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## Exploring Energy-Water Issues in the United States

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*Sandia National Laboratories*

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*Carnegie Mellon University*

***Crosscutting Research and Rare Earth Elements Review***

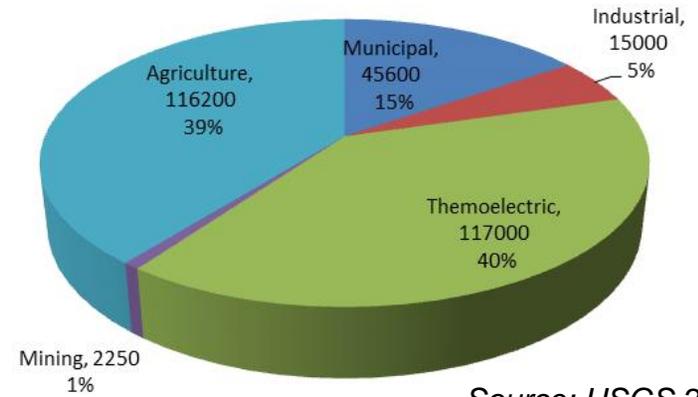
***April 20, 2016***



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

# Challenge

Thermoelectric energy production withdraws more water in the U.S. than any other use sector.



Source: USGS 2014

Energy-Water Nexus Issues are playing out all across the U.S.

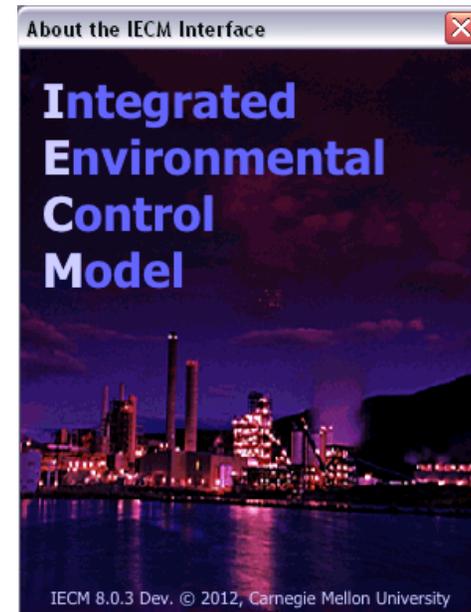
- Power plant outages
- Constrained hydropower
- Infrastructure damage by extreme events
- Curtailed energy resource extraction
- Permitting of New Facilities



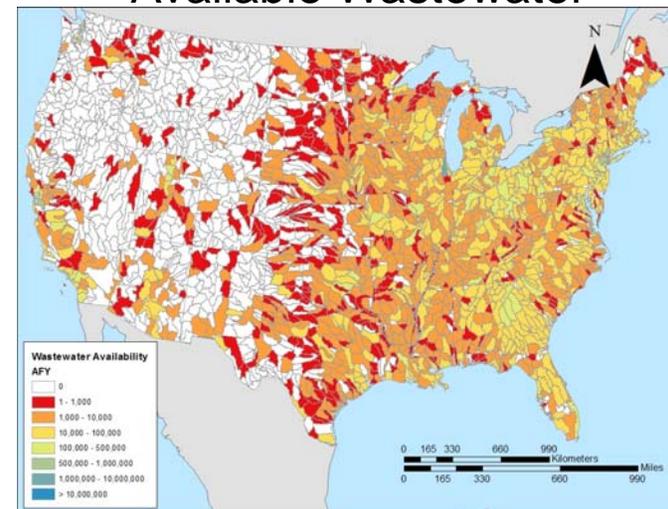
Source: DOE 2013

# Objectives

- Extend capabilities of the Integrated Environmental Control Model (IECM) to assess alternative options for designing and managing power plant water systems at the unit level.
- Develop a National Water Atlas, estimating water availability, cost and projected future demand at the watershed level (8-digit HUC, or roughly 2250 watersheds)



Available Wastewater



# ***Power Plant Lifecycle Water Use***



# Configure a Plant with Wet or Dry or Hybrid Cooling to Assess Plant-Level and Life Cycle Water Use

The screenshot displays the IECM Interface 10.0.0.2 Beta software window. The title bar reads '\*PC, none CCS, hybrid cooling [IECM Interface 10.0.0.2 Beta]'. The menu bar includes 'File', 'Edit', 'Go', and 'Help'. The toolbar contains icons for file operations and navigation. The main window is titled 'CONFIGURE SESSION: Plant Design'. On the left, a tree view shows the project structure, with 'Water Systems' and 'Water Life Cycle Assessment' highlighted by red dashed ovals. The 'Water Systems' folder is expanded to show '1. Hybrid Cooling System', '2. Dry Unit', and '3. Wet Unit'. The 'Water Life Cycle Assessment' folder is expanded to show 'Coal', 'Natural Gas', 'Plant Infrastructure', 'Plant Operation', and 'Chemical Production'. The main configuration area on the right is divided into several sections: 'Configuration' (set to '<User Defined>'), 'Combustion Controls' (Fuel Type: Coal, NOx Control: In-Furnace Controls), 'Post-Combustion Controls' (NOx Control: Hot-Side SCR, Particulates: Cold-Side ESP, SO2 Control: Wet FGD, Mercury: None, CO2 Capture: None), and 'Water and Solids Management' (Cooling System: Hybrid Cooling System, Wastewater: Once-Through, Flyash Disposal: Hybrid Cooling System). A schematic diagram on the right shows a process flow involving a furnace, SCR, ESP, FGD, and cooling towers.

**Configuration:** <User Defined>

**Combustion Controls**

Fuel Type: Coal

NOx Control: In-Furnace Controls

**Post-Combustion Controls**

NOx Control: Hot-Side SCR

Particulates: Cold-Side ESP

SO2 Control: Wet FGD

Mercury: None

CO2 Capture: None

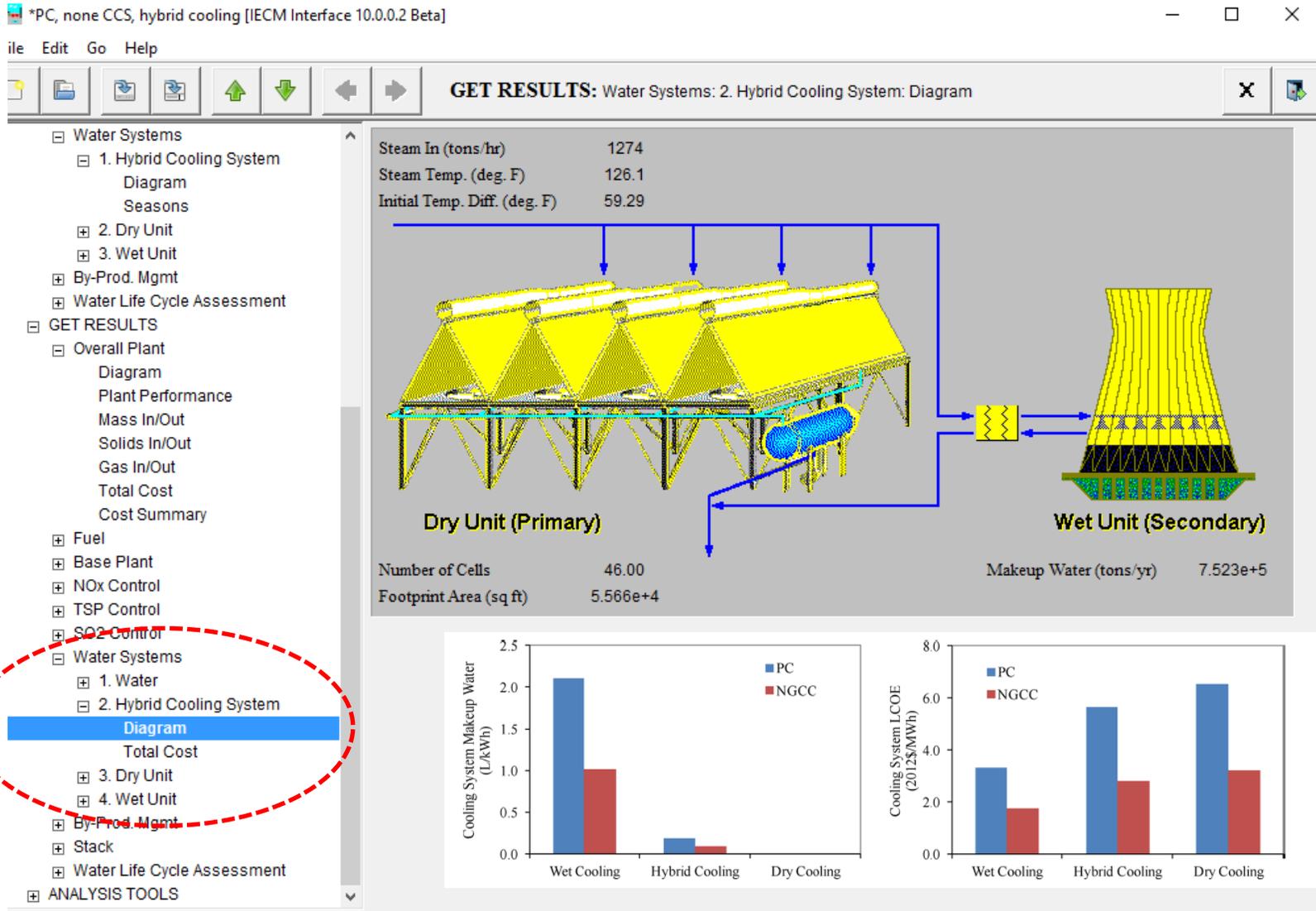
**Water and Solids Management**

Cooling System: Hybrid Cooling System

Wastewater: Once-Through

Flyash Disposal: Hybrid Cooling System

# Hybrid Cooling System



# Life Cycle Water Use

water LCA [IECM Interface 10.0.0.2 Beta]

