Direct Solar Thermal Forward Osmosis Desalination of Produced Waters

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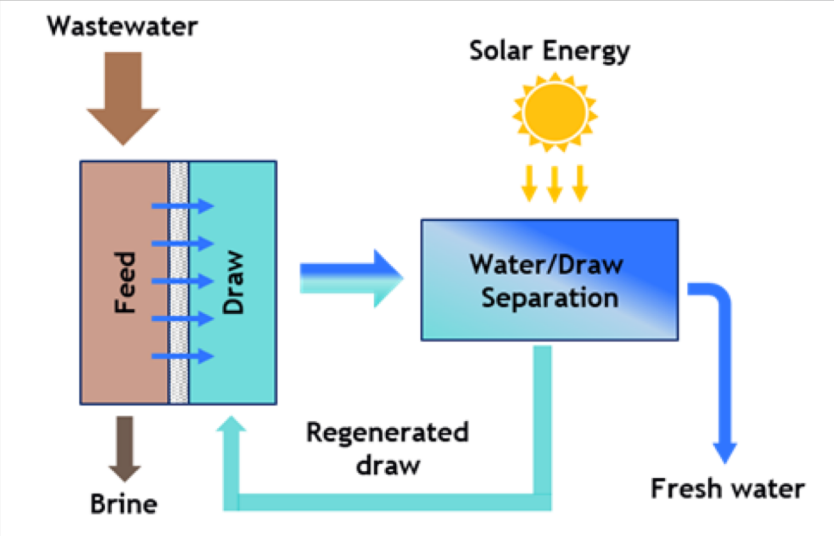
LBNL and CRC are developing a new integrated ionic liquid-based forward osmosis (FO) water treatment system for produced waters of high salinity and/or TDS levels from oil & gas fields



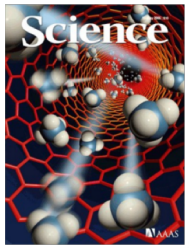
- This new technology combines an advanced forward osmosis (FO) membrane technology, unique, ionic liquid based thermally-responsive, recyclable FO draw solute chemistry and photonic infrared heaters.
- The project goals are to develop key components of the system and assembly a working prototype for field tests at CRC site.

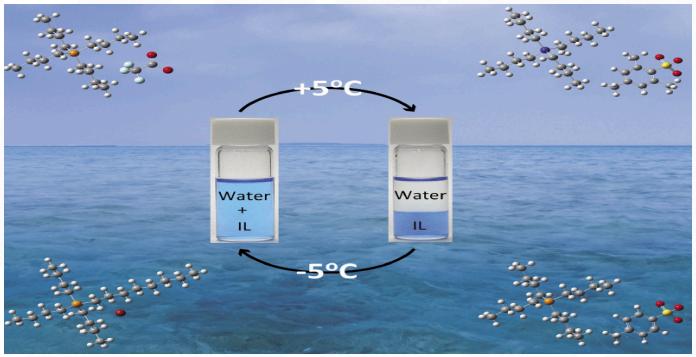
The objective of this project is to demonstrate that it is technically viable to utilize low temperature solar heat resources to provide the energy necessary for FO treatment of highly saline produced water from oil and gas fields

Budget (3 years): $800k (EERE) + $200k (CRC cost share)

FO vs RO for Produced Water

- FO can be competitive with RO given sufficient difference in osmotic pressure, high degree of salt rejection, and use of inexpensive clean energy source(s).
- FO membranes appears to be less prone to biofouling and more tolerant to toxic chemistry of produced waters.





- Challenges with FO?
  - Draw solution challenges: (i) high osmolarity, (ii) must be easily and economically removed from the effluent water.
  - Multiple components in a FO, losses through heat exchanger, pumping.

Our Innovation

- Use of chemically and thermally tunable ionic liquids.
- No need of costly and cumbersome heat exchangers. Separation is achieved by directly absorbing the solar radiation in the IL/Water mixture.
- Three step continuous operation (unlike previously proposed FO systems).
- No pretreatment, high rate of salt rejection – less problems with brine disposal.

