NMSU College of Engineering Dean's Advisory Council

February 23, 2018

Development of Alternative Water Supplies – Water Reuse and Desalination

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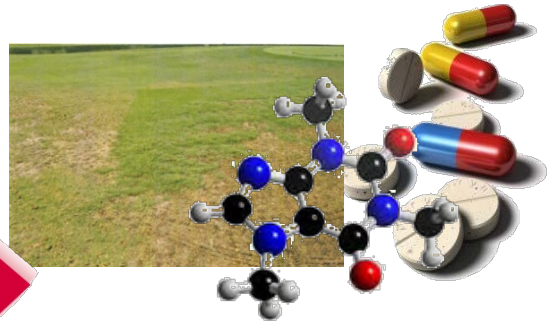
Development of Alternative Water Supplies is Crucial for Water Security

Water Conservation

Elevated Salinity
High sodium adsorption ratio

Water Scarcity

Water Reuse



Contaminants of emerging concerns

Desalination

Concentrate

Challenges of Alternative Water Supplies

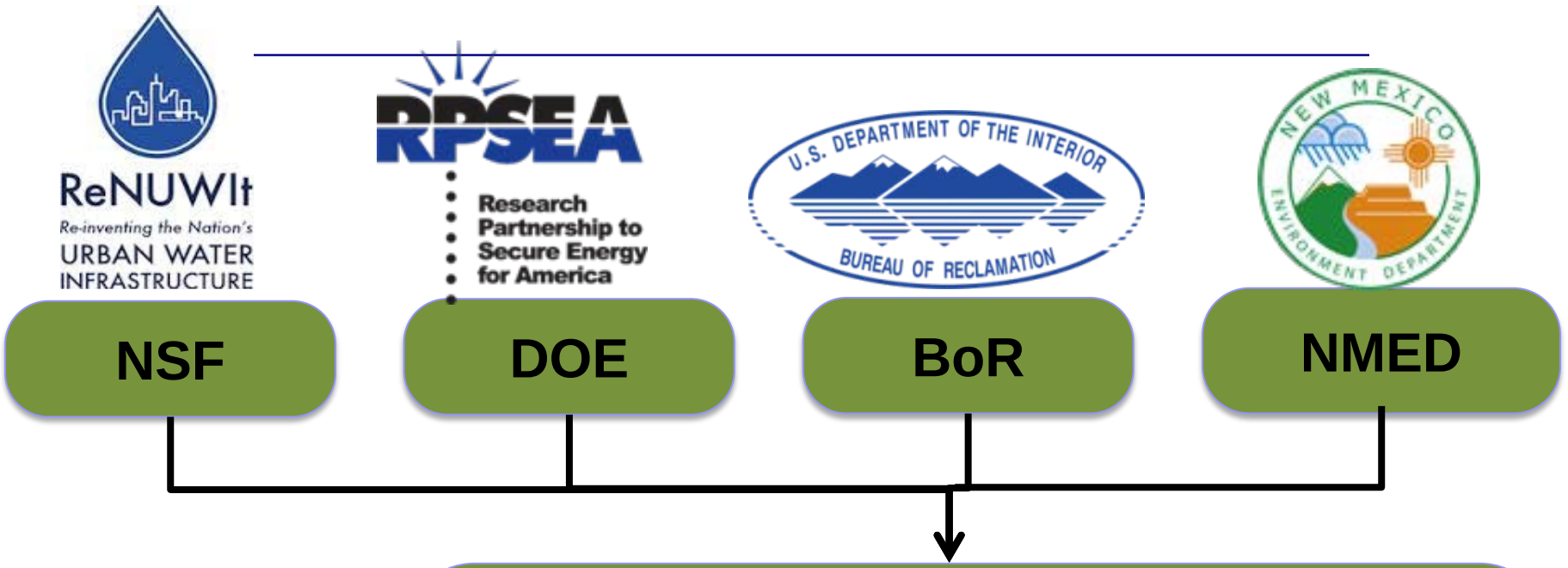
- Water quality concerns
- Intensive energy use
- Concentrate and waste management

Need Innovative Approaches

Short-term solutions: Modify and optimize current technologies

Long-term solutions: Develop next generation of technologies

Research Areas



NMWRRI

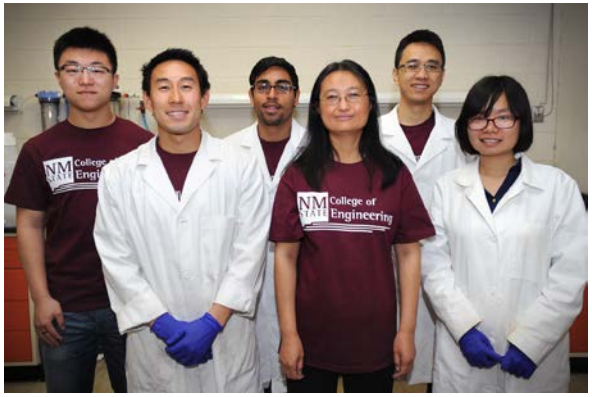
Industry /Water Utilities

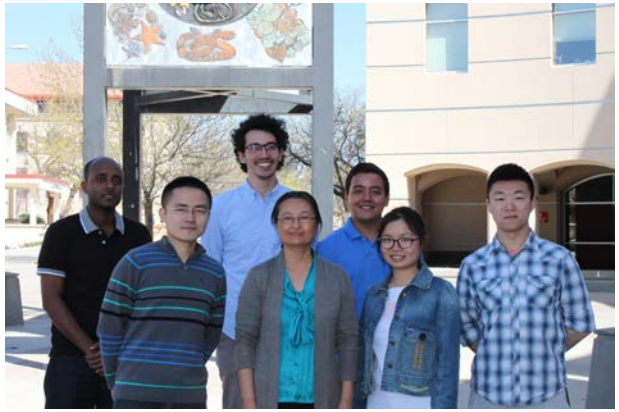
Sustainable Water and Wastewater Systems for

- Wastewater treatment and reuse
- Membrane processes & desalination
- Water and energy
- Resources recovery

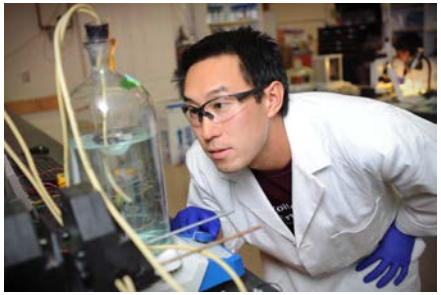
Funding and Research Group

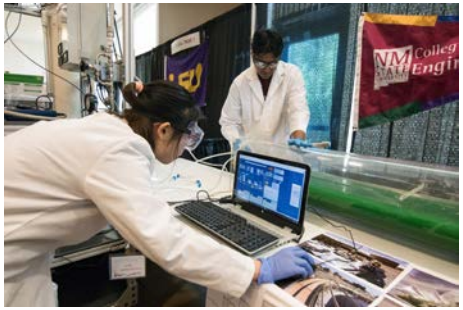
- $3M funding since 2013, averaging $0.5M per year
- Current research group
  - 2 full-time postdocs
  - 1 senior researcher
  - 4 PhD students
  - 3 Master graduate students
  - Undergraduate students
- Peer-reviewed journal publications: 5 to 8 per year

