NARUC Winter Policy Summit

Joint Session of The Committee on Energy Resources and the Environment and The Committee on Water

Solar Desalination

NARUC Winter Policy Summit
Washington, DC

Joint Session with

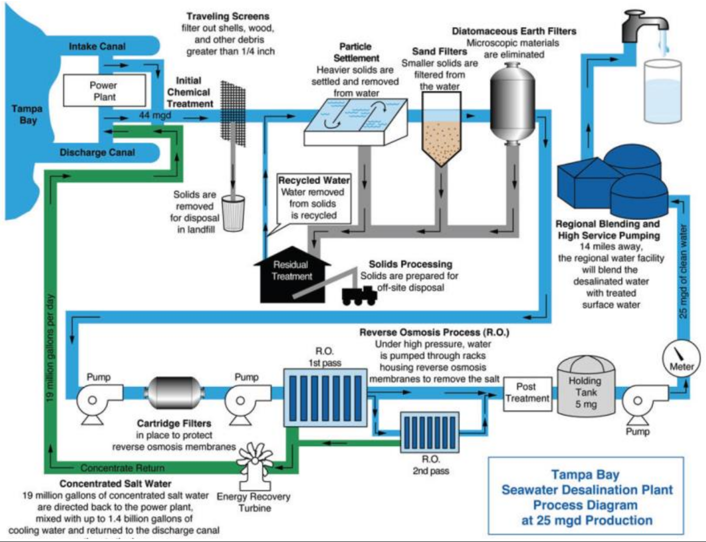
Committee on Water and Committee on Energy Resources and the Environment

Donald J. Polmann Ph.D., P.E.
Commissioner
Florida Public Service Commission
February 12, 2018

Overview

- Solar & Desalination – Technology Pairing
- Experience with Tampa Bay Water Authority
- Expert Presentations – Technical & Economic Feasibility
- Discussion & Questions

Traditional Reverse Osmosis



Sample Year - 2013

- Volume – 10.34 MGD
- Total Operating Cost – $12.9 M
- Energy Use – 14,120 kWh/MG

Questions?

Donald J. Polmann Ph.D., P.E.

Commissioner

Florida Public Service Commission

(850) 413-6044
Commissioner.Polmann@psc.state.fl.us

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Panel on Solar Desalination of Drinking Water

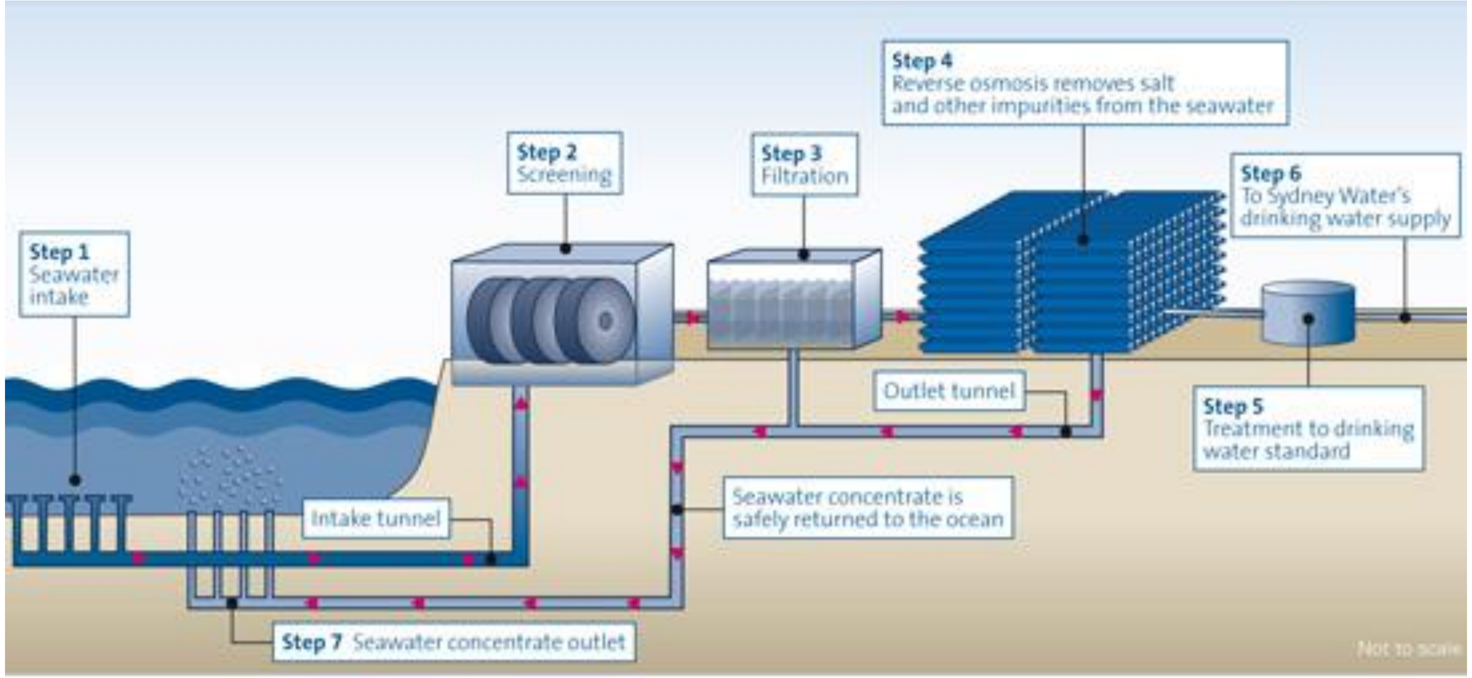
NARUC Winter Meeting
Washington, DC

February 12, 2018

Committee on Water
&
Committee on Energy Resources and the Environment

Peter E. Shanaghan, M.Eng.
Senior Environmental Engineer
United States Environmental Protection Agency
Office of Ground Water and Drinking Water
Washington, DC 20460

Sea Water Desalination
Major Capital and Operating Cost Drivers

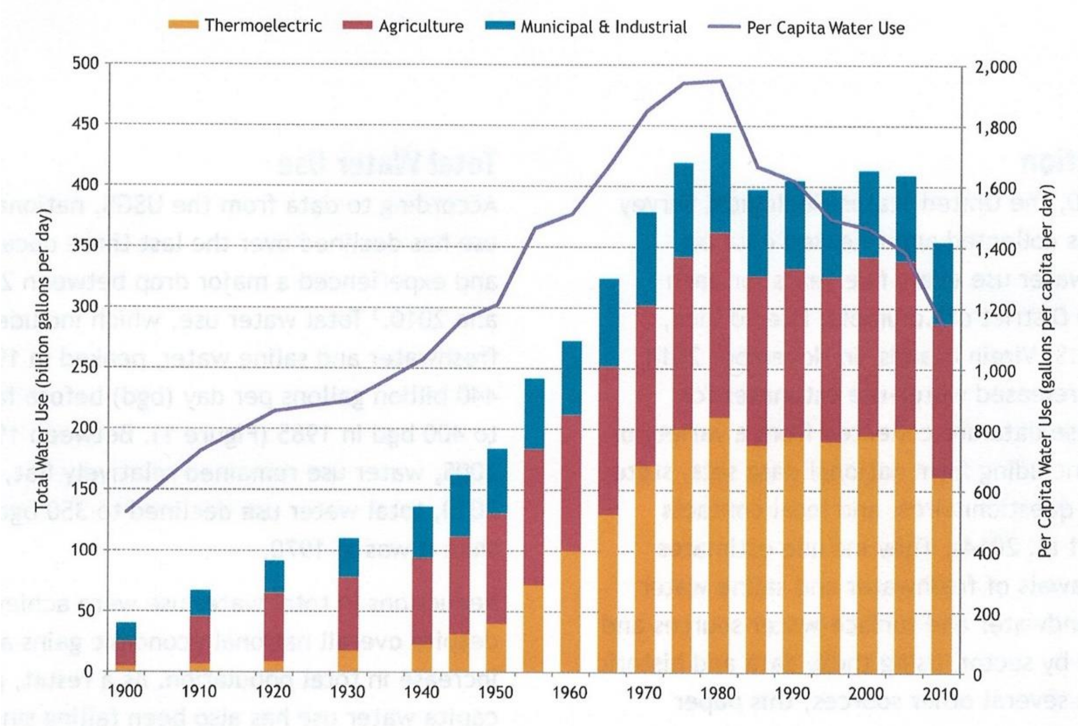


- Finished Water Quality
- Transmission of Finished Water
- Feedwater Quality and Variability
- Raw Water Intake
- Brine Disposal
- Permitting and Regulatory Issues
- Project Delivery Method
- Power Cost & Proximity
- Labor
- Technology

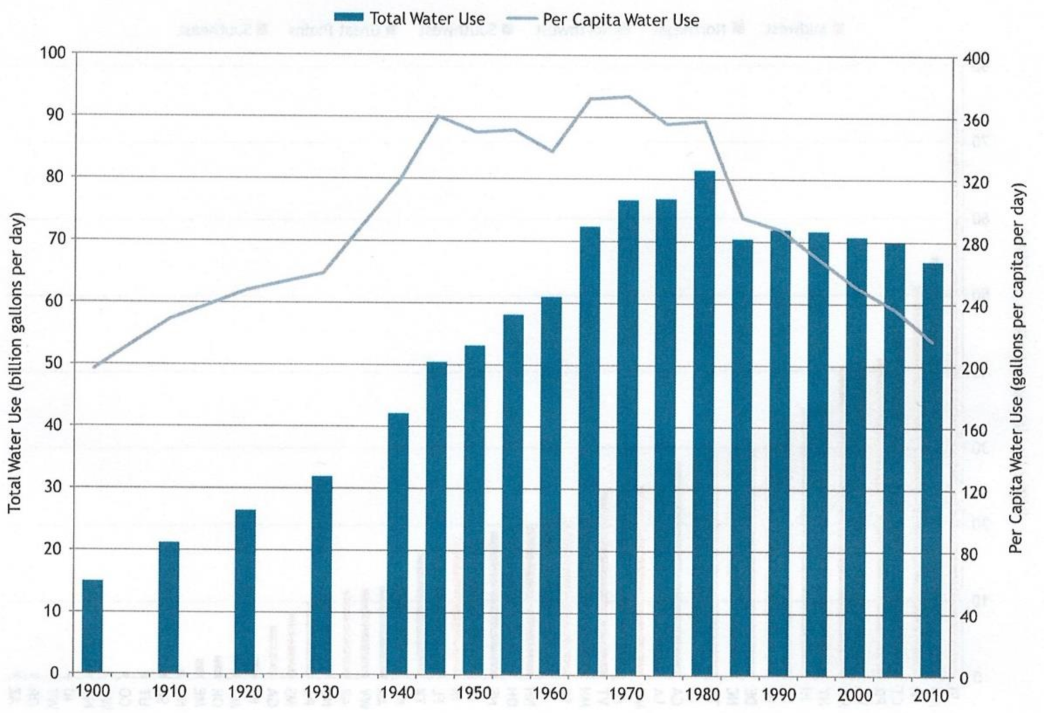
Specific Project Costs are VERY site specific!!

Declining TOTAL and PER CAPITA Water Use in the United States

Total Water Use

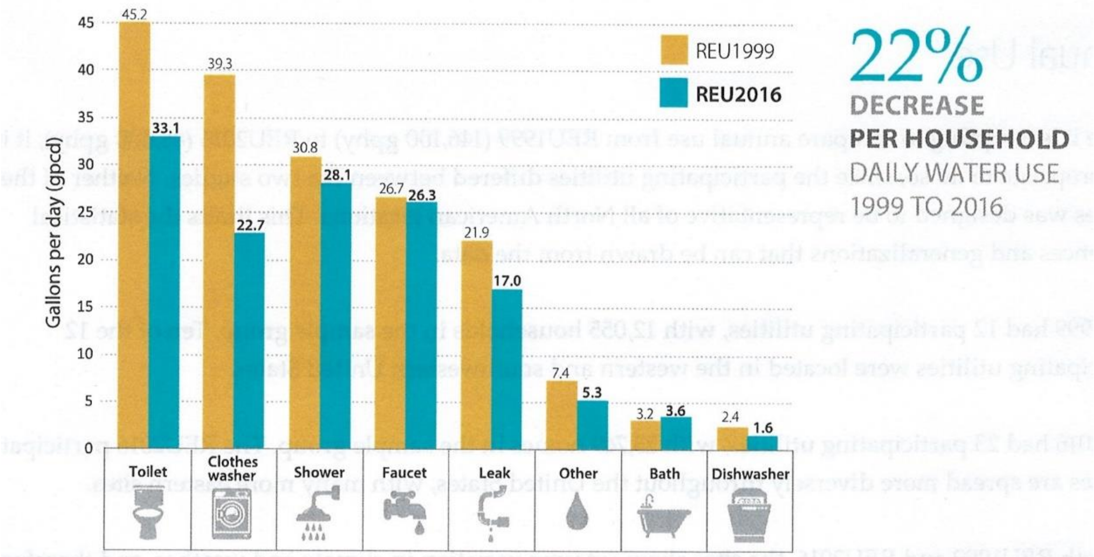


Municipal and Industrial Sector



Declining Indoor Water Use

Figure 4. Average daily indoor per household water use REU1999 and REU2016

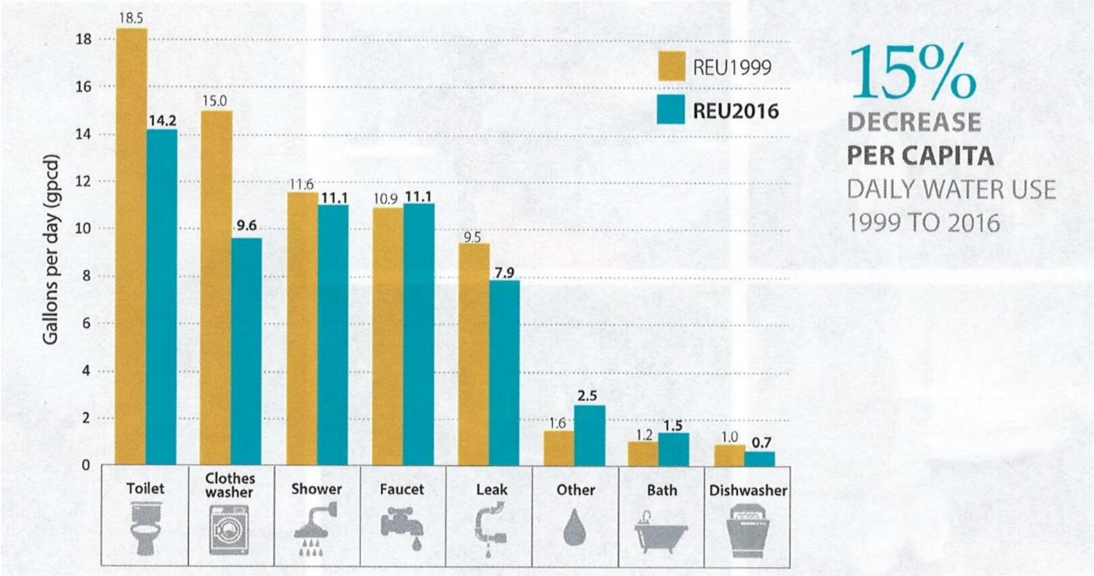


22% Decrease

in per Household Daily Water Use

1999-2016

Figure 5. Average daily indoor per capita water use REU1999 and REU2016



15% Decrease

In per Capita Daily Water Use

1999-2016

Panel Questions

1. Is the pairing of Solar Technology with Desalination Technology technically feasible?

    - Yes
    - Over ½ of the world's installed desalination capacity uses solar power

2. Is the pairing economically feasible?

    - Depends on site and objectives

3. Is solar powered desalination a possible solution for drought challenged water utilities in the United States?

    - CSP is potentially a "game changer" for the US Water Sector
        - Moving water is our major cost (Pumping)
        - Could make desalination cost competitive supply source (future)
    - **Demand Side Efficiencies remain to be achieved**
    - **Brine disposal remains challenging**

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The Committee on Water

Solar Energy Desalination

POTENTIAL FOR CLEAN AND AFFORDABLE NEW WATER SOLUTIONS.