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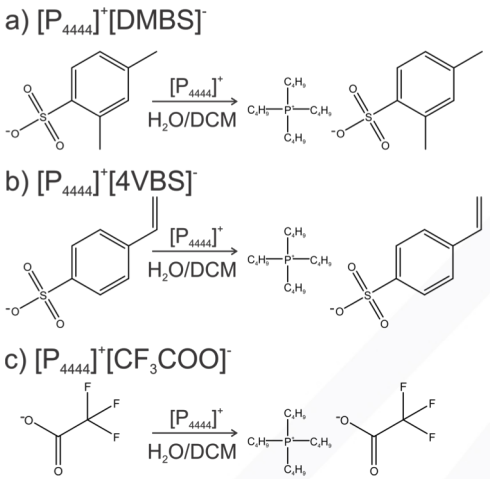
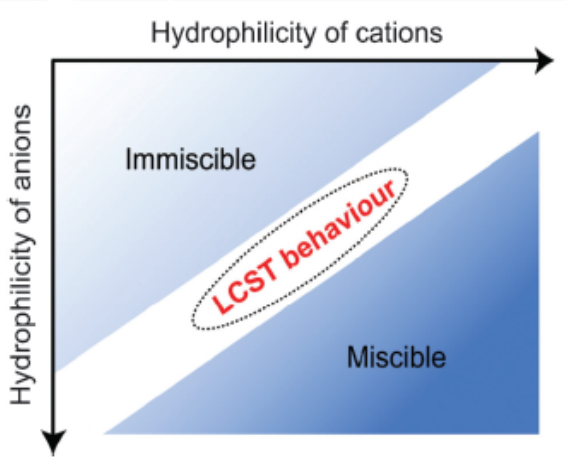
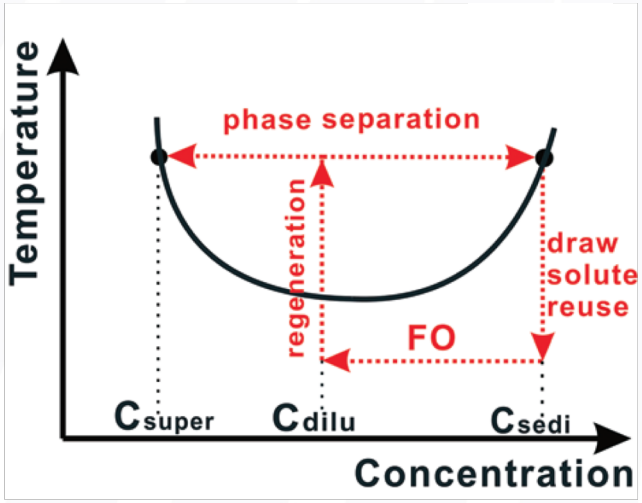
Task 1. Selecting and testing IL-water mixtures phase behavior





Studies of how the structure or mixing of different hydrophobic and hydrophilic ions/ILs can:

1. Fine tune the Lower Critical Solution Temperature (LCST) of the IL-water mixtures.
2. Increase osmolality of the draw solute.
3. Increase C_{sedi} and decrease C_{super} in water- and IL-rich phases, respectively.



