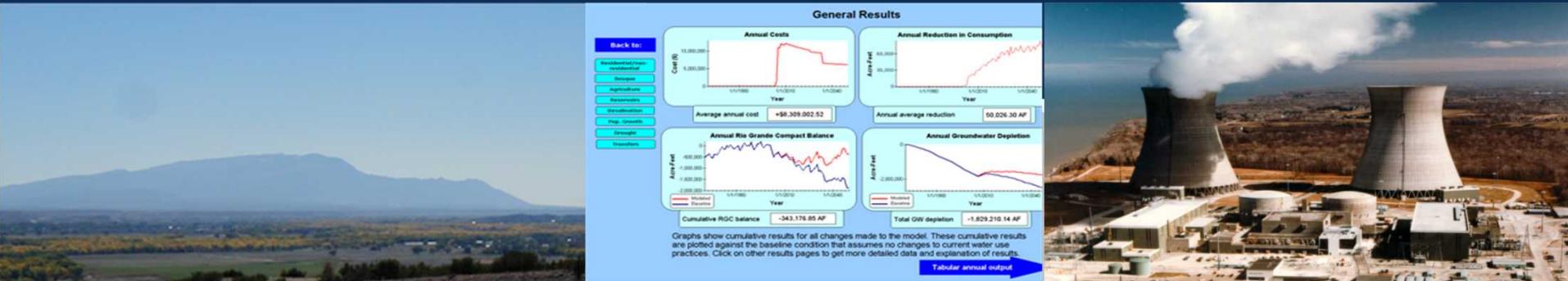


Exceptional service in the national interest



Energy-Water Nexus Past, Present and Future

Vincent Tidwell

Sandia National Laboratories

State of America's Water: Present and Future

February 10, 2015

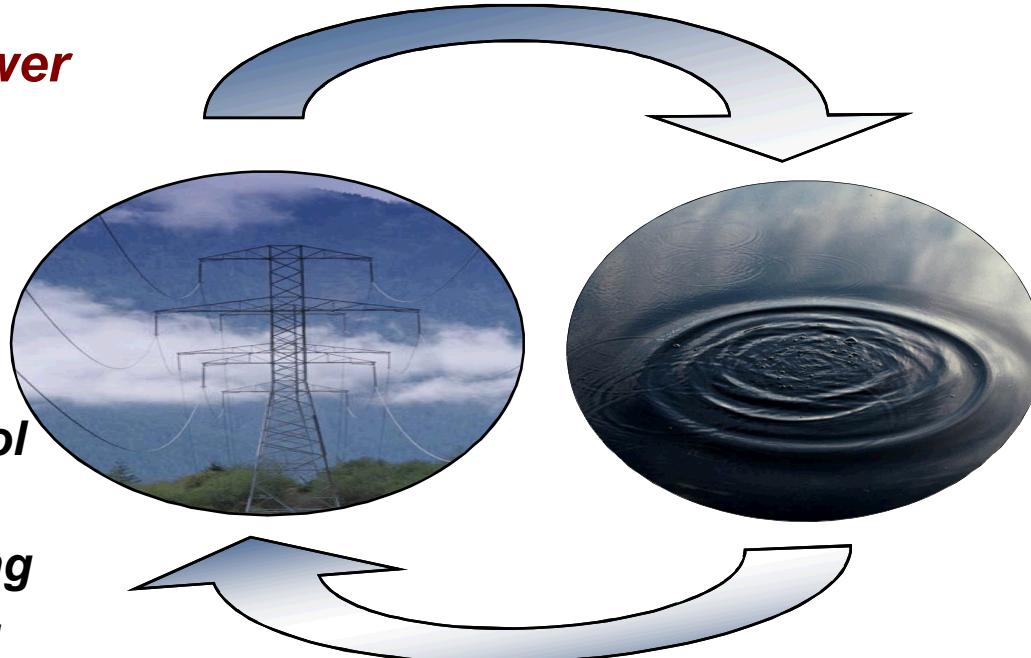


Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Energy-Water Nexus

Energy and power production requires water

- ***Thermoelectric Cooling***
- ***Emission Control***
- ***Energy Minerals Extraction/Mining***
- ***Fuel Processing (fossil fuels, H₂, biofuels)***

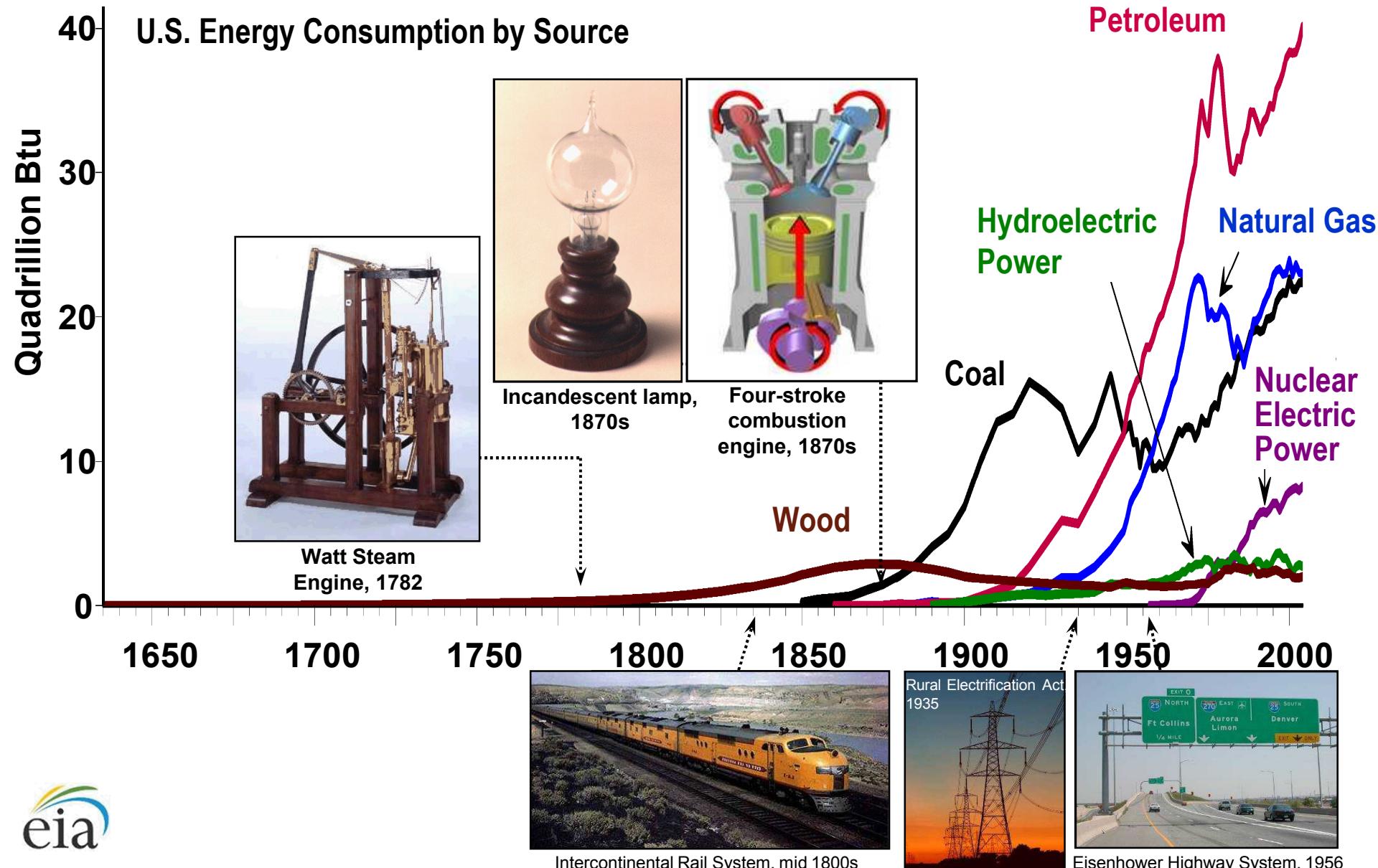


Water production, processing, distribution, and end-use requires energy

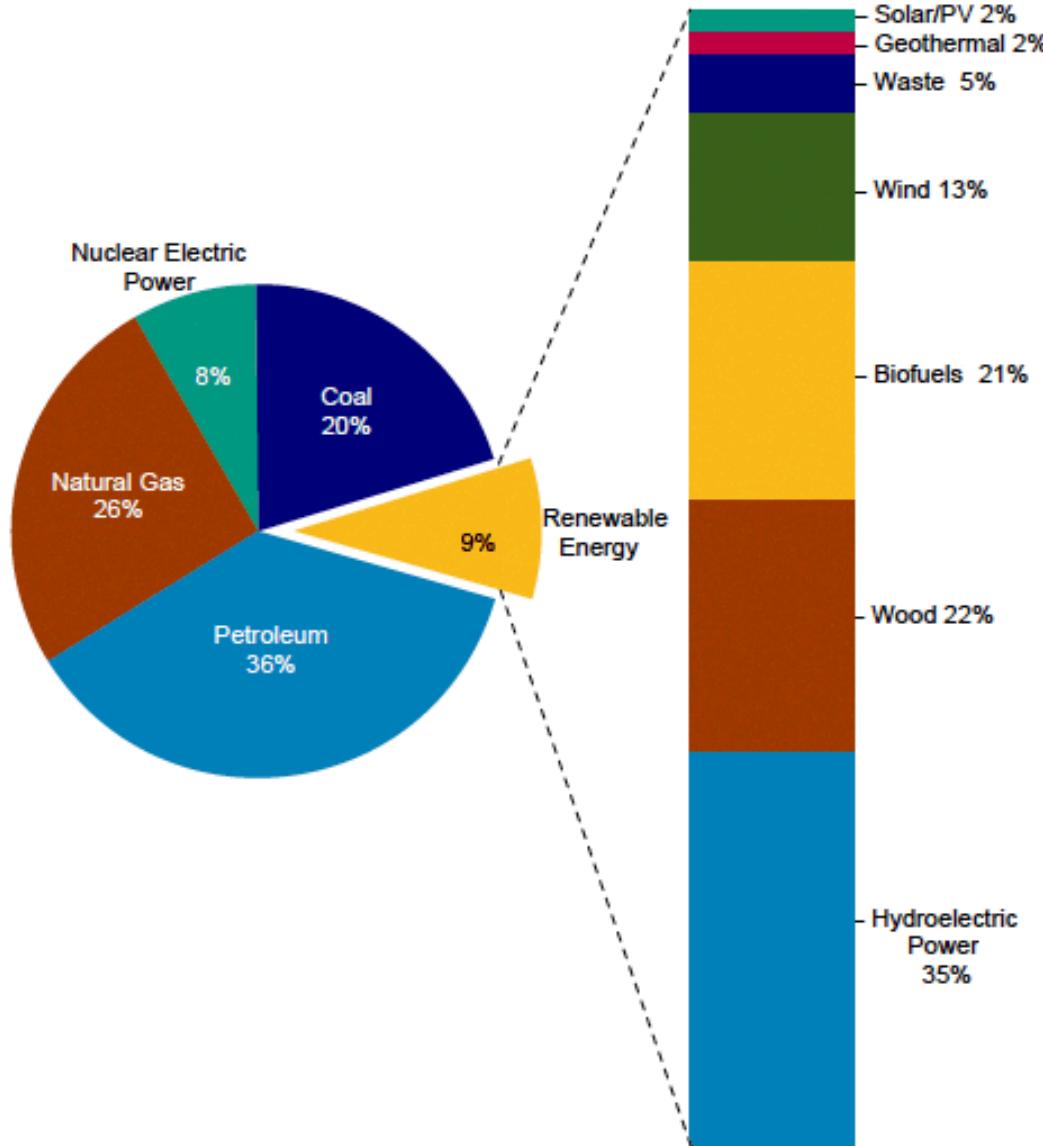
- ***Pumping***
- ***Conveyance***
- ***Treatment***
- ***Distribution***
- ***Use Conditioning***

*Energy-
Water
Nexus
Past*

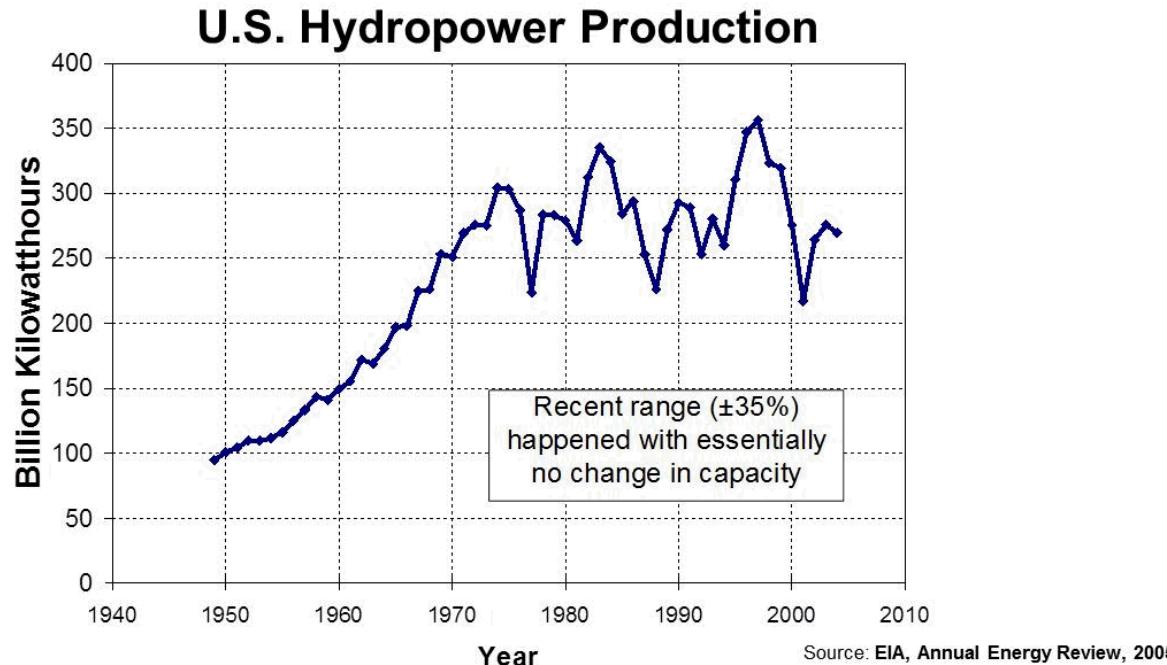
400 Years of Energy Use in the U.S.



