Porifera

Fertilizer Driven Osmosis and Other Novel FO Desal Applications

CA/NV AWWA Finding Water in the Arid West

October 2014

Porifera

- Founded in 2009 in Hayward, CA
- FO - now; CNT - future
- FO membranes & elements
- FO and FO+RO systems
- Products works with brines, multiple industrial salts, or proprietary draw solutions

FO: Salt & Osmosis Powered Water Purification & Reuse

- **Water:** New ways to desalinate seawater and reuse wastewaters
  New solution for near ZLD of high COD wastes
- **Energy:** Reduced energy for high purity treatment
  Salinity gradient power
  Unique applications in oil & gas
- **Food:** Use fertilizers to power purification for irrigation
  Concentrate naturally instead of heat based concentration

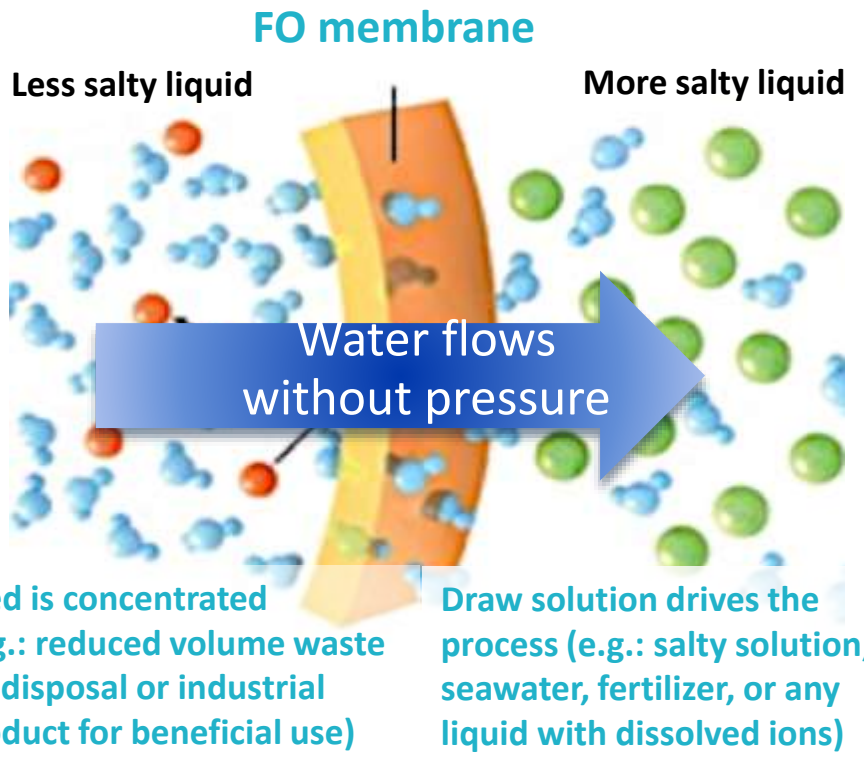
What is Forward Osmosis?

Allows use of "Salt Power" and Osmosis to purify water

Water molecules migrate across a membrane by **diffusion**, **without energy input**, into a salt solution (i.e., the "draw solution").

Opposite dynamic of Reverse Osmosis which **requires energy** to push water across the membrane.

Key benefit:
A new tool, uniquely suited to **inexpensively filter or concentrate highly fouling waters** that clog other types of membranes.

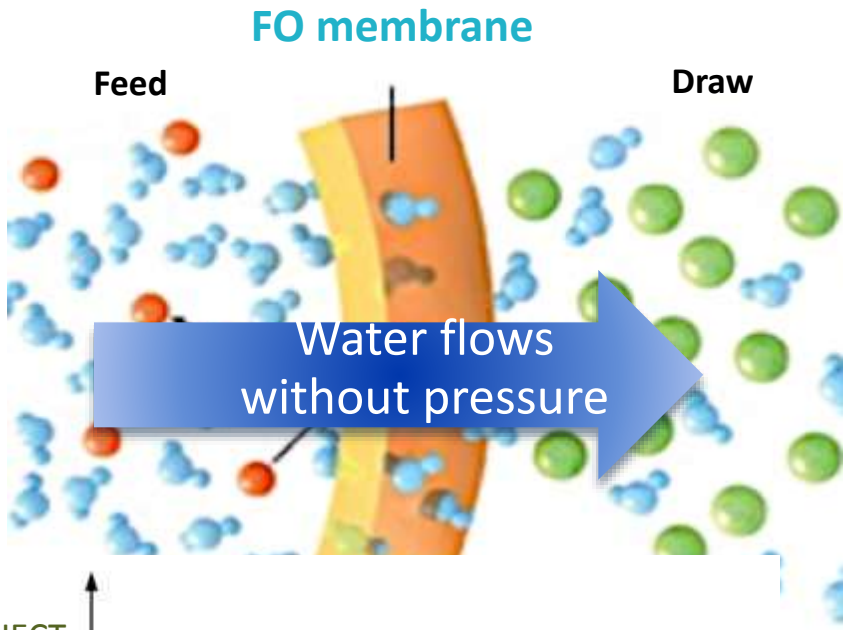


Source: National Geographic

Example Feed and Draw Solution Exercise

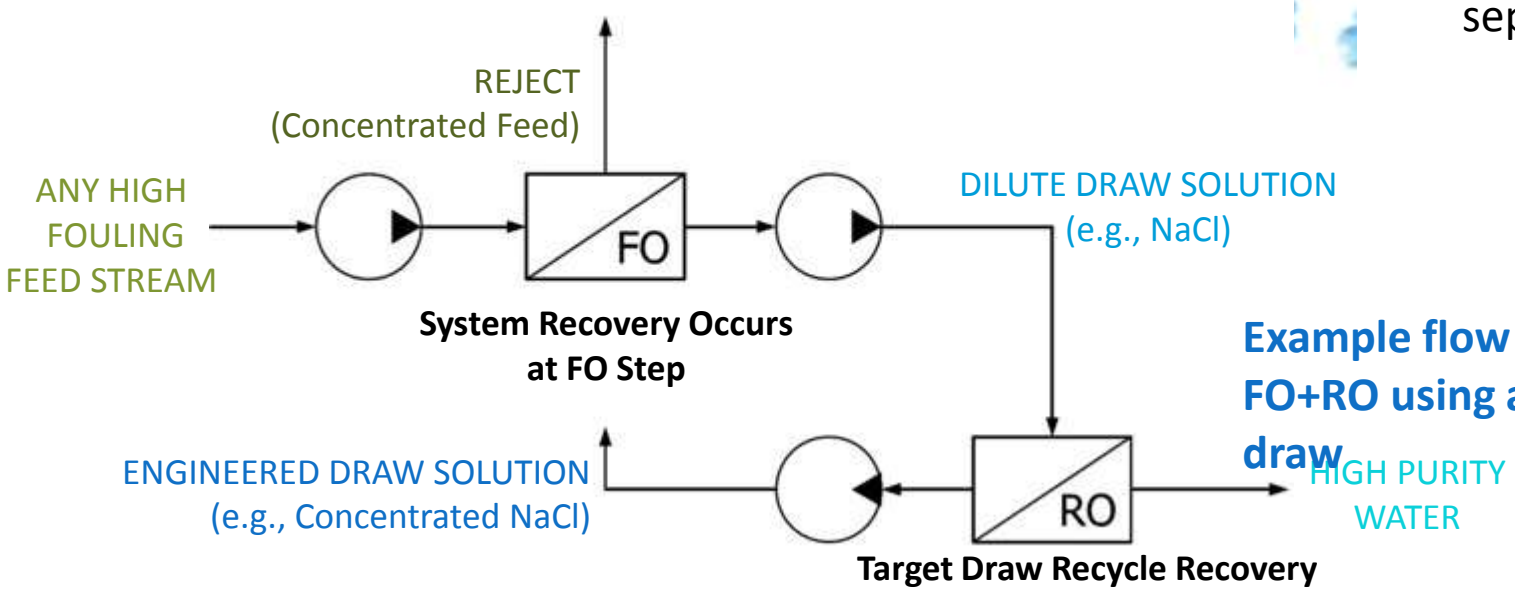
Example Feeds:

