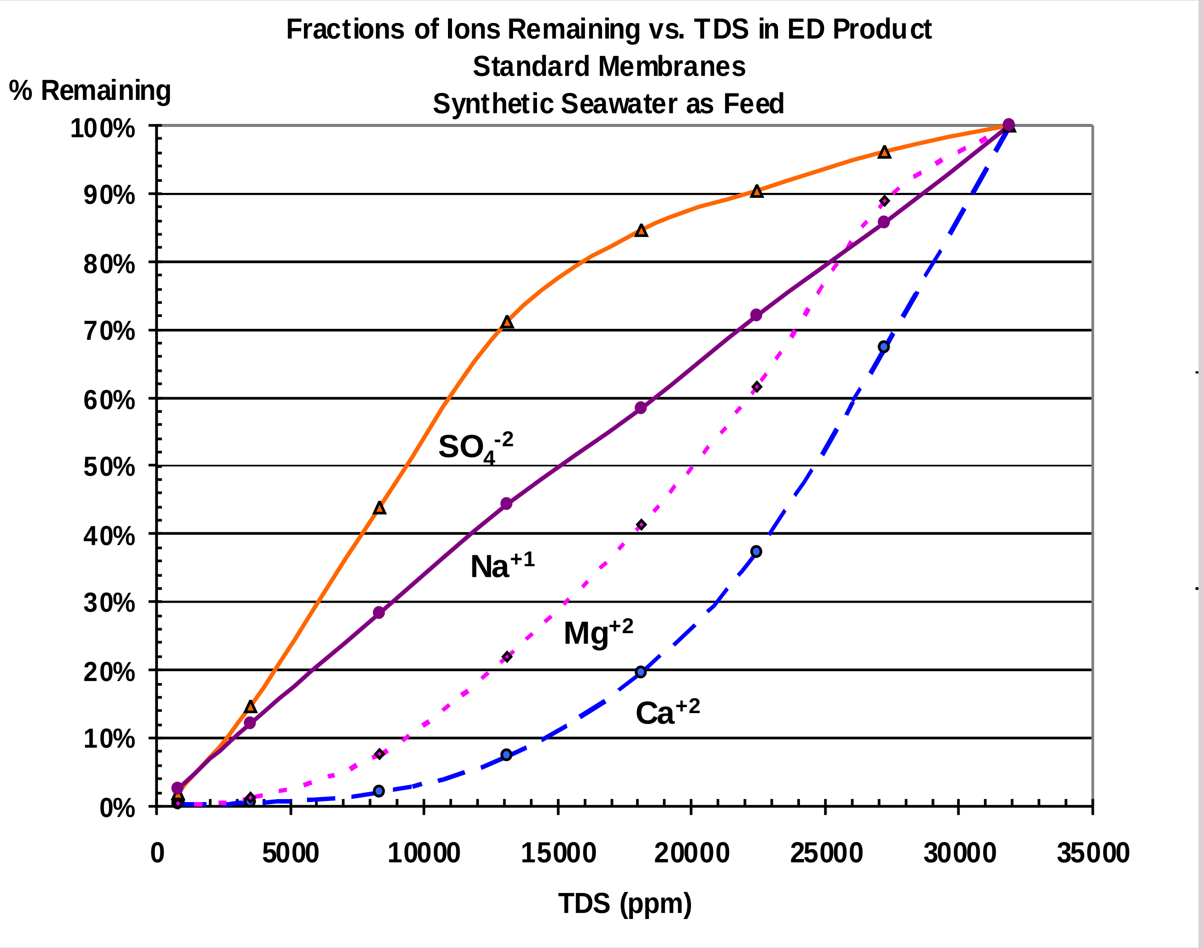

Mass Transfer, Boundary Layer Simulations
(RWTH Aachen University, Prof. W. Marquardt)