High Fossil Fuel Use

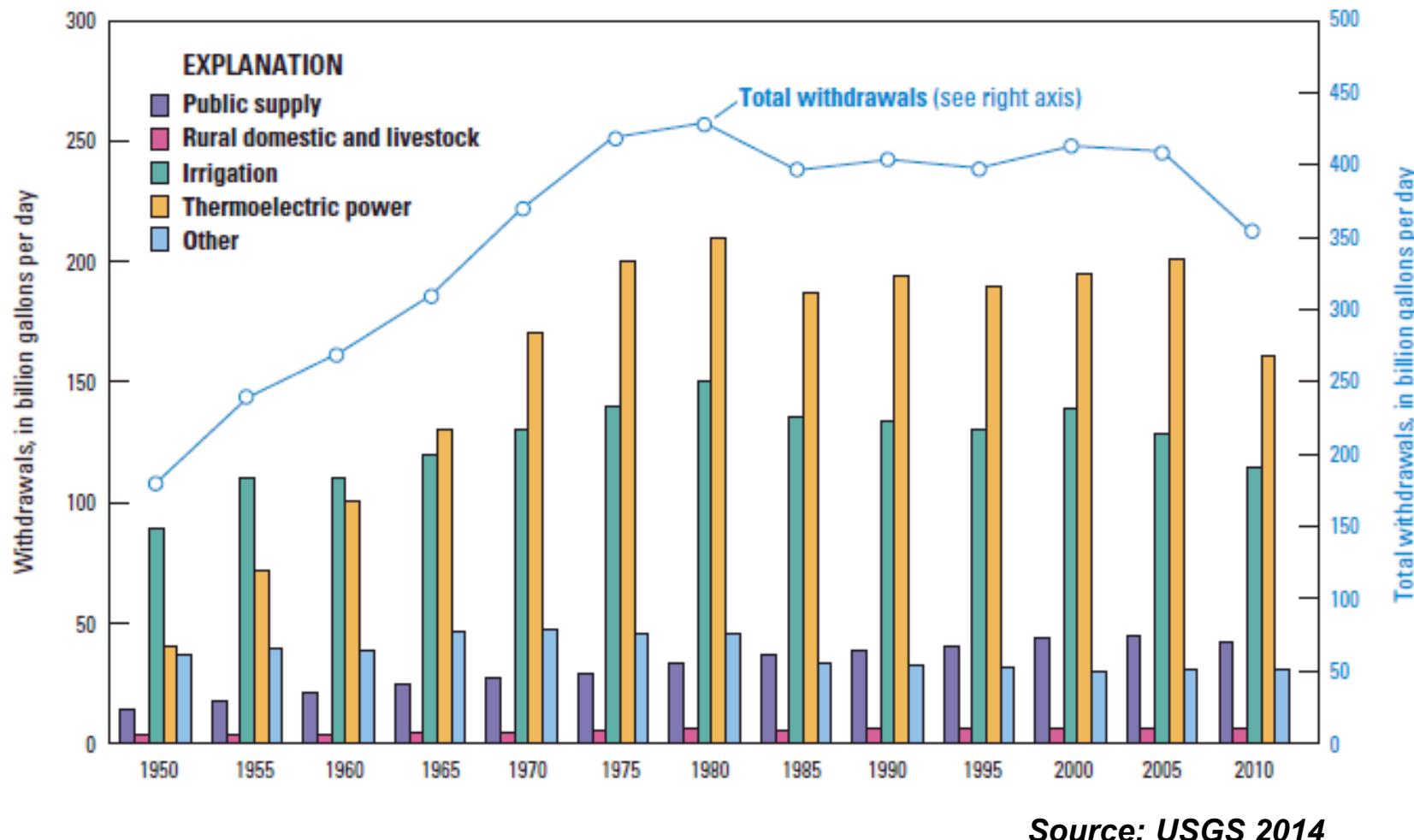


Variability of Hydropower Production

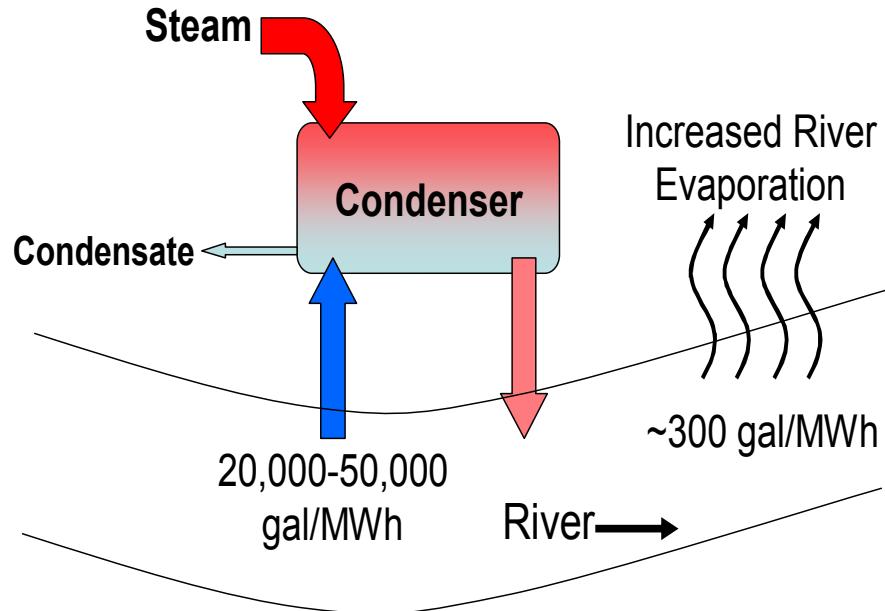


- Since 1980s, hydroelectric power has satisfied about 6% of the Nation's total electricity demand.
- Dispatchable renewable energy source often used to balance wind and solar production.
- 3,700 MW of generating capacity on the lower Colorado River is particularly vulnerable due to variety of issues.

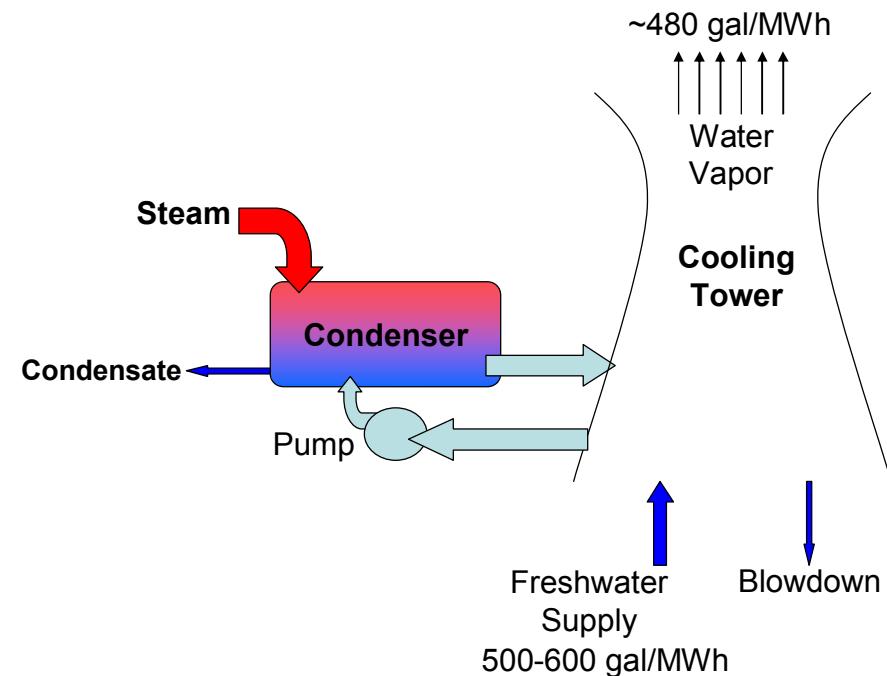
Trends in Water Use by Category: 1950-2010



Power Plant Cooling Options



Open-loop “once-through” cooling cycle



Closed-loop cooling cycle

Source: EPRI 2002

Energy-Water Nexus



“Many times in recent years, water use practices proposed for new energy conversion facilities have been the subject of great controversy. Many people anticipate that the frequency and bitterness of these conflicts will increase.”

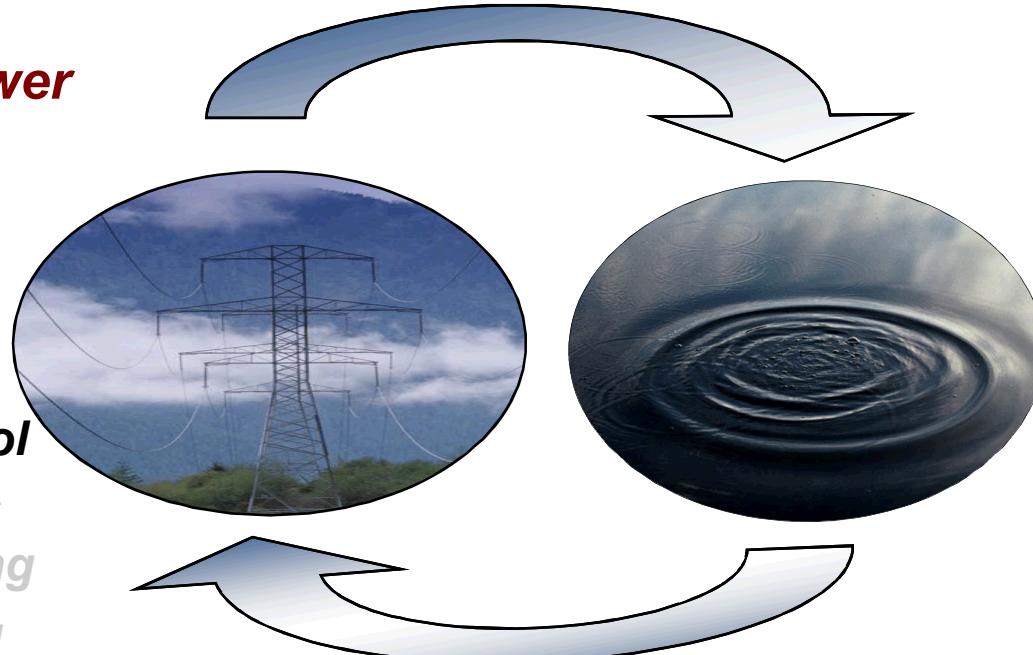
(DOE, 1980)

*Energy-
Water
Nexus
Present*

Energy-Water Nexus

Energy and power production requires water

- ***Thermoelectric Cooling***
- ***Emission Control***
- ***Energy Minerals Extraction/Mining***
- ***Fuel Processing (fossil fuels, H₂, biofuels)***

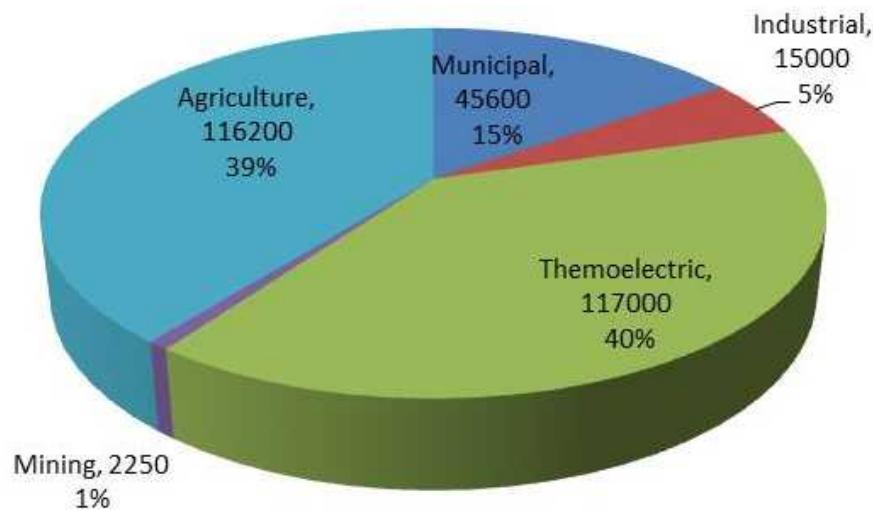


Water production, processing, distribution, and end-use requires energy

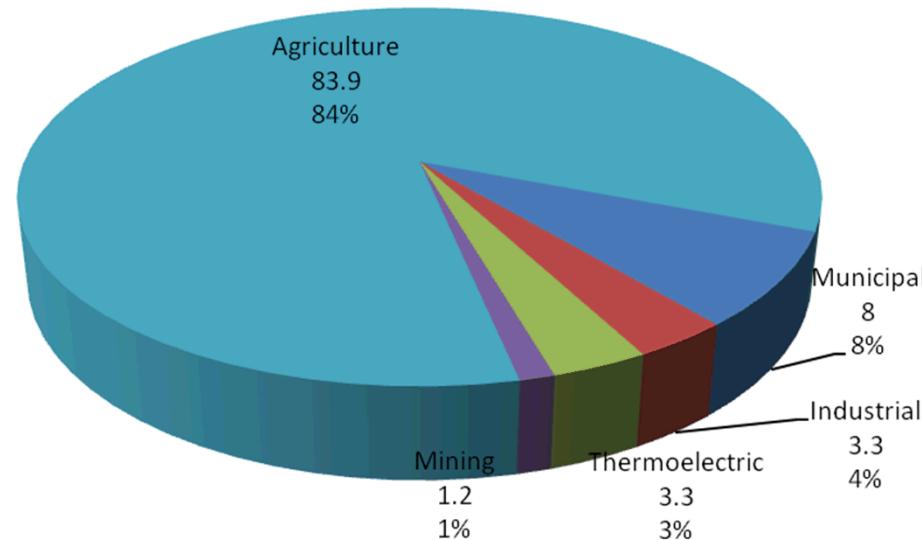
- ***Pumping***
- ***Conveyance***
- ***Treatment***
- ***Distribution***
- ***Use Conditioning***