- Graywater or brackish irrigation water
- Wastewater discharge
- Wine finishing
- Brackish or seawater
- Any high fouling feed water for reuse



Example Draws for FO:

- Fertilizer and soil enhancers
- SWRO brine (PRO)
- Sugar packets
- Table salt (NaCl) + RO
- Any clean salt + RO as salt recycle and separation (see below)



Example flow diagram for FO+RO using a simple salt draw

Fast forward: recent FO advancements address hurdles and misconceptions

FO ≠ RO replacement

FO enhances RO & reduces cost

Special draw → not necessary

Savings possible now using simple salts

FO beachhead applications:

water reuse, high COD, and high TDS applications

Forward Osmosis: Improving Sustainability FO

is a new tool for higher purity and reduced cost and lower energy purification

WASTEWATER REUSE

Higher COD, oil, and grease limits than other membranes

Easy to operate

Low cost, high purity

Sustainability: Less Energy, Less Waste, More Water

GRAYWATER REUSE

Can handle hair, soaps, and other common contaminants

High purity, low maintenance

Provides water for ultra-high purity reuse

DESALINATION

New approach to:

* Reduce energy

* Improve environmental permitting

* Reduce cost

No impingement, entrainment or brine discharge

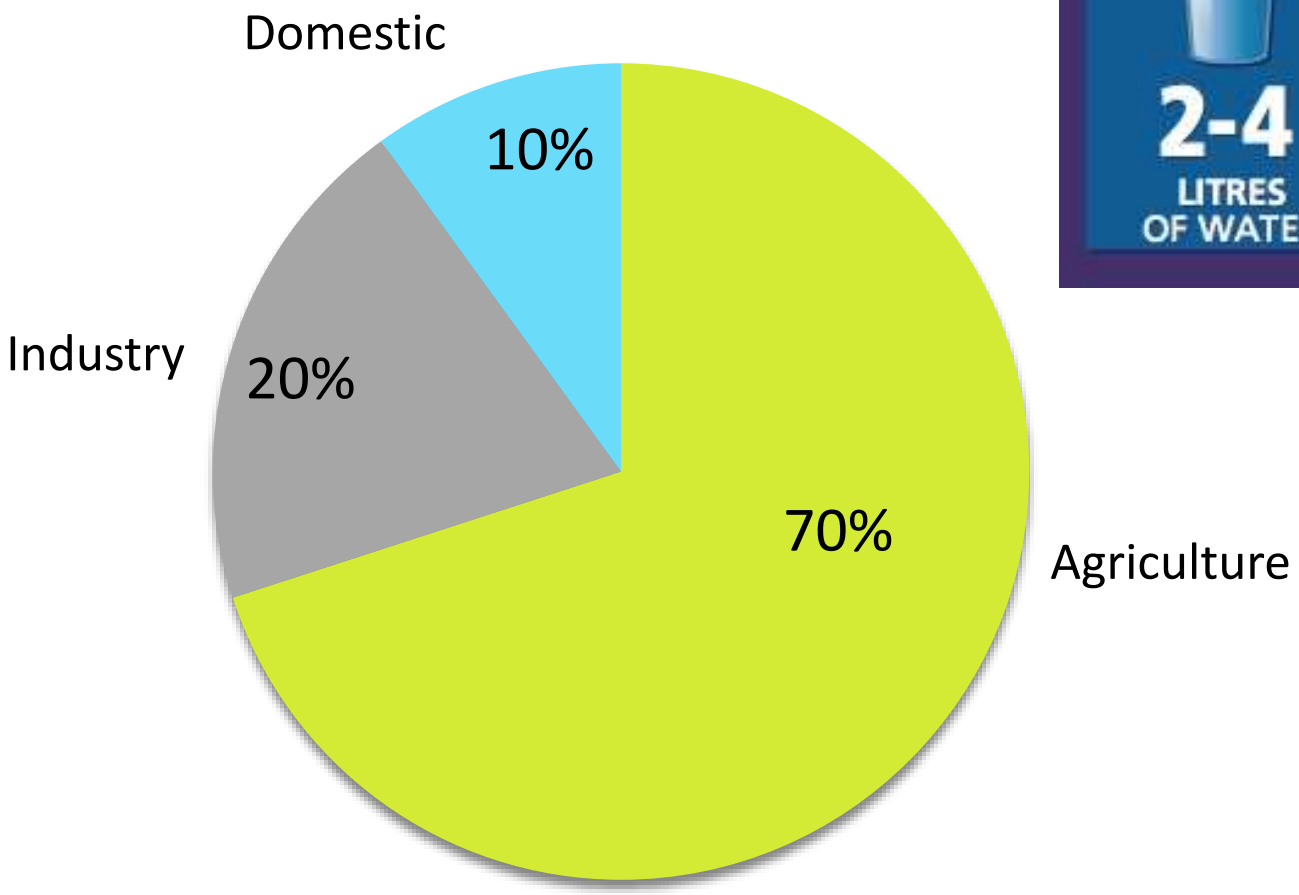
FERTILIZER DRIVEN OSMOSIS

Near zero energy purification

Allows simple, localized reuse for irrigation

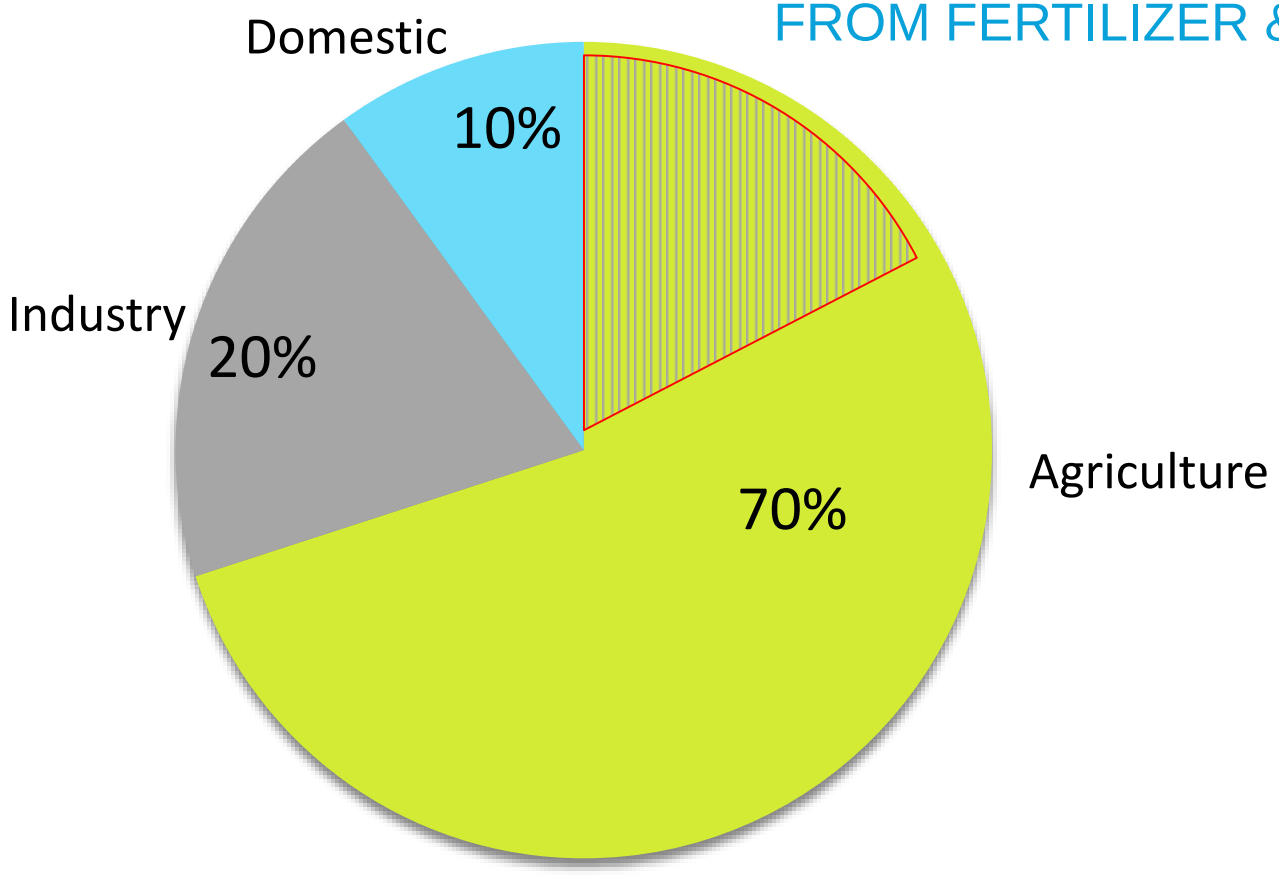
May require other water for dilution

Global Water Use



Global Water Use

WHAT IF WE CAN SUPPLY A PORTION OF IRRIGATION WATER FROM FERTILIZER & OSMOSIS?



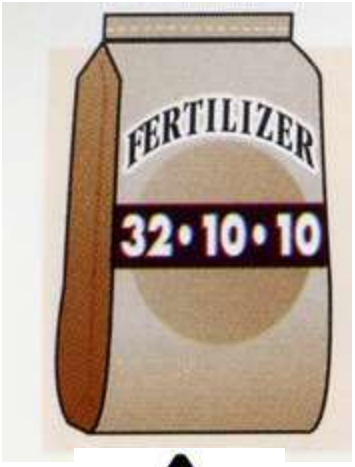
Fertilizer Driven Osmosis
A New Source of Reuse Water for Irrigation

Graywater

+

or

Wastewater



Minimal energy needed

=

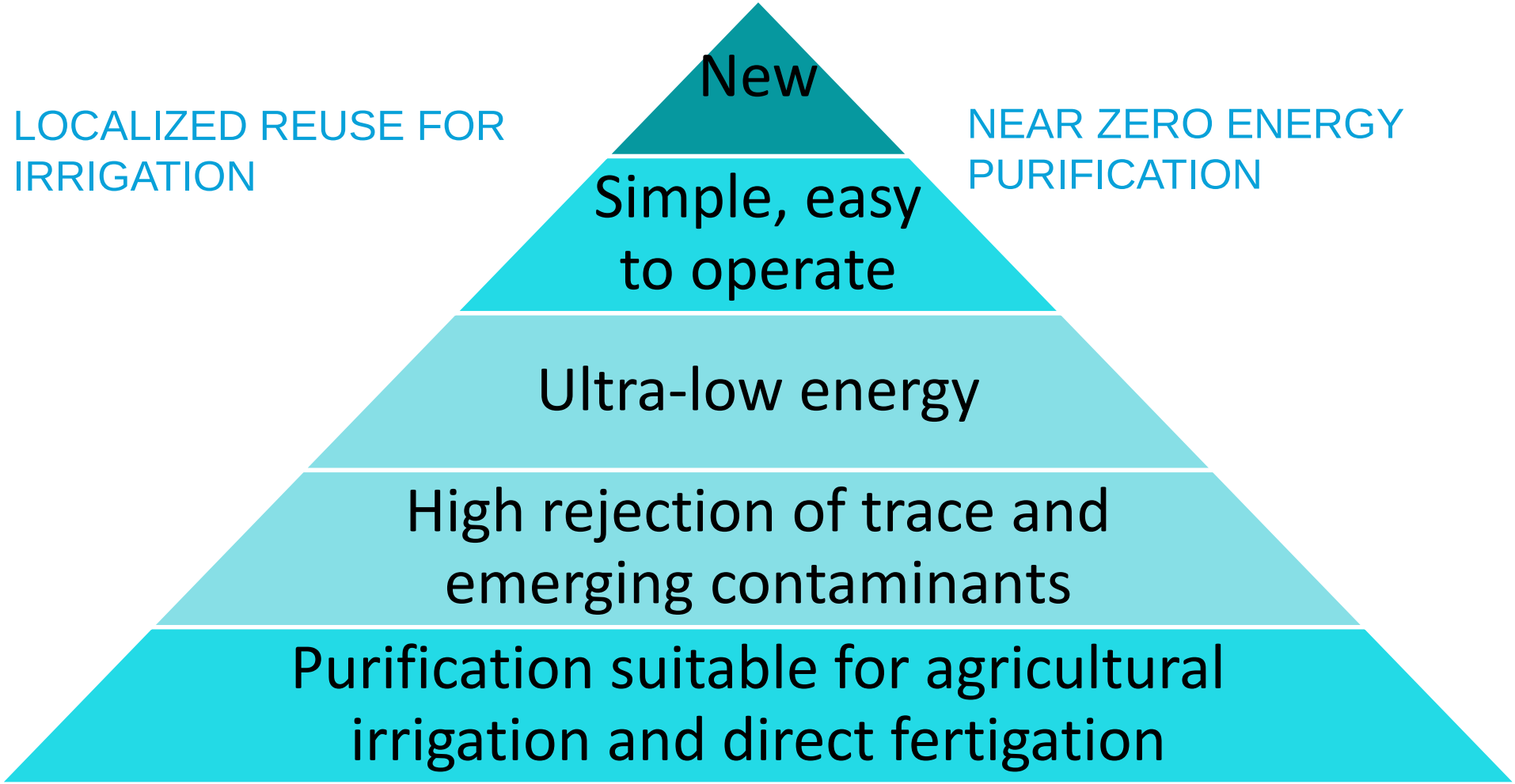
water suitable for irrigation

FDO Benefits

New reuse technology for ultra-low energy purification; for irrigation reuse only

