Membrane Water Treatment Technology Usage and Needs in the United States

Hosted by:

AMTA/WEF/WateReuse

Washington DC - September 7, 2017

Introductions

Dr. Harold Fravel
Executive Director
American Membrane Technology Association

- Introductions
- Brief Review of Membrane Technology
- Four Utility Presentations
- Four Corporate Presentations
- Question and Discussion

Presenters

- Rebecca Wilder, *Assistant Facilities Manager, Town of Jupiter, FL*
- Michael Markus, *General Manager, Orange County Water District, CA*
- Christine Owen, *Water Quality Senior Manager Tampa Bay Water, FL*
- Hector Gonzalez, *Government Affairs Manager El Paso Water Utilities, TX*

Presenters

- *Cedella Beazley, Commercial Director for the Americas Dow Water & Process Solutions*
- *Ben Soucy, General Manager of the Memcor Membrane Business, Evoqua Water Technologies*
- *Dr. Geert-Henk Koops ,Technology Leader UF/MBR GE Water and Process Technologies*
- *Lynne Gulizia, Sales Director-Americas*

  Toray Membrane USA

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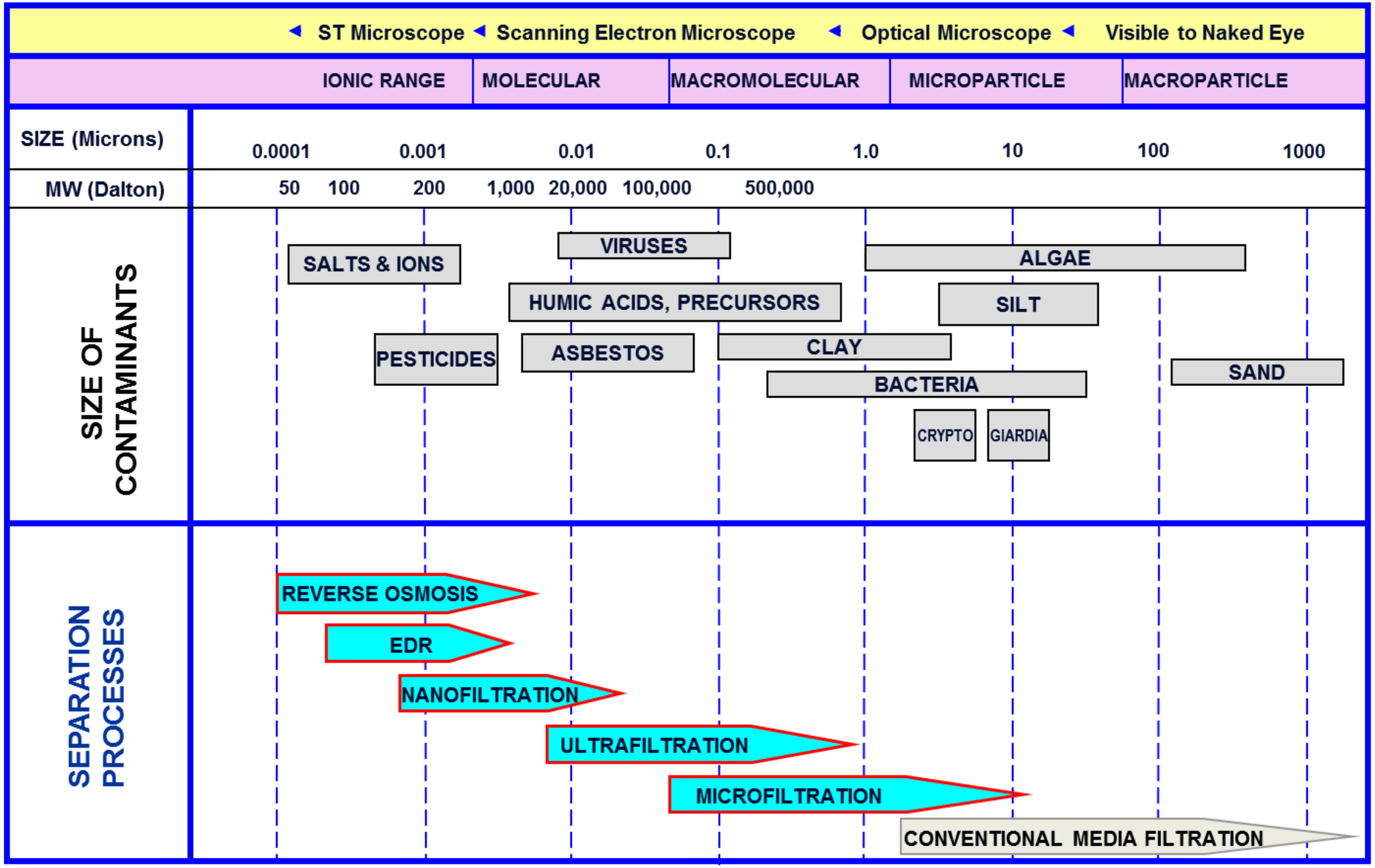
Basic Overview of Membrane Technologies

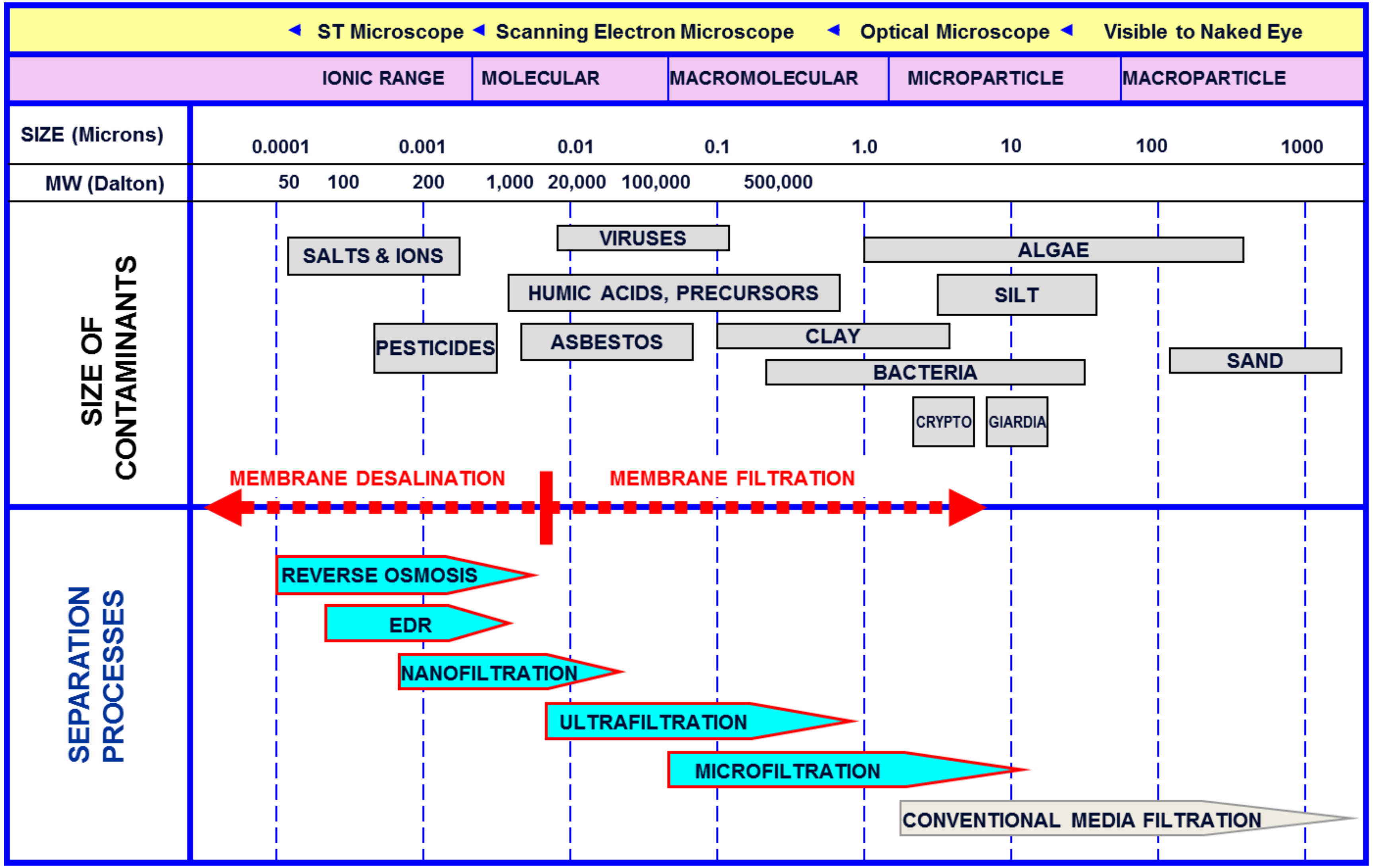
Ben Movahed, P.E., BCEE

WATEK® ENGINEERING CORPORATION

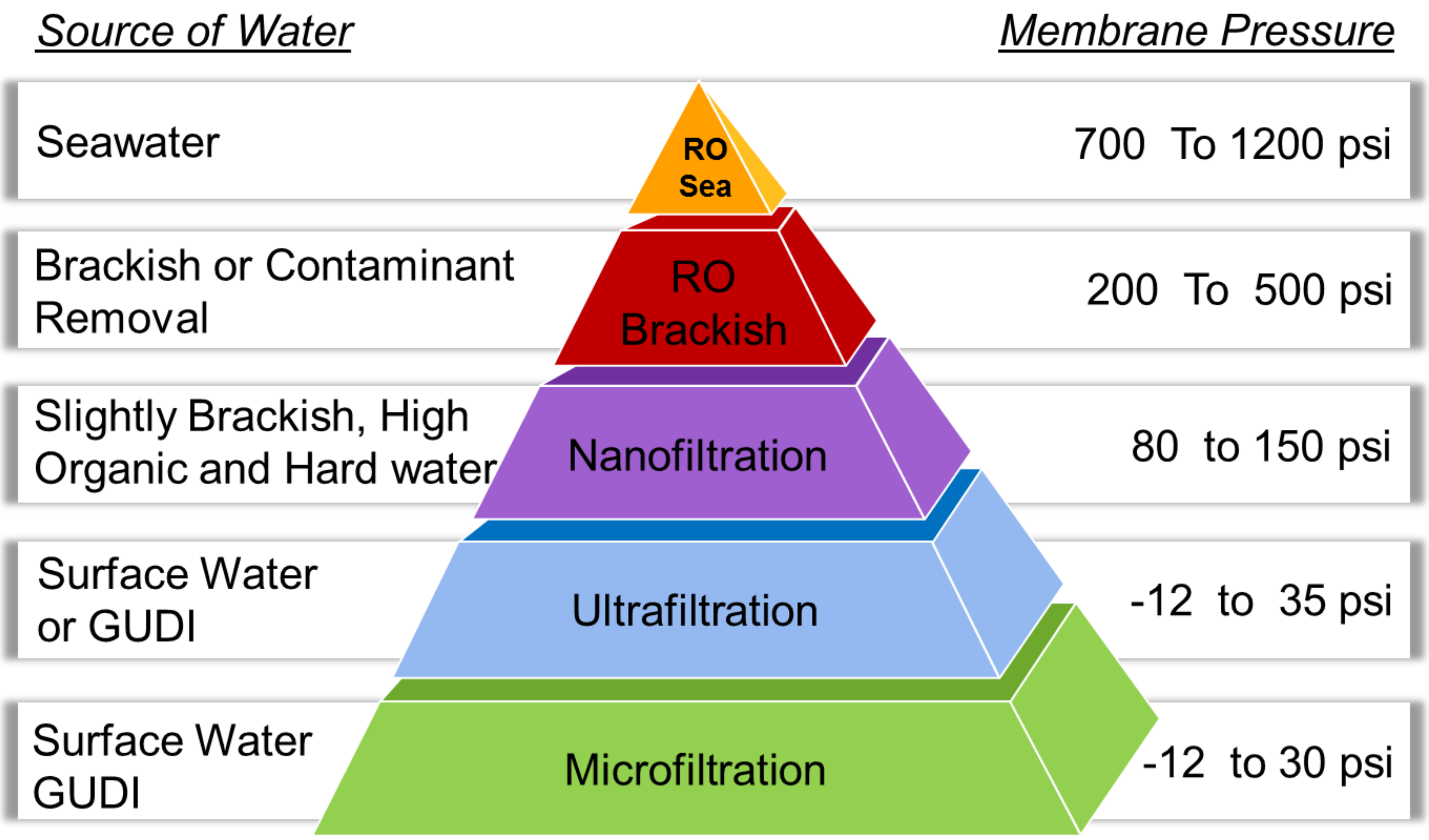
Membrane separation processes relative to contaminants



Two Very Different Categories



Membrane choice is based on source type and economic considerations



Four general configurations

Hollow Fiber
(MF/UF/MBR

Spiral Wound
(RO/NF)

Flat Plates
(MBR/EDR)

Flat Sheets
(MBR)

Newer Materials and Innovations

Ceramic

Tubular

MF/UF (low pressure) Membrane Applications

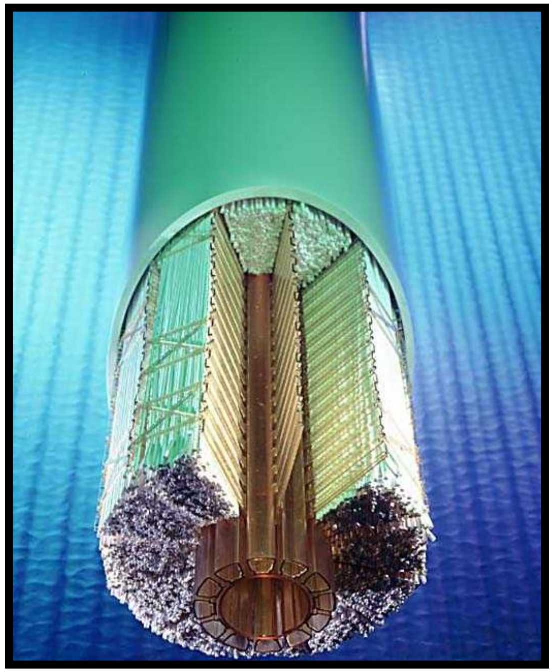
- Surface Water Treatment
- Groundwater Under Direct Influence of Surface Waters (GUDI)
- Wastewater Treatment
- Recycle / Reuse
- Integrated Membrane Systems (IMS)
- Conventional Plant Retrofit (membrane conversion)

Packaged in Different Configurations

- Hollow Fiber
  - Pressurized
  - Vacuum (immersed)
- Tubular
- Ceramic & Discs
- Flat sheets

