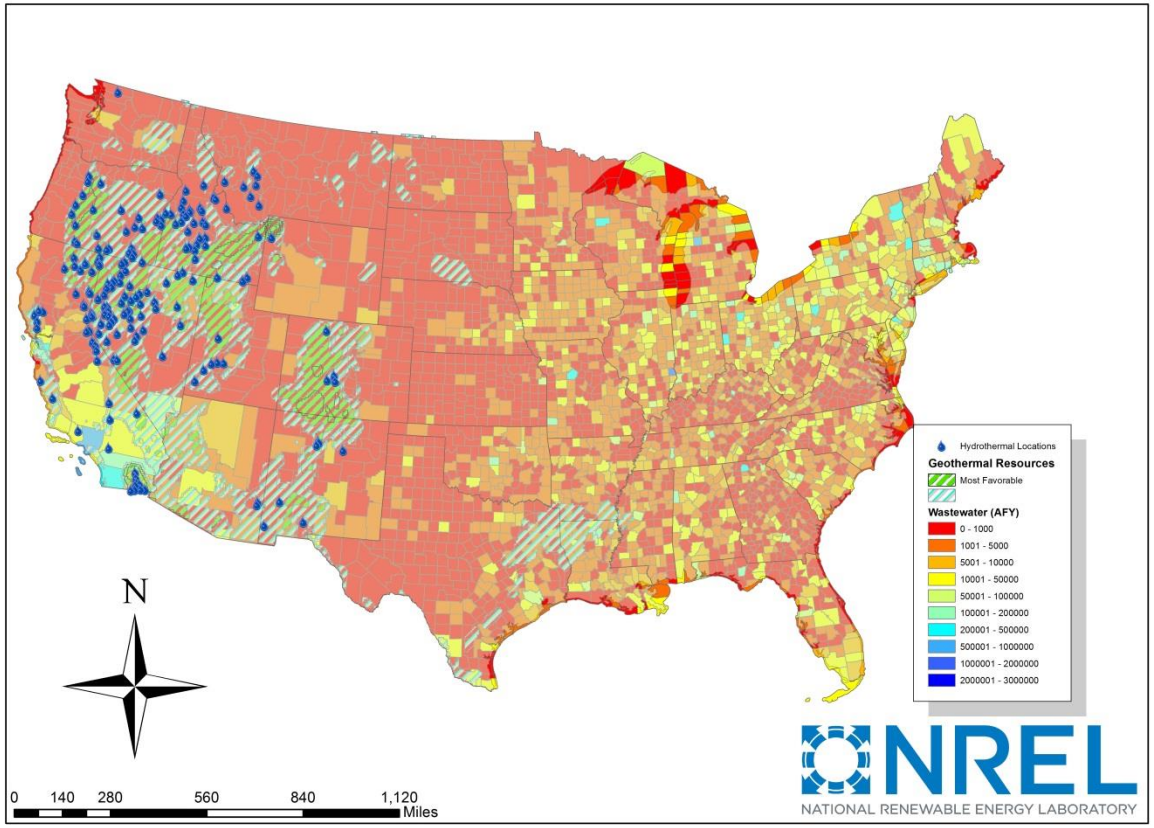
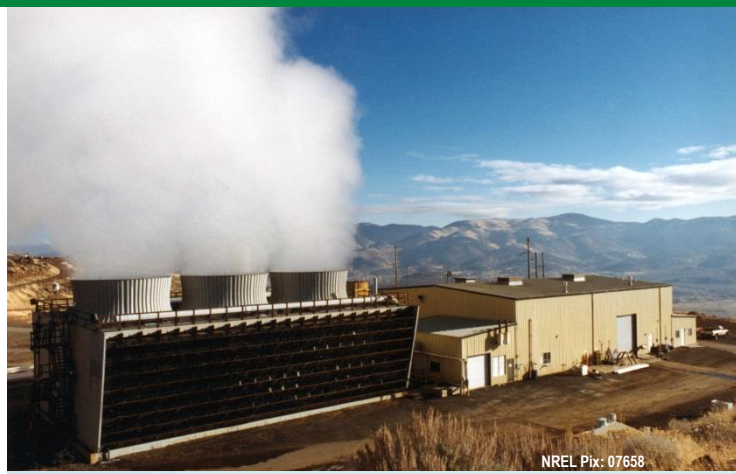
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Geothermal Resource Availability and Alternative Water Resources





Projected Deployment of Geothermal Technologies Subject to Water Quality Constraints

Project Officer: Arlene Anderson

Total Project Funding: $75,000

May 11, 2015

PI: Jordan Macknick

National Renewable Energy Laboratory

Systems Analysis, Resources Assessment, Data System Development & Population, Education

Relevance/Impact of Research

Objective

- Geothermal technologies require water for development and operation
- Geothermal resources are often in arid areas where obtaining freshwater is politically, technically, or economically challenging.
- This project has **two** primary objectives:

1. Assess to what extent freshwater could be a limiting factor in the deployment of Enhanced Geothermal Systems (EGS) and other geothermal technologies

2. Evaluate the tradeoffs associated with utilizing different cooling systems, alternative (non-fresh) water resources, or other methods used to mitigate impacts on local water resources, in order to maximize geothermal deployment and minimize impacts on water resources

GTO Goals

Systems Analysis:

- Drive industry deployment of a targeted 100+ GW of EGS
- Lower risks and costs of development and exploration
- Accelerate development of 30 GWe of undiscovered hydrothermal resources

Hydrothermal:

- Lower risks and costs of development and exploration
- Accelerate development of 30 GWe of undiscovered hydrothermal resources

EGS:

- Drive industry deployment of a targeted 100+ GW of EGS

Relevance/Impact of Research

Challenges Addressed

- Geothermal resources are often located in arid areas that lack plentiful supplies of freshwater, yet they require water for operations
- Geothermal technologies can require water for drilling and construction, cooling, make-up for subsurface water loss, make-up for flash steam cycle water loss, and for well field stimulation
- EGS systems can have higher water requirements than hydrothermal systems
- Many geothermal technology processes can utilize low-quality water resources

Industry/GTO Impact

- Research into freshwater limitations and opportunities for using alternative water resources will assist accelerating near-term geothermal growth by providing industry and researchers with the capability to identify exploration sites that have sufficient water resources of all types
- Analytical accomplishments in this research can help improve regional and local geothermal planning decisions by incorporating water resources as a constraint and an opportunity