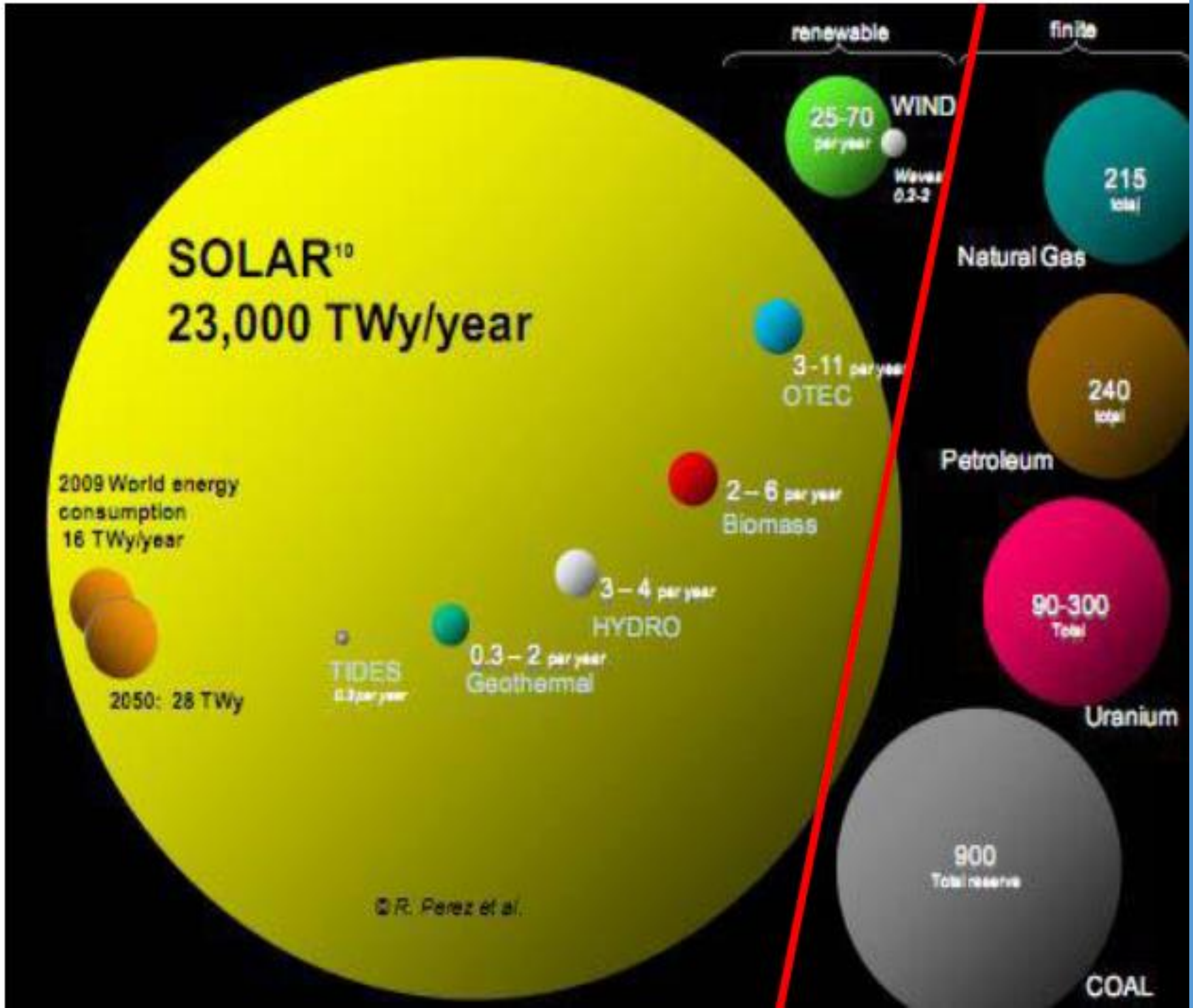
Leon Awerbuch-President International Desalination Consultancy Associates LLC
Chairman of Energy and Environment Committee and Dean IDA Desalination Academy
of International Desalination Association

NARUC
National Association of Regulatory Utility Commissioners

2018 NARUC Winter Policy Summit
February 11 - February 14, 2018
Renaissance Washington Hotel
Washington, D.C.

SOLAR ENERGY COMPARISON

The annual solar radiation on the earth surface is 1400 times higher than the annual world energy consumption and 25 times higher than the total coal reserves



Solar energy is a source of renewable energy and the oceans are unlimited source of water.

We know that desalination is proven technology to produce clean water from the sea and brackish resources. Desalination however is relatively energy-intensive, and sustainable solar systems are under development to reduce energy and environmental impact.

Today Solar revolution both in PV and CSP is going cheaper by the day,

- In Abu Dhabi JinkoSolar and Marubeni sign 25-year PPA for 1177 MW Sweihan project at $0.0242/kWh. The power price is one of the lowest ever achieved by a utility scale project globally.
- Dubai will get Solar Power Day and Night without subsidy at Lower Cost than Gas-fired Electricity

ACWA Power was awarded 700 MW CSP at a levelized tariff of US $7.30 cents per kilowatt hour; a cost level that competes with fossil fuel generated electricity without subsidy for reliable and dispatchable solar energy through the night. By far the largest single-site thermo-solar power plant in the world the plant uses a state-of-the-art combination of a central tower and parabolic trough concentrated solar power (CSP) technologies and molten salt storage of energy.

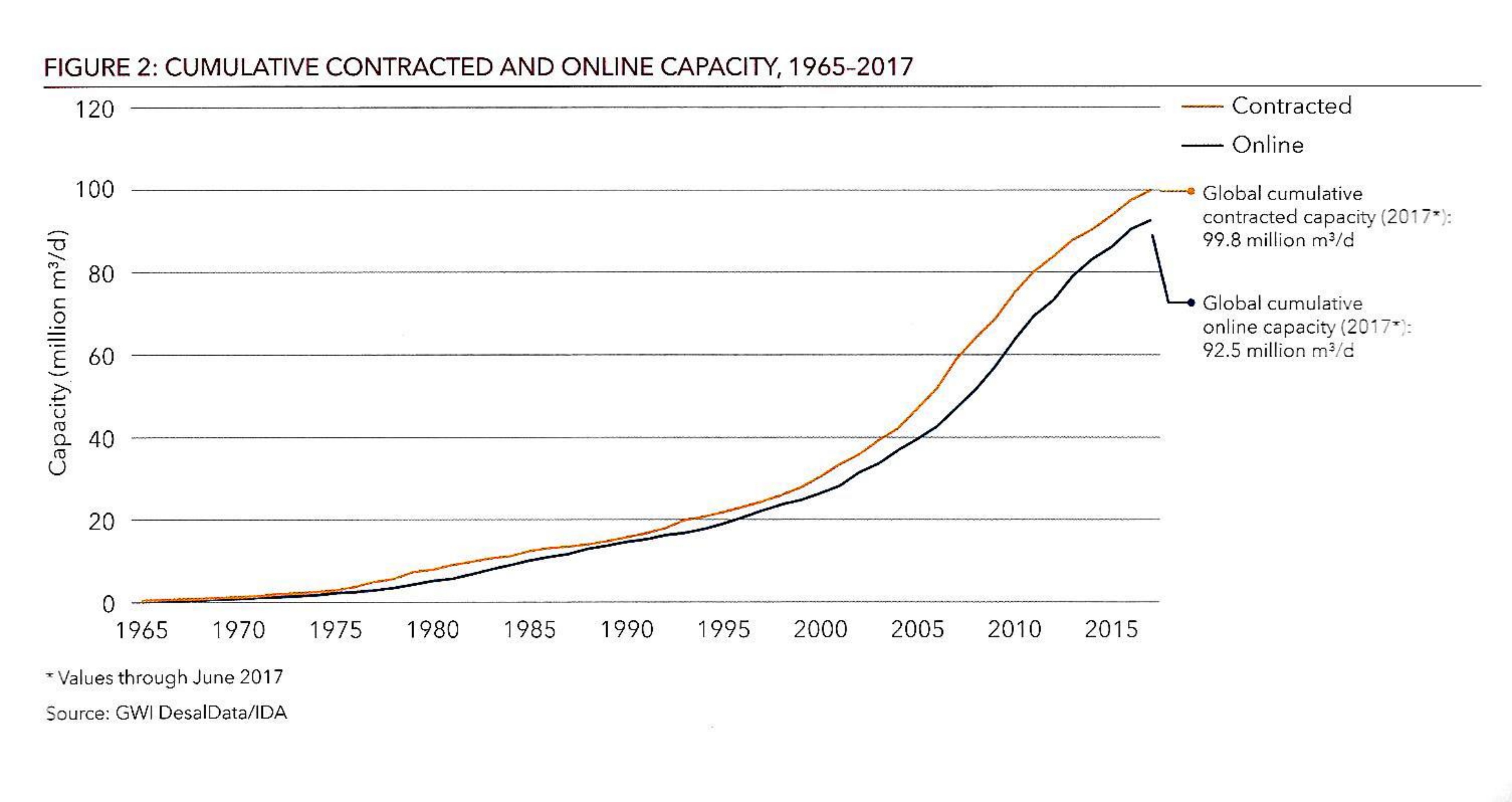
How much desalinated water is produced worldwide?

The IDA/GWI Inventory data show that there contracted plants with a total capacity of 99.8 million m^3/d (26.4 billion gallons per day) of which a total capacity of 92.5 million m^3/d (24.4 billion gallons per day) have been commissioned.

How many desalination plants are there around the world?

***There are almost 20,000 desal plants*, in over 150 countries**

Global cumulative installed contracted and commissioned desalination capacity, 1965 – 2017



Source: GWI DesalData / IDA, 2017

Energy Requirements for Desalination

	Process/energy type	MED	MED -TVC	MSF	RO
	Specific heat consumption, kJ/kg, PR kg/2326 kJ/kg	178 13	221-250 11.0-9.3	250-273 9.3-8.5	
	Steam pressure, ata	0.3 - 0.4	2.5-3.5	2.5-3.5	_
	Electric energy equivalent, kWh/m^3	3-4.5	5.4-8*	5.6-8.0	_
	Electric consumption, kWh/m^3	1.0--1.5	0.9-1.8	3.4-4.5	3.3-4.0
	Total electric energy equivalent, kWh/m^3	4.0-5.0	6.3-9.8	9.0-12.5	3.3-4.0

Courtesy of Leon Awebuch

Solar Thermal and Solar Membrane Desalination

- Since thermal desalination Multi Effect Distillation (MED) proces require relatively large quantities of heat sources at low temperatures below 90 deg C , this creates enormous opportunity to use solar hot water to store and drive the desalination process 24/7.The electrical energy requirements for MED is in range only of 1.0 kWh to 1.5 kWh/m^3.

- Membrane Reverse Osmosis process for seawater requires electrical energy of 3.3 to 4.0 kWh/1.5 kWh/m^3 and faces challenge of intermediate supply and today relative high cost of battery storage.
- Desalination and Solar industry works intensively to solve challenges of intermediate supply and in case of seawater desalination the interconnection between solar plants location and costal requirements for desalination plants.
- We join forces in Global Clean Water Desalination Alliance to work together on large utility size system and small grid independent plants.

The Global Clean Water Desalination Alliance – H_20 minus CO_2

The action plan includes obtaining amplified commitment by all Alliance members to use clean energy sources to power new desalination plants and to retrofit existing plants, whenever possible. Further focus is on improved energy efficiency of desalination processes, increased efforts on R&D and demonstration projects, better dissemination of innovative technologies, capacity building and analysis and formulation of adequate policies and regulatory frameworks. The concept of the Alliance underlines that the initiative will ensure the sustainability of the entire desalination process is taken into account beyond the sole issue of energy sources.

We call on all to join the Alliance to bring the vision to reality

"IDA is proud to be a founding member of the Global Clean Water Desalination Alliance. We have long been a champion of environmental responsibility in desalination practices including lower energy consumption and an increase in the use of renewable energy to power desalination, resulting in the reduction of CO2 emissions. This has been a goal of IDA's Energy and Environmental Committee, and we believe that the GCWDA initiative will bring us ever-closer to realizing this objective,"

IDCA

IDA International Desalination Association®

Solar Desalination provides hope to the world community that we can provide water, the essence of life, at a reasonable cost, solving the scarcity of existing water supplies, avoiding regional and territorial conflicts, and providing the water resource for sustainable development.

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Solar Water Desalination Technologies

Kelly Beninga
President & CEO
SkyFuel, Inc.
Lakewood, CO

2018 NARUC Winter Policy Summit
February 11 – February 14, 2018
Renaissance Washington Hotel

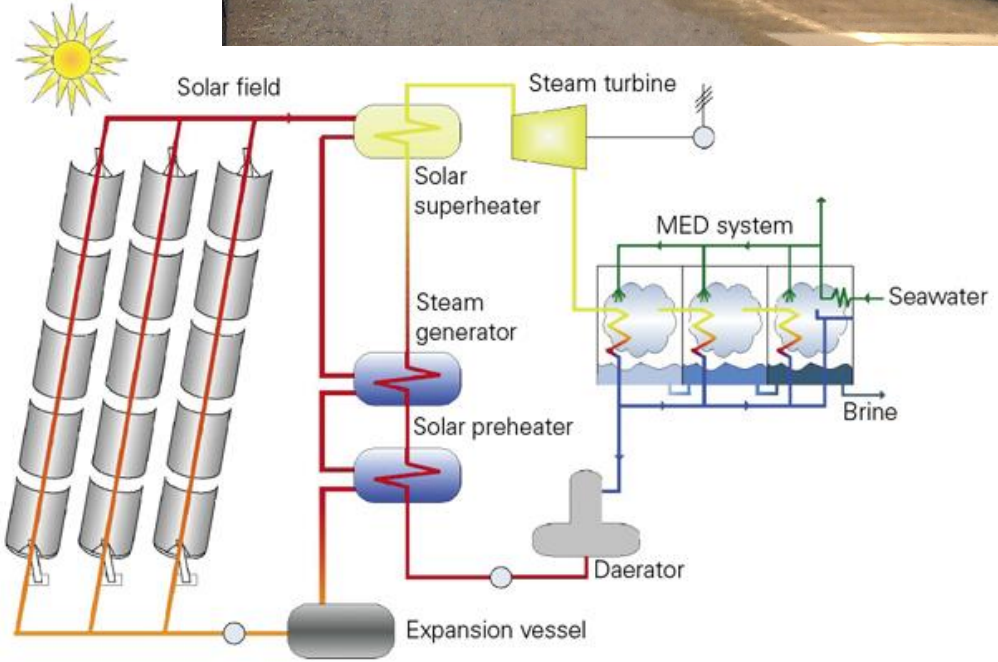
Solar Desalination Technologies

	PV/ Reverse Osmosis	CSP / Multiple Effect Distillation	CSP / Forward Osmosis
Heat Consumption (kwh_t/m^3)	0	45	16
Power Consumption (kwh_e/m^3)	3.5	1.5	0.2
Cost to Operate* ($/m³)	0.28	0.57	0.18
Zero Liquid Discharge?	No	Yes	Yes

* Electricity @ 0.08 $/kwh
Thermal energy @ 0.01 $/kwh
10,000 to 100,000 m^3/day plant

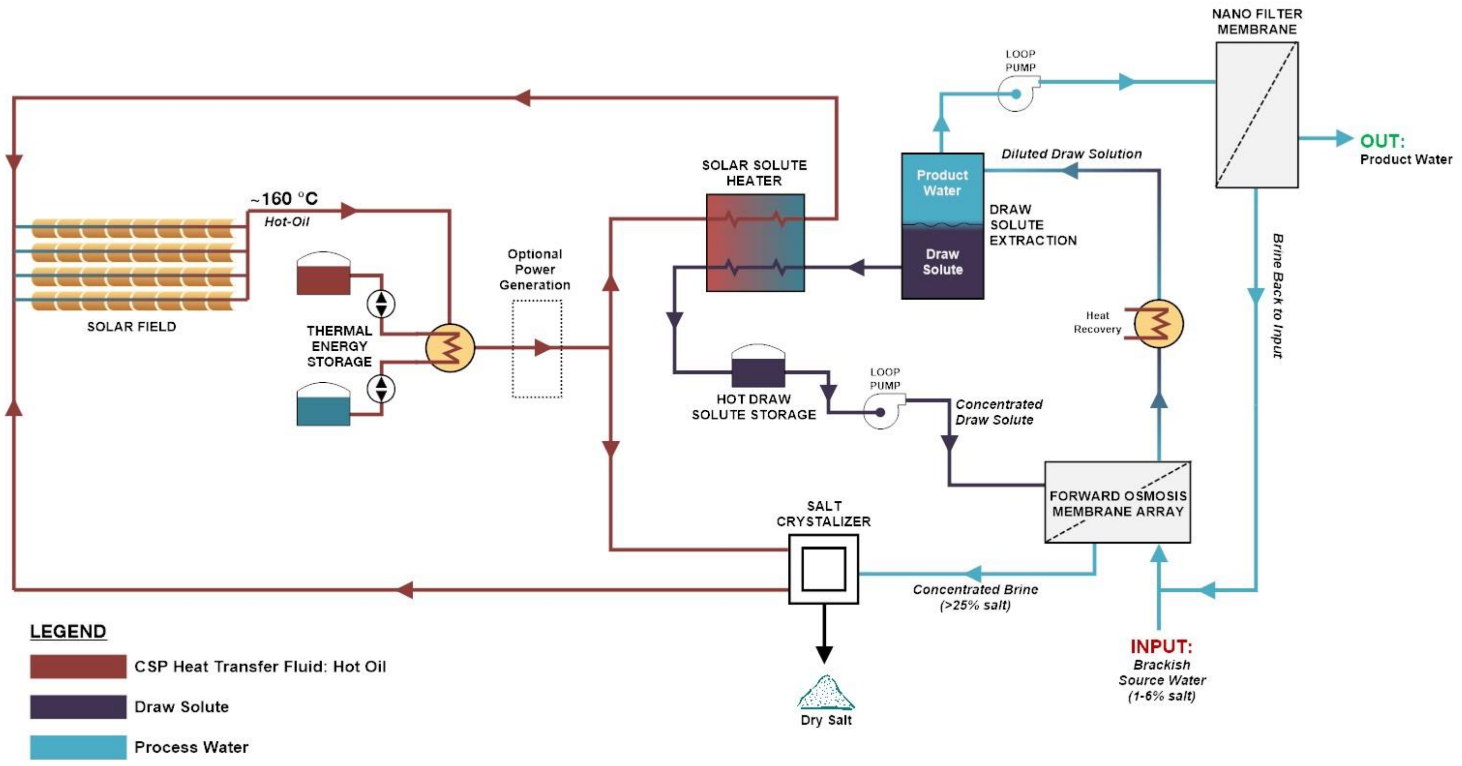
Solar Multiple Effect Distillation System

- Solar heat used to boil water in successive stages
- Optional steam power generation prior to desalination process
- Well developed and broadly used desalination technology
- Demonstrated by SkyFuel and partners at Panoche Water District - Firebaugh, CA (near Fresno)
- Fresh water for agricultural use produced from brackish ground water
- Successfully demonstrated 500 gal/hr water production with Zero Liquid Discharge



Solar Forward Osmosis Desalination System

- Advanced solar desalination system under development by SkyFuel and partners
- Greatly improved energy efficiency compared to RO and MED
  - 6% of electricity consumption compared to RO
  - 35% of heat consumption compared to MED
- Heated chemical solute used to induce osmotic pressure across membrane rather than using pumping power
- Zero Liquid Discharge for inland applications



Contact:
Kelly Beninga
President & CEO
SkyFuel, Inc.
kelly.beninga@skyfuel.com
303-330-0276

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The Committee on Water

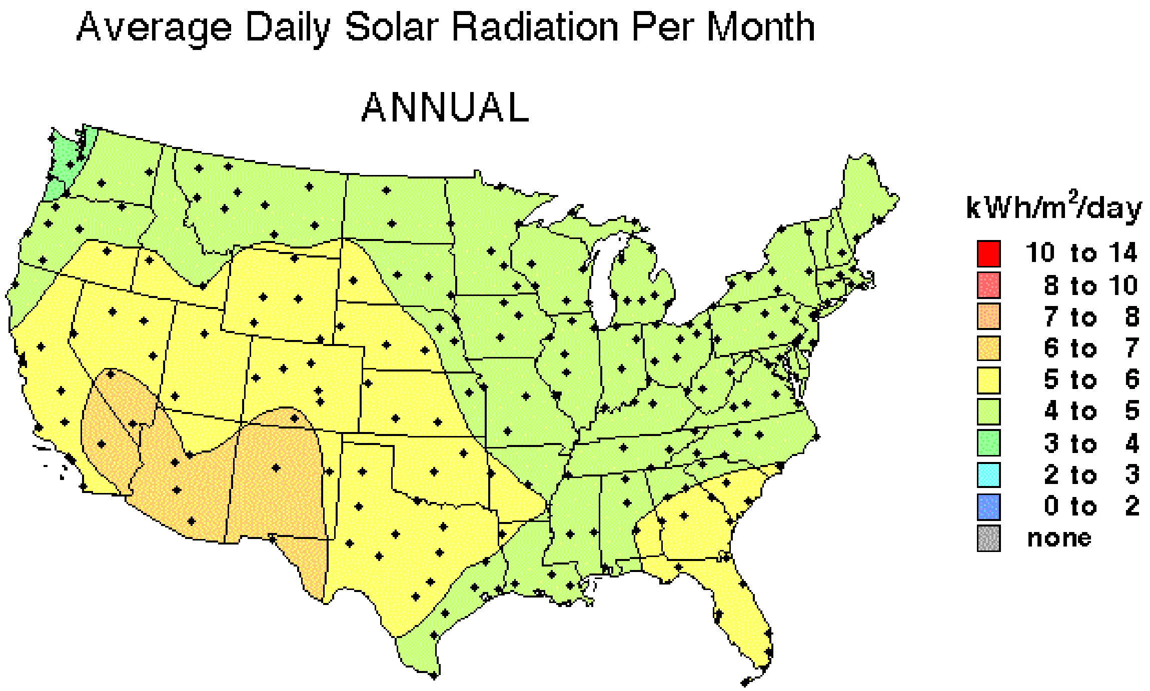
Applications of Nanotechnology In Solar Desalination

François Perreault, Ph.D.

