Water Availability in the West: Will we power our iPads but not have a drop of water to drink?

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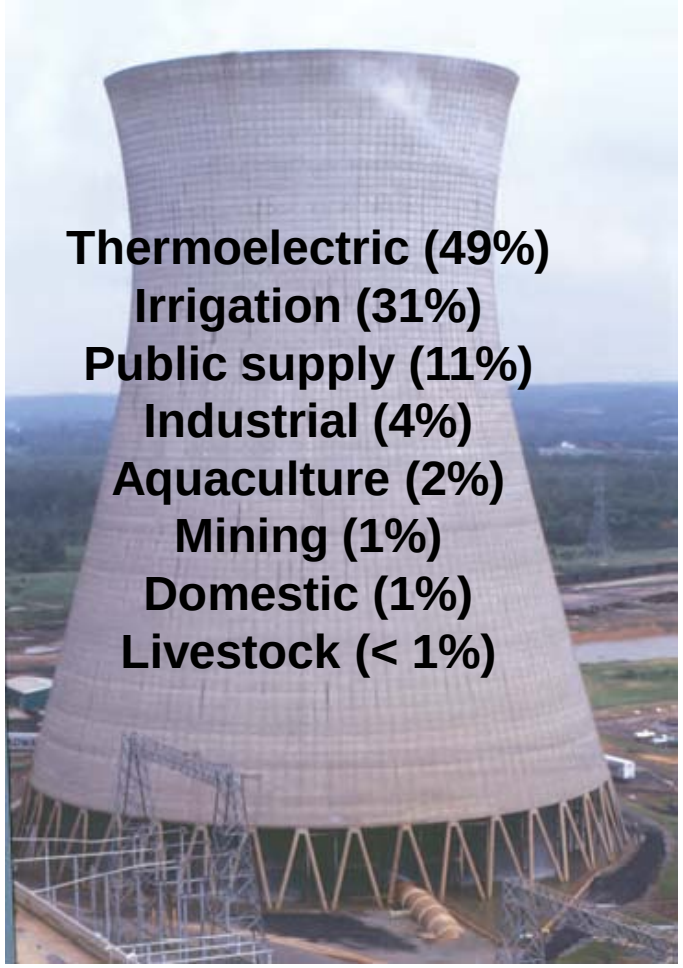
Water and Energy Use in the U.S.

U.S. water withdrawals for energy production

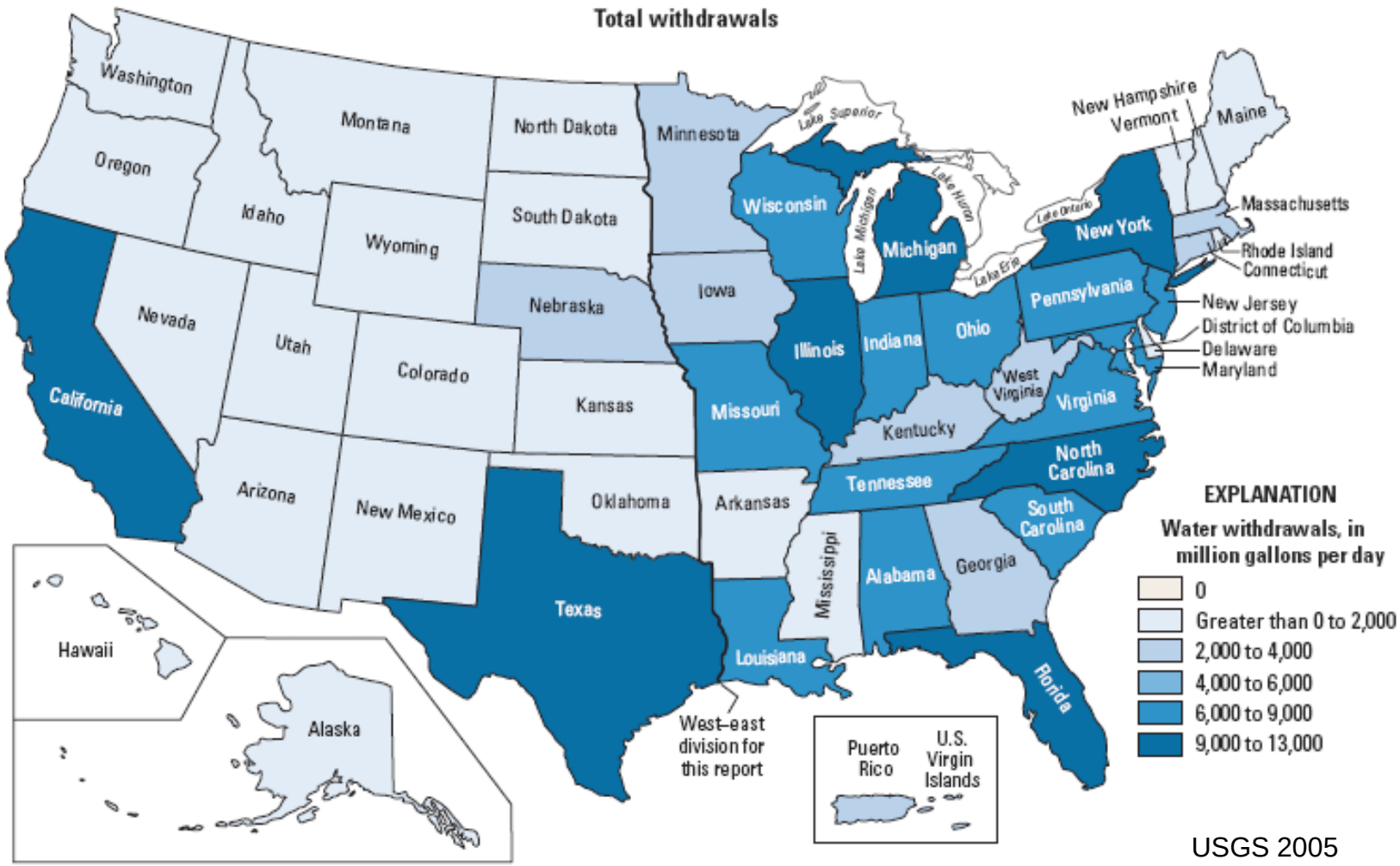
- 410,000 Mgal/d
  - 80% Surface Water; 20% Groundwater
  - Thermoelectric: 201,000 Mgal/d (49%)*
  - Irrigation: 128,000 Mgal/d (31%)