Water for Thermoelectric Power Generation

Water Withdrawal (BGD) 2010

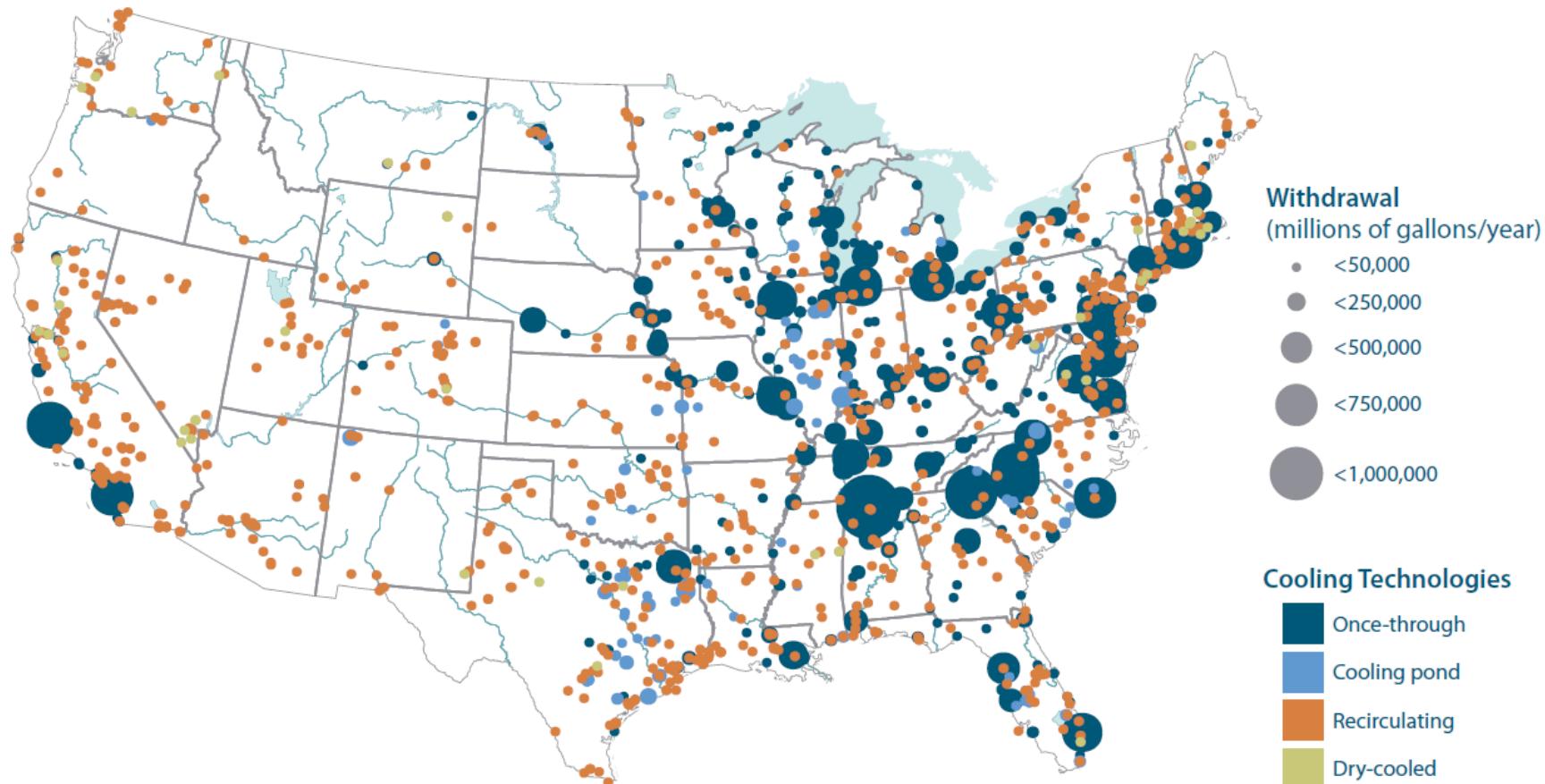


Water Consumption (BGD) 1995



Source: USGS 1995, 2014

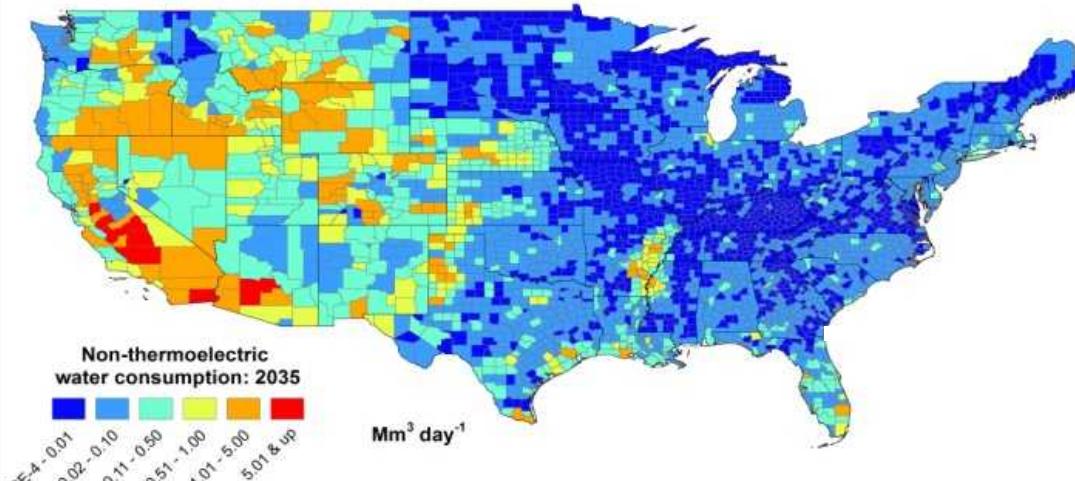
Power Plant Water Withdrawals: 2008



Source: UCS 2011

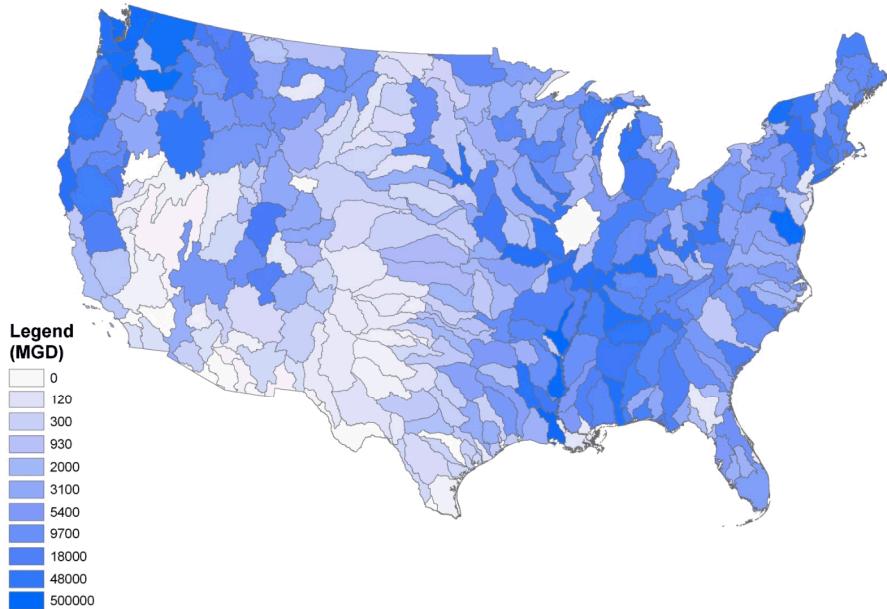
Place Matters: Water Consumption

Non-Thermoelectric Consumption 2010

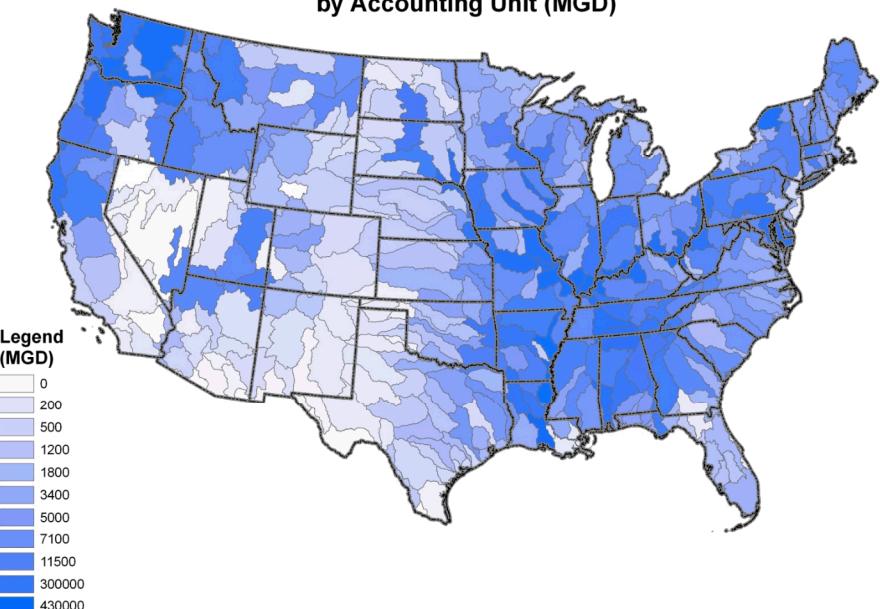


Place Matters: Water Supply

Sustainable Groundwater Recharge

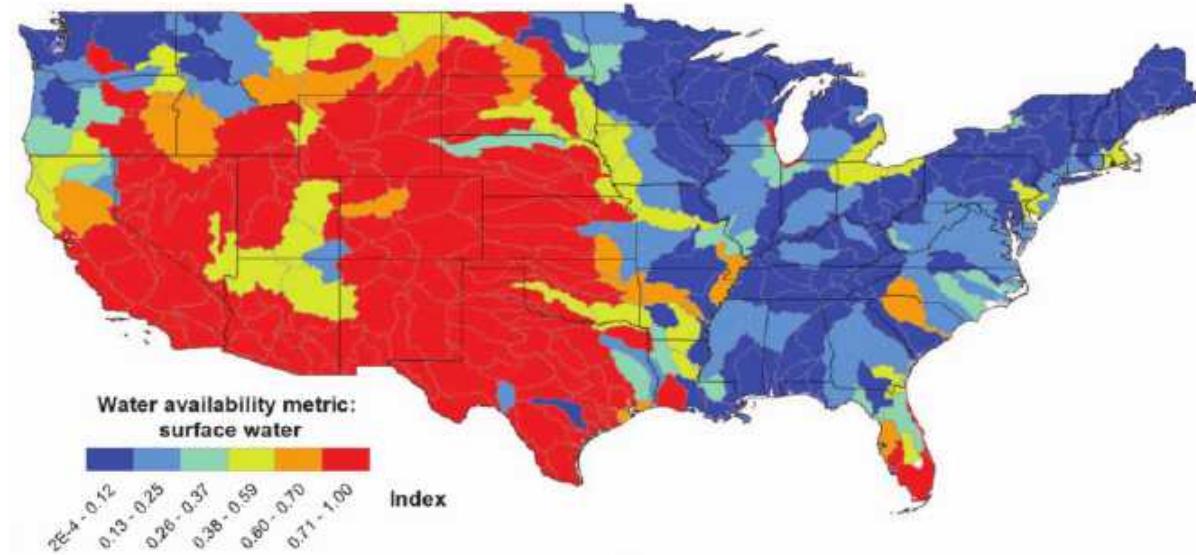


Annual Average Flow by Accounting Unit (MGD)

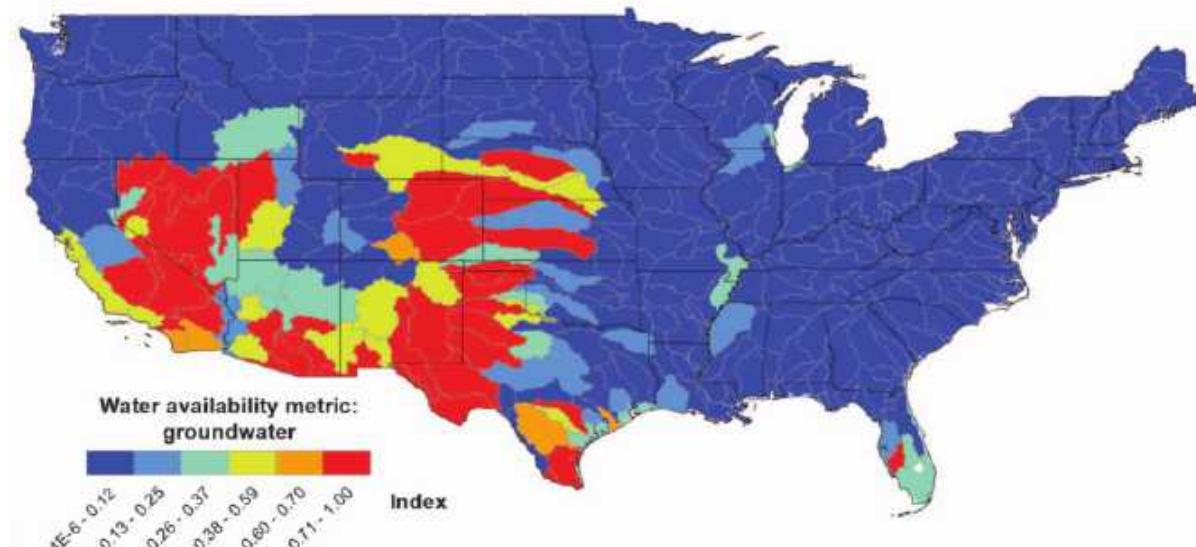


Limited Water Basins

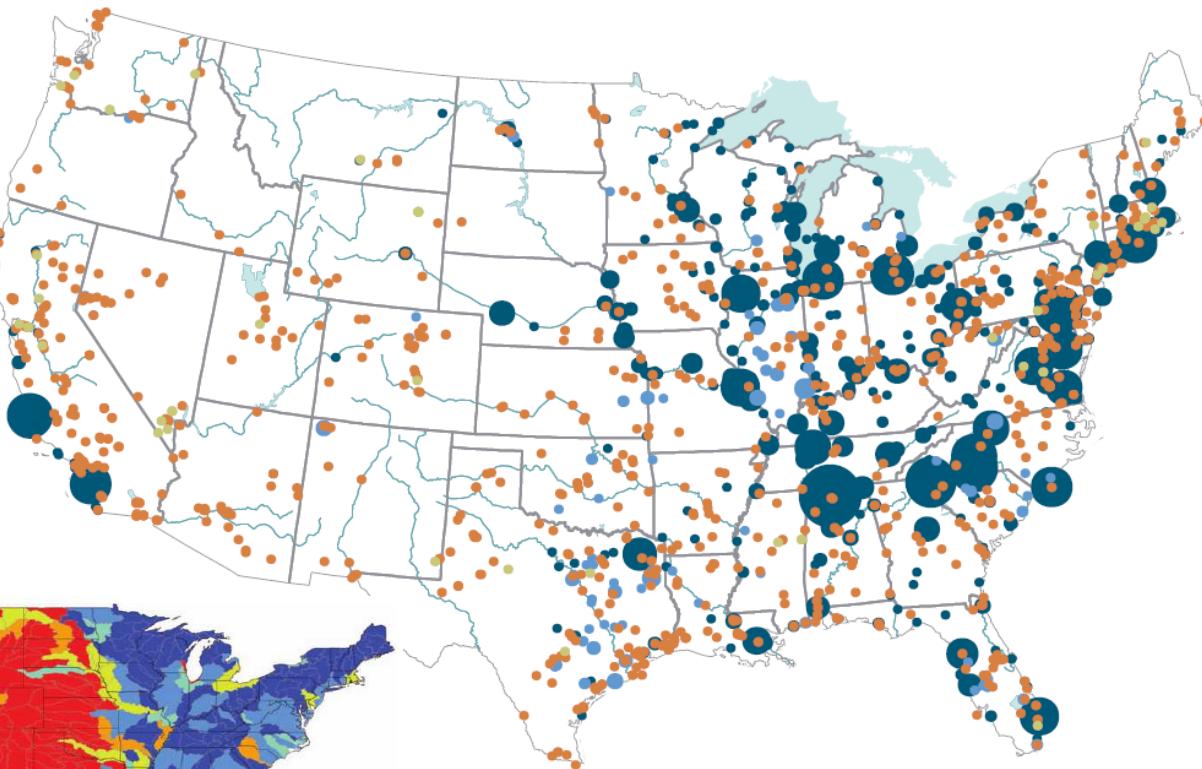
Limited
Surface Water



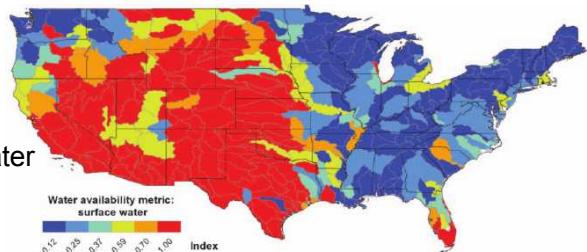
Limited
Groundwater



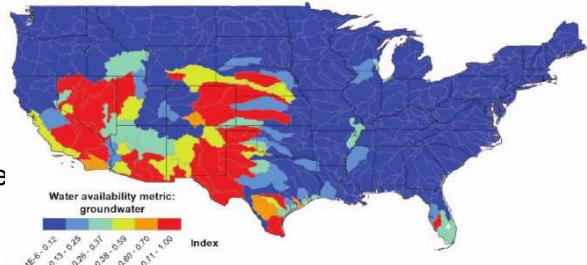
Energy-Water Nexus



Surface Water Availability



Groundwater Availability

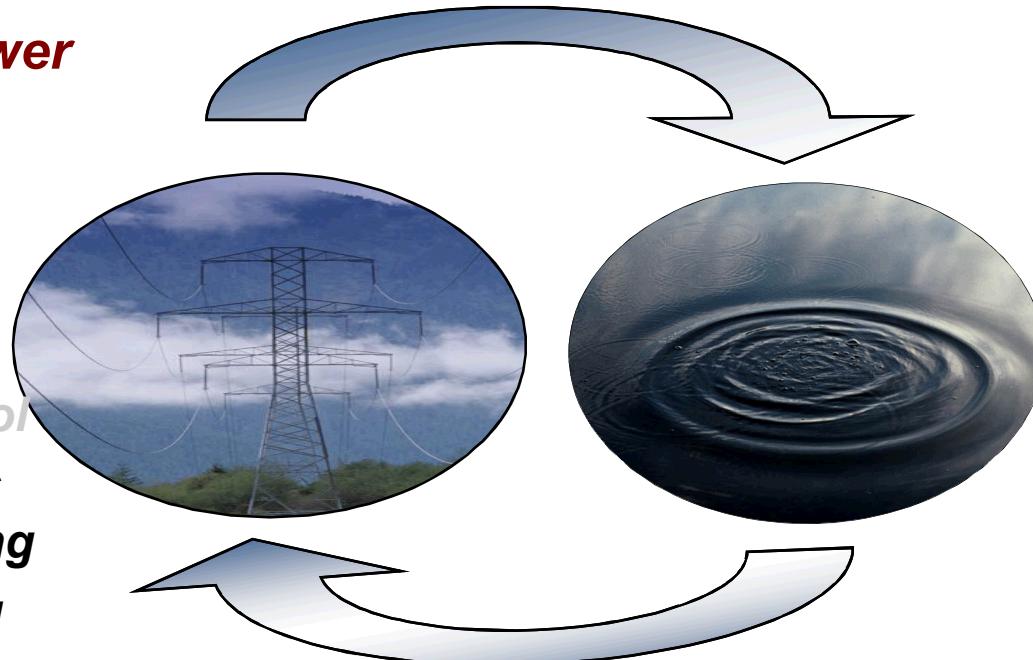


Source: UCS 2011

Energy-Water Nexus

Energy and power production requires water

- Thermoelectric Cooling
- Emission Control
- ***Energy Minerals Extraction/Mining***
- ***Fuel Processing (fossil fuels, H₂, biofuels)***