School of Sustainable Engineering and the Built Environment
Ira A. Fulton Schools of Engineering
Arizona State University

Solar Energy For Desalination

Average sun irradiation per surface area



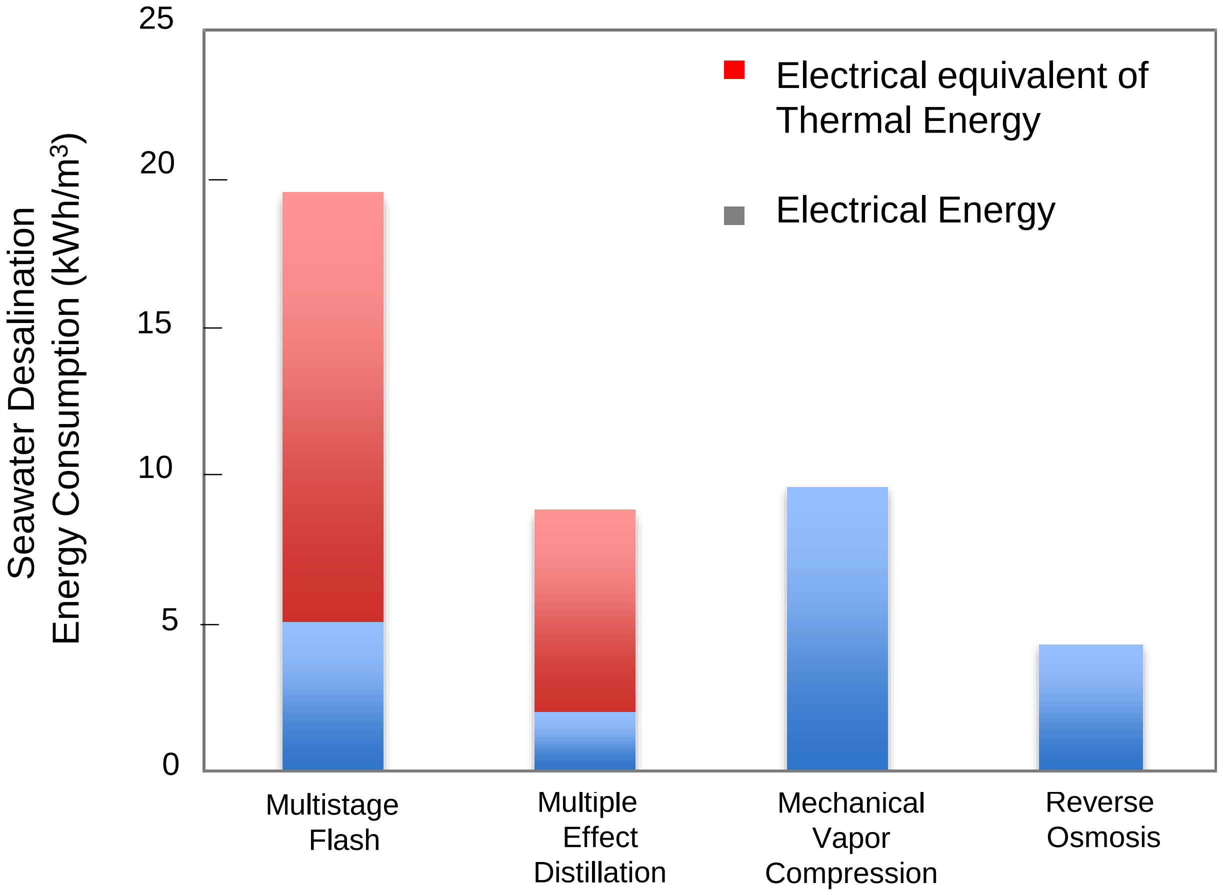


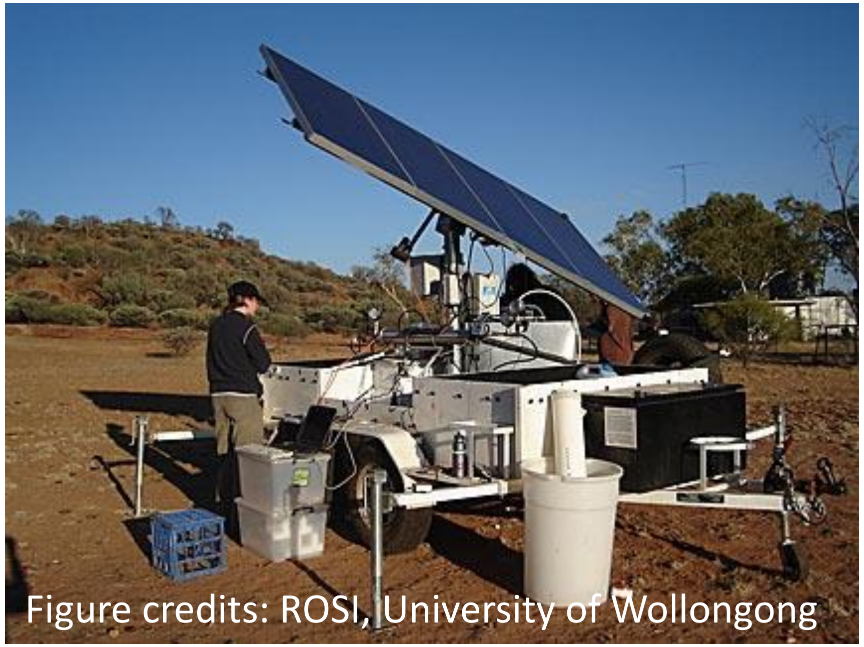
Figure credits: NREL

1 Data source: Water Reuse Association, Seawater desalination cost, January 2012

Off-grid Solar Desalination

Solar thermal

Photovoltaics



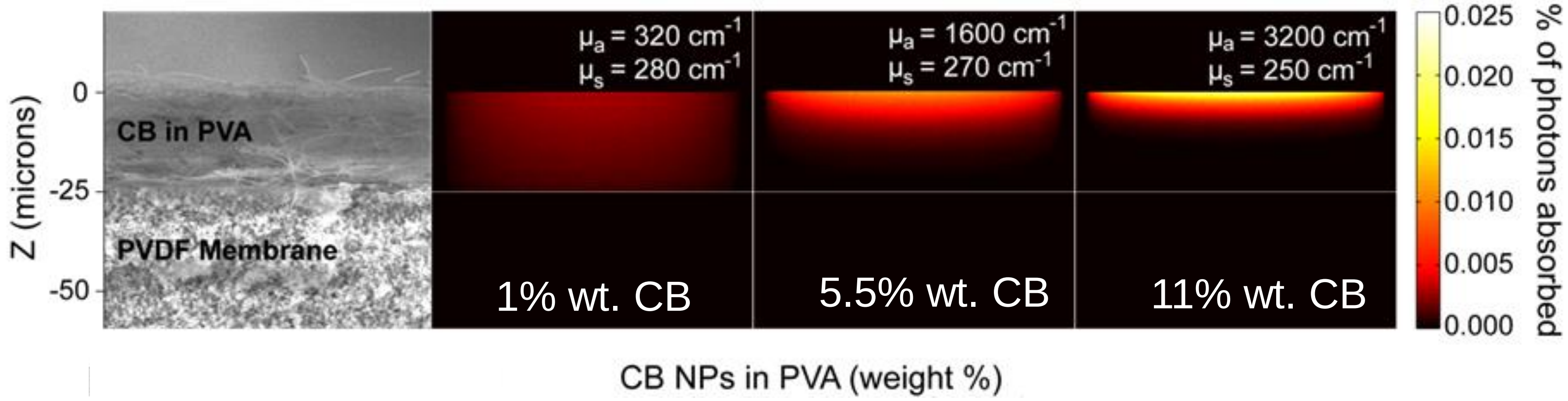
How to best capitalize the solar energy available ?

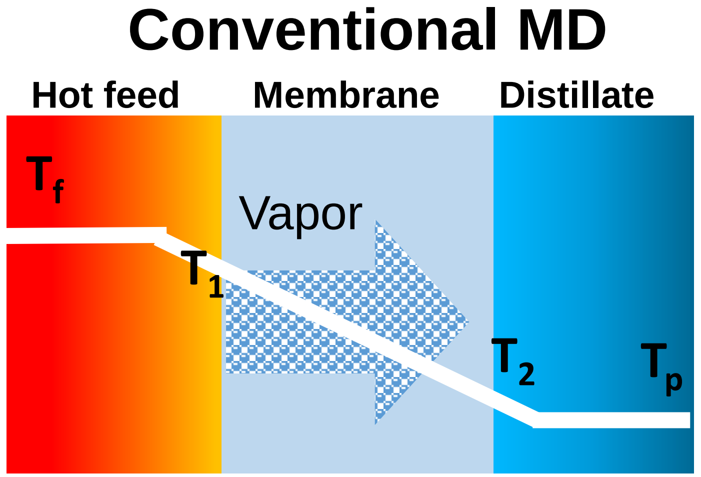
Solar Membrane Distillation

Duong et al. JMS 2017

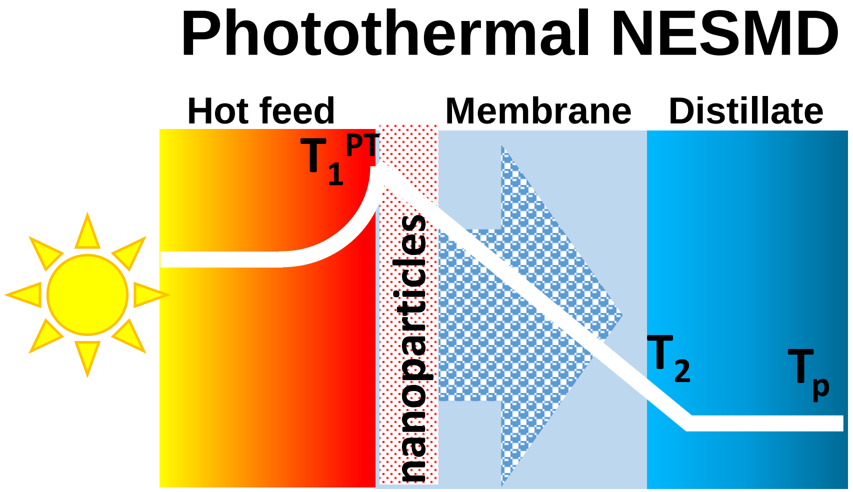
Fraunhofer ISE, Desal. Water Reuse 2008

NEWT – Nanophotonics Enhanced MD





Temperature polarization (T_1-T_2<T_f-T_p) causes low efficiency

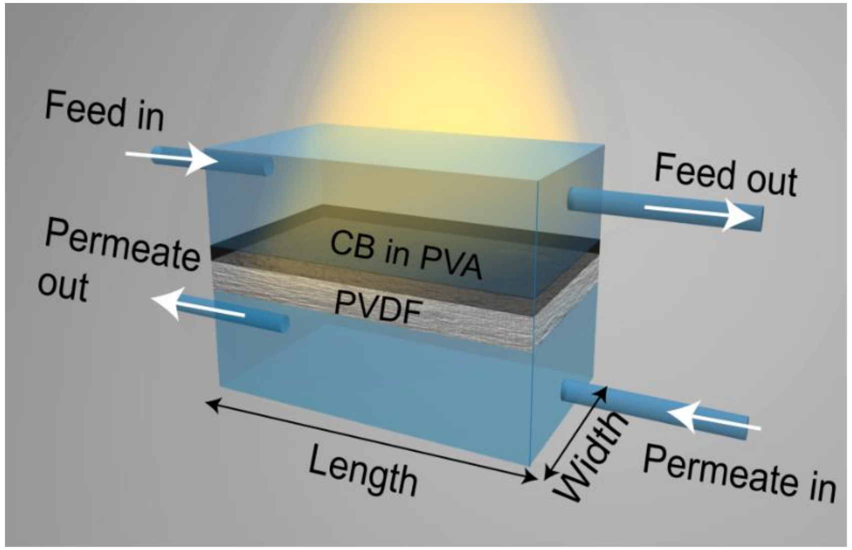


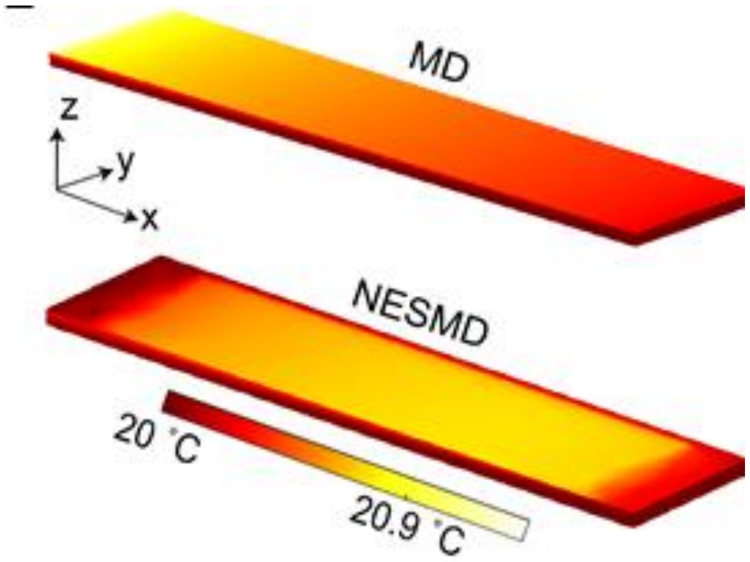
Higher $\Delta T \rightarrow$ increased efficiencies!

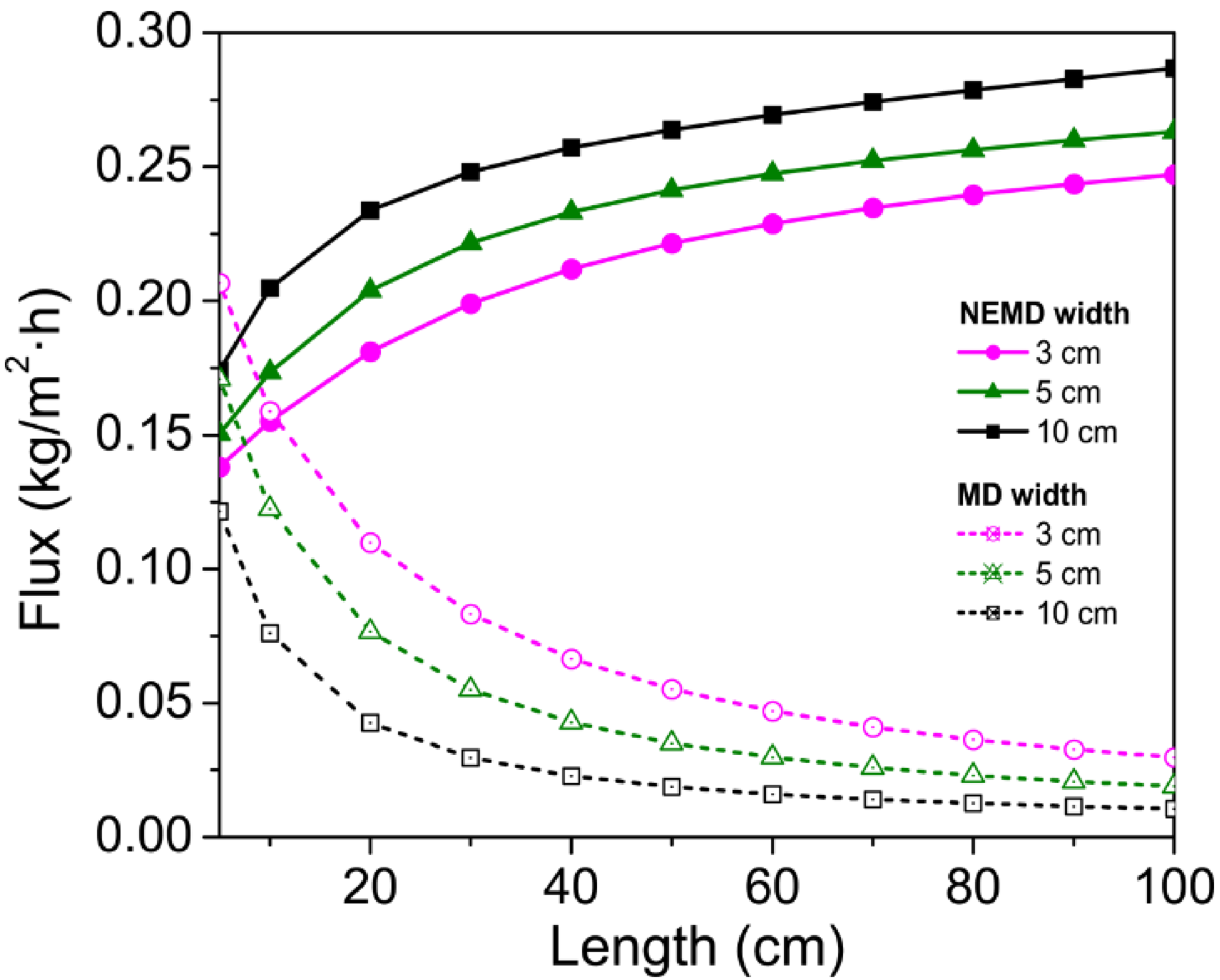
NESMD harvests the energy of the sun to enhance permeation in membrane distillation