USGS 2005

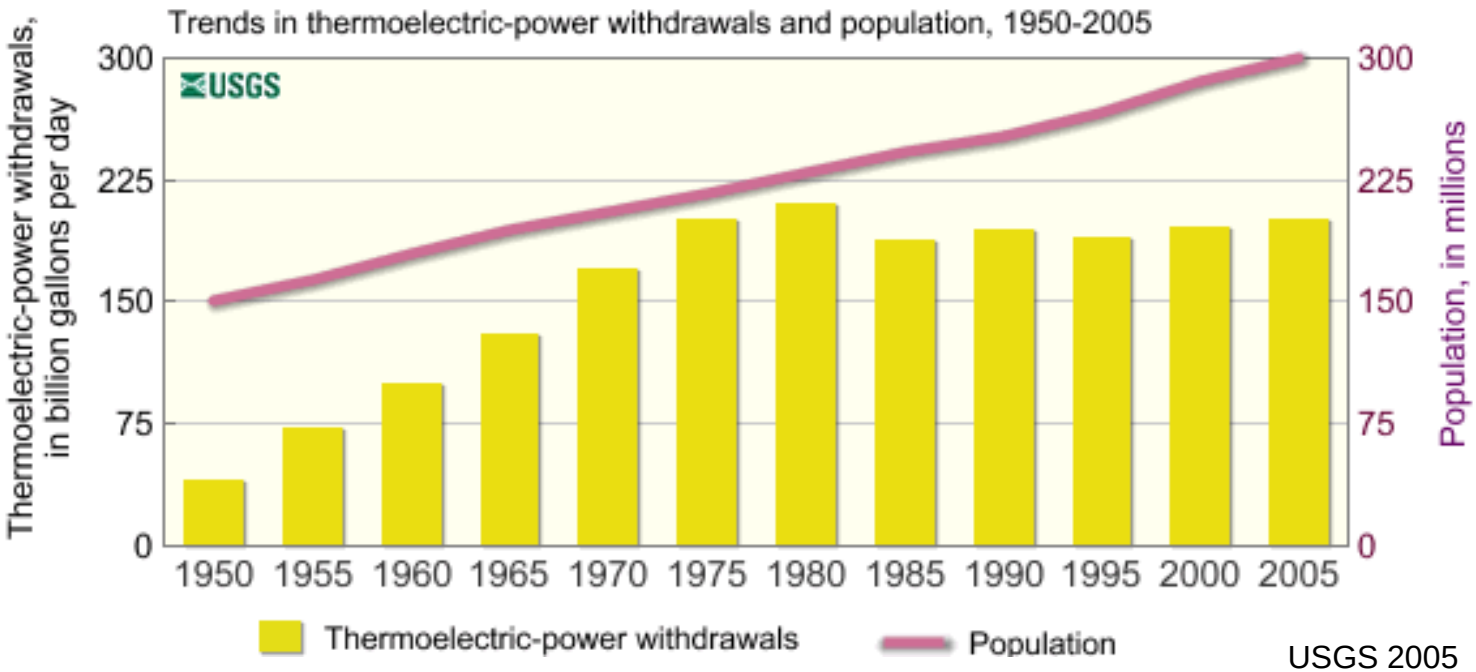
*Freshwater = 72%

Thermoelectric Power Water Use



USGS 2005

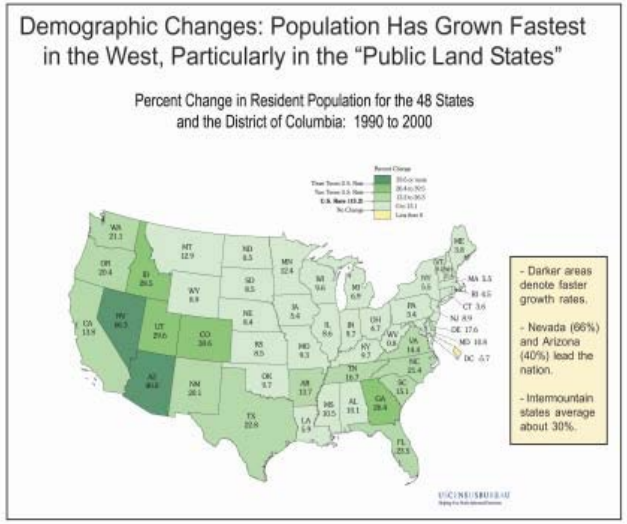
We are becoming more energy efficient

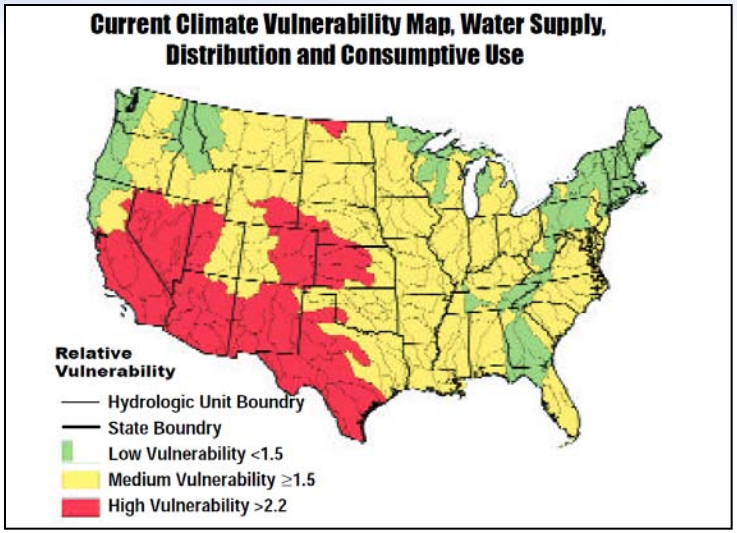