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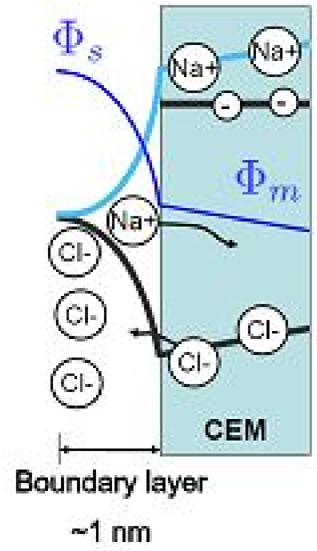
- Advanced computer modeling (gPROMS) to simulate mass transfer
- Investigating potential gradient at electrolyte-membrane interface
- Expand to multi-component mixtures
  - Allow modeling of mixed-salt solutions

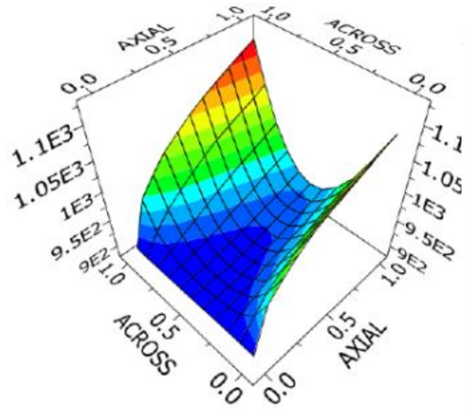
Poisson equation

$$\nabla^2 \Phi = -\frac{F}{\epsilon} \sum c_i z_i$$

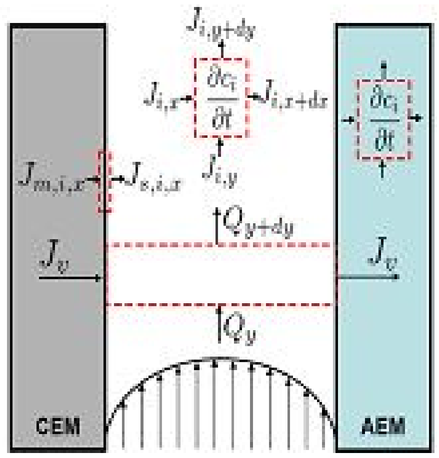
N component mass balances

$$\frac{\partial c_i}{\partial t} = -\nabla \cdot \mathbf{J_i}$$