Dongare et al., PNAS 2017

NEWT – Nanophotonics Enhanced MD



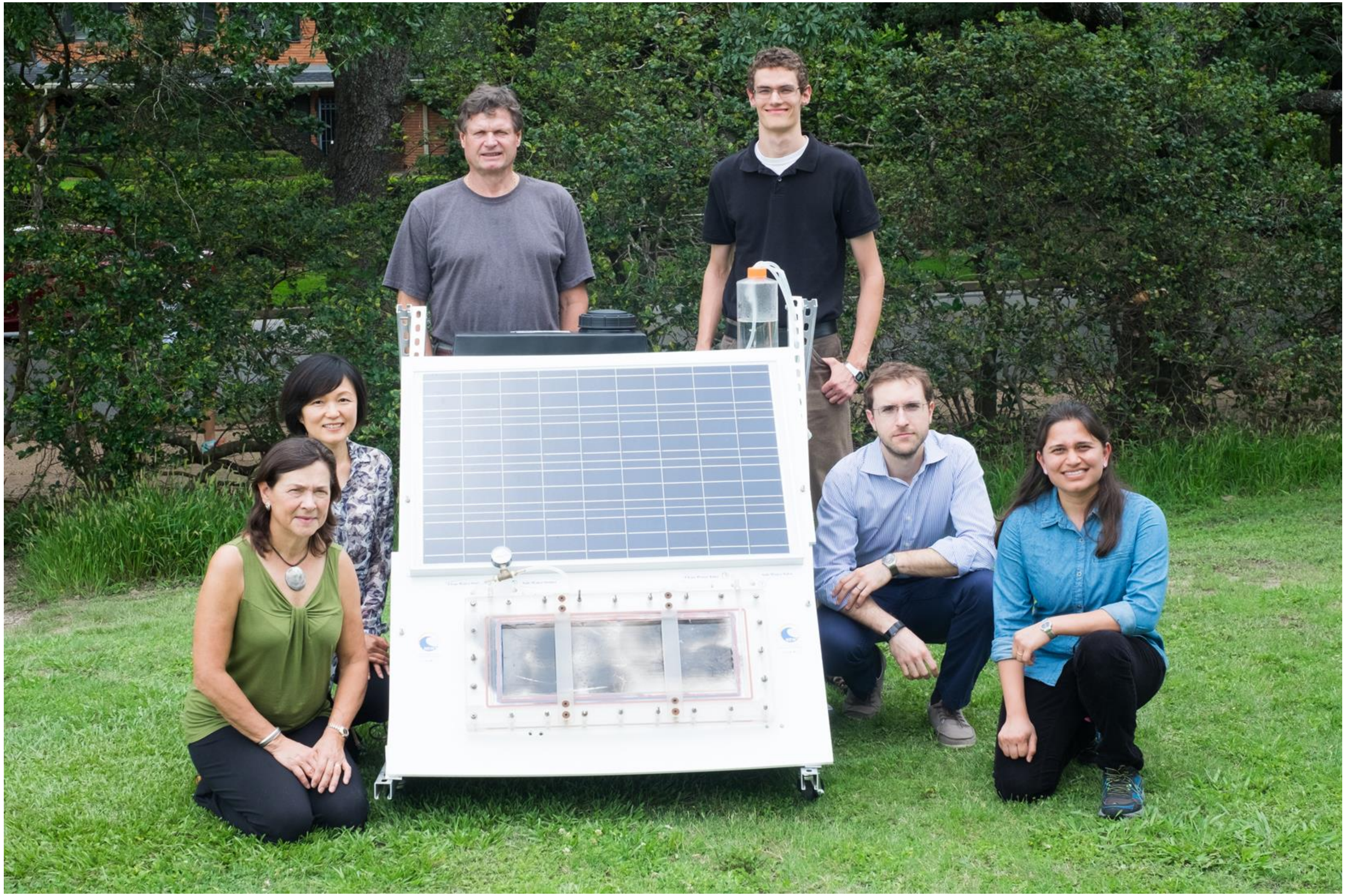




- Process scales up with module length

Dongare et al., PNAS 2017

NEWT – Nanophotonics Enhanced MD



http://www.newtcenter.org/

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SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

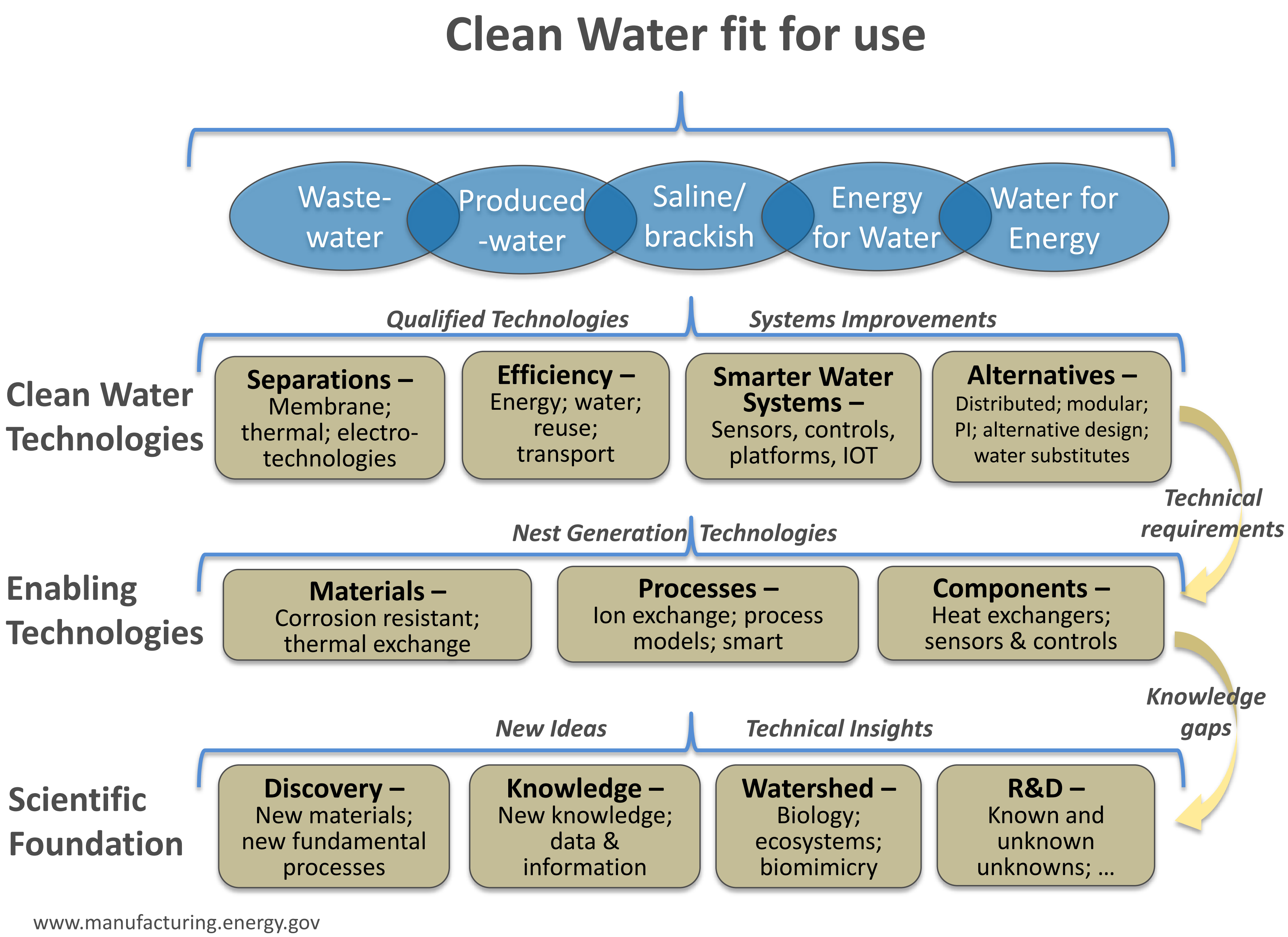
U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
ADVANCED MANUFACTURING OFFICE

Clean Water and Solar Desalination

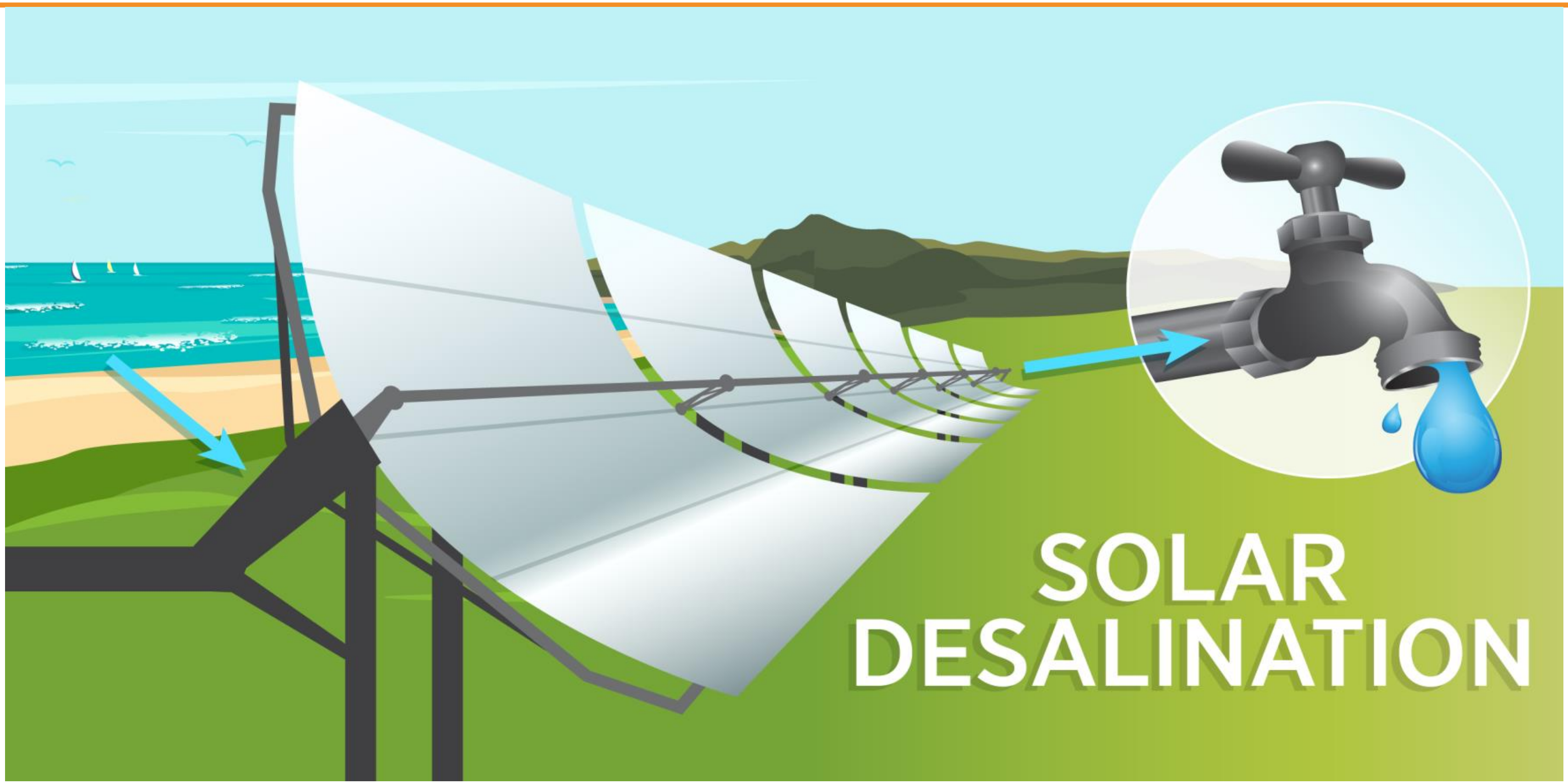
Joe Cresko, Advanced Manufacturing Office
Joe.Cresko@ee.doe.gov

Avi Shultz, Solar Energy Technologies Office
Abraham.Shultz@ee.doe.gov

www.manufacturing.energy.gov
energy.gov/solar-office


Clean Water fit for use
Waste-water
Produced-water
Saline/ brackish
Energy for Water
Water for Energy
Qualified Technologies
Systems Improvements
Clean Water Technologies
Separations – Membrane; thermal; electro-technologies
Efficiency – Energy; water; reuse; transport
Smarter Water Systems – Sensors, controls, platforms, IOT
Alternatives – Distributed; modular; PI; alternative design; water substitutes
Technical requirements
Nest Generation Technologies
Enabling Technologies
Materials – Corrosion resistant; thermal exchange
Processes – Ion exchange; process models; smart
Components – Heat exchangers; sensors & controls
Knowledge gaps
New Ideas
Technical Insights
Scientific Foundation
Discovery – New materials; new fundamental processes
Knowledge – New knowledge; data & information
Watershed – Biology; ecosystems; biomimicry
R&D – Known and unknown unknowns; …
www.manufacturing.energy.gov

Solar Desalination at DOE

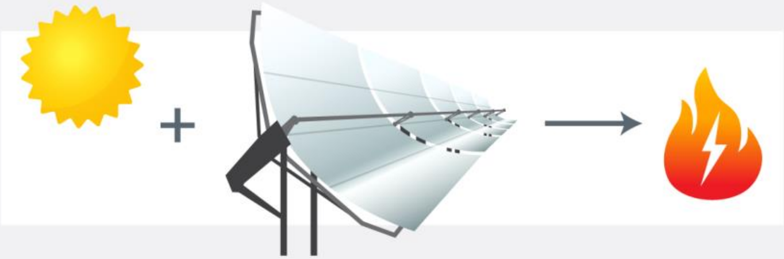


- SETO is currently running a funding opportunity announcement focused on solar **thermal** desalination.
- Solar technology uses collectors to concentrate sunlight on receivers which converts photons into heat.
- In order to be competitive with Reverse Osmosis, further reductions in capital cost and energy cost (and increased energy efficiency) are required.

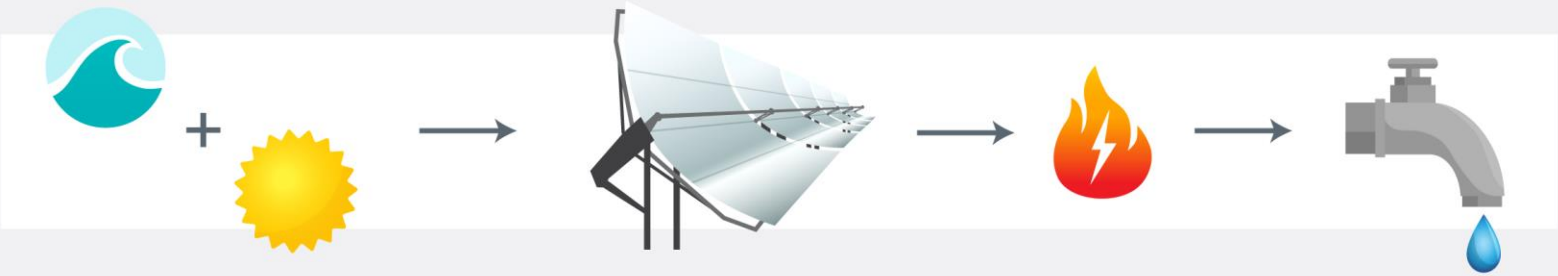
Solar Desalination FOA Topic Areas

TOPIC AREA 1:
Innovations in thermal desalination technologies

TOPIC AREA 2:
Low-cost solar thermal heat



TOPIC AREA 3: Integrated solar desalination systems



TOPIC AREA 4: Analysis for solar thermal desalination

Cost Targets for Solar Desalination

- Solar Thermal Desalination FOA Focuses on Two Cost Targets:
  - LCOW = Levelized Cost of Water, $\$/m^3$
  - LCOH = Levelized Cost of Heat, $\$/kWh_{th}$

- $$LCOW = \frac{\text{Total lifetime costs (capital,financial,O\&M)}}{\text{Total lifetime clean water generation}}$$

- $$LCOH = \frac{\text{Total lifetime costs (capital,financial,O\&M)}}{\text{Total lifetime thermal generation}}$$

Cost Targets for Solar Thermal Desalination

- Cost targets for large and small capacity thermal desalination plants

Capacity	Feedwater salinity (TDS)	LCOW Target ($\$/m^3$)
Large (>10,000 m^3/day)	> 30,000 ppm	0.50
Small (<2000 m^3/day)	> 100,000 ppm	1.50*

* small-scale systems should target Zero Liquid Discharge (ZLD)

Technology Innovation at DOE for Clean Waters

Separations /treatment:
- Membranes
- Thermal

Fluids Pumping:
- Motor driven systems
- Materials

Heat transfer:
- Corrosion resistant materials
- Waste heat integration

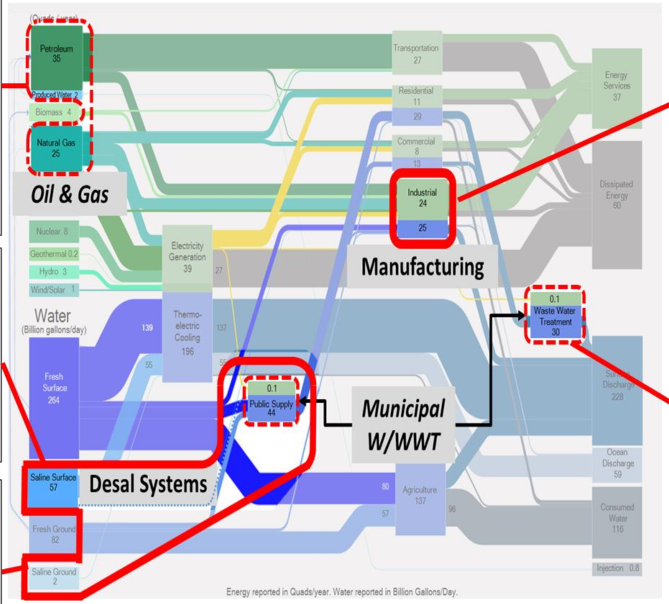
Infrastructure:
- Piping
- Structural materials

Where do core technologies .....