Y. Kohno, H. Ohno, Physical Chemistry Chemical Physics 14 (2012) 4993
Cai et al, Env. Sci.Water Res.&Tech., Feb. 2015

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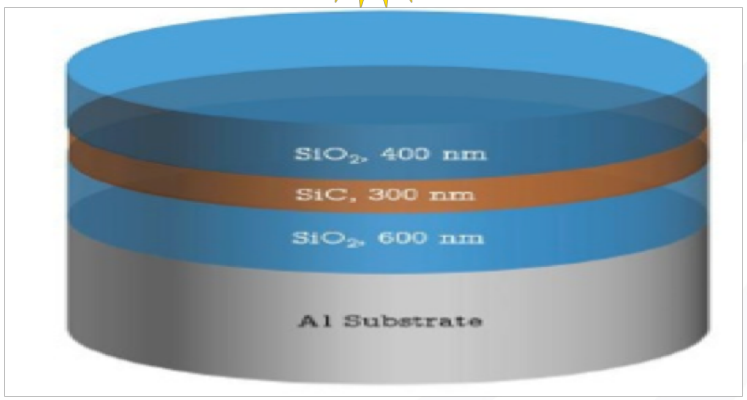
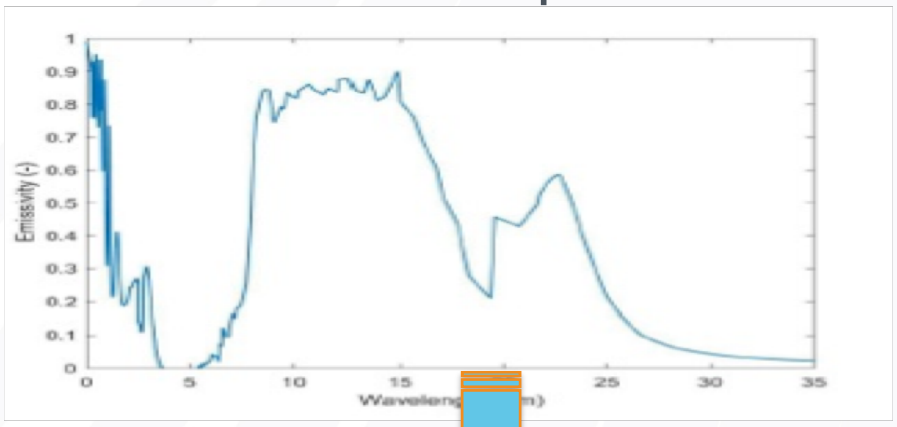
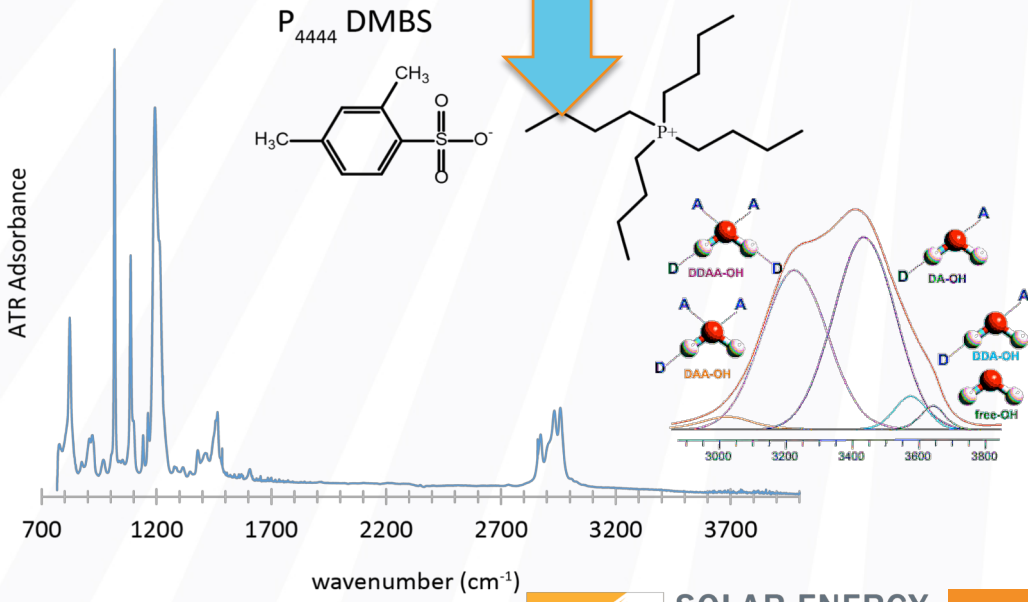
Task 2: Photonic solar infrared heater development







Create metamaterial based photonic structures to tailor that emissivity to match the absorption spectrum of the IL/ H_2O mixture. These photonic structures will be designed and optimized using transfer matrix method.