File Edit Go Help

GET RESULTS: Water Life Cycle Assessment: Water Withdrawals

- Performance
- Regulations & Taxes
- Financing
- Fuel & Land Cost
- Capital Cost
- O&M Cost
- Fuel
- Base Plant
- NOx Control
- TSP Control
- SO2 Control
- Water Systems
- By-Prod. Mgmt
- Water Life Cycle Assessment
  - Coal
  - Natural Gas
  - Plant Infrastructure
  - Plant Operation
  - Chemical Production
- GET RESULTS
  - Overall Plant
  - Fuel
  - Base Plant
  - NOx Control
  - TSP Control
  - SO2 Control
  - Water Systems
  - By-Prod. Mgmt
  - Stack
  - Water Life Cycle Assessment
    - Water Withdrawals
    - Water Consumption
- ANALYSIS TOOLS

|    | A                                | B                          |    | A                       | B                          |
|----|----------------------------------|----------------------------|----|-------------------------|----------------------------|
| 1  | Process/Chemical                 | Water Withdrawal (gal/MWh) | 1  | Process/Chemical        | Water Withdrawal (gal/MWh) |
| 2  | Fuel Extraction                  | 2.170                      | 2  | Fuel Supply             | 15.90                      |
| 3  | Fuel Processing                  | 13.01                      | 3  | Plant Infrastructure    | 16.30                      |
| 4  | Fuel Transport                   | 0.7234                     | 4  | Chemical Production     | 3.509                      |
| 5  | <b>Total Fuel Supply</b>         | <b>15.90</b>               | 5  | Plant Operation         | 657.5                      |
| 6  |                                  |                            | 6  | <b>Total Life Cycle</b> | <b>693.2</b>               |
| 7  | <b>Plant Infrastructure</b>      | <b>16.30</b>               | 7  |                         |                            |
| 8  |                                  |                            | 8  |                         |                            |
| 9  | Ammonia                          | 1.030                      | 9  |                         |                            |
| 10 | Limestone                        | 2.479                      | 10 |                         |                            |
| 11 | Amine (30-wt% MEA)               | 0.0                        | 11 |                         |                            |
| 12 | <b>Total Chemical Production</b> | <b>3.509</b>               | 12 |                         |                            |
| 13 |                                  |                            | 13 |                         |                            |
| 14 | <b>Plant Operation</b>           | <b>657.5</b>               | 14 |                         |                            |
| 15 |                                  |                            | 15 |                         |                            |
| 16 |                                  |                            | 16 |                         |                            |

```

    graph LR
      subgraph Fuel_Supply [Fuel Supply]
        direction LR
        E[Extraction] --> P[Processing]
        P --> T[Transport]
      end
      subgraph Plant_Operation [Plant Operation]
        direction TB
        PO1[Plant w/o CCS]
        PO2[Plant w/ CCS]
      end
      subgraph Plant_Infrastructure [Plant Infrastructure]
        PI[Plant Infrastructure]
      end
      subgraph Chemical_Production [Chemical Production]
        CP[Chemical Production]
      end
      subgraph Electricity [Electricity]
        direction LR
        ELEC[Electricity]
      end

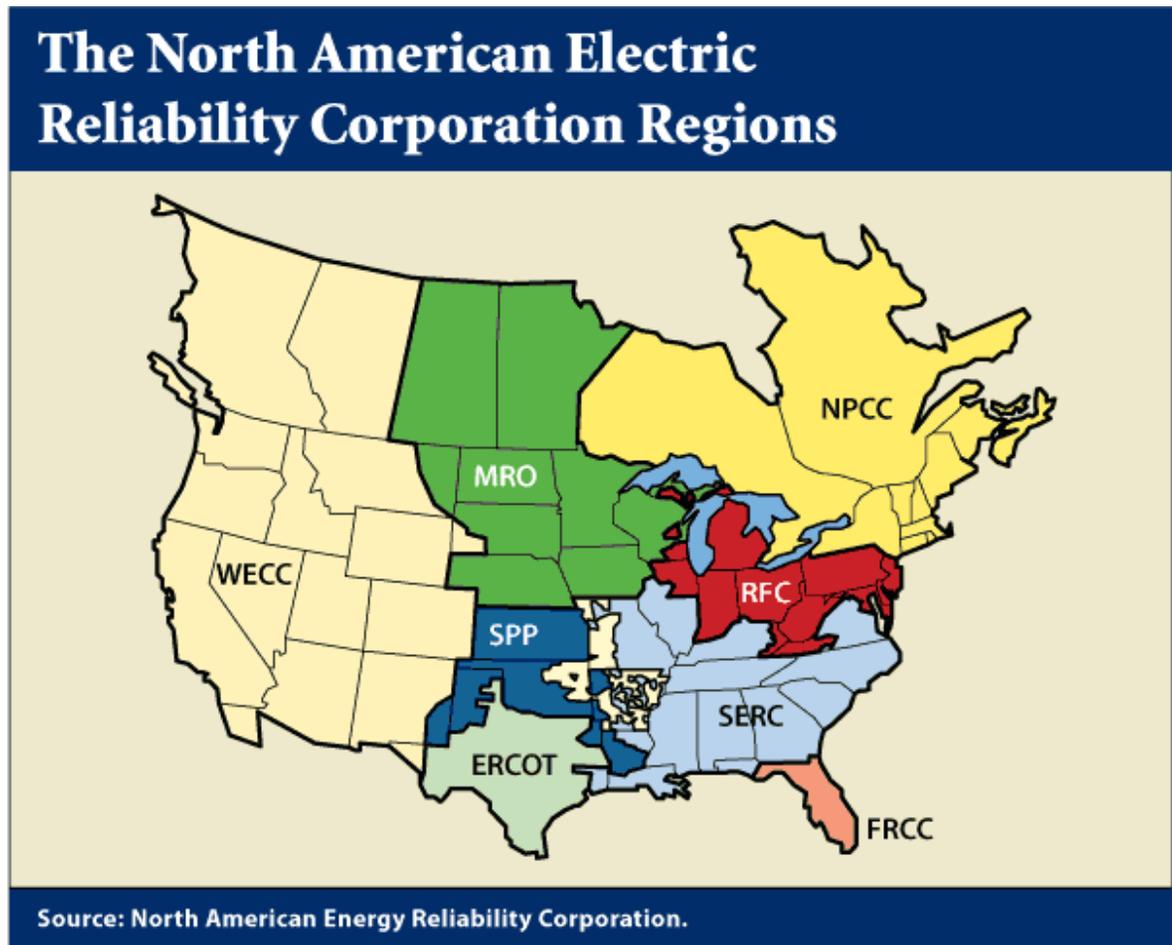
      Fuel_Supply --> Plant_Operation
      Plant_Infrastructure --> Plant_Operation
      Plant_Operation --> Electricity
      Plant_Operation --> Chemical_Production
  
```

# ***Water for Thermoelectric Development***



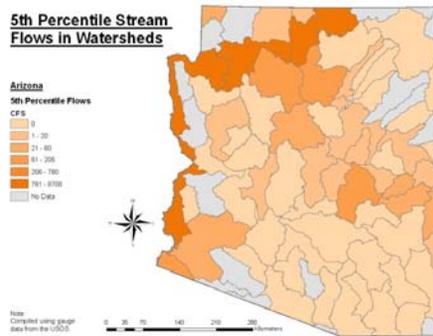
# Integrated Transmission Planning

- Interconnections are conducting long-range transmission planning (20 yrs.)
  - Siting of new power plants
  - New transmission capacity
- Address water issues:
  - Reduce impact of development on water resources,
  - Reduce vulnerability of system to “water interruptions”