High Salinity feed water with variable contaminant mix to produce industrial/ag grade water w/ FO, RO viable candidates

Seawater for municipal potable water w/ RO, MSF, and MED candidates in focus

Brackish water for potable water w/CDI, EDR, MF/NF, RO as candidates



Reduce energy & water in specific sectors w/ sectors chosen based on watershed impact

Reduce energy consumption of the water and wastewater sectors, including advanced resource recovery and reuse possibilities

System integration:
- Smart technologies
- Modular designs
- Processes
- Joint energy grid/water system management

Sustainability:
- RE integration
- Consumptive water use
- Chemicals (alternatives)
- Life cycle water use
- Fit-for-use, reuse
- ZLD

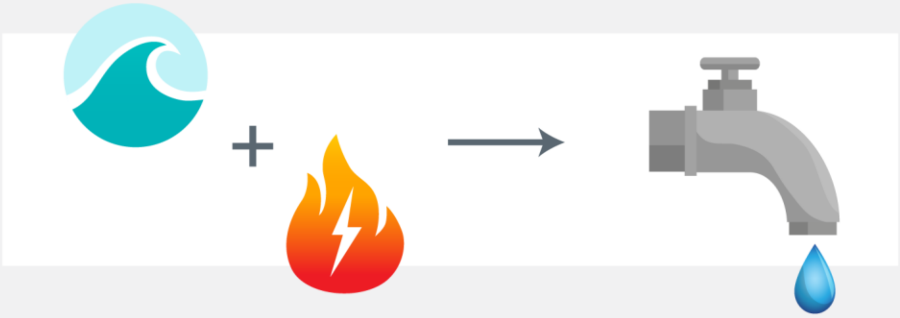
...and cross-cutting technologies have pervasive impact

Back up Slides

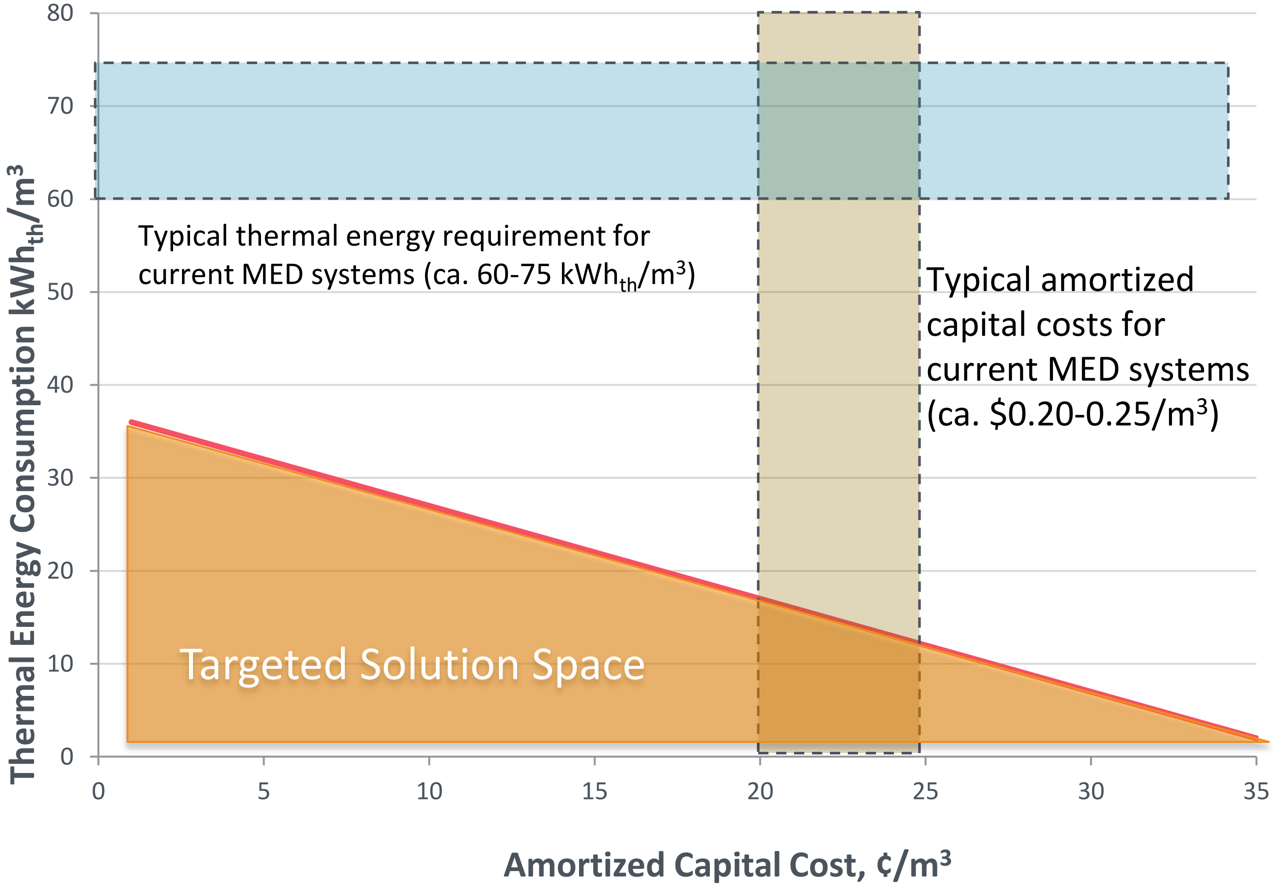
Solar Desalination FOA Topic Areas

TOPIC AREA 1:

Innovations in thermal desalination technologies



Topic Area 1: Innovations in Desalination Technologies

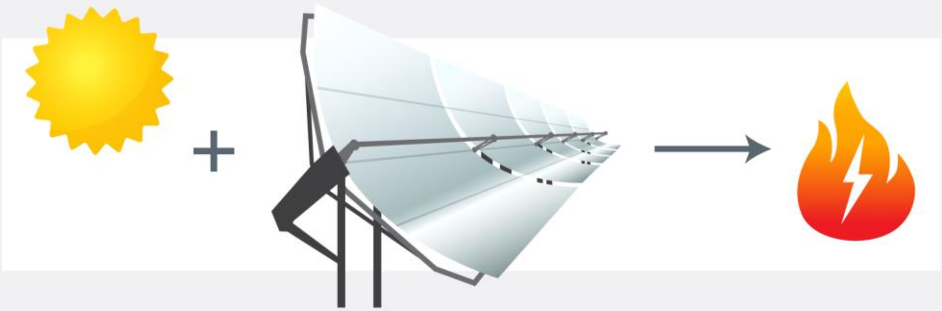


- Justify how proposed innovations enable a thermal energy consumption and capital cost that fall **on or below the red line** (represents LCOW of $0.50/m^3)

Solar Desalination FOA Topic Areas

TOPIC AREA 2:

Low-cost solar thermal energy



Topic Area 2: Low Cost Thermal Energy

- $\text{LCOH} = \frac{(\text{Installed } \mathbf{Cost})*(\text{FCR})+(\text{Annual O\&M})}{\text{Annual Thermal Generation (kWth)}}$
- FCR is Fixed Charge Rate, and is defined as the product of project financing factor, construction financing factor, and capital recovery factor

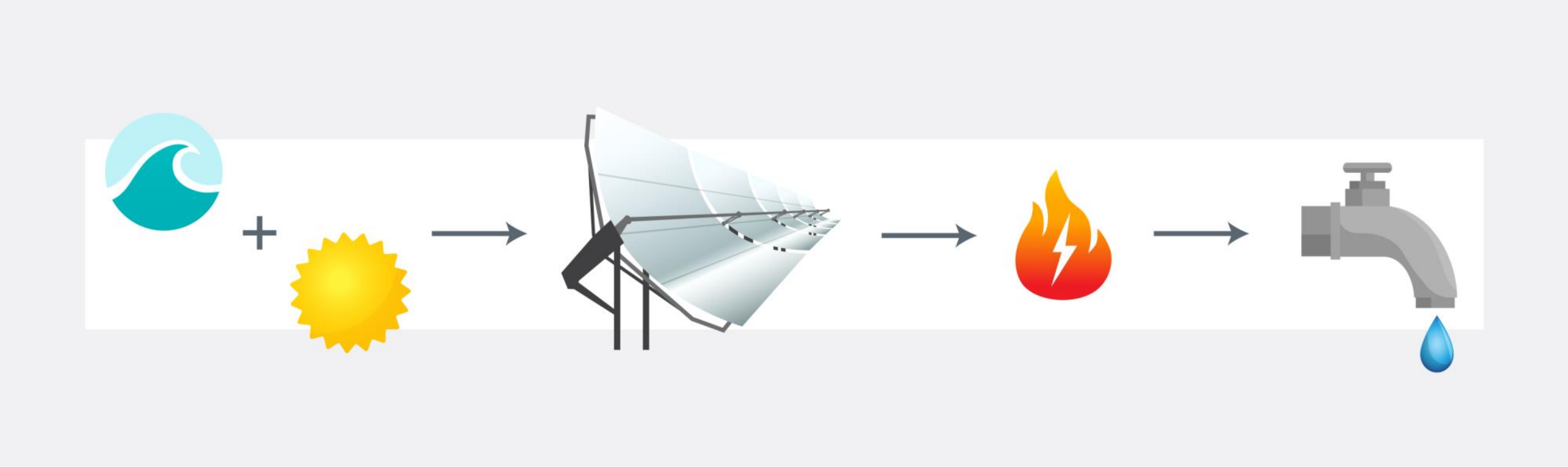
- **Target LCOH ≤ $0.01/kWh$_{th}$** (~50% reduction in cost from current technology)

- Low-cost thermal energy storage solutions in the range of 120 – 180 °C may be necessary

Solar Desalination FOA Topic Areas

TOPIC AREA 3:

Integrated solar desalination systems



Topic Area 4: Analysis for Solar Thermal Desalination system

- **Develop analytical tools that will simplify the planning, design, and valuation of solar thermal desalination**

- Potential applications of interest may include:
  - User-friendly software that identifies and models high-value opportunities where solar desalination may have the most impact
  - Integration of thermal desalination with advanced power cycles well-suited to concentrating solar power (e.g. supercritical-CO_2 power cycles)

Timeline

Oct. 12, 2017– Informational webinar (Intro. & Concept papers)

Dec. 4, 2017– Concept papers due (mandatory)

Mar. 16, 2018– Full applications due (mandatory)

Apr. 16, 2018– Submission Deadlines for Merit Review Comments

June 2018– Selection notifications (expected date)

August 2018– Awards made (expected date)

Topic Area 1: Innovations in Desalination Technologies

- **Assume** LCOH of $ 0.01/kWh$_{th}$ for large systems, and $0.015/kWh$_{th}$ for small systems
- Capital Cost and Energy Efficiency Reductions to attain LCOW $\leq$ 0.5 \$/m^3 (large) and $\leq$ 1.5 \$/m^3 (small)
- Two potential strategies:
  - dramatic improvements in established technologies and components that can lead to the achievement of the FOA cost targets proposed in Slide 5;
  - development low TRL novel thermal desalination techniques that, if further developed, can achieve the FOA targets.

Topic Area 2: Low Cost Thermal Energy

- LCOH Cost Target for Solar Field, 10 Hours of Storage

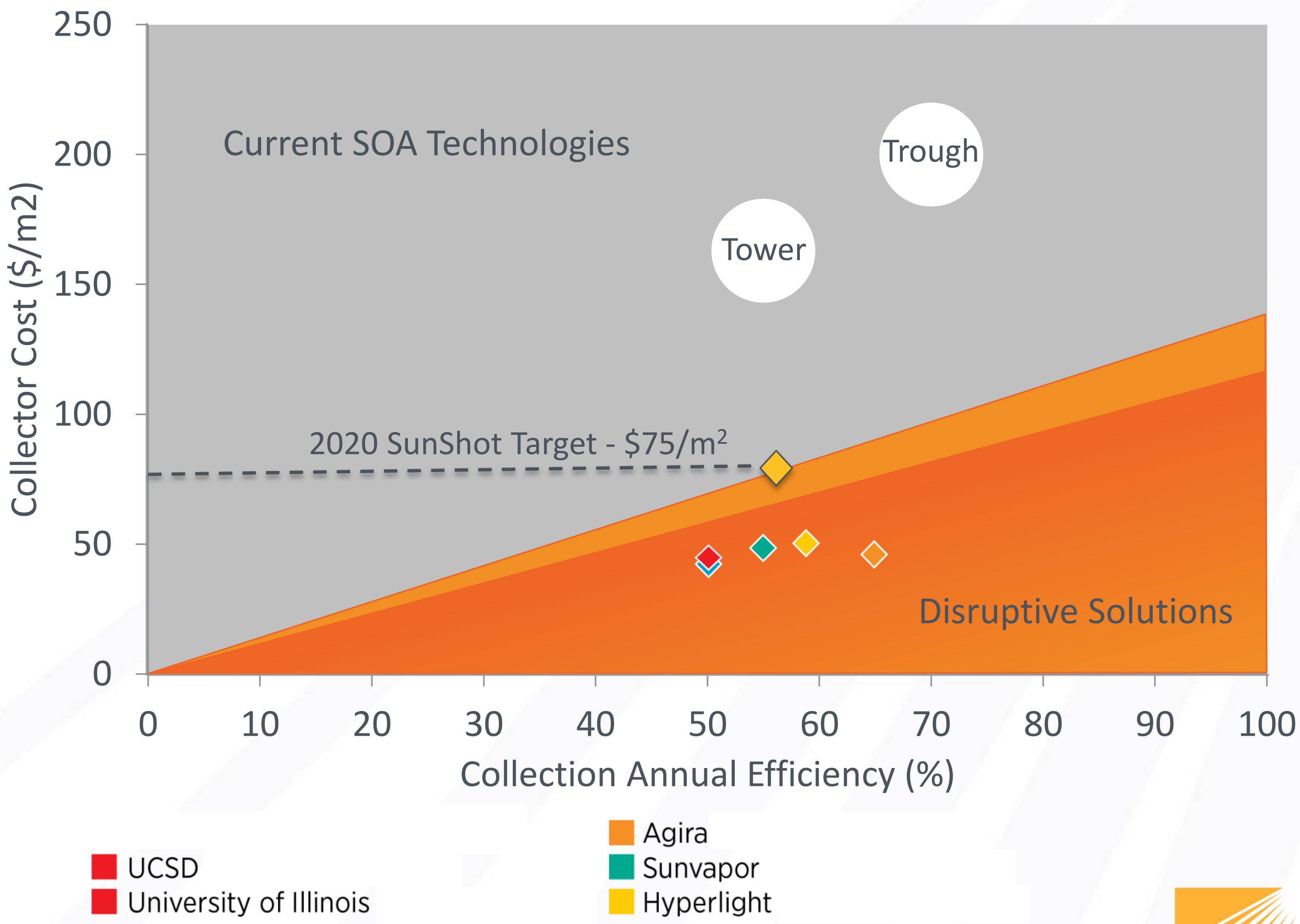
Component	Current (NREL 2015)	Large ($0.50/m^3)	Small ($1.50/m^3)
LCOH ($/kWh$_{thermal}$)	**0.027**	**0.01**	**0.015**
Total direct cost ($/m^2)	350	110	180
Site Prep ($/m^2)	30	20	10
HTF Receiver ($/m^2)	70	30	50
Collector ($/m^2)	170	45	100
O&M ($/m^2)	15	5	5
Storage ($/kWh$_{thermal}$)	20	10	10

Topic Area 3: Integrated Solar Thermal Desalination system

- Applicants should justify that:
  - The target LCOW and thermal desalination Capital Cost/Energy Consumption described in the previous Topics can be achieved
  - The integrated system will be a relevant model for scale-up to a large scale system
  - The proposed LCOW, capital cost, LCOH targets are appropriate for a commercially operating system
- Applicants to this Topic Area should propose full system designs with solar as primary energy source
- Demonstration activities will be subject to 50% cost share
- Integration activities that are not full demonstrations but still target the energy efficiency of coupling solar thermal collection to thermal desalination will also be considered under this topic area

Concentrating Optics for Lower Levelized Energy Costs

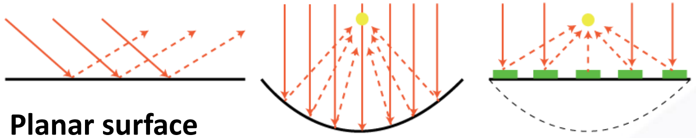
COLLECTS Awards



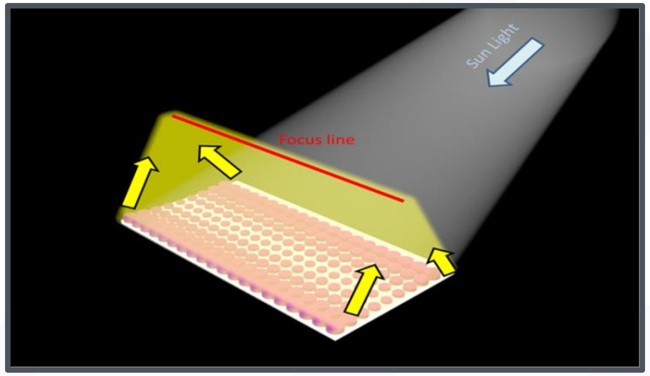
Metasurface planar reflectors

UC San Diego

PI: Prof. Boubacar Kante



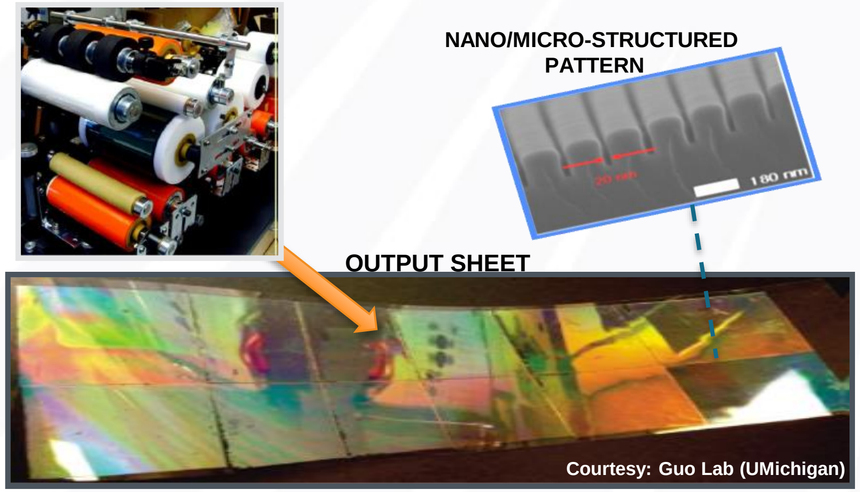
Planar surface **Parabolic mirror** **Planar Metasurface**



- Fabricated 1st generation TiO_2 metasurface with top-down etch process using PVD on a SiO_2 substrate.