Innovation

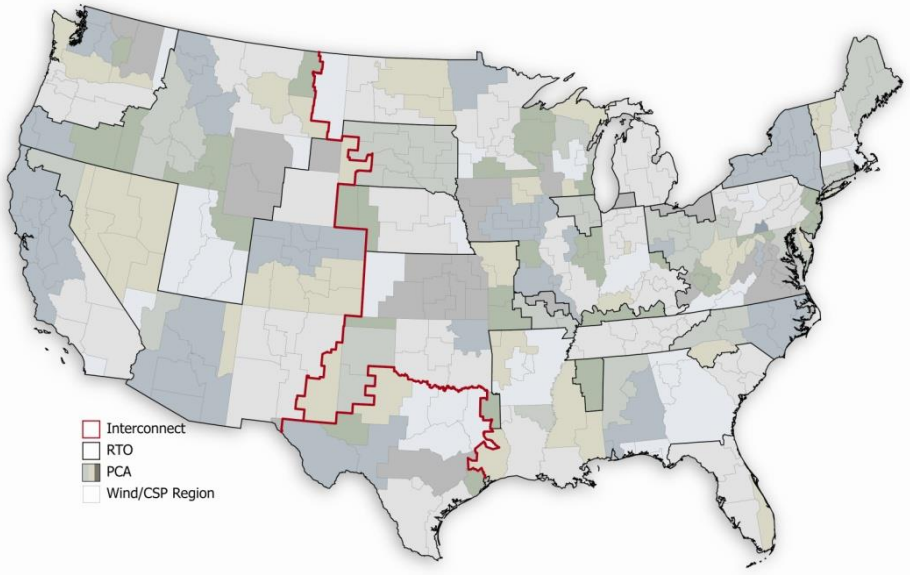
- This research builds off unique capabilities at the national laboratories for integrating water resources as a constraint for future developments in the power sector
- This research provides the foundation for future efforts that can optimize geothermal siting decisions, evaluate economic tradeoffs of utilizing different types of alternative water resources, and integrate with other GTO projects such as geothermal-powered desalination

Technical Approach

- Key Features of the Technical Approach
  - Model Modification
    - This project leverages prior NREL-supported work identifying the costs and availability of different water resources available for energy development and the implementation of water resource constraints and analysis capabilities into the ReEDS model. The ReEDS model has been modified to accommodate greater detail on geothermal technology cost and performance characteristics.
  - Scenario Analysis
    - Multiple electricity scenarios, assessing different levels of geothermal cost, performance, and water-use characteristics, as well as available water resources are analyzed.
  - Results Dissemination
    - Results from this work will be summarized in a technical report and incorporated into a online interactive formats (e.g., Geothermal Prospector) for user exploration and analysis.

NREL's ReEDS (Regional Energy Deployment System) Model

- a premier tool for U.S. electricity system capacity expansion modeling



- **Projects electric sector growth to 2050 under different economic, technology, and policy assumptions**
- **Spatially resolved into 356 wind/solar regions, 134 balancing areas (BAs) for demand and other renewables**
- **Serves load, meets planning and operating reserves requirements, and obeys physical constraints**

Generation technologies

- ✓ Coal (pulverized, IGCC, & IGCC-CCS)
- ✓ Nuclear
- ✓ Natural Gas (combustion turbine(NGCT), combined cycle(NGCC), & CC-CCS)
- ✓ Biomass (dedicated, cofired with coal, landfill-gas/MSW)
- ✓ **Geothermal (hydrothermal & EGS)**
- ✓ Hydropower, Marine Hydrokinetic
- ✓ Solar (concentrating solar power & PV)
- ✓ Wind (onshore & offshore)

Storage: pumped hydropower storage, CAES, batteries

Demand-side technologies: plug-in hybrid/electric vehicles (PHEVs), thermal energy storage in buildings, interruptible load

Key Features of This Project:

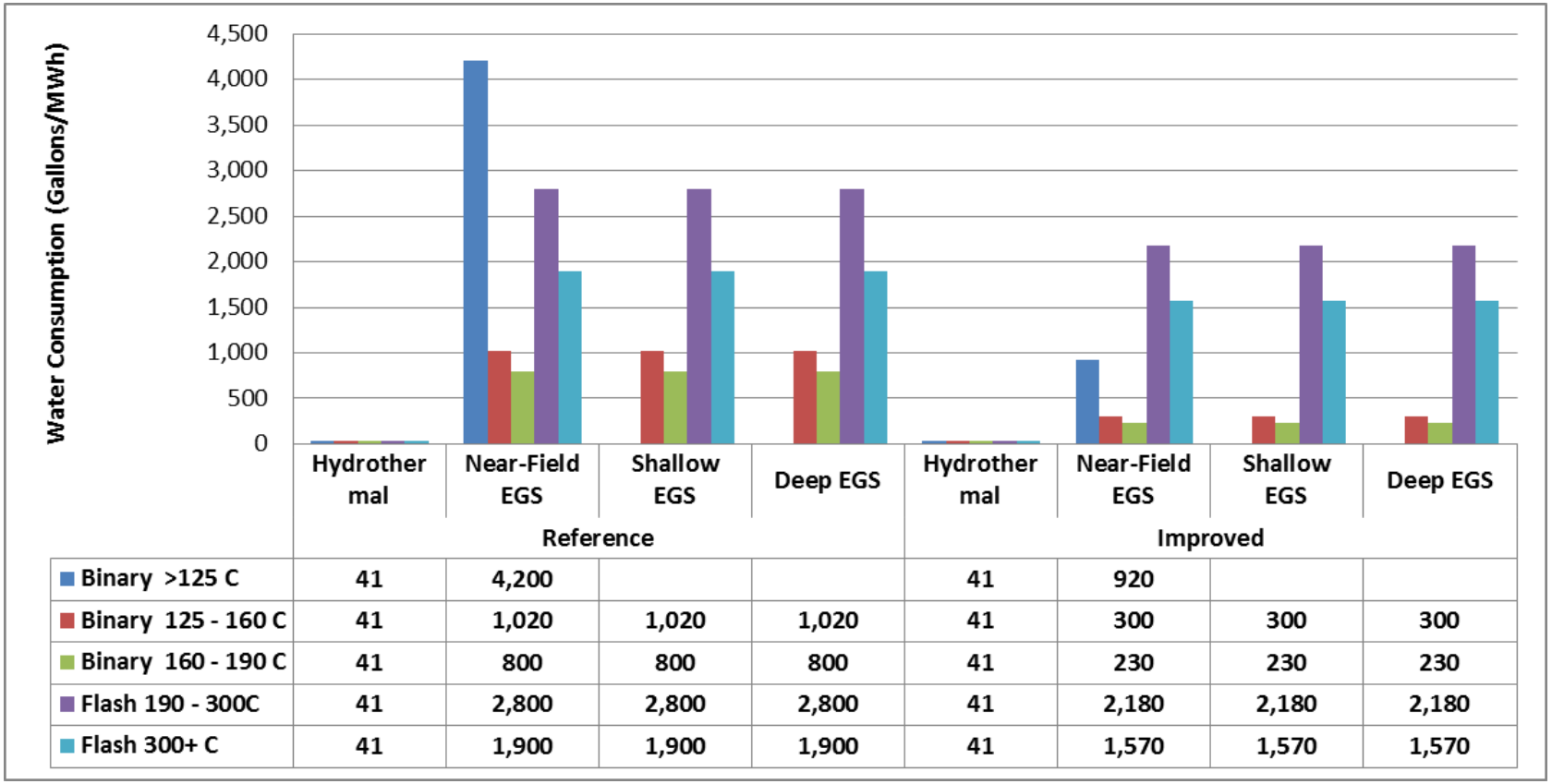
- **Make use of new unique capability of incorporating water resources as a constraint in electricity sector**
- **Developing greater resolution of geothermal technologies and their operating characteristics**

