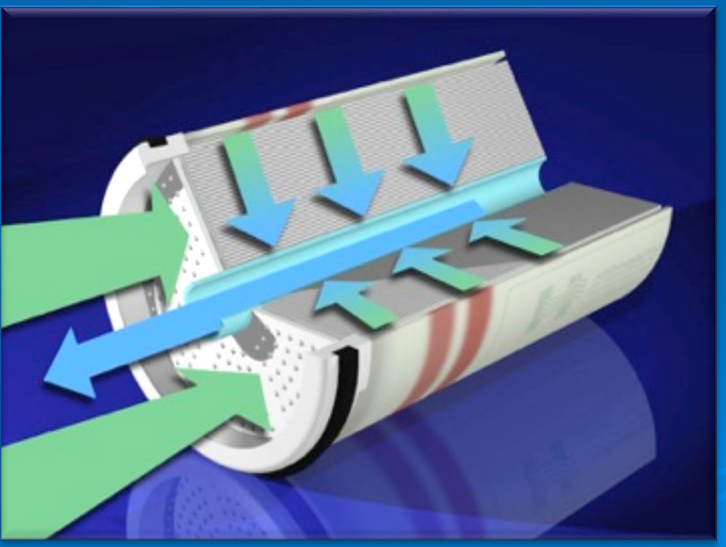
Presentation

Seawater Desalination Current Status and Trends

May 13, 2019

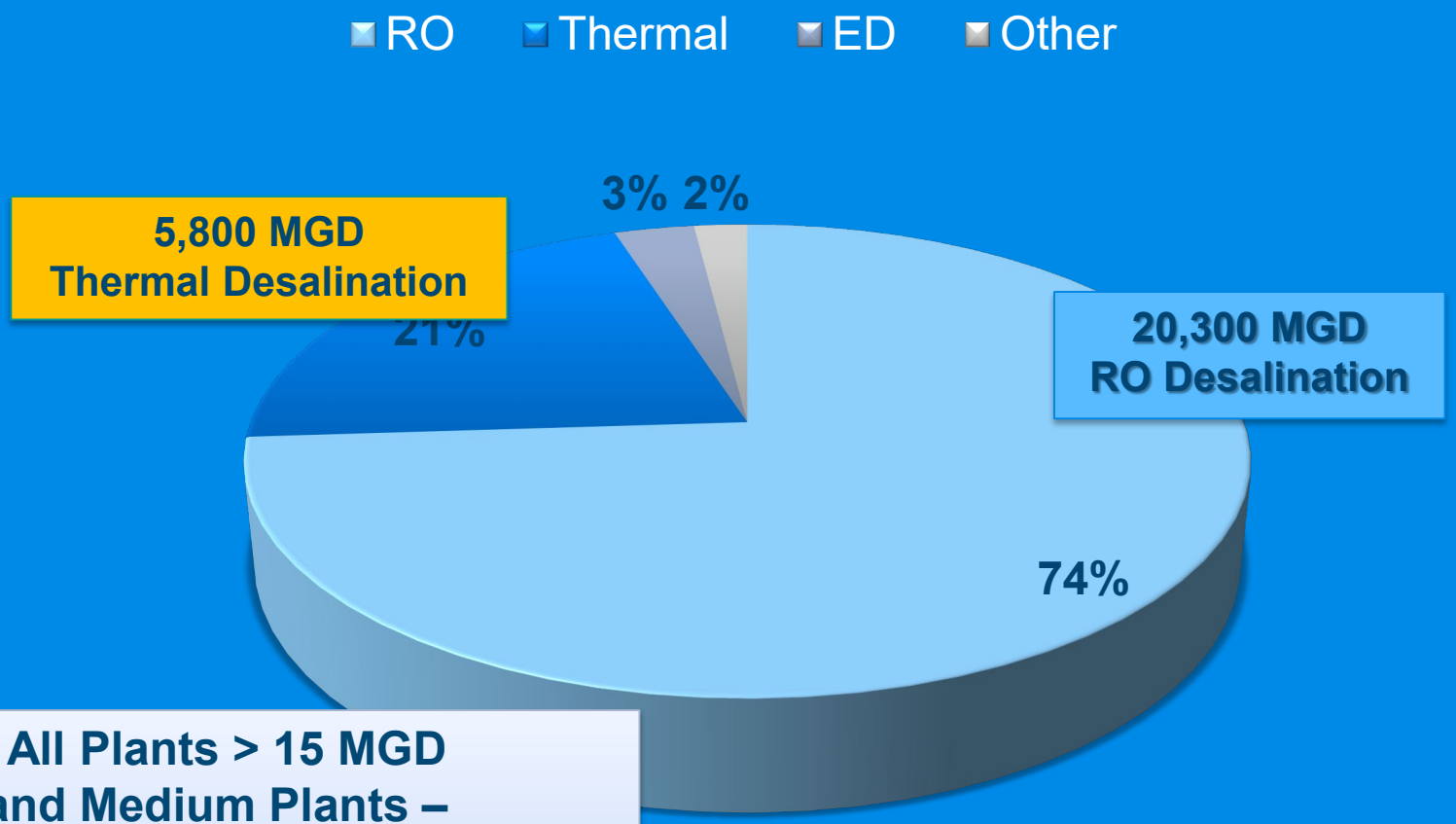


Water Globe Consultants

Nikolay Voutchkov, PE, BCEE

Desalination – Where Are We Today?

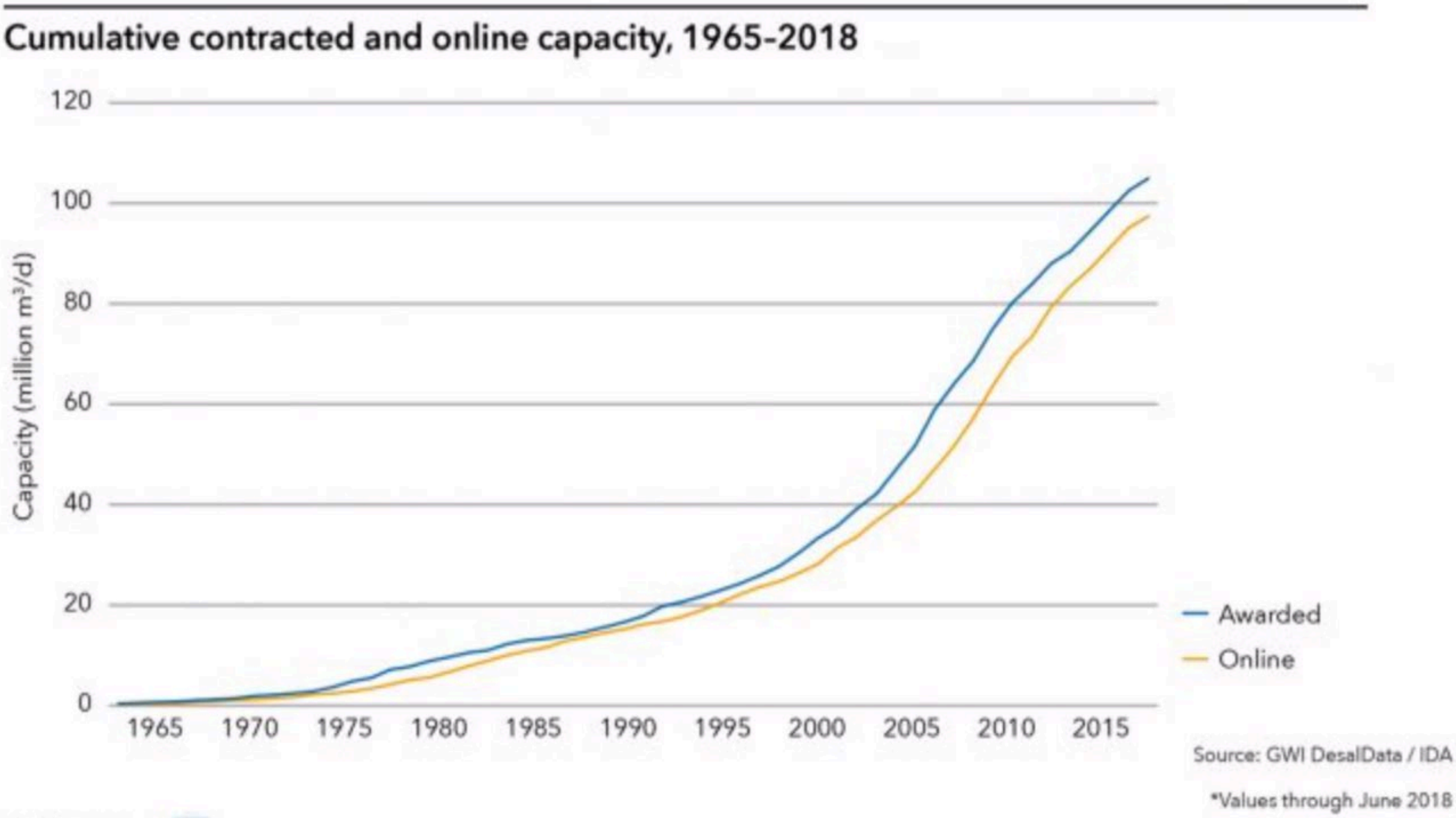
20,000 Desalination Plants Worldwide – 27,500 MGD of Installed Capacity