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

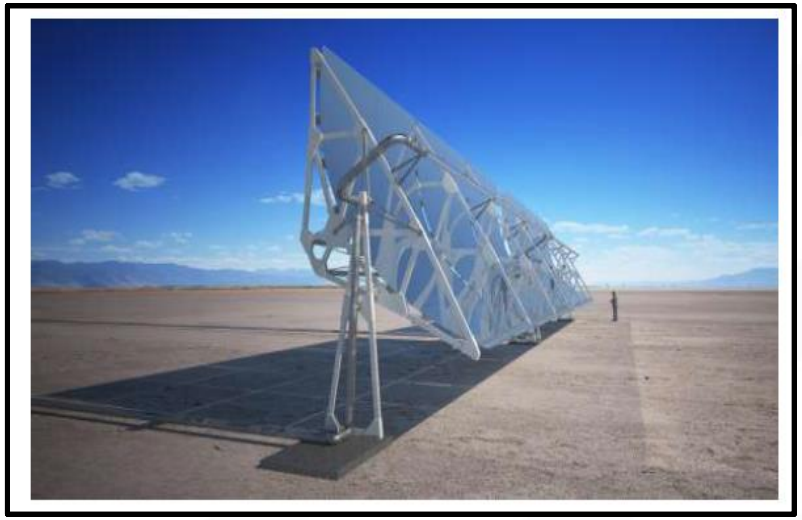
PI: Prof. Kimani Toussaint



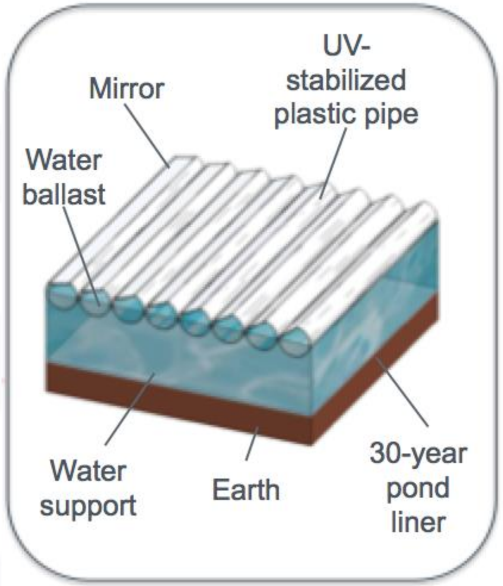
- 1st Generation PFC fabricated using different techniques (including solid-state superionic stamping) and characterized.
- Measured Hemispherical Reflectance for λ (400-700nm) of 84.5%.

Traditional Designs, New Materials

SUNVAPOR
RENEWABLE PROCESS HEAT



- Sunvapor is prototyping wood-based 'green' parabolic trough collectors (GPTC) to substantially reduce materials cost
- The 2 year project will culminate in on-sun testing of a full-scale prototype



Hyperlight® Energy

Hyperlight is reducing costs by redesigning a linear Fresnel field for an extruded polymer-based collector structure

Issues with water at current state-of-the-art

- **<u>Water Transport:</u>** Cost and energy associated with transporting water from a centralized water treatment facility for fresh water is high (~$0.05/m^3 for 100 m vertical lift or 100 km of flat horizontal transport).
- **<u>Water Location:</u>** Regional non-fresh water sources are more readily available and if utilized would reduce or eliminate the cost and energy demands of transporting clean water from one region to another.
- **<u>Energy Intensity and cost:</u>** The cost and energy associated with processing brackish or seawater is also high.
- **<u>Energy Efficiency:</u>** Current treatment centers and associated systems used, particularly the distributed ones are not energy efficient.
- **<u>Lack of Applications for Water Reuse:</u>** Approx. 290 billion gallons of water a day is discharged back into the ocean or other surface water locations instead of being recycled back. Non-"reuse" volume represents near 95% of total.
- **<u>Broader Systems Impacts:</u>** All above impact energy demand, resiliency and robustness from watershed to water use.

https://www.sierracollege.edu/ejournals/jsnhb/v6n1/null.html

Vast amounts of untapped water resources could be utilized if key technical challenges are addressed, including processing and purifying water in a low cost and energy-efficient manner.

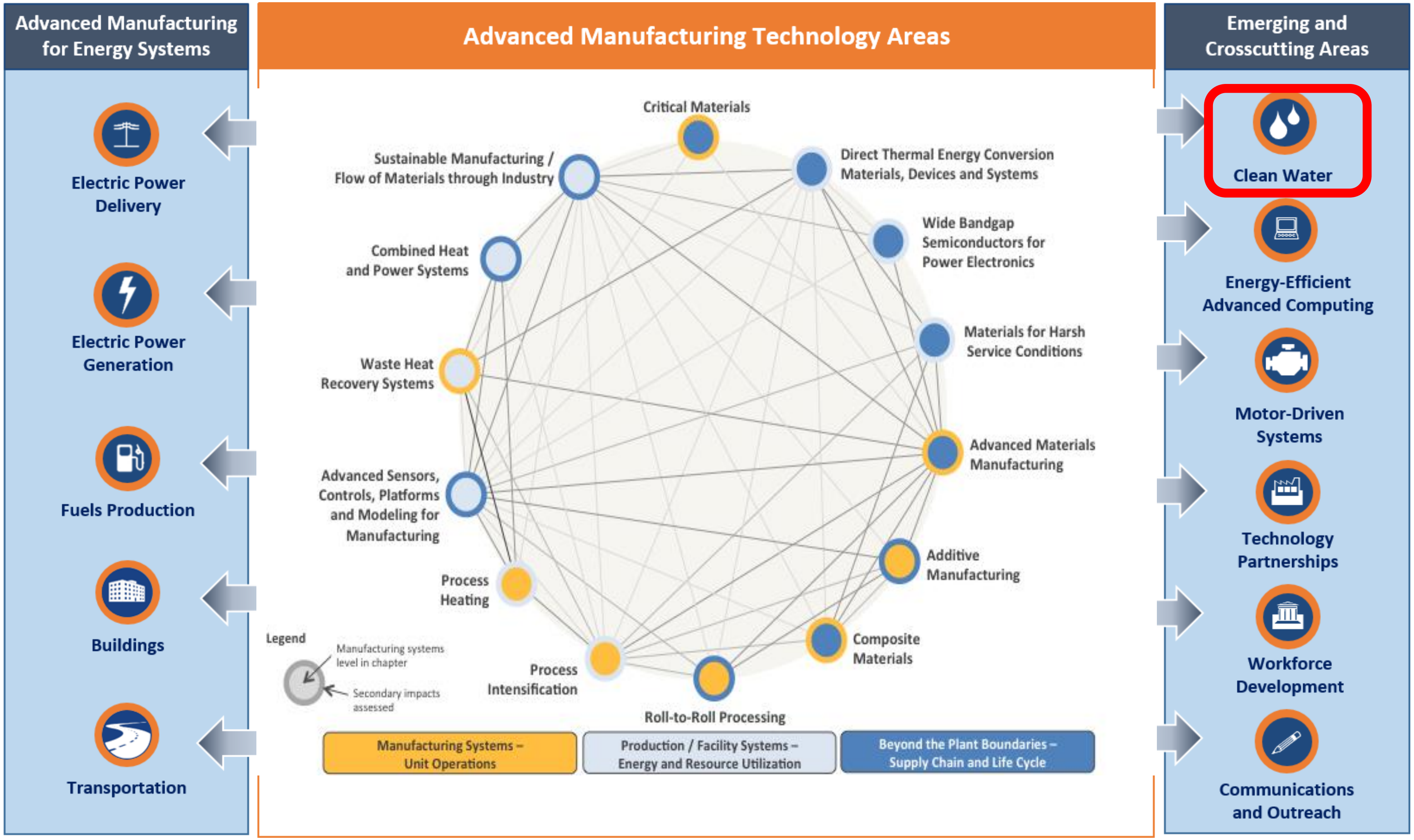
Advanced Manufacturing Office Multi-Year Program Plan

https://energy.gov/eere/amo/downloads/advanced-manufacturing-office-amo-multi-year-program-plan-fiscal-years-2017

AMO Strategic Goals	Example Clean Water Goals
Improve the productivity and energy efficiency of U.S. manufacturing.	Improve the productivity and energy efficiency of "water processing"
Reduce lifecycle energy and resource impacts of manufactured goods.	Reduce lifecycle footprint of processing water. [unit ops; facility; supply chain/watershed]
Leverage diverse domestic energy resources in U.S. manufacturing, while strengthening environmental stewardship.	E.g. - waste heat; renewables (connect to SETO FOA). Watershed; ZLD; co-products optimization; etc.
Transition DOE supported innovative technologies and practices into U.S. manufacturing capabilities.	Innovate: water for energy; energy for water; new/better uses for water in mfg.; water substitutes, etc.
Strengthen and advance the U.S. manufacturing workforce.	Manufacture of clean water technologies/products

AMO MYPP Framework and Clean Water

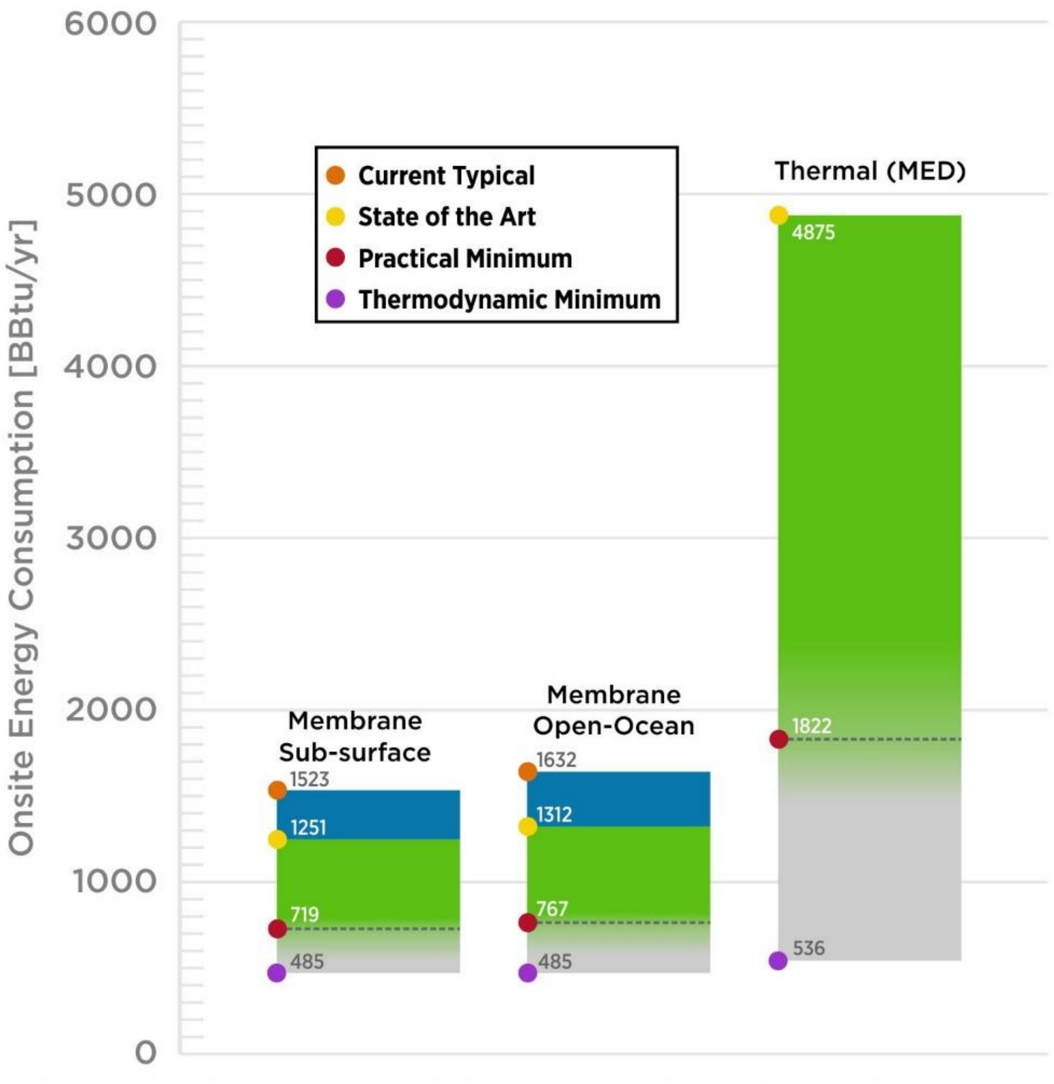
https://energy.gov/eere/amo/downloads/advanced-manufacturing-office-amo-multi-year-program-plan-fiscal-years-2017



Manufacturing Technology Assessments can be found here:

https://energy.gov/under-secretary-science-and-energy/quadrennial-technology-review-2015-omnibus#chap6ta

Energy Consumption and Savings Opportunity for 3 Systems

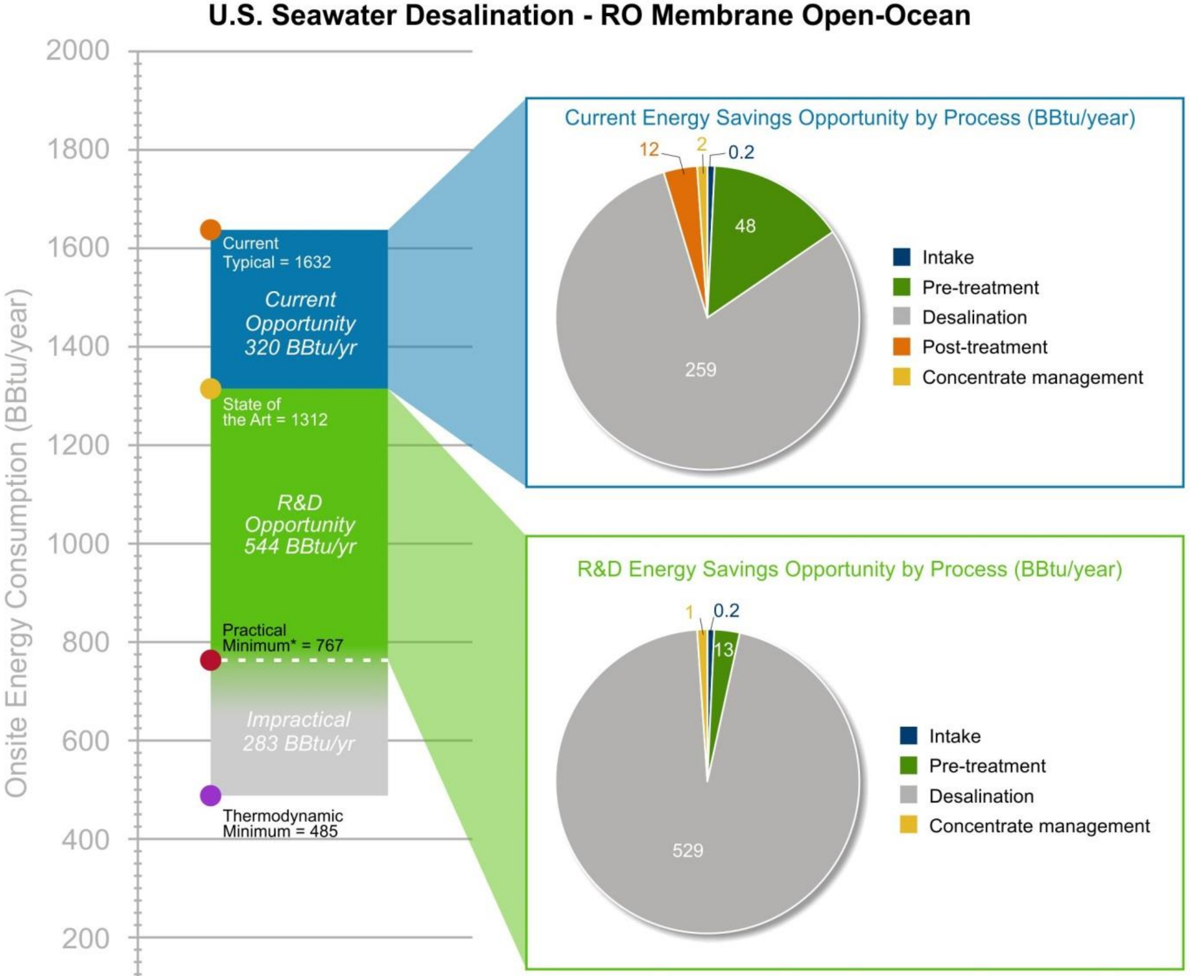


Membrane Sub-surface: RO-based w/ subsurface intake operating at 50% recovery of 500 ppm (0 ppm for TM) product water from 35,000 ppm feedwater

Membrane Open-Ocean: RO-based Open ocean intake at 50% recovery of 500 ppm (0 ppm for TM) product water from 35,000 ppm feedwater

Thermal: MED-based system at 35% recovery of <25 ppm (0 ppm for TM) product water from 45,000 ppm feedwater