See also: Short, W.; Sullivan, P.; Mai, T.; Mowers, M.; Uriarte, C.; Blair, N.; Heimiller, D.; Martinez, A. (2011). Regional Energy Deployment System (ReEDS).NREL Report No. TP-6A20-46534.

Geothermal Water Consumption Values Vary by Resource Type and Geothermal Technology

- Most geothermal processes could use alternative water resources instead of freshwater

Geothermal Water Consumption (Gal/MWh) by Resource, Technology, and Scenario



	Reference				Improved			
	Hydrothermal	Near-Field EGS	Shallow EGS	Deep EGS	Hydrothermal	Near-Field EGS	Shallow EGS	Deep EGS
Binary >125 C	41	4,200			41	920		
Binary 125 - 160 C	41	1,020	1,020	1,020	41	300	300	300
Binary 160 - 190 C	41	800	800	800	41	230	230	230
Flash 190 - 300C	41	2,800	2,800	2,800	41	2,180	2,180	2,180
Flash 300+ C	41	1,900	1,900	1,900	41	1,570	1,570	1,570

Geothermal water use data are from ANL report (ANL/EVS-14/2)- "Geothermal Water Use: Life Cycle Water Consumption, Water Resource Assessment, and Water Policy Framework"

Technical Approach

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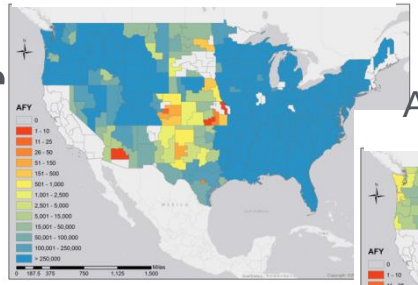
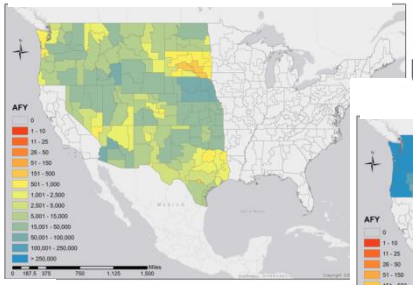
Water availability and cost at the national level

Availability

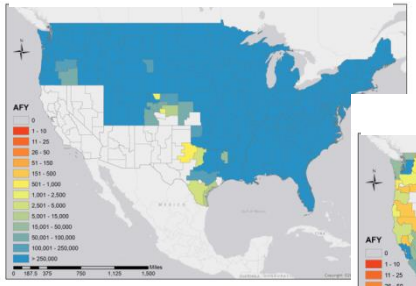
Groundwater



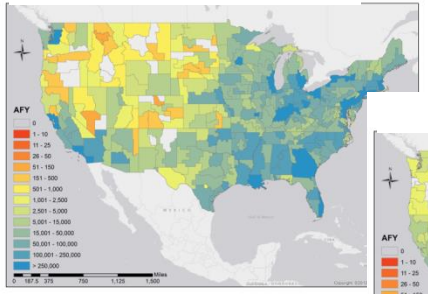
Appropriated Water



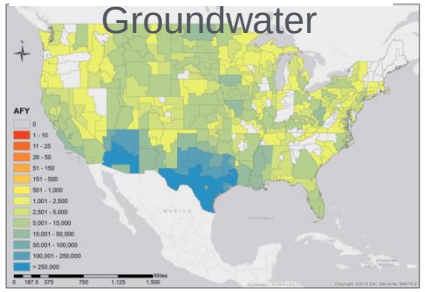
Unappropriated Water



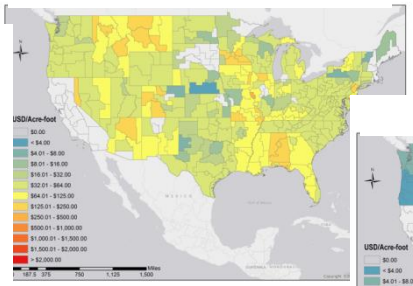
Wastewater

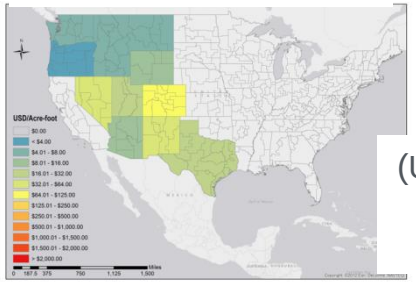


Brackish Groundwater

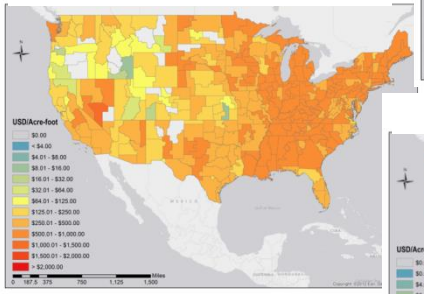


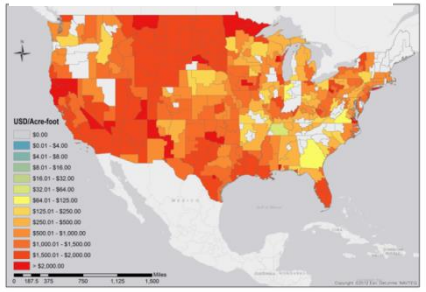
Cost





(Unappropriated Water Cost is negligible)





Sources: Tidwell, V.; Zemlick, K.; Klise, G. (2013). "Nationwide Water Availability Data for Energy-Water Modeling." SAND2013-9968. Albuquerque, NM: Sandia National Laboratories. SNL: Tidwell et al., 2014. Mapping water availability, projected use and cost in the western United States. Environmental Research Letters 9: 064009.