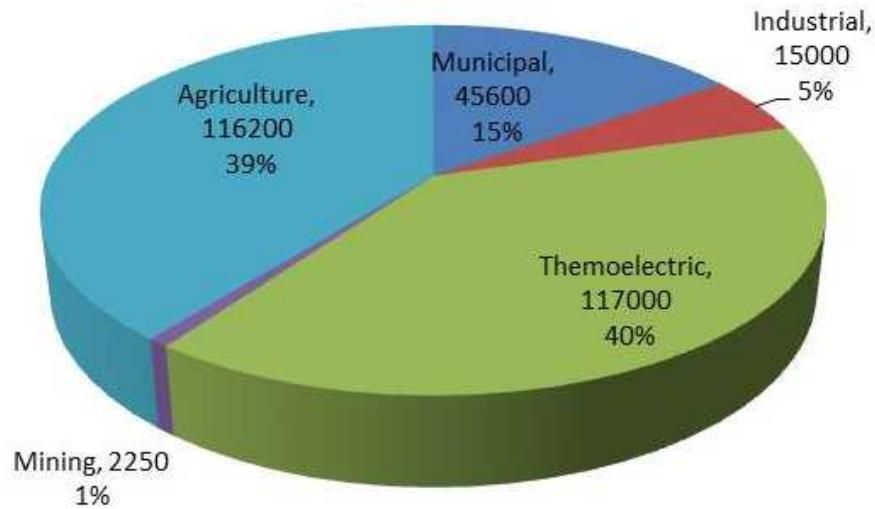


Water production, processing, distribution, and end-use requires energy

- Pumping
- Conveyance
- Treatment
- Distribution
- Use Conditioning

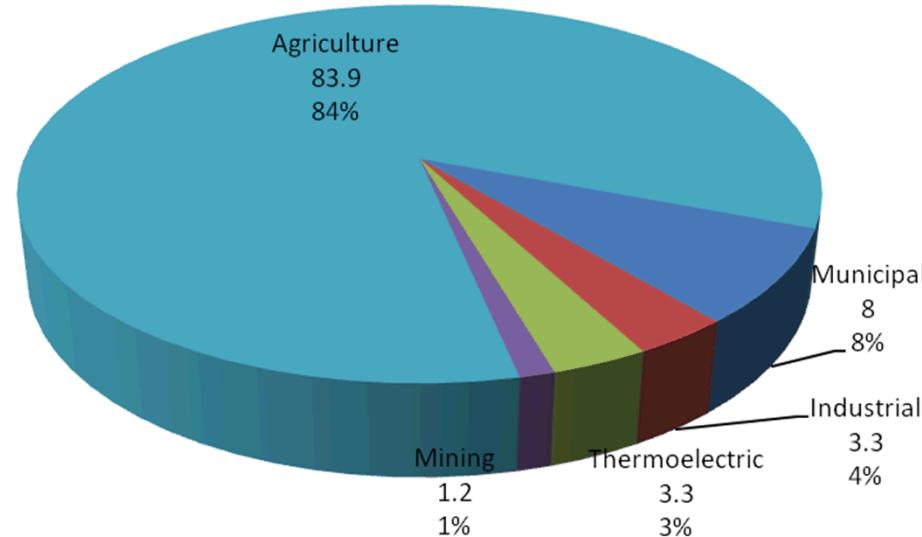
Water for Mining and Fuel Processing

Water Withdrawal (BGD) 2010



*Estimated at ~2.6 BGD consumed
in mining and fuel processing*

Water Consumption (BGD) 1995

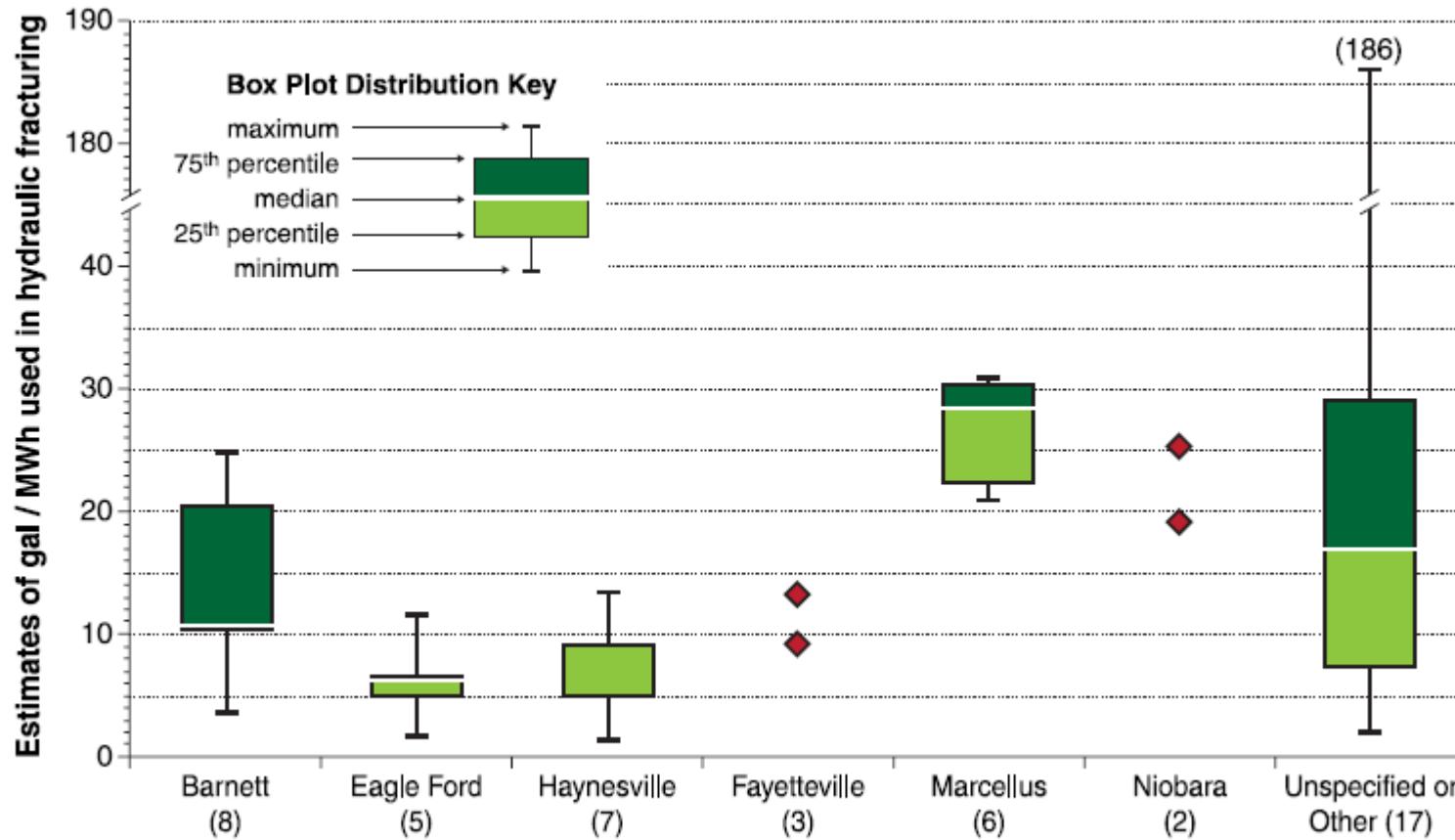


Source: USGS 1995, 2014

Gas and Oil Shale Development



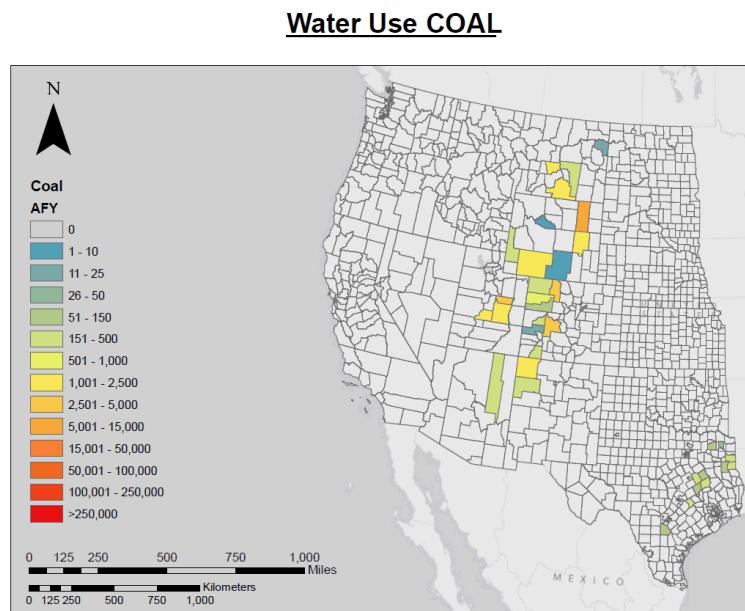
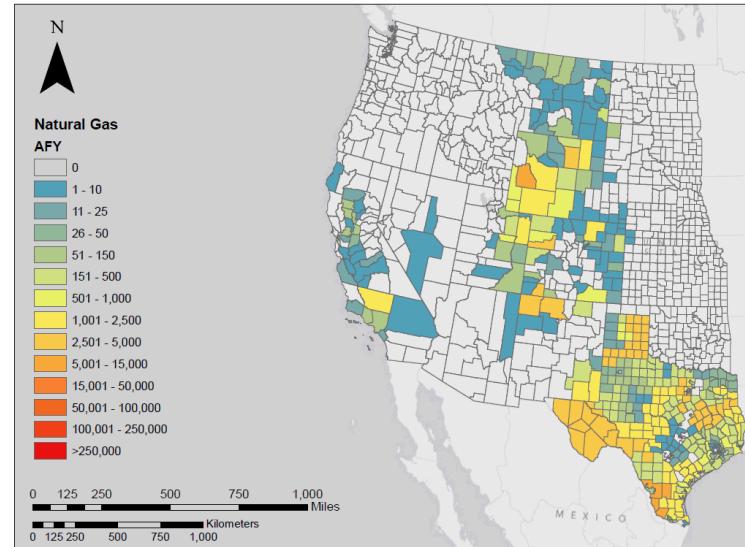
Water Use in Hydraulic Fracturing



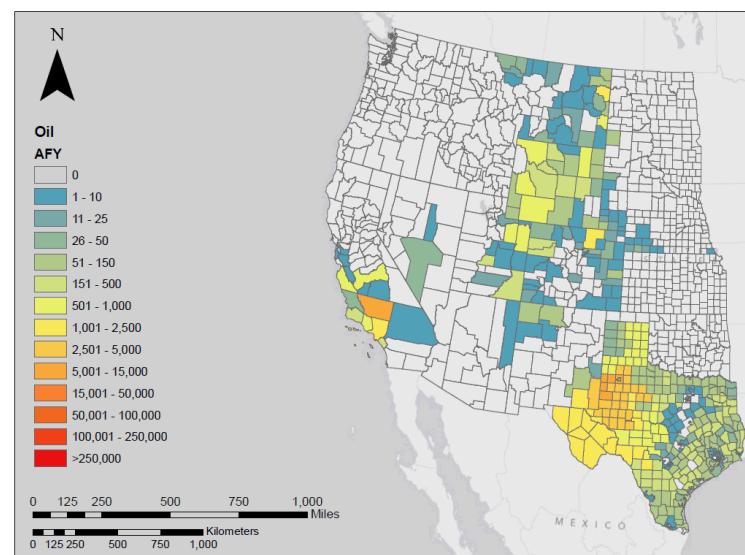
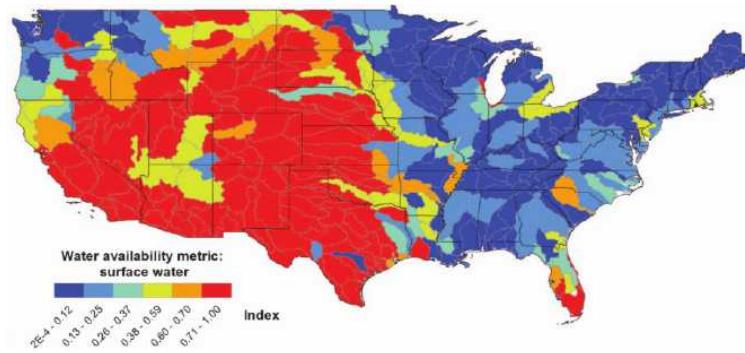
Source: Meldrum et al. 2013

Water for Fuel Extraction

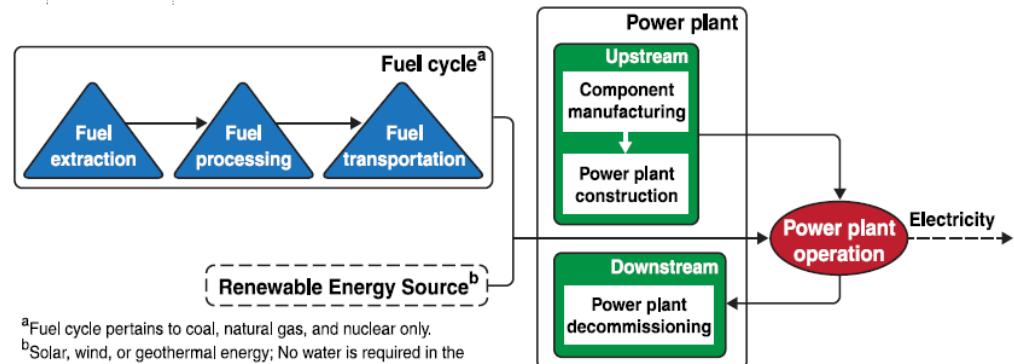
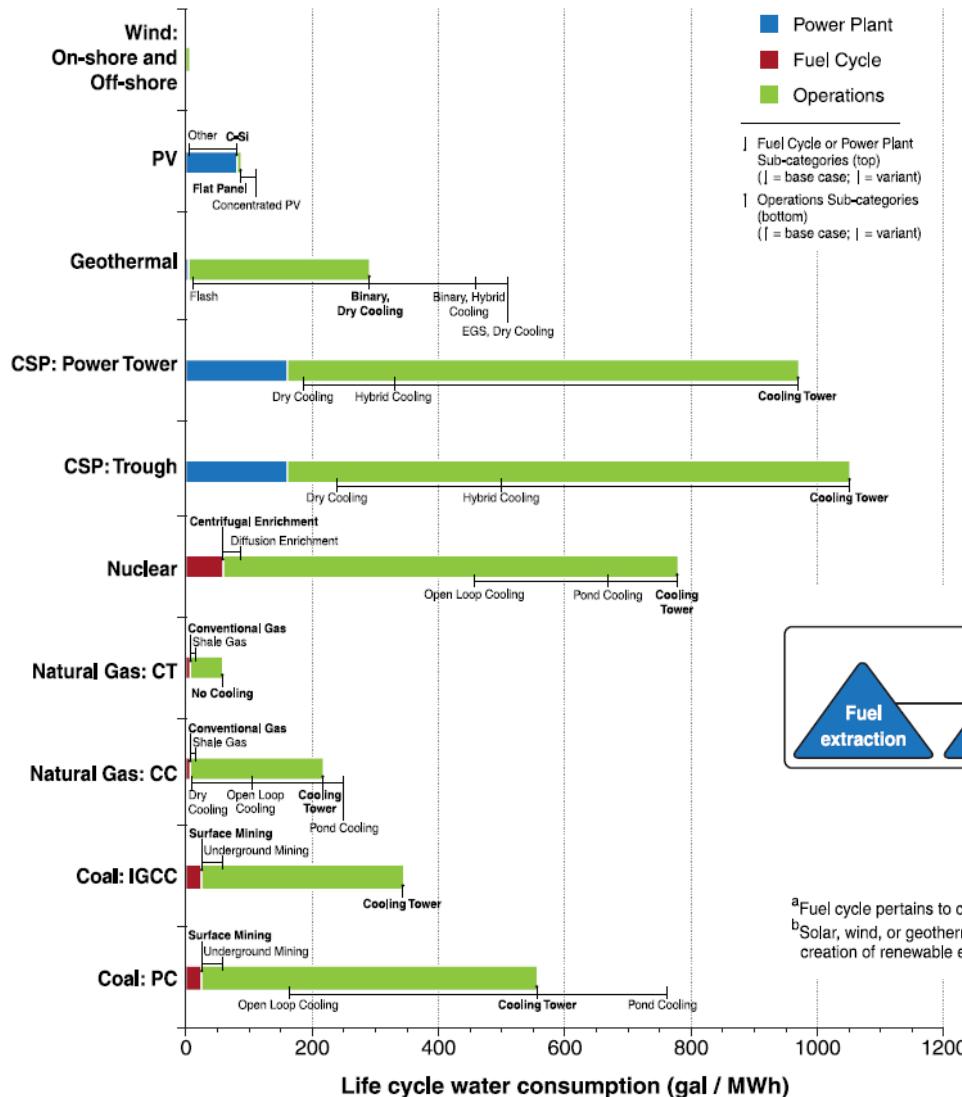
Water Use NATURAL GAS



Limited Surface Water



Life Cycle Water Use



^aFuel cycle pertains to coal, natural gas, and nuclear only.