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

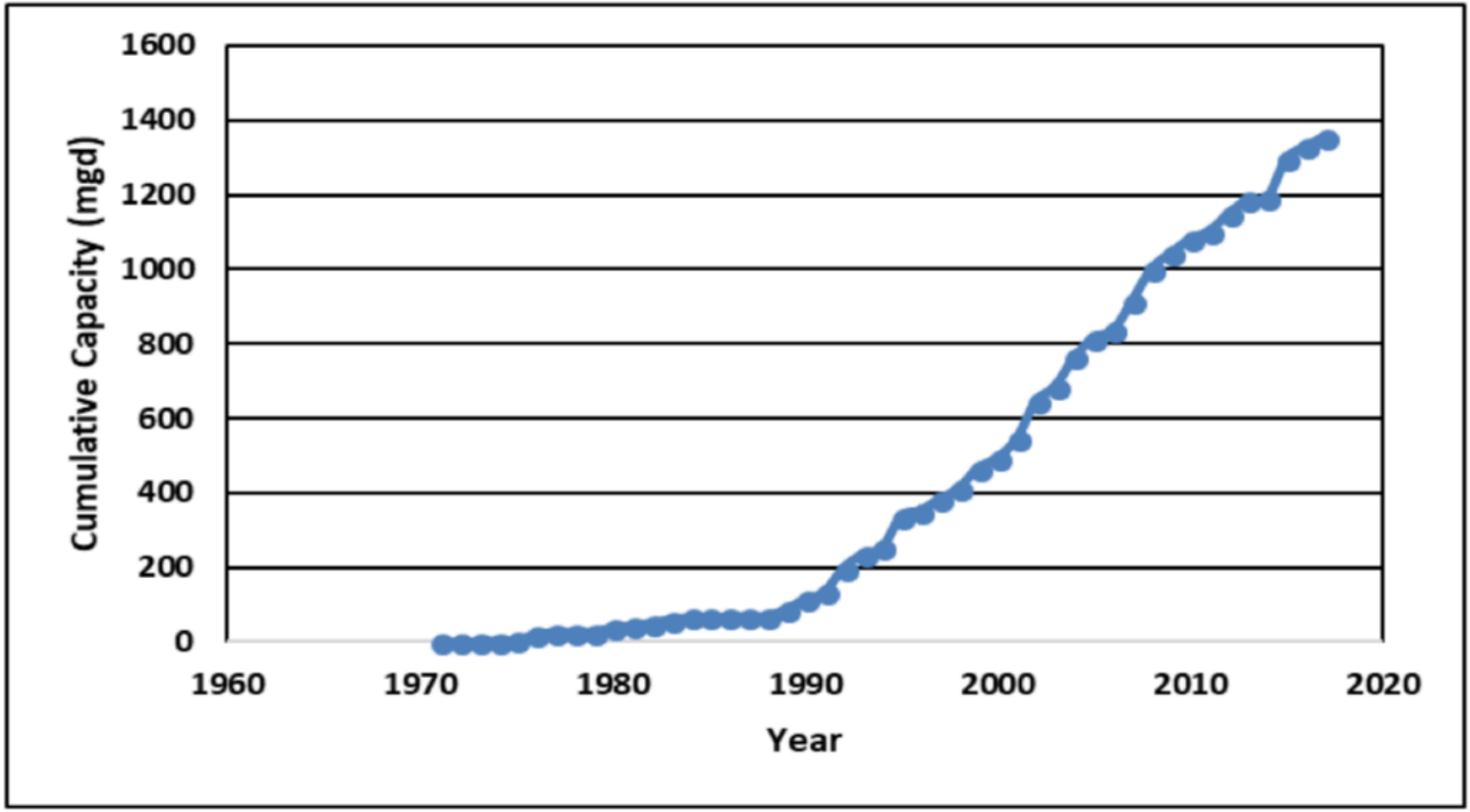
Source: IDA Desalination Yearbook 2018-2019