Technical Approach

Scenario Analysis:

- Variations in Geothermal Technology Cost/Performance/Water-use Characteristics

- Variations in Water Availability

Scenario	Water Constraint Characteristics	Geothermal Technology Characteristics
RefGeo-NoCon	No Water Constraints	Reference
RefGeo-AllWat	All Water Types	Reference
RefGeo-LimWat	Limited Water Types	Reference
ImpGeo-NoCon	No Water Constraints	Improved
ImpGeo-AllWat	All Water Types	Improved
ImpGeo-LimWat	Limited Water Types	Improved

Limited Water Availability only includes brackish groundwater and municipal wastewater

Geothermal technology data are from ANL report (ANL/EVS-14/2)- "Geothermal Water Use: Life Cycle Water Consumption, Water Resource Assessment, and Water Policy Framework

Accomplishments, Results and Progress

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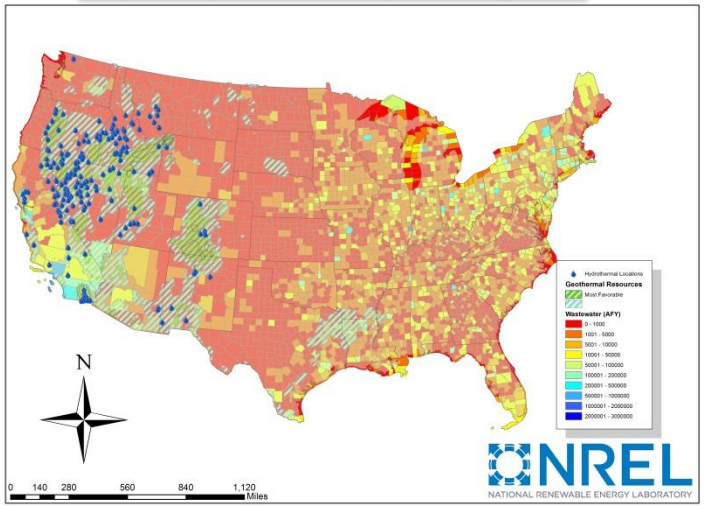
Original Planned Milestone/ Technical Accomplishment	Actual Milestone/Technical Accomplishment	Date Completed
Complete initial map overlaying water resource availability, geothermal resources, and existing electricity infrastructure.	Delayed	1/2014
Complete initial draft of geothermal penetration scenarios. This is for review to determine which scenarios are highest priority for a detailed assessment	Delayed	1/2014
Milestone: Modification of ReEDS electricity model to incorporate all geothermal technology types, cooling types, and resource supply curves. This will provided ReEDS with an industry unique capability to consider water resources as a constraint for geothermal deployment	As described	3/2014
Final geothermal penetration scenarios developed. After review, these are the final scenarios that will be analyzed in depth	Delayed	7/2014
Final geothermal penetration scenario analysis using the ReEDS model	Delayed	1/2015
Final water cost analysis using data from ReEDS analysis and ANL	Delayed	1/2015
SMART Milestone: Results/Analysis summarized in Technical Report	Delayed	2/2015
Results/Analysis displayed in draft online interactive map format	Delayed	2/2015

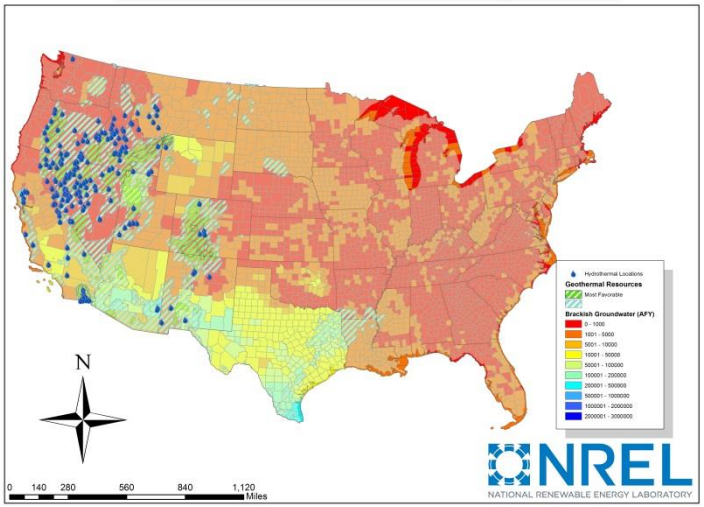
•In FY14, the project was delayed by four months due to a combination of the government shutdown and due to funds not being received at NREL. In late FY14, the project was again delayed by three months, delaying all subsequent milestones (covering scenario development and modeling) due to a delay in NREL receiving the "Geothermal Water Use: Life Cycle Water Consumption, Water Resource Assessment, and Water Policy Framework" (ANL/EVS-14/2) report and data that was published by Argonne National Laboratory in June 2014, but which was held up in DOE review. This report contained crucial information regarding geothermal technology characteristics and water use required for modeling and scenario development, and this had the effect of delaying all subsequent milestones of the project and also affected the schedules of NREL staff.

Accomplishments, Results and Progress

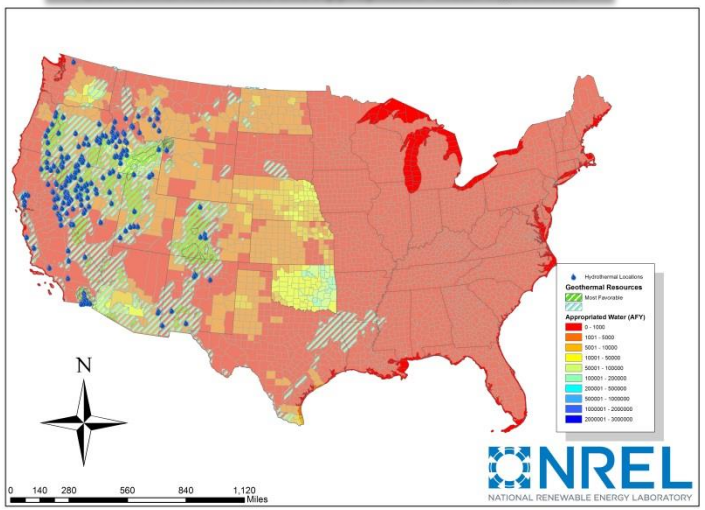
Geothermal Resources and Wastewater Resources