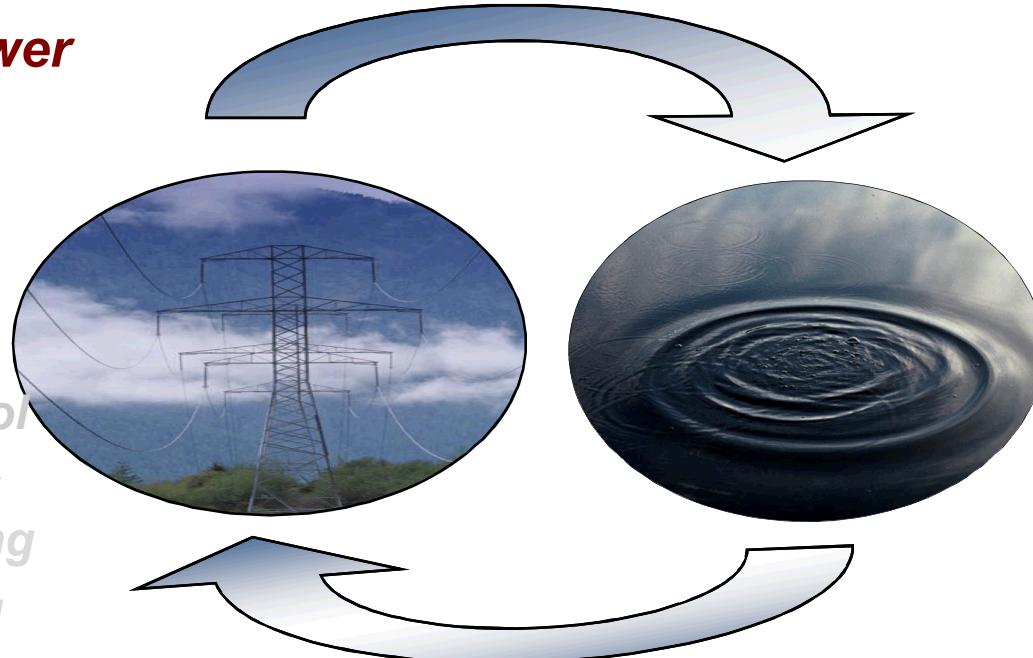
^bSolar, wind, or geothermal energy; No water is required in the creation of renewable energy resources.

Source: Meldrum et al. 2013

Energy-Water Nexus

Energy and power production requires water

- Thermoelectric Cooling
- Emission Control
- Energy Minerals Extraction/Mining
- Fuel Processing (fossil fuels, H_2 , biofuels)

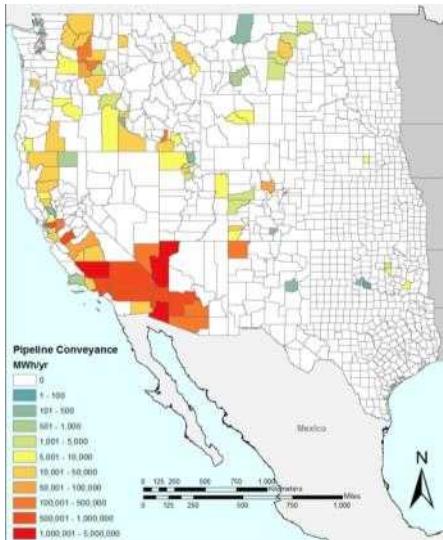


Water production, processing, distribution, and end-use requires energy

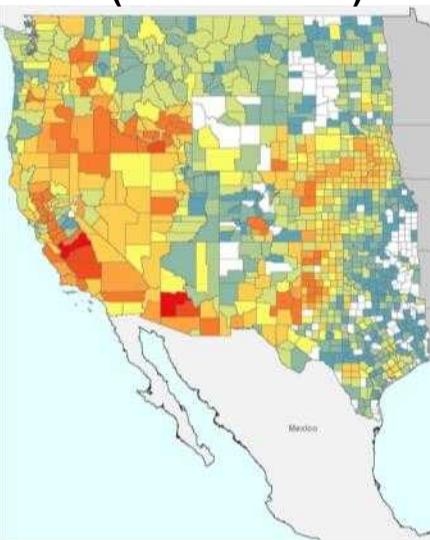
- Pumping
- Conveyance
- Treatment
- Distribution
- Use Conditioning

Energy for Water

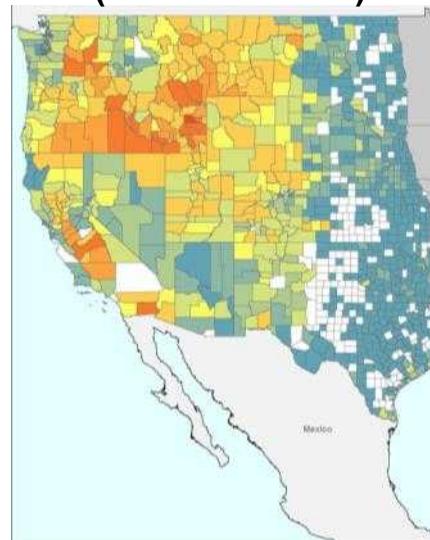
Large-Scale Conveyance



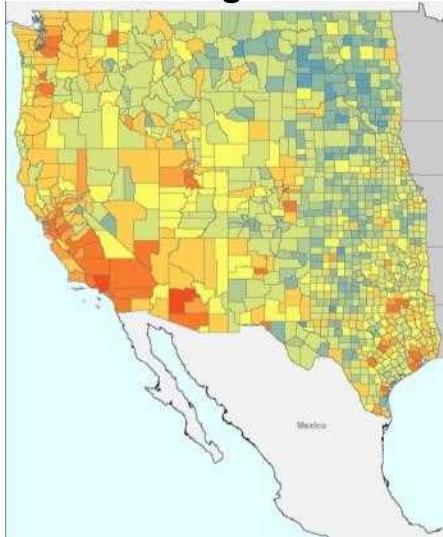
Agricultural Pumping (Groundwater)



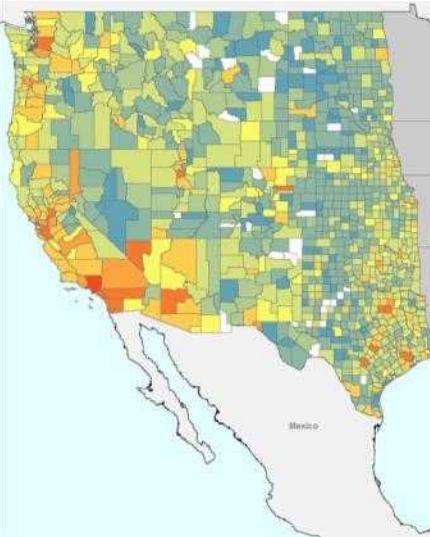
Agricultural Pumping (Surface Water)



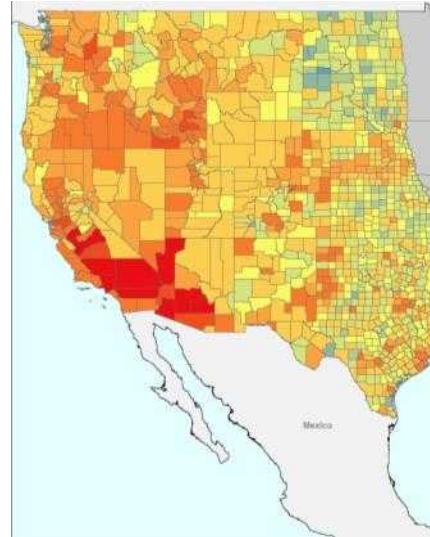
Drinking Water



Municipal Wastewater



All Water Services



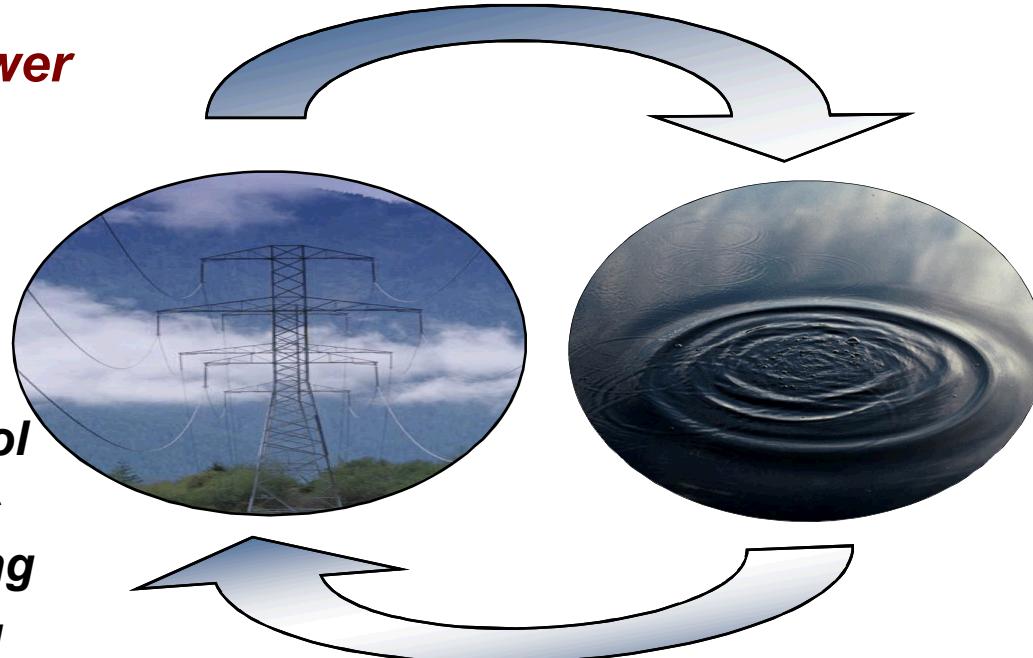
~6% of
electricity use
goes to
providing
water services.

Source: Tidwell et al. 2014

Energy-Water Nexus

Energy and power production requires water

- ***Thermoelectric Cooling***
- ***Emission Control***
- ***Energy Minerals Extraction/Mining***
- ***Fuel Processing (fossil fuels, H₂, biofuels)***

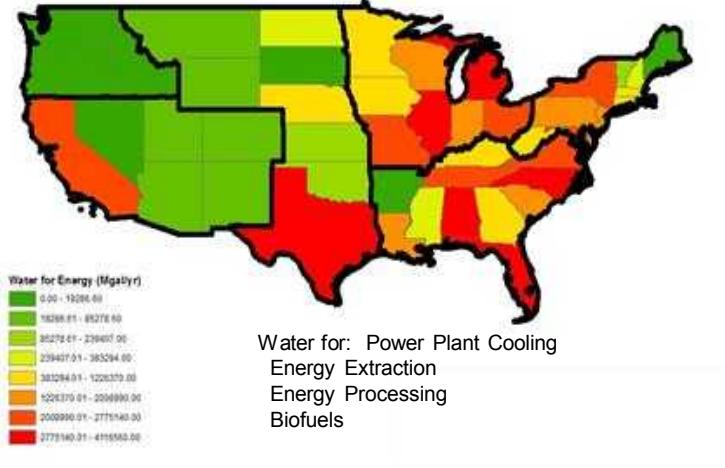


Water production, processing, distribution, and end-use requires energy

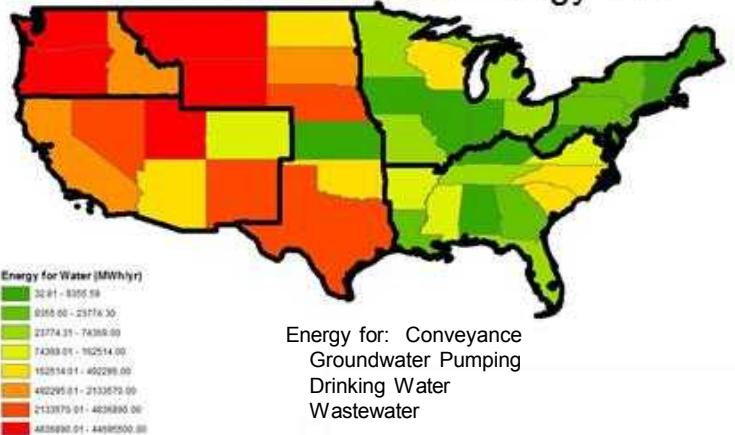
- ***Pumping***
- ***Conveyance***
- ***Treatment***
- ***Distribution***
- ***Use Conditioning***

Regional Challenge

Effect of energy on water use



Effect of water on energy use



Regional Challenges

West Coast: Seawater desalination and interbasin transfers

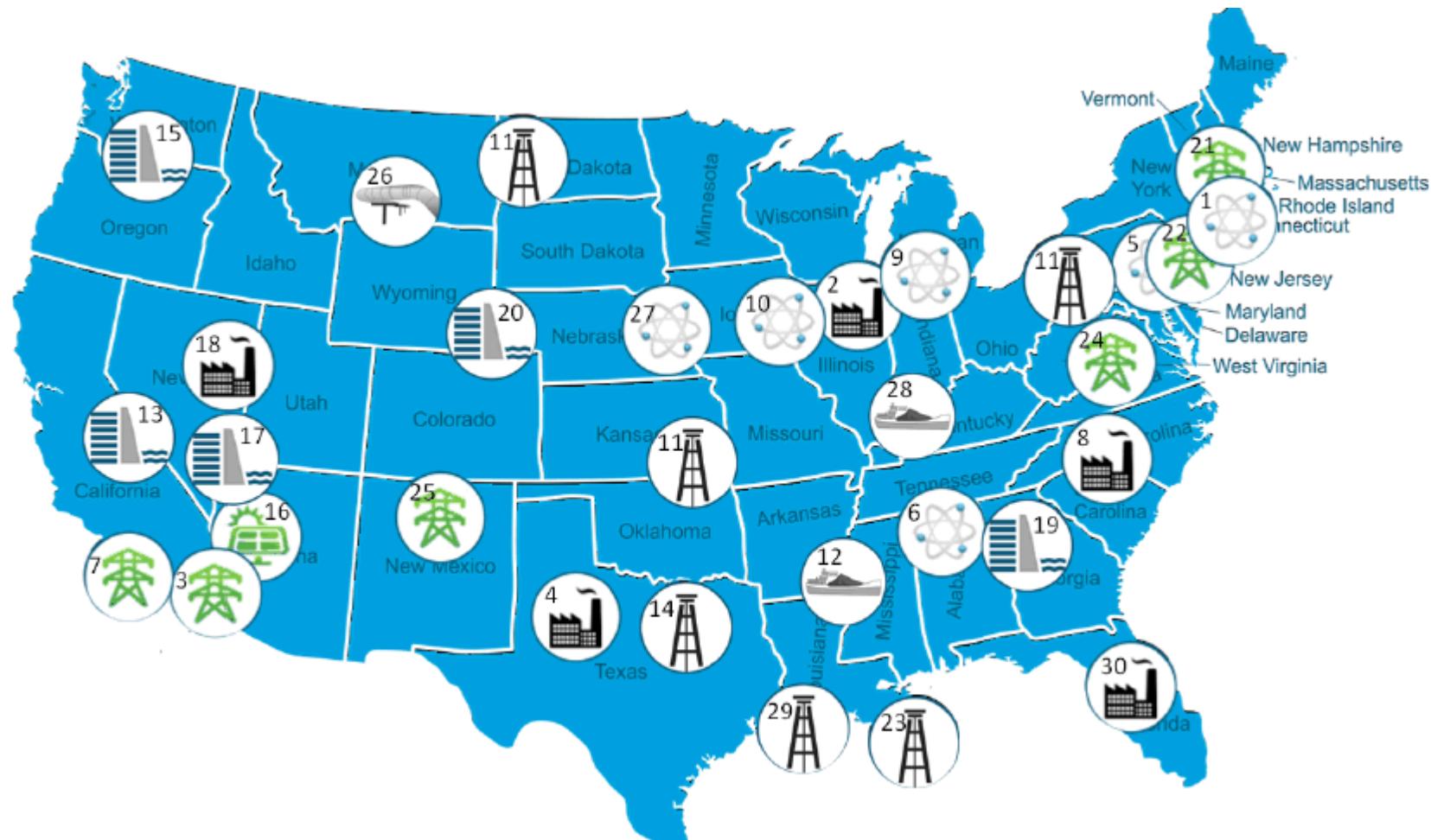
Rocky Mountain/Southwest: Brackish desalination, alternative water resources, unconventional oil & gas, thermoelectric cooling

Central region: Biofuels, thermoelectric cooling

Eastern: Infrastructure, thermoelectric cooling, flooding, urban issues, shale gas

Gulf: Oil and gas exploration, storm impacts, nuclear impacts, and seawater cooling