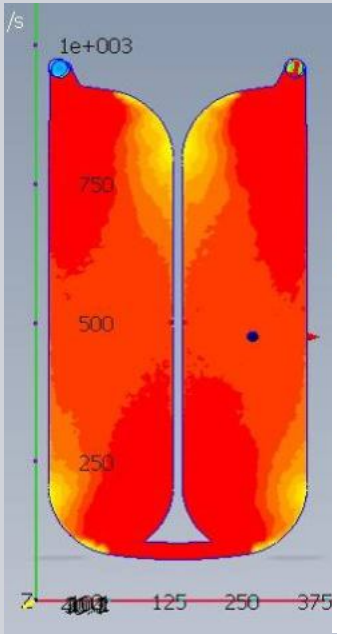


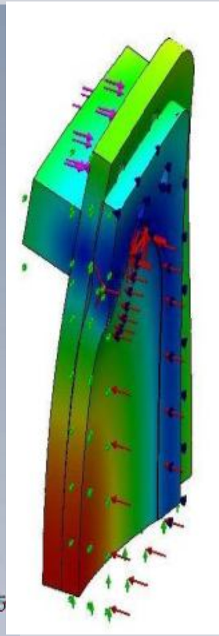


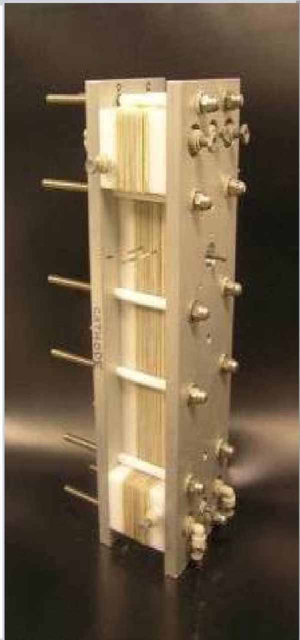
Concentrate

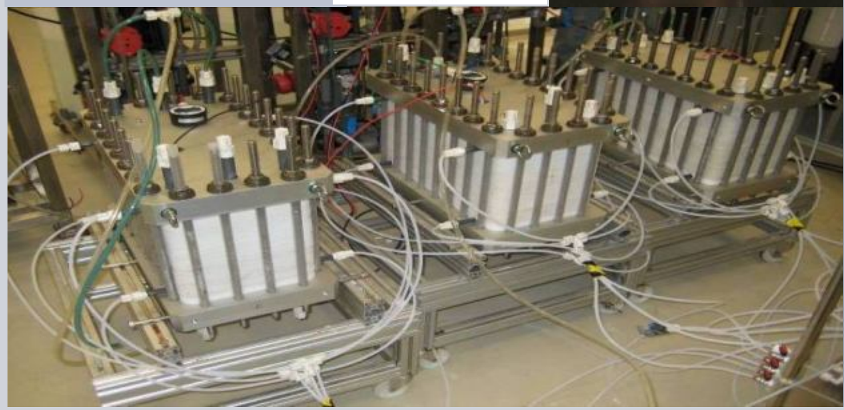


Prototype Testing









- Initial lab tests confirmed feasibility of achieving 1.5 kWh/m^3
- Lab tests recycled water until 500 ppm TDS was achieved; voltage drops per cell pair were totaled
- Prototype modules produced drinking water quality in a single pass
- A prototype system yielded deionization energy of 1.7 kWh/m^3; this value excluded pumping energy