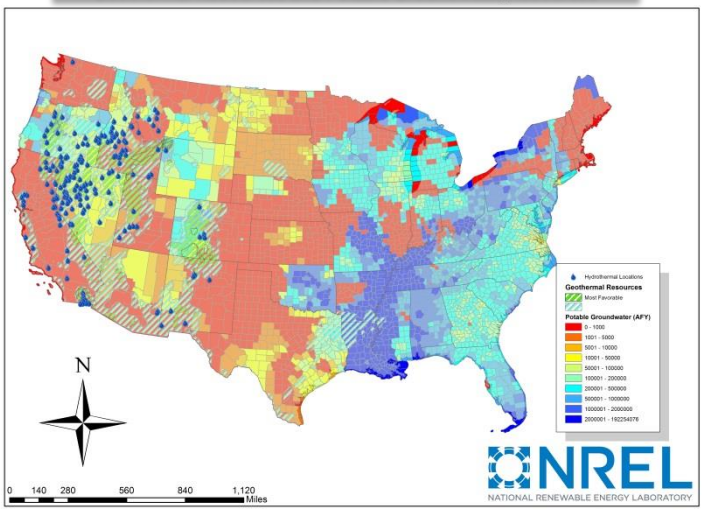
Geothermal Resources and Brackish Water Resources



Geothermal Resources and Appropriated Water Resources



Geothermal Resources and Potable Groundwater Resources

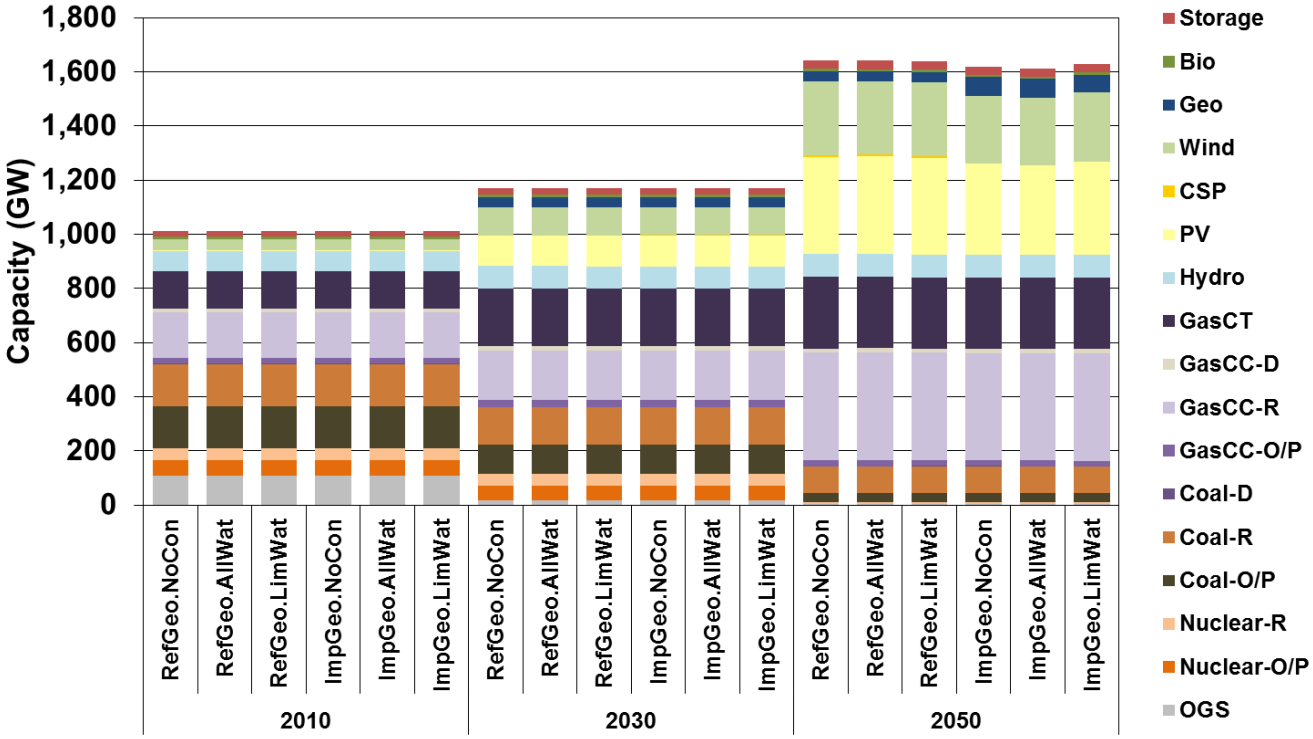


Geothermal Resources in the context of water availability for fresh sources as well as non-fresh sources

Although geothermal resources aren't often in areas with abundant fresh water resources, alternative water resources can be plentiful

National Geothermal Capacity

- Impact of improved cost/performance data for geothermal could lead to almost a doubling in geothermal capacity by 2050
  - Baseline geothermal deployment (2050): ~37 GW
  - Improved geothermal tech deployment (2050): ~70GW



Draft Results
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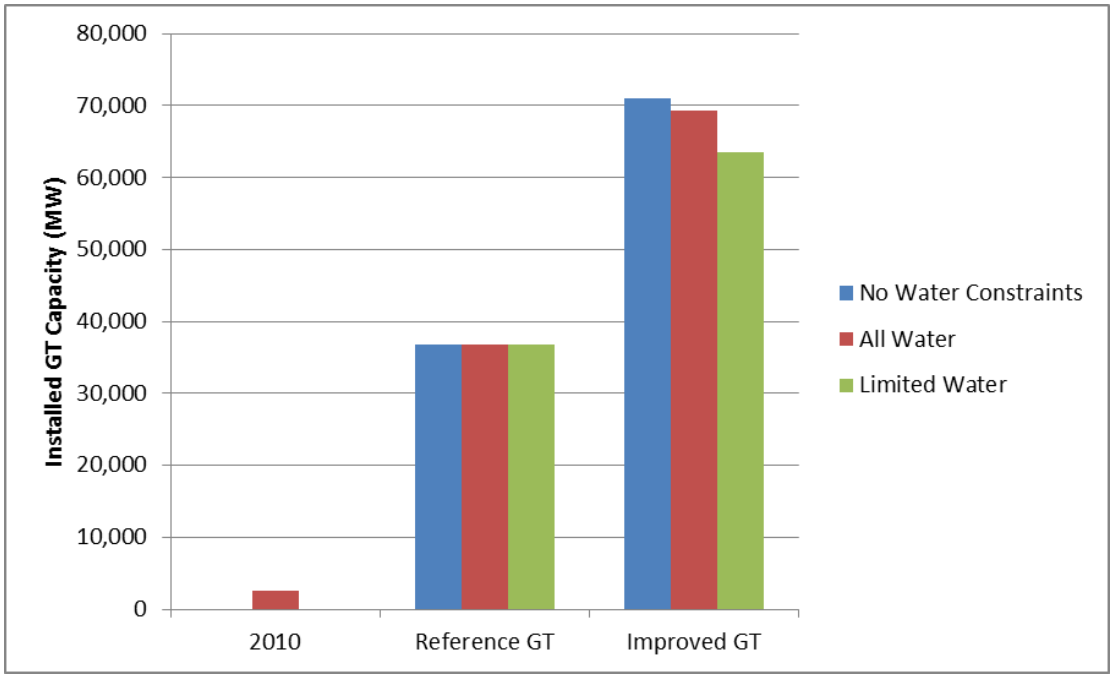
National Geothermal Capacity