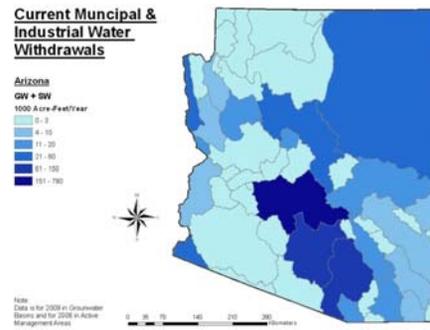
# Methods: Collected Data from States

## Water Supply



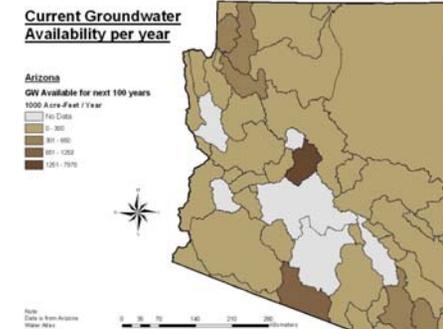
Mean Gauged Streamflow

## Water Demand

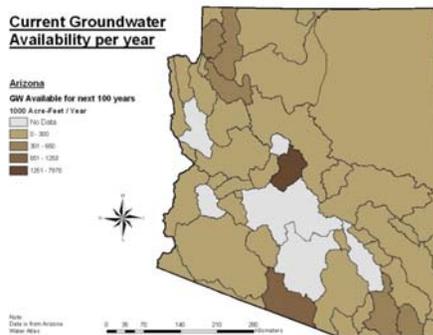


Municipal Demand

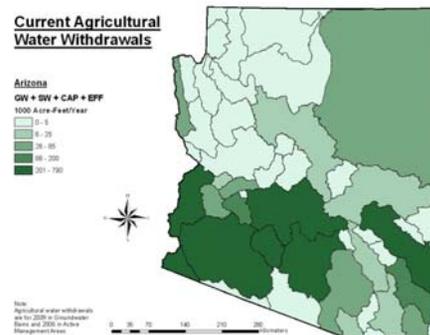
## Water Institutions



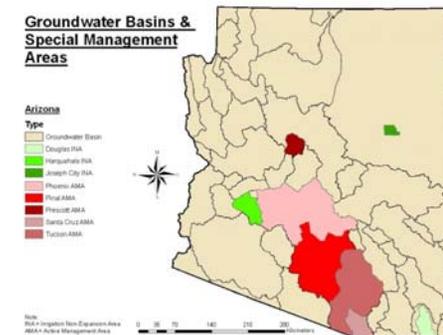
Unappropriated Water



Groundwater Depletion



Irrigation Demand



Administrative Control Areas

# Methods: Metric Development

- Data on “available water” are rare
- As such, metrics were estimated from available information
- Assisted by volunteer team from WSWC
  - Bret Bruce (USGS)
  - Dan Hardin (TX)
  - Sara Larsen (WSWC)
  - Dave Mitamura (TX)
  - Andy Moore (CO)
  - Ken Stahr (OR)
  - Todd Stonely (UT)
  - Steve Wolff (WY)
  - Dwane Young (WSWC)

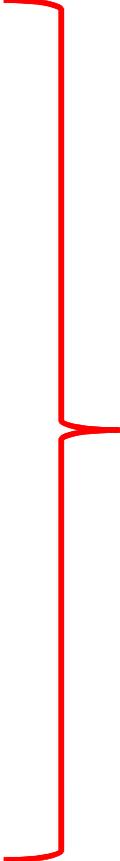
# Methods: Water Sources

- **Potable Water**

- **Unappropriated surface water**
- **Unappropriated groundwater**
- **Appropriated water (rights transfers)**

- **Non-Potable Water**

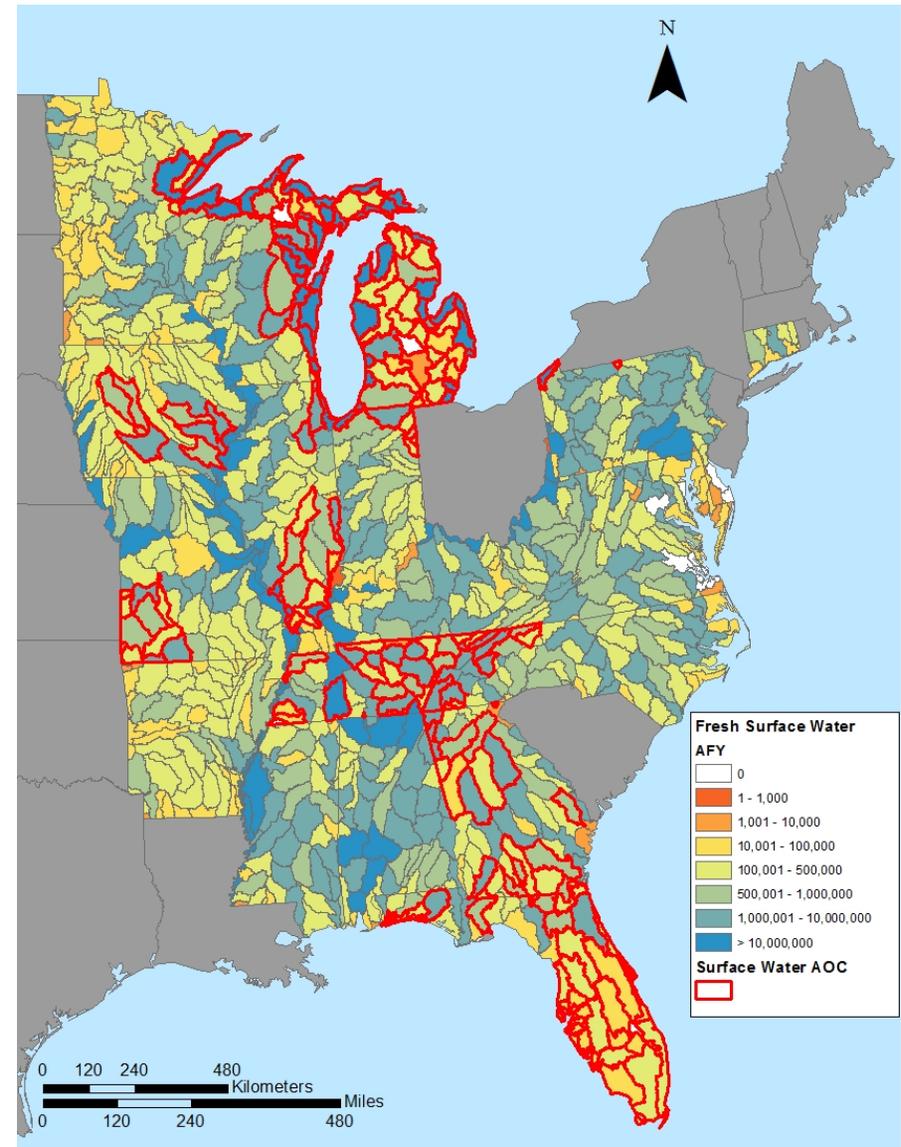
- **Municipal/Industrial wastewater**
- **Shallow brackish water**



**Relative  
Availability  
and Cost**

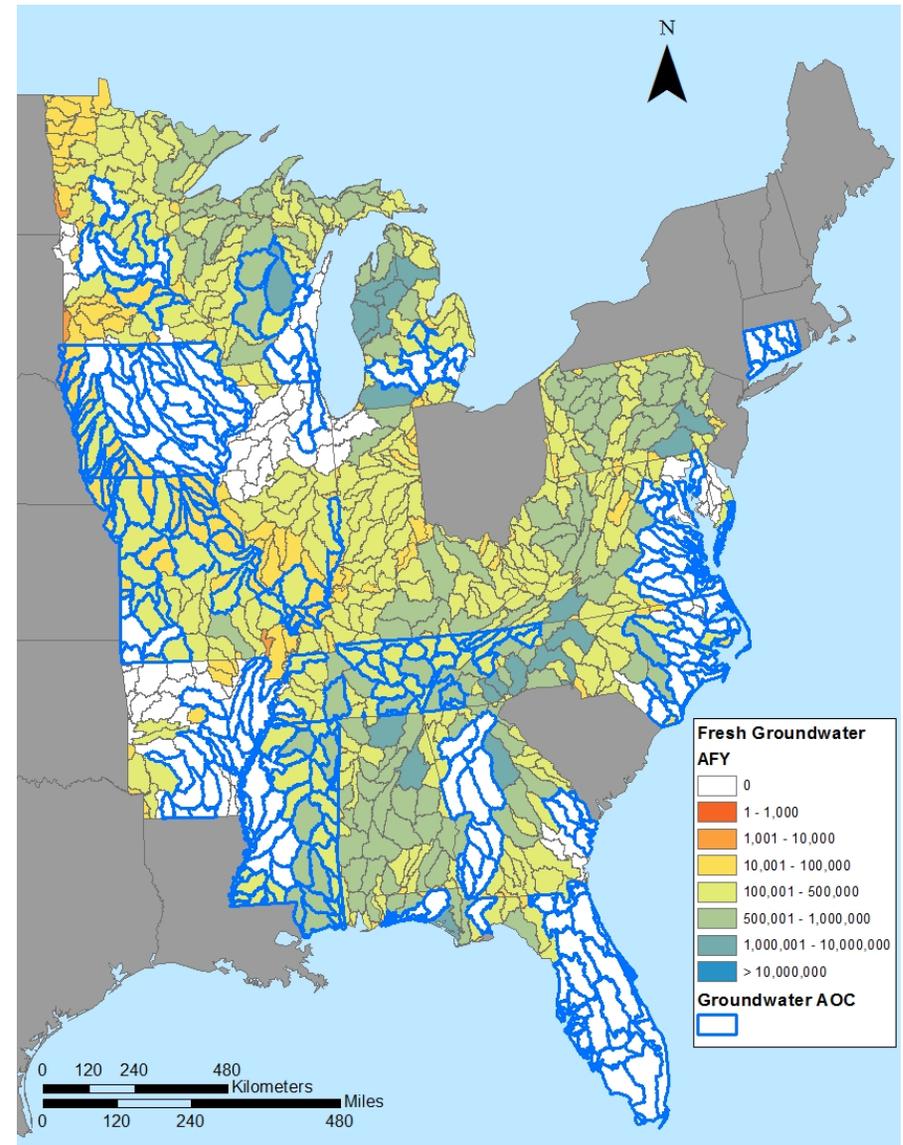
# Water Availability: Fresh Surface Water

- Surface water beyond current use that is available for new development.
- Based on environmental constraint:
  - $Q_{sw}^j = 0.5 * (Q_p^j + C^j) - C^j$
- Areas of Concern (basins outlined in red) designated regions requiring additional permitting.