USGS 2005

However…

Changing Populations, Climates, Infrastructure & Uses

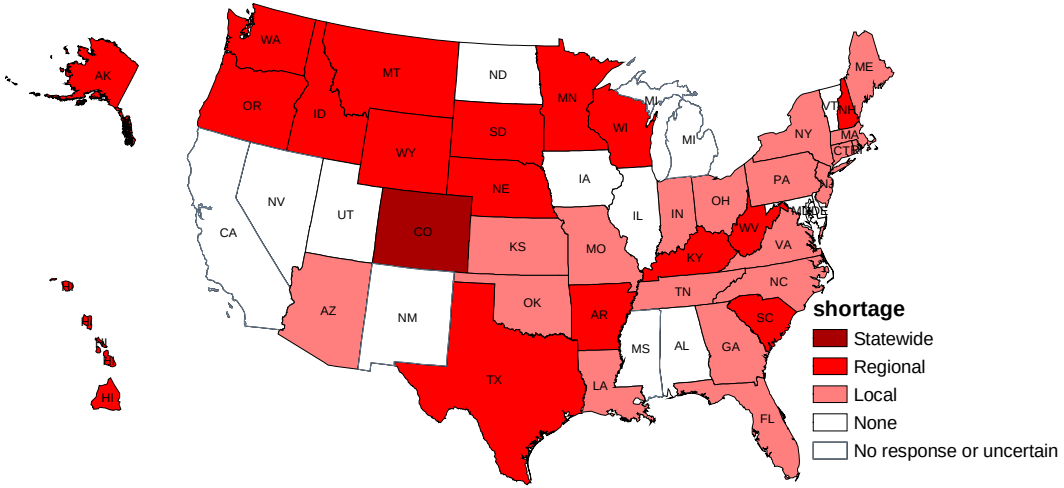




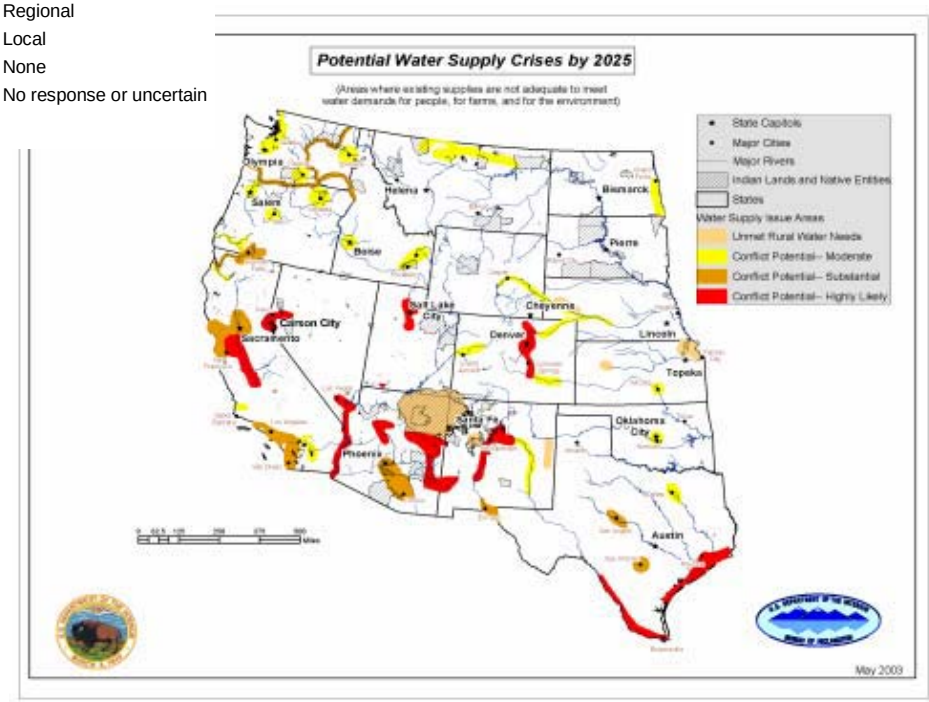
Number of Deficient Dams in United States by Repair Status (ASCE 2009)