Most popular for municipal medium/large plants

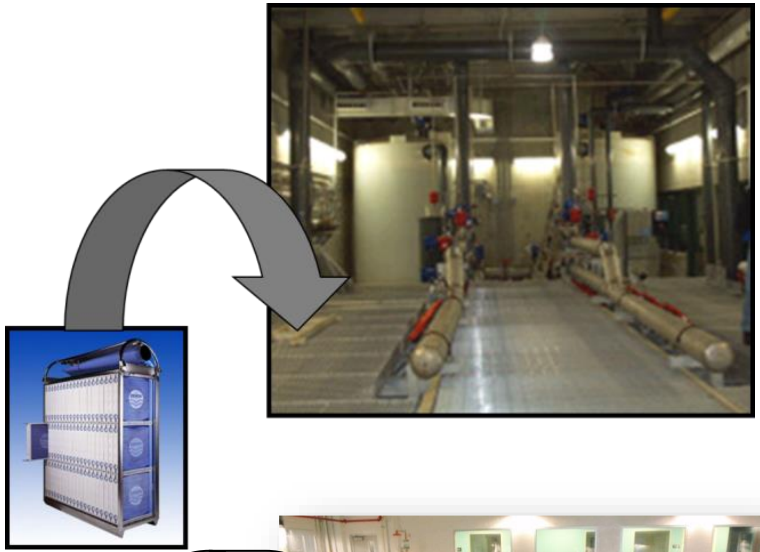
Many different module shapes and types

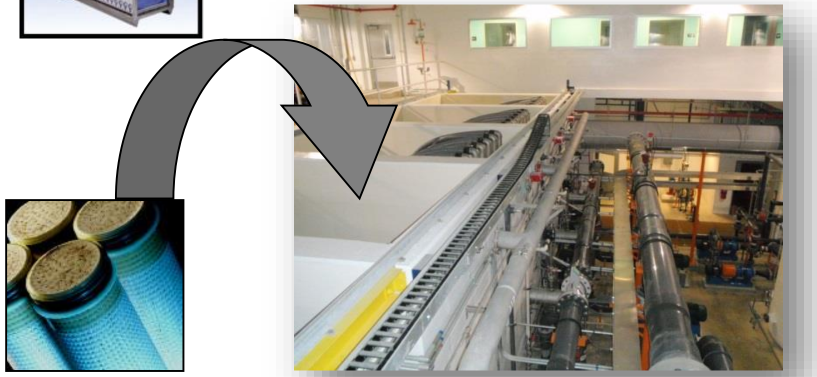


Two modes of operation

Pressurized

Submerged / Vacuum

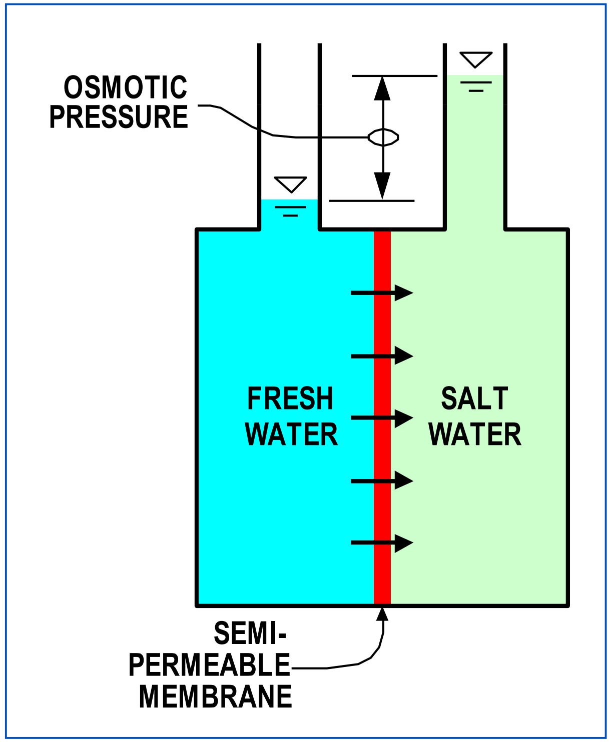




Reverse Osmosis and Nanofiltration Systems

Natural Osmotic Pressure:

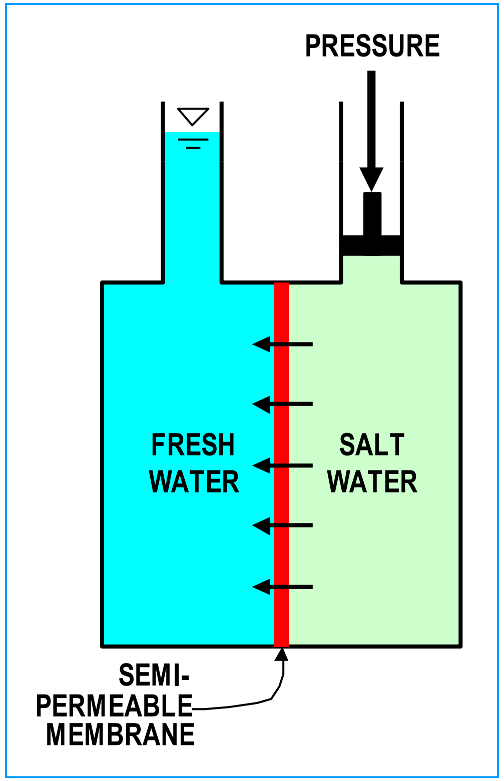
Water will migrate from a region of low concentration to a region of high osmotic potential to equalize the two sides



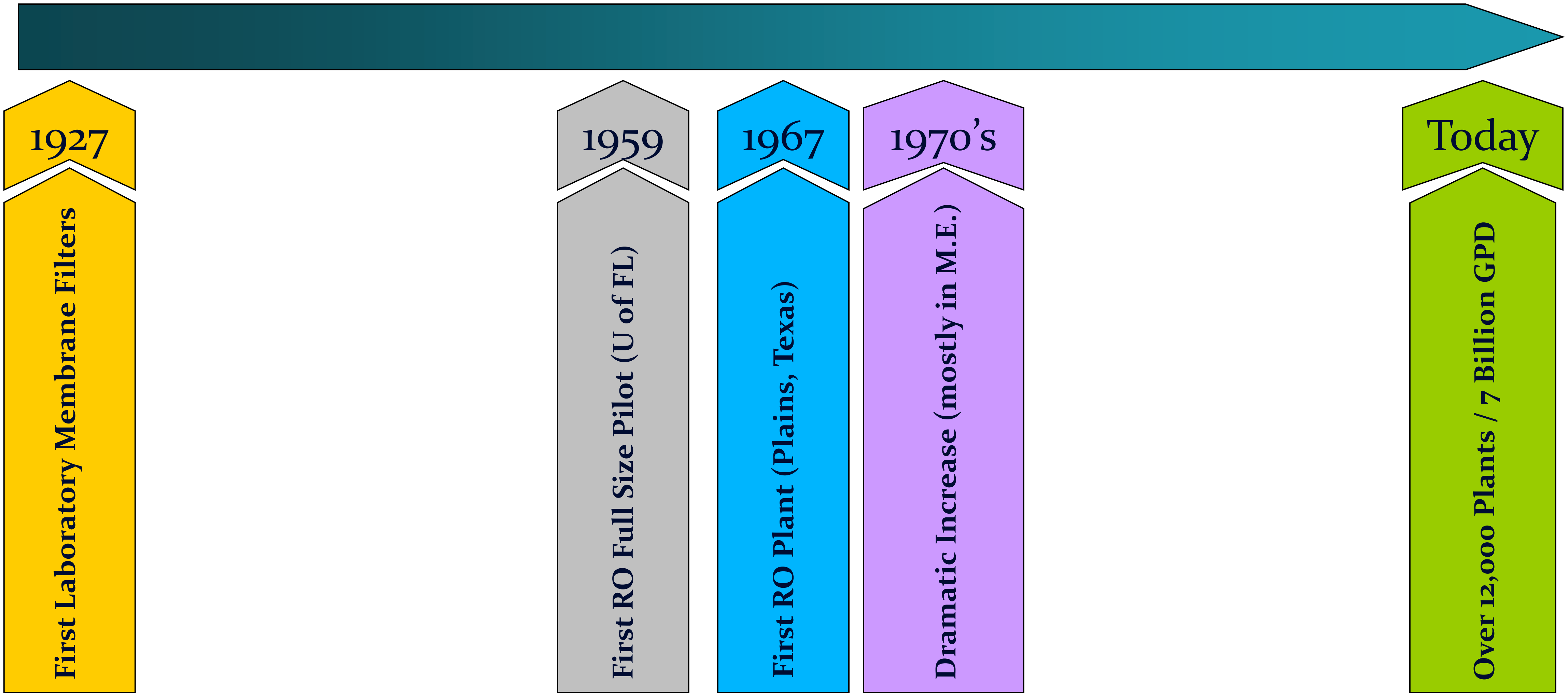
Reverse Osmosis:

Reverses the natural flow path

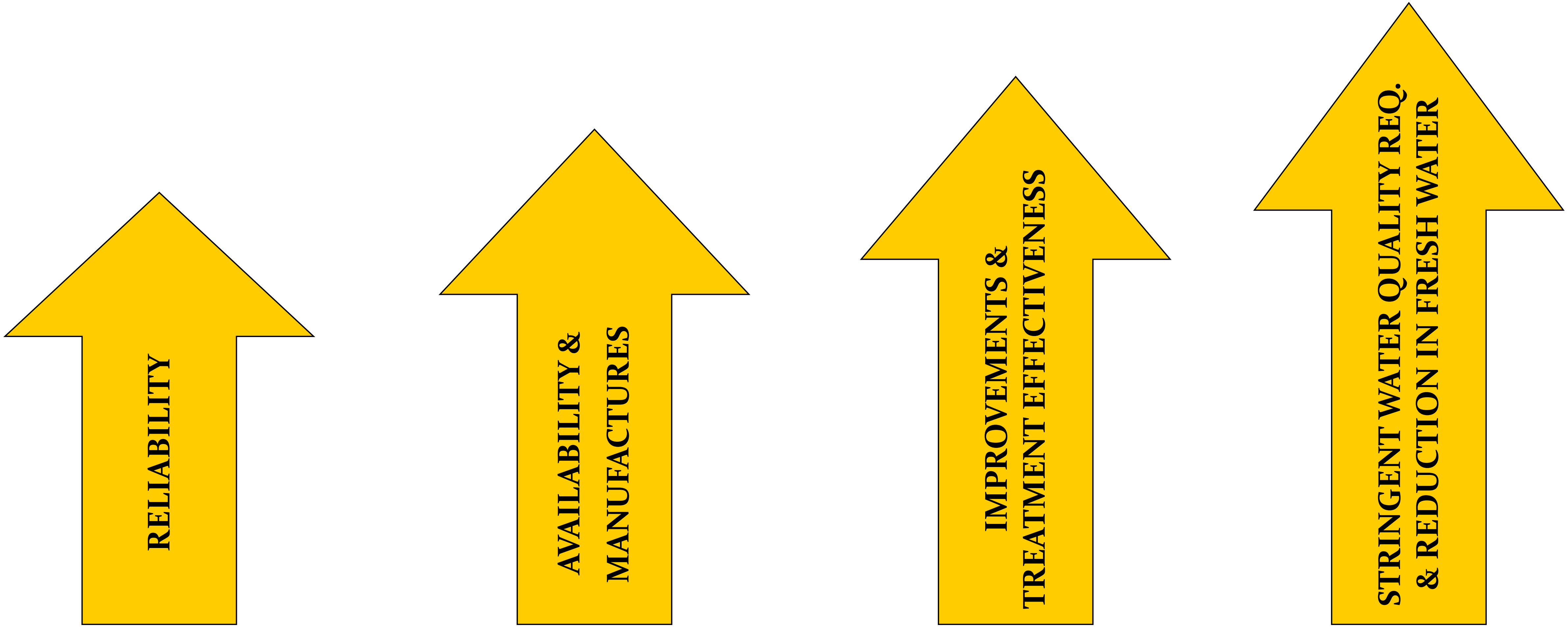
Applied pressure > Osmotic pressure



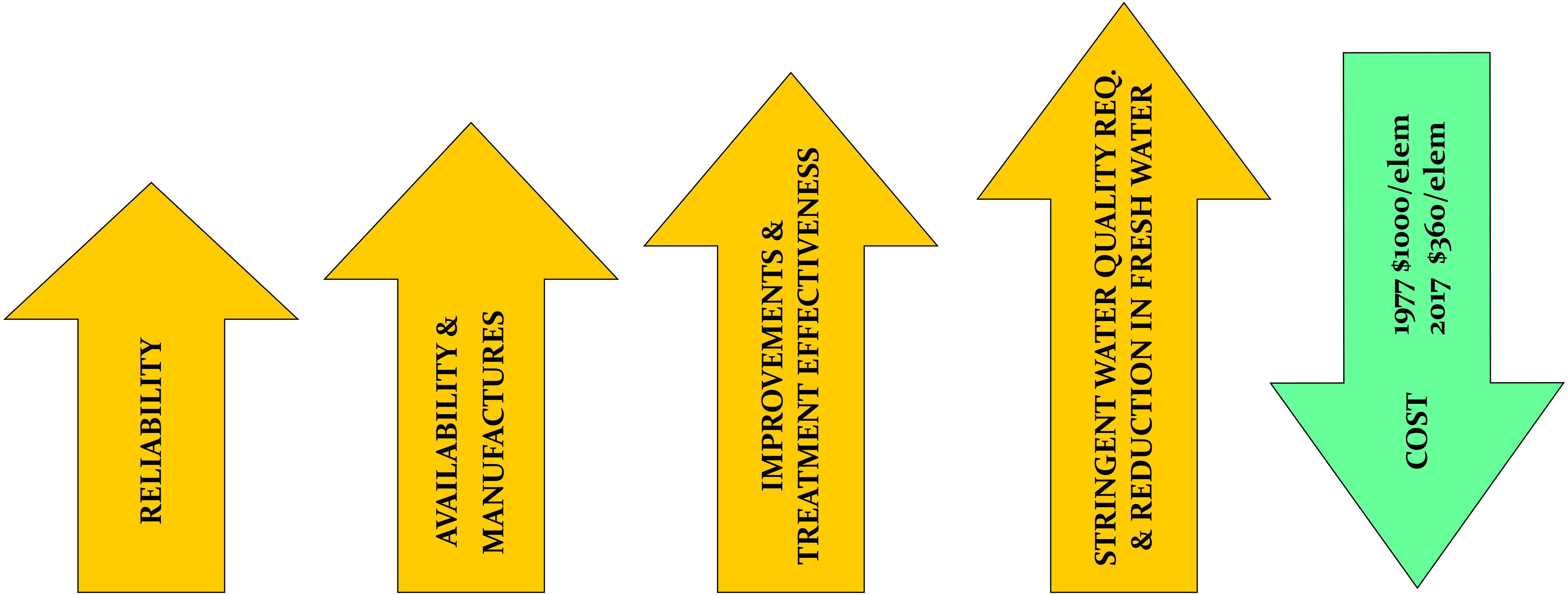
We have used membrane concept since 1927!