LOCALIZED REUSE FOR IRRIGATION

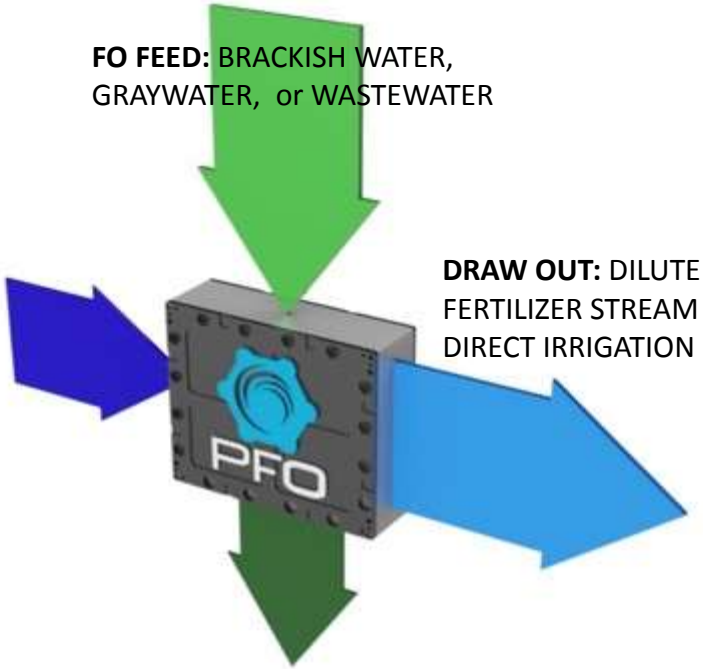
NEAR ZERO ENERGY PURIFICATION



PFO For Graywater or Wastewater Reuse:

Fertilizer draw can be used to power FO treatment = near zero energy reuse

Can provide 20 to 70% of reuse water for irrigation depending on feed water chemistry and soil/plant requirements.



How it works:

- Commercial (often existing onsite) fertilizers and soil additives are liquefied in a tank; FO membranes are submerged in the tank
- Feed water is circulated (<5 psi) through FO on the other side of the membrane
- Stored osmotic energy in the fertilizer and additives purifies water by osmosis for direct reuse
- Purified water with fertilizer is used for irrigation; often requires further dilution depending on soil and plant fertilizer requirements

Fertilizer Driven Osmosis: > 20 times dilution of fertilizer

Fertilizer composition
Used for current FDFO experiments

NPK: 6-2-4	%
Nitrogen (N)	6%
Phosphate (P)	2%
Potash (K)	4%
Conductivity	~77.7 ms/cm**

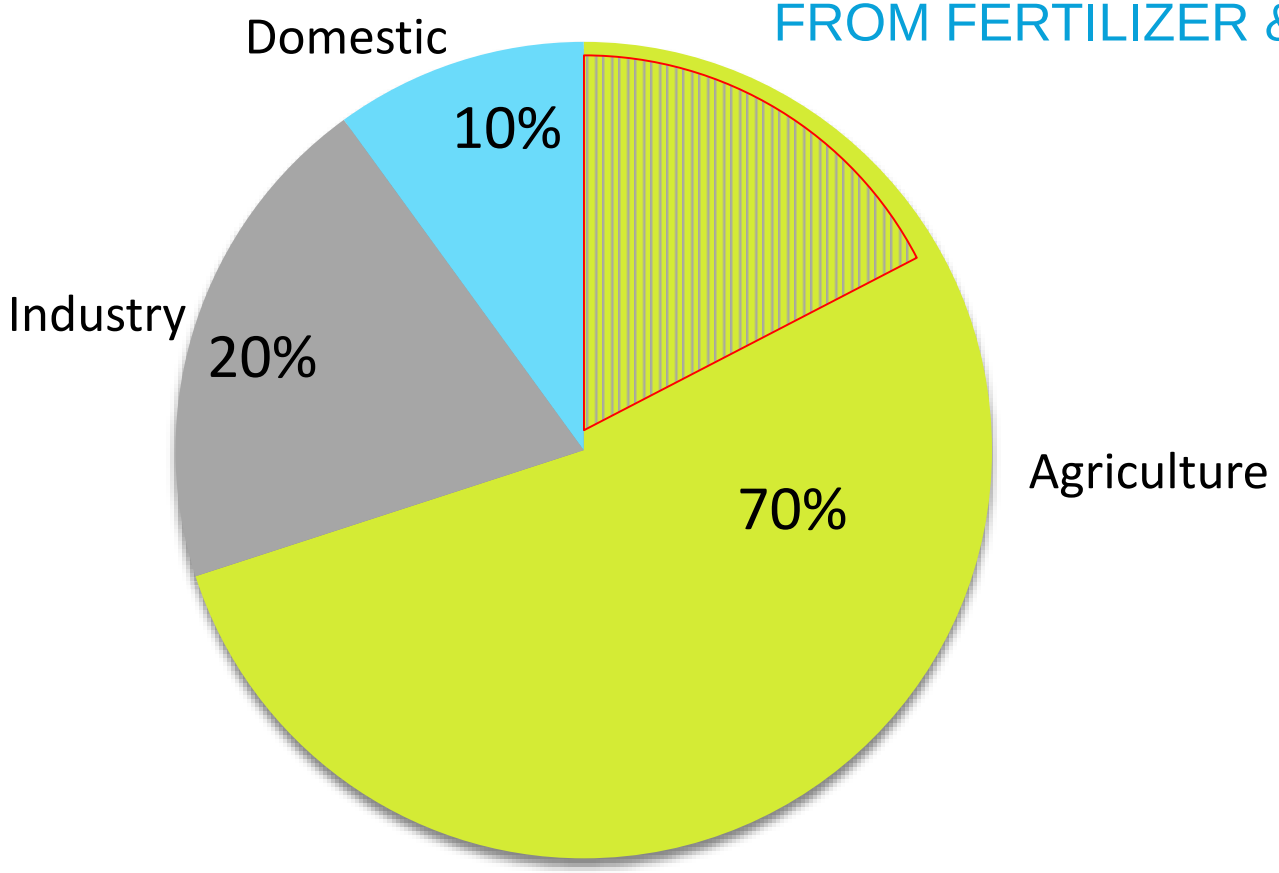
****Osmotic pressure: ~ 550 psi**

Fertilizer Draw Input Before Entering FO Process

Fertilizer Draw Diluted by Osmosis with Purified Water from Wastewater

Global Water Use

WHAT IF WE CAN SUPPLY A PORTION OF IRRIGATION WATER FROM FERTILIZER & OSMOSIS?