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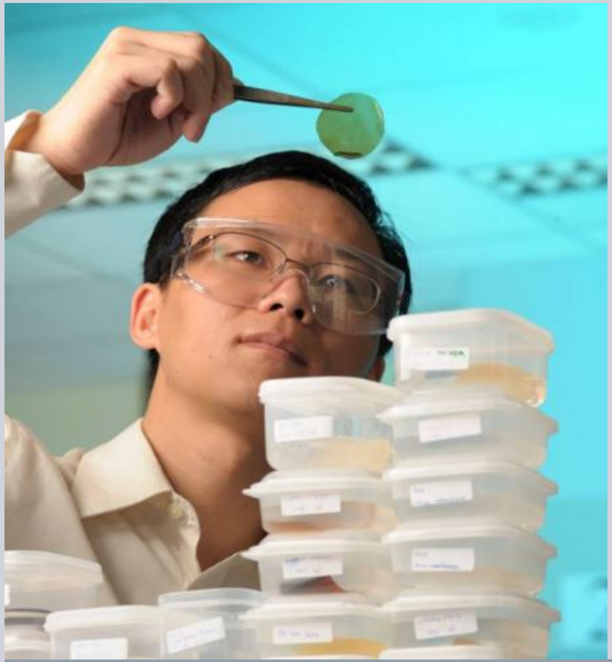
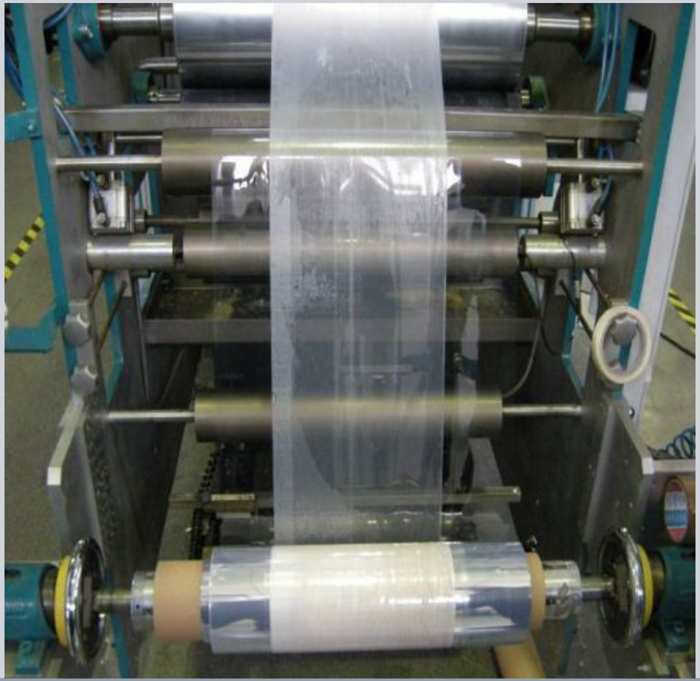
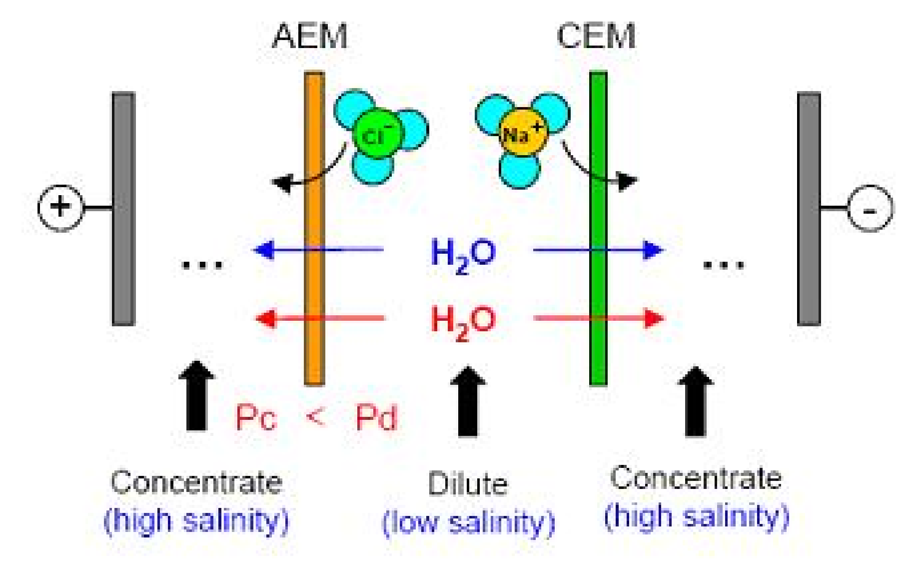
Membrane Development