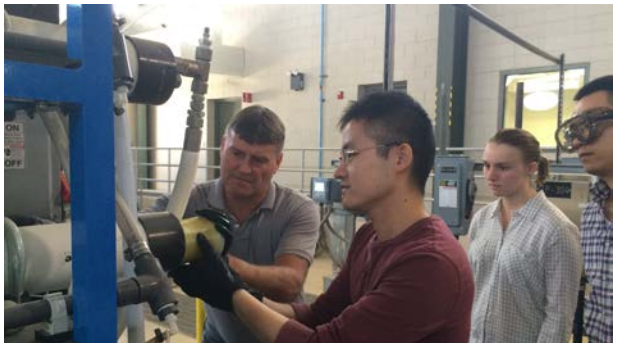




From Fundamental Laboratory Study to Field Demonstration Testing







Highlights of Research Projects

- Selective electrodialysis for non-potable water use, e.g., irrigation and thermal power plant cooling water
- Hybrid algal-membrane system for potable water reuse
- Produced water treatment and beneficial reuse

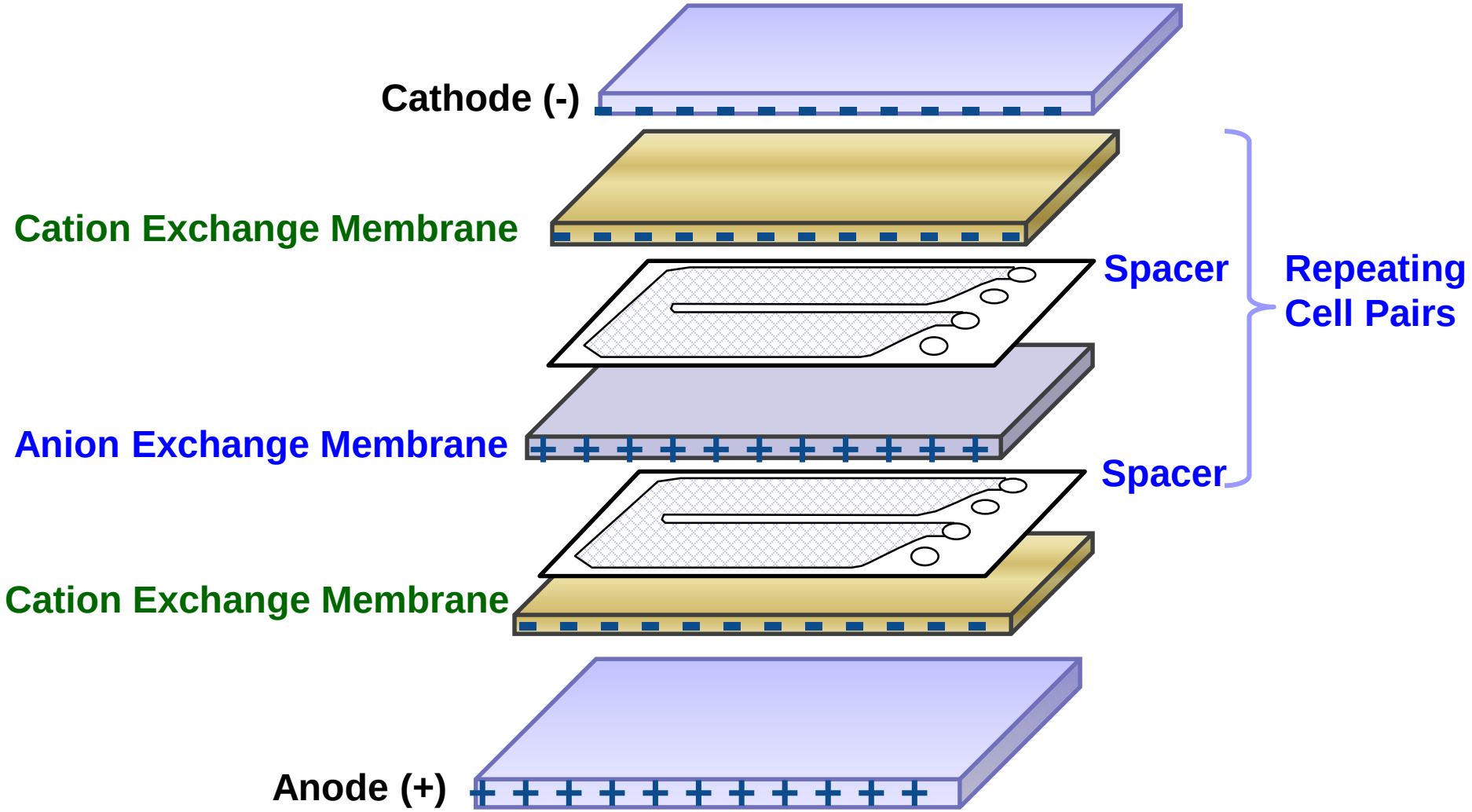
High Sodium to Hardness Ratio Resulted in Reuse Challenges

- SAR = Sodium Adsorption Ratio

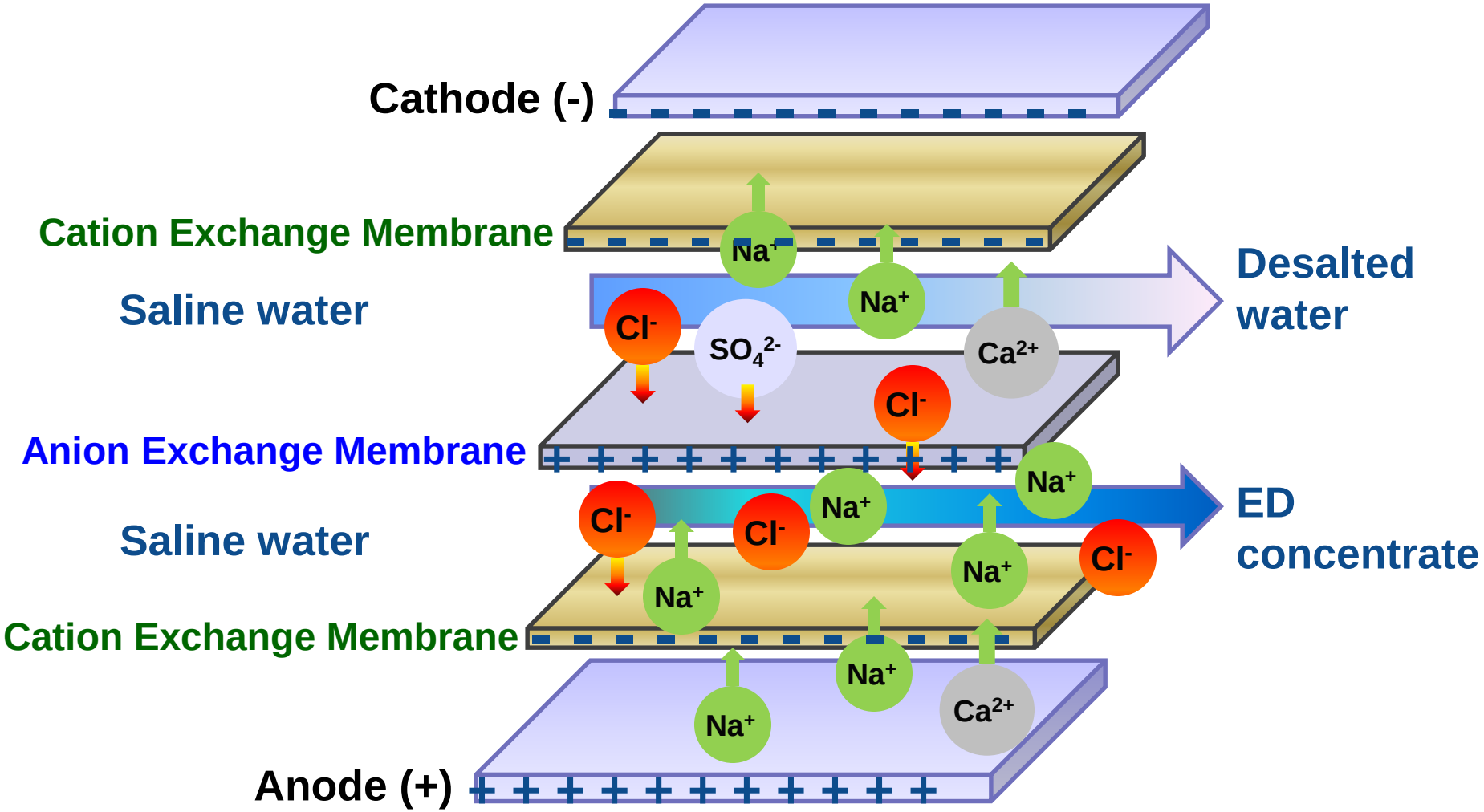
$$SAR = [Na^{+}] / \{([Ca^{2+}] + [Mg^{2+}]) / 2\}^{1/2}$$ (use meql units)

≤3	6 to 9	> 9

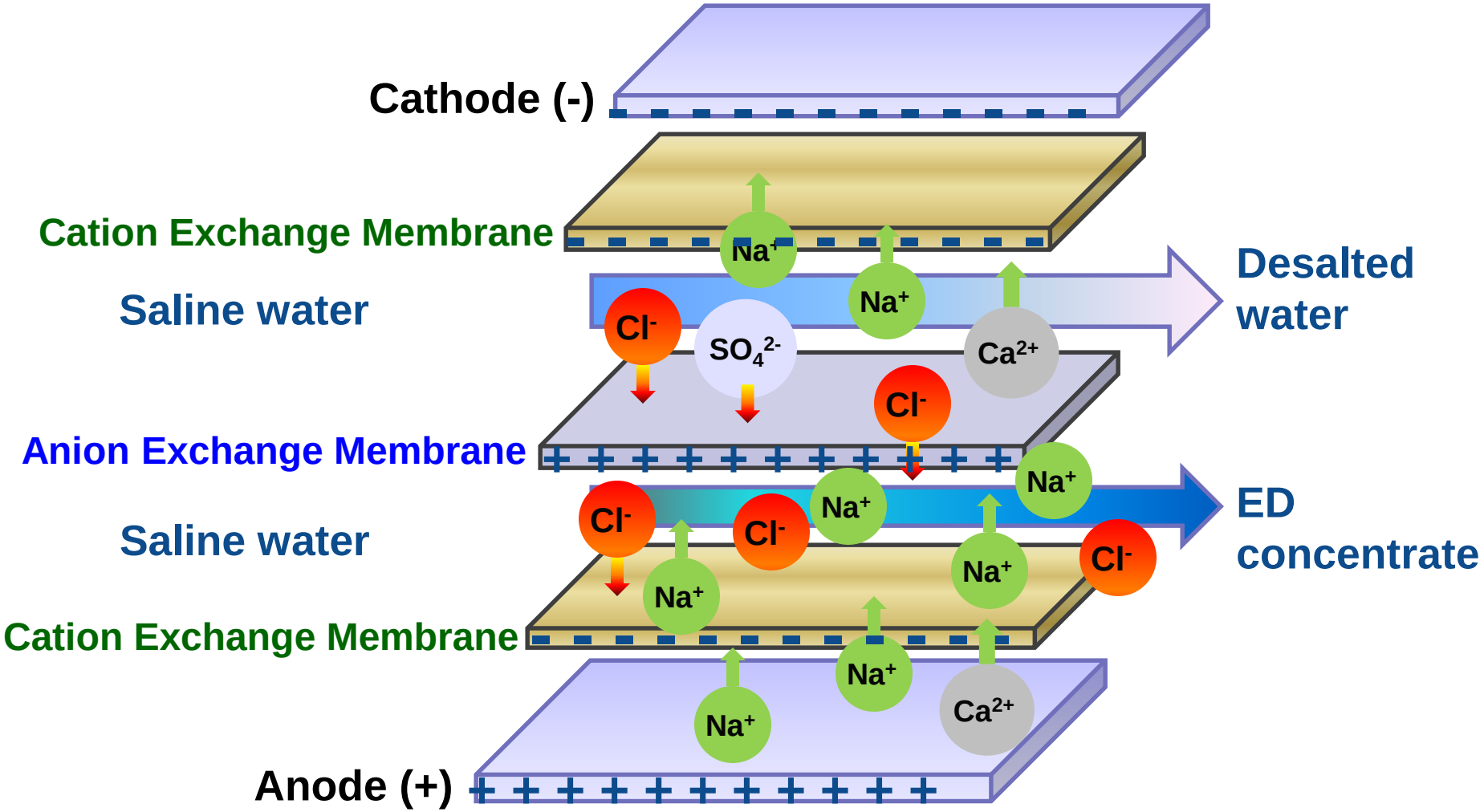
Electrodialysis Consists of Electrodes and A Stack of Membrane Cell Pairs



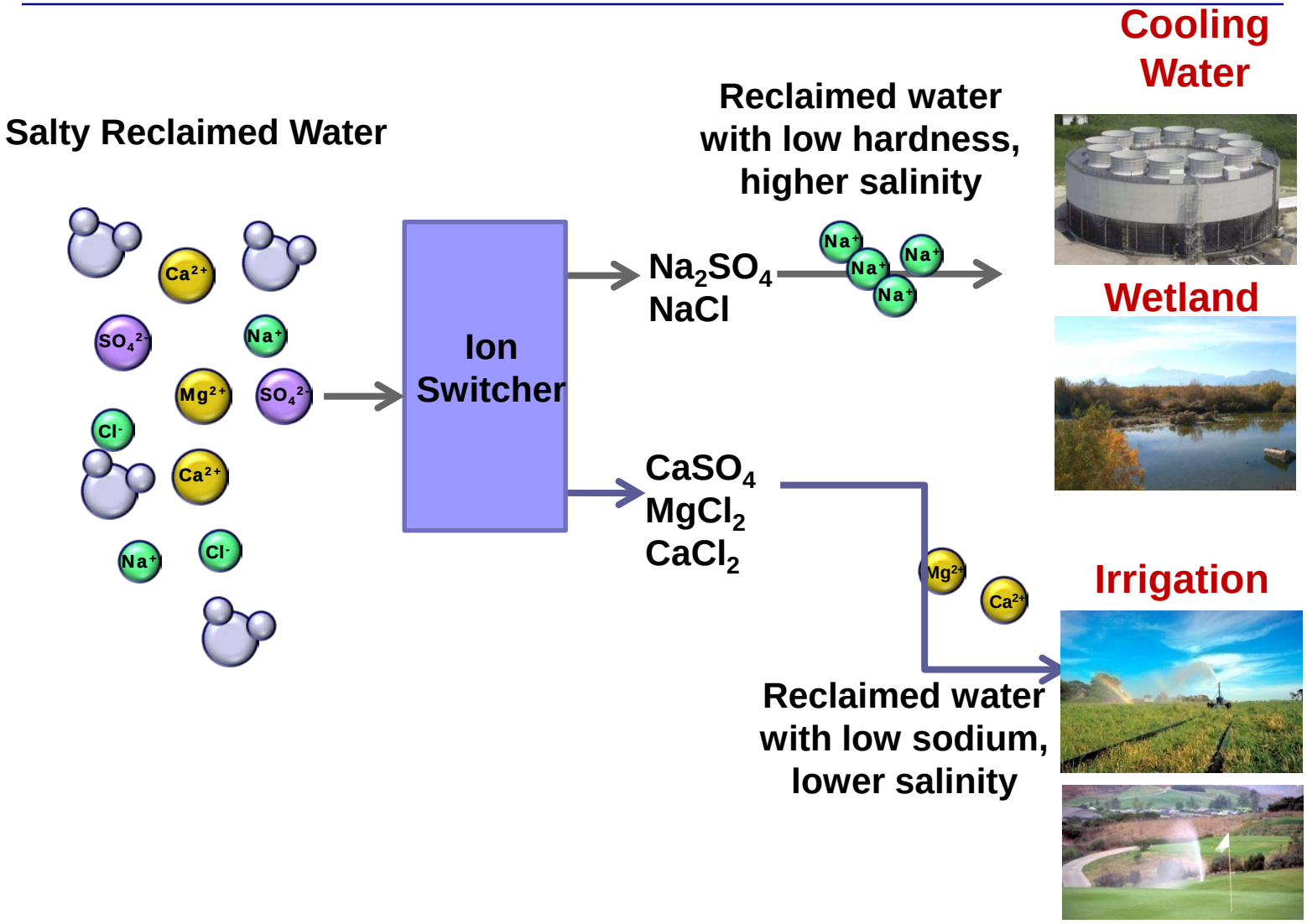
Electrodialysis with Normal Grade IX Membranes Remove All Cations and Anions



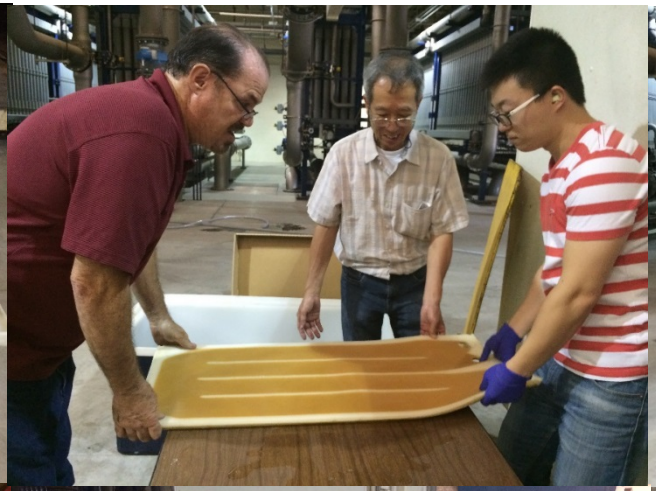
Electrodialysis with Selective IX Membranes Remove Preferentially Monovalent Ions



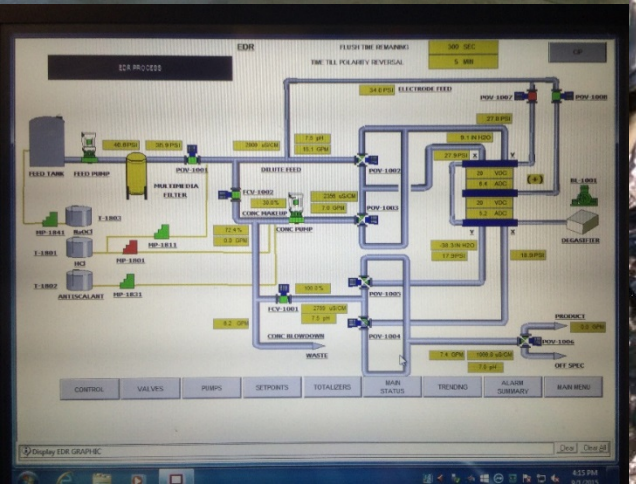
Selective Electrodialysis for ZLD of Reclaimed Water



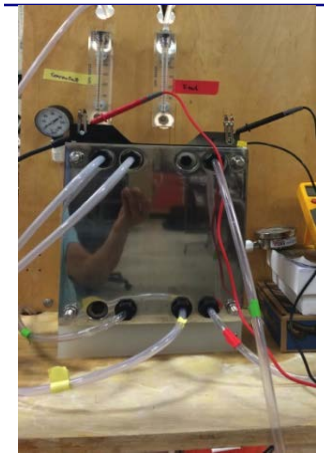
Selective Membrane Coating



Pilot Site Development



Modeling and Full Scale Design



Bench Testing

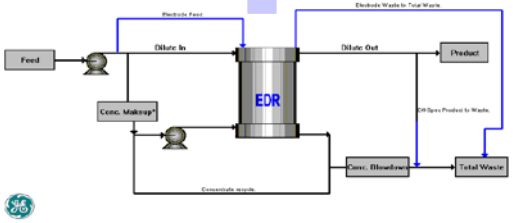
Pilot Testing

Minitab 17

Data Fitting and Mathematical Modeling

BLUE PLAN-IT™
DECISION SUPPORT SYSTEM

Water and Salt Balance, Process Modeling
Cost Analysis



WATSYS: Specialty EDR Projection Model by GE
(Normal Grade Membrane Only)

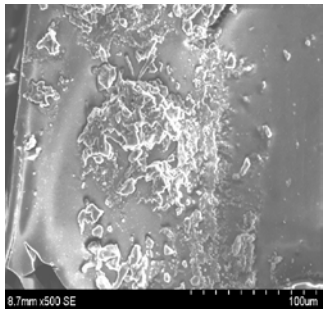
Full Scale Design

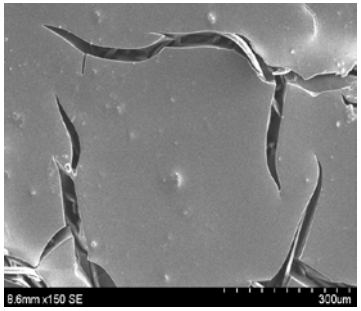
Scottsdale Blending Analysis and Cost Comparison – 1 MGD Reclaimed Water

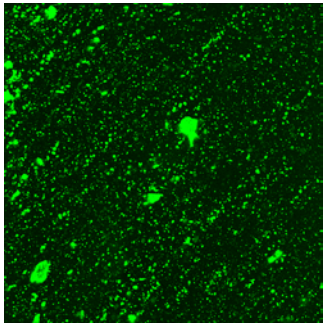
	Baseline Alternative	Alternative 1A	Alternative 1	Alternative 2
	UF + RO	Normal EDR - WATSYS	Normal EDR - Testing	Selective EDR
Feed Water Flow (mgd)	1			
Feed Water Sodium (mg/L)	235			
% Flow Treated	60.5%	69.0%	78.0%	57.5%
Overall Recovery	88%	93%	92%	94%
Unit Recovery	**85%**	**90%**	**90%**	**90%**
Blended Water Flow (mgd)	0.88	0.93	0.92	0.94
Product Water Sodium (mg/L)	110			
Product TDS (mg/L)	530	522	433	634
Concentrate Flow (gpm)	60	48	54	40
Concentrate TDS (mg/L)	7530	9662	9662	9662
Concentrate Sodium (mg/L)	1524	1927	1715	2287
Number of Product Line	-	7	6	6
Number of Stages	-	4	4	4
Capital ($/gpd product flow)	$6.1	$6.5	$7.6	$6.5
O&M ($/kgal)	**$1.09**	**$0.88**	**$0.83**	**$0.81**

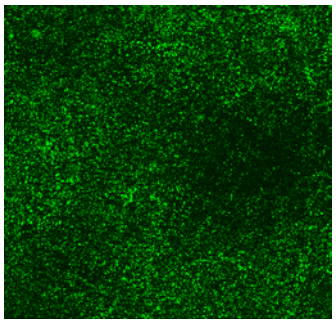
26% cost reduction using selective electrodialysis

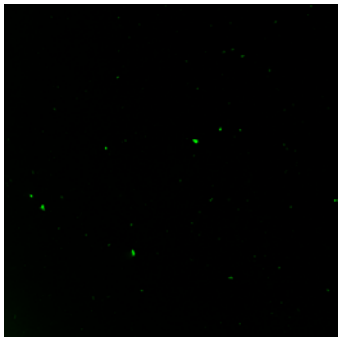
Development of Antifouling Ion-exchange Membranes

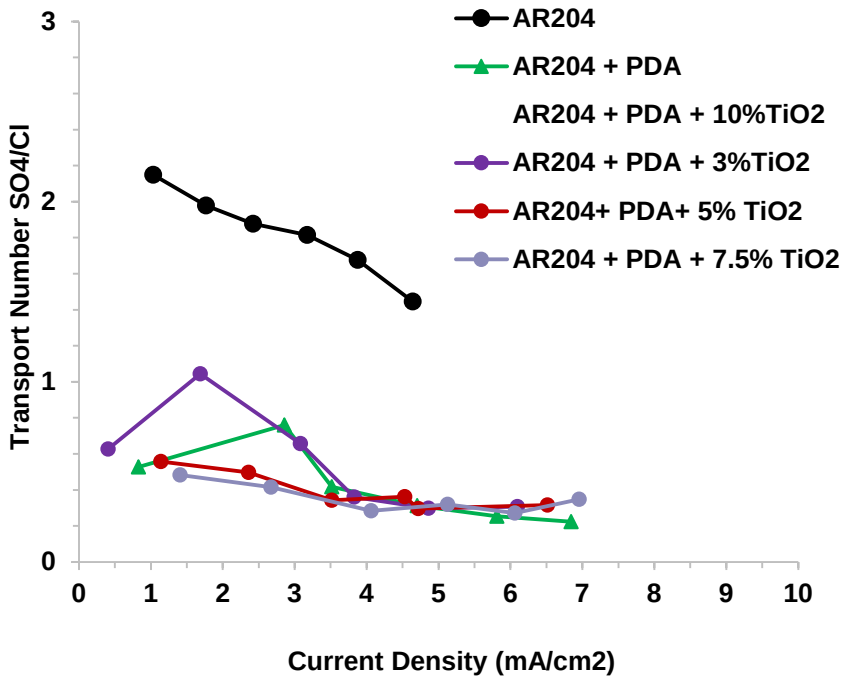


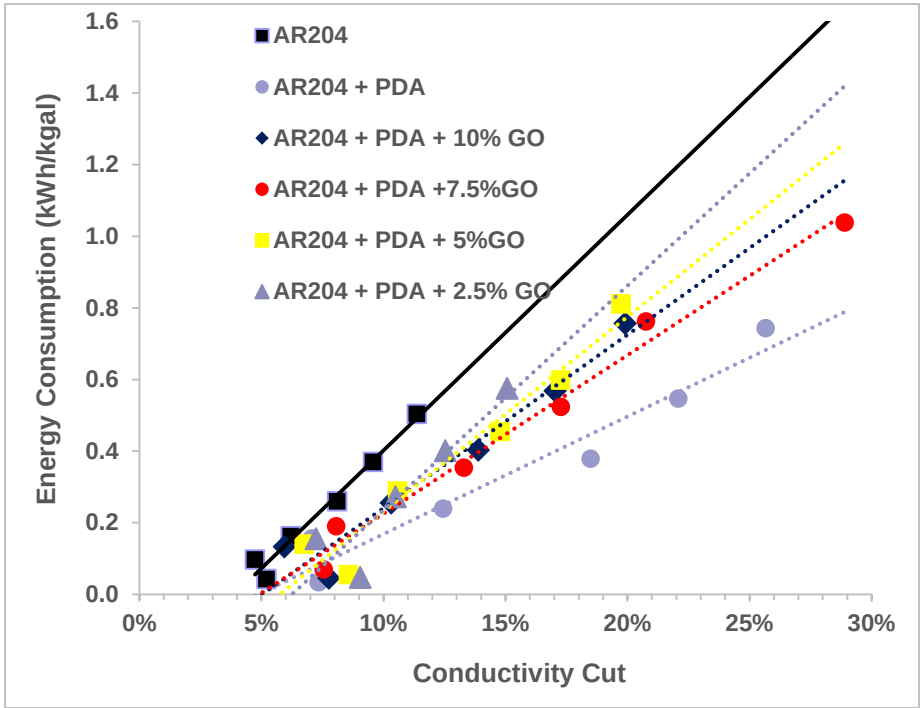












Highlights of Research Projects

- Selective electrodialysis for non-potable water use, e.g., irrigation and thermal power plant cooling water
- Hybrid algal-membrane system for potable water reuse
- Produced water treatment and beneficial reuse

Treatment Technologies Leading to Potable Water Reuse

Primary&Secondary treatment

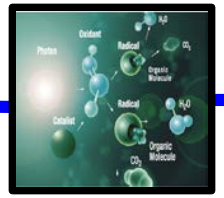
Tertiary filtration

Disinfection

Microfiltration

Degas/Lime

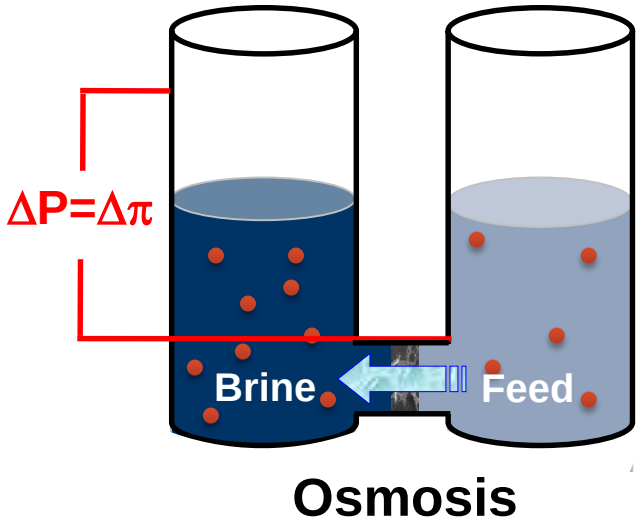
Advanced Oxidation



Injection

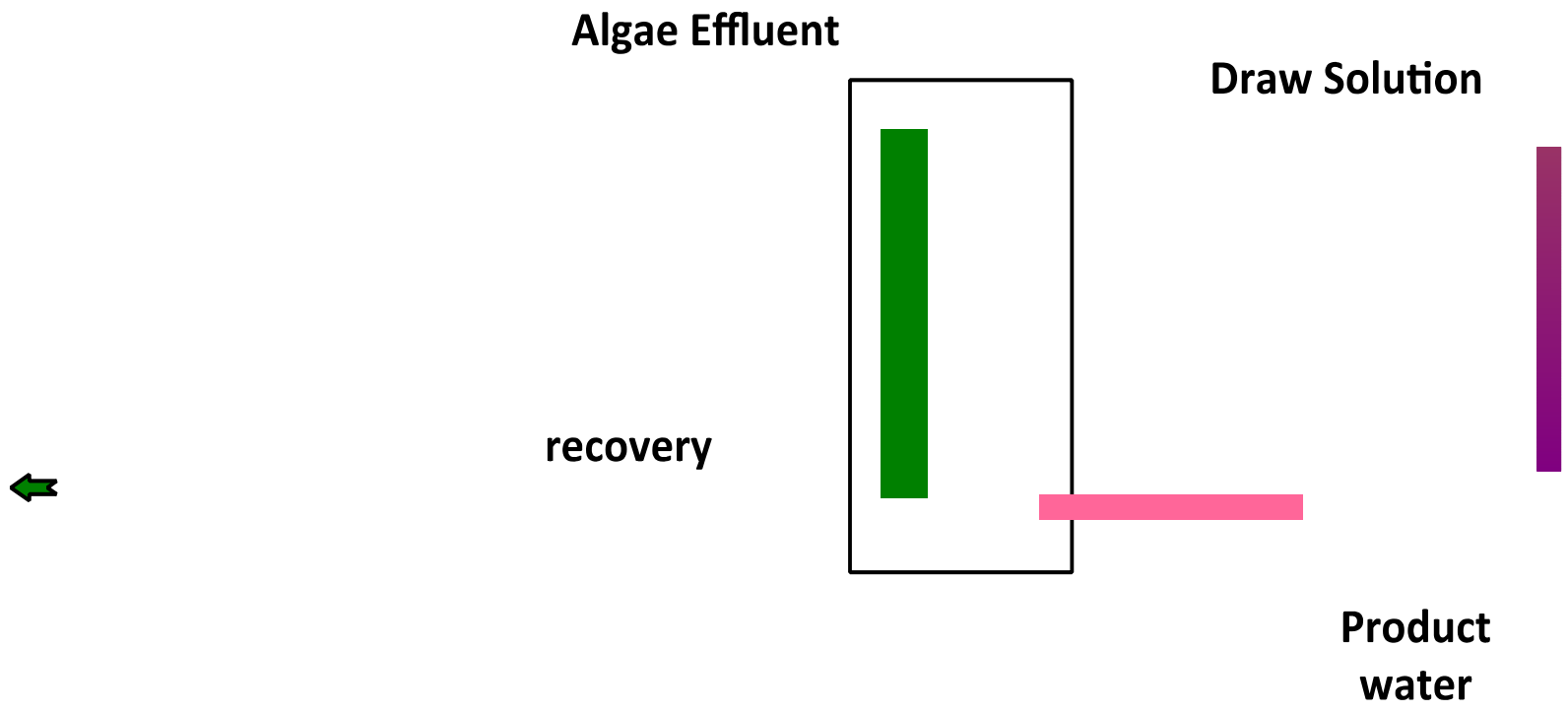
Reverse Osmosis

Energy Savings in ‘Engineered Osmosis’



Osmosis

Integrated FO-RO System for Algae Separation and Potable Water Recovery



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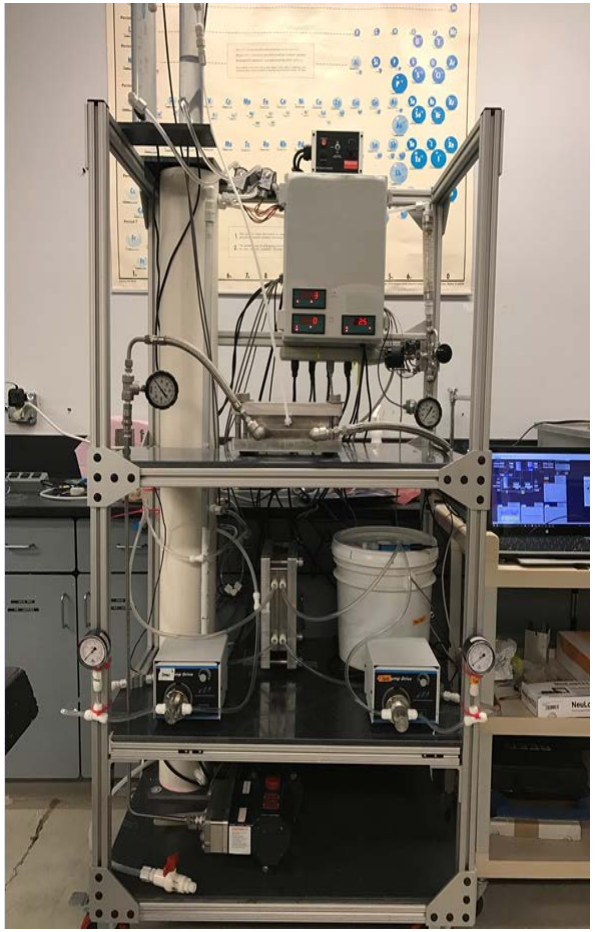
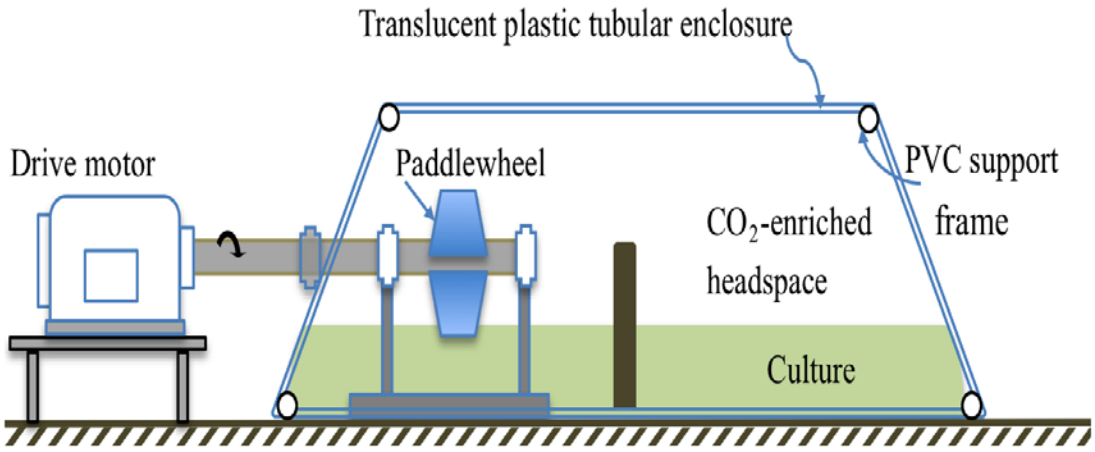
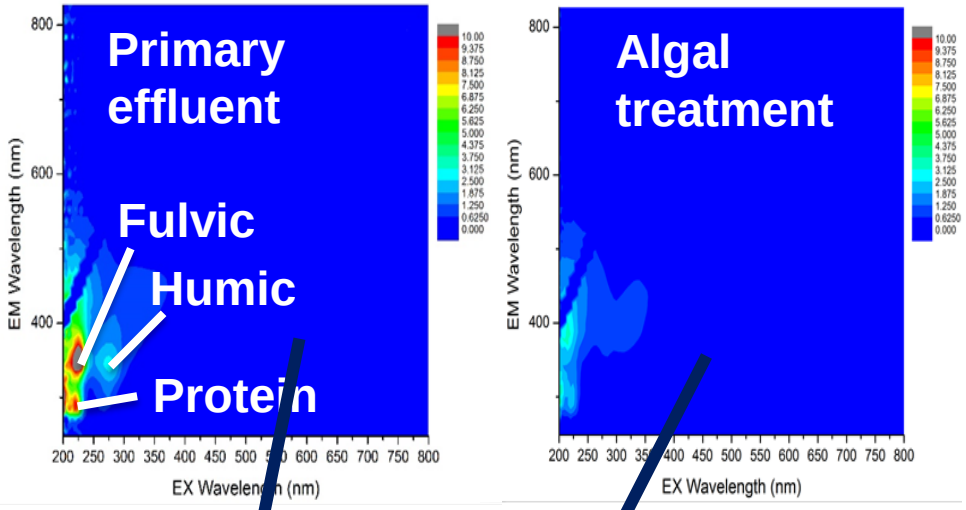


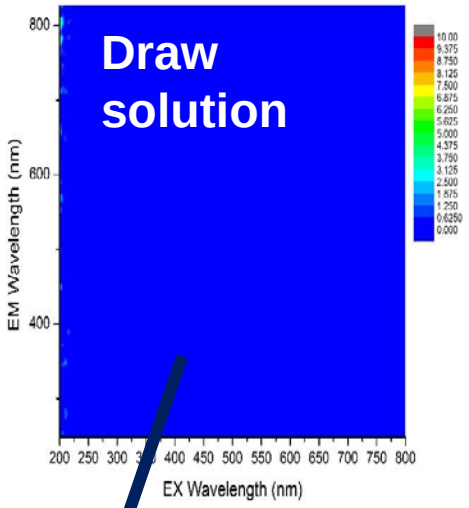


Potable Water Recovery

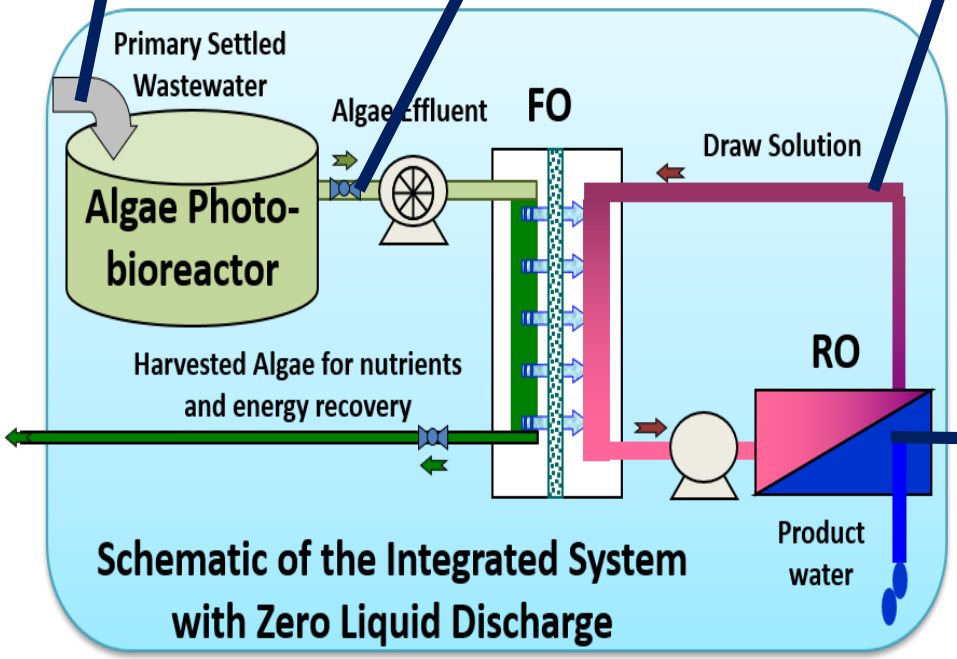
Parameters	Primary effluent	Product water	Primary and Secondary Maximum Contaminant Level
pH	7.64	6.65	√ 6.5-8.5
TDS (mg L^{-1})	765	311	√ 500
TOC (mg L^{-1})	30.7	2.0	
Na^+ (mg L^{-1})	142	103	√ 250
Cl^- (mg L^{-1})	187	174	√ 250
NO_3^- (mg L^{-1})	2.5	2.4	√ 10
F^- (mg L^{-1})	0.02	BDL (<0.008)	√ 2
SO_4^{2-} (mg L^{-1})	131	1.1	√ 250
Cr (µg L^{-1})	14.7	6.41	√ 100
Fe (µg L^{-1})	1145.8	23.89	√ 300
As (µg L^{-1})	2.7	0.06	√ 10
Se (µg L^{-1})	6.3	BDL (<0.01)	√ 50
Cd (µg L^{-1})	0.2	0.05	√ 5
Ba (µg L^{-1})	19.6	3.15	√ 2000
Pb (µg L^{-1})	3.9	0.97	√ 15

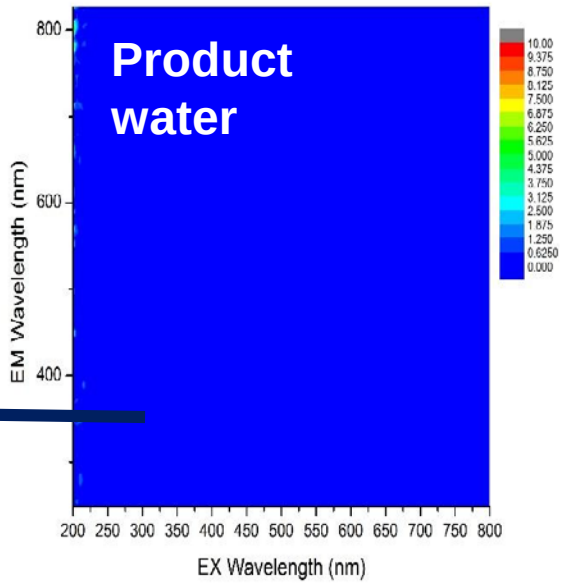
Fate and Transport of Organic matter



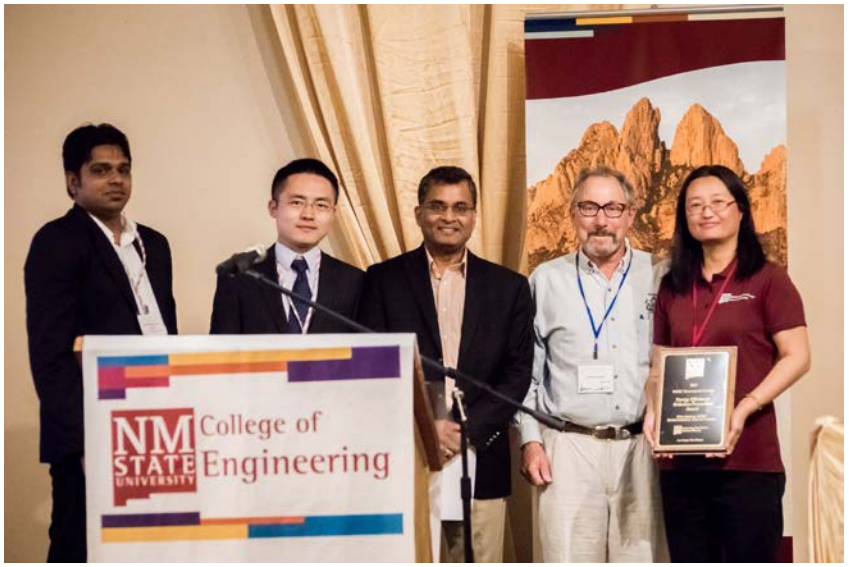


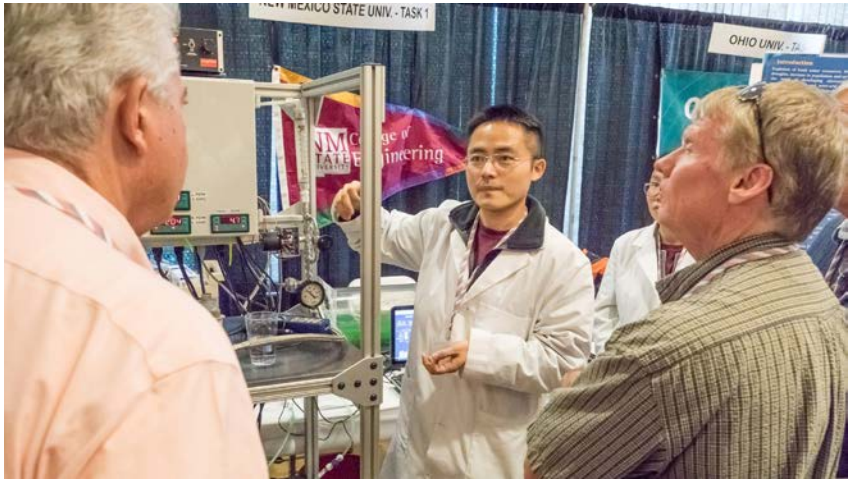
Fluorescence excitation emission matrix

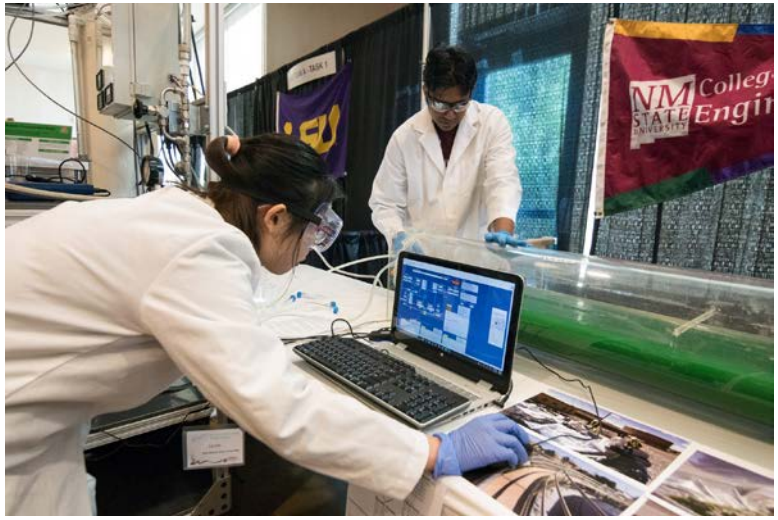




2017 International Environmental Design Contest Awards



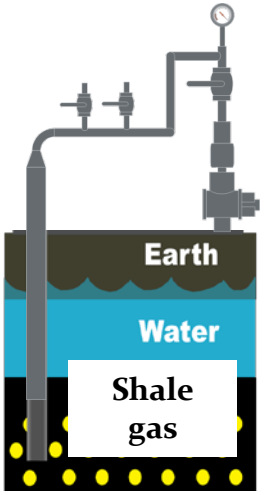




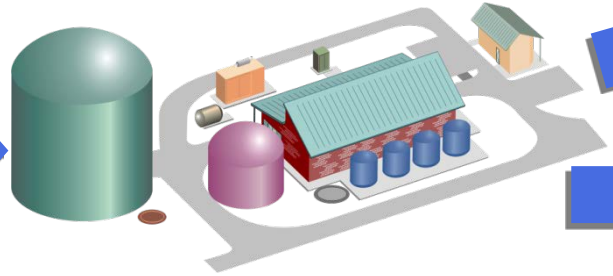
Highlights of Research Projects

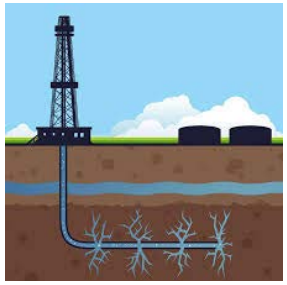
- Selective electrodialysis for non-potable water use, e.g., irrigation and thermal power plant cooling water
- Hybrid algal-membrane system for potable water reuse
- Produced water treatment and beneficial reuse

Produced Water Treatment and Beneficial Uses

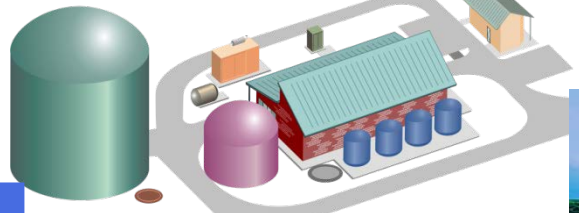


Produced Water Treatment Plant





Stream augmentation



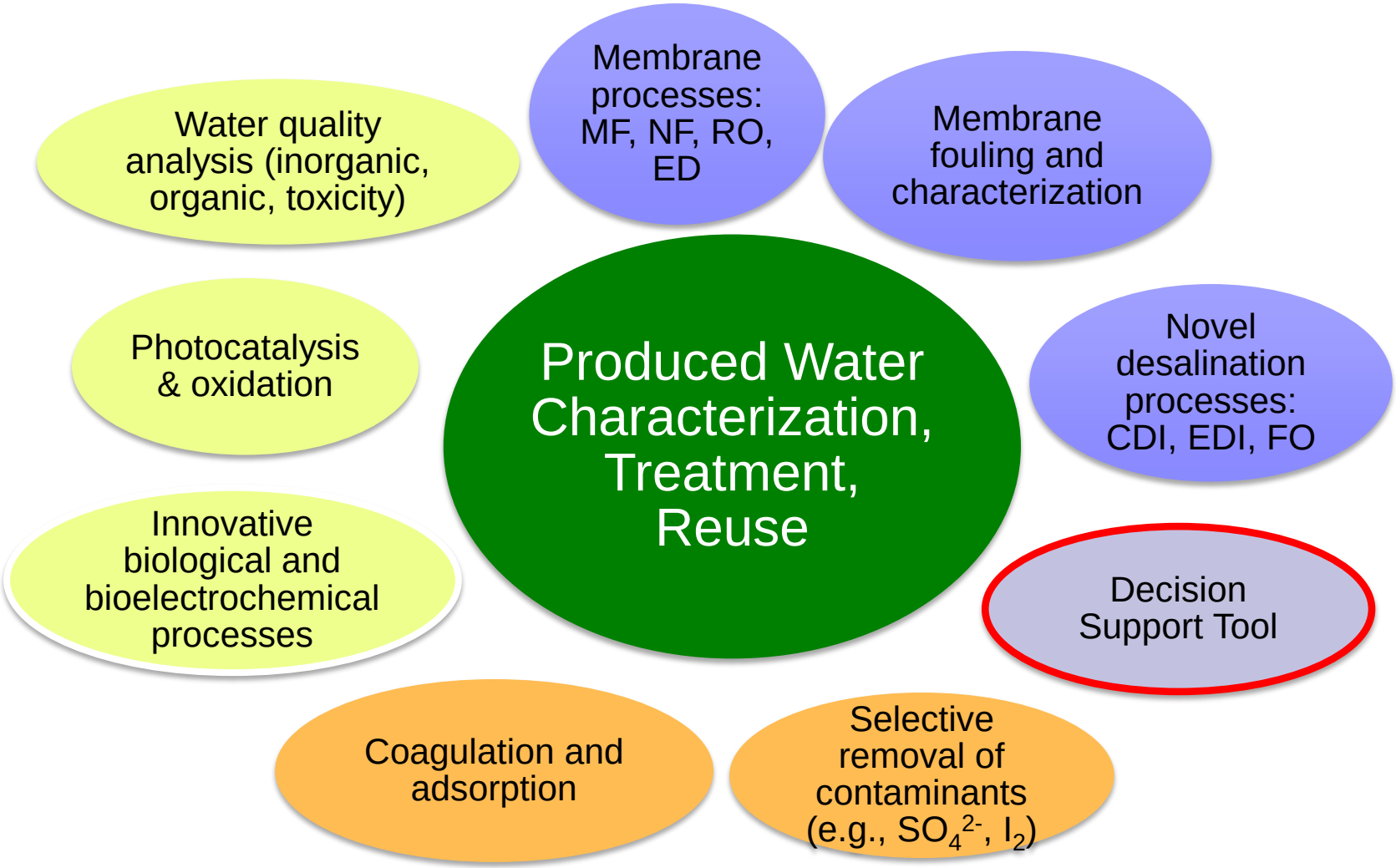
Potable Water Treatment Plant

Domestic Home Use

Livestock & Crop Irrigation

- **Other beneficial reuse options**
  - Hydraulic fracturing
  - Industrial processes, power plants
  - Municipal- Dust and fire control
- **Disposal via deep well injection**
- **Target water quality requirements are defined for each beneficial use category based on existing standards**

Produced Water Treatment Tool Box Developed in Xu's Research Group



Challenges – Limited Lab Space

Thank you!

Pei Xu: pxu@nmsu.edu