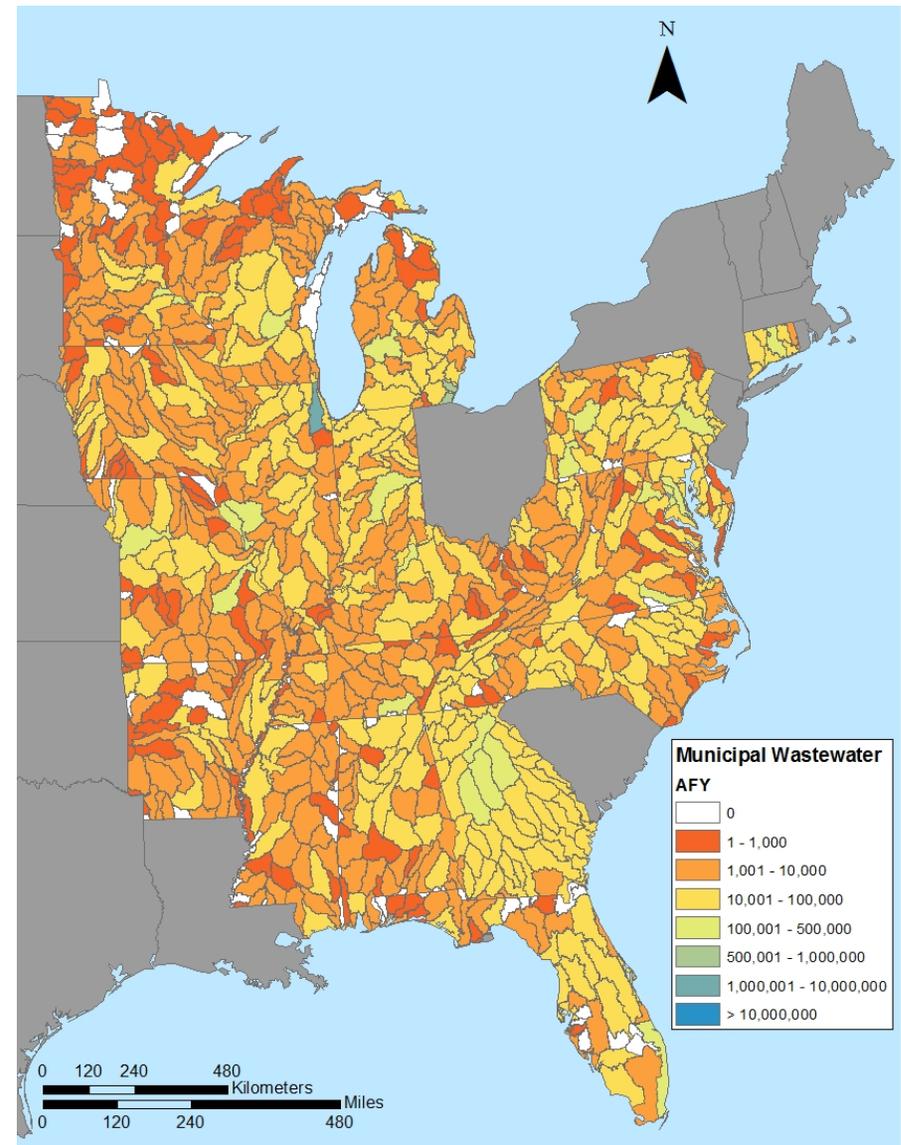
# Water Availability: Fresh Groundwater

- Groundwater beyond current use that is available for new development.
- Difference between sustainable recharge and pumping while considering:
  - Areas of overdraft, and
  - Principle aquifers.
- Areas of Concern (basins outlined in blue) designated regions requiring additional permitting.



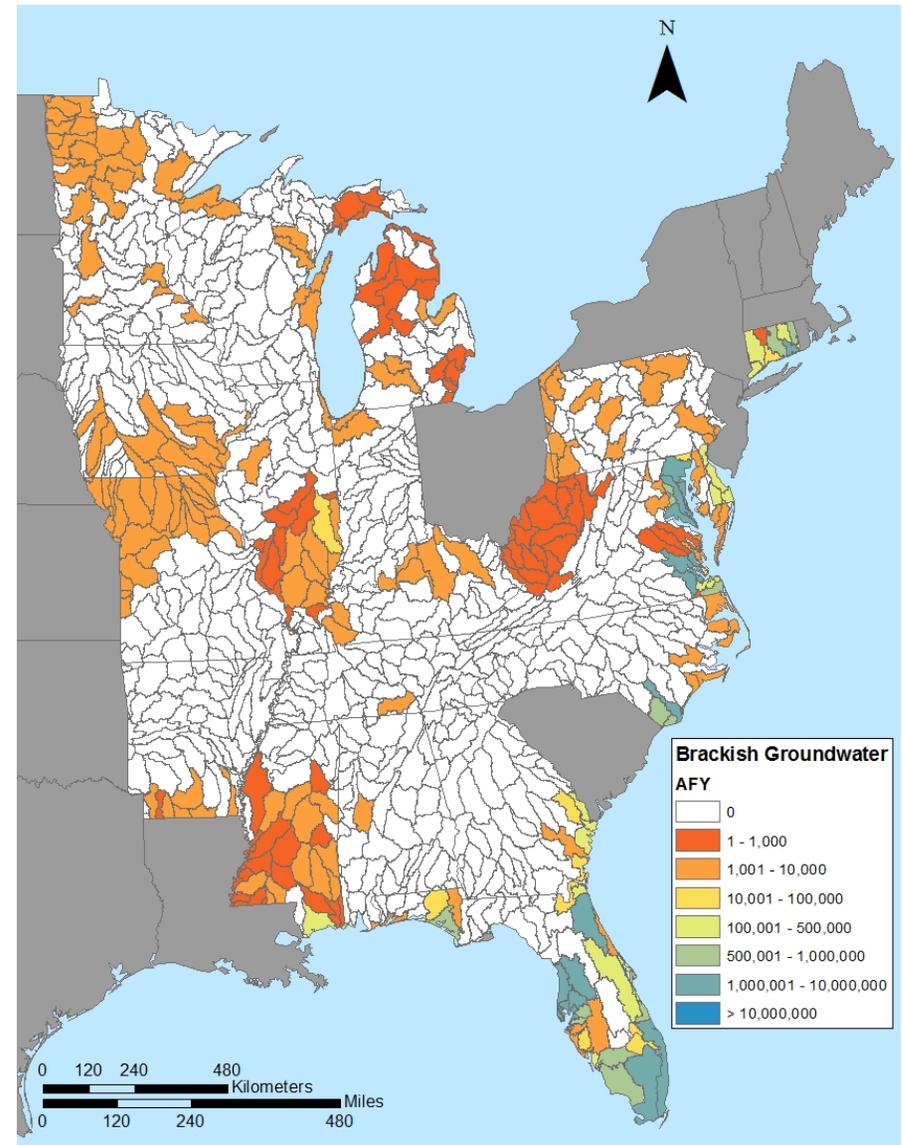
# Water Availability: Wastewater

- Projected future wastewater (2030) available for re-use.
- Reflects wastewater currently being reused.



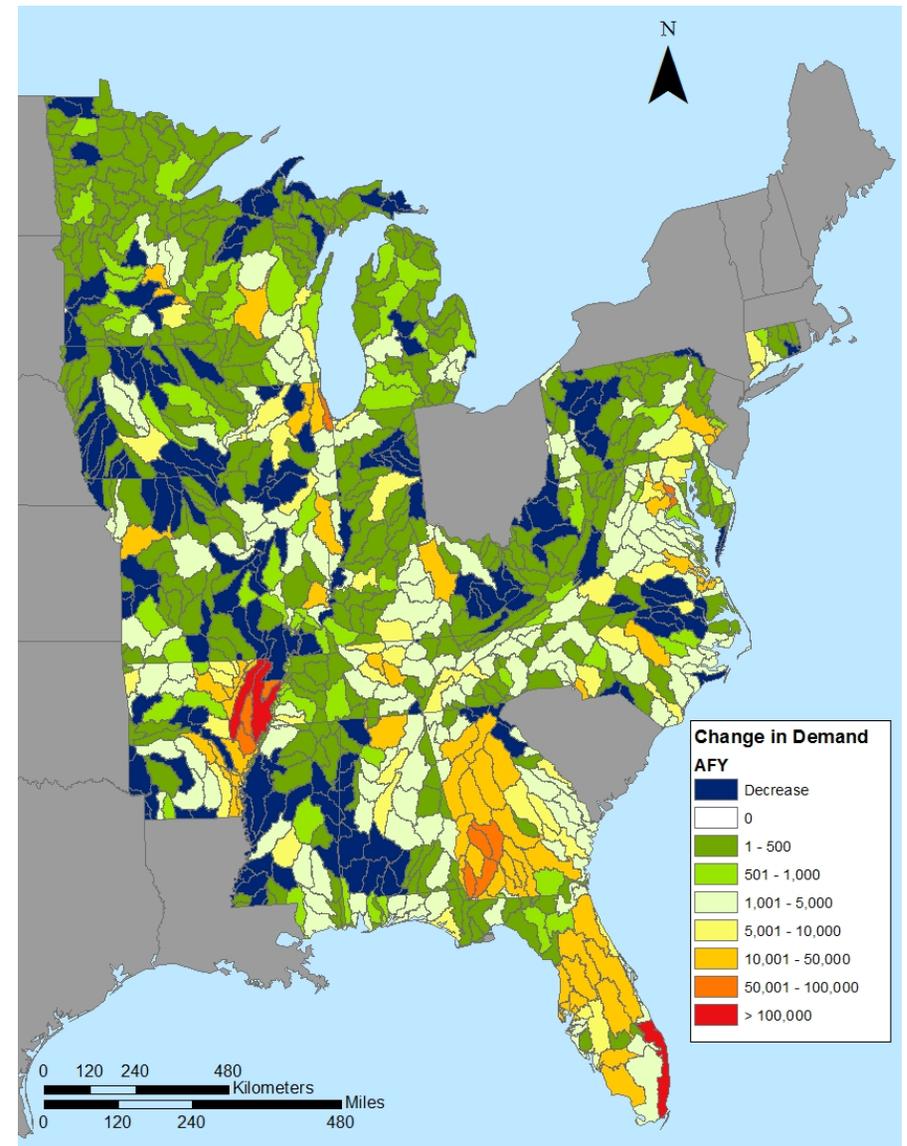
# Water Availability: Brackish Groundwater

- Brackish water defined by salinities between 1,000 and 10,000 ppm TDS no deeper than 2500 ft.
- Estimates are data limited based on:
  - Current brackish water use, and
  - USGS well logs that indicated brackish water availability.