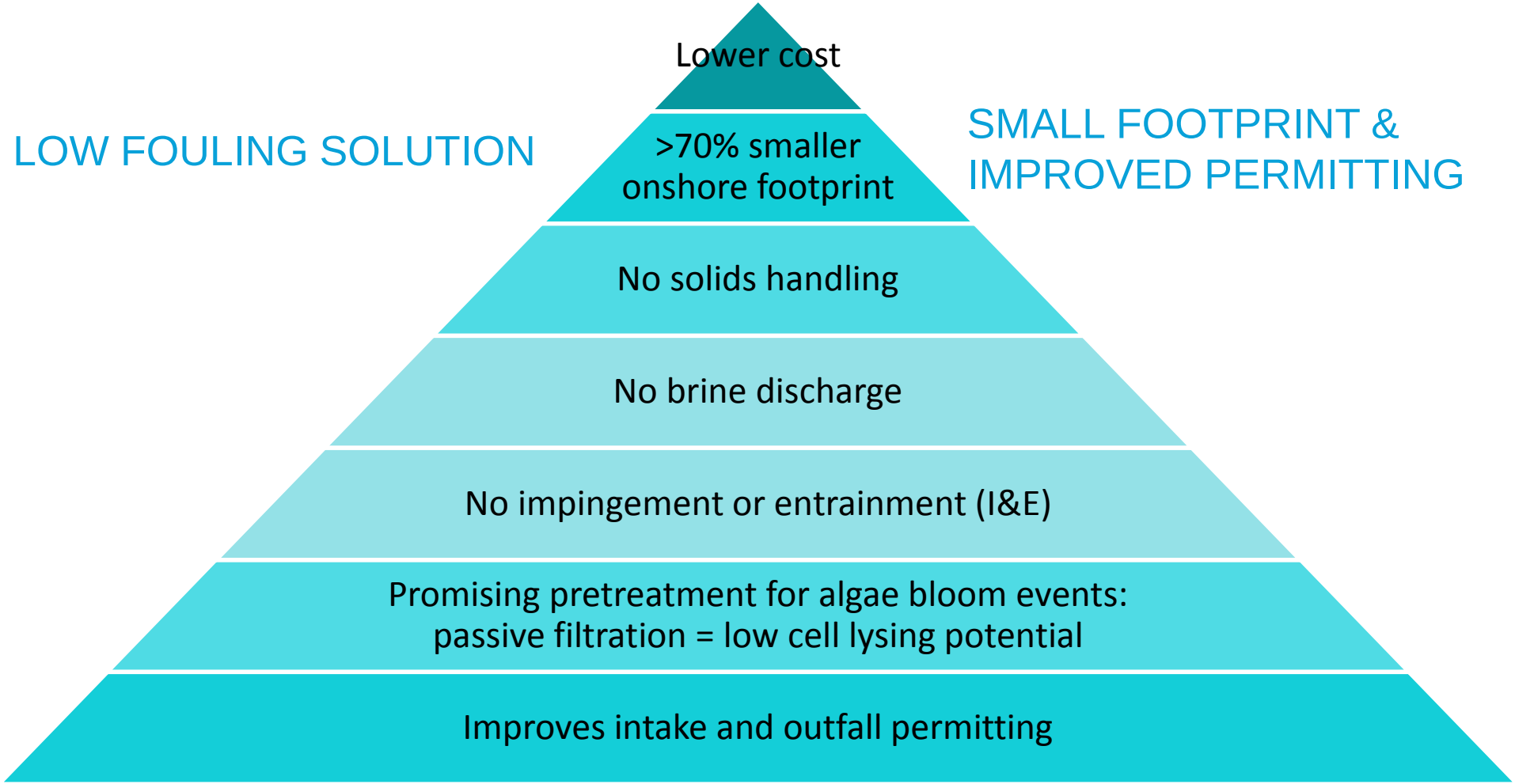
CURRENTLY LOOKING FOR SOIL AND FERTILIZER EXPERT AND PILOT PARTNERS

PFO For Seawater Desalination:

Small footprint, reduced environmental impact

LOW FOULING SOLUTION

SMALL FOOTPRINT & IMPROVED PERMITTING

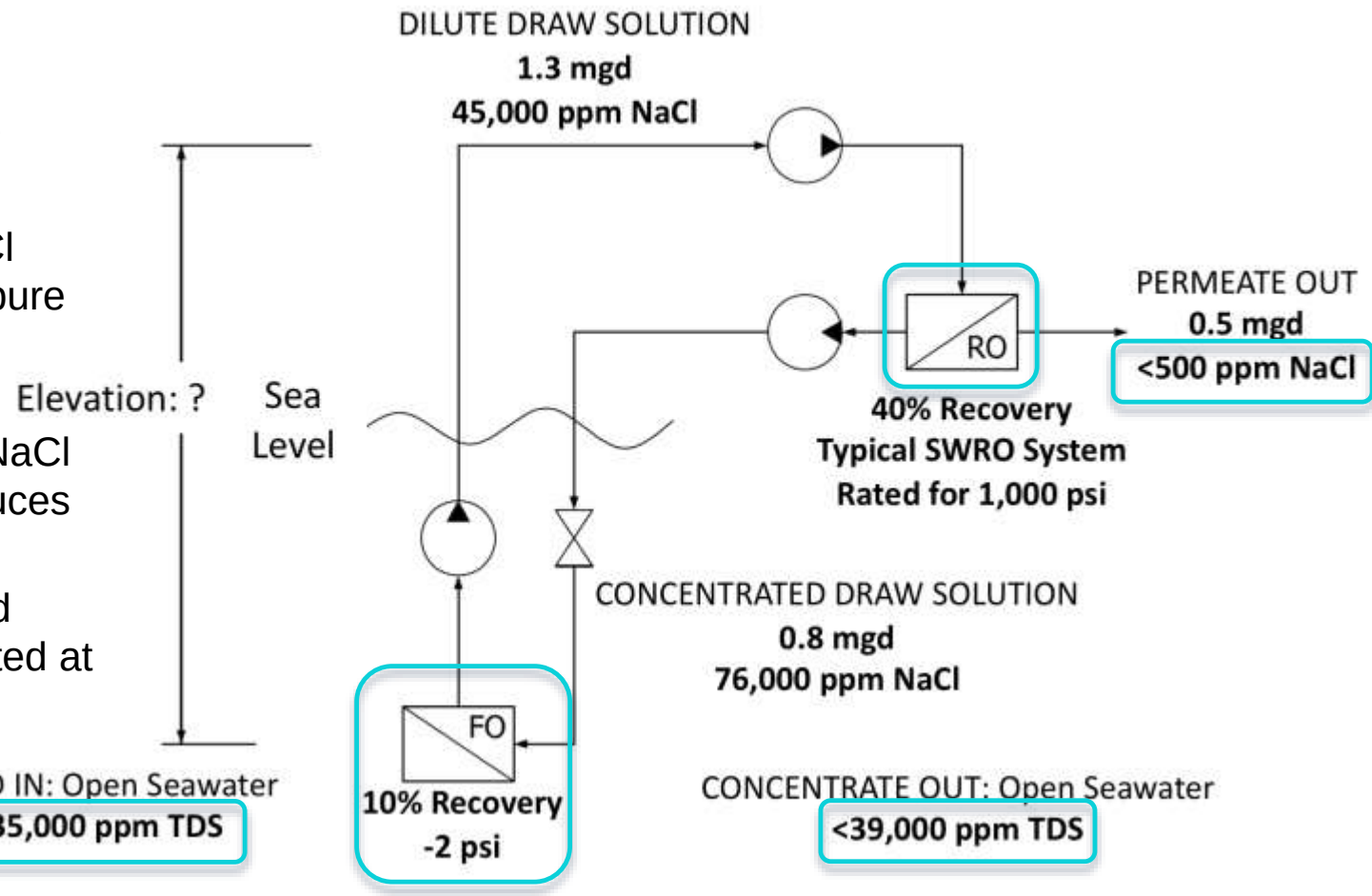


PFO: Combined Intake, Pretreatment, & Outfall Concept

Small footprint and simplified intake and outfall permitting

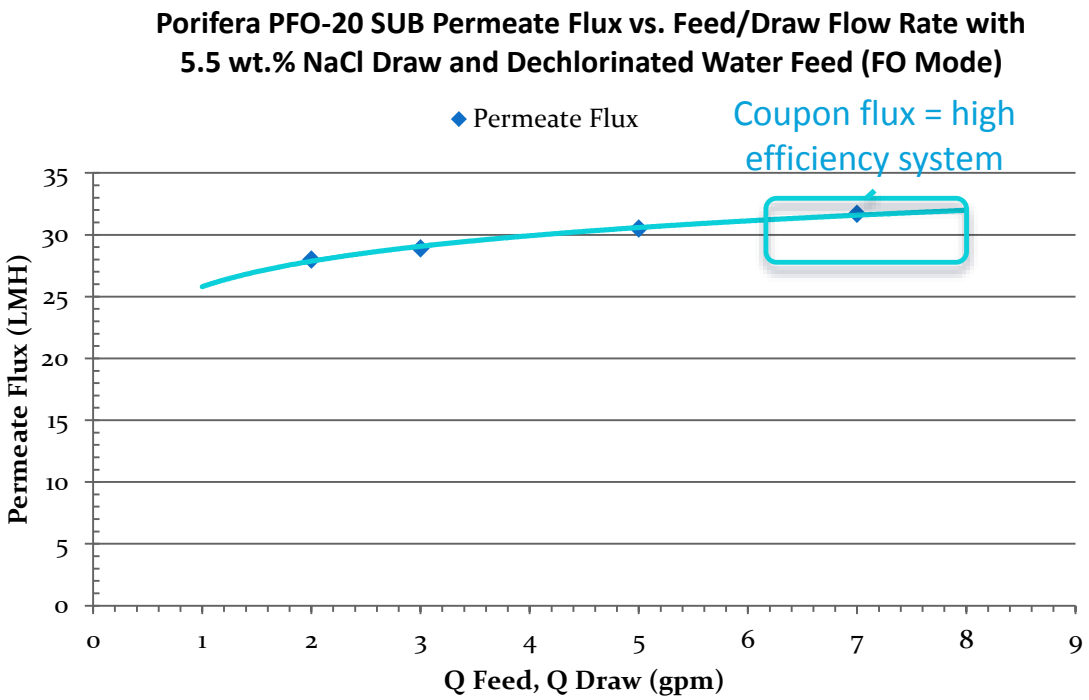
How it works:

- FO submerged under water (e.g., on a pier)
- Stored energy in NaCl draw solution draws pure water into system by osmosis (no I&E)
- RO re-concentrates NaCl back to FO and produces potable water
- Brine is not generated because FO is operated at low recovery rate
- "Draw integrated" energy recovery



Submersible proof of concept testing:

Sufficient Mixing Achieves Coupon Flux in Element



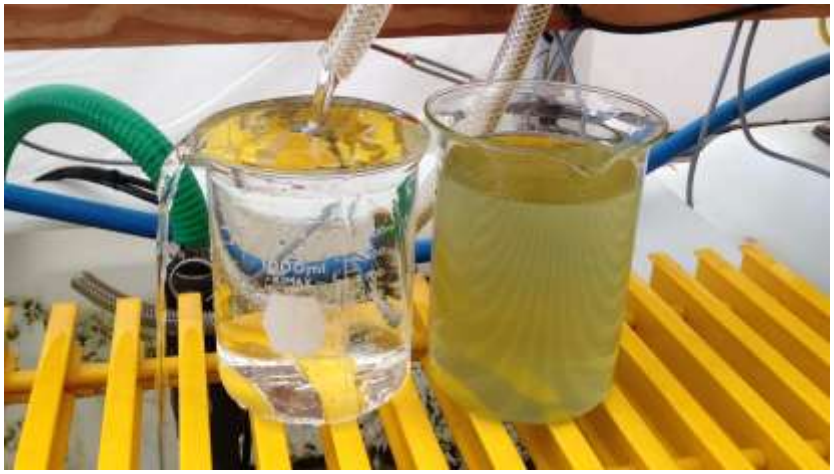
STAGNANT WATER? MIXING DESIRED (FROM WAVES)

Flux in 1M NaCl bath vs. plumbed tap feed (PRO mode)	
Without Air Diffuser	23 LMH
With Air Diffuser (1 psi pressure)	38 LMH

Currently looking for partner and funding for further development and demonstration testing

Successful High Fouling Seawater Demonstration Pilot

- Product: 75 gallons per hour, <500 ppm TDS using 2.7 kWh/m^3
- Low fouling: Purified challenge water without reduced productivity.
- Challenge water was designed to rapidly plug UF membranes.
- Ideal for red tide & polluted sources?



