**Desalination – Where Are We Today?**

20,000 Desalination Plants Worldwide – 27,500 MGD of Installed Capacity

- **RO** (74%)
- **Thermal** (21%)
- **ED** (3%)
- **Other** (2%)

5,800 MGD Thermal Desalination

20,300 MGD RO Desalination

* 54% of All Plants > 15 MGD
* Large and Medium Plants – 90% of total world production
* 92% of New Plants in 2018 - SWRO

Source: IDA Desalination Yearbook 2018-2019
Global Desalination Capacity

Cumulative contracted and online capacity, 1965-2018

Source: GWI DesalData / IDA
*Values through June 2018

Source: IDA Desalination Yearbook 2018-2019
US Desalination Plants – Cumulative Capacity
US Desalination Plants – Cumulative Number
What is Membrane Desalination?

- Separation of Fresh Water from Seawater by Filtration Through Special Membranes Under Very High Pressure

- Pressure Applied for Separation = 60 to 70 Times the Atmospheric Pressure

- Process Used for Separation – Reverse Osmosis

- Membranes are Semi-permeable – they Reject over 99.5% of the Salts in the Water
What is Osmosis and Why It Has to be Reversed?

- SALT WATER
- FRESH WATER
- SEMI-PERMEABLE MEMBRANE
- OSMOTIC PRESSURE
- PRESSURE

MEMBRANE FILTRATION

Feed water

Permeate

Membrane
Reversing the Natural Flow of Water to Keep the Fresh Water Separated from the Saline Feed Water
One SWRO Membrane Has...

Diameter = 8 inches
Length = 40 inches
Weight = 36 lbs
Cost = US$400

Production of 3500 to 4000 gallons/day – Water for 50 people
50 MGD Carlsbad SWRO Plant – the Largest in the USA
SWRO Membrane Train with Energy Recovery System
### Typical Cost and Energy Ranges (Medium & Large SWRO Plants)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Cost of Water Production (US$/kgal)</th>
<th>SWRO System Energy Use (kWh/kgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-End Bracket</td>
<td>2.0 - 3.0</td>
<td>9.5 – 10.5</td>
</tr>
<tr>
<td>Medium Range</td>
<td>3.5 – 5.0</td>
<td>11.0 - 12.0</td>
</tr>
<tr>
<td>High-End Bracket</td>
<td>6.5 - 11.5</td>
<td>12.5 – 14.0</td>
</tr>
<tr>
<td>Average</td>
<td>4.0</td>
<td>11.5</td>
</tr>
</tbody>
</table>
## Costs of Recent US SWRO Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Status</th>
<th>Capital Cost (US$)</th>
<th>Annual O&amp;M Cost (US$/kgal)</th>
<th>Cost of Water (US$/kgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 MGD Sand City, CA</td>
<td>In Operation since 2010</td>
<td>US$11.9 MM</td>
<td>US$2.6/kgal</td>
<td>US$4.2/kgal</td>
</tr>
<tr>
<td>50 MGD Carlsbad, CA</td>
<td>In Operation since 2015</td>
<td>US$860 MM</td>
<td>US$3.6/kgal</td>
<td>US$6.5/kgal</td>
</tr>
<tr>
<td>7.5 MGD Santa Barbara, CA</td>
<td>In Operation since May 2017</td>
<td>US$48 MM</td>
<td>US$2.4/kgal</td>
<td>US$4.4/kgal</td>
</tr>
</tbody>
</table>
Cost of Water Breakdown

- RO System Constr. Cost: 30%
- Power Cost: 26%
- Other Costs: 9%
- RO/CF Replacement: 6%
- Project Eng. & Permitting: 7%
- Pretreatment Constr. Cost: 12%
- Intake & Discharge Constr. Cost: 10%
- Other Costs: 9%
Key Factors Affecting Costs

- Plant Size – Bigger is Better
- Source Water Quality - TDS, Temperature and Solids
- Product Water Quality – TDS, Disinfection Compatibility
- Concentrate Disposal Method;
- Power Supply & Unit Power Costs;
- Project Delivery Method & Financing;
- Other Factors:
  - Intake and Discharge System Type;
  - Pretreatment & RO System Design;
  - Plant Capacity Availability Target.
Desalination Plant Construction Cost as Function of Capacity