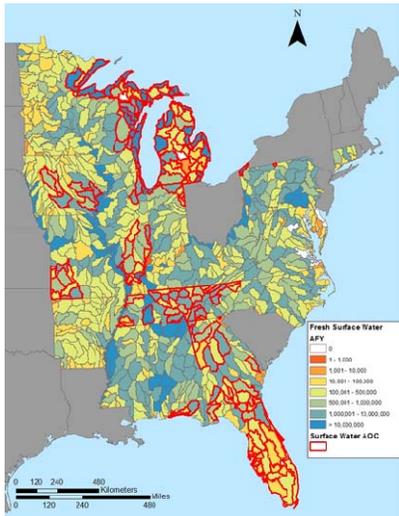
# Projected Future Use 2010-2030

- Water needed for development after 2010.
- Based on estimates directly from states.
- Does not include thermoelectric water demand.

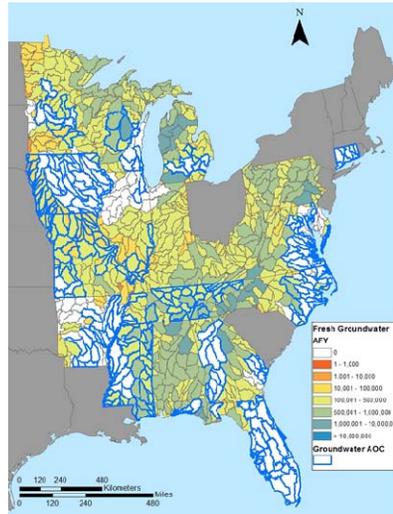


# Water Supply Availability

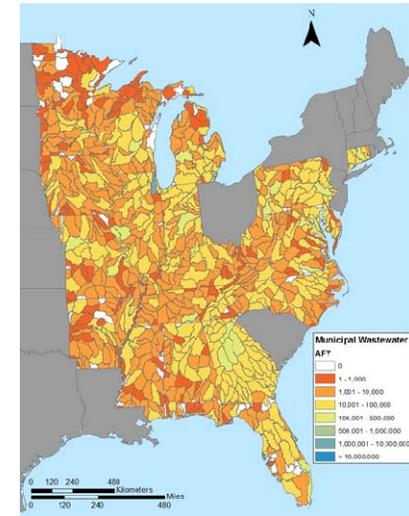
**Fresh Surface Water**



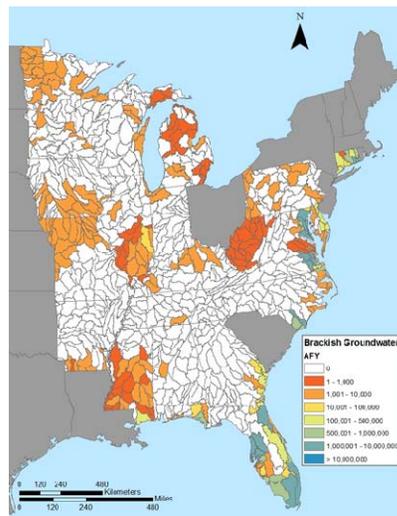
**Fresh Groundwater**



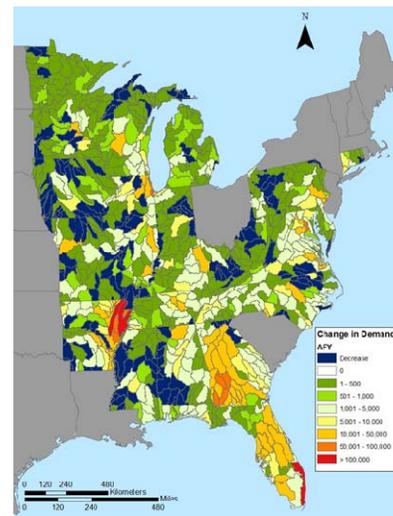
**Municipal Wastewater**



**Brackish Groundwater**

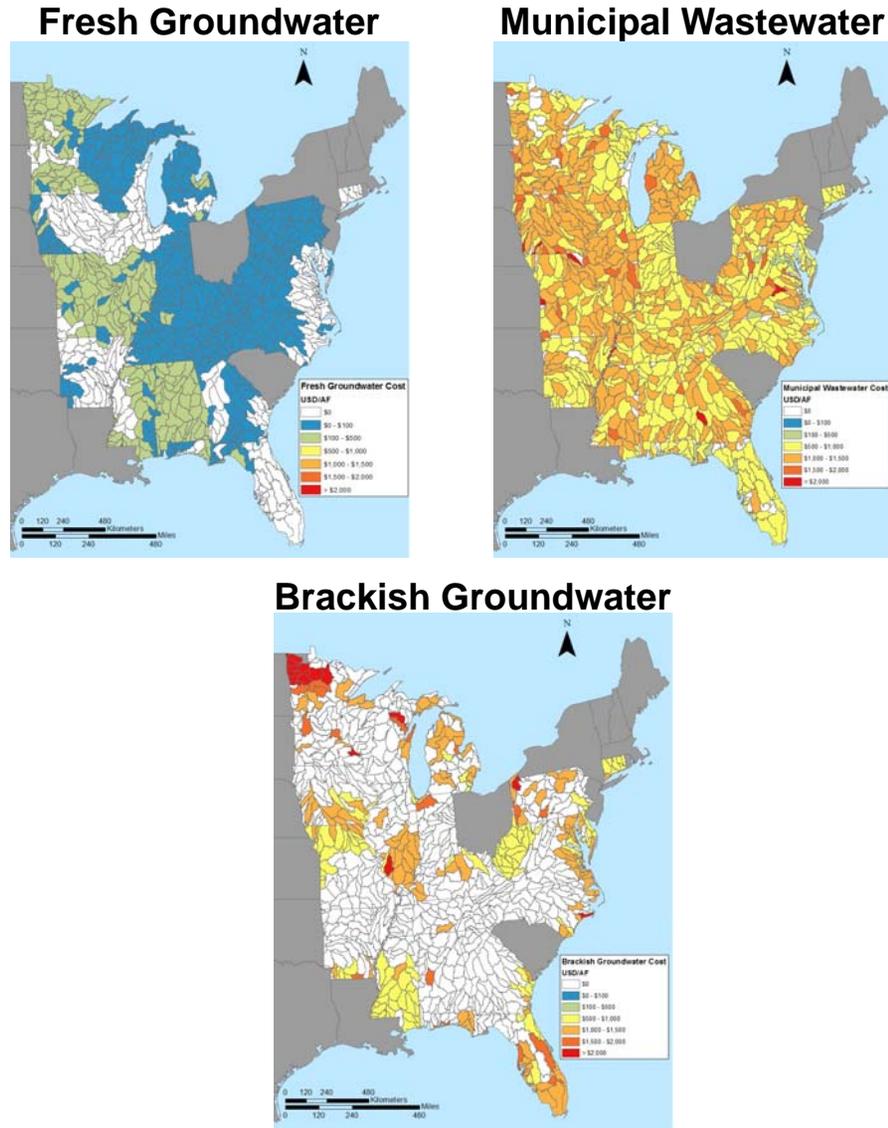


**Consumptive Demand 2010-2030**



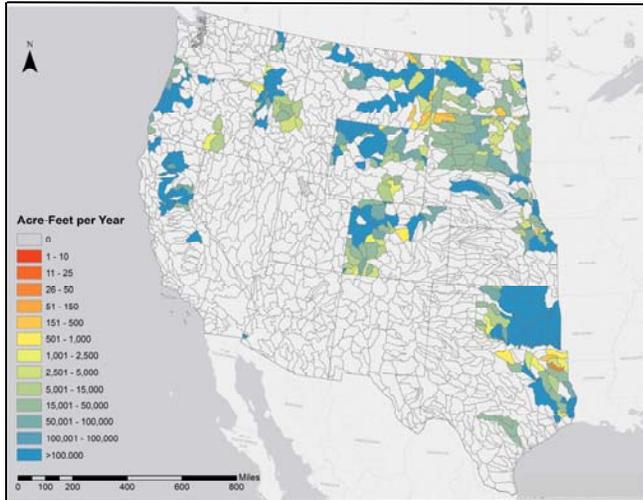
# Water Cost

- Goal is to establish a consistent and comparable measure of cost to deliver water of potable quality to the point of use
- Basic costs considered:
  - Capital costs:
    - Purchase water,
    - Wells,
    - Conveyance, and
    - Treatment.
  - Operation and Maintenance:
    - Electricity,
    - Labor,
    - Consumables, and
    - Disposal.