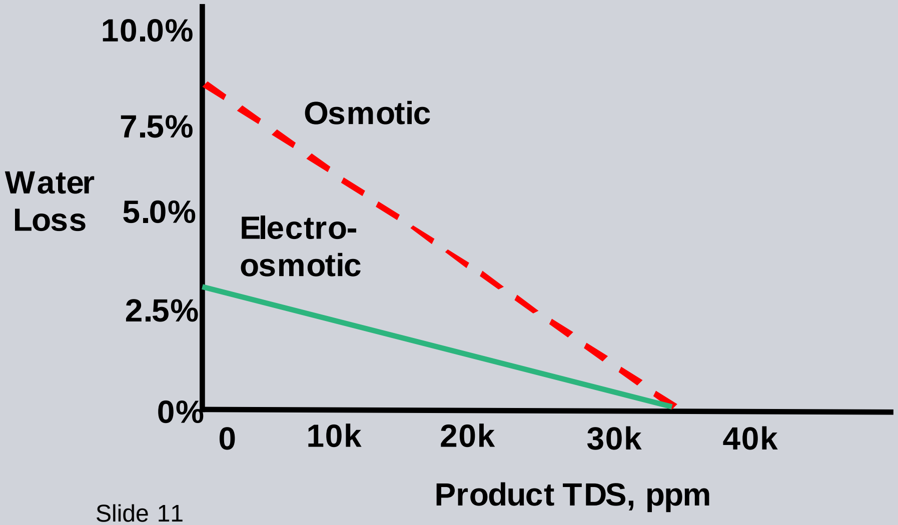




- Available membranes were characterized for resistance, permselectivity, strength, dimensional swelling, & others
- Available membranes used for industrial electrodialysis, diffusion dialysis, and fuel cells are not conducive to seawater desalting & are very expensive
- Internal development has progressed well, including a trial run

Transport Inefficiencies (Water Loss)





- Other membrane properties were discovered which adversely affect deionization efficiency, including:
- Hydraulic Water Permeation due to pressure gradient
- Osmotic Water Permeation due to concentration gradient
- Electro-osmotic Water Permeation due to ion hydration

Module & Spacer Development

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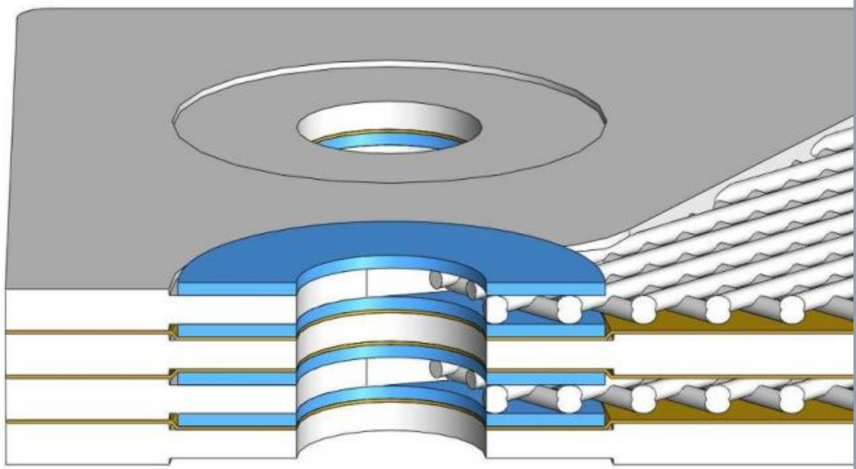

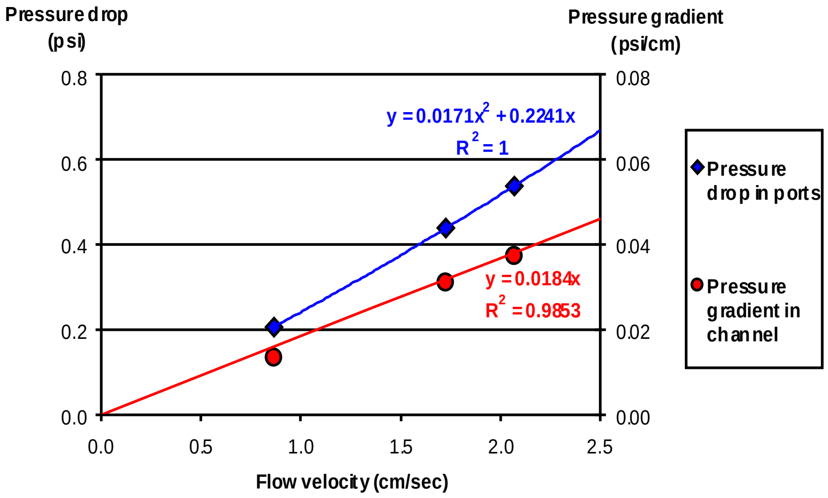

- Module & Spacer designs seek to:
- Maximize deionization efficiency
- Minimize pumpage energy
- Minimize energy penalties due to cross leakage, current leakage
- Minimize Donnan Potential, Concentration Polarization
- Minimize electrode voltage, scaling potential