Unit Construction Cost (US$ MM/MGD)
Larger Desalination Plants Typically Use Less Energy

<table>
<thead>
<tr>
<th>Plant</th>
<th>SWRO Plant Energy Use (w/o Water Delivery) (kWh/kgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 MGD</td>
<td>22-25</td>
</tr>
<tr>
<td>10 MGD</td>
<td>16-18</td>
</tr>
<tr>
<td>50 MGD</td>
<td>13-15</td>
</tr>
</tbody>
</table>
Example –
The Energy Use of the Carlsbad SWRO Plant

RO System – 72%
(10.6 kWh/kgal)

Product Water Delivery 8%
(1.2 kWh/kgal)

Pretreatment – 10%
(1.5 kWh/kgal)

Other Facilities 5%
(0.75 kWh/kgal)

Intake – 5%
(0.75 kWh/kgal)

Total Energy Use 14.8 kWh/kgal
For TDS = 35 ppt & Temp. = 75°F
Power Needed to Produce Drinking Water from Seawater for One Family for One Year = Power Used by Family’s Refrigerator (2,100 kW/yr)!

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Power Use (kWh/kgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Surface Water</td>
<td>1.5 to 2.2</td>
</tr>
<tr>
<td>Brackish Water Desalination</td>
<td>2.5 to 6.5</td>
</tr>
<tr>
<td>Reclamation Of Municipal Wastewater</td>
<td>3.0 to 3.5</td>
</tr>
<tr>
<td>Seawater Desalination</td>
<td>10.0 to 15.0</td>
</tr>
</tbody>
</table>
# Main Desalination Challenges & Industry Response

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Industry Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relatively High Fresh Water Production Costs</td>
<td>Accelerated Development of Higher Productivity RO Membranes and Lower Cost Pretreatment Systems and Plant Components</td>
</tr>
<tr>
<td>High Energy Use</td>
<td>Investment in Non-RO Technologies</td>
</tr>
<tr>
<td>Environmental Impacts</td>
<td>Advances in Low Energy Desalination Technologies &amp; RO Energy Recovery Systems</td>
</tr>
<tr>
<td></td>
<td>Coupling of Desalination Plants with Green Power Sources (Wind Power)</td>
</tr>
</tbody>
</table>
Concentrate Management – Key Challenges

- Establishing the Salinity Tolerance Threshold in the Area of Discharge;

- Providing Efficient Salinity Dispersion:
  - Disposal of Brine Through Existing Wastewater & Power Plant Outfalls;
  - Mixing with Ambient Seawater vs. Long Outfalls;
  - Near-Shore vs. Off-Shore Discharge;
  - Shallow Coastal Well Disposal.
Concentrate Management – US Experience

Percentage Use of Disposal Option

- surface discharge: 45%
- sewer discharge: 25%
- deep well injection: 15%
- land application: 10%
- evaporation pond: 5%
- recycle: 0%

Disposal Option
Concentrate Management – Texas Experience

Bar chart showing the percent use of disposal options over different time periods:
- Surface discharge
- Sewer discharge
- Deep well injection
- Land application
- Evaporation pond
- Recycle

Time periods indicated by different colors:
- <1993
- 1993-2002
- 2003-2009
- 2010-2017
Disposal through Existing Outfalls – Most Commonly Used for Seawater Desalination Plants
Key Desalination Project Implementation Steps

1. Determine Desired Plant Size;
2. Select Plant Site;
3. Decide on Intake and Concentrate Discharge Types;
4. Assess Source Water Quality;
5. Determine Product Water Quality;
6. Complete Environmental Impact Analysis;
7. Pilot Test Alternative Technologies and Designs;
Concluding Remarks

- Seawater Desalination is Drought Proof – Allows to Tap Into 97.5% of the Water Resources on the Planet
- Seawater Desalination is Affordable if Plant Site and Size are Selected Appropriately
- Energy Use for Seawater Desalination is Reasonable – Comparable to Energy Use for Food Refrigeration
- Seawater Desalination is Environmentally Safe if Plant Intake and Discharge are Designed Appropriately
- Science and Technology Developments Are Likely to Result in Further Reduction of Energy Use and Costs for Production of Desalinated Water