Global Desalination Capacity

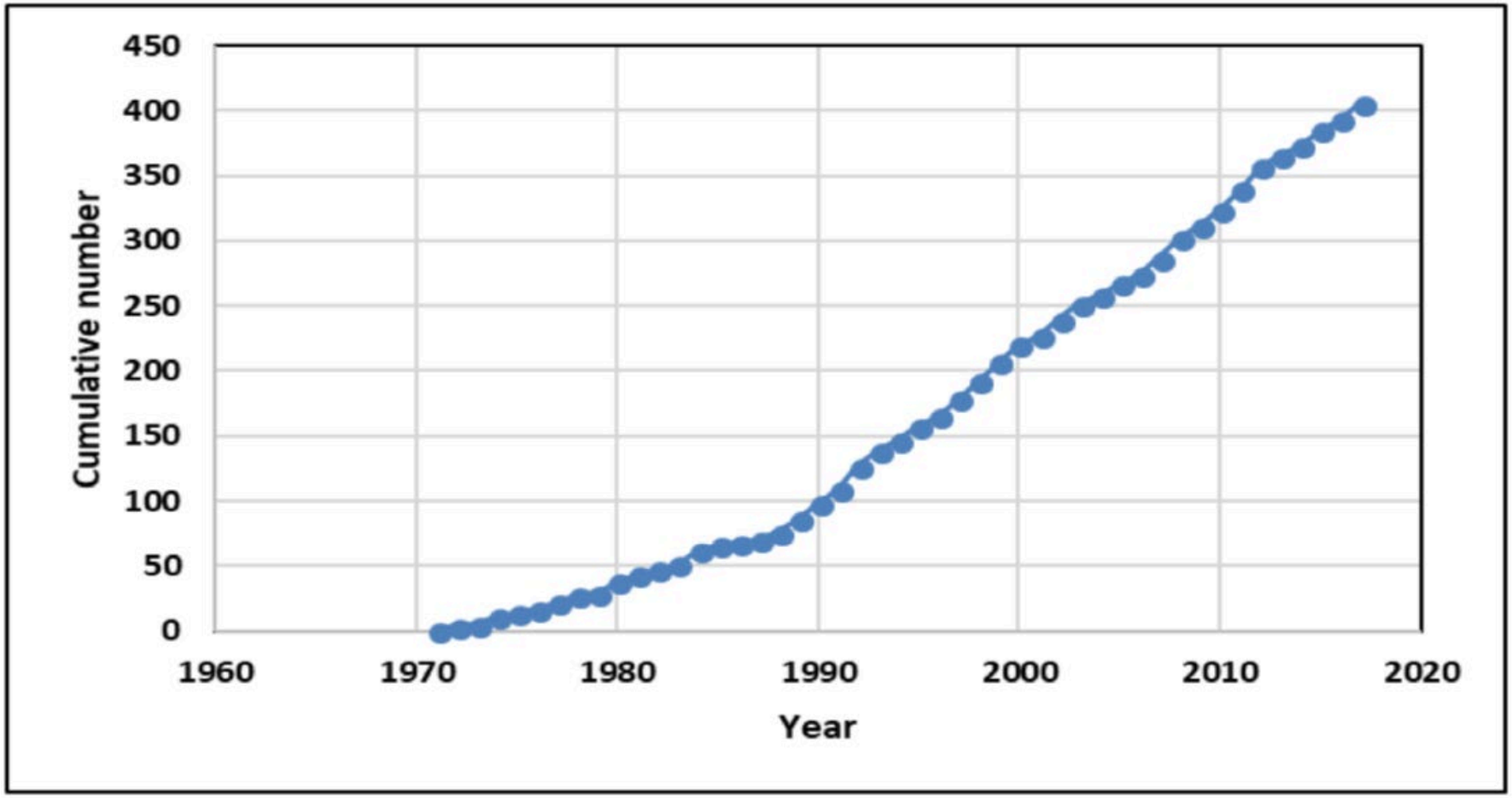


Source: IDA Desalination Yearbook 2018-2019

US Desalination Plants – Cumulative Capacity



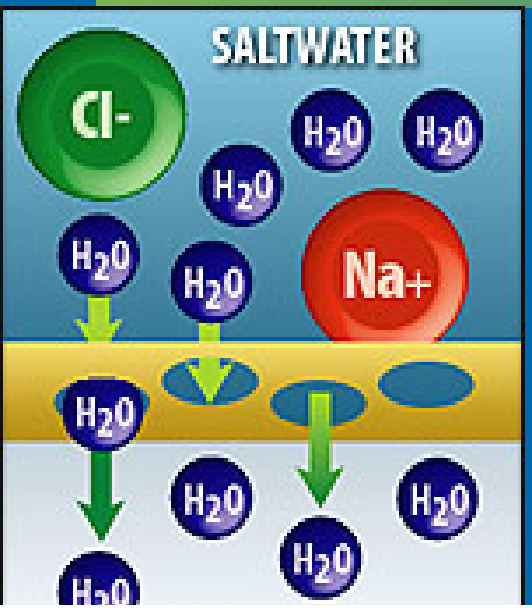
US Desalination Plants – Cumulative Number



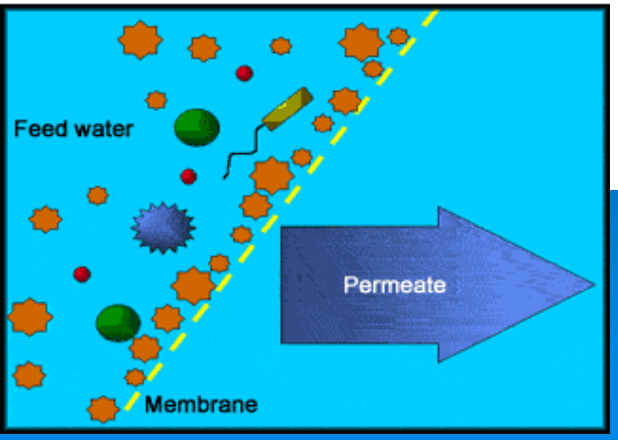
What is Membrane Desalination?

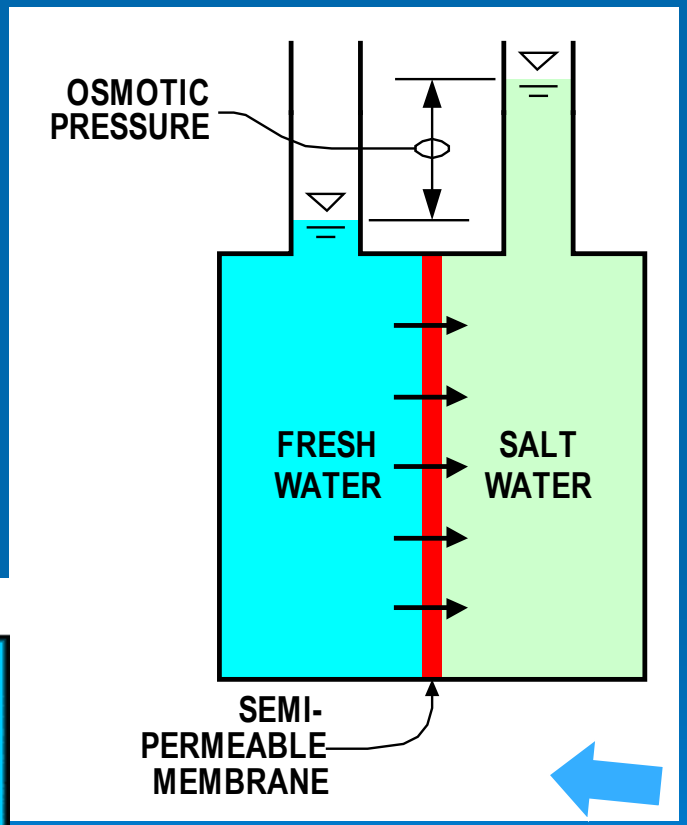
- Separation of Fresh Water from Seawater by Filtration Through Special Membranes Under Very High Pressure
- Pressure Applied for Separation = 60 to 70 Times the Atmospheric Pressure
- Process Used for Separation – Reverse Osmosis
- Membranes are Semi-permeable – they Reject over 99.5% of the Salts in the Water

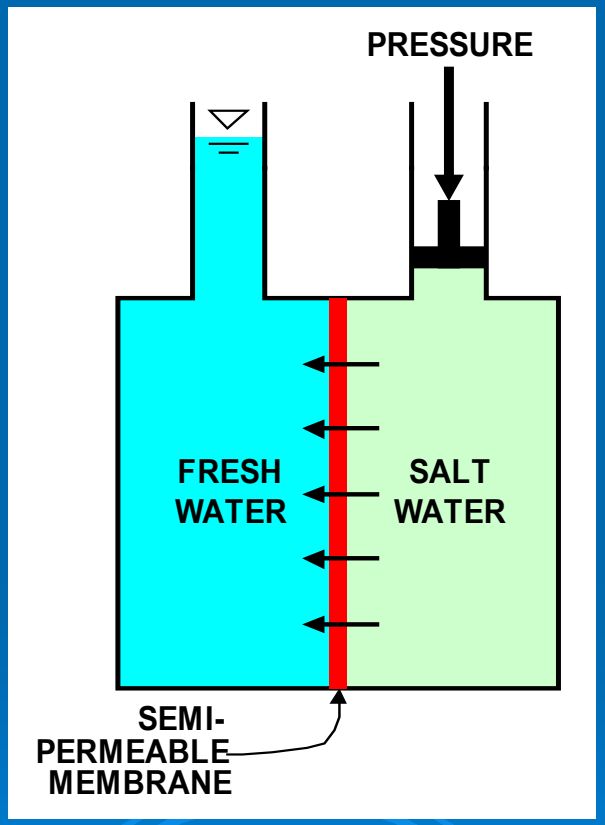
What is Osmosis and Why It Has to be Reversed?