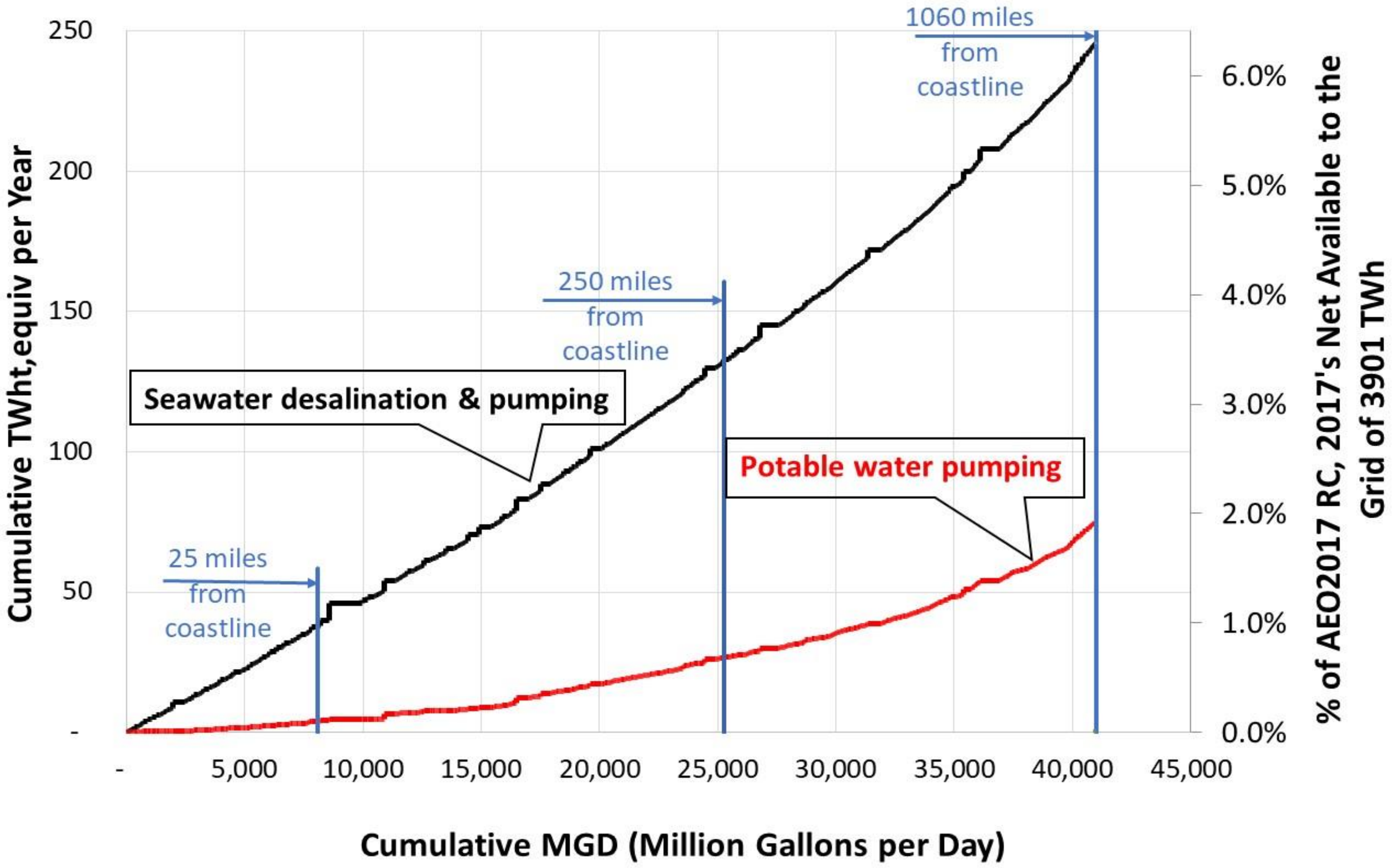
Desalination Technology Example:
Energy Savings Opportunity for RO system w/Open Ocean Intake



CT, SOA, TM operating conditions: RO-based system at 50% recovery of 500 ppm (0 ppm for TM) product water from 35,000 ppm feedwater. PM operating conditions: semi-batch RO-based system at 42% recovery of 379 ppm product water from 36,357 ppm feedwater.

- **91% of the energy saving opportunity is in the desalination operation**
- **Pretreatment offers the next largest opportunity (7%)**
- **Much of U.S. production already operating at SOA conditions**

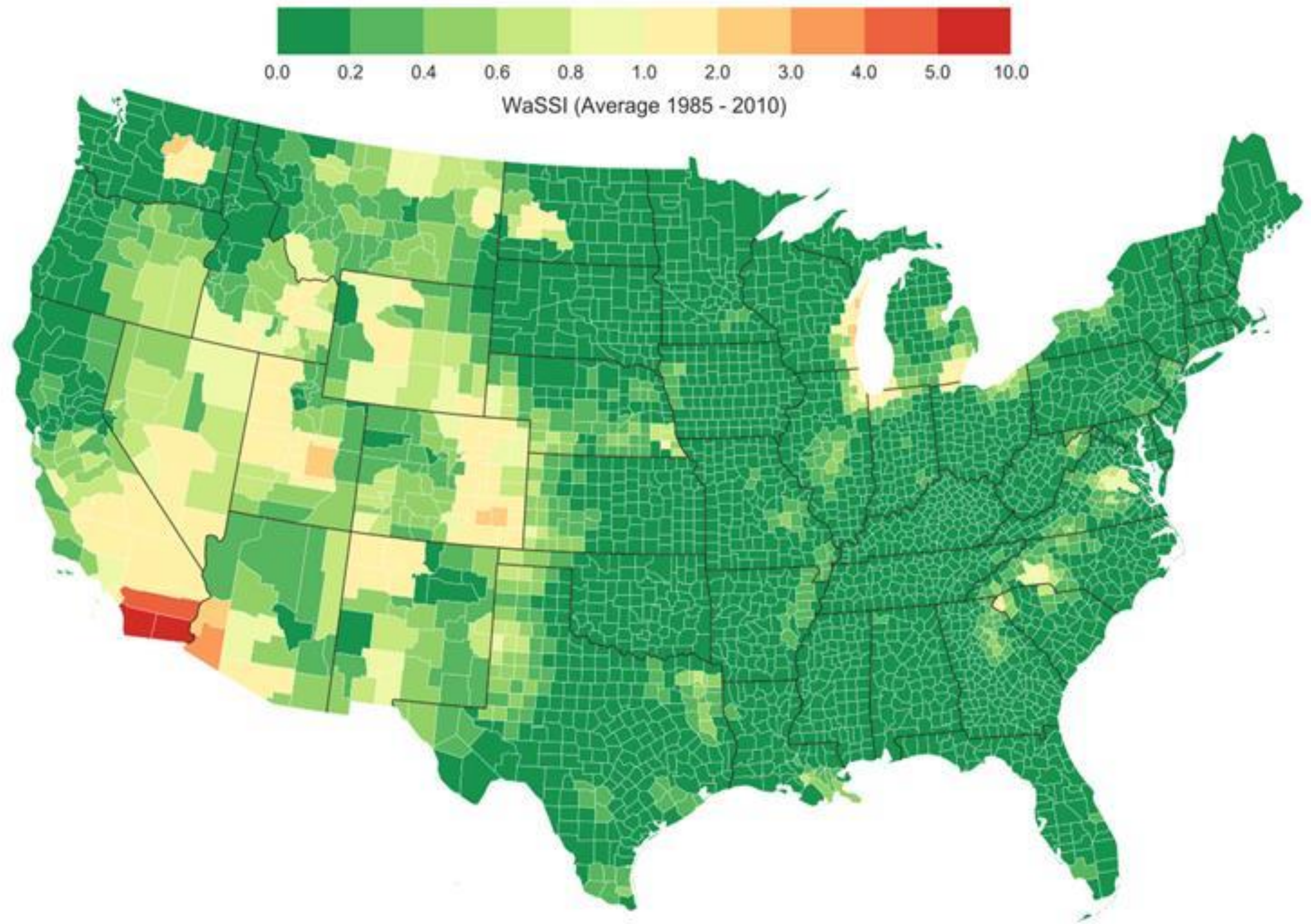
Scenario 1: Supplying All Municipal Water



Though impractical, sourcing all U.S. municipal water from seawater would represent ~**6% of projected 2017 electricity production**.

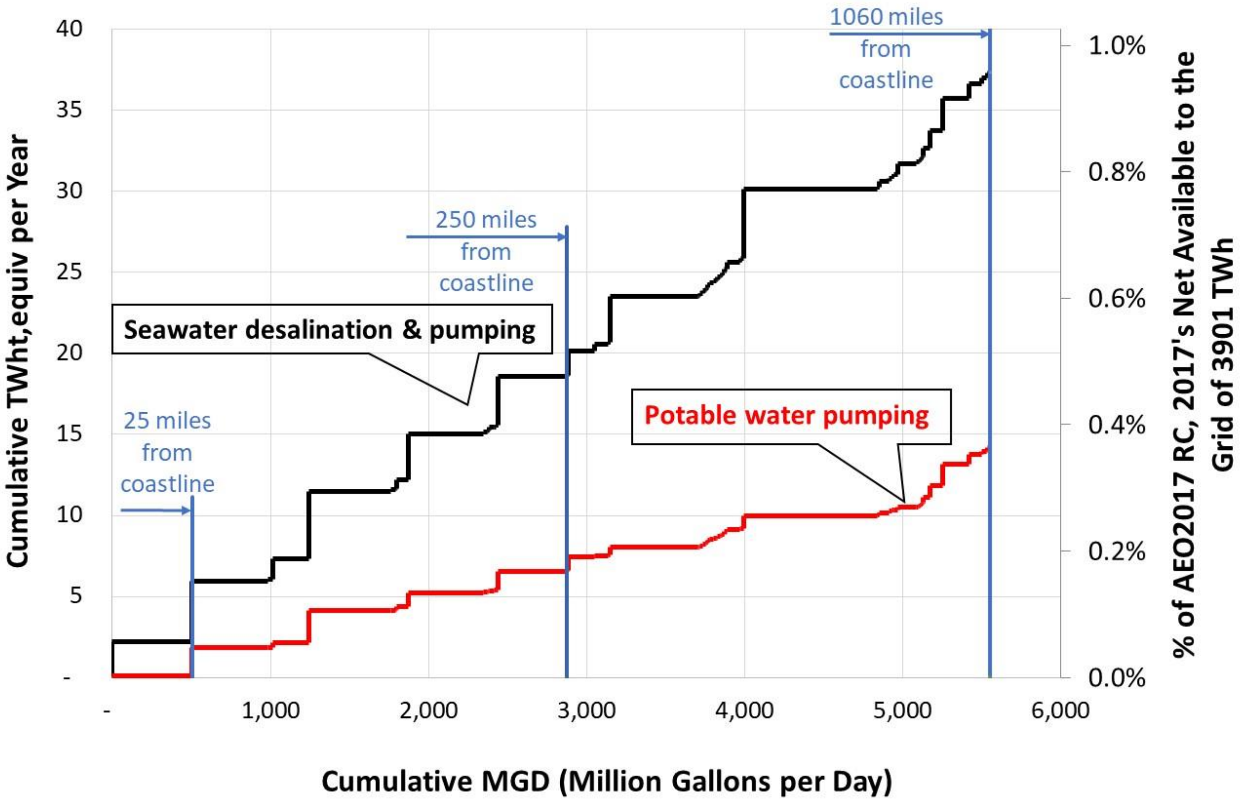
Provides an upper bound for seawater desalination impact on electric grid

Water Supply Stress Index



WaSSI estimated using *WaSSI Ecosystems Services Model* by NC State, USDA, and US Forest Service

Scenario 2: Supplying Water Stressed Counties



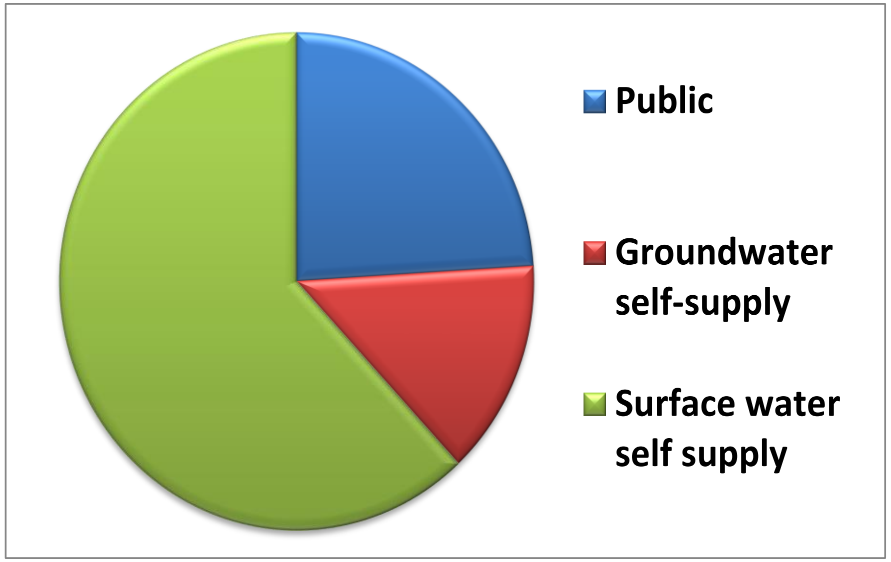
Supplying public water for counties with WaSSI > 1 and 250 miles from a coastline would require **0.5% of projected 2017 electricity production**

More likely that these counties would diversify water sources and some could meet a portion of their public water demand from seawater.

Industrial water use in 2010

75% (~16,000 MGD) is estimated to be self supplied (e.g. onsite surface or ground)

- Mostly freshwater; only 6% saline
- Down 12% from 2005
- Down 38% from 1985



25% (~5,000 MGD) is estimated to be supplied from public supply

- USGS stopped estimating public supply by end use sector after 1995
- Assumed, based on 1995 estimates, that 12% of public supply is for industry

Estimates based on USGS data

Water rates in the US – wide range, but relatively low cost

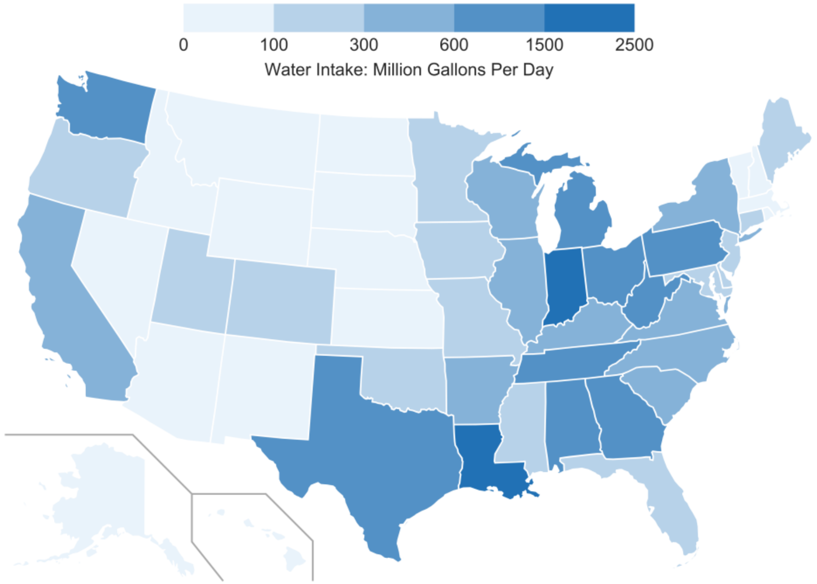
Water costs (cost to industrial customers)

Water Supply		
City, State	**Water Authority**	**Range of water supply rate (per m^3)**
Asheville, NC	City of Asheville	\$0.64 - \$1.17
Hartford, CT	Metropolitan District Hartford, CT	\$0.94
Kansas City, MO	Kansas City Water Services	\$0.97 - \$1.68
Los Angeles, CA	LA Department of Water and Power	\$1.68 - \$2.27
Milwaukee, WI	Milwaukee Water Works	\$0.41 - \$0.70
San Antonio, TX	San Antonio Water System	\$0.52 - \$0.91
Virginia Beach, VA	City of Virginia Beach	\$1.16

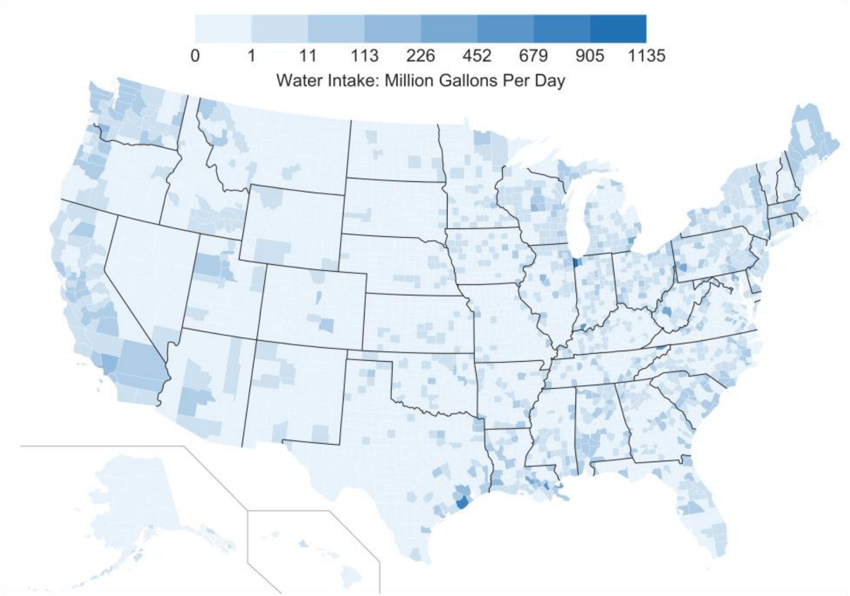
Rates taken from water authority website winter of 2016
Base and seasonal charges are not included
For more details see: DOE. 2016. Developing a Corporate Water Management Strategy for Manufacturers.