Year	Deficient Dams	High Hazard Deficient Dams	High Hazard Repaired Dams	High Hazard Dams Needing Repair
2001	1,348	488	124	364
2002	1,536	646	163	483
2003	2,004	648	120	528
2004	3,000	979	100	879
2005	3,271	1,367	138	1,229
2006	3,346	1,308	139	1,169
2007	4,095	1,826	83	1,743

Both Federal and state officials predict future shortages and potential conflicts



GAO 2003



BOR 2009

Question: What is our energy and water future – will there be enough water to meet our future energy and other water needs in the West?

The Energy and Water in the Western and Texas Interconnects Project

Project Background

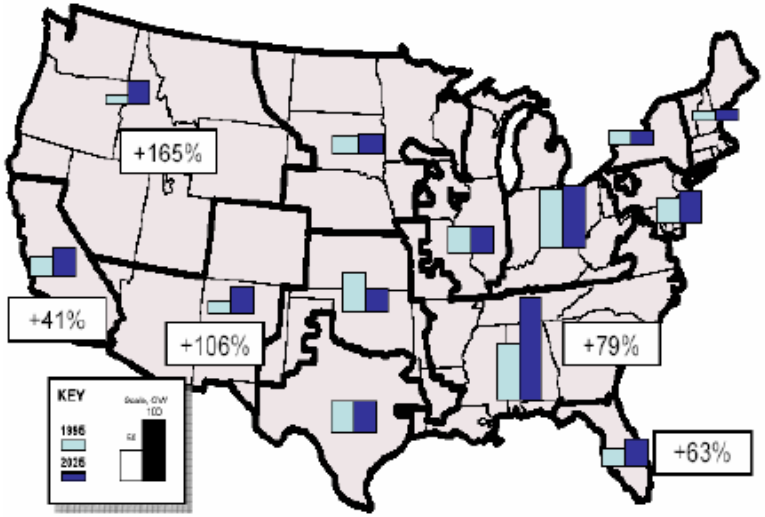
- This is in year two of a three year ARRA (Stimulus) Funded Water/Energy Nexus Project
- Three overarching objectives:
  1. Develop an integrated Energy-Water Decision Support System (EWDSS) that will enable planners in the Western and Texas Interconnections to analyze the potential implications of water stress for transmission and resource planning
  2. Pursue the formulation and development of the Energy-Water DSS through a strongly collaborative process between members of the proposal team and the Western Governors' Association (WGA), Western Electricity Coordinating Council (WECC), the Electric Reliability Council of Texas (ERCOT) and their associated stakeholder teams
  3. Exercise the EWDSS to investigate water stress implications of the transmission planning scenarios as put forward by WECC, WGA, and ERCOT

Project Participants

- Lead laboratory - Sandia National Laboratory
- Six supporting institutions:
  - Argonne National Laboratory (ANL)
  - Idaho National Laboratory (INL)
  - National Renewable Energy Laboratory (NREL)
  - Pacific Northwest National Laboratory (PNNL)
  - University of Texas (UT)
  - Electric Power Research Institute (EPRI)

The Need

- Currently there are no long-range transmission plans for the Western and Texas Interconnections to assess how various infrastructure options balance reliability, cost, and the environment from an interconnection-wide perspective
- This project will:
  - Create a comprehensive package of stakeholder-vetted, regional planning models, data, and conclusions that are coordinated at the interconnection-wide level
  - Substantially improve the quality and quantity of information available to industry planners, state and federal policymakers and regulators.
  - Supplement interconnection-wide transmission planning studies with information on water availability



Projected Thermoelectric Increases
1995 to 2025 (NETL, 2004)

Project Goals

- Two primary criteria were established for this project:
  1. Development of an integrated Energy-Water Decision Support System (EWDSS)
  2. WECC and ERCOT planners will utilize the EWDSS in their transmission planning process
- The overall goal is to develop a comprehensive, systematic, data-driven process which can reduce the time and tensions associated with the siting of future power plants

*Overall project tasks**

1. Water Withdrawal and Consumption Calculator for Current and Planned Electric Power Generation
2. Water Demand Projection Model
3. Water Availability Model
4. Environmental/Climate Change Calculator
5. Water Cost Calculator
6. Energy for Water Calculator
7. Control Model
8. Decision Support System Interface
9. Study Case Analysis

*Non-Administrative Tasks

Examples of questions being addressed

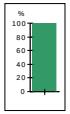
- Where will future thermoelectric development be in direct competition with other water use sectors?
- Where will “free” surface water and groundwater potentially be available for future thermoelectric development; conversely, where can water supplies be purchased or traded?
- Where could power production be at risk due to droughts or groundwater overdrafts?
- What “alternative” water resources are available and at what cost (e.g., produced water, wastewater, mine drainage, salt and brackish water)?
- What areas are off-limits to future development (e.g., environmental & regulatory constraints)?
- What future impediments may be imposed by “global change” (e.g., climate change, land use change, urbanization, water use changes)?
- Can power plant siting requirements be used (and adjusted) to screen possible areas for future thermoelectric power development?