Reason for membrane technology growth



Capital Cost Reduction was also an important factor



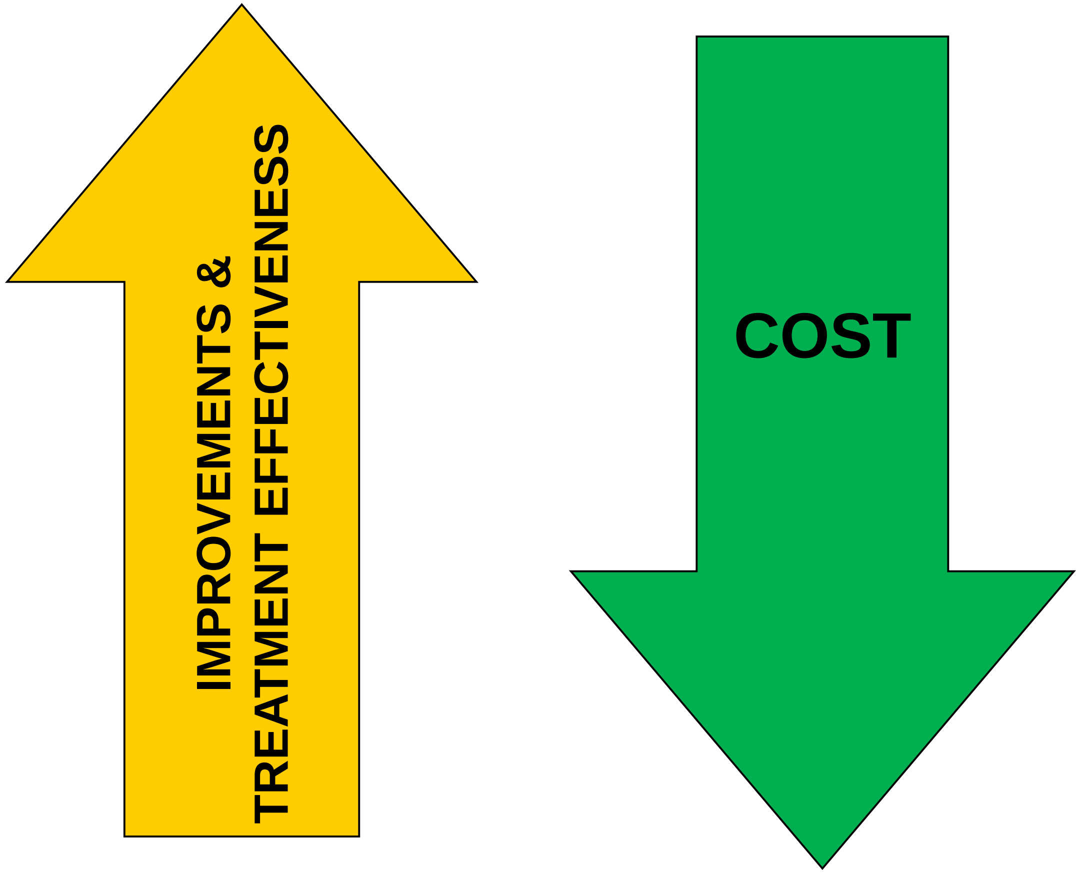
Improvements and Cost Reduction in last 30 years have been significant

Example 1:

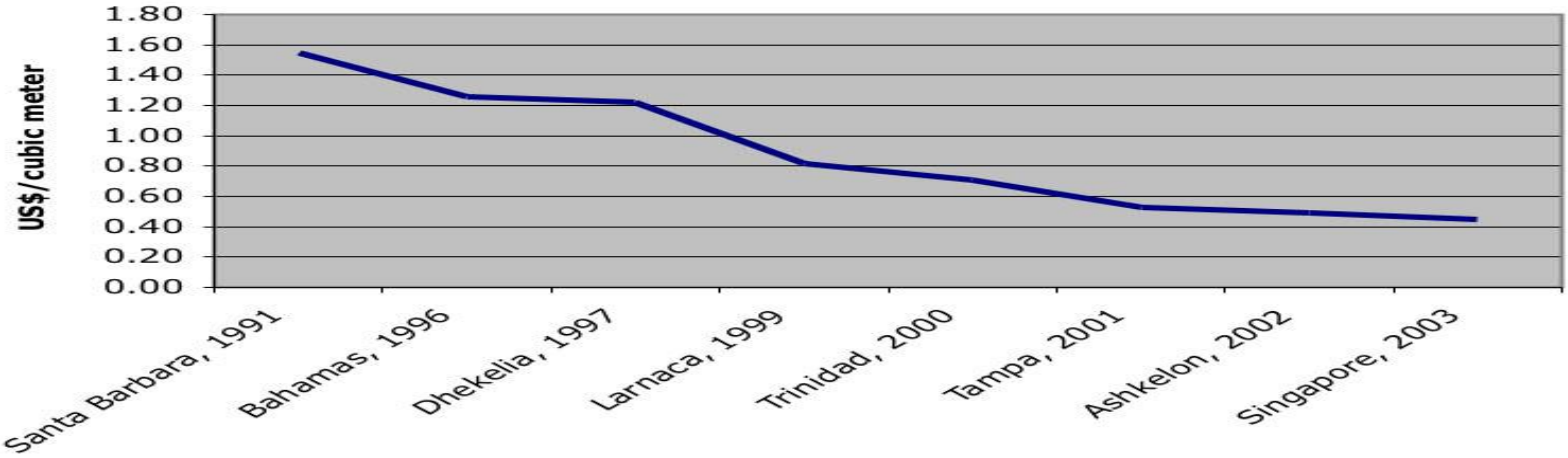
1977 400 psi 15 gpd flux
2015 225 psi 20 gpd flux

Example 2:

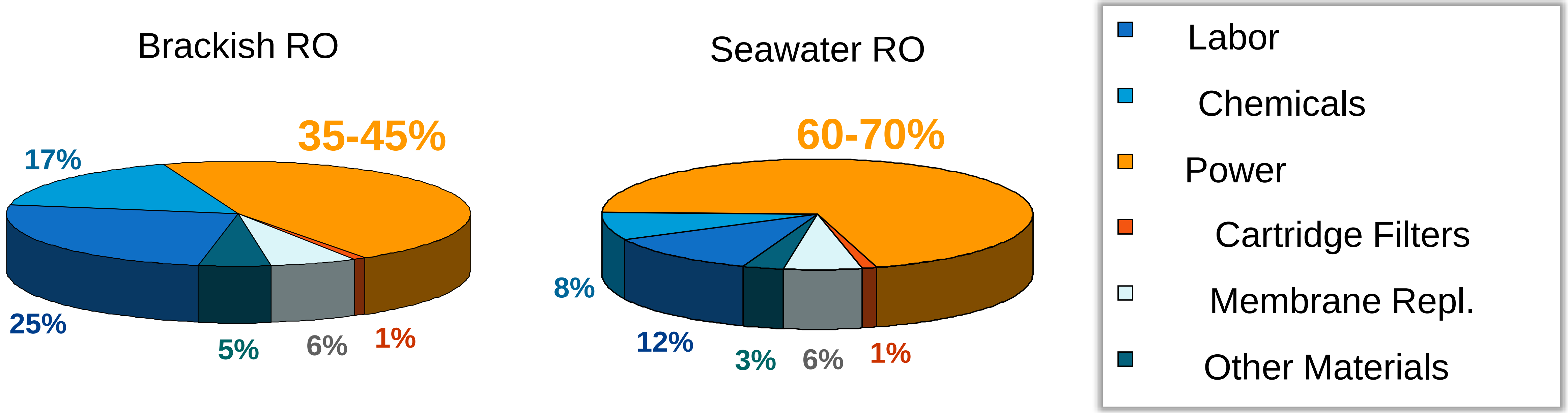
1990, 8" element, 6,000 gpd, 99.5% salt rejection
2015, 8" element 9,000 gpd, 99.75% salt rejection



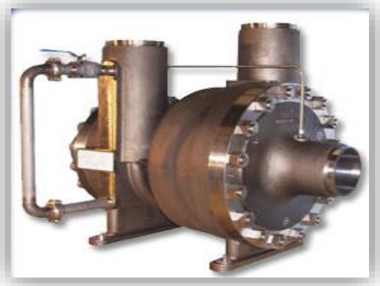
Seawater project cost reduction



Power is a major component of RO desalination cost



Energy Recovery in SWRO is the main reason in power cost reduction



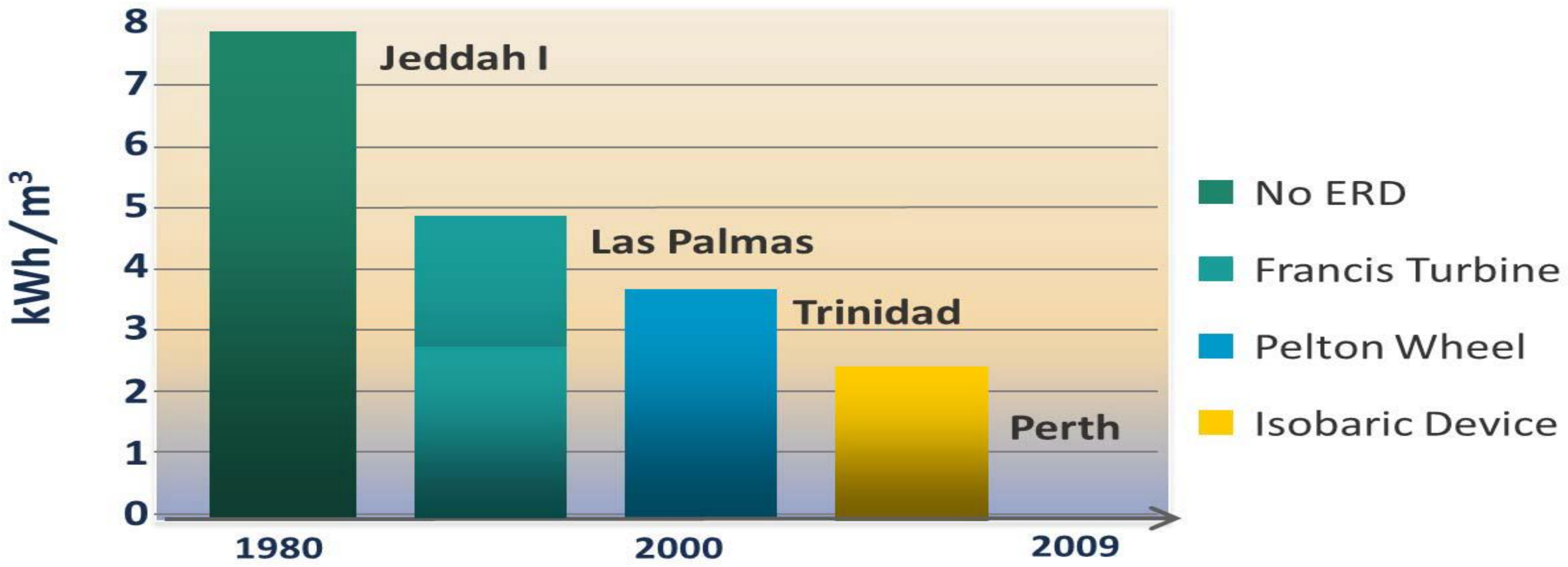
1970s:
NONE!
(0%)

1980s:
Pelton Wheels
(70-80%)

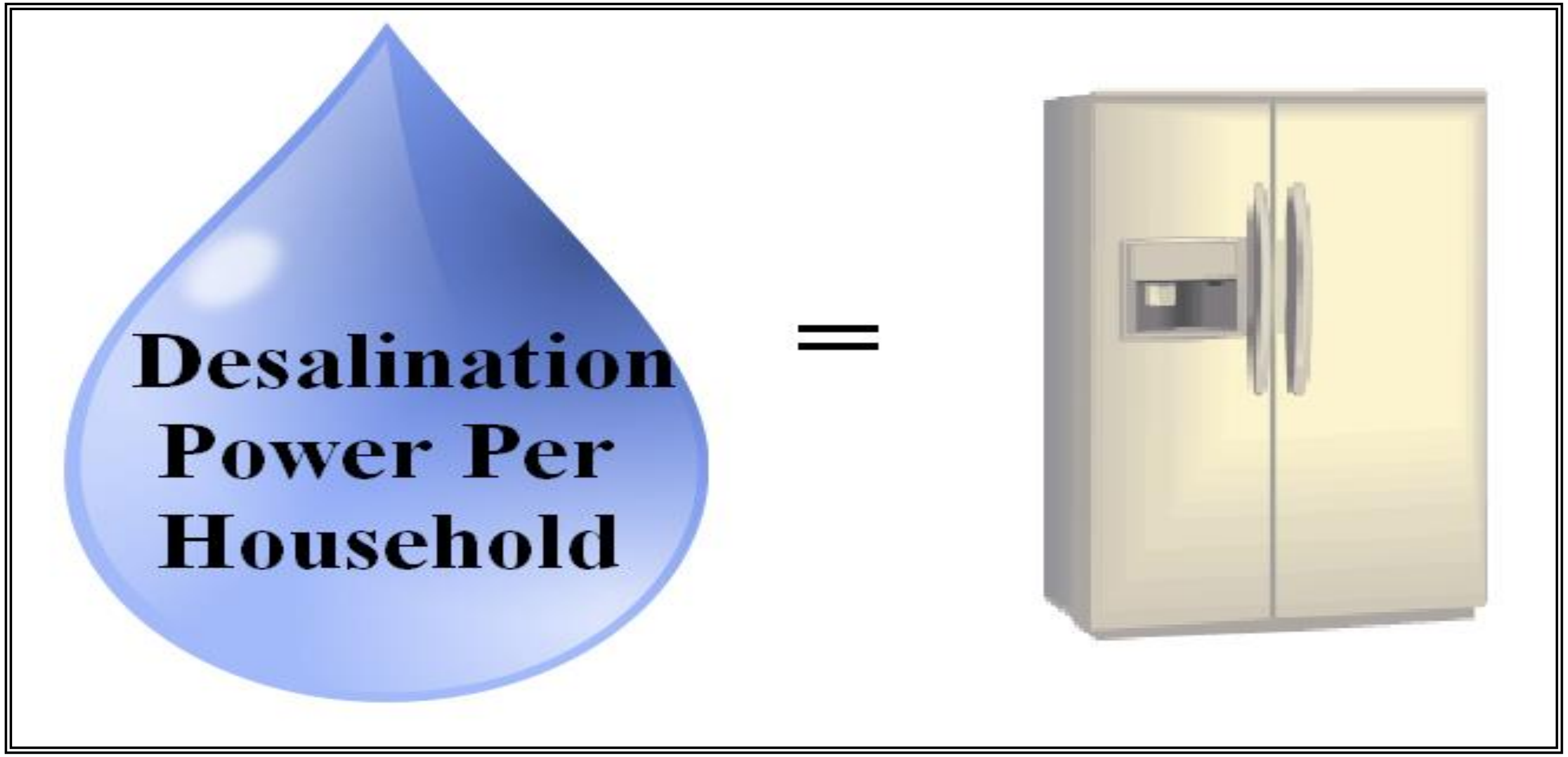
1990s:
Turbines
(80-90%)

2000s:
Pressure Exchangers
(85-95%)