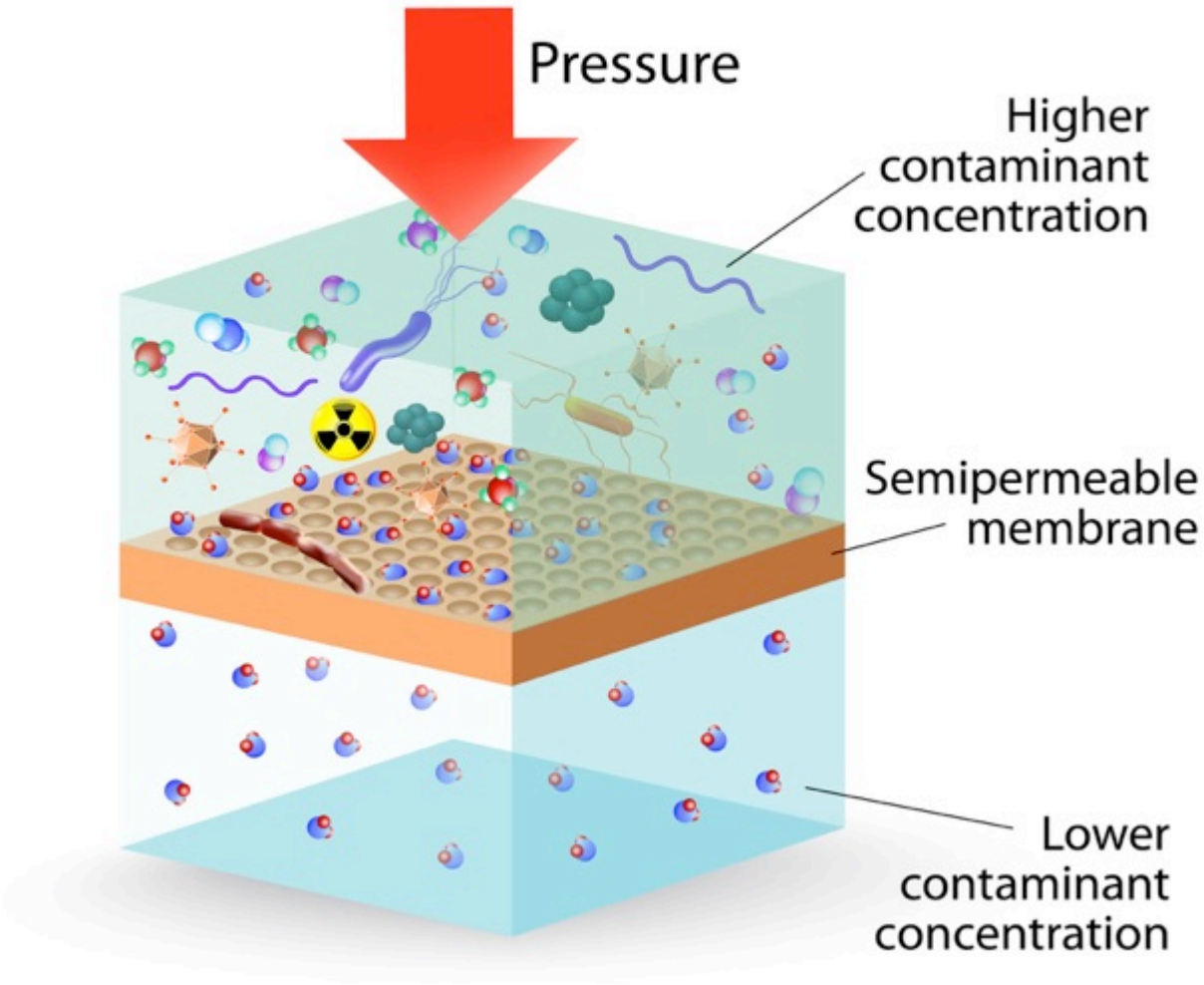
MEMBRANE FILTRATION







REVERSE OSMOSIS



Reversing the Natural Flow of Water to Keep the Fresh Water Separated from the Saline Feed Water