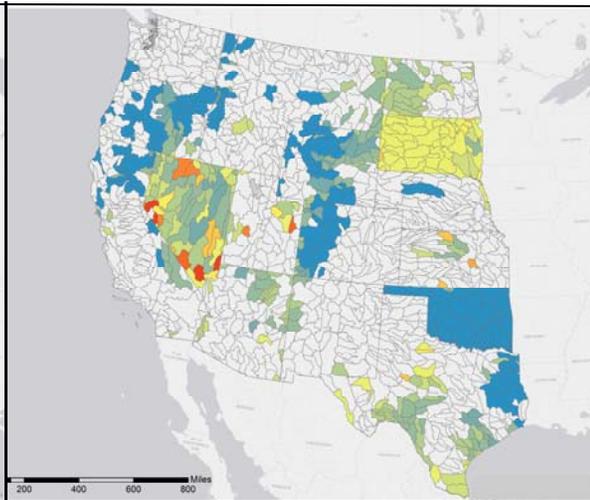


# Water Supply Availability: West

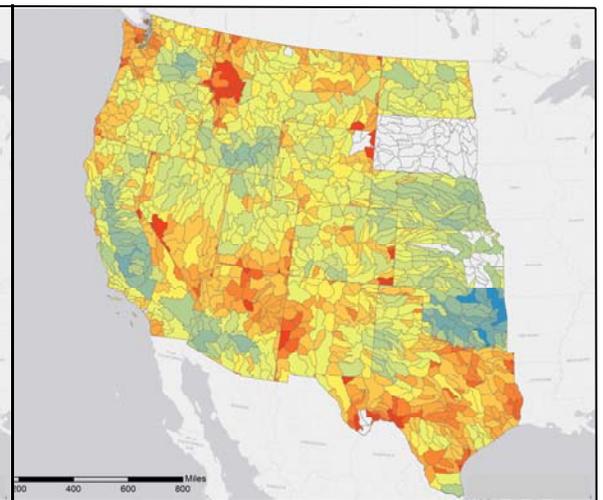
Unappropriated Surface Water



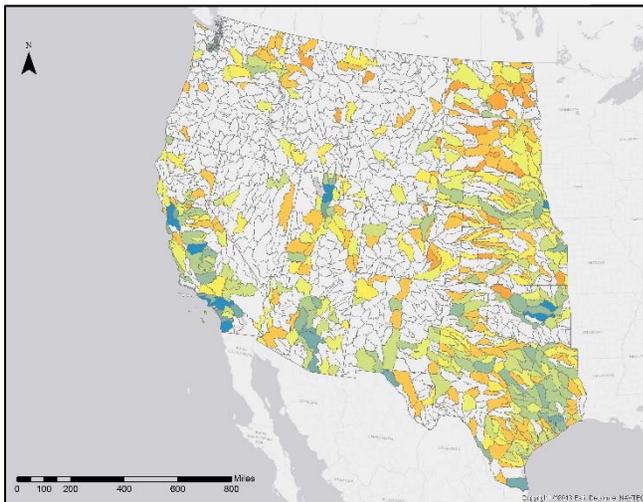
Unappropriated Groundwater



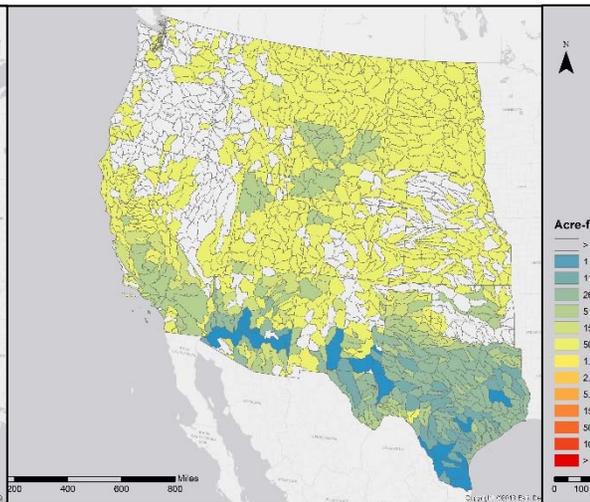
Appropriated Water



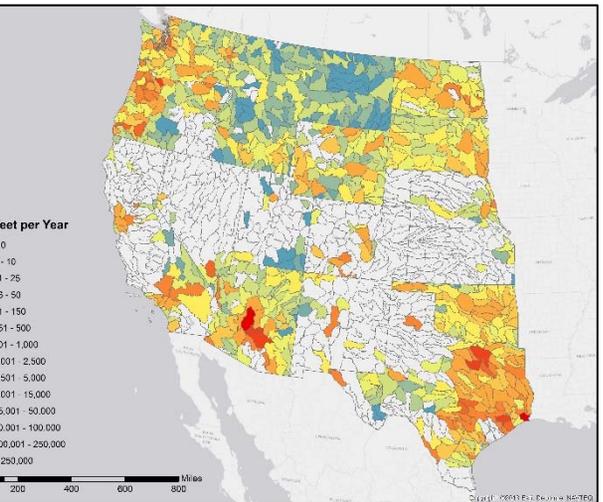
Municipal Wastewater



Brackish Groundwater

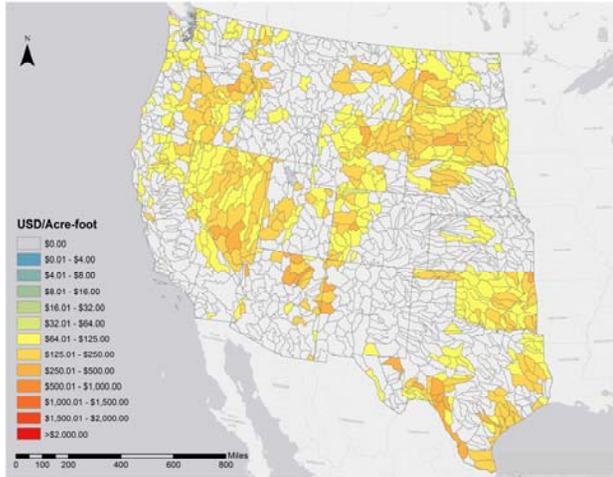


Consumptive Demand 2010-2030

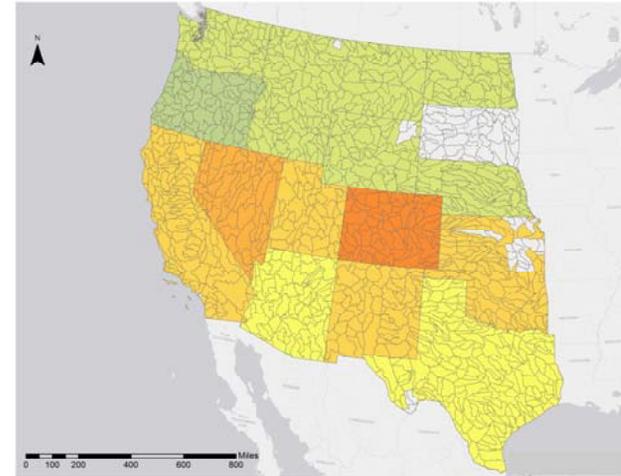


# Relative Cost of Water: West

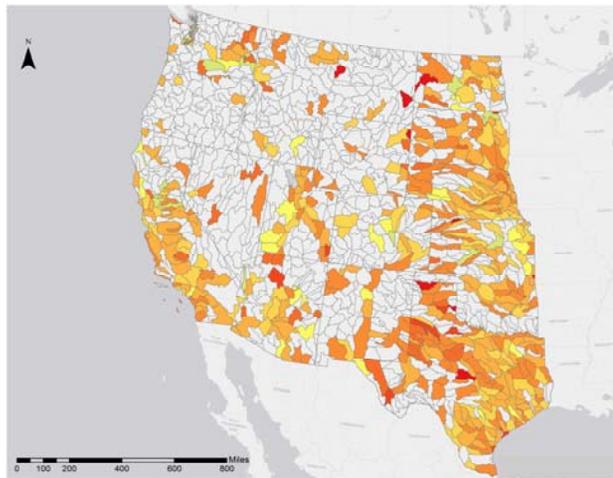