Energy Reduction by ERD



Even Seawater RO Desalination has manageable energy requirement

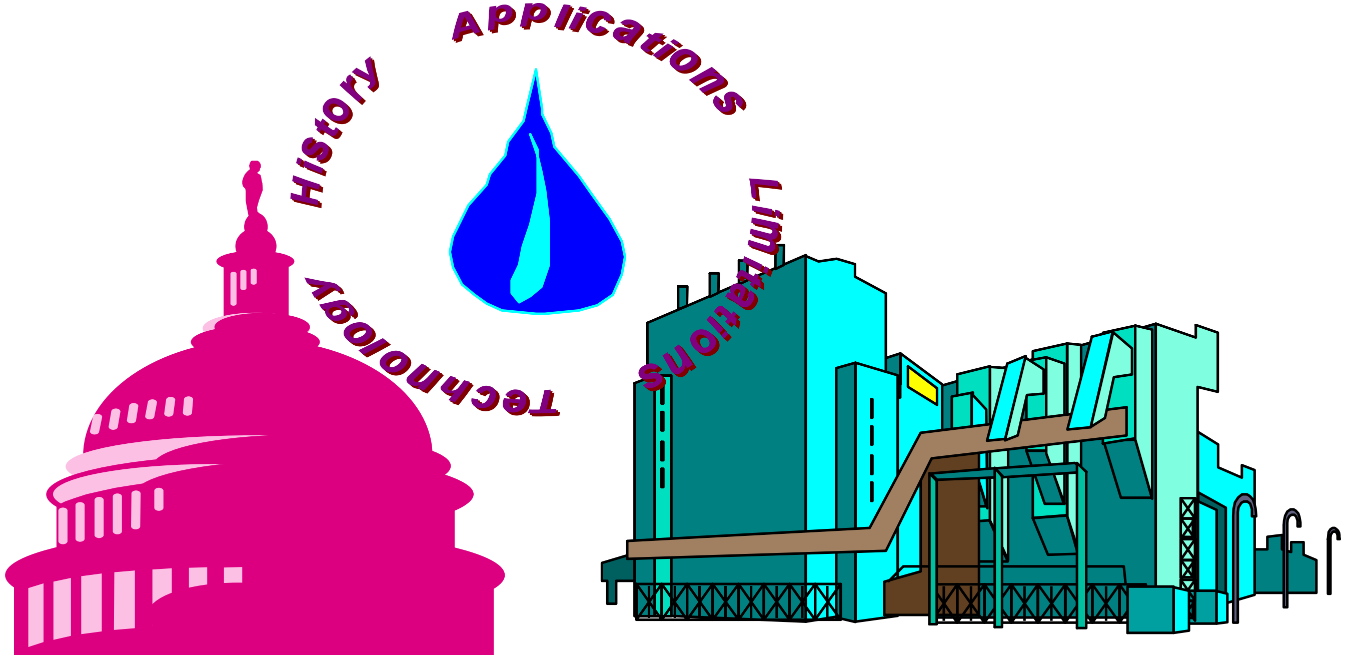


NF and RO show excellent performance for reducing Emerging Contaminants

Classification	AC	O3	UV	NF	RO
Pesticides	✓	✓ (grey)	✓	✓ (grey)	✓
Industrial Chemicals	✓	✓ (grey)	✓	✓	✓
Steroids	✓	✓	✓	✓ (grey)	✓
Metals	✓ (grey)	✗	✗	✓ (grey)	✓
Inorganics	✗	✗	✗	✓	✓
Organometallics	✓ (grey)	✗	✓ (grey)	✓	✓
Antibiotics	✓	✗	✓ (grey)	✓	✓
Antidepressant	✓	✗	✓ (grey)	✓	✓
Anti-inflammatory	✓	✓	✓	✓	✓
Lipid regulators	✓ (grey)	✓	✓ (grey)	✓	✓
X-ray contrast media	✓	✗	✓ (grey)	✓	✓
Psychiatric control	✓	✗	✓ (grey)	✓	✓
Synthetic musks	✓	✗	✓	✓	✓
Sunscreens	✓	✗	✓ (grey)	✓	✓
Antimicrobials	✓ (grey)	✗	✓ (grey)	✓	✓
Surfactants/detergents	✓	✓ (grey)	✓ (grey)	✓	✓

✓= > 90% Removal
✓ (grey)= 40-70% Removal
✗ = < 40% Removal

EPA Regulations and Membrane Filtration Guidance Manual (2005) are all good steps to tap into this valuable technology



Unfortunately not All Requirements are Always Clear!

- Mandatory piloting requirements by several states
- Repeated material testing on proven materials
- Prove what is proven many times!
- Things are getting better, but still need more consistent national guidelines and standards !

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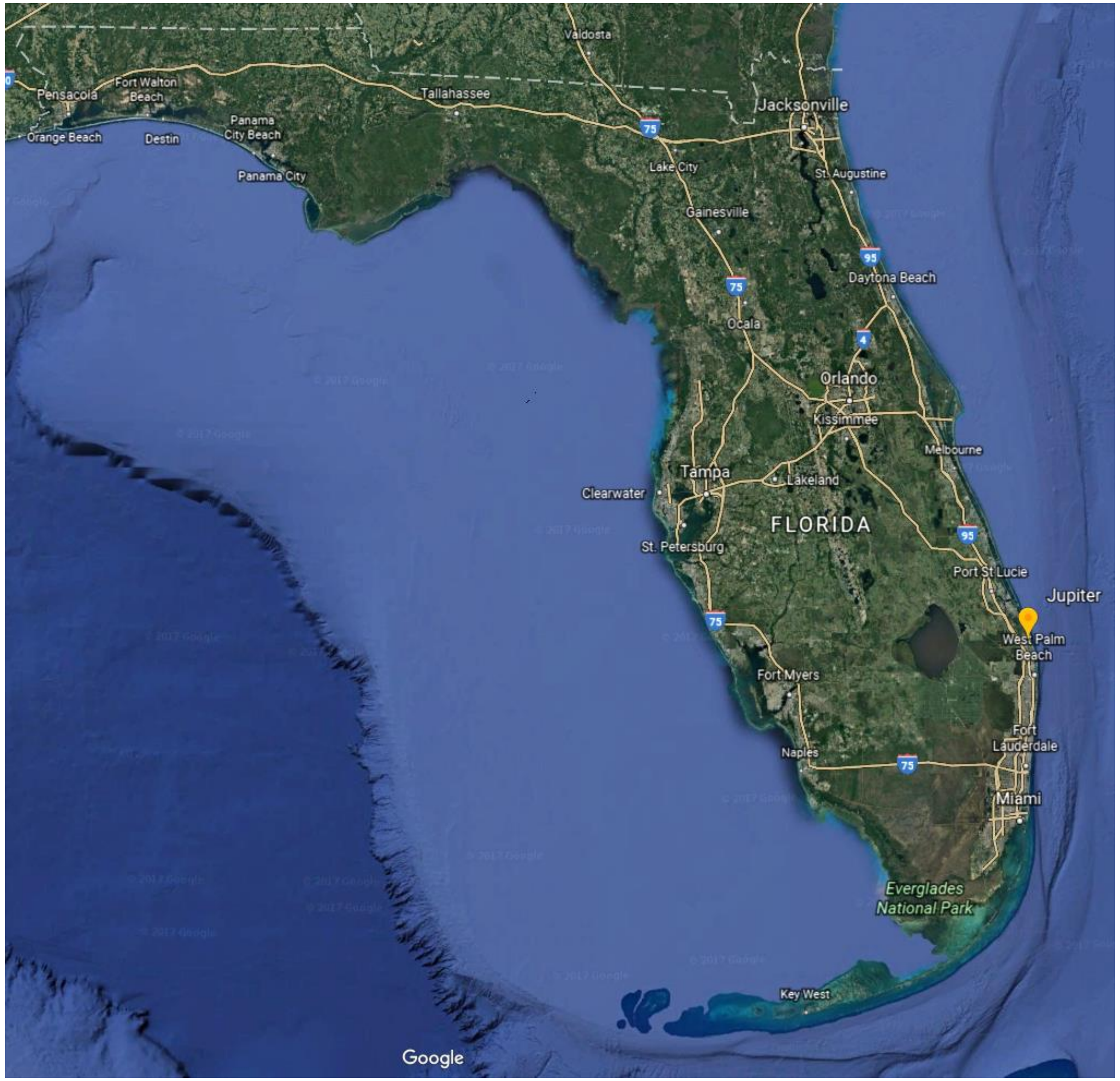
Application of Membrane Technologies at the Town of Jupiter

Rebecca Wilder
Assistant Facilities Manager
Town of Jupiter Utilities

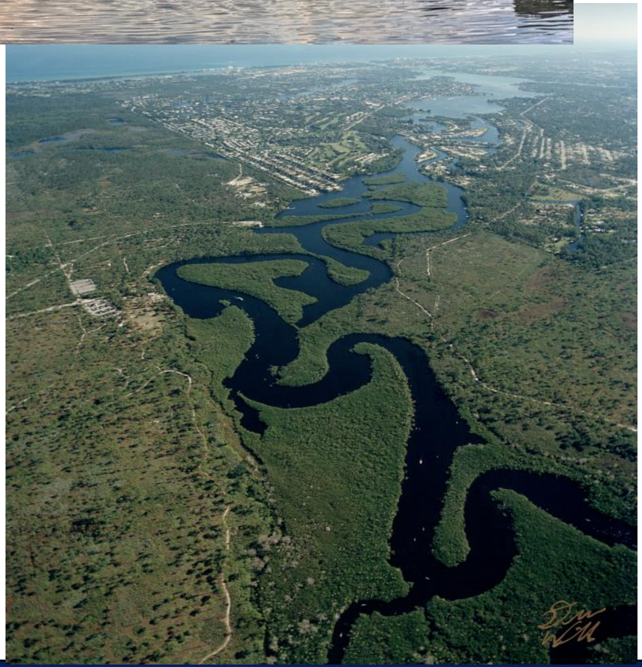
Town of Jupiter, Florida

- SE Coastal Florida
- 15 miles North of Palm Beach
- Population served: ~90,000
- Design capacity: 30 million gallons per day (MGD)
- Reverse Osmosis and Nanofiltration technologies



Jupiter's Water Supply Program History

- Small fishing village until 1970s
- During 1980s began experiencing tremendous growth
- Water demands forecasted to 30 million gallons per day (MGD), while safe yield from local shallow aquifer only 20 MGD
- No water supplied from regional system to area
- No option but to fend for itself



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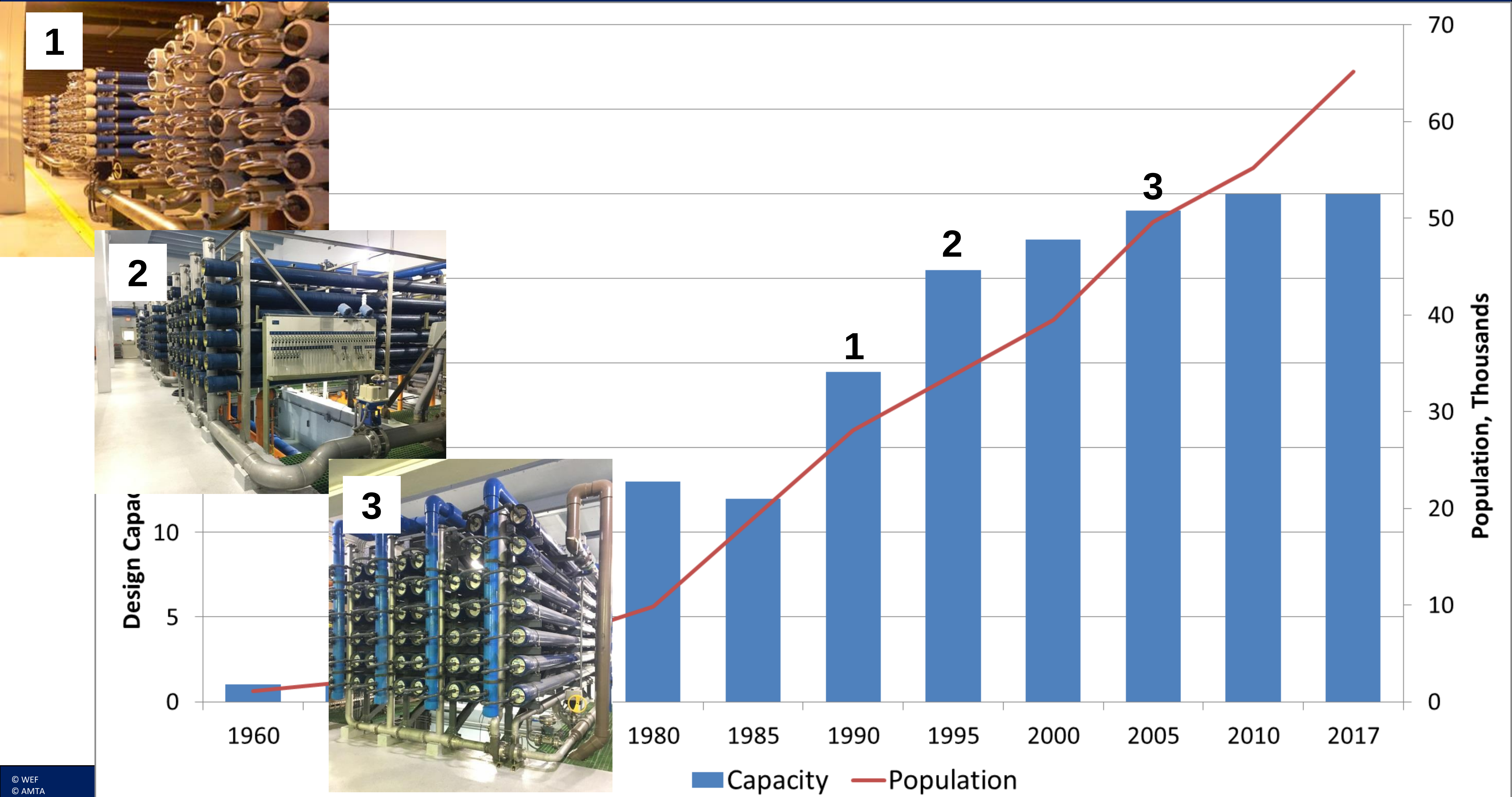


Reverse Osmosis Process

- First, large scale municipal application of reverse osmosis in SE Florida.
- Membrane technology was the solution:
  - Growth and water demand
  - Preservation of local environment and freshwater supplies
  - High quality product
- Very successful, lead now followed by other utilities

Jupiter's Water Supply Program History

- With growth came a customer base with desires for very best water quality possible
- Increasingly stringent regulations made the historical lime softening process obsolete.
- The Utility set a course toward using membrane treatment for 100% of its supply

Nanofiltration Process

- Nanofiltration was the first choice for replacement of the aging lime softening process
- In 2010, the 14.5 million gallon per day nanofiltration facility was completed
  - Unique design features provide for 50% energy savings
- Today, Jupiter employs only membrane technologies
  - 50/50 blend of reverse osmosis and nanofiltration

What's Next?

- Chemicals are being discovered in water that previously had not been detected – Compounds of Emerging Concern (CECs)

- Many CECs are in common household products that eventually end up in wastewater
- The use of treated wastewater to address growing water demands – both for irrigation and consumption

Compounds of Emerging Concern

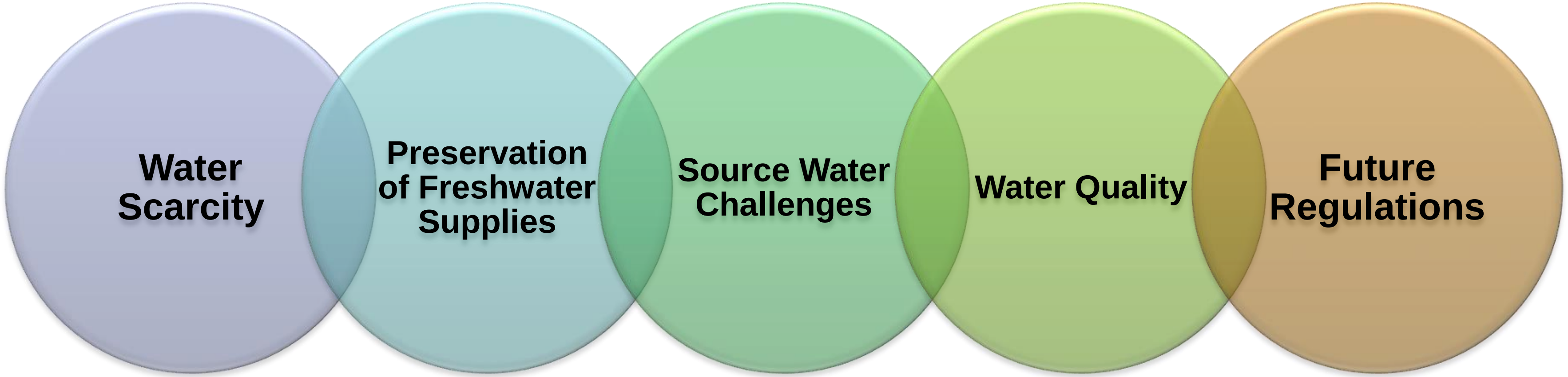
- In Jupiter, ~90% of treated wastewater effluent is delivered to the reuse system for golf course, commercial and residential irrigation demand
- Compounds of emerging concern have been detected in Jupiter's freshwater aquifer in the vicinity of reuse application
- Compounds include pharmaceuticals and sucralose
- Detected levels are very low – parts per trillion
- Existing membrane technology removes these compounds in both pilot and full scale evaluations