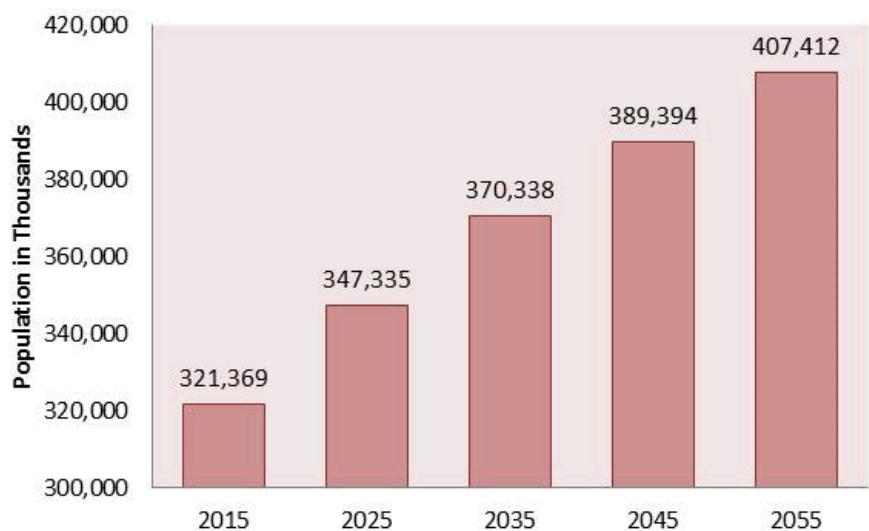
Energy-Water-Climate Nexus in the News



Source: DOE 2013

Energy- Water Nexus Future

Growth and Change

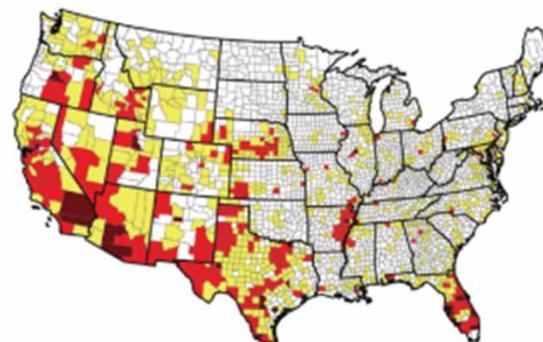


Source: U.S. Census Bureau 2014

Growing Population & Climate Change

Water Supplies Projected to Decline

No Climate Change Effects

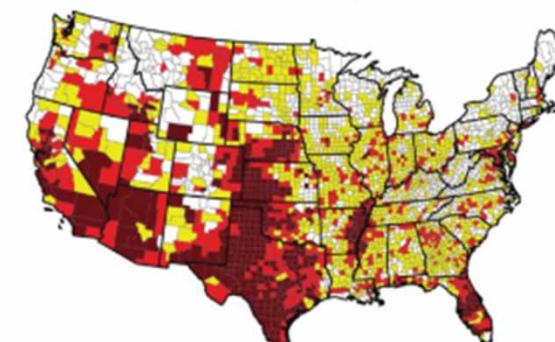


Water Supply Sustainability Risk Index (2050)

- Extreme (29)
- High (271)
- Moderate (821)
- Low (2020)

Source: National Climate Assessment 2014

Climate Change Effects

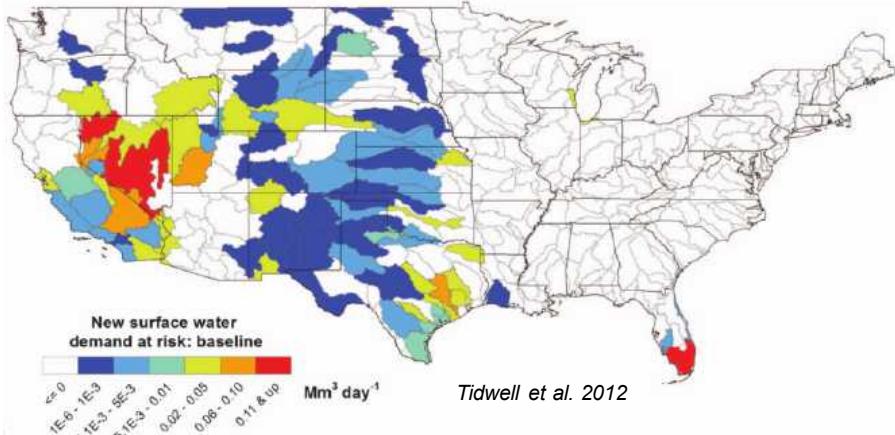


Water Supply Sustainability Risk Index (2050)

- Extreme (412)
- High (608)
- Moderate (1192)
- Low (929)

Growing Demands

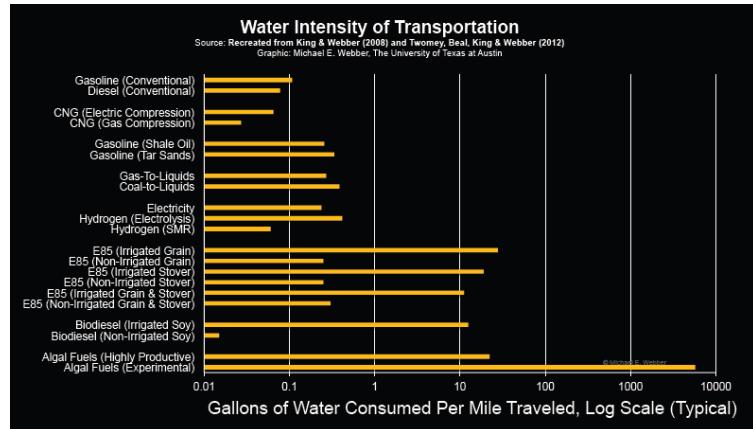
Thermoelectric Demands for Water



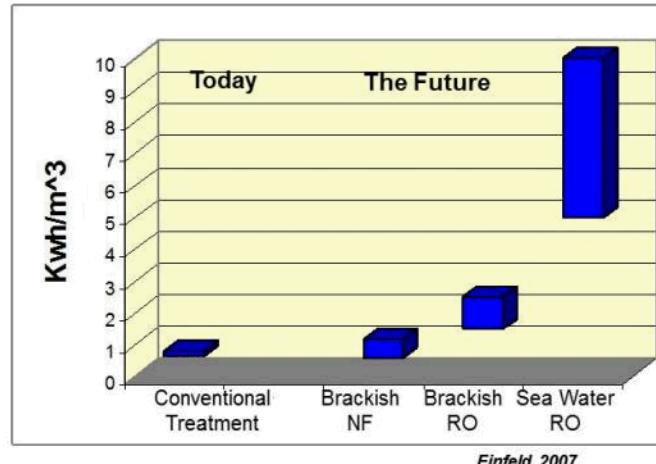
Shale Gas/Oil Demands for Water



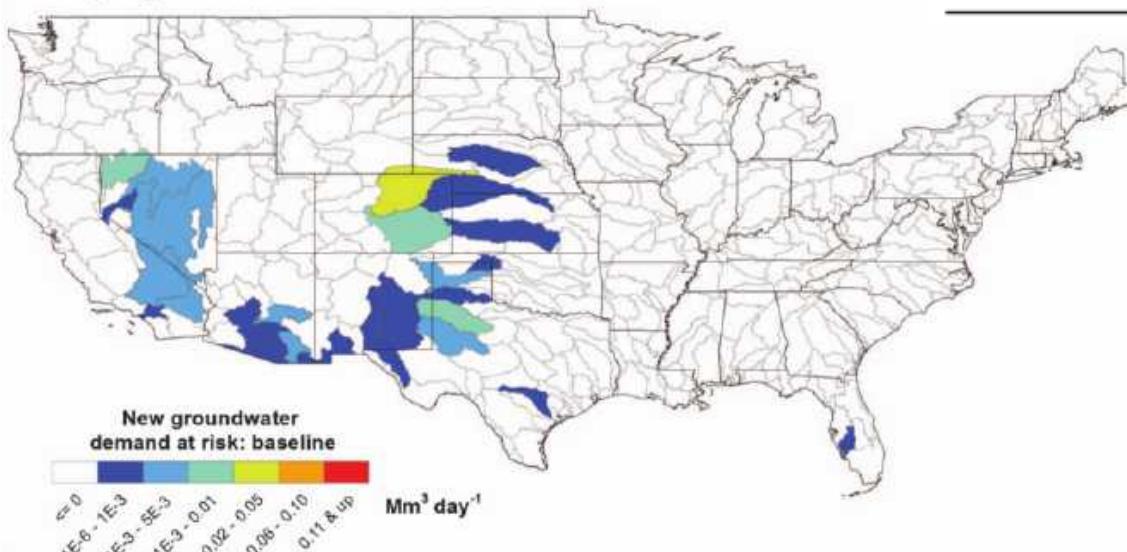
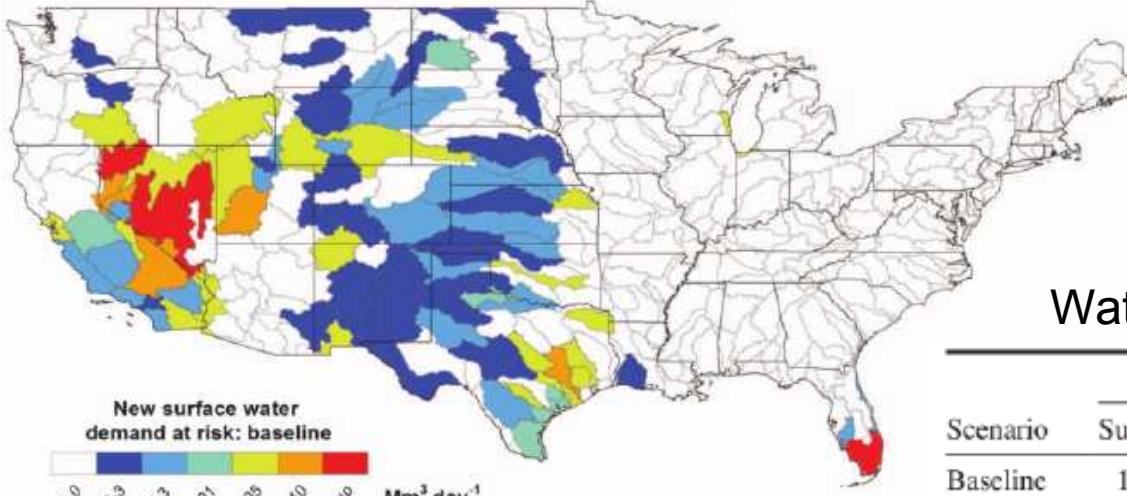
Liquid Fuels Demand for Water



Energy Demands for Water Treatment



Thermoelectric Development in Water Limited Basins



Water and Power at Siting Risk

Scenario	Power (MMWh)		Water (Mm^3/day)	
	Surface water	Ground water	Surface water	Ground water
Baseline	163 (18%)	11 (1%)	1.18 (24%)	0.06 (1%)
Fossil	139 (15%)	19 (2%)	1.24 (23%)	0.10 (2%)
Renewable	84 (9%)	5 (0.5%)	0.85 (19%)	0.04 (1%)