One SWRO Membrane Has…

Diameter = 8 inches

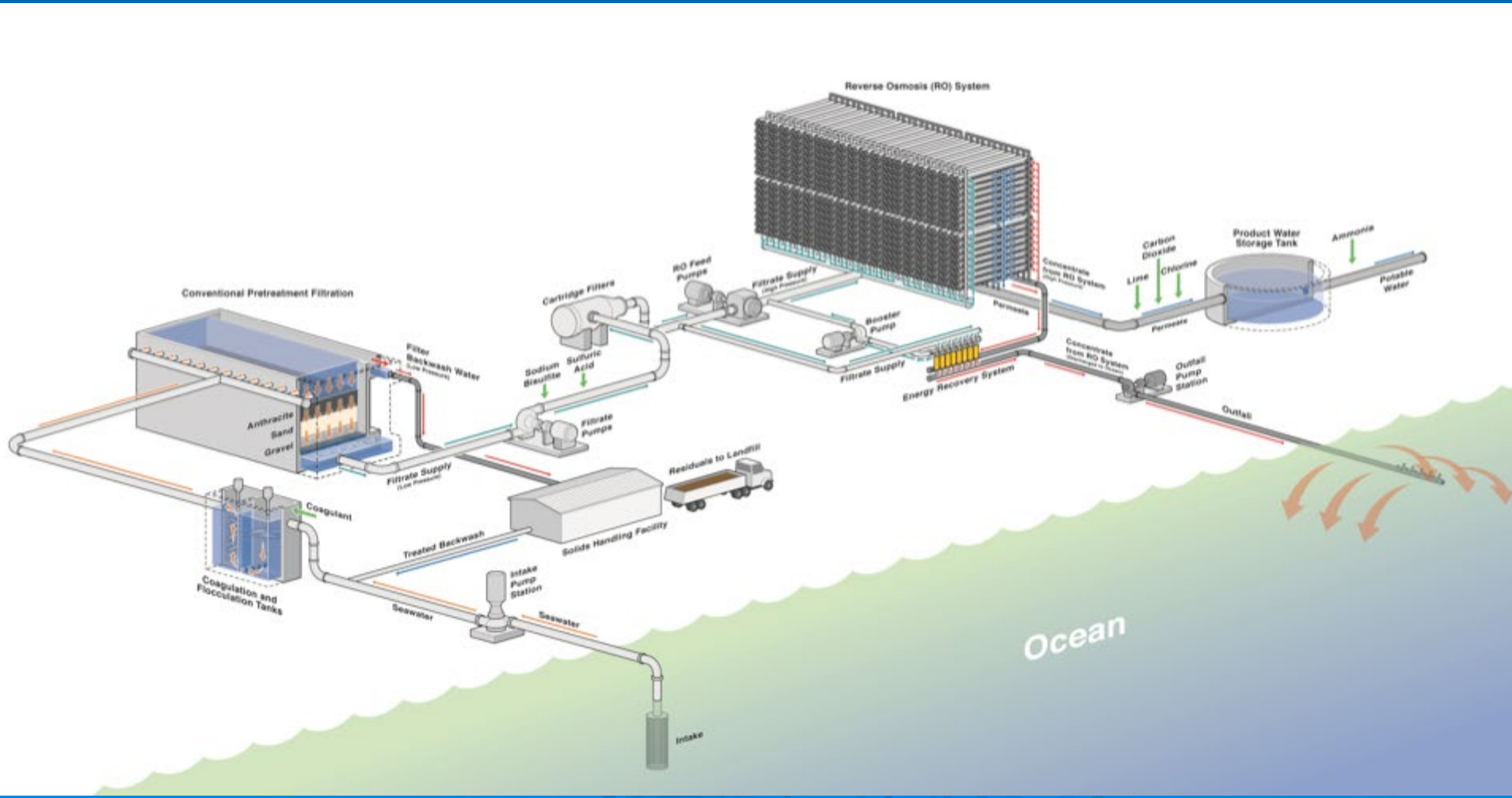
Length = 40 inches

Weight = 36 lbs

Cost = US$400

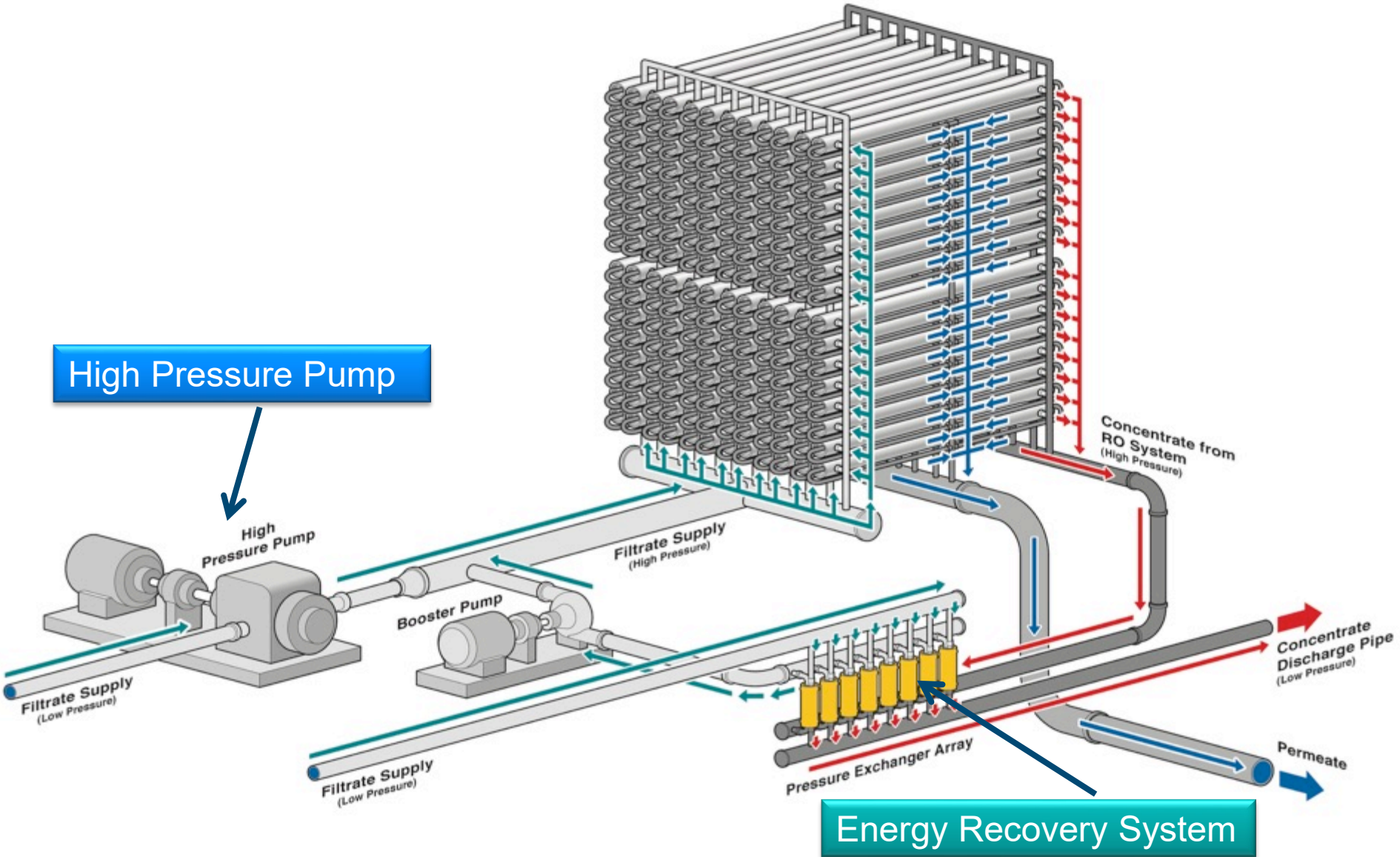
Production of 3500 to 4000 gallons/day – Water for 50 people

Schematic of Typical SWRO Desalination Plant



50 MGD Carlsbad SWRO Plant – the Largest in the USA

SWRO Membrane Train with Energy Recovery System



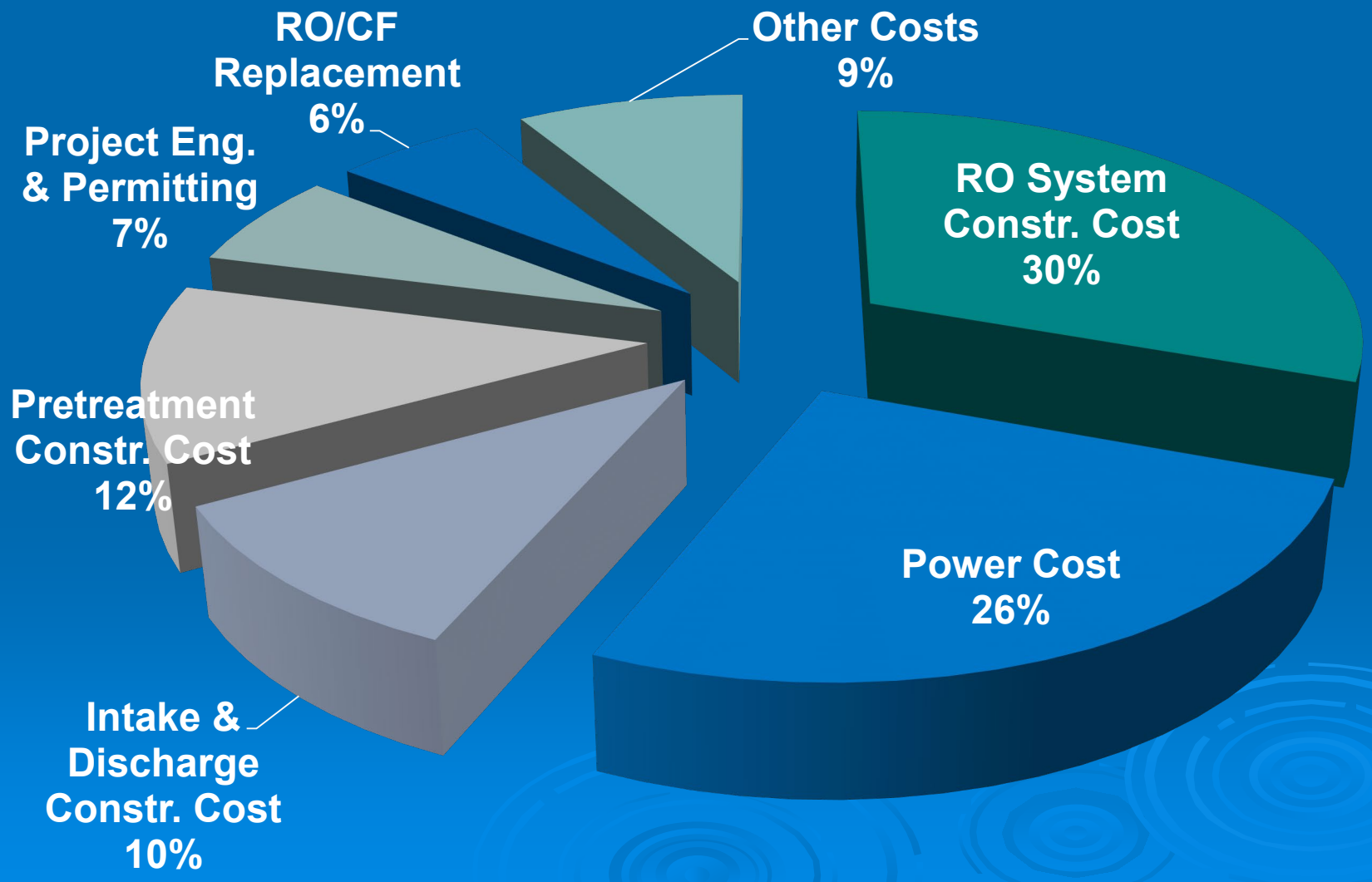
Typical Cost and Energy Ranges
(Medium & Large SWRO Plants)