Compounds of Emerging Concern

- There is growing public interest and concern on PPCPs and EDCs in the environment
- Majority of these compounds are not currently regulated where a large proportion are in everyday products that people use
- The issues surrounding compounds of emerging concern present a unique opportunities for research, proactive information gathering to keep the public informed and application of innovative treatment technologies

Closing Remarks

- Jupiter's history has demonstrated that membrane technology has provided consistent solutions to past, present and future challenges



- Membrane technology will be key in assisting the water industry with navigating the issue of compounds of emerging concern

Water Environment Federation
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The Groundwater Replenishment System

Michael R. Markus, P.E., D.WRE, BCEE, F.ASCE
Orange County Water District

ORANGE COUNTY WATER DISTRICT (OCWD)

- Formed in 1933 by an act of the California legislature to manage the OC groundwater basin and protect OC's rights to the Santa Ana River water
- Basin provides groundwater to 19 municipal and special water districts that serve 2.4 million customers in north and central Orange County
- Basin currently supplies 75% of the water supply for north and central OC

THE GROUNDWATER REPLENISHMENT SYSTEM (GWRS)

- 100 million gallon per day (MGD) advanced water purification facility
- Takes sewer water that otherwise would be discharged to the ocean, purifies it to near distilled quality and then recharges it into the groundwater basin
- Provides a new 103,000 acre-feet per year (afy) source of water, which is enough water for nearly 850,000 people
- Operational since January 2008 (70 MGD) expanded May 2015 (30 MGD)
- Largest potable reuse project in the world

ORANGE COUNTY WATER DISTRICT SINCE 1933

ORANGE COUNTY SANITATION DISTRICT PROTECTING THE ENVIRONMENT

MICROFILTRATION (MF) PROCESS SYSTEM

- 120 MGD Evoqua CMF-S Microfiltration System
- In basin submersible system
- Tiny, straw like hollow fiber polypropylene membrane
- 0.2 micron pore size
- Recovery rate: 90%
- Removes bacteria, protozoa, and suspended solids

REVERSE OSMOSIS (RO) PROCESS

- 100 MGD Reverse Osmosis System
- 3 stage: 78-48-24 array
- Hydranautics ESPA-2 and DOW XFRLE-400 Membranes
- Recovery rate: 85%
- Removes dissolved minerals, viruses, and organic compounds (incl. pharmaceuticals)
- Pressure range: 150 – 200 psi

ADVANCED OXIDATION PROCESS (AOP)

- 100 MGD Trojan UVPhox System
- Low pressure – high output lamp system
- Destroys trace organics
- Uses hydrogen peroxide to create an Advanced Oxidation Process
- After treatment, water is so pure that minerals (lime) are added back into the water

GWRS PROVEN RELIABILITY

- California Department of Public Health developed permit requirements
- Test for over 400 compounds with all results well below permit levels or at non-detection (ND) levels
  - 28 Volatile Organic Compounds – All ND
  - 39 Non-Volatile Synthetic Organic Compounds – All ND
  - 8 Disinfection By-Products – All ND
  - 10 Unregulated Chemicals – All but one ND, all below permit levels
  - 51 Priority Pollutants – All ND
  - 16 Endocrine Disrupting Chemicals and Pharmaceuticals – All ND

PROJECT FUNDING

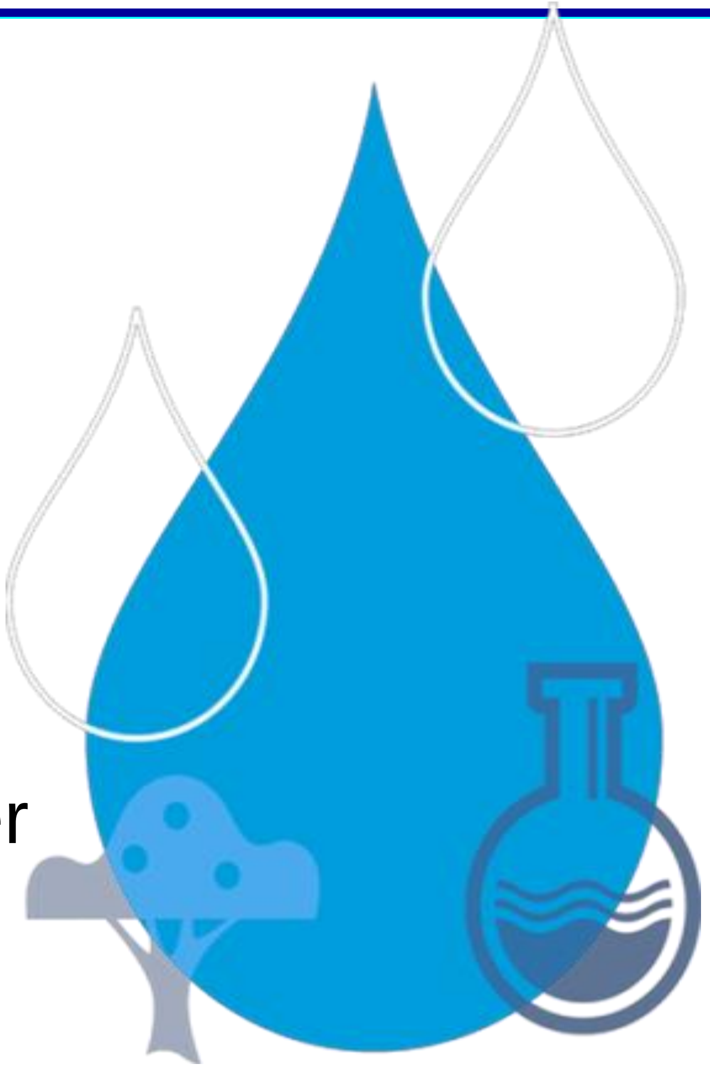
- Original Project Cost: $481 million
  - Split equally between OCWD and OCSD
  - Received $92 million in state and federal grants, and $4 million per year (21 year) operation and maintenance subsidy from Metropolitan Water District
- Expansion Project Cost: $142 million
  - Received $1 million in state grants
- Costs comparable to imported water
- Both projects used State Revolving Fund (SRF) loans
- Costs $525 per acre-ft ($850 per acre-ft without subsidies)

PUBLIC OUTREACH

- Many projects stopped by public and political opposition
- Outreach began early, over 10 years prior to start-up
- Researched public concerns
- Face to face presentations
- Community leaders
- Measured effects of outreach
- Community support
- Outreach continues today, assisted by media interest
- No active opposition

BENEFITS OF GWRS

- Creates a new local water supply
- Reuses a wasted resource
- Increases water supply reliability
- Costs less than water from the Colorado River and the State Water Project
- Uses one-half the energy it takes to import water and one-third the energy to desalinate seawater
- Improves quality of water in the basin



GWRS SUCCESS

- 40+ awards
- National & international media attention
- 38,000+ visitors

QUESTIONS?

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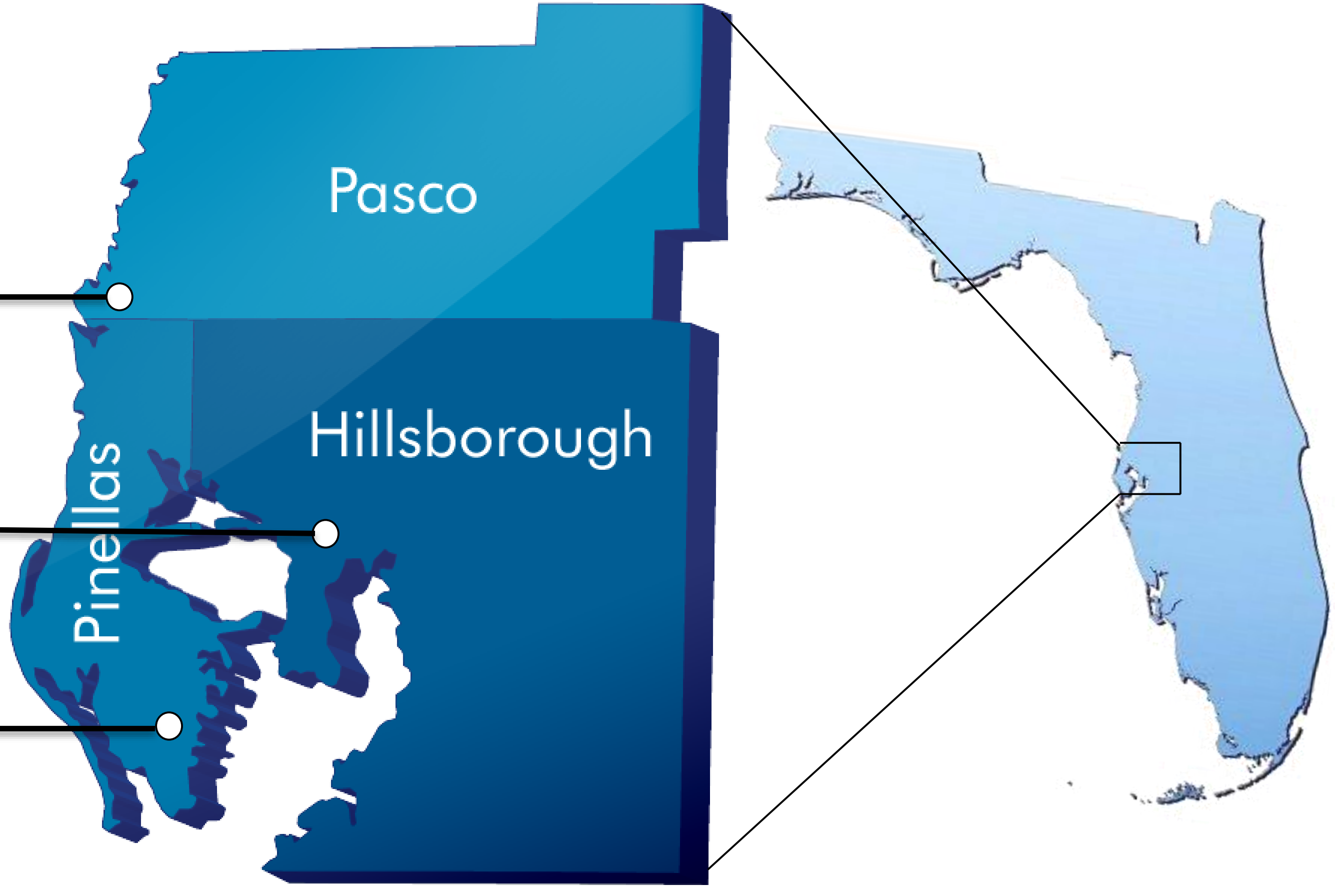
Tampa Bay Water's Desalination Facility

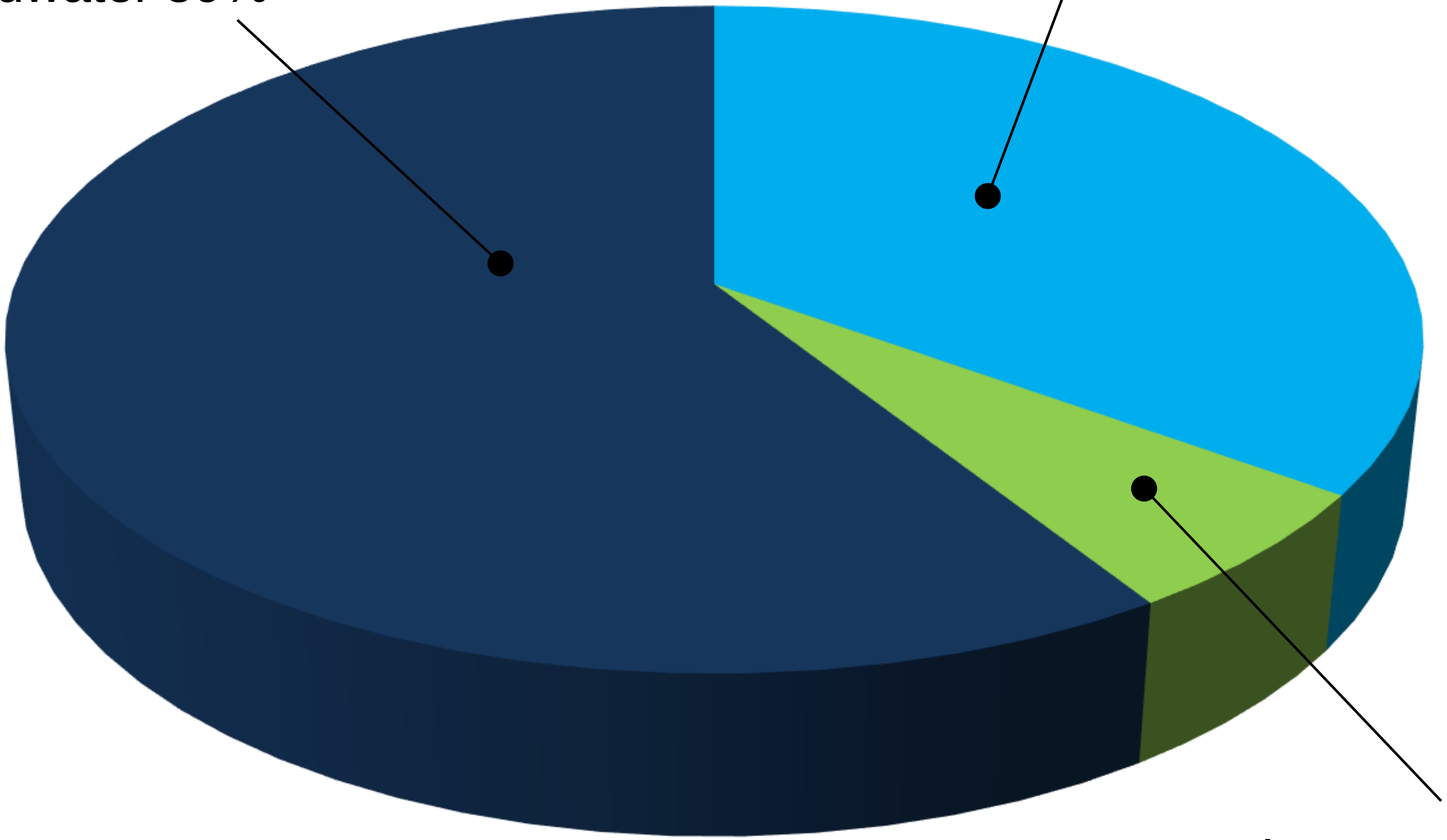
Christine Owen

Tampa Bay Water

Tampa Bay Water: Who We Are



Tampa Bay Water Supply 2016



The Regional Solution to Our Water Supply Problem

- Ended litigation
- Constructed $1 billion interconnected, regional water supply system
- Developed river water and desalinated seawater alternative supplies
- Reduced groundwater pumping from 147 mgd in 1998 to 80 mgd in 2014