Water Use and Consumption for Electric Power Generation

Plant-type	Cooling Process	Water Use Intensity (gal/MWh$_e$)		
		Steam Condensing		Other Uses
		Withdrawal	Consumption	Consumption
Fossil/ biomass steam turbine	Open-loop	20,000–50,000	~200-300	~30
	Closed-loop	300–600	300–480	
Nuclear steam turbine	Open-loop	25,000–60,000	~400	~30
	Closed-loop	500–1,100	400–720	
Natural Gas Combined-Cycle	Open-loop	7,500–20,000	100	7–10
	Closed-loop	230	180	
Integrated Gasification Combined-Cycle	Closed-loop	200	180	150
Carbon sequestration for fossil energy generation	~25% increase in water withdrawal and consumption			
Geothermal Steam	Closed-loop	2000	1350	50
Concentrating Solar	Closed-loop	750	740	10
Wind and Solar Photovoltaic	N/A	0	0	1-2

EWDSS Assessment Tool

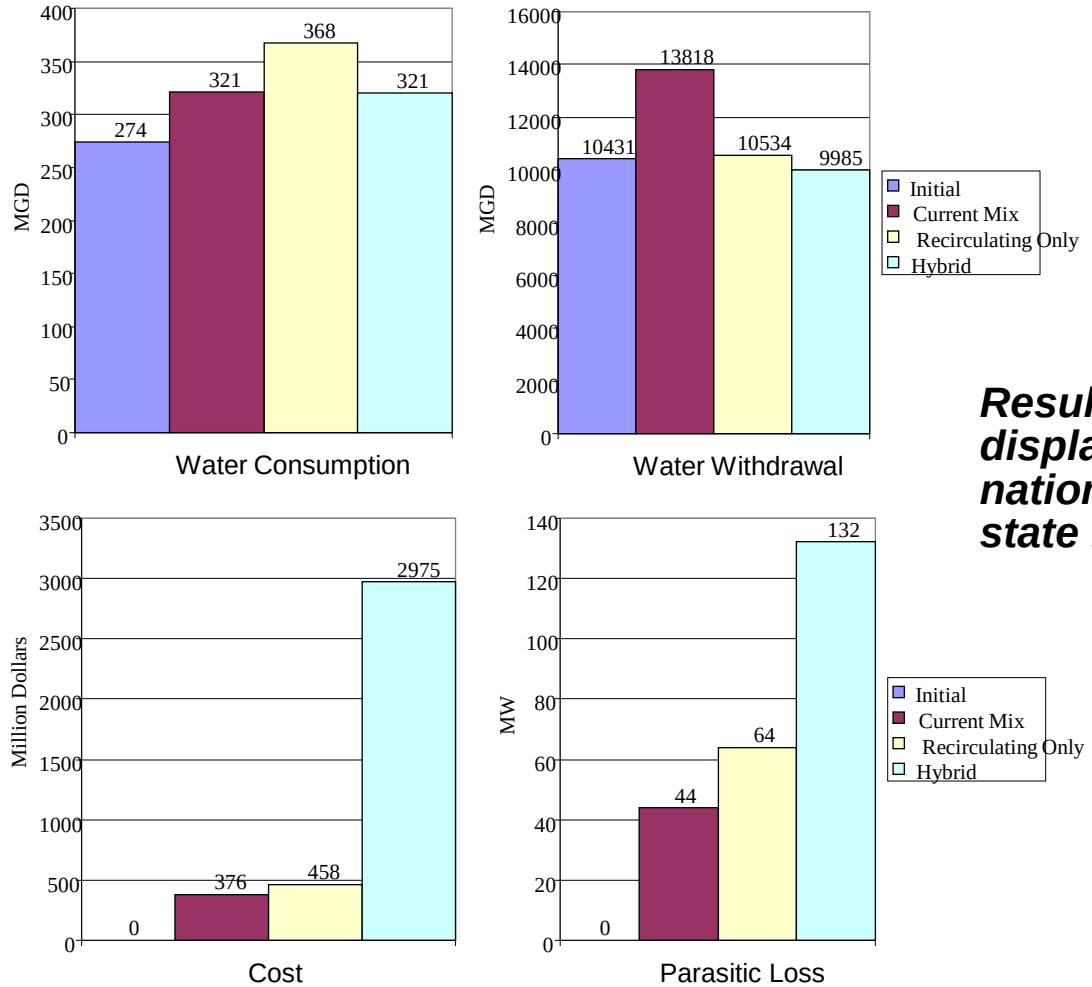
Fuel mix of future power plant fleet by NERC region