## Unappropriated Groundwater



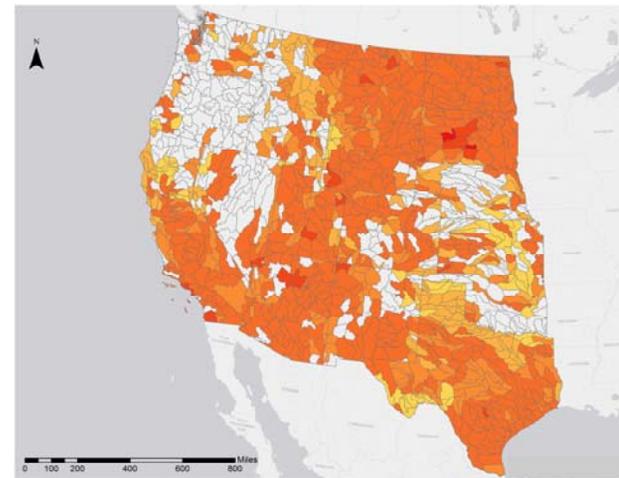
## Appropriated Water



## Municipal Wastewater



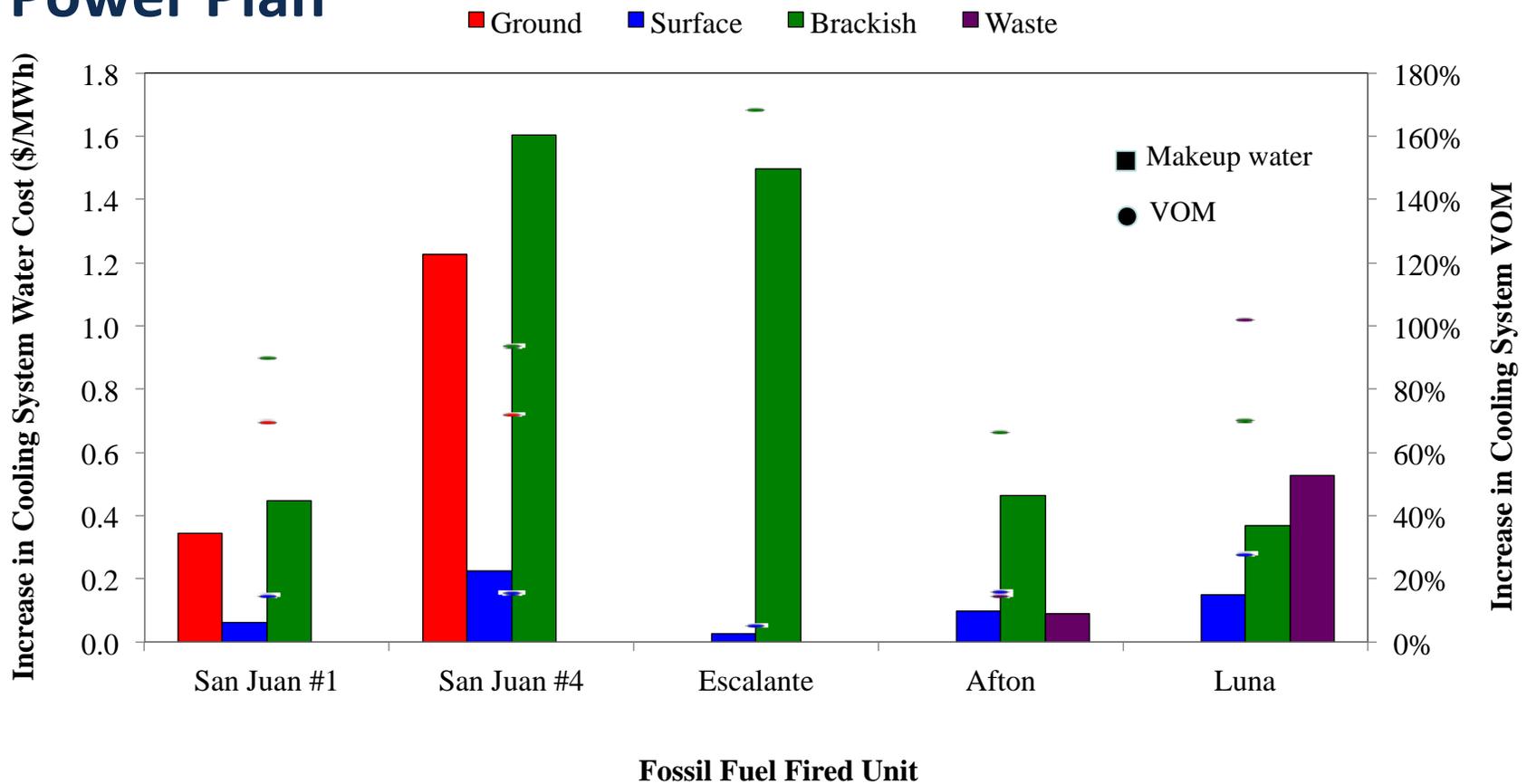
## Brackish Groundwater



# ***Integrated Energy-Water Planning***



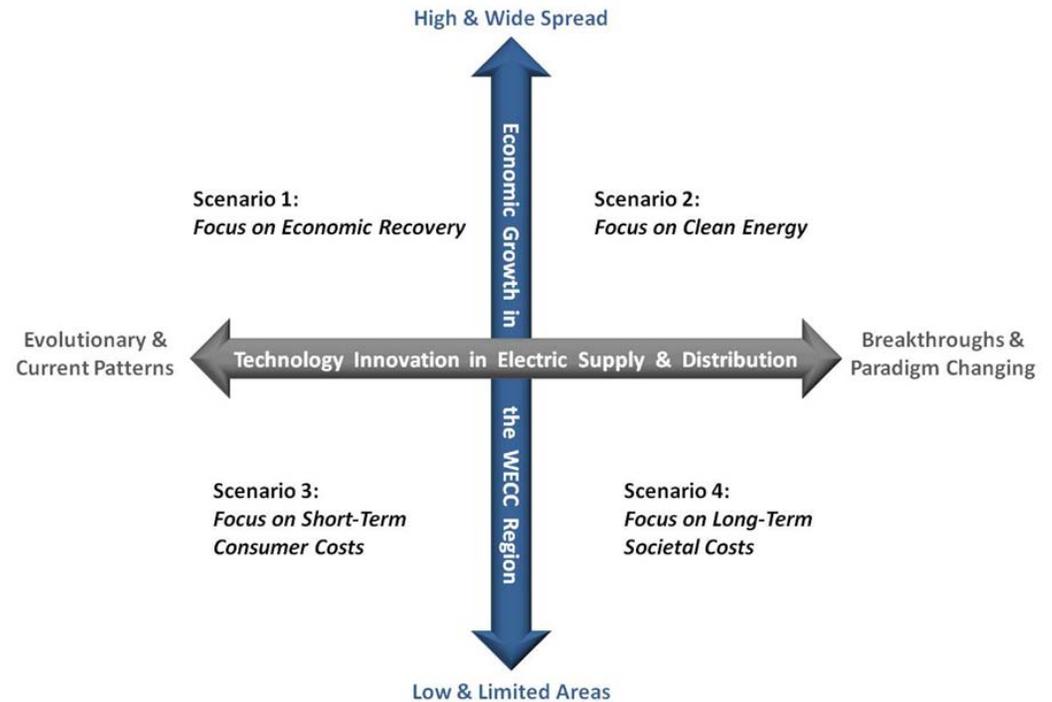
# Effects of Alternative Water Sources as Makeup Water for Cooling System on Annual Levelized Water Use Cost and Total Variable O&M Cost for Units under the Rate-based Emission Standard outlined by Clean Power Plan\*



\*In the base case, the water price for fresh water already in use is assumed to be \$0/kgal.