TAMPA BAY WATER
Supplying Water To The Region

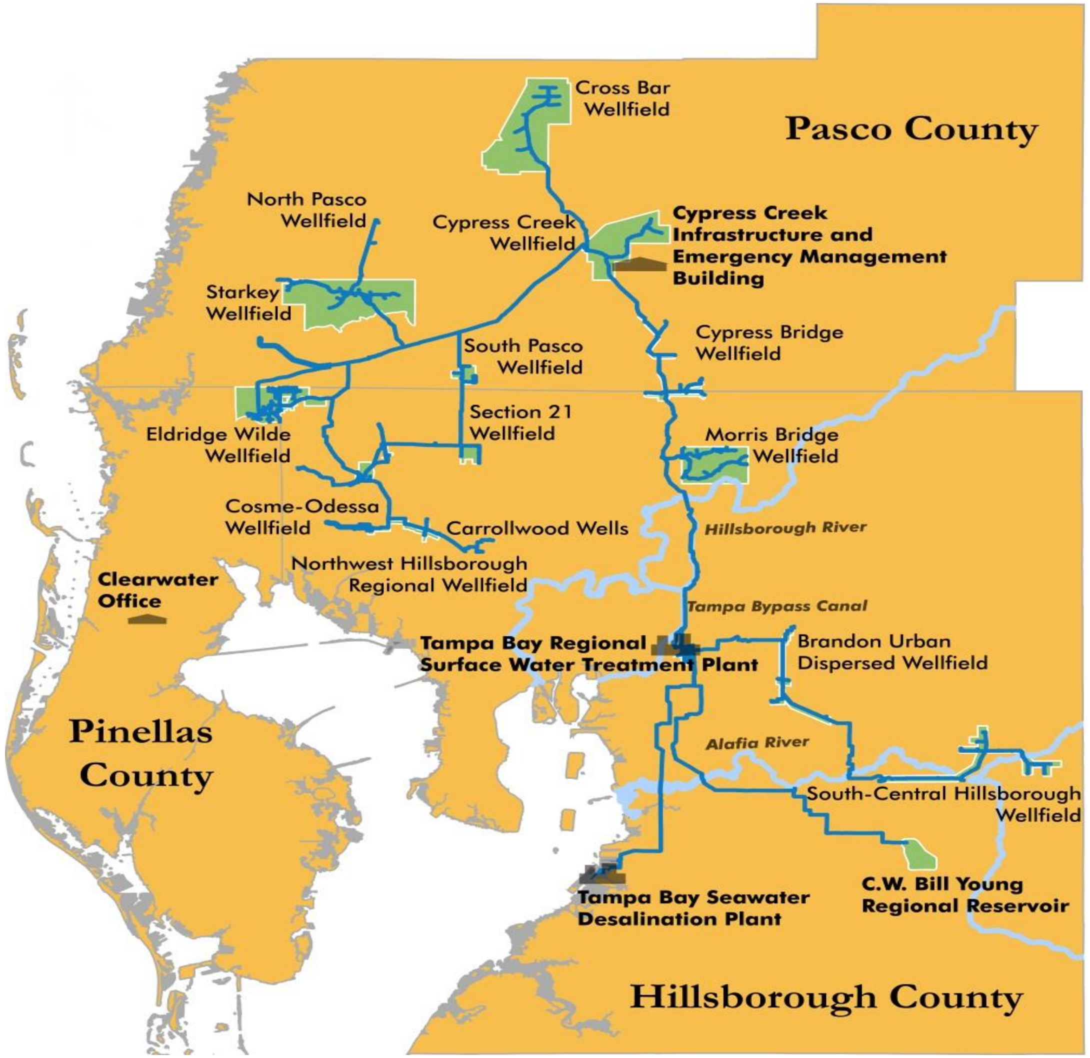
Sustainable Supplies Means Water for the Environment

Morris Bridge Wellfield - 2005

Morris Bridge Wellfield- 2013

The Plan

An integrated, *flexible* system that produces a *sustainable and reliable* water supply



The Region's First Alternative Supplies

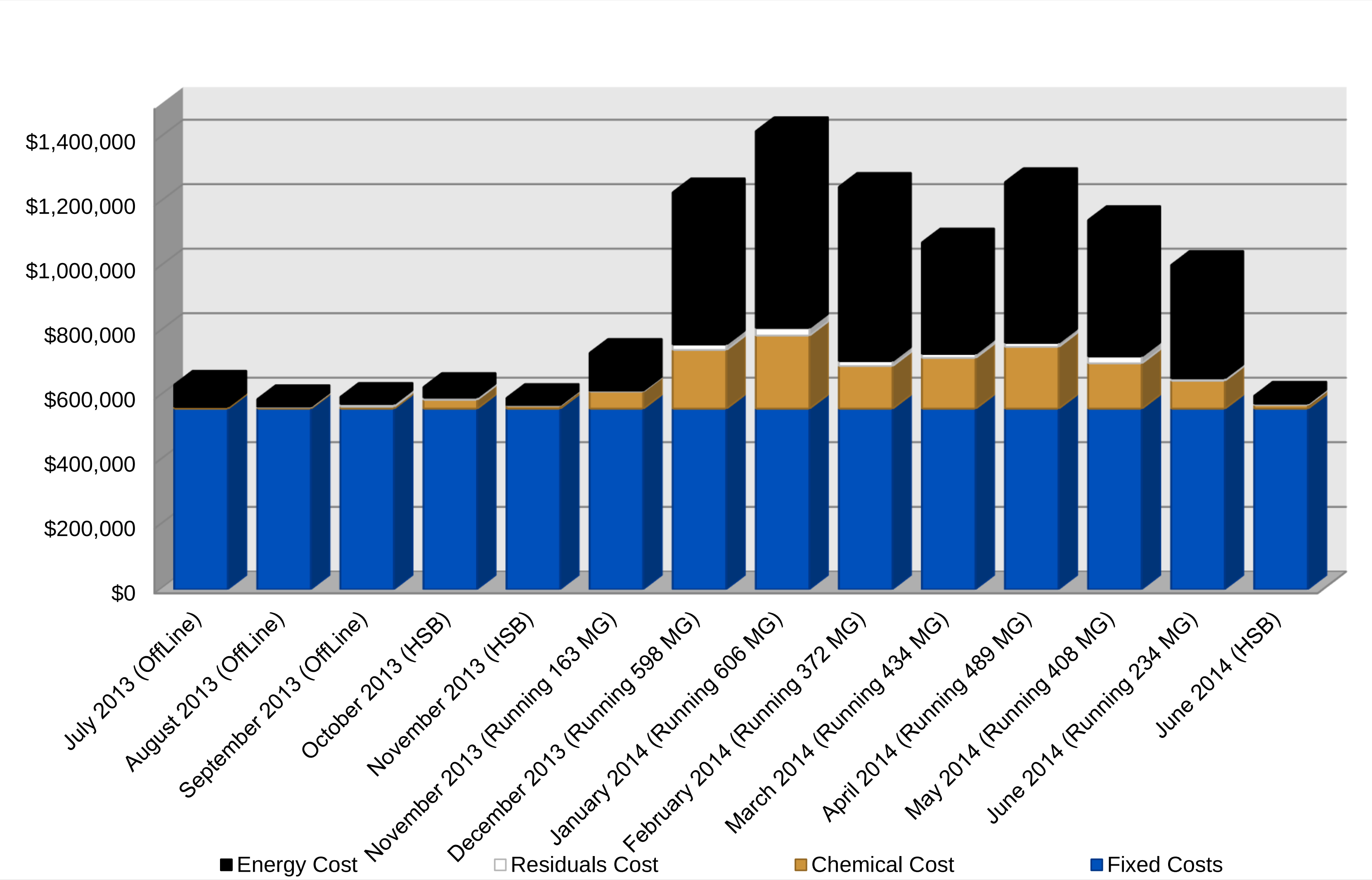
Regional Desalination Facility (25 MGD)

Regional Surface Water Treatment Plant (120 MGD)

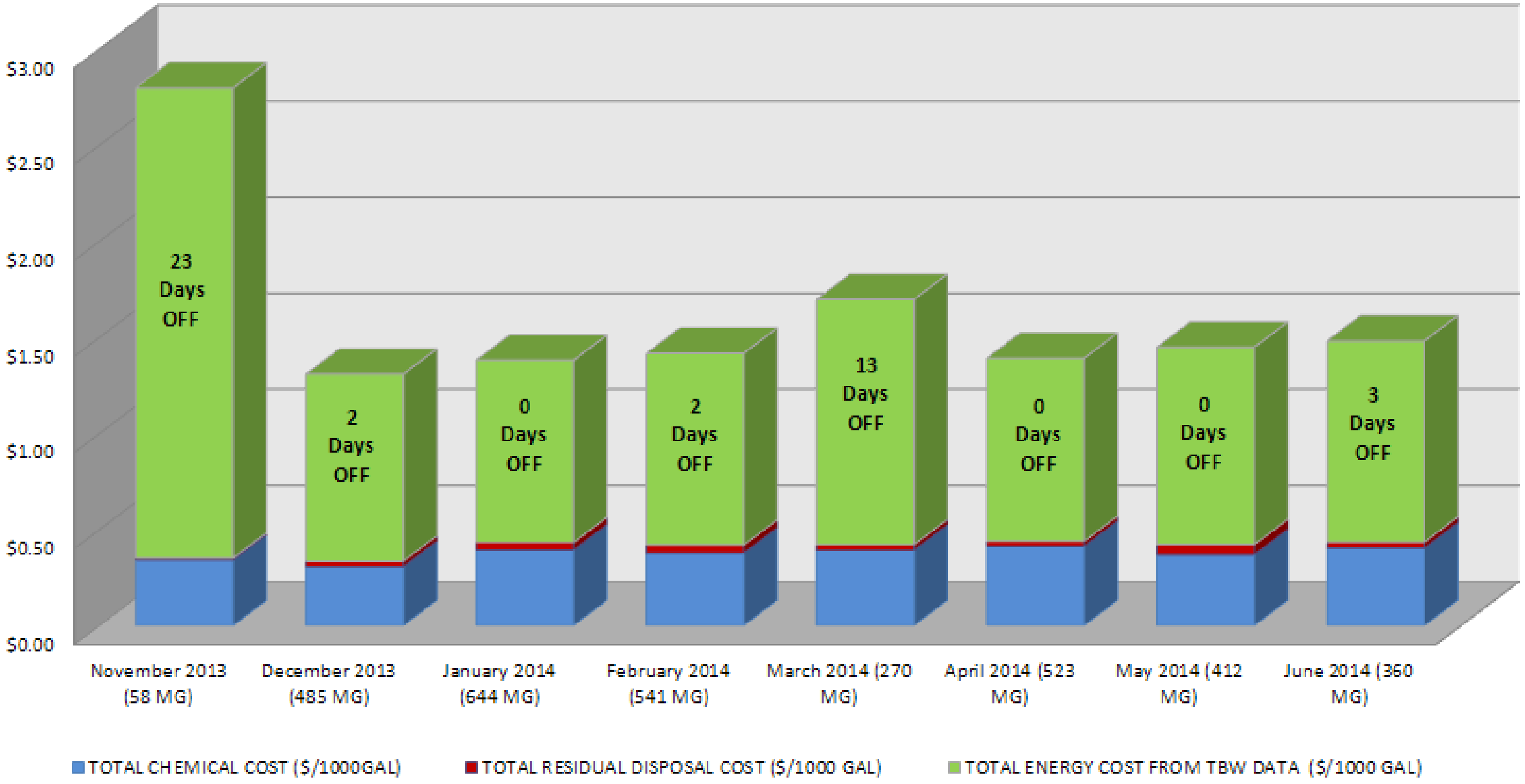
Storage Adds Reliability, Drought Resistance

Seawater Desalination is "Drought Proof"

2013-2014 Tampa Bay Desalination Monthly Costs



Variable Cost/1000 gallons



$/kWh							
nov-13	dec-13	jan-14	feb-14	mar-14	apr-14	may-14	jun-14
0.114	0.076	0.075	0.078	0.091	0.076	0.081	0.079

Lessons Learned

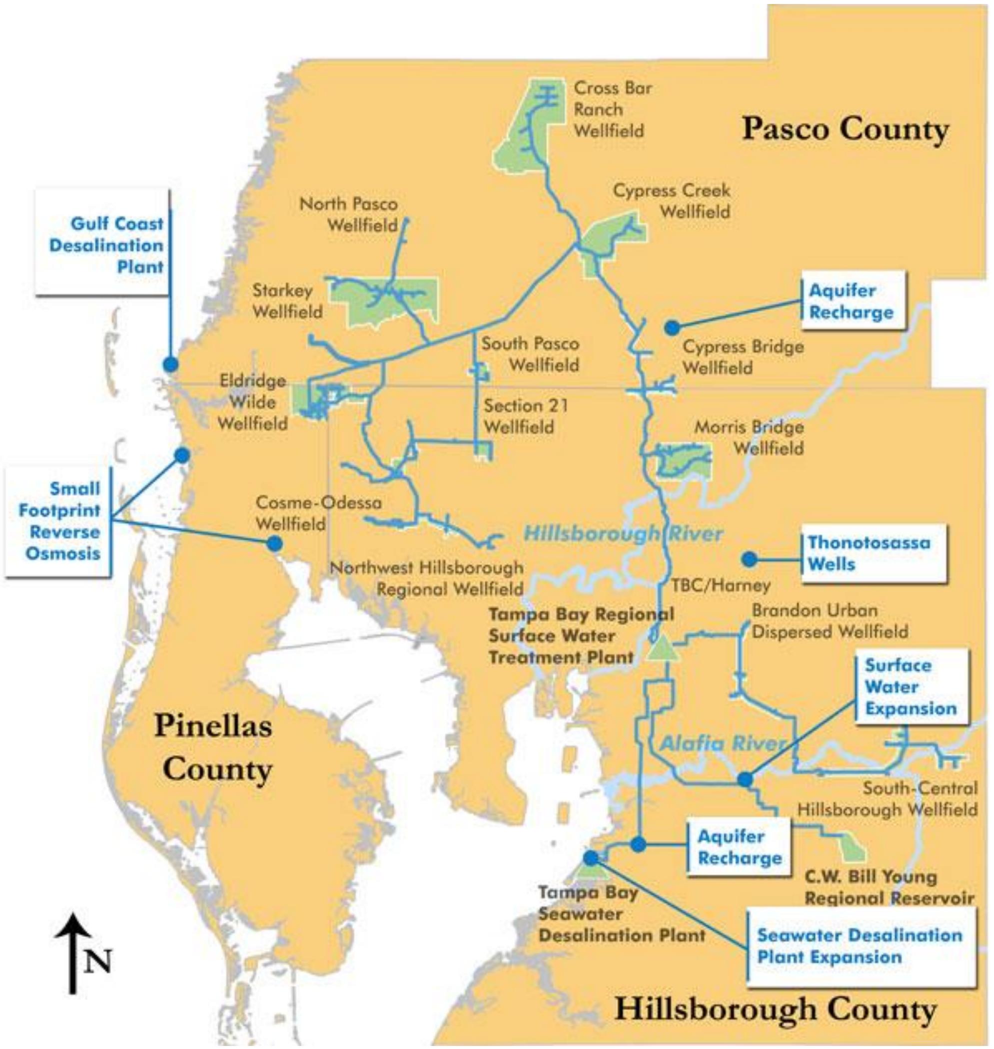
- Performance Risk
- Ownership Transfer Considerations
- Comprehensive Pilot Testing
- Developer Qualifications
- Property Acquisition
- Permitting Challenges

Permitting

- State by state variability
- Removal credits
- Pilot requirements
- Demonstrations
- Staff familiarity with technology

Water Supply Options Beyond 2020

- Small Footprint Reverse Osmosis
- Seawater Desalination Expansion
- Gulf Coast Desalination
- Surface Water Expansion
- Aquifer Recharge Project



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Kay Bailey Hutchison Desalination Plant

