

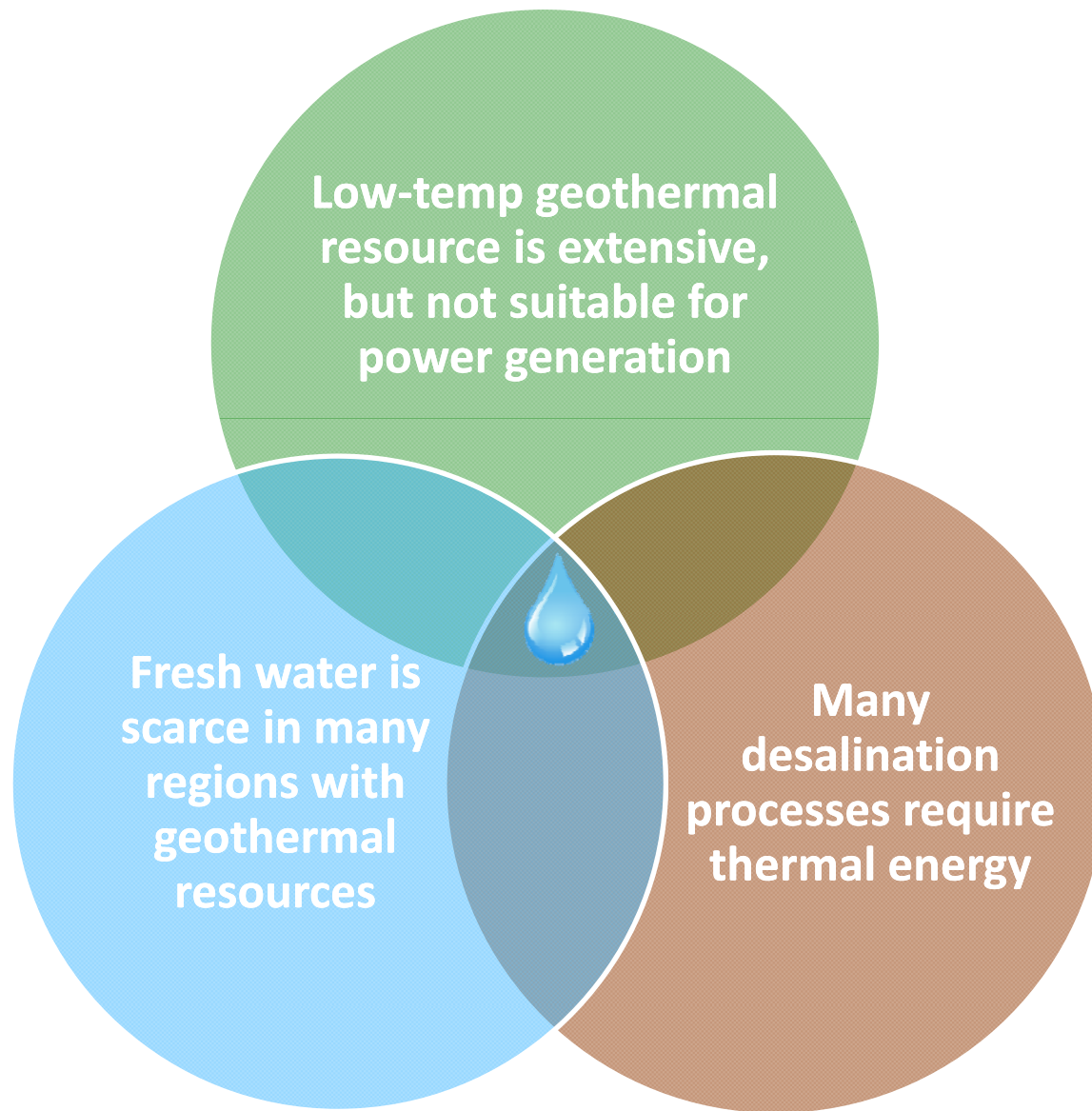
Geothermal Desalination



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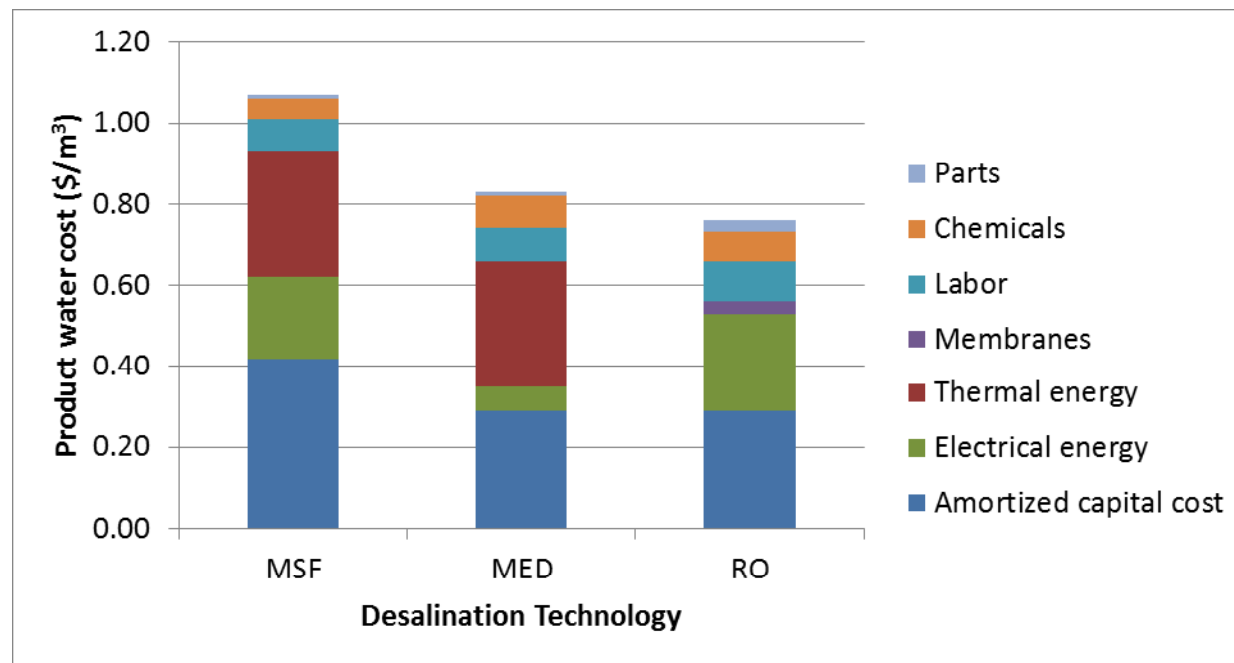
Motivation



Effective integration of low-temperature geothermal energy requires selecting the right desalination technology and the right application.

Cost of Desalination

Distribution of cost by category for the three most common desalination technologies. Energy cost and consumption is key.



MSF = Multistage Flash (thermal)
MED = Multi-effect Distillation (thermal)
RO = Reverse Osmosis (electrical)

Ziolkowska in *Water Resources Management* (2015). Values are based on a large seawater desalination plant.

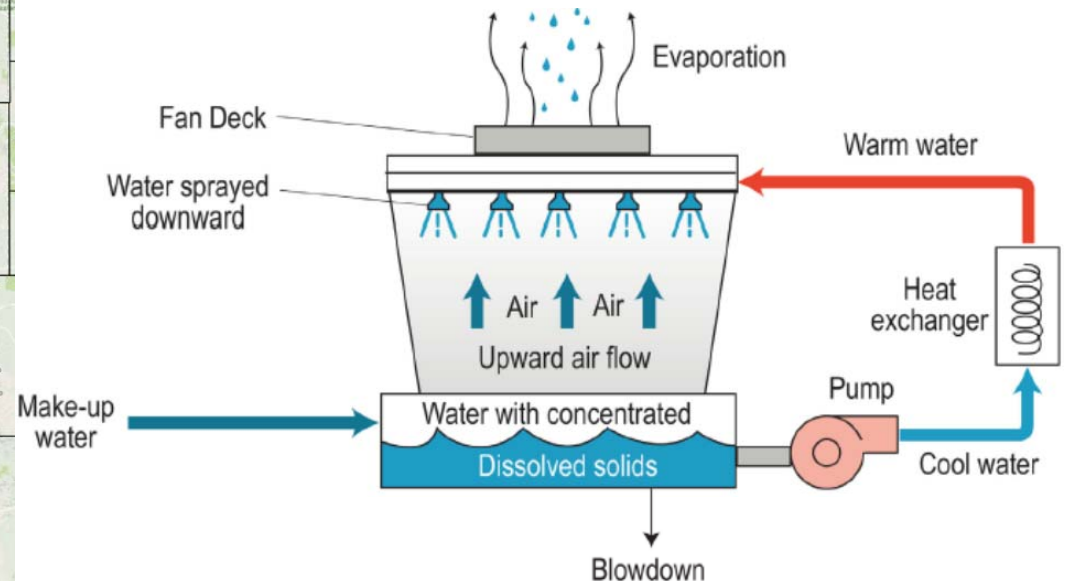
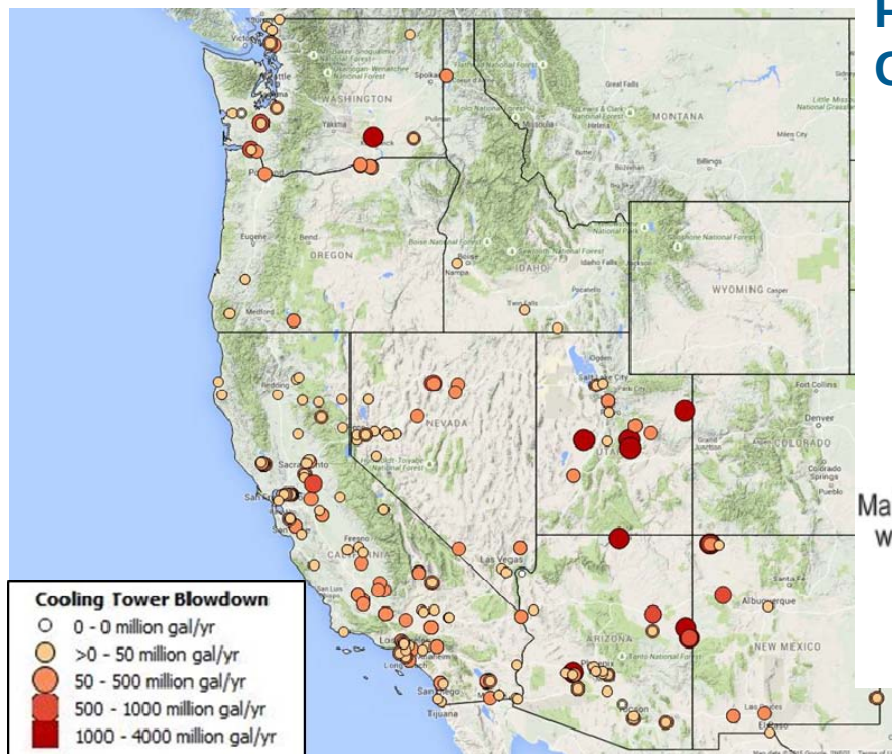
Applications

Cost effective geothermal desalination requires:

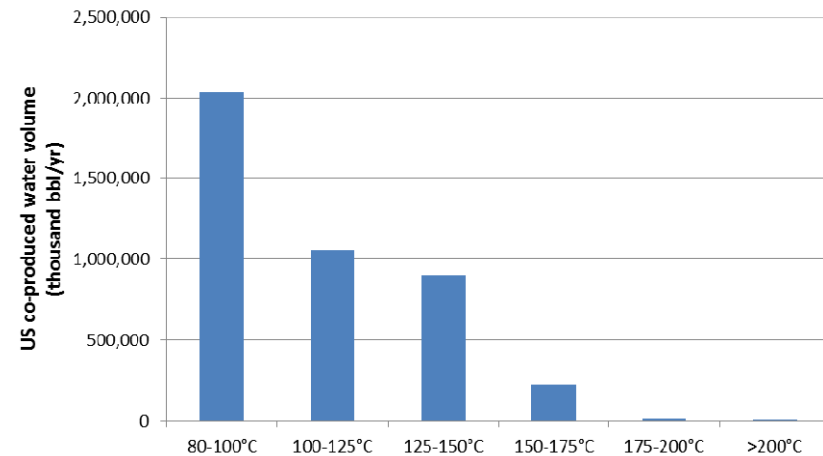
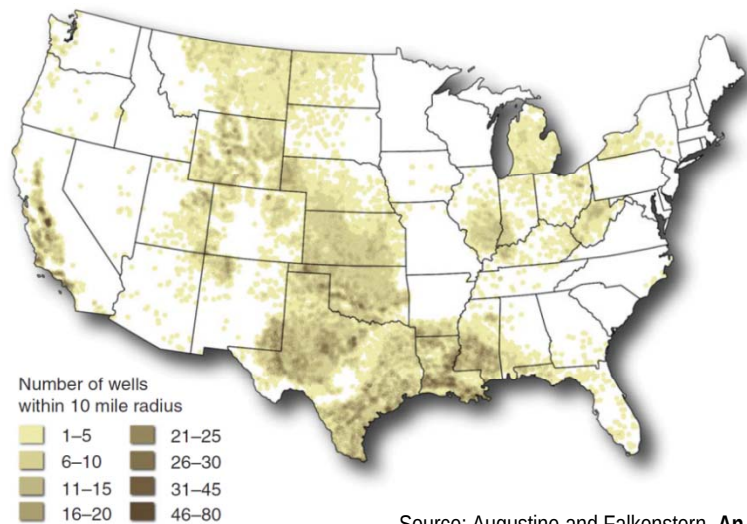
1. thermal energy that can be tapped for very low cost (it's never free),
2. impaired source water that is a wastewater disposal issue, and
3. a need/customer for fresh water.

Examples include oil & gas field water (e.g., frac flowback), cooling tower blowdown, agricultural drainage water, RO rejection brine, etc.

**For example,
Cooling tower blowdown:**



Oil & Gas Co-Produced Water Treatment

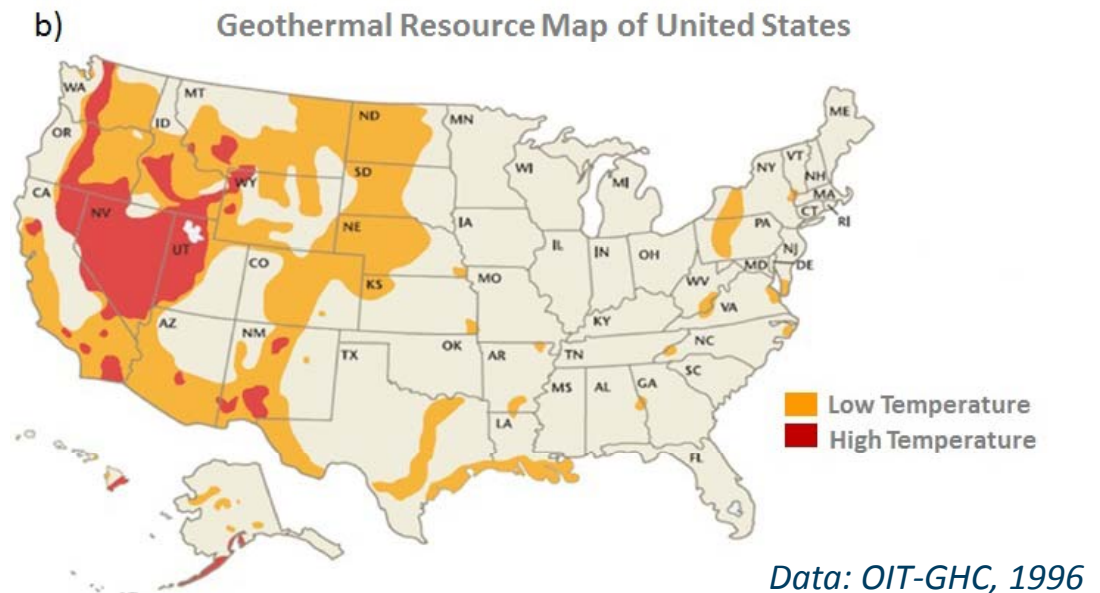
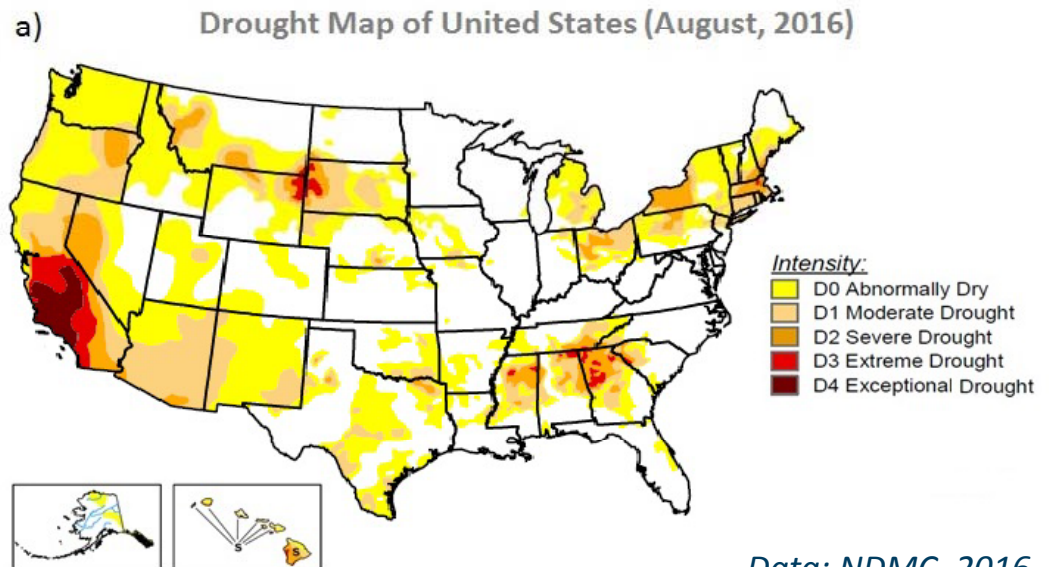


Source: Augustine and Falkenstern, *An Estimate of the Near-Term Electricity-Generation Potential of Coproduced Water From Active Oil and Gas Wells*. *SPE Journal*, 2014, 19, 530-541.

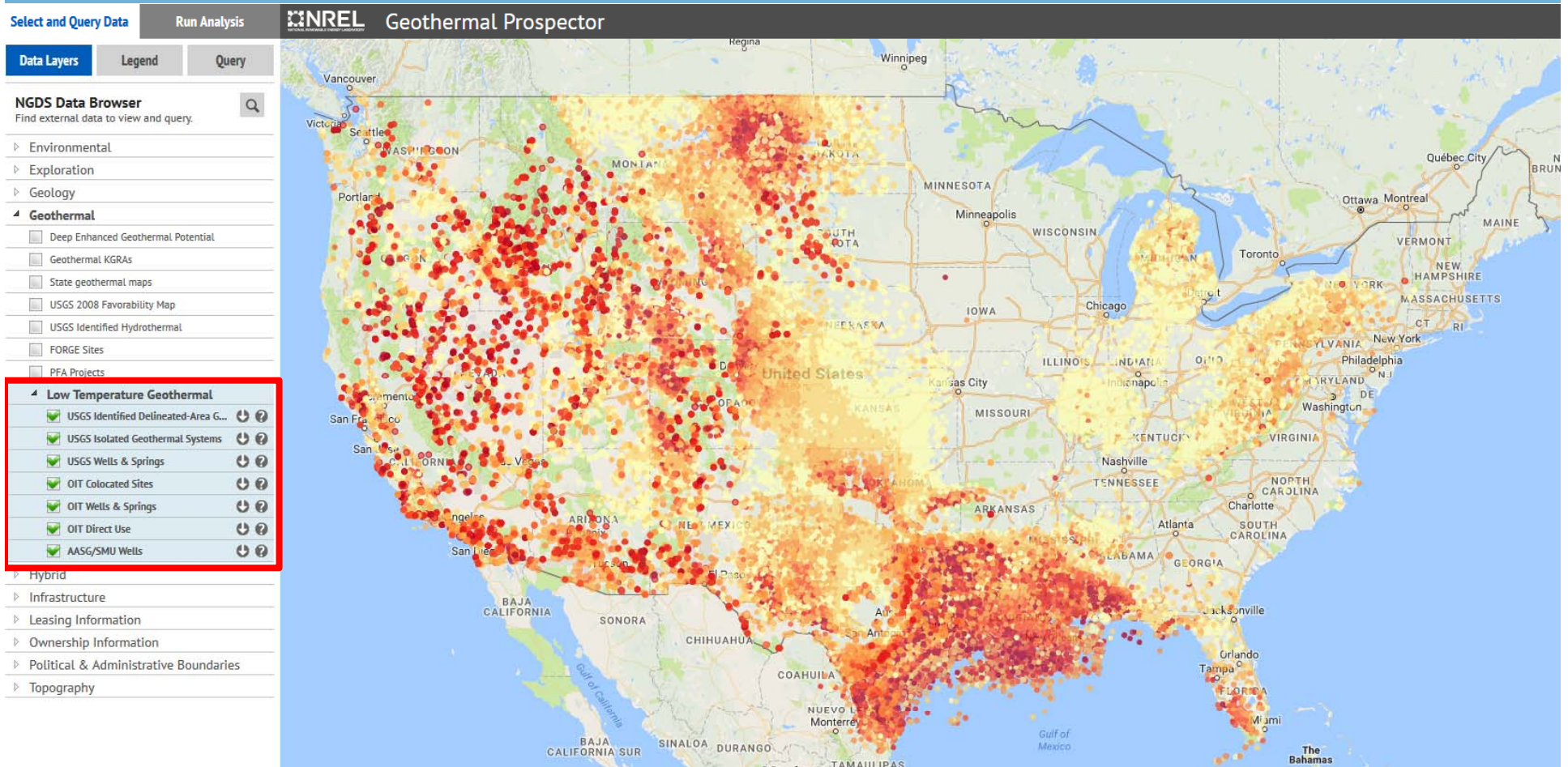
- Approximately 15 billion bbl/yr of co-produced water from U.S. oil & gas production operations
- Majority of produced water is disposed of via injection at a typical cost of ~\$1/bbl (\$6.3/m³). Desalination could:
 - Reduce volume requiring disposal
 - Provide additional water source for subsequent beneficial uses
 - Decrease risk of induced seismicity related issues

Colocation of Geothermal Heat and Fresh Water Demand

- Potential source waters:
 - brackish surface or groundwater,
 - seawater,
 - brines co-produced from oil and gas operations,
 - industrial wastewater,
 - blowdown water from water-cooled power plants
 - agriculture drainage water
 - geothermal brine
- Geothermal resources are primarily located in the western states and are categorized into high-temperature and low-temperature resources.



Low-temp Well Data on Geothermal Prospector



Data Sources:

- United States Geological Survey (USGS)
- Southern Methodist University (SMU)
- Association of American State Geologists (AASG)
- Oregon Institute of Technology Geo Heat Center (OIT-GHC)

<https://maps.nrel.gov/geothermal-prospector>

Geothermal Desalination Projects

Goal: Expand the use of underutilized, low-temp geothermal resources for fresh water production.

1. Production of fresh water at geothermal power plants via Membrane Distillation (NREL/Colo School of Mines)
2. Treatment of co-produced water in the oil & gas sector via Forward Osmosis (INL/LBNL)

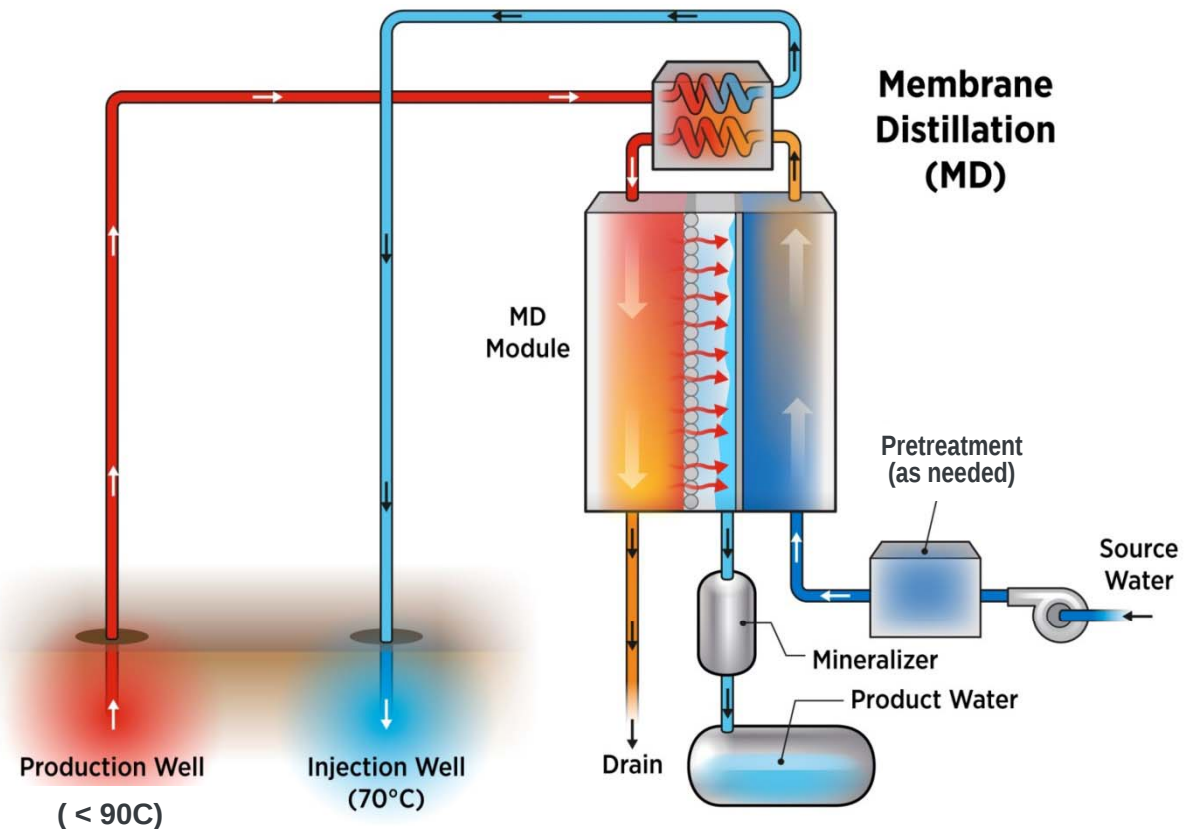


Membrane Distillation

Membrane Distillation was selected as the best match for small-capacity systems powered by low-grade heat.



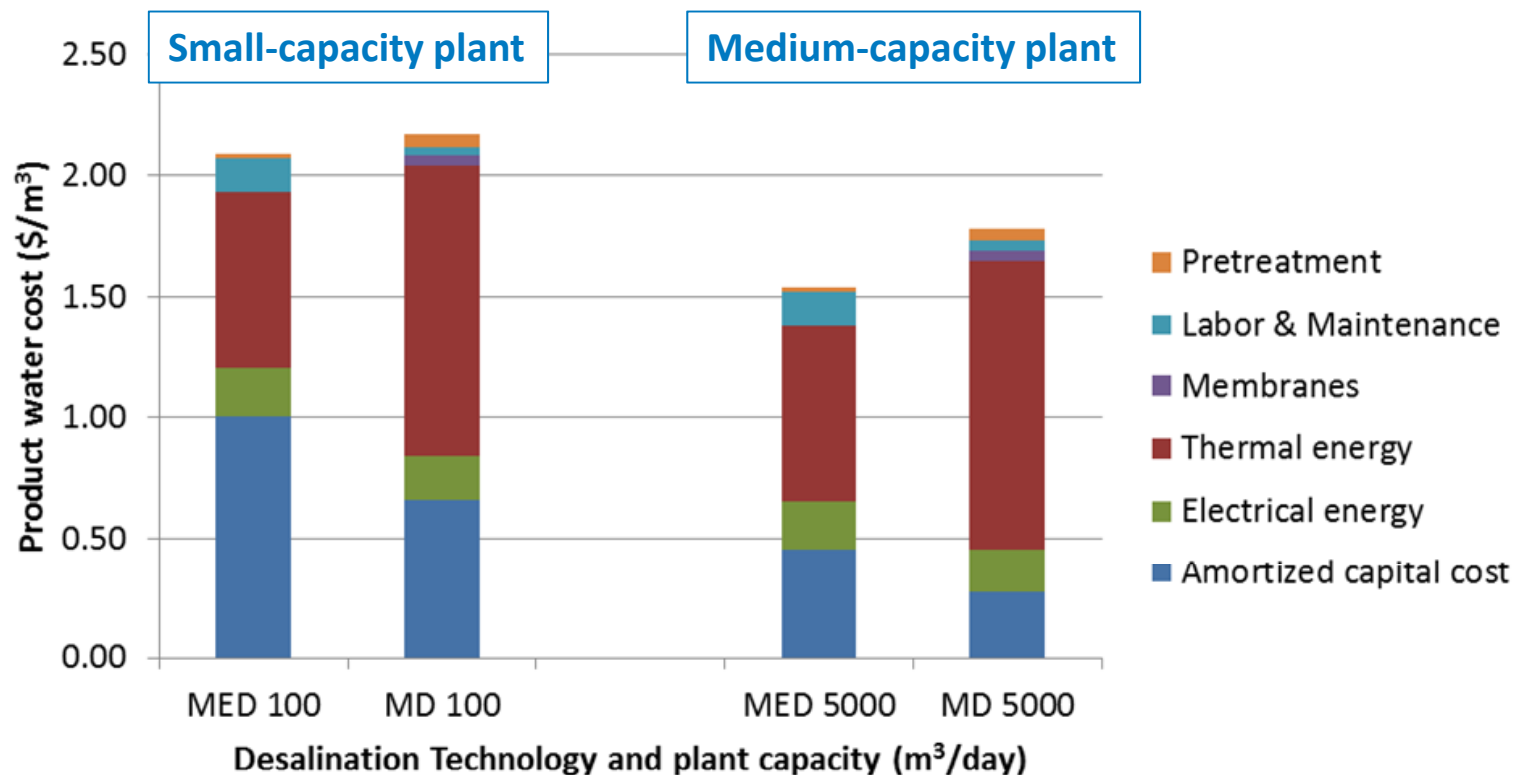
Project will use a Vacuum-MD pilot unit for the testing.



Optimum MD systems maximize mass flux thru the membrane while minimizing thermal flux thru the membrane.

Membrane Distillation (MD)

MD advantages are more apparent at small scale that is representative of a geothermal well flow. Lower thermal energy costs could allow MD to undercut MED costs.



Kesieme et al., 2013.

Advantages of Membrane Distillation

- Uses membranes that can be made of low-cost polymers due to modest pressure and temperature conditions and a pore size that is larger than required for RO membranes,
- Can treat higher-salinity brines than RO and can be used for enhanced recovery from RO systems,
- Uses low-grade heat for primary energy input (50 to 90°C),
- Accommodates sensible (e.g., hot water) heat input,
- Operates at near-ambient pressure, and
- Provides a modular design that is amenable to small-scale facilities

Test Site

- Candidate sites visited in February 2016
- Site logistics reviewed and water samples collected
- Sample analysis performed at Colo School of Mines
- Tuscarora Geothermal Plant selected for field testing



Membrane Optimization

Conducting carbon nanotubes (CNTs) are deposited on the membrane surface. This allows one to apply electrical potential to the membrane.

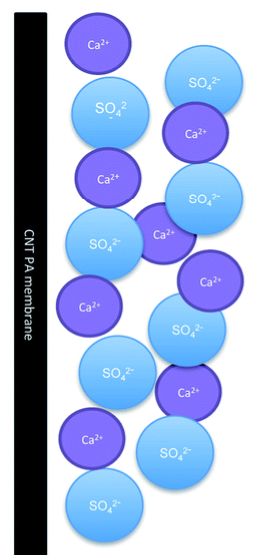


Untreated membrane

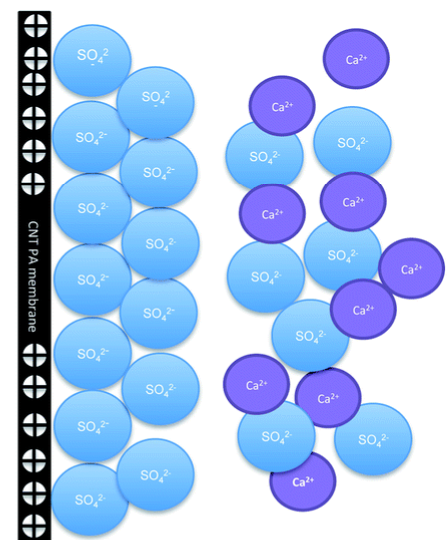


CNT-coated membrane

Near-neutral membrane

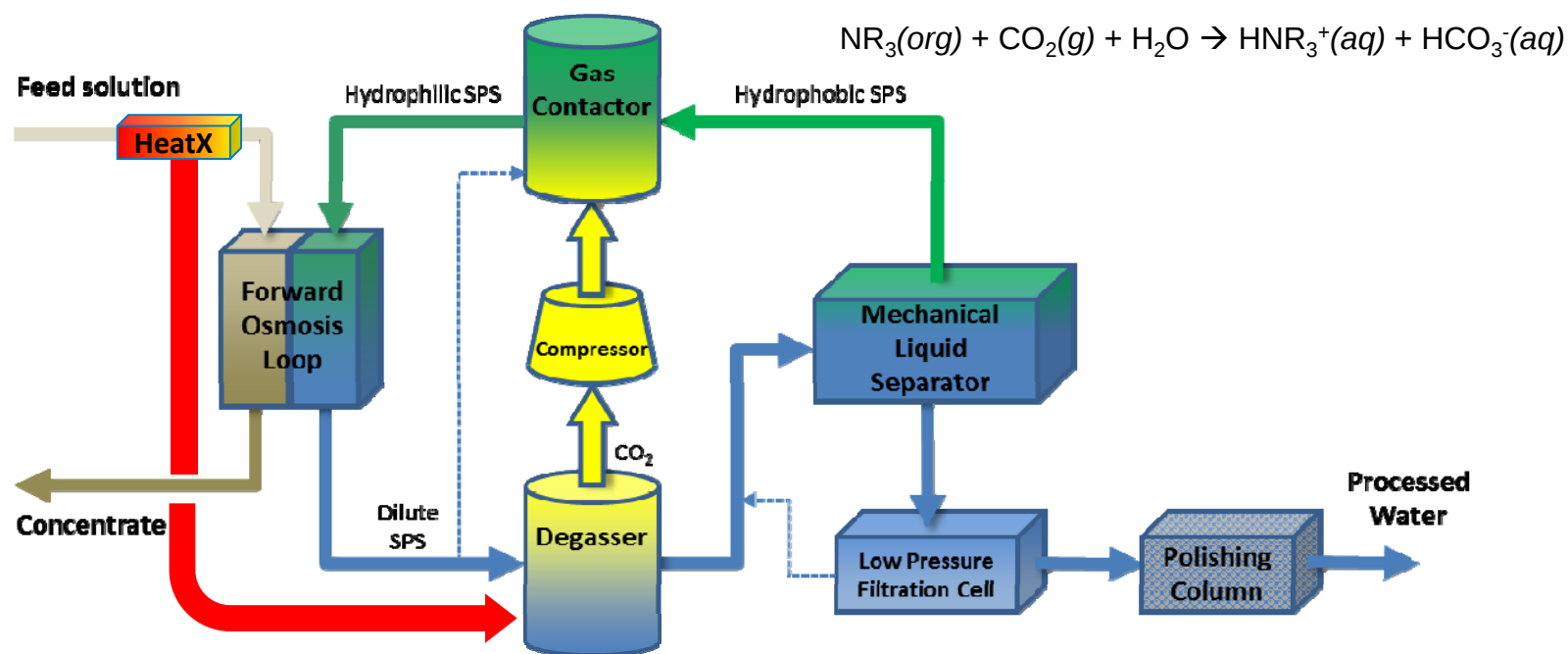


Electrically charged membrane



Electrical bias can be used to influence water chemistry at the membrane surface

Forward Osmosis (FO)



- Switchable Polarity Solvent (SPS) FO process:
 - Intrinsically fouling resistant technology that can treat high salinity brines
 - High water recovery possible (~90% demonstrated in lab testing of produced water)
 - Process thermal energy can be obtained from produced water feed stream ($T \leq 80^\circ\text{C}$)
- Current research focused on process optimization and scale-up, with field demonstration targeted for FY18

For more information attend GRC presentation or contact Dan Wendt (daniel.wendt@inl.gov) or Aaron Wilson (aaron.wilson@inl.gov)

Summary

- Economics favor RO desalination when possible
- Best thermal desal applications will avoid a waste treatment cost and produce valuable fresh water, e.g., treat cooling tower blowdown water, agricultural runoff, RO brine, or co-produced water.
- DOE's Geothermal Technologies Office is supporting two projects looking at the use of low-grade geothermal heat for desalination:
 - Membrane Distillation is an emerging thermal-desal method. Advantages include simple design and use of common membranes.
 - Forward Osmosis uses a special “draw solution” to pull pure water from an saline source. Thermal energy is used to recover the water and regenerate the draw solution.
- An major cost in thermal desalination systems is for thermal energy; pairing with low-cost geothermal can reduce overall costs.

Contact information

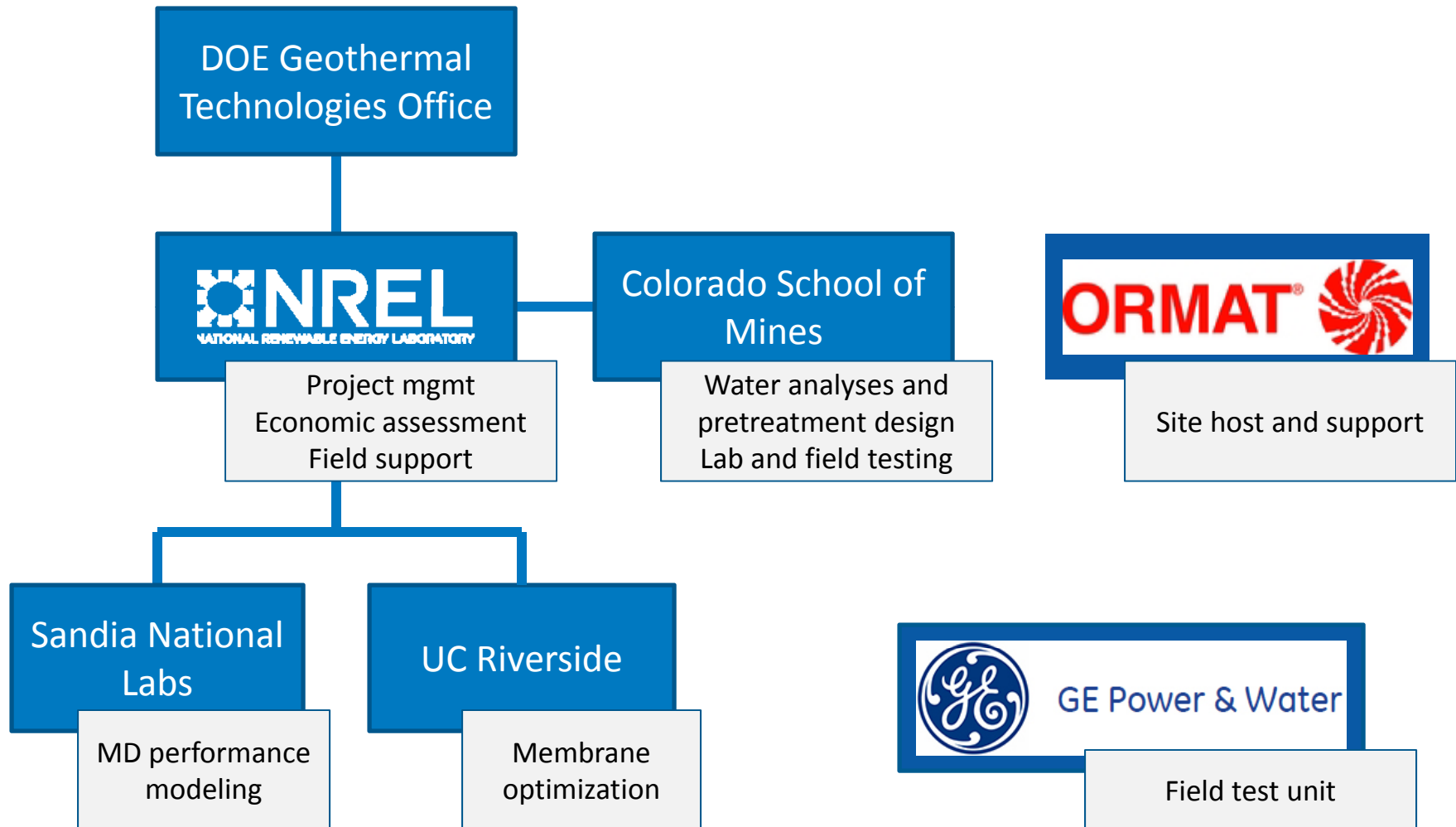
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Backup Slides

Project Partners & Roles



Desalination Decision Support Tool