Cooling types associated with the future fleet of power plants

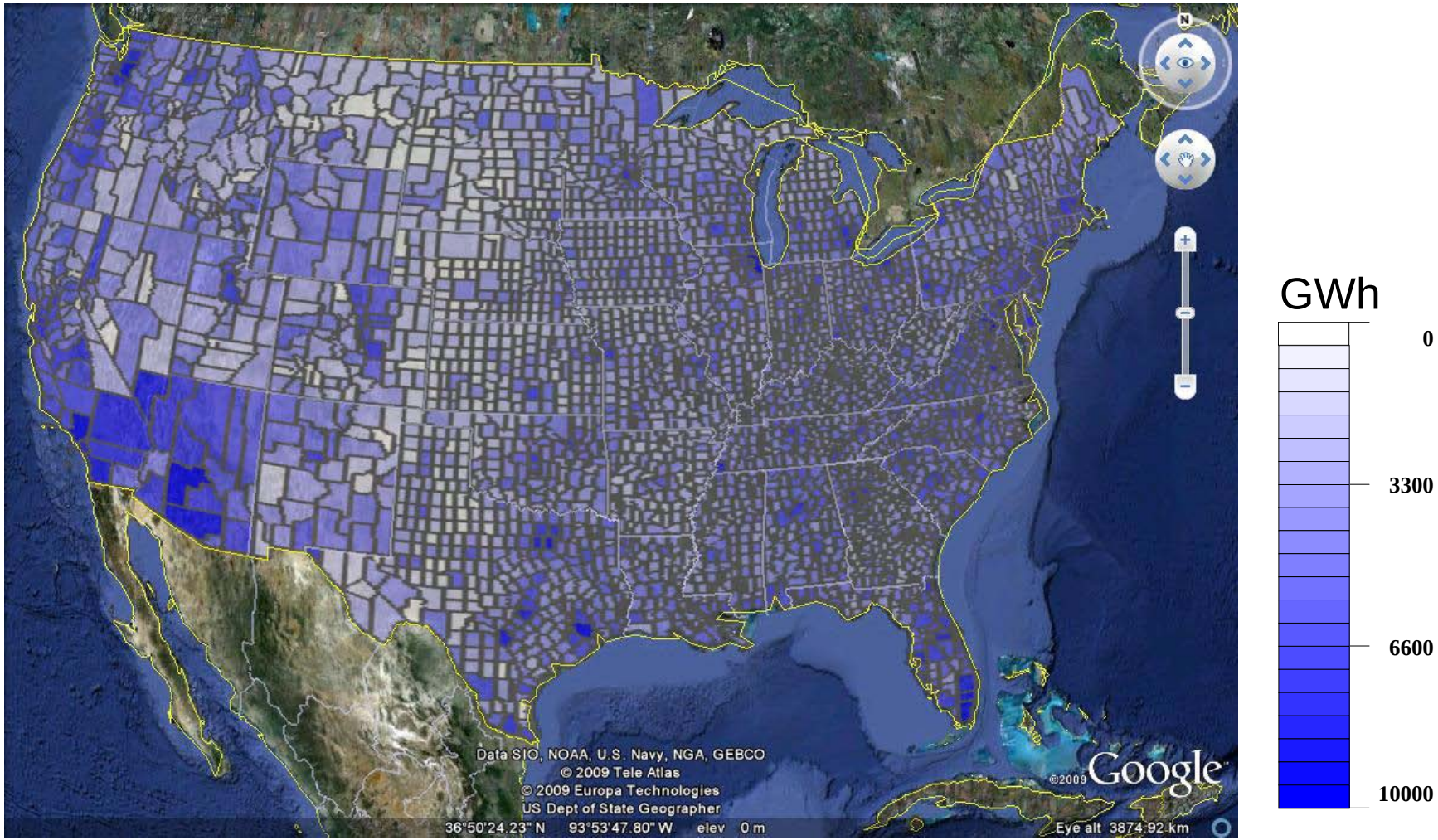
Comparison of thermoelectric water use and consumption along with costs and parasitic energy losses for different cooling options