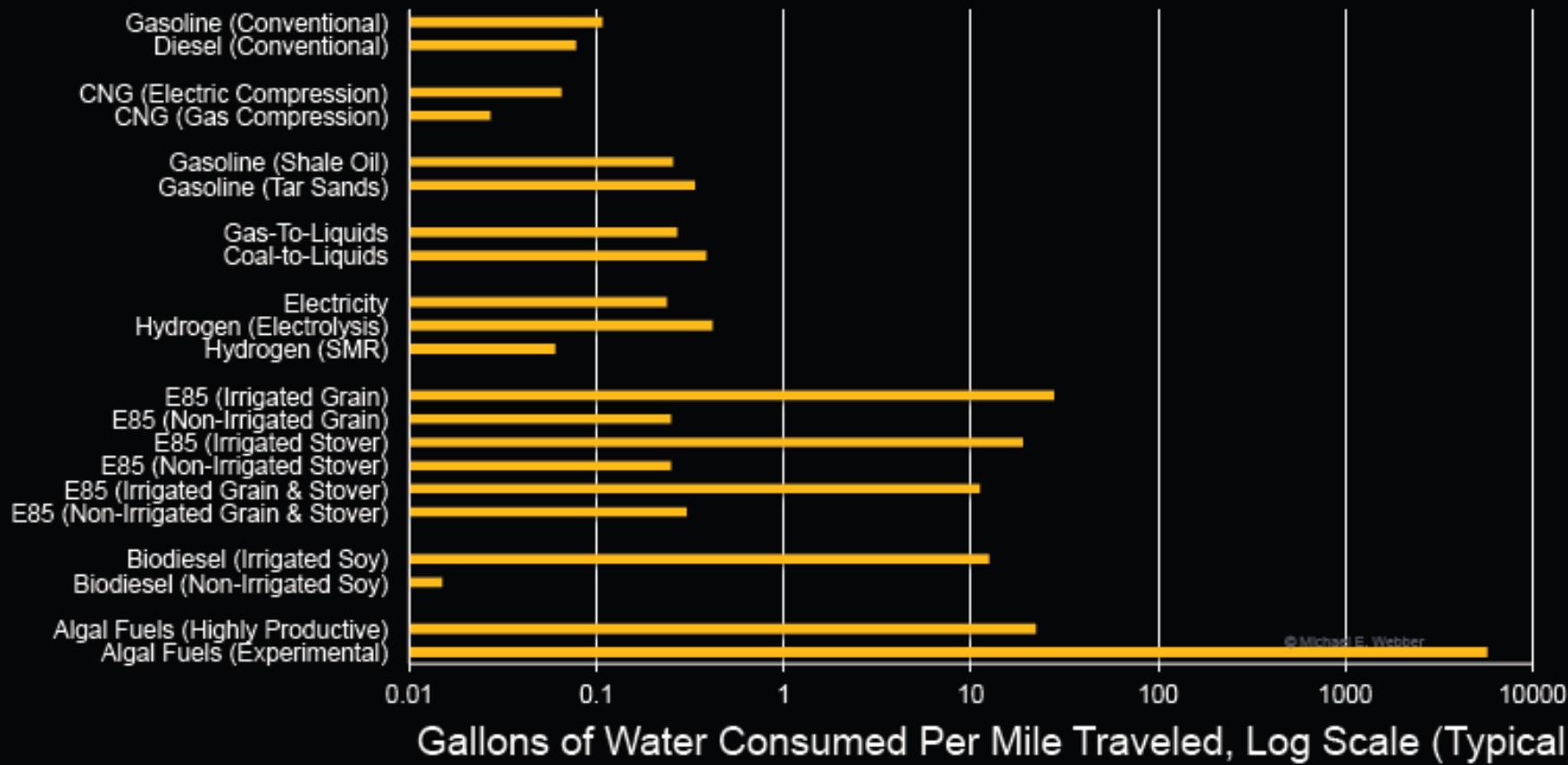
Source: Tidwell et al. 2012

Water for Transportation Fuels

Water Intensity of Transportation

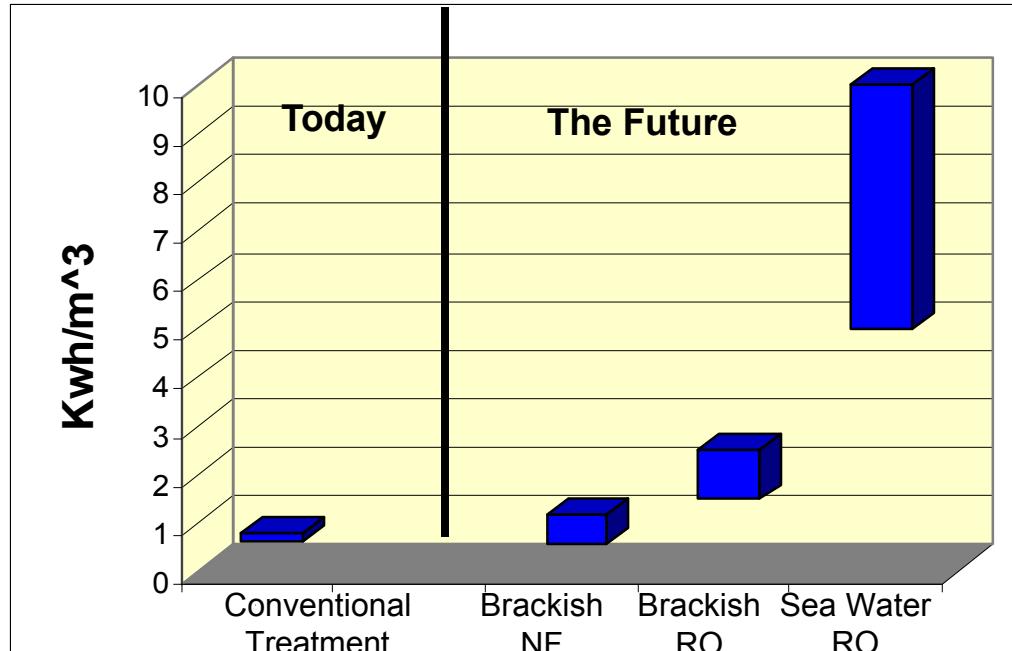
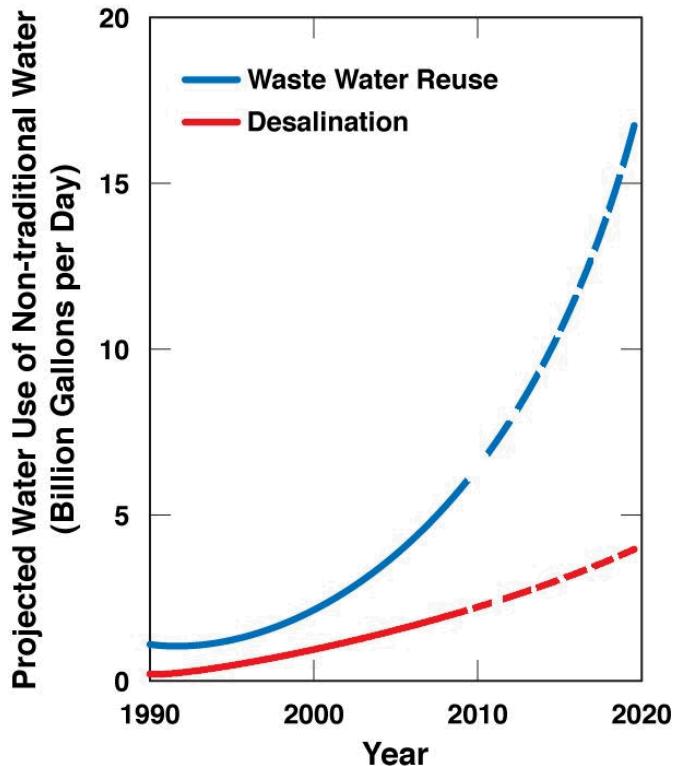
Source: Recreated from King & Webber (2008) and Twomey, Beal, King & Webber (2012)

Graphic: Michael E. Webber, The University of Texas at Austin



Energy for Water

Power Requirements For Treatment



(Modified from Water Reuse 2007, EPA 2004, Mickley 2003)

(Einfeld 2007)

- Desal growing at 10% per year, waste water reuse at 15% per year
- Non-traditional water use is energy intensive

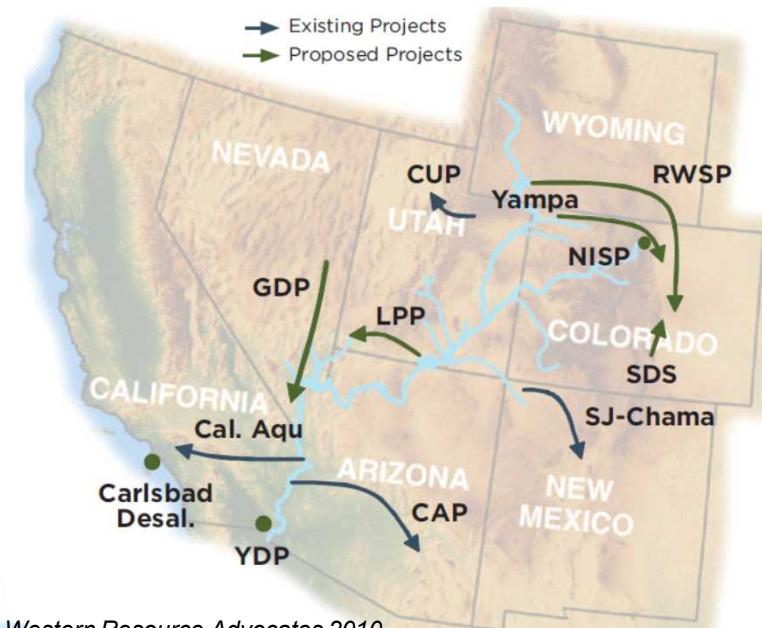
Energy for Water

- EPA is struggling with regulating pharmaceuticals in our Nation's drinking water.
- Treatment technologies for removing these contaminants at these concentrations are energy intensive.
- Numerous pipelines for trans-basin water transfers are in the planning and construction stage.



Source: detoxifynow.com

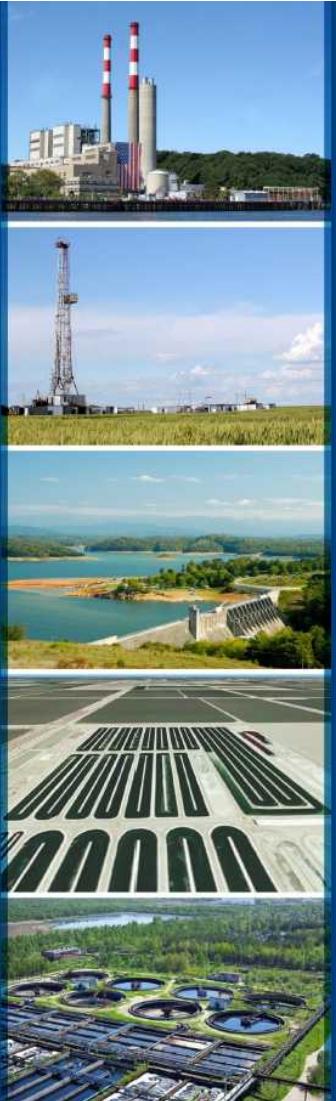
Existing and Proposed Western Water Supply Projects



Water-Energy Nexus Report

The Water-Energy Nexus: Challenges and Opportunities

June 2014

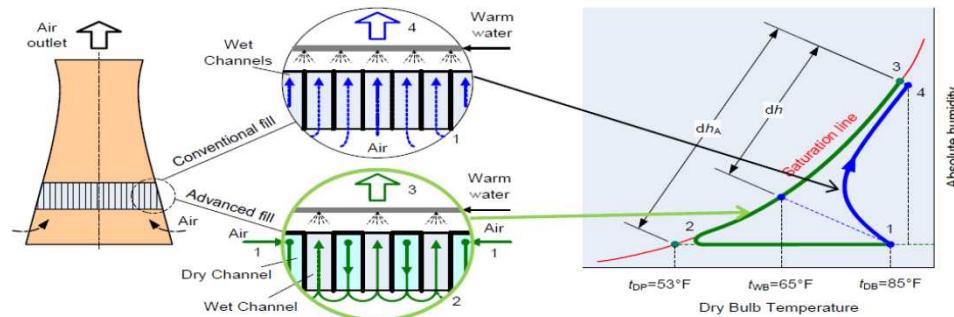


- Prepared by the Department of Energy
- Released June 2014
- Purpose:
 - Provides a foundation for future DOE action,
 - Provide data and analysis to frame opportunities, and
 - Broadly engage others in the dialogue.

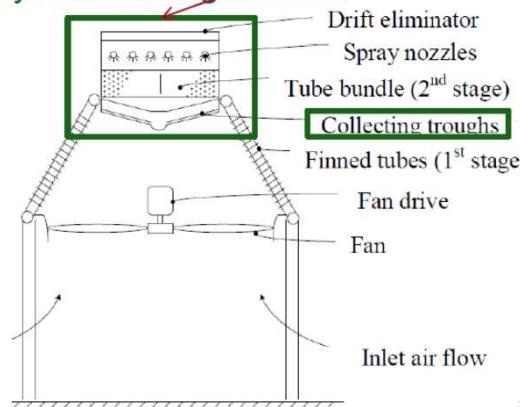
Six Strategic Pillars to Address Water-Energy Nexus

- Optimize the freshwater efficiency of energy production, electricity generation and end use systems.

Enhanced Wet and Dry Cooling Systems



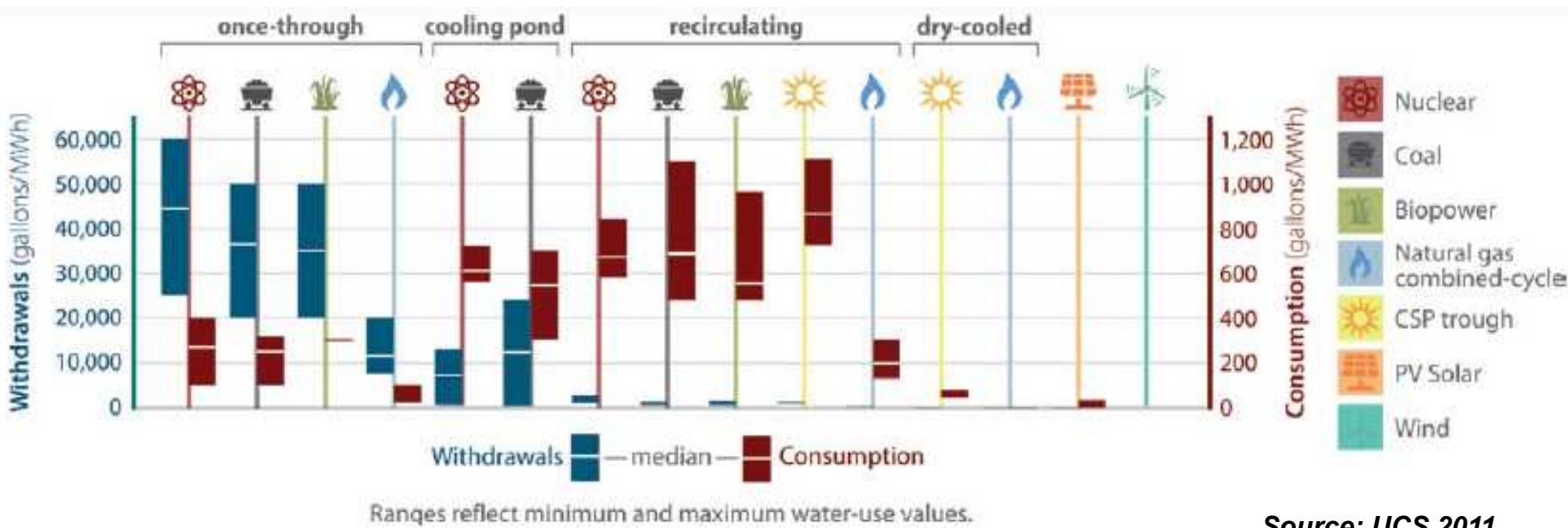
Dry/Wet Cooling Addition



Water for Thermoelectric Power

- Water use influenced by:

- Fuel type,
- Cooling type,
- Emission controls,
- Age, and
- Location

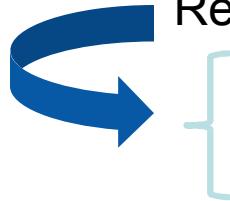


Source: UCS 2011

Transitioning to Zero Freshwater Withdrawal

Retrofits considered: *average difficulty, according to EPA guidelines*

Recirculating cooling (first step for once-through cooling systems)



- Dry cooling
- Municipal waste water
- Brackish groundwater

Costs:

Capital

Operating and Maintenance (O&M) costs

Capture (e.g., conveyance costs for waste water, drilling and pumping costs for brackish groundwater)

Treatment

Parasitic energy losses

Availability:

Municipal waste water: within 50 miles

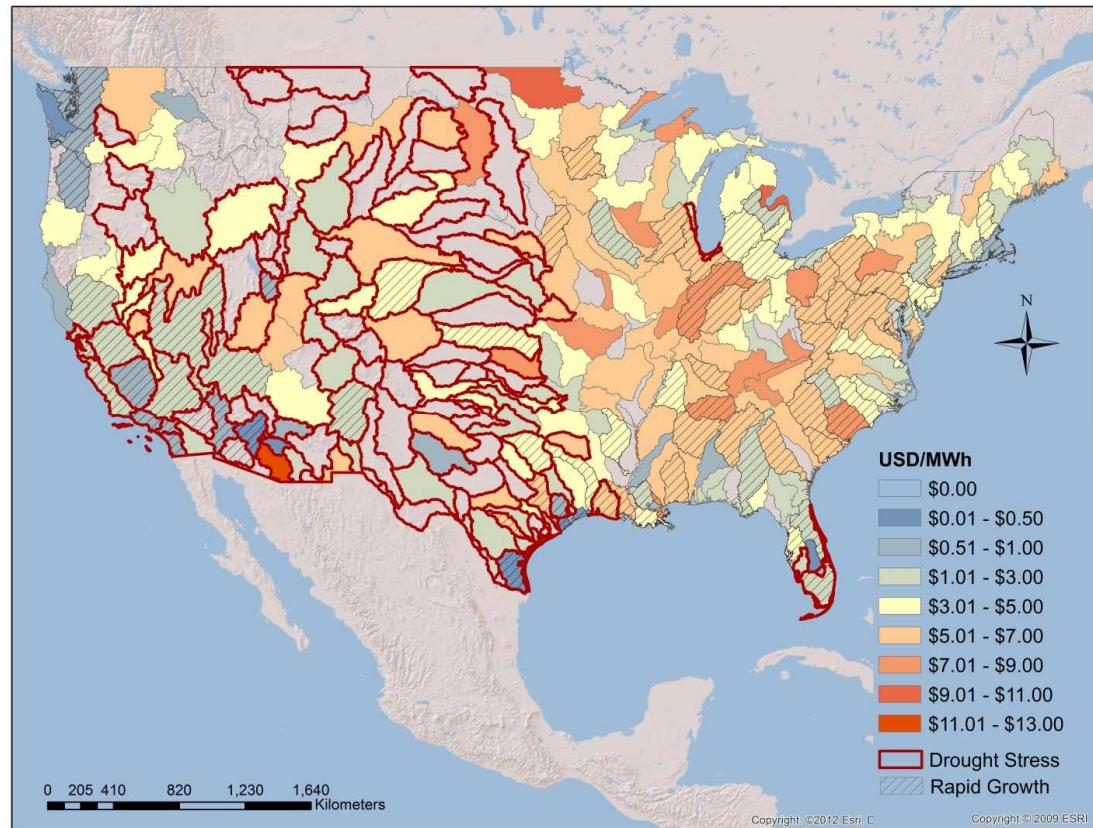
Brackish water: <2500 ft deep, salinities>10,000 TDS

* NOTE: not taking into consideration site-specific constraints such as land availability, local regulations, technology vintage

Opportunities for Retrofit

Technology	Number of plants
Waste water	823
Brackish water	109
Dry cooling	246

Note: Δ LCOEs tend to be lower in the West, Texas Gulf Coast and south Florida, which are areas prone to drought stress



Source: Tidwell et al. 2014

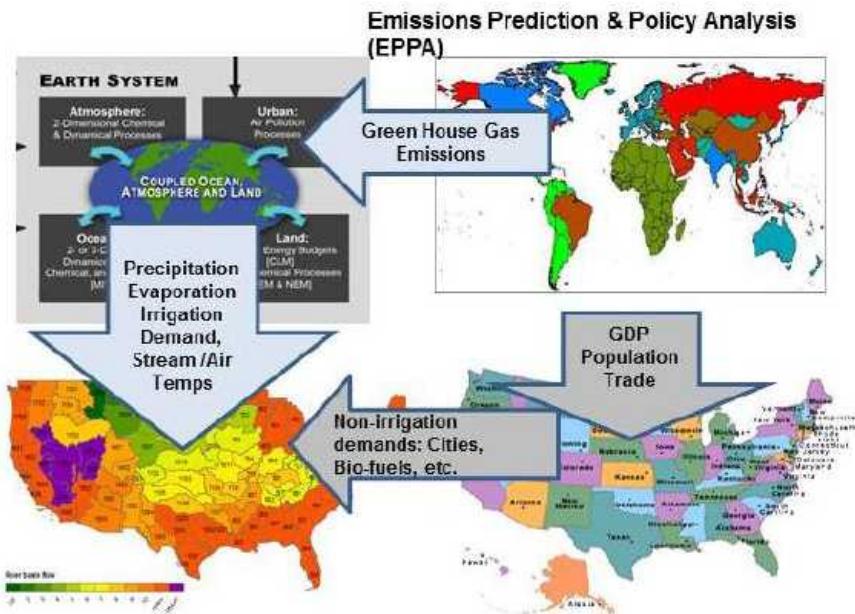
With wholesale cost of electricity about \$40/MWh, many retrofits could be accomplished at levels that would add less than 10% to current power plant generation expenses.*

*average 2012 wholesale cost over 3 US trading hub regions

Six Strategic Pillars to Address Water-Energy Nexus

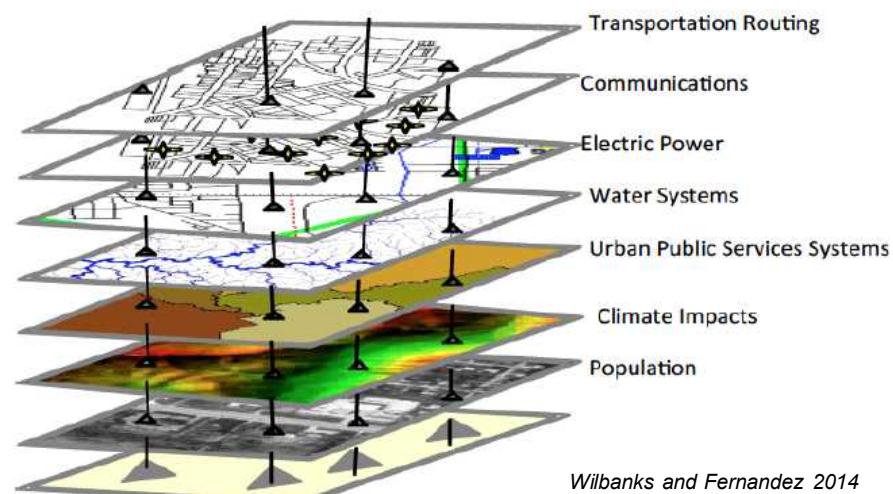
- Enhance the reliability and resilience of energy and water systems.