- Geothermal deployment levels in 2050 can be affected by water availability
  - Under reference case, geothermal deployment is unaffected by water availability
  - Under improved geothermal tech assumptions, water can have an impact:
    - No water constraints: 71 GW by 2050
    - Current water availability: 69 GW (2.5% reduction) by 2050
    - Limited water availability: 64 GW (11% reduction) by 2050



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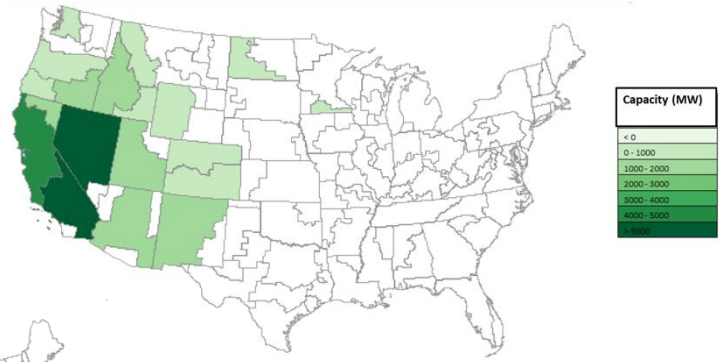
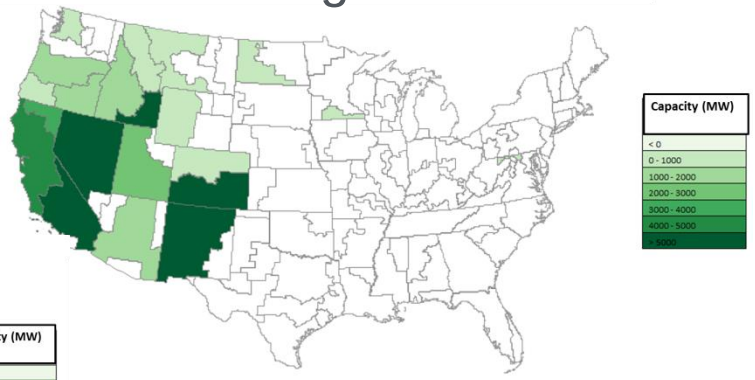
Regional Geothermal Capacity

- Current geothermal capacity exists in 8 ReEDS BA regions
  - Under reference case, geothermal expands to 19 BA regions in 2050
  - Under improved case, geothermal expands to 20 BA regions in 2050

2050 Capacity
Reference Case
No Water Constraints





2050 Capacity
Improved Case
No Water Constraints

2010 Capacity

Draft Results
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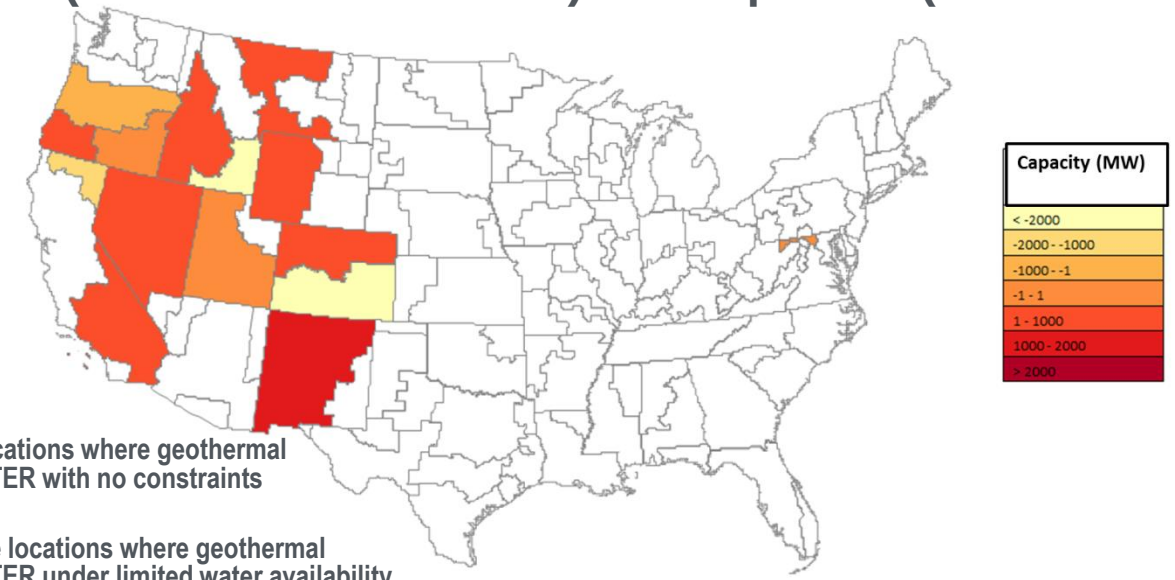
Regional Geothermal Capacity

- Under improved cases, water availability constraints affect regional geothermal deployment in 11 of 20 BA regions
  - Under water constraints, regions with lower quality geothermal resources but more water availability see increases in geothermal capacity

2050 Geothermal Capacity Differences
Improved (No Water Constraints) vs. Improved (Limited Water Availability)



Red areas indicate locations where geothermal deployment is GREATER with no constraints

Orange areas indicate locations where geothermal deployment is GREATER under limited water availability

Draft Results
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National Water Withdrawal and Consumption

- National levels of water **withdrawals** decline substantially for scenarios
  - 2010: 46 trillion gallons/yr → 2050: 8 trillion gallons/yr
- National levels of water **consumption** decline substantially for reference cases; reductions are less dramatic for improved geothermal cases
  - 2010: 1.5 trillion gallons/yr
  - 2050 (Reference): 1.0 trillion gallons/yr
  - 2050 (Improved): 1.3 trillion gallons/yr