Hector Gonzalez
El Paso Water

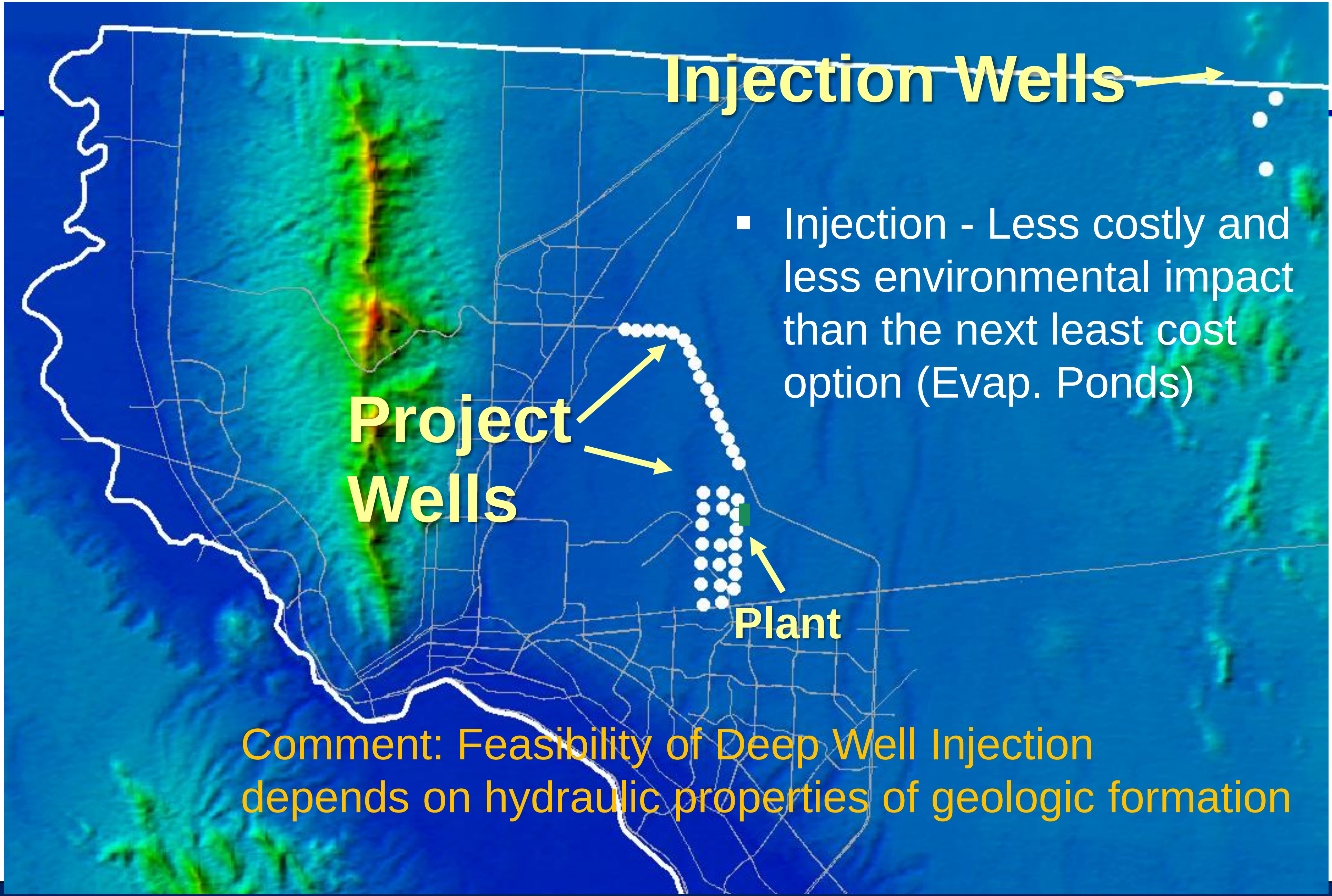
Kay Bailey Hutchison Desalination Plant

Opened in 2007 to deal with:

- Drought
- Emergency situations
- Growth
- Brackish water intrusion

Desalination Plant Details

- Up to 27.5 MGD capacity
- Utilizes 5 reverse osmosis skids
- Year round usually runs at 1-2 skids
- Operated at full capacity for the first time on a sustained basis in May 2012



- Injection - Less costly and less environmental impact than the next least cost option (Evap. Ponds)

Comment: Feasibility of Deep Well Injection depends on hydraulic properties of geologic formation

Regulatory Concepts

- Safe Drinking Water Act (SDWA) prohibits injection which endangers an underground source of drinking water which is considered any source with TDS < 10,000 mg/L.
- Natural groundwater in the injection zone does not meet national and state primary drinking water standards for arsenic, gross alpha, nitrite, and radium.
- Membrane treatment would be required prior to use. It is not a source of drinking water.

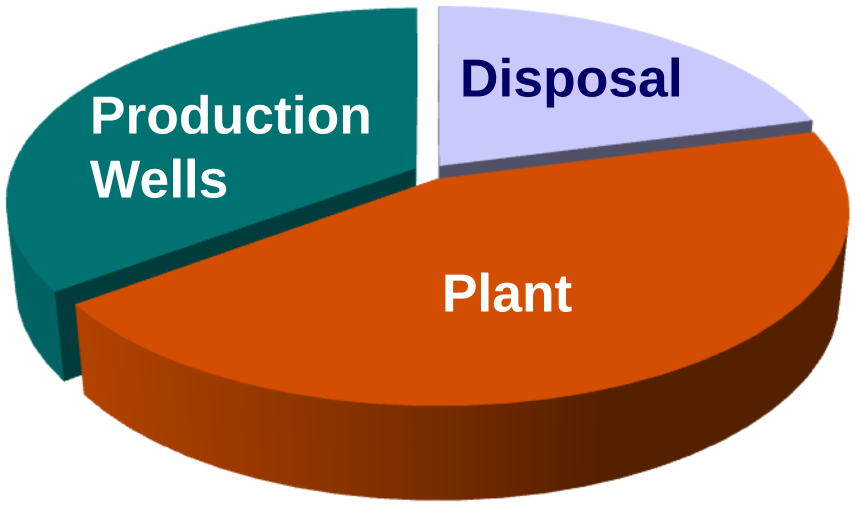
Regulatory Concepts

- Approval of Aquifer Exemption Application allows EPW to inject concentrate that does not meet primary drinking water standards.

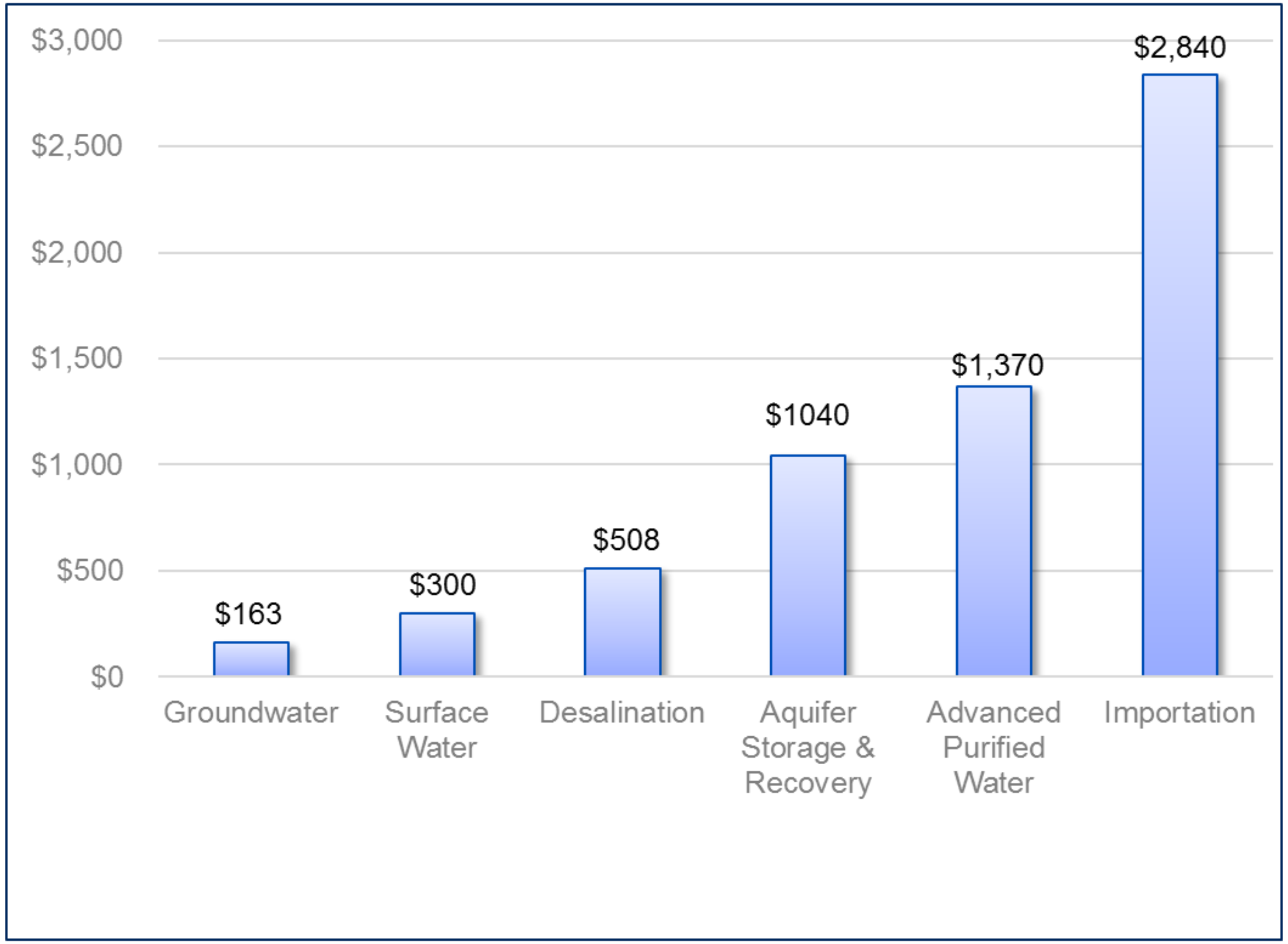
- Current Class V Authorization recognizes approval of Aquifer Exemption Application. EPW is allowed to inject concentrate that does not meet primary drinking water standards.

Capital Costs (21 Contracts)

Production wells and collectors	$ 32 Million
Plant and Near-Plant Pipes	$ 40 Million
Concentrate Disposal	$ 19 Million
Total Cost	**$ 91 Million**



New water sources are more expensive



Cost per acre foot comparison

Current Desalination Efforts

- Finding ways to improve water recovery
- EWM Plant
- Reviewing Draft USBR-Title XVI feasibility study for expansion of desalination plant

Lessons Learned

- Drought has increased attention and discussion toward desalination as a means of meeting future water resources
- “Concentrate Management Policy Analysis For the Arid West” - Report to identify barriers to concentrate disposal; finalized late summer 2014
- Significant time and funding are currently needed to allow for feasibility and permitting

Going Forward

- Deep Well Injection can be considerably less expensive than evaporation ponds for municipal sized concentrate disposal projects.
- Appropriate geologic conditions for successful injection have to verified.
- State of Texas should inventory subsurface geology to determine suitable areas for injection
- TCEQ needs to provide a Permit by Rule to allow injection of concentrate in those locations identified

KBH Desalination Plant enables utility to leverage brackish portions of aquifer

- Current production capacity: 27.5 mgd
- EWM returns: 2.25 mgd
- Feasibility plan underway for project to increase capacity to 42 mgd

Contact Information

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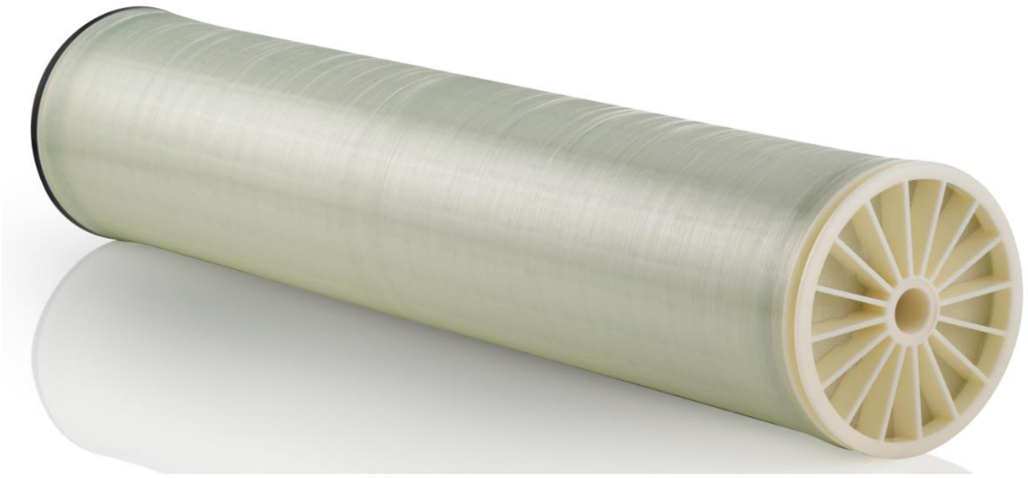
The Evolution and Innovation of Reverse Osmosis Membranes

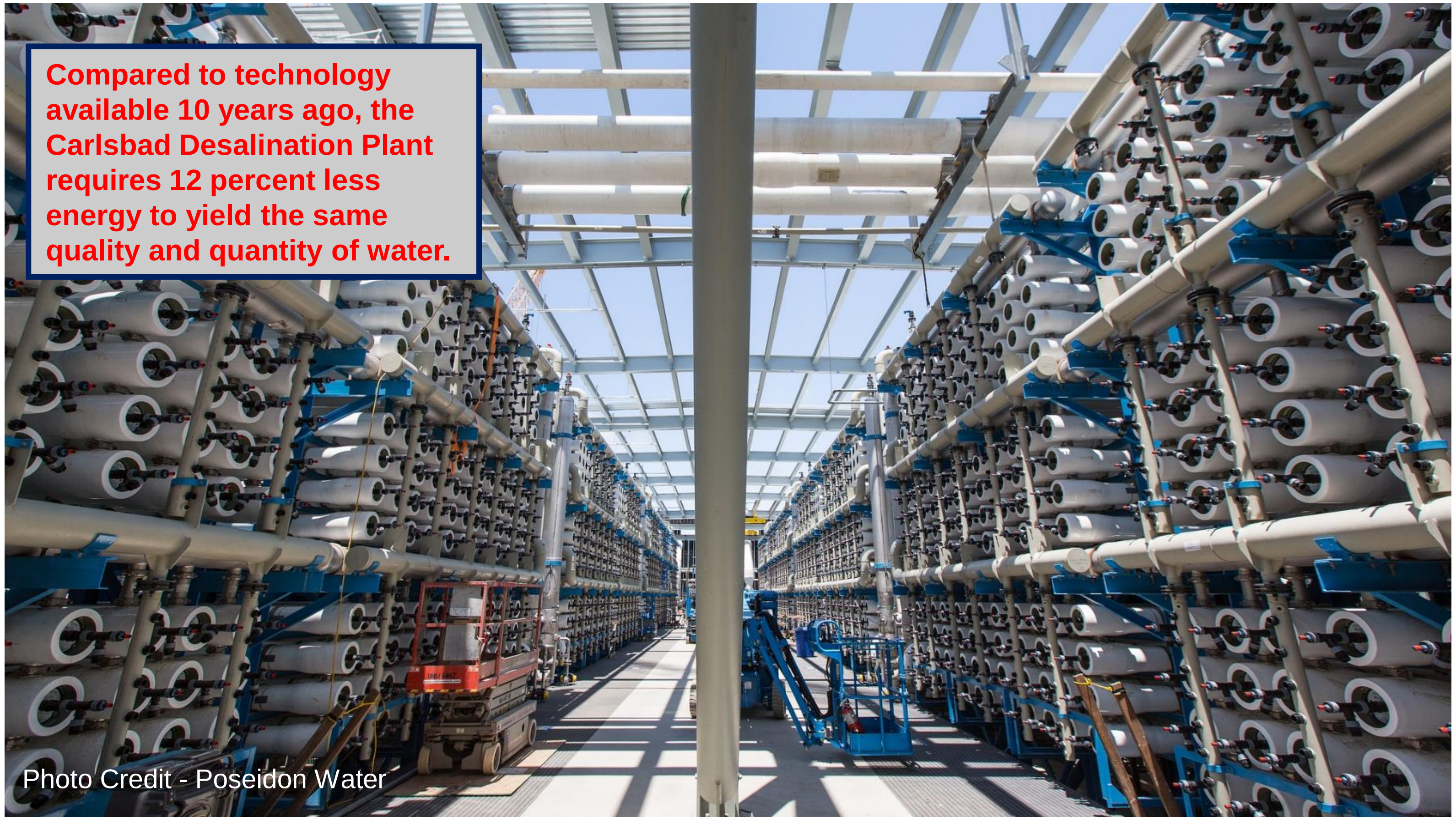
Cedella Beazley
Dow Water & Process Solutions

Reverse Osmosis: Setting the Stage

- Reverse osmosis (RO) technology has been used successfully in the industry for over 40 years.
  - Novel membrane chemistry has become the gold standard worldwide.
- Local regulatory compliance drives continued innovation and production cost improvements.