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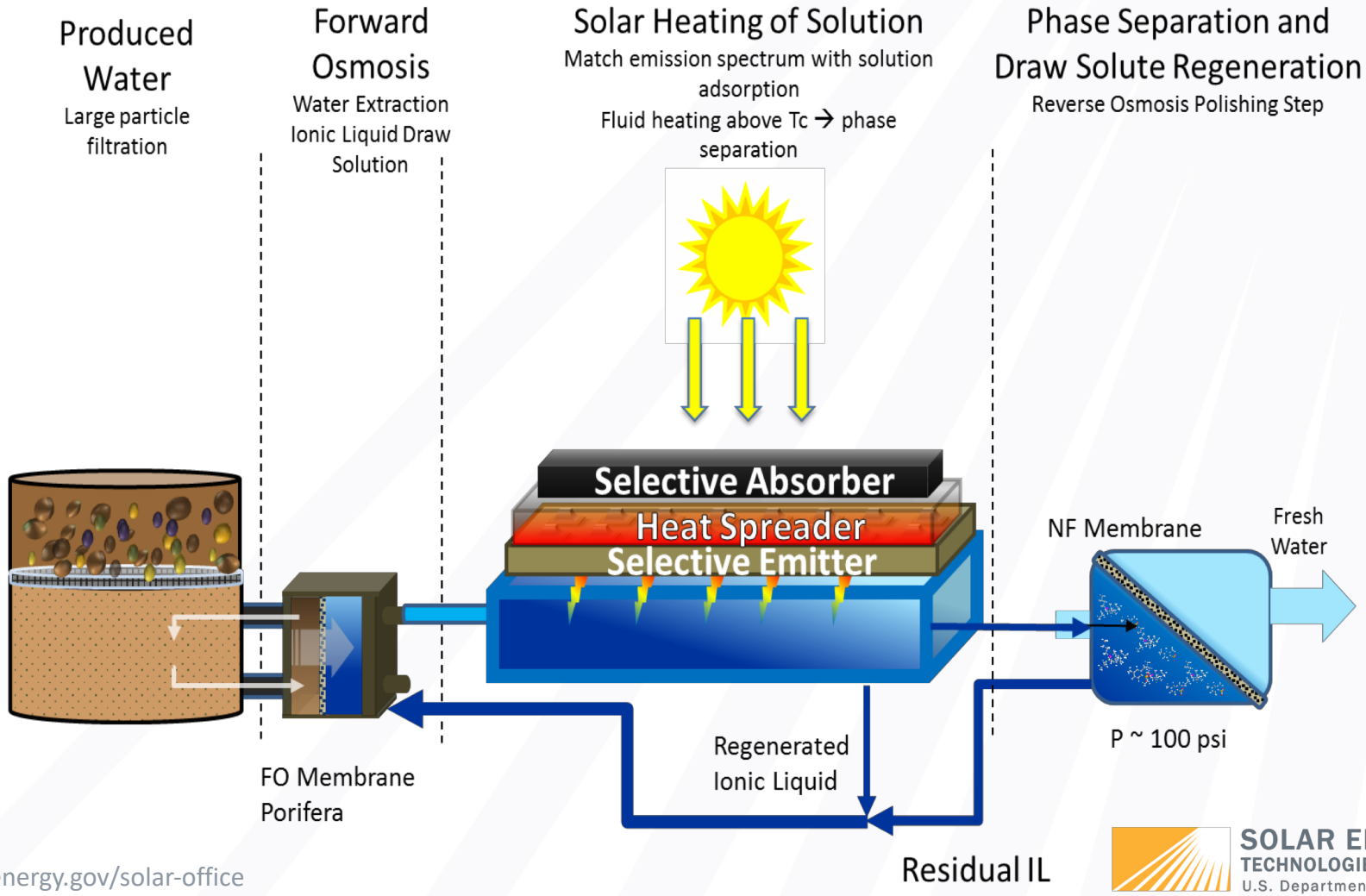
Task 3: FO solar thermal system integration