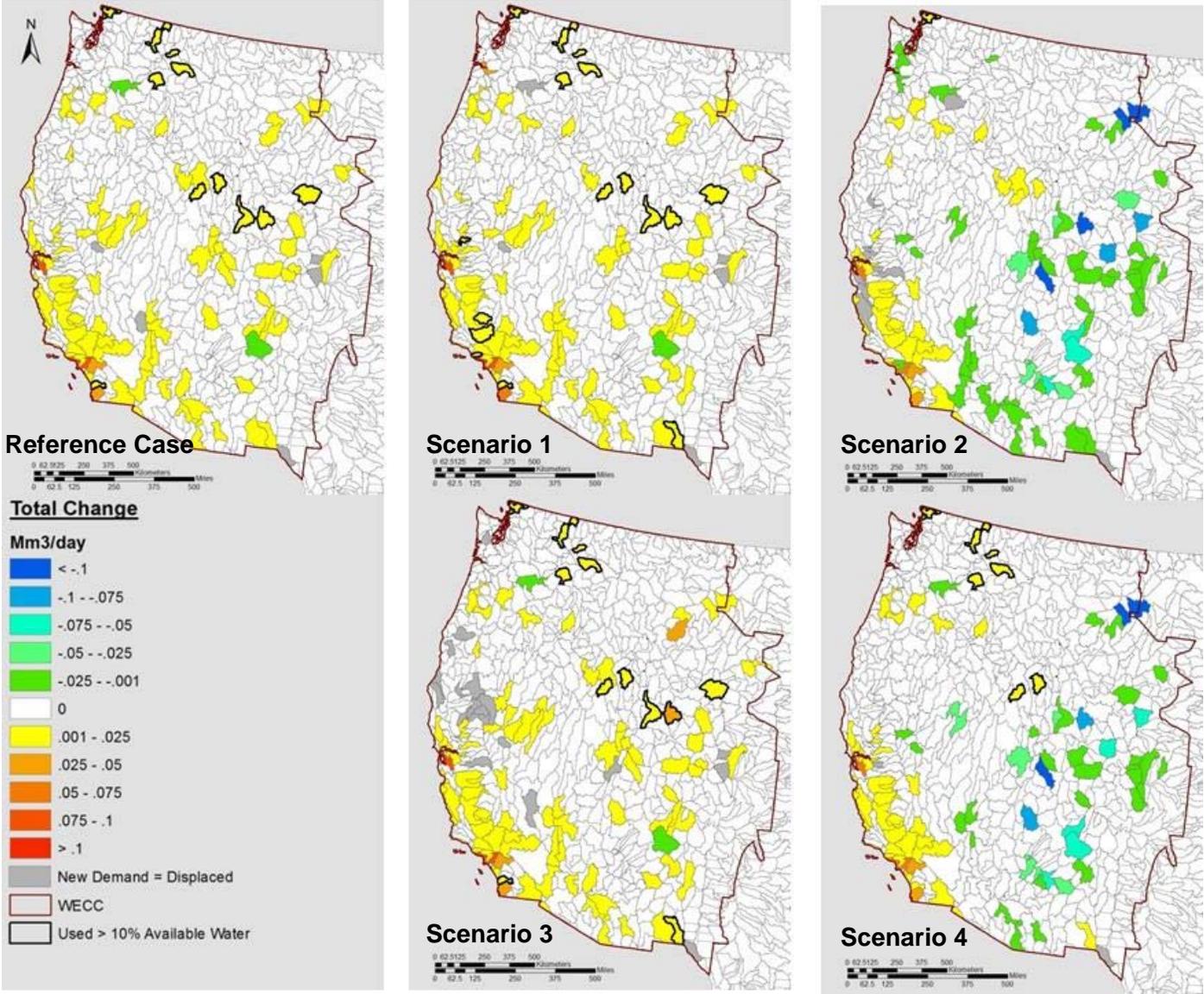
# Methods: Scenario Development

- **Reference Case:** adopted trajectory of recent WECC planning information.
- **Scenario One:** favored continued trends in growing use of natural gas and renewables.
- **Scenario Two:** distinct shift toward renewables, energy efficiency and significant carbon tax.
- **Scenario Three:** reliance on traditional technologies while simply meeting current state renewable portfolio standards.
- **Scenario Four:** similar technology development and policies as in scenario two except limited by sluggish economic growth.



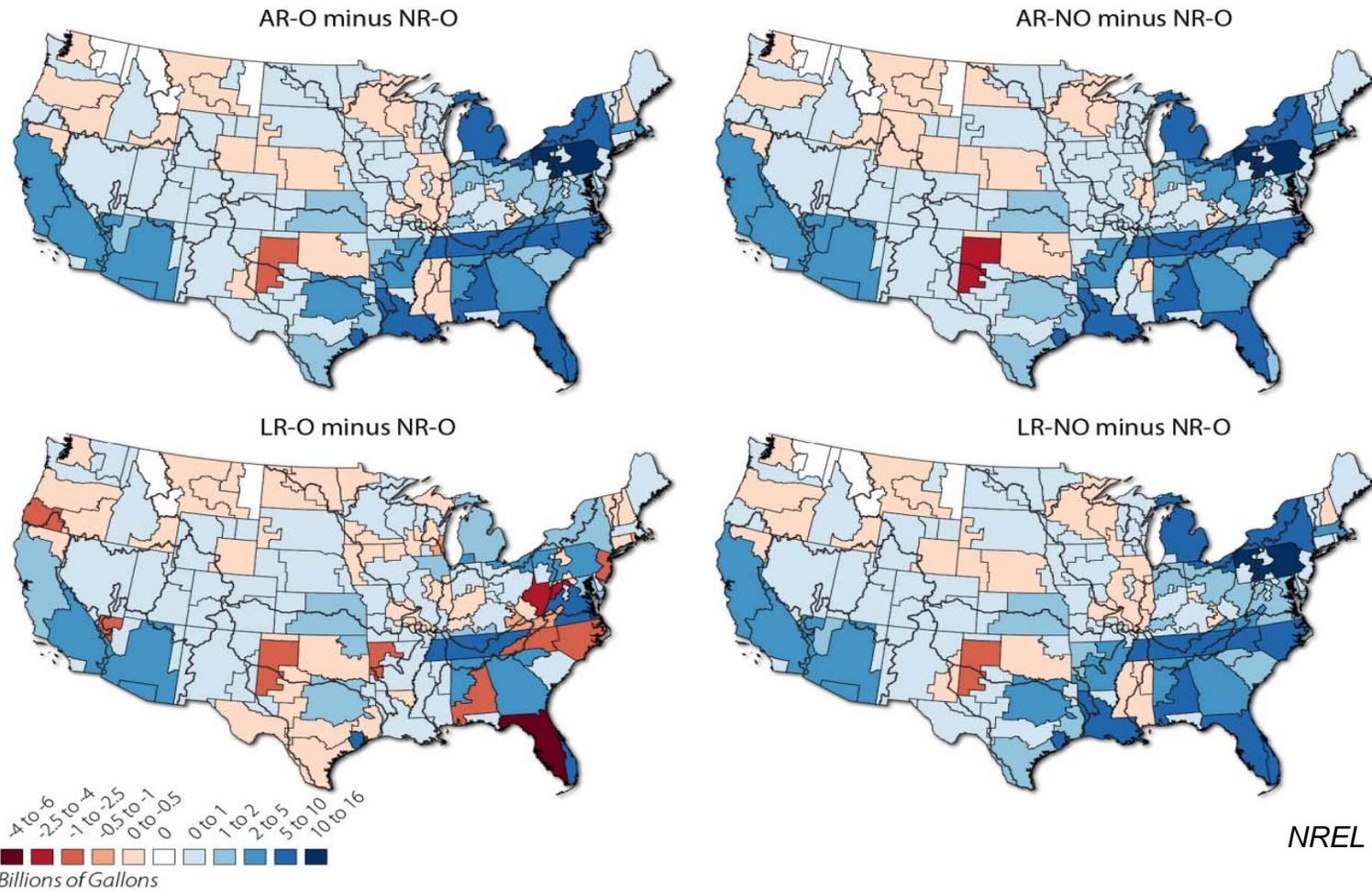
Source: WECC 2013

# Data Utilization: Transmission Expansion Planning



# Data Utilization: Integration in Regional Energy Deployment System model (ReEDS)

## *Effect of Water Constraint on Future Thermoelectric Water Consumption*



# Data Utilization: EISPC EZ Mapping Tool

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## EISPC EZ Mapping Tool

Home | About the Study | Energy Resources | Data | Policies & Regs | Maps | Documents | Links | Launch Tool

### EISPC EZ Mapping Tool

A map-based tool for identifying areas within the eastern United States that may be suitable for clean power generation.

Launch Tool



### About the Tool

The EISPC Energy Zones Mapping Tool is a free online mapping tool to identify potential clean energy resource areas within the Eastern Transmission Interconnection.

This web site provides information [about the study](#), background on the [energy resources](#), and details on the [data layers](#) used in the tool. There are also links to [policies and regulations](#), printable [maps](#), [documents](#), and related [links](#).

### Features

- Nine energy resources: [Biomass](#), [Clean Coal](#), [Geothermal](#), [Natural Gas](#), [Nuclear](#), [Solar](#), [Storage](#), [Water](#), and [Wind](#)
- Flexible analysis of siting factors such as slope and land protections
- Analysis of potential collocation of energy technologies
- Informed analysis to reduce new transmission construction

### Getting Started

Click the [Launch Tool](#) button above to start the tool, on the image below to view an introductory [video](#), or use the Help menu at the top of the page for more detailed directions.



We are interested in your feedback. Please email your comments to [ezmi@anl.gov](mailto:ezmi@anl.gov).

#### News

March 16, 2016  
[New Energy Infrastructure and Related Data](#)  
The following energy infrastructure layers, and related themes, have been added to the...

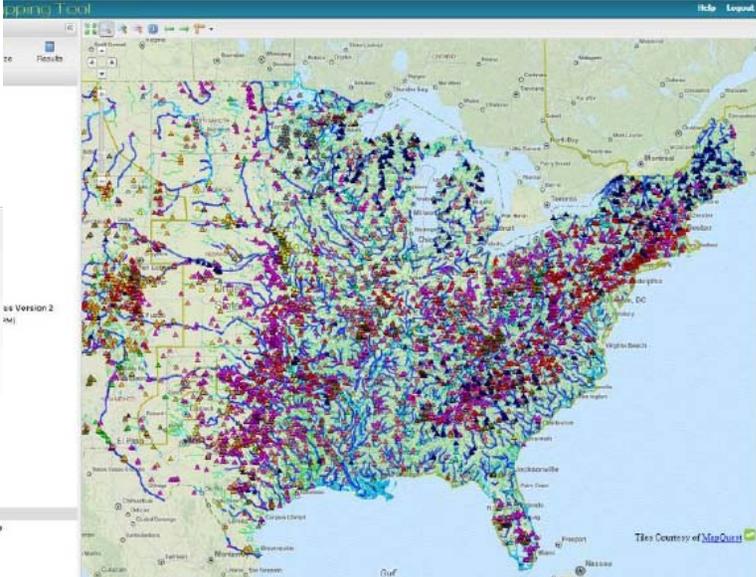
March 15, 2016  
[Updates to Commercially Licensed Data](#)  
Due to expiration of the commercial license on **March 15**.

- The following...

March 01, 2016

### Partners and Sponsors

The study is led by the Eastern Interconnection States' Planning Council (EISPC). The research support and technical assistance to EISPC is provided by Argonne National Laboratory, National Renewable Energy Laboratory, and Oak Ridge National Laboratory. Funding is provided by the U.S. Department of Energy. [More >](#)



Version 2 (M)

Layers:  
- 44,500 - 125,000  
- 125,000  
- Water Body  
- EISPC Regions  
- Base Maps  
- None  
- MapQuest Open StreetMap  
- MapQuest Imagery

The Courtesy of MapQuest

# Summary

- Seeing clear impacts today from the climate-energy-water nexus.
- Need data and tools to integrated water into energy planning.
- The Integrated Environmental Control Model (IECM) has been extended to aid in designing and managing power plant water systems at the unit level.
- Water Atlas is being developed to map water availability, cost and future use at the 8-digit HUC level for different sources of water.