Geographic Spread of U.S. Manufacturing Water Withdrawal (Estimated)

State



County



Estimates based on USGS data

Issues with U.S. Manufacturing Water Data Availability

- Water use conservation driven by risk mitigation within the manufacturing sector
- Little to no data on U.S. manufacturing water use and related characteristics
  - Limited to USGS 5-year estimates
  - Some data at individual state level or by sector
- Water use issues and risk are a local phenomena requiring data at the watershed level
  - Research based on broad national data may not target at-risk industries

Need for better data

Analysis Approach

Leverage existing data sets to:

Quantify manufacturing water withdrawals and consumption at the national, state, and county-levels broken down by sector using Canadian water and economic, USGS, and U.S. Economic Census data

↓

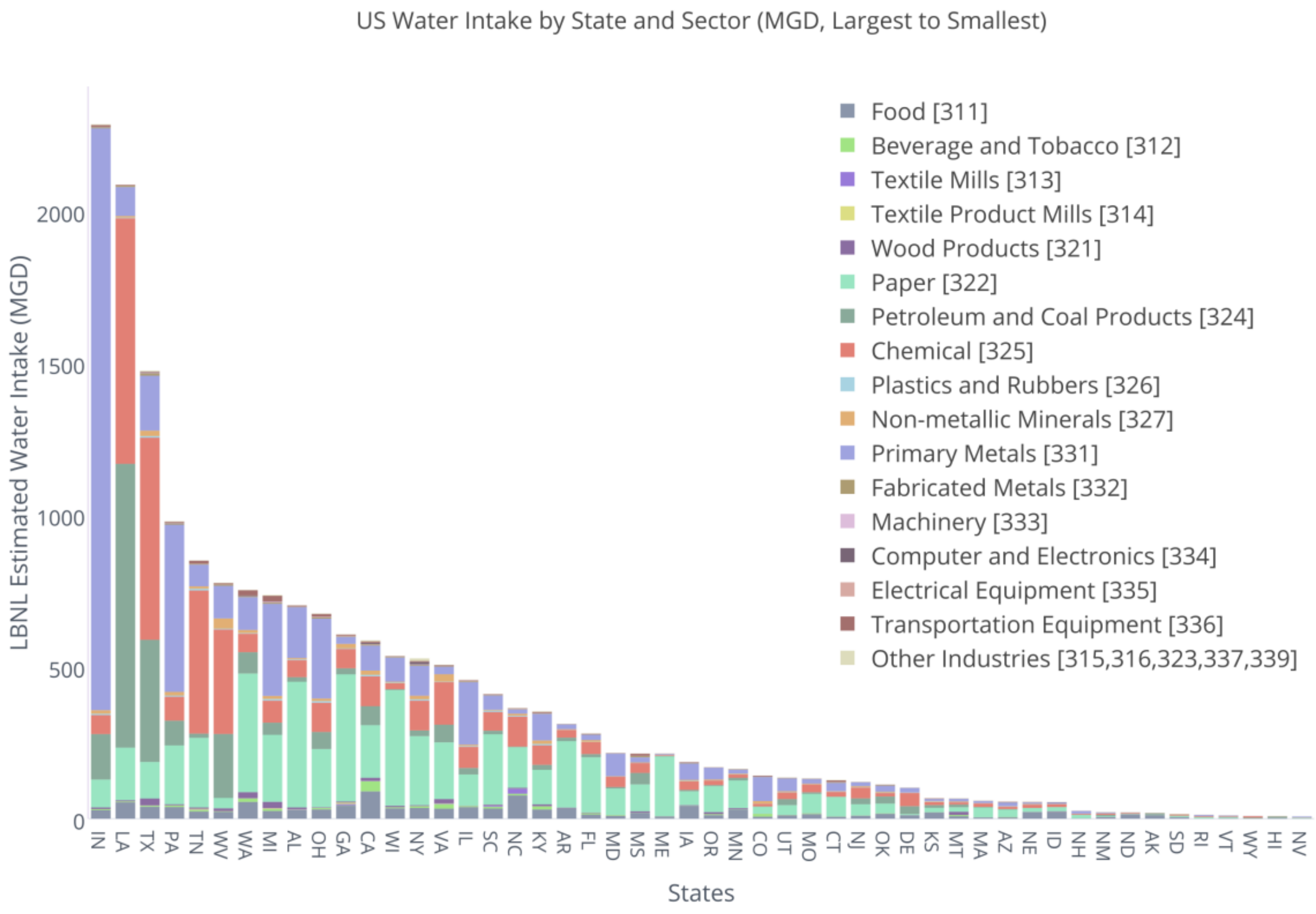
Identify sectors at-risk, defined as those sectors with large footprints in areas with long-term over-usage of locally available water supplies

↓

Use the results from 1 and 2 to identify sectors for subsequent Energy-Water Bandwidth Studies and other manufacturing water use-related research

For further details on methods and results for estimates presented on slides 36-38, see: Rao, P., Sholes, D., Morrow, W.R., and J. Cresko. 2017. "Estimating U.S. Manufacturing Water Use". American Council for an Energy Efficient Economy Summer Study on Energy Efficiency in Industry. Denver, CO. August 16 – 18.

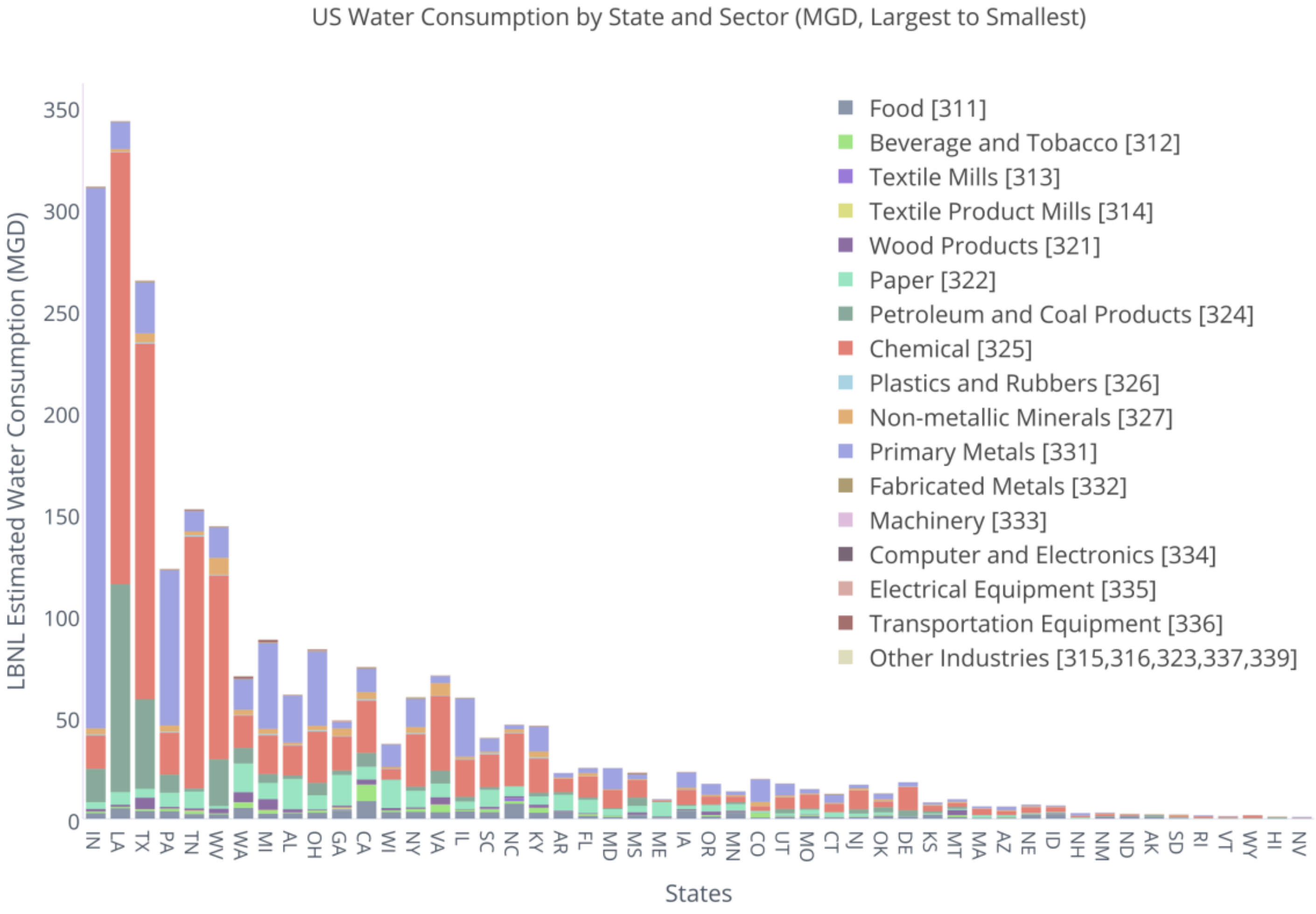
U.S. Manufacturing Water Withdrawals by Sector and State



Allows for better understanding of water use distribution:

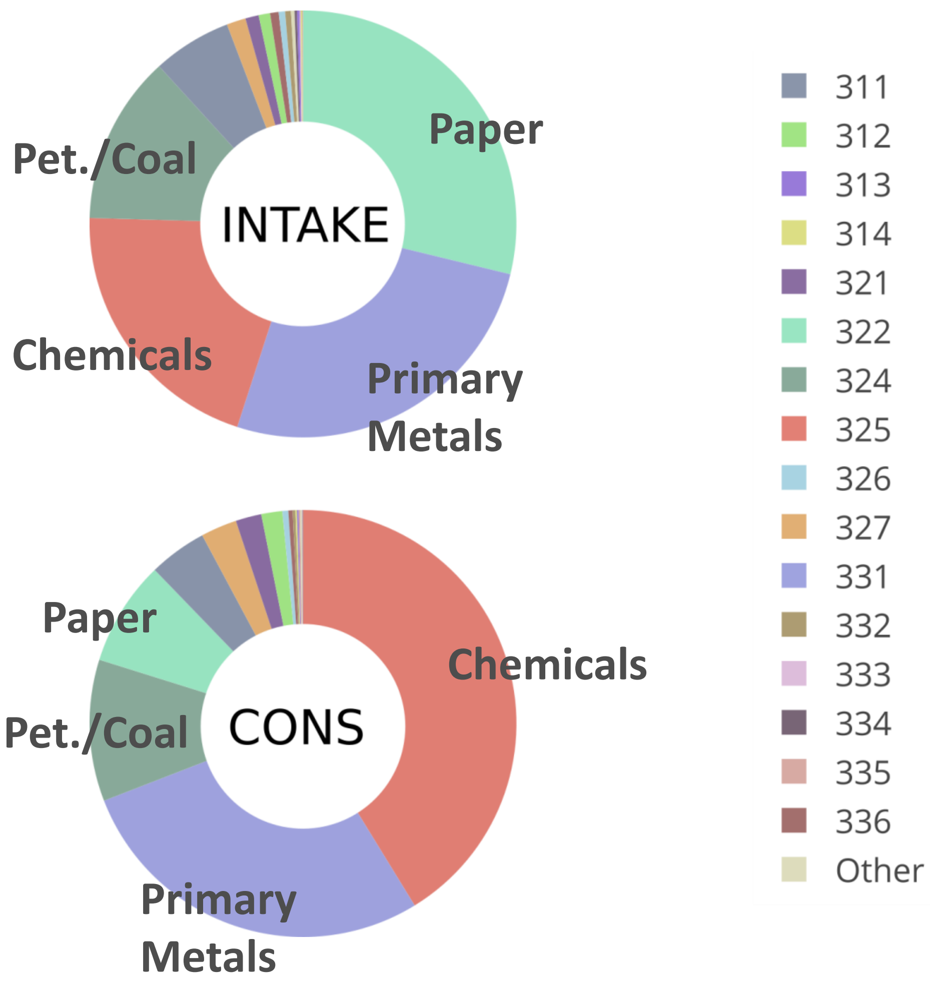
- IN and LA estimated to have the largest annual withdrawals
- Withdrawals in some states dominated by single industry (i.e., primary metals in IN, paper & pulp in ME)
- Other states have more diversity in their water withdrawals (e.g., MI, TX, NC)

U.S. Manufacturing Water Consumption by Sector and State



- Consumptive use will have greater impact on operational risk than withdrawals
- LA has highest amount of consumptive use
- Two of the top ten states in terms of consumption are drought prone (CA and TX)

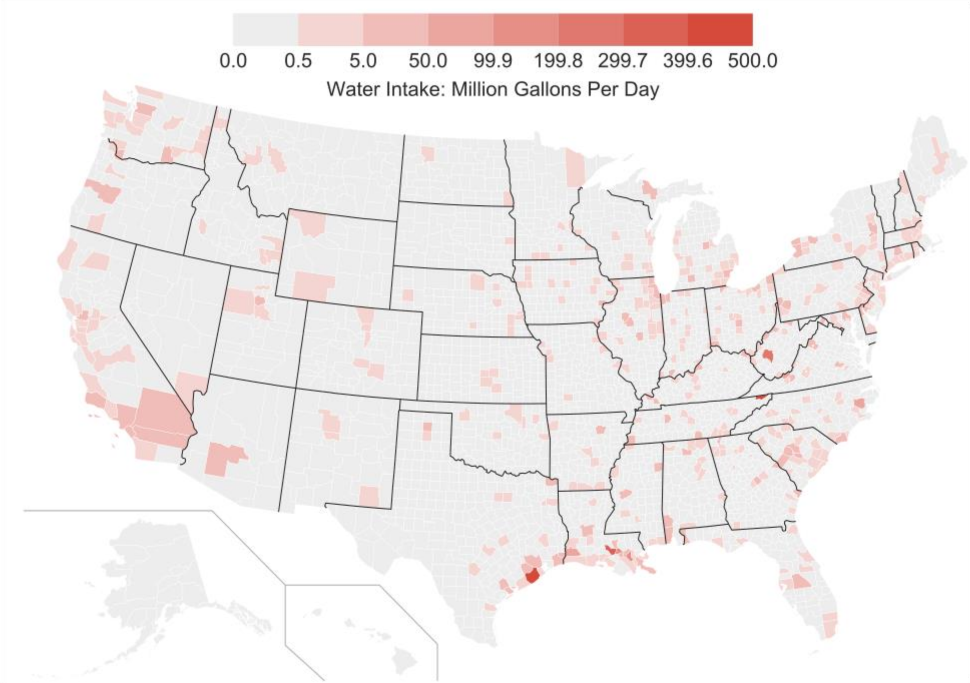
U.S. Manufacturing Water Withdrawals and Consumption



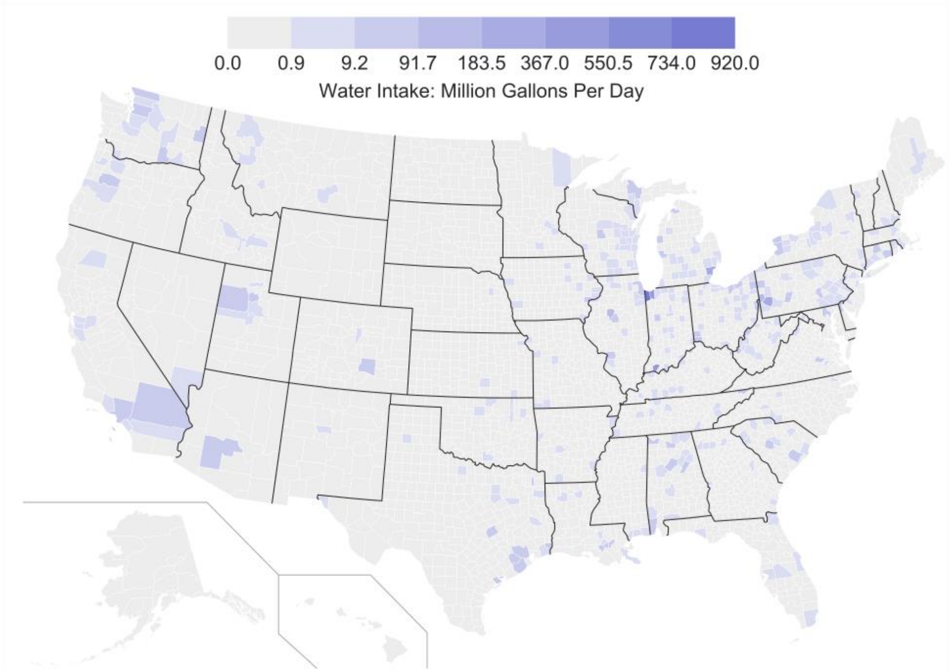
311	Food manufacturing
312	Beverage and tobacco product manufacturing
313	Textile mills
314	Textile product mills
321	Wood product manufacturing
322	Paper manufacturing
324	Petroleum and coal product manufacturing
325	Chemical manufacturing
326	Plastics and rubber products manufacturing
327	Non-metallic mineral product manufacturing
331	Primary metal manufacturing
332	Fabricated metal product manufacturing
333	Machinery manufacturing
334	Computer and electronic product manufacturing
335	Electrical equipment, appliance and component manufacturing
336	Transportation equipment manufacturing
Other	Other Industries

Water Withdrawals by Sector and County

325 - Chemicals



331 – Primary Metals



Evaluation of Sector Water Use “At-Risk”

Sectors in red are those that have the highest share of their water use in locations with WaSSI > 1 (i.e., locations where total water use exceeds local supplies)

Manufacturing Sector	Estimated % Water Intakewithin each WaSSI Bin				
	[0.0,0.2)	[0.2,0.4)	[0.4,0.8)	[0.8,1.0)	[1.0,inf)
Food	72	11	7	3	7
Beverage and Tobacco Product	71	9	11	2	6
Textile Mills	80	9	4	6	2
Textile Product Mills	88	5	2	2	3
Wood Product	84	6	3	6	2
Paper	79	8	5	1	6
Petroleum and Coal Product	52	29	9	1	**9**
Chemical	66	25	5	1	3
Plastics and Rubber Products	71	13	5	3	**9**
Non-metallic Mineral Product	68	11	6	7	**8**
Primary Metal	52	8	5	1	**35**
Fabricated Metal Product	68	14	6	3	**10**
Machinery	70	15	6	2	**8**
Computer and Electronic Product	68	13	8	5	7
Electrical Equipment	76	12	5	3	5
Transportation Equipment	72	9	6	2	**10**
Other Industries [315,316,323,337,339]	74	10	3	4.	8

NARUC Winter Policy Summit

Joint Session of The Committee on Energy Resources and the Environment and The Committee on Water