Classification	Cost of Water Production (US$/kgal)	SWRO System Energy Use (kWh/kgal)
Low-End Bracket	2.0 - 3.0	9.5 – 10.5
Medium Range	3.5 – 5.0	11.0 - 12.0
High-End Bracket	6.5 - 11.5	12.5 – 14.0
Average	4.0	11.5

Costs of Recent US SWRO Projects

Project	Status	Capital Cost (US$)	Annual O&M Cost (US$/kgal)	Cost of Water (US$/kgal)
0.6 MGD Sand City, CA	In Operation since 2010	US$11.9 MM	US$2.6/kgal	US$4.2/kgal
25 MGD Tampa Bay, FL	In Operation since 2008	US$138 MM	US$1.4/kgal	US$3.6/kgal
50 MGD Carlsbad, CA	In Operation since 2015	US$860 MM	US$3.6/kgal	US$6.5/kgal
7.5 MGD Santa Barbara, CA	In Operation since May 2017	US$48 MM	US$2.4/kgal	US$4.4/kgal

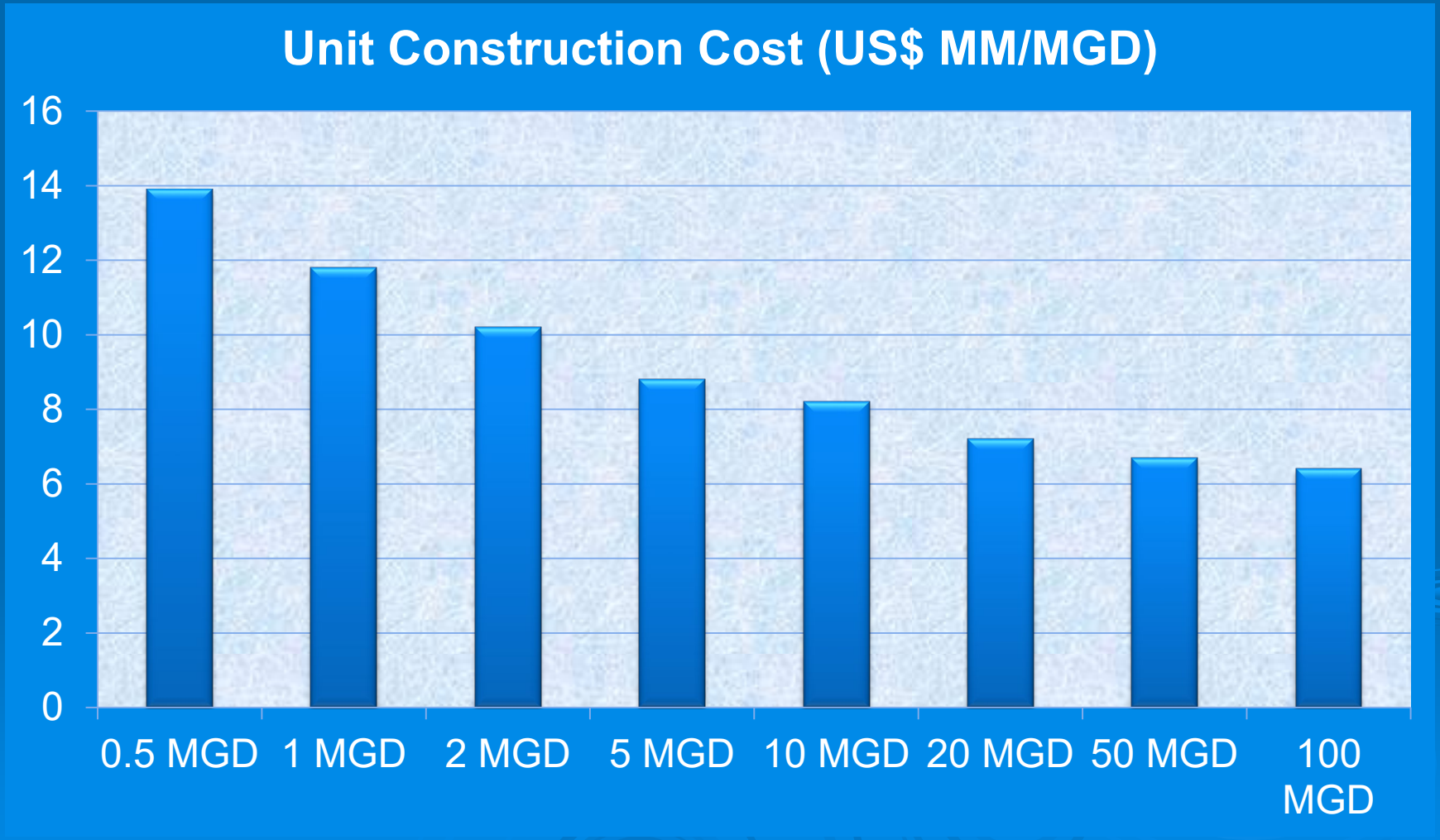
Cost of Water Breakdown



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



Larger Desalination Plants Typically Use Less Energy

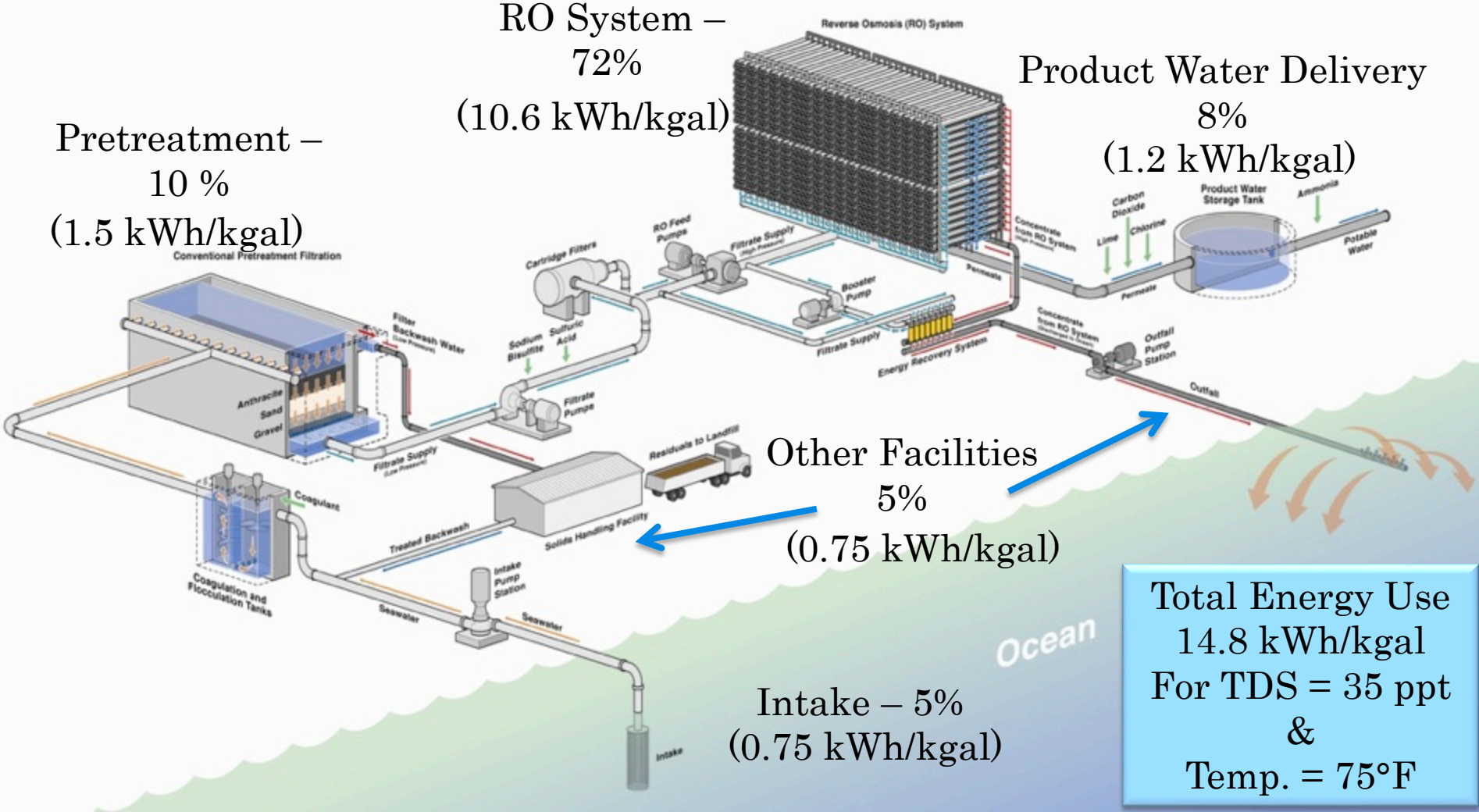
Plant	SWRO Plant Energy Use (w/o Water Delivery) (kWh/kgal)
0.5 MGD	22-25