ERCOT

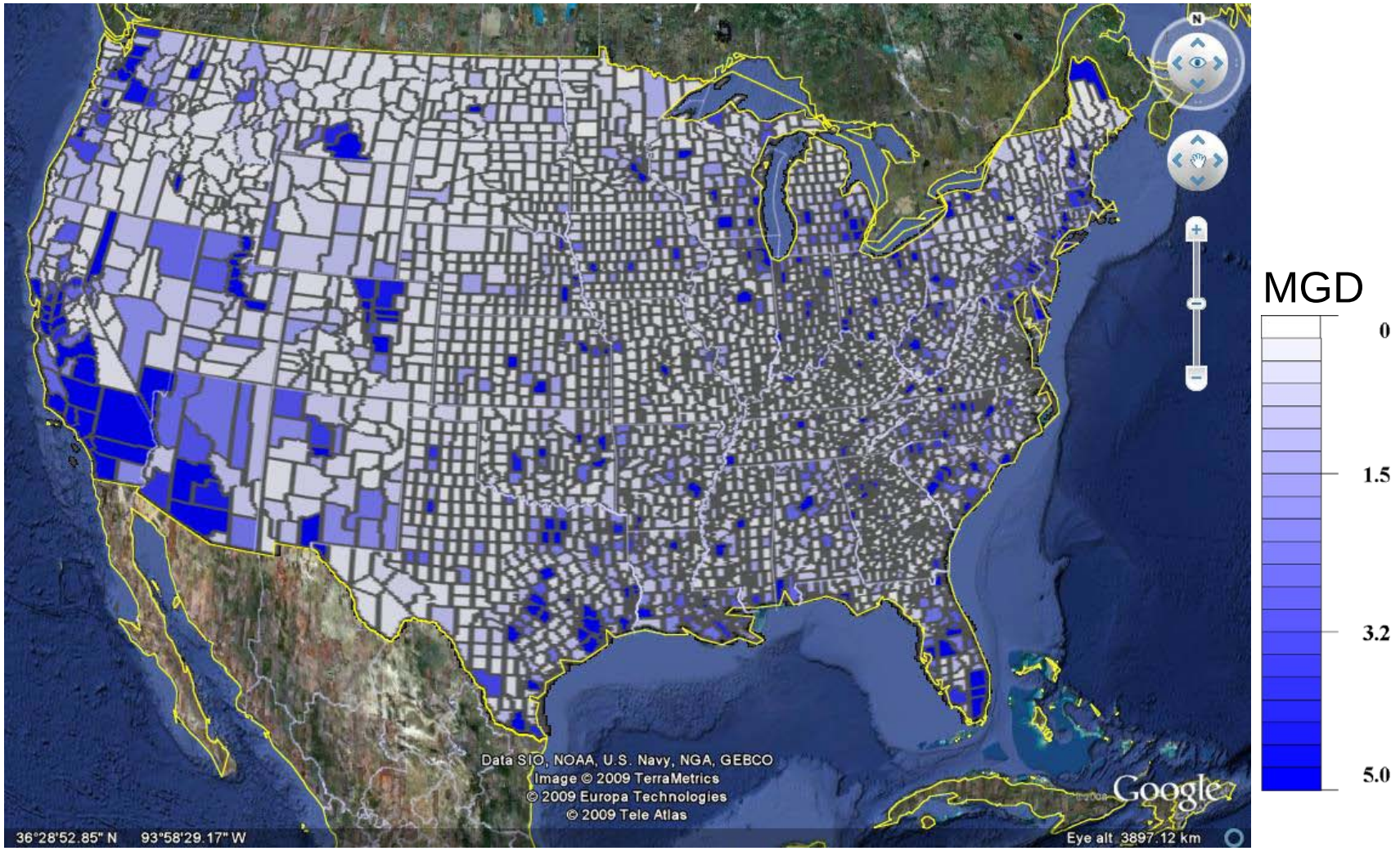


Results can be displayed at the national, NERC, or state level

Projected Increase Demand for Electricity: 2004-2030



Projected Increase in Non-Thermoelectric Water Consumption 2004-2030



Sandia National Laboratory

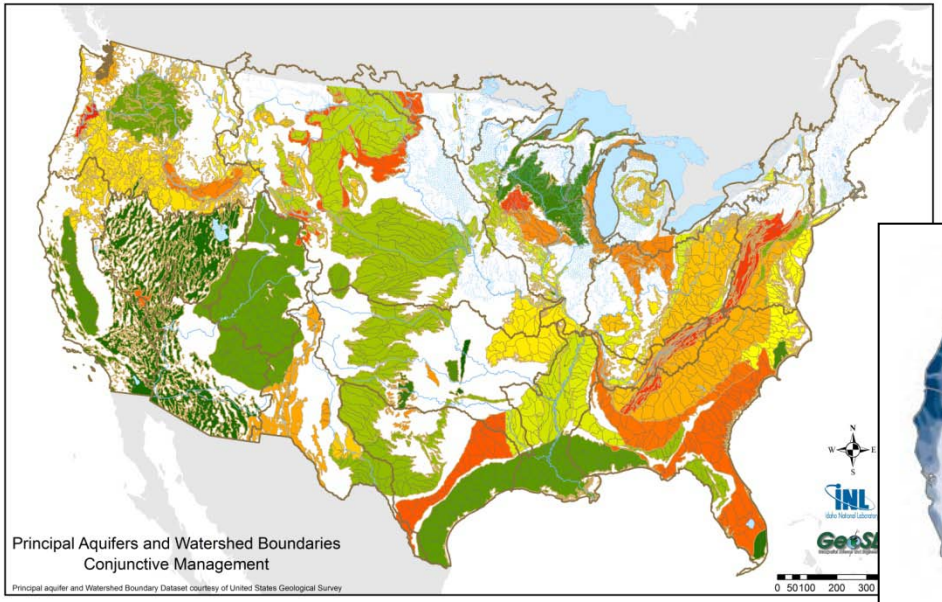
INL specific tasks/deliverables

- **Biofuels water use calculator** - evaluate geographic and climate specific water requirements for energy crops
- **VHP synthetic streams to 8-digit HUC** - integrate 3 to 5 mi^2 synthetic stream-flow data into EPWSim
- **Groundwater availability** - collect, analyze and integrate groundwater quantity/quality data available from Federal and state sources into EPWSim
- **Non-potable water sources** - collect, analyze and integrate non-potable source data into EPWSIM
- **Water Policy** - support development of water institutions tool
- **Environmental Flows** - support assessment of “environmental flows”
- **Legally Available Water** – estimate the potential legally available quantities in the future for Idaho, Montana and Washington