Innovation in the RO Space



- Innovation has improved performance and economic viability of RO membranes.
  - The amount of treated water generated by a single element has more than tripled.
  - Desalination today costs only half of what it did 10 to 15 years ago.
- Over the past 10+ years, rejection of specific contaminants has improved.

What's Next on the Horizon?

- Research to improve understanding of U.S. waterways and interconnections.
- Findings are vital to inform local, long-term decision-making on water infrastructure.
- Incentives and a supportive policy framework are needed to lower risk and other hurdles.

Membrane Water Treatment Technology Usage and Needs in the United States

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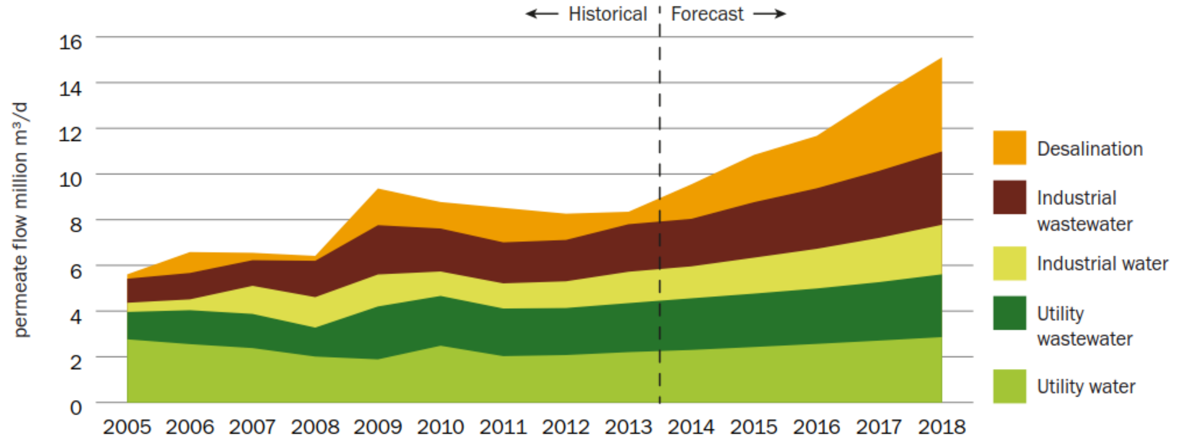
Adoption of Innovative Technology Requires Incentives

Ben Soucy

Evoqua Water Technologies

UF & MBR Membrane Treatment – Growth driven by Regulation and Innovation



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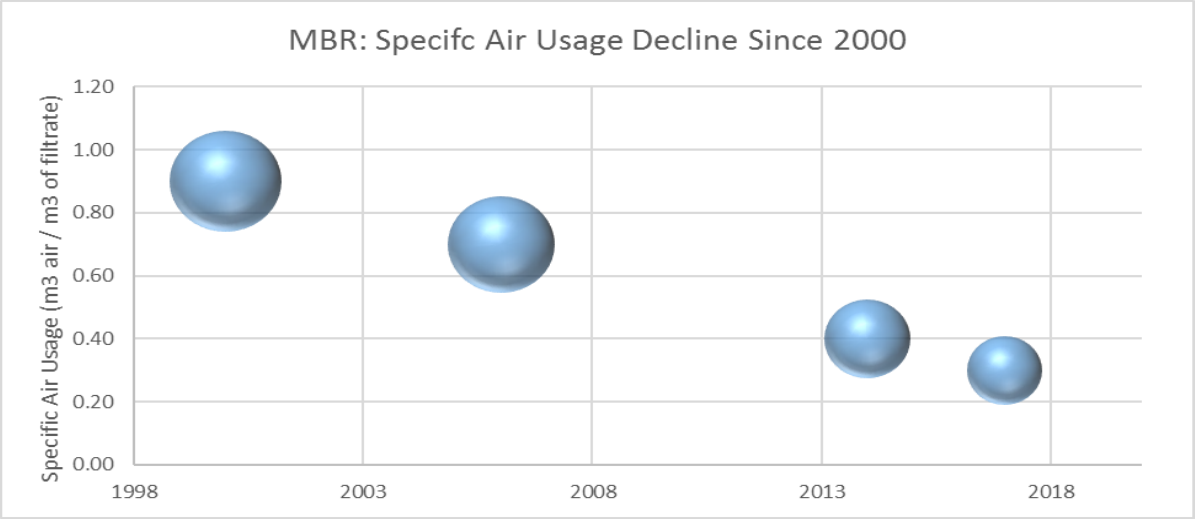

- The past decade experienced ~2.5x increase in MF/UF/MBR treatment
- Economies of scale in membrane production coupled with dramatic decreases in O&M Costs
- Cost improvements up to 4x in Capital, Energy, Chemical, and Footprint driven by regulatory requirements with competitive forces

A National Reuse & Reclamation Strategy is Critical!!

Example Technology Developments

Direct Integrity Testable MBR

- Reduced Capex & Opex
- Small Footprint
- Improved Effluent Quality

E-Desal - Lower Energy Desalting

- 33% Energy Savings
- 15% Recovery Improvement
- High quality effluent for reuse

Chem-Free Advanced Oxidation

- Up to 60% installation cost reduction
- Peroxide eliminated
- NDMA, other micro pollutants removed

Incentives required to drive rapid adoption of more sustainable innovative treatment options

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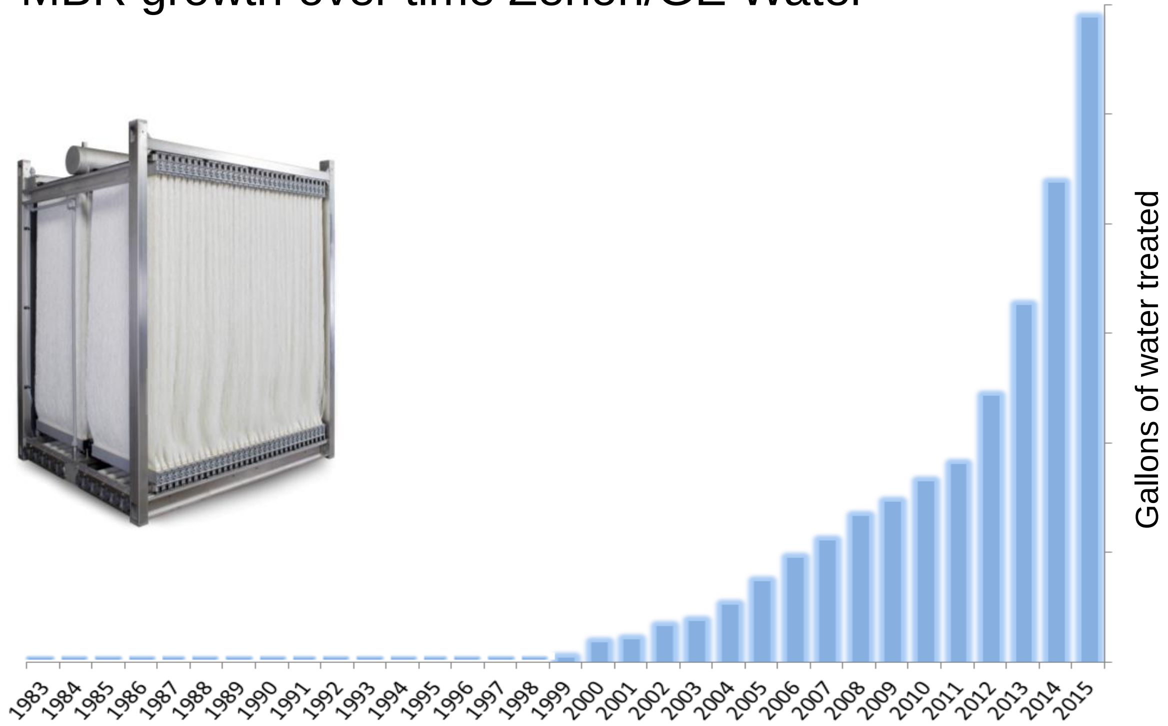
Adoption of Innovative Technology Requires Incentives

Henk Koops

GE Water & Process Technologies

Innovative Technology adoption – acceptance timeline

MBR growth over time Zenon/GE Water



- It took well over 10 years before MBR became accepted as a wastewater treatment technology
- At that time MBR was our only product and the whole company was focused on making MBR successful
- Today, multi-national companies carrying multiple products do not have the patience to wait and invest that long

Innovative Technology adoption – why Incentives?

- Membrane processes can do amazing things… remove micropollutants, clean up produced water and turn any type of water into drinking water… from seawater to wastewater
- Water treatment engineers /plants are rather conservative and > 96% still use (100 years old) conventional technologies… they work, but are not as reliable and do not produce the same quality of water
- Customers do want to see proof… (subsidized) pilot & demonstration plants needed
- Without proper incentives Innovative Technology adoption will be very slow
- Without proper incentives Innovation may get lost

We need Grants, Subsidies and Loans for end-users that apply innovative technology over conventional

Innovative Technology adoption – Incentive examples

- Switzerland: Ordinance for water protection regarding micropollutants in force since Jan'16… it has driven R&D activities in micropollutant removal
- Denmark: Taxes on levels of nitrate, phosphorous and organic matter in discharge water… incentive to look for technology and solutions to drive concentrations down in wastewater effluent
- China: Rapid urbanization, population growth and climate change poses large stress on the source water supply in China. The government launched a technical policy on municipal water reclamation (2006) **encourages the use of MBR**… consequently the MBR annual growth rate is 2-3 times faster in China than in the rest of the world
- Canada – Ontario: Government provides grant and loan funding to support projects that create jobs, **encourage innovation**, collaboration and cluster development, and attract private sector investment

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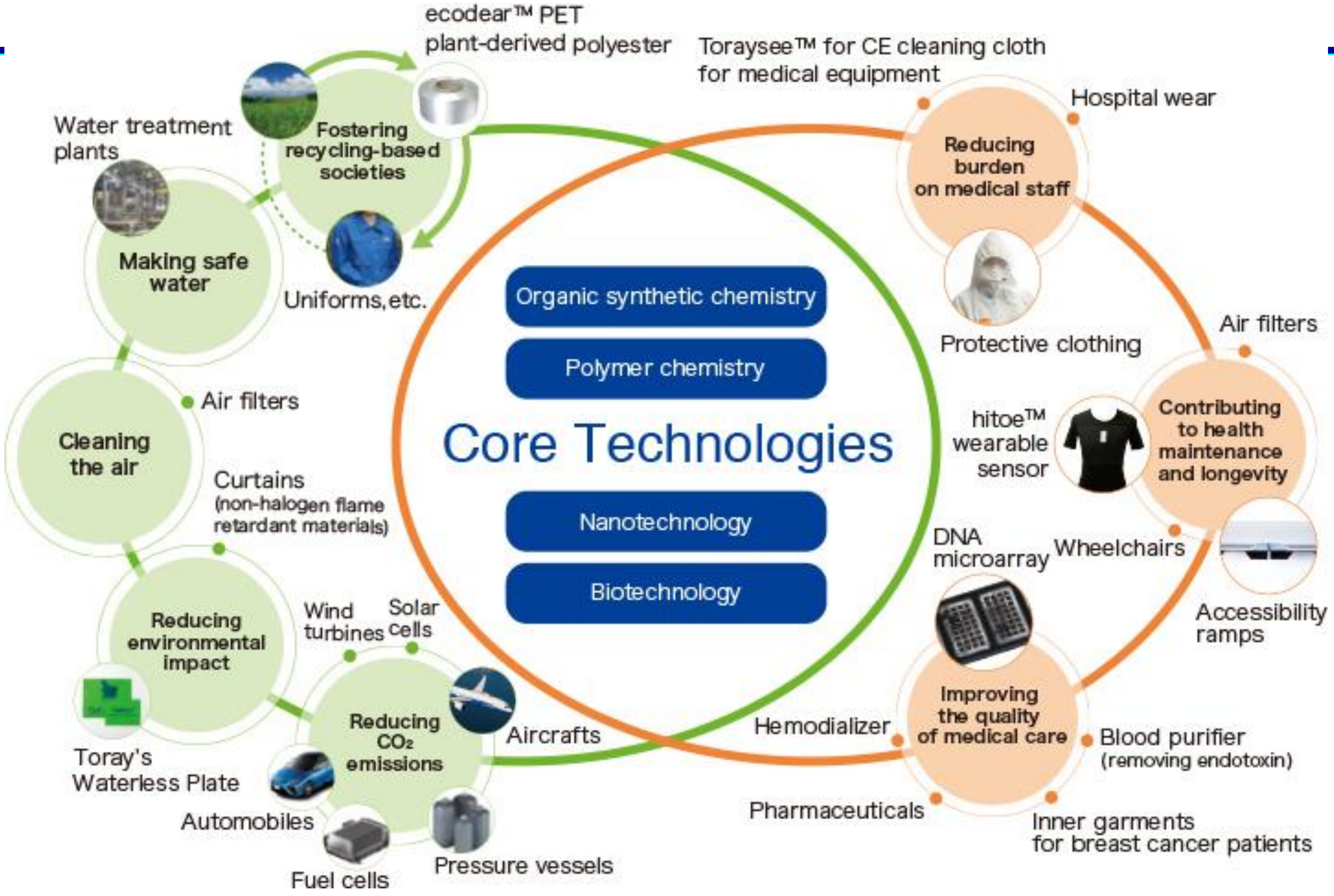
Regulations and the Membrane Industry

Lynne M. Gulizia
Toray Membrane USA, Inc.



The Toray Group is engaged in group-wide projects to develop advanced materials that make the most of its technological strengths and infrastructure, to realize innovative businesses that address environmental issues (Green Innovation) and help people live healthier lives (Life

life innovation

TORAY

Regulatory Hurdles

- Regulations differ from state to state, district to district – add confusion and cost
- Environmental conditions on the ground not always taken into consideration
- Significant, conflicting regulatory hurdles add to project cost – even in the same state
- Insistence on testing of proven technology adds to cost (pilots)
- Some misunderstanding on the part of regulators as to how the technology works (concentrate characterized as industrial waste and then subject to different regulations)
- Technological advances not quickly or easily incorporated into regulations

Regulatory Advantages

- Tightening of regulations drives membrane product innovation
- Increased use of membranes adds more support companies (services, parts, chemicals) into the sector creating jobs
- Protection of public health
- Environmental protection
- Advantage in having a more skilled workforce to run these plants (better prepared for changes in workforce/job requirements in the 21st century)
- Cost reduction by increased manufacturing throughput and competition
- U.S. is the hub of this technology which is fueled by having to meet regulatory requirements. Innovations in the technology are exported worldwide

Thank you Presenters

In the remaining time we wish to have a dialogue on application of membrane technologies to address national water priorities