10 MGD	16-18
50 MGD	13-15

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

Putting Desalination Energy Use In Perspective

Power Needed to Produce Drinking Water from Seawater for One Family for One Year = Power Used by Family's Refrigerator (2,100 kW/yr)!

Treatment	Power Use (kWh/kgal)
Conventional Surface Water	1.5 to 2.2
Brackish Water Desalination	2.5 to 6.5
Reclamation Of Municipal Wastewater	3.0 to 3.5
Seawater Desalination	10.0 to 15.0

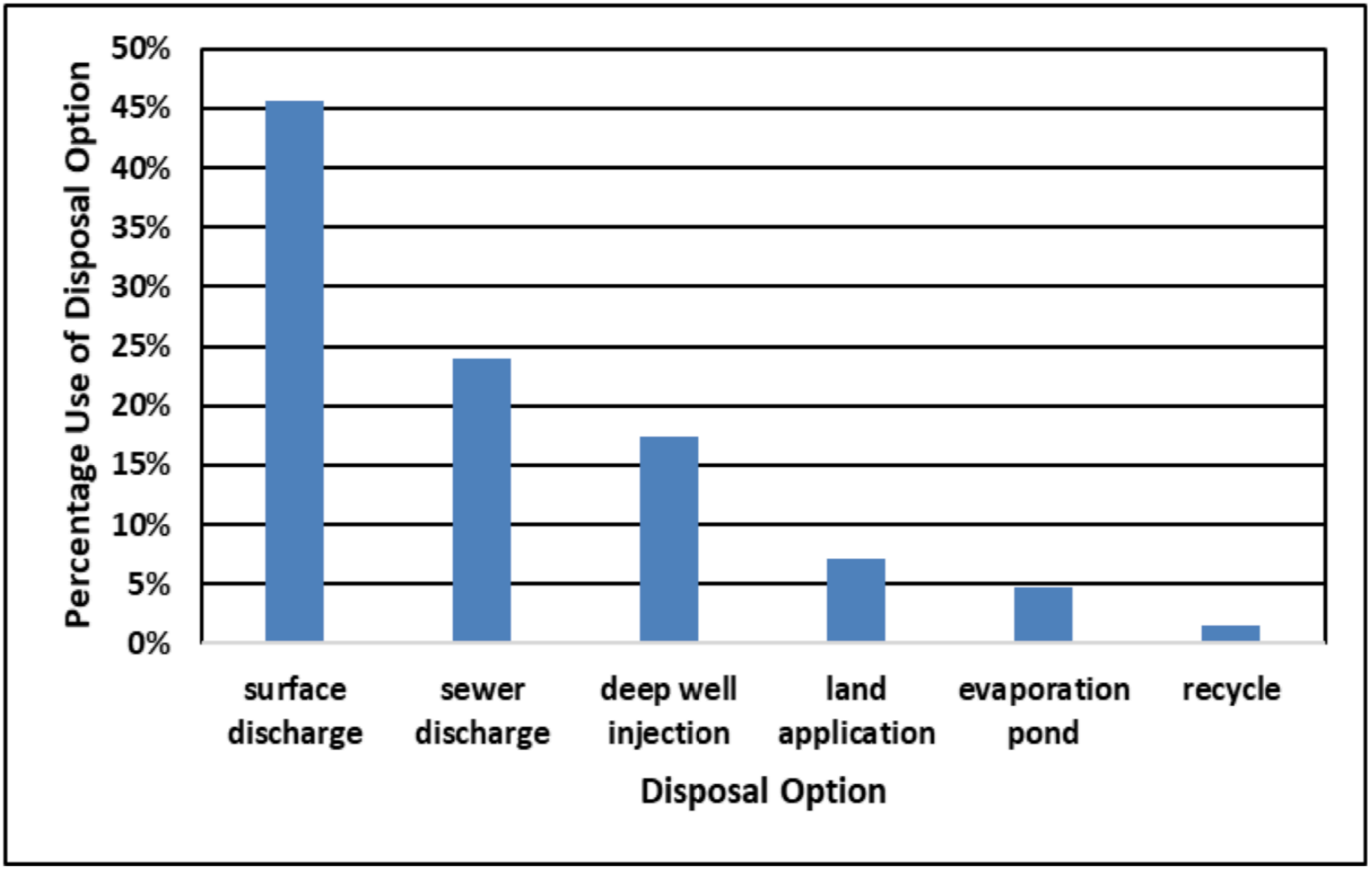
Main Desalination Challenges & Industry Response

Challenge	Industry Response
Relatively High Fresh Water Production Costs	Accelerated Development of Higher Productivity RO Membranes and Lower Cost Pretreatment Systems and Plant Components Investment in Non-RO Technologies
High Energy Use	Advances in Low Energy Desalination Technologies & RO Energy Recovery Systems
Environmental Impacts	Coupling of Desalination Plants with Green Power Sources (Wind Power)