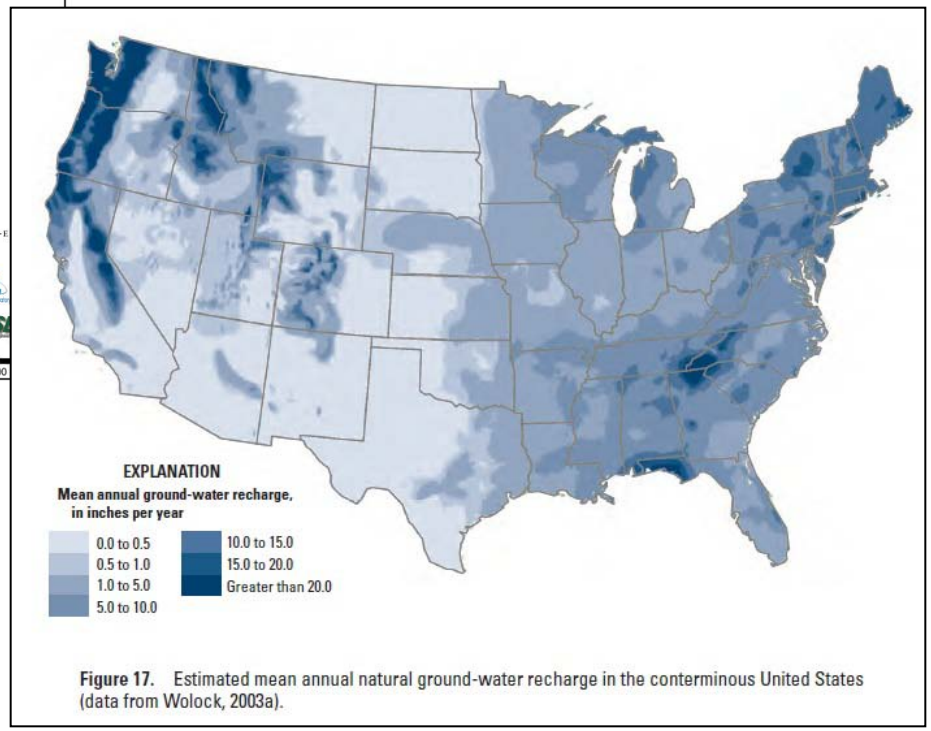
Preliminary results of the INL's scientific contribution to the project…

- Develop "conjunctive management" maps for HUC 8 watersheds and principle aquifers
  - Built database of over 150,000 wells:
    - Average annual depth to water
    - Elevation of water
  - Tried to estimate potential surface/ground water interactions for HUC 8 stream segments, based on the proximity of streams to wells and springs
- Developed a database of produced water (annual bbls per county)
- We're developing a technique for estimating irrigated acres and groundwater recharge
- Participated in state data gathering for potentially legally available water

Examples of on-going assessments



Assessment of potential conjunctive management units



Assessment of potential groundwater recharge (USGS Circular 1323)

Examples of major challenges and barriers

- This project provides many insights into the difficulties associated with developing a scientifically credible assessment of the potentially legally available water supply in the western U.S.
  - Variations between state legal requirements, and state planning and management approaches
  - Federal and state data availability, accessibility and compatibility issues, including a lack of sufficient:
    - Short-term and seasonal water use data
    - Groundwater supply data
    - Consumptive use data
  - Significant amounts of data are privacy-protected or are otherwise unavailable for use (e.g., crop land and infrastructure data)
  - Insufficient information on market forces and mechanisms
  - Inadequate predictions of future climate change

Example - Calculating Legally Available Water

Code	Name	Source
LAW	Legally Available Water	1. Provided by State 2. Physical Supply minus water rights minus compacts
PS	Physical Supply	Sum of surface and groundwater supply for a HUC 8 Area
SS	Surface Supply	USGS Gage stations at bottom of HUC 8 area
GWS	Groundwater Supply	1. Aquifer Volume within HUC 8 or 2. Ratio of Aquifer area within HUC 8 area times average aquifer depth or 3. Recharge (R) within HUC 8 area
IWU	Irrigation Water Use	2005 USGS Flood Irrigation Water Use aerial weighted average to HUC 8
R	Total Recharge	Sum of Natural Recharge (NR), Artificial Recharge (AR) and Irrigation Recharge
NR	Natural Recharge	USGS Natural Recharge aggregated to HUC 8 area
AR	Artificial Recharge	Currently Unknown
IR	Irrigation Recharge	The total flood irrigation water use minus ET for a HUC 8 area
ET	Evapotranspiration	Currently Unknown
WR	Water Rights	Sum of water associated with a water right at points of diversion within a HUC 8 area
C	Compacts	Water obligated to other states per compact
IA	Irrigated Acres	From each state if available, processed to a HUC 8 area
NIR	Net Irrigation Require.	From each state if possible, averaged for all crops

1. LAW = PS – WR – C
   PS = SS + GWS

2. LAW = SS + GWS – WR – C
   GWS = R = NR + AR +IR
   R = NR + AR +IR
   IR = IWU - ET

3. LAW = SS + (NR + AR +IWU - ET)
   – WR – C

4. If ET is unknown use IA and NIR in its place if it is available.

Summary

- This project represents one of the first comprehensive regional analysis of the energy-water nexus in the U.S. undertaken collaboratively by federal and state agencies, the power industry, NGOs and other interested stakeholders
- By conducting a large scale analysis in collaboration with these partners, we are:
  - Developing consistent west-wide approaches/methodologies,
  - Learning where the critical data/information gaps are
  - Determining new approaches for estimating west-wide supplies and demands, and
  - Developing techniques for overcoming data short-comings
- The data and tools the INL is developing are being incorporated into the EWDSS for water availability west-wide scenario analyses by WECC, ERCOT and the WGA

Thank You for your Time and Attention!