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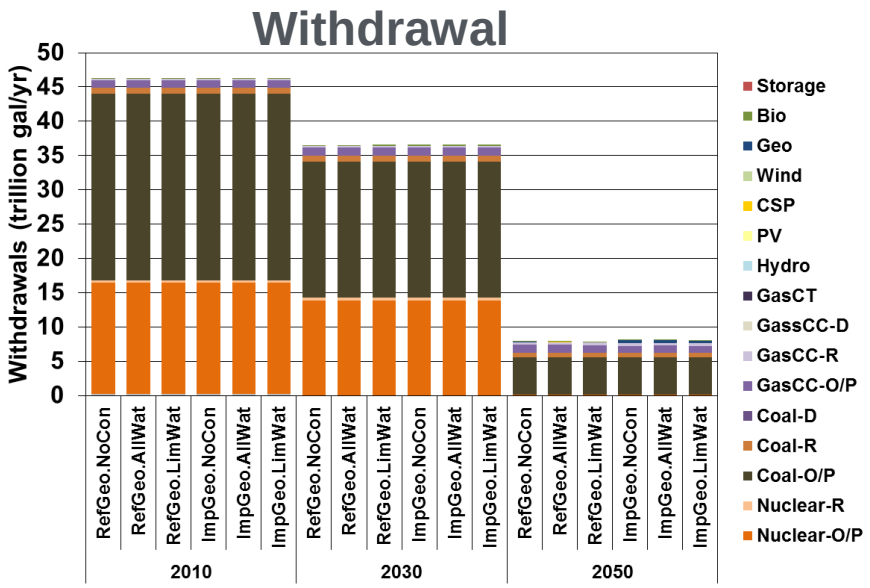
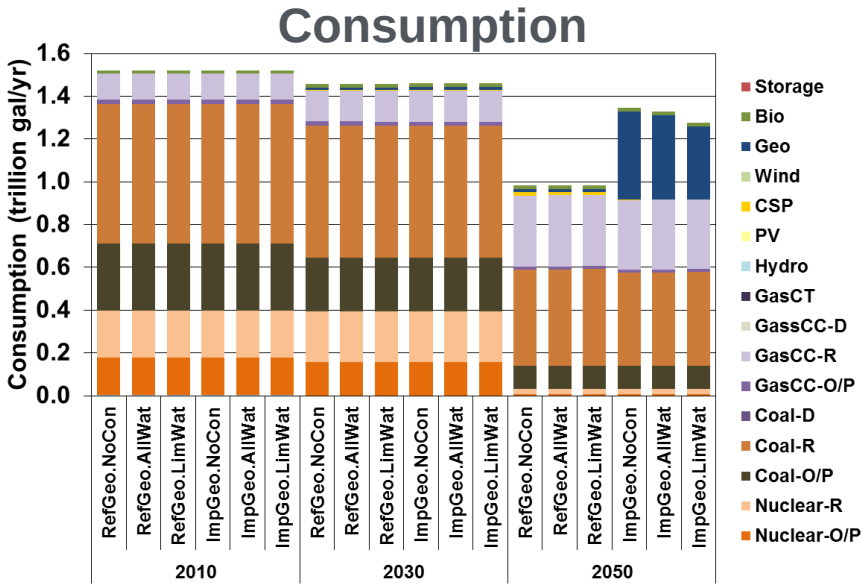
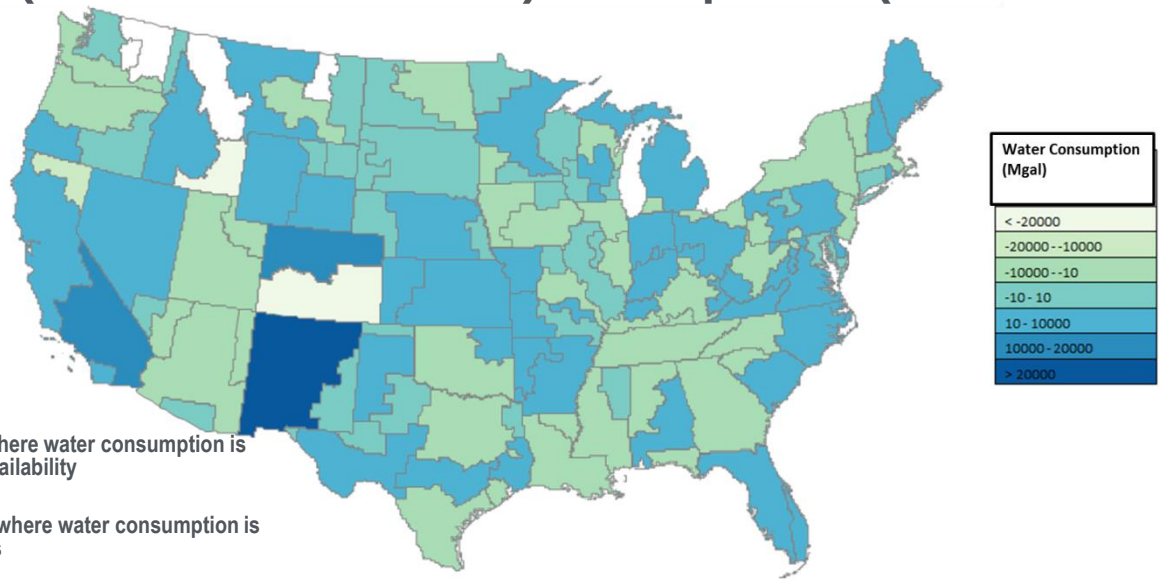




Regional Water Consumption

- Highest levels of change in water consumption from the Improved cases to the reference cases in 2050 occurs in geothermal development areas
  - Most water consumption increases in the limited water case are for non-fresh water resources

2050 Water Consumption Differences
Improved (No Water Constraints) vs. Improved (Limited Water Availability)



Blue areas indicate locations where water consumption is GREATER with limited water availability

Green areas indicate locations where water consumption is GREATER under no constraints

Draft Results
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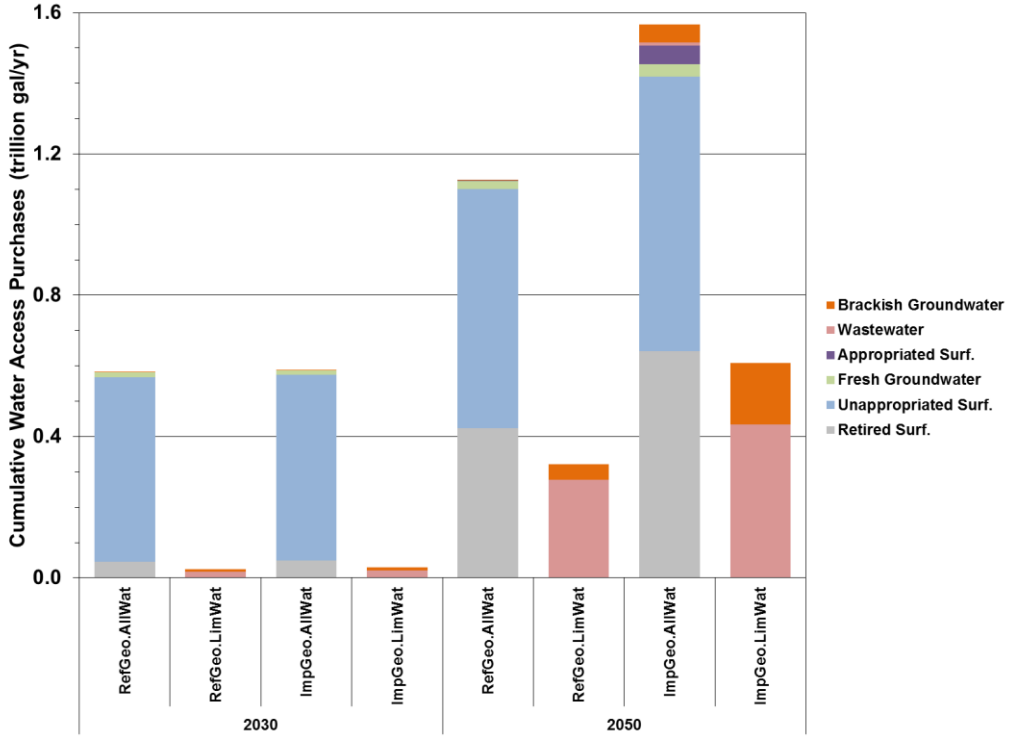
Water Access Purchases by Water Quality