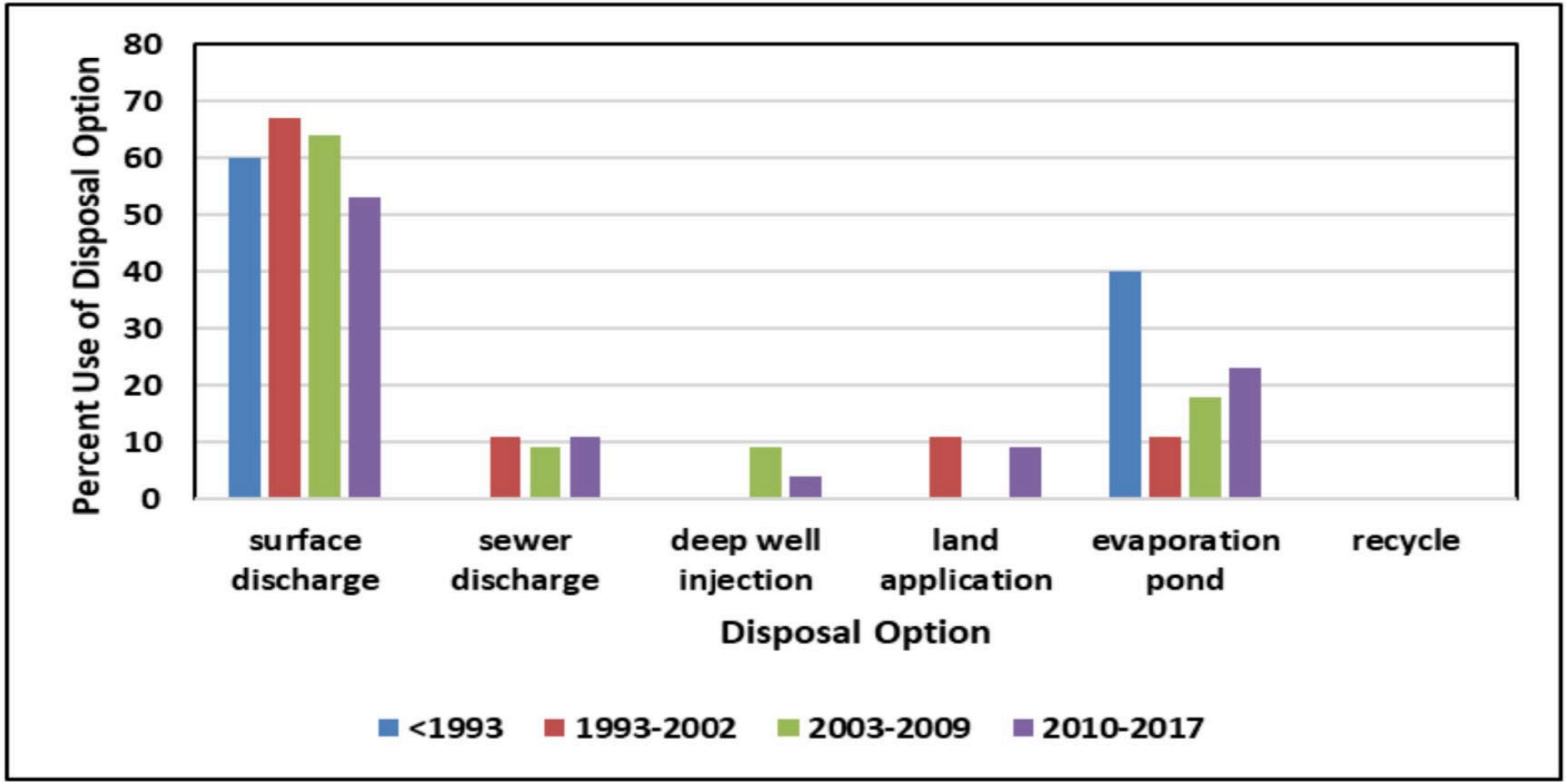
Concentrate Management – Key Challenges

- 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.

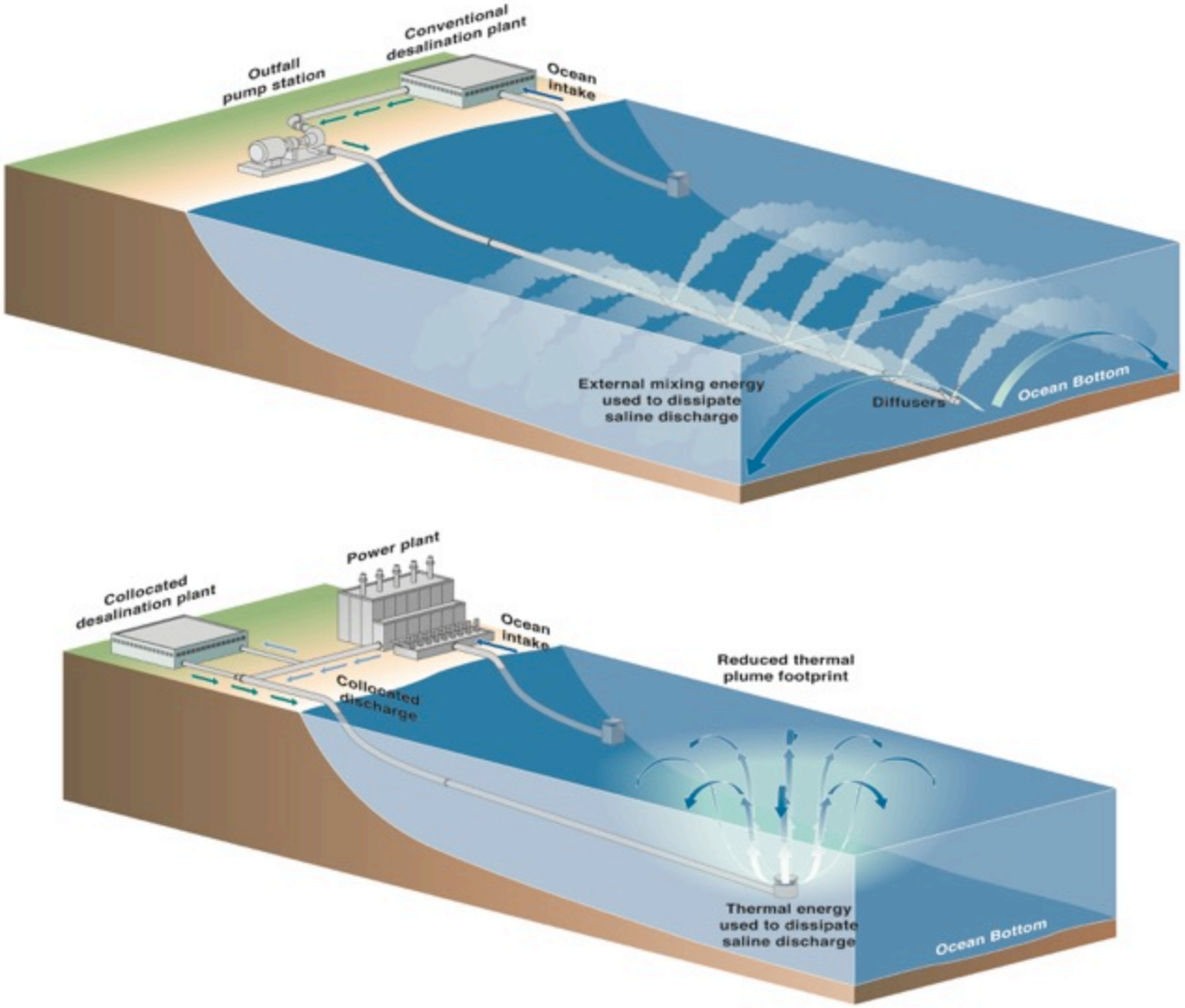
Concentrate Management – US Experience



Concentrate Management – Texas Experience



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;
8. Complete Detailed Plant Design, Construction and Start-up.

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