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Power Contributing Processes

- UF Pretreatment
- Pre-chlorination feed pump
- ED 1, 2, 3 Desalting energy (applied DC Current)
- ED 1, 2,3 conc, dilute pumping energy
- CEDI 1, 2, 3 Desalting energy (applied DC Current)
- CEDI 1, 2, 3 conc, dilute pumping energy
- ED, CEDI DC power supply efficiency factor
- ED, CEDI electrode solution pumps
- Boron Removal IEX column pumping energy

EWI Project Deliverable

- 50 m^3/d demonstration unit
- Location: PUB Variable Salinity Plant, Pasir Ris, Singapore

Demo Trailer – ED, CEDI

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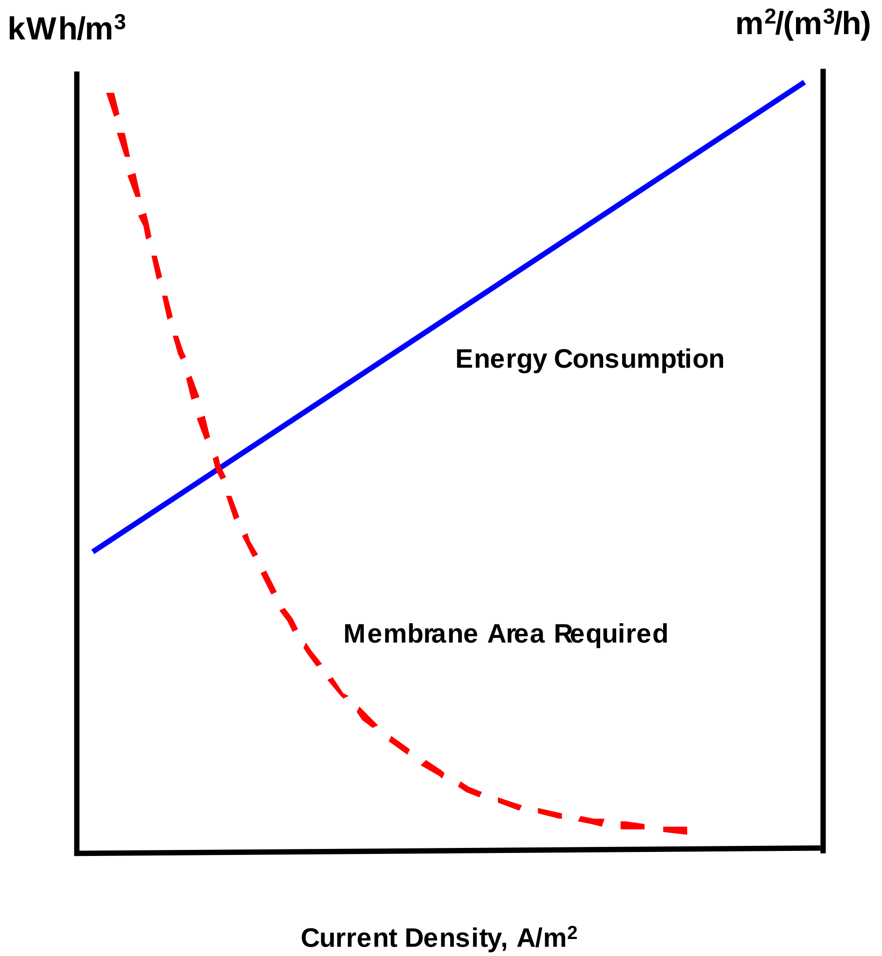
Steps Towards Commercialization



- A balance is needed, optimizing the combination of applied current & membrane area, e.g. Energy costs vs. Capital costs
- Alternate module configurations are being explored
- The objective is to provide Siemens customers with the lowest total cost of ownership
- The goal remains to transform seawater to drinking water economically across the globe

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