Integrated Modeling



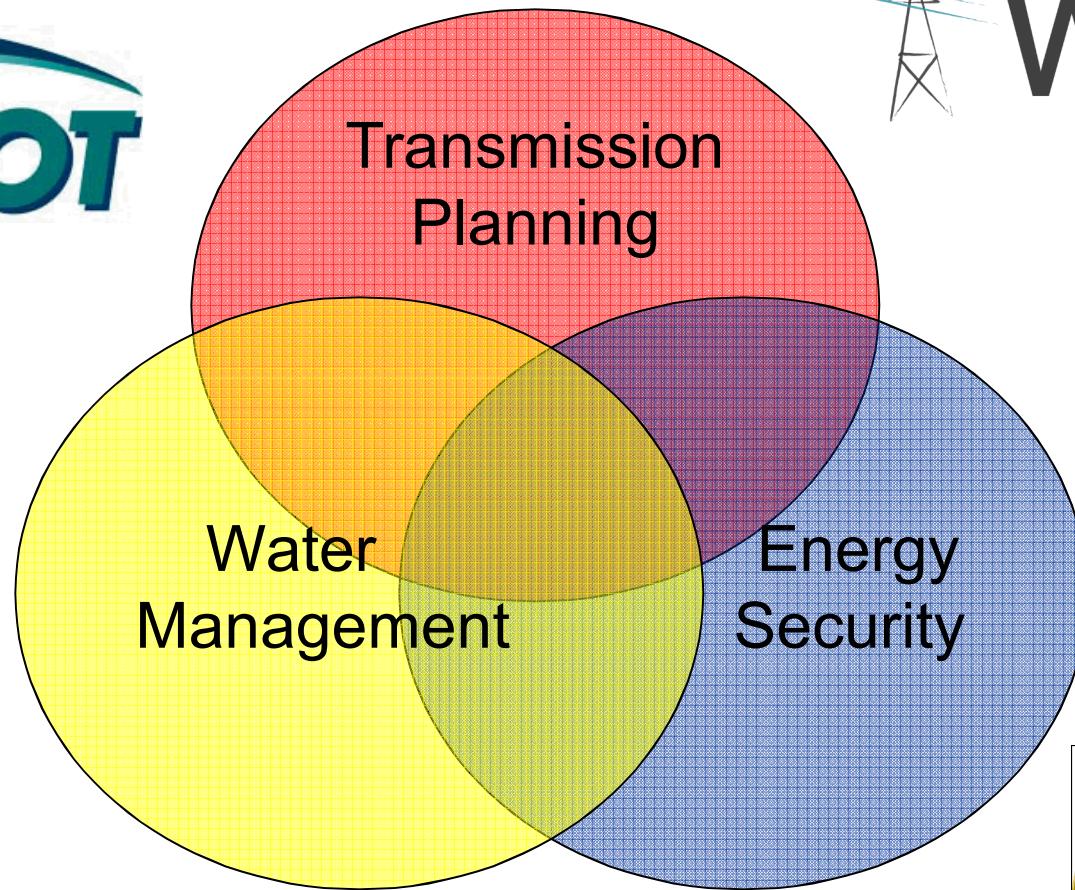
Schlosser et al. 2014

Infrastructure Risk Analysis



Wilbanks and Fernandez 2014

Integrated Planning

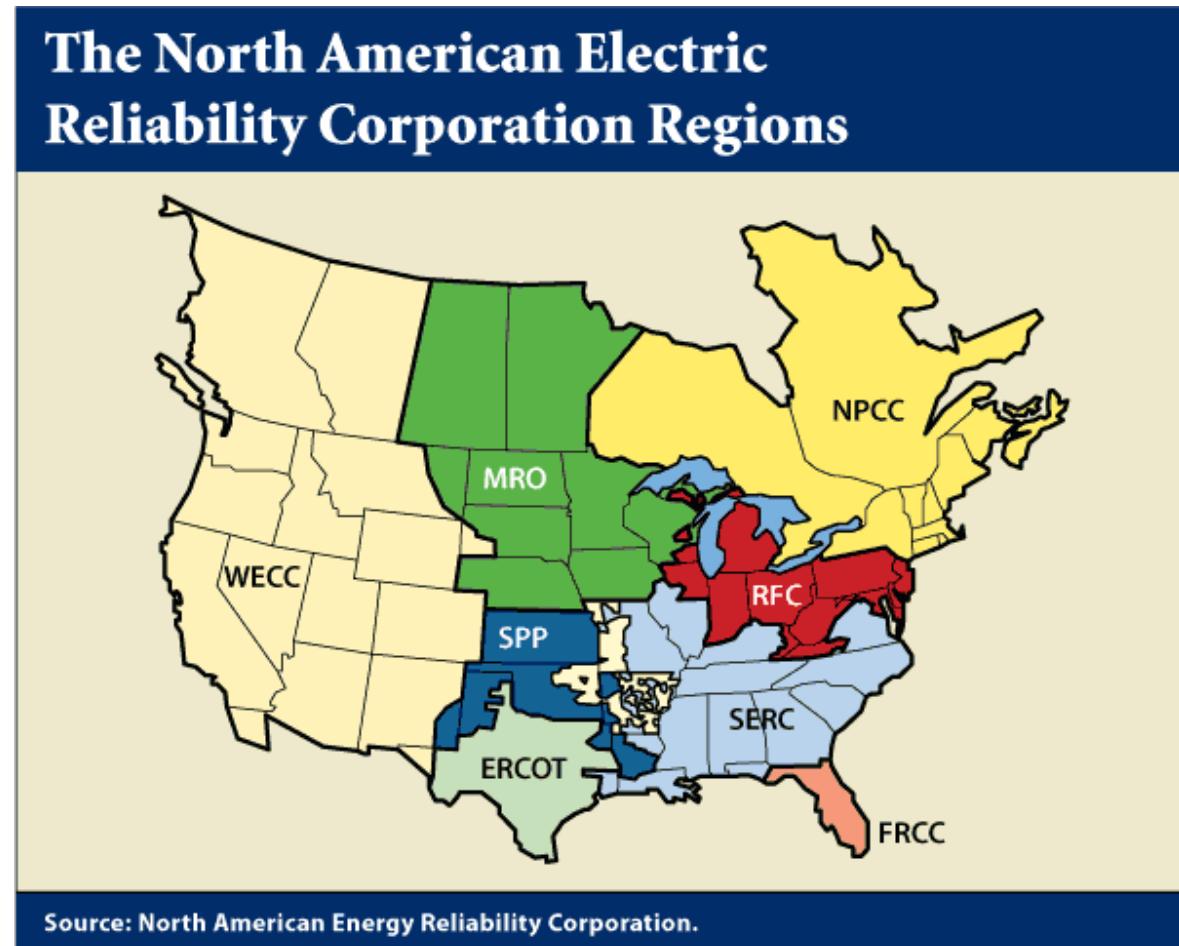


Serving the Governors of 19 States and 3 US-Flag Pacific Islands



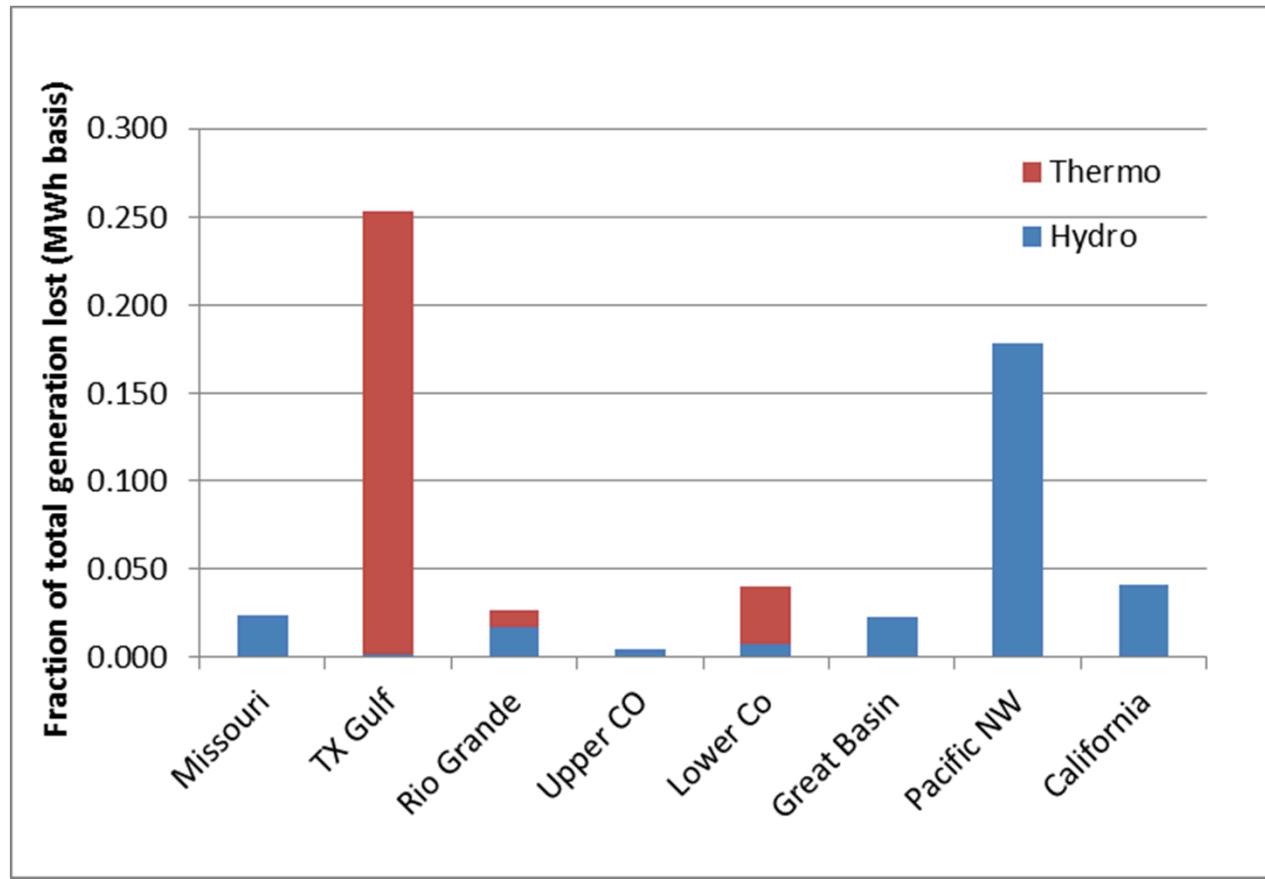
Transmission Planning

- WECC and ERCOT are conducting long-range transmission planning (20 yrs.) to direct:
 - Siting of new power plants
 - New transmission capacity



Climate Impact on Existing Plants

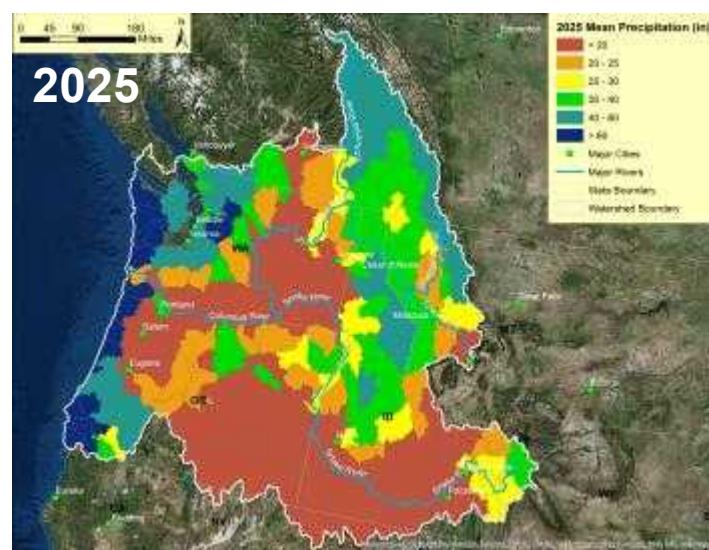
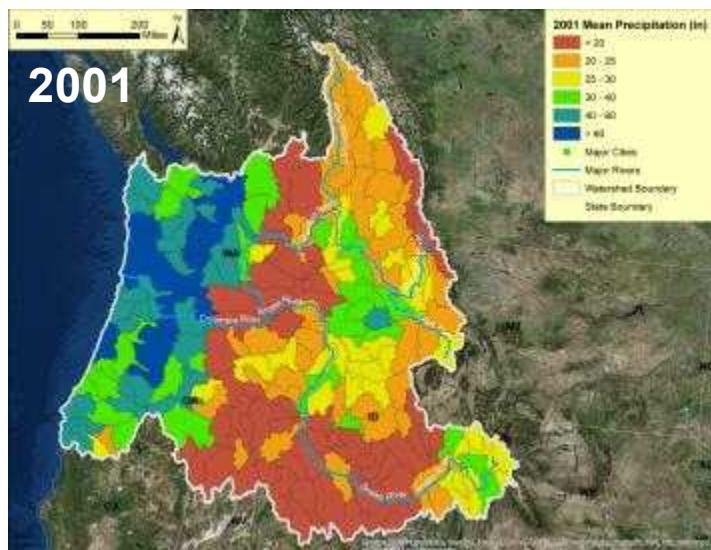
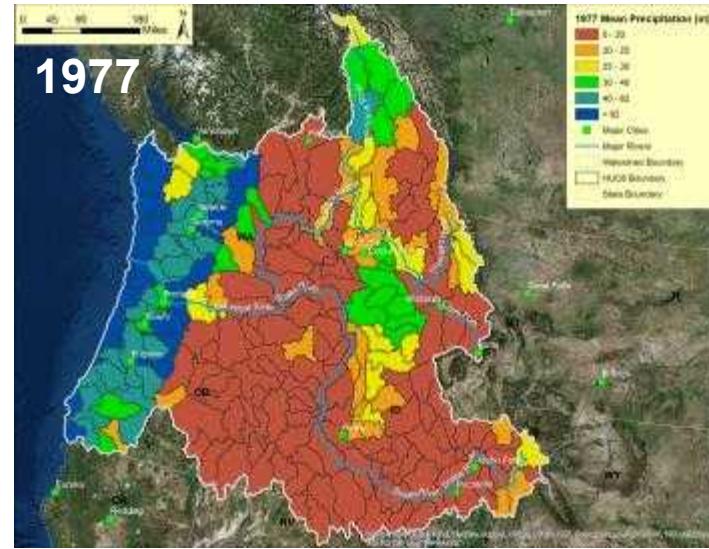