Porifera's product water

High turbidity challenge solution

Advantages of PFO Technology

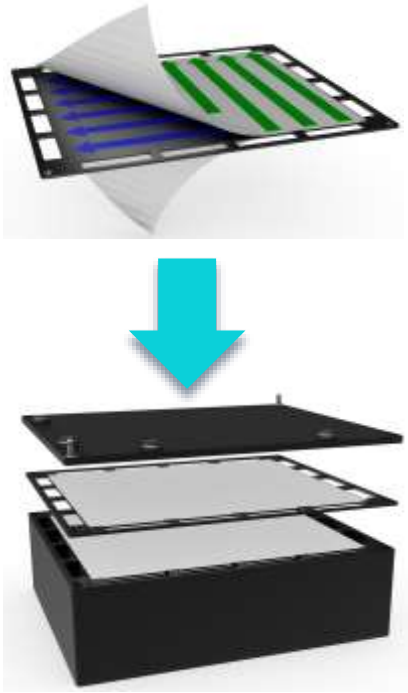
Membrane Spec Sheet Comparison

FO membrane comparison (flat sheet) at 1 molar NaCl driving force

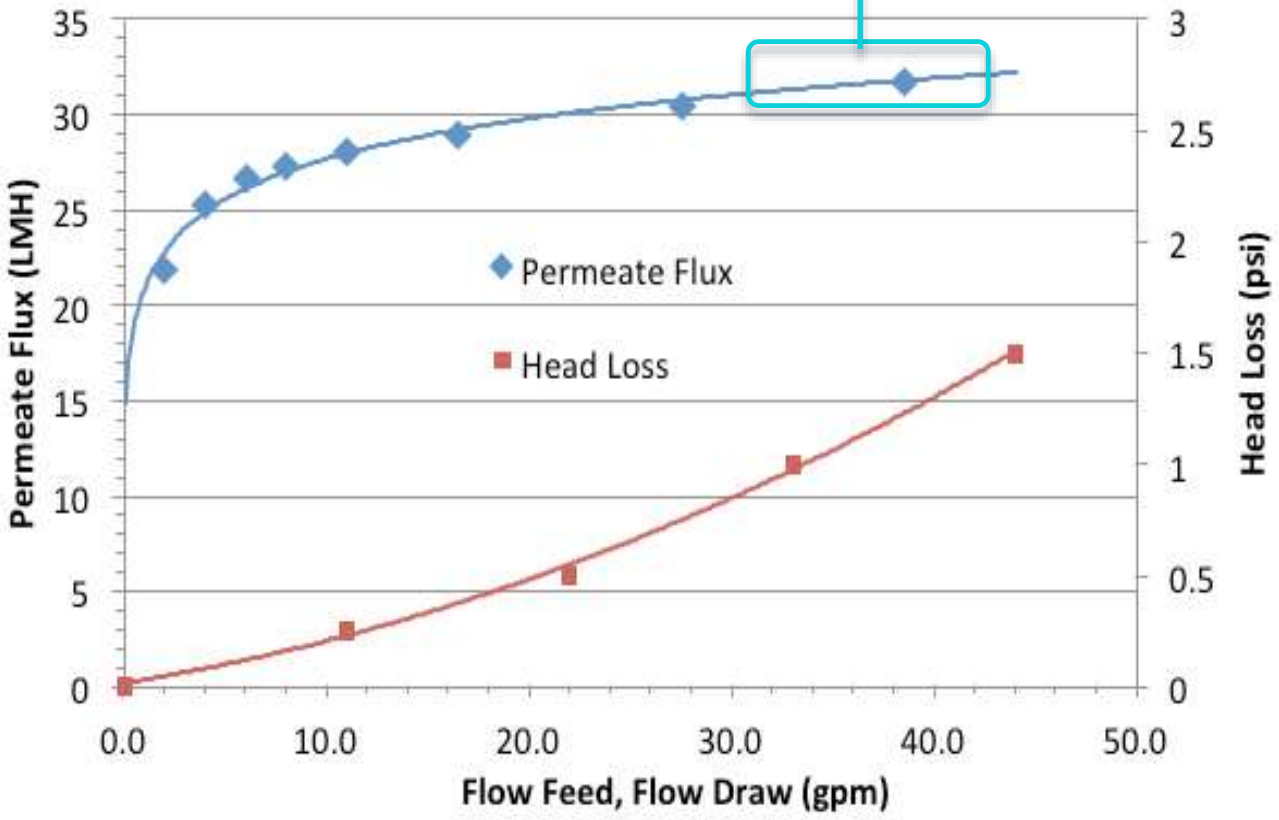
Supplier	flux [LMH]	Specific flux [LMH/bar]	RSF [g/l]	Structural parameter S [um]	Source
Aquaporin Flat Sheet	7	0.15	0.29	N/A	Data Sheet, SIWW 2014
HTI CTA	12	0.26	0.58	500	T. Cath et al. Desalination 2012, doi:10.1016/j.desal.2012.07.005
HTI TFC	17.5	0.37	0.41	N/A	Data sheet, Weftec 2013
Oasys TFC	30	0.64	1.67	375	T. Cath et al. Desalination 2012, doi:10.1016/j.desal.2012.07.005
Porifera	33	0.70	0.40	215	Data Sheet, SIWW 2014
Toray Chemical Korea (formerly Woongjin)	46 ** not scaled to 1M	0.49	0.50	N/A	Data Sheet, March 2014; ** measured at 2M instead of 1M driving force

System Level Specific flux (not only membrane) is the key parameter that will drive down cost and footprint of FO

New element design achieves coupon flux

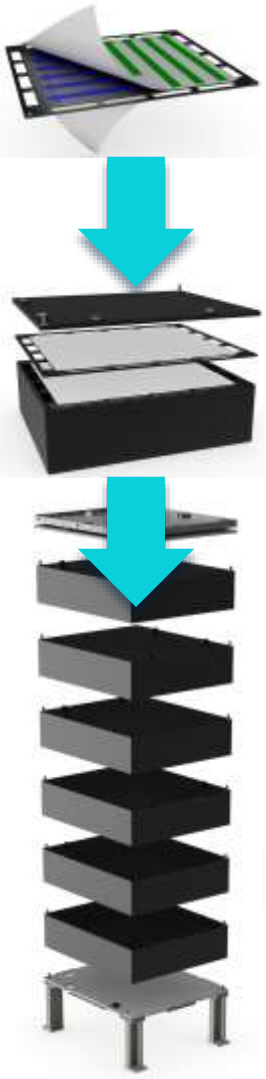


Coupon flux at same conditions



Flux rate and headloss curves versus feed and draw flow for a Porifera PFO-100 Element (7 m^2)

Systems achieve >90% coupon specific fluxes



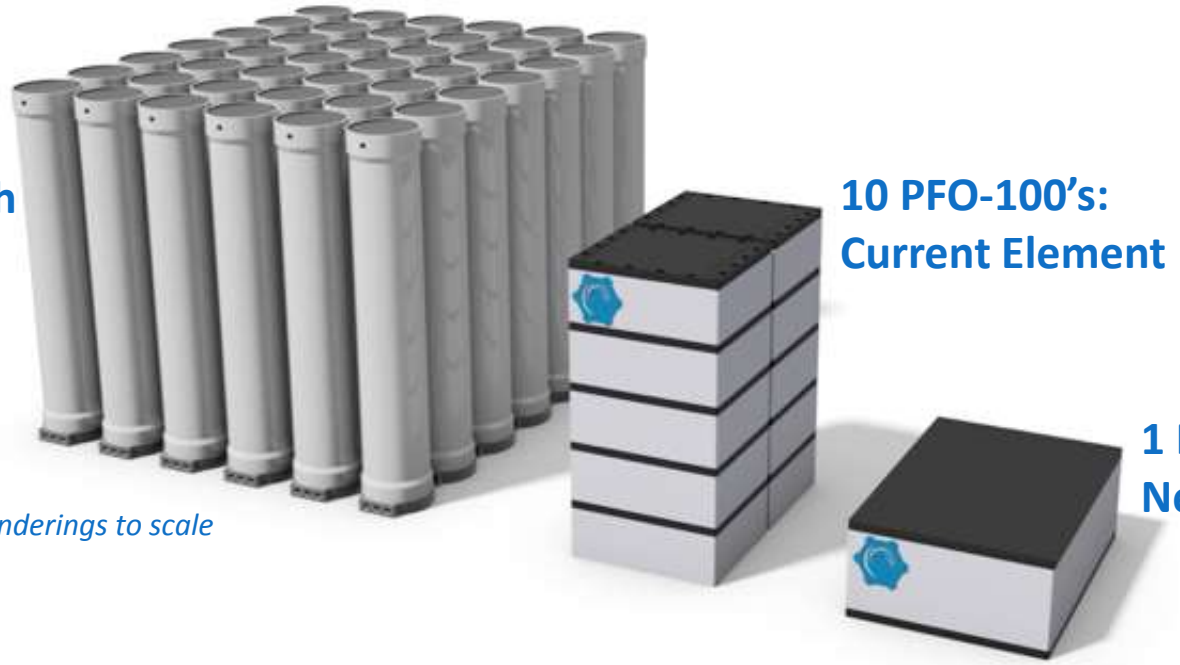
Coupon flux	Element Flux	System flux
15.5 lmh	15.4 lmh	14.8 lmh
0.60 lmh/bar	0.59 lmh/bar	0.57 lmh/bar

Why Porifera FO?

Low Fouling, Highest Efficiency = Low Cost & Small Footprint System

42 = 10 = 1

Competing 8-inch Spiral Elements



10 PFO-100's: Current Element

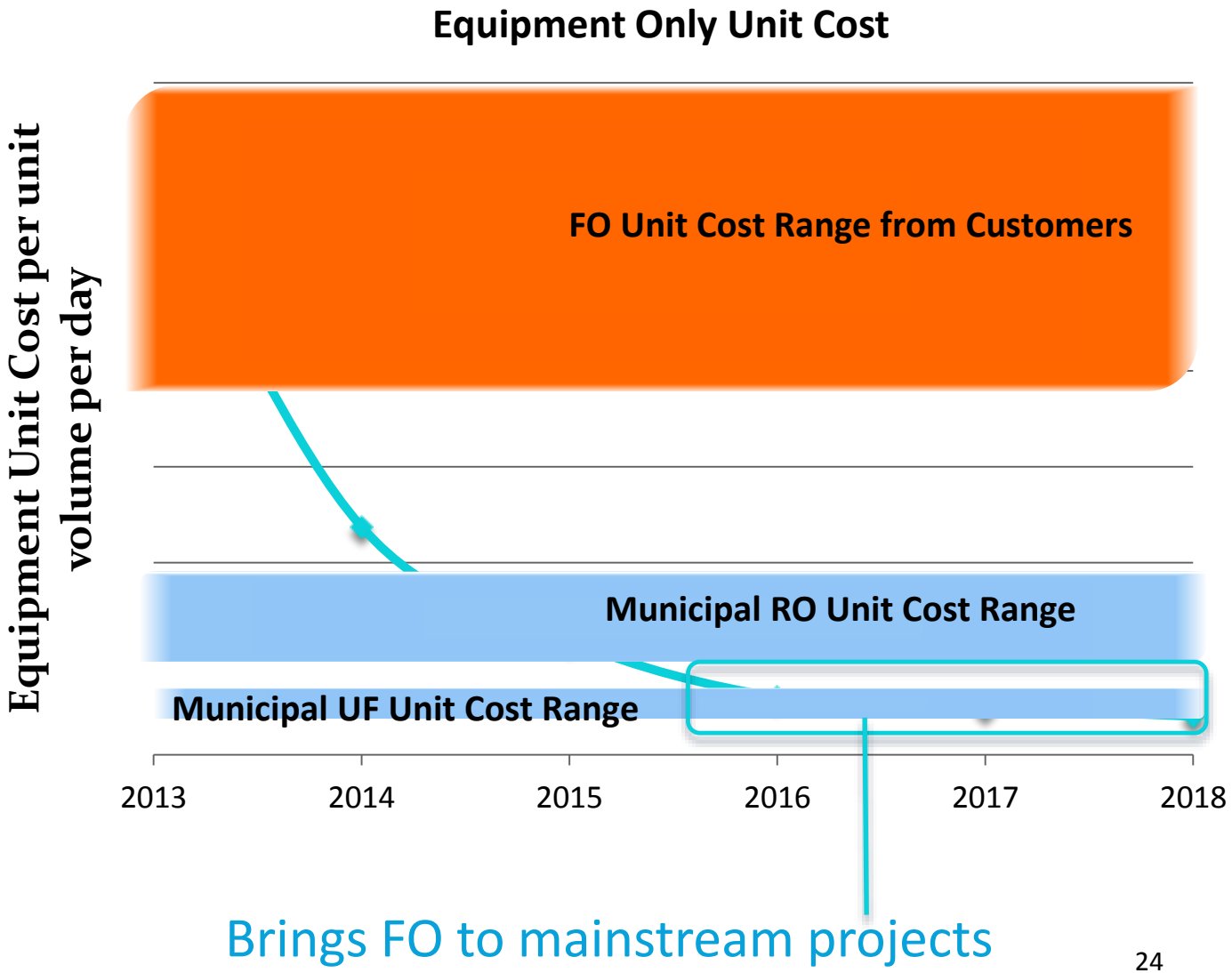
1 PFO-200: NextGen Element

renderings to scale

Large Footprint FO
High Material Cost

Porifera FO Innovations
Higher Purity & Efficiency; Lower Cost

Innovations: FO+RO to be cheaper than UF+RO



Brings FO to mainstream projects

FO: a tool to reduce total project costs

Requires total project cost comparison

FO+RO CAPEX: >20% savings for sweetspot projects; >30% when including land

- **Pretreatment*
- **Support systems*
- Post-treatment
- **Footprint/land*
- **Intake and outfall*
- Other project costs

FO+RO OPEX: >20% savings for sweetspot projects; >40% when including disposal costs

- Chemicals
- Salt replacement
- *Membranes*
- *Electricity*
- Labor/maintenance
- **Disposal costs*

Questions?

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