- Water access purchased under the improved geothermal case is approximately 35% greater than under the reference case, when all water types are available
- Under water constraints, water purchases are 75% lower in the reference case and 50% lower in improved tech case

Water access purchases by scenario and water quality type



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Future Directions

- Future plans for FY 2015 include:
  - Finalization of technical report
  - Finalization of online platform for data and integration with GDR
  - Dissemination of results and data via conference presentations

- Future areas of research interest:
  - Optimize geothermal siting decisions
  - Evaluate economic tradeoffs of utilizing different types of alternative water resources on a site-specific basis
  - Integrate with other GTO projects such as geothermal-powered desalination

Mandatory Summary Slide

- This research helps GTO meet its goals and objectives of lowering the risk and cost of geothermal exploration by identifying and demonstrating the importance of water resources for geothermal deployment, while also highlighting opportunities to utilize alternative water resources to increase geothermal deployment opportunities.

- This project has provided important new information to the field regarding geothermal development and water availability constraints:
  - Under reference case assumptions of geothermal cost and performance, geothermal deployment is not substantially affected by water resource constraints.
  - Under improved geothermal cost and performance assumptions, national levels of geothermal deployment can be reduced by 11% just due to water constraints.
  - Region-specific changes in geothermal deployment can be greater than national-level changes under scenarios of water constraints, with some regions showing increases in geothermal deployment and other regions showing decreases due to lack of water.

- Future work can provide greater detail for opportunities to increase geothermal deployment by utilizing alternative water resources

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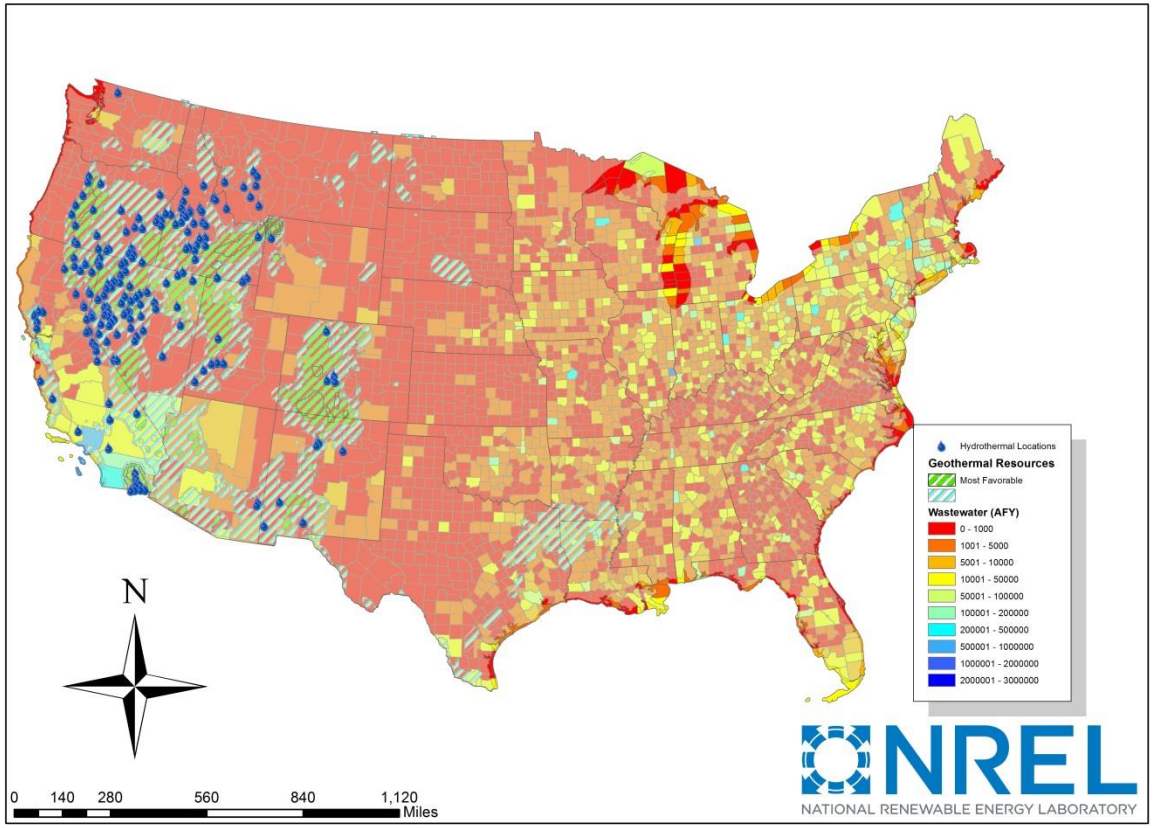

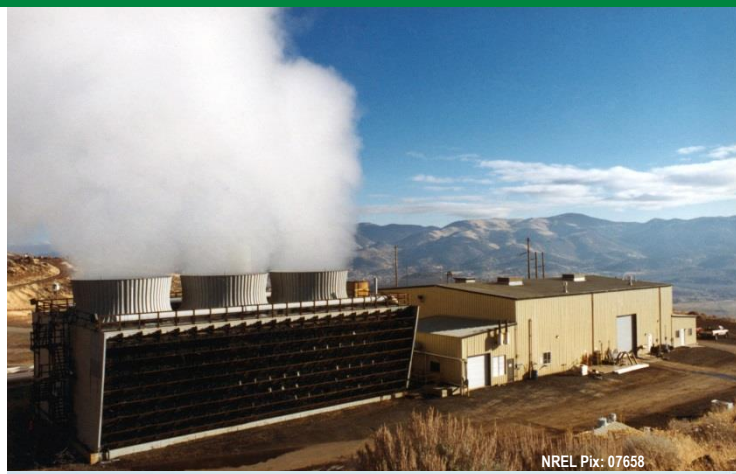

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Project Officer: Arlene Anderson

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