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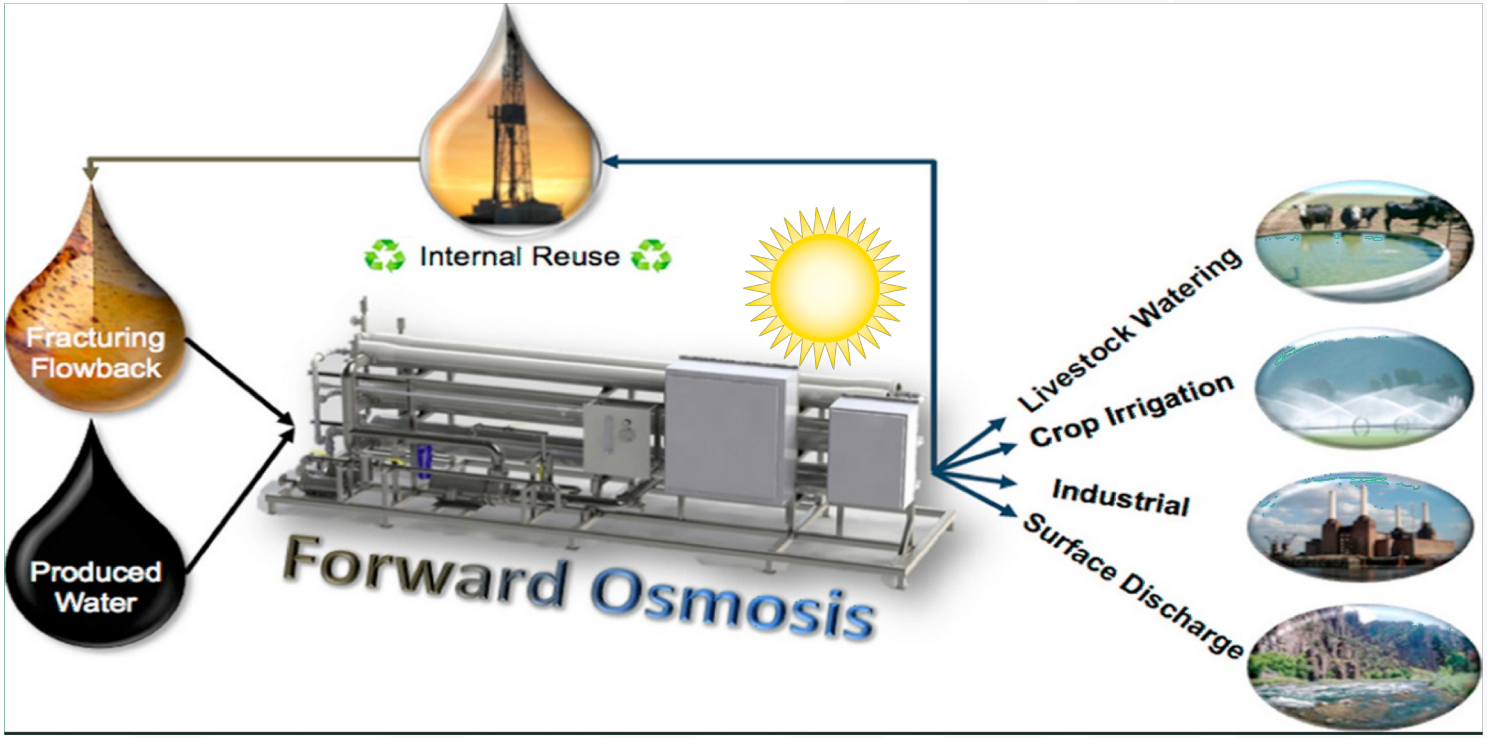
Task 4: Prototype development and field demo



*J. Membrane Science, **488**, 2015, 40*

- Provided success of the lab-scale tests by March 2020, a prototype-scale Solar-IL-FO unit will be designed and constructed.
- By October 2021 complete field test of the Solar-FO Prototype for at least 8 hrs/day for 10 days.

Impact

1. Paradigm shift in desalination processes, direct coupling with solar heat.
2. Overall reduction in energy consumption and the associated greenhouse gas emissions.
3. Limiting fresh water withdrawals, and provision of a previously untapped water supply for agricultural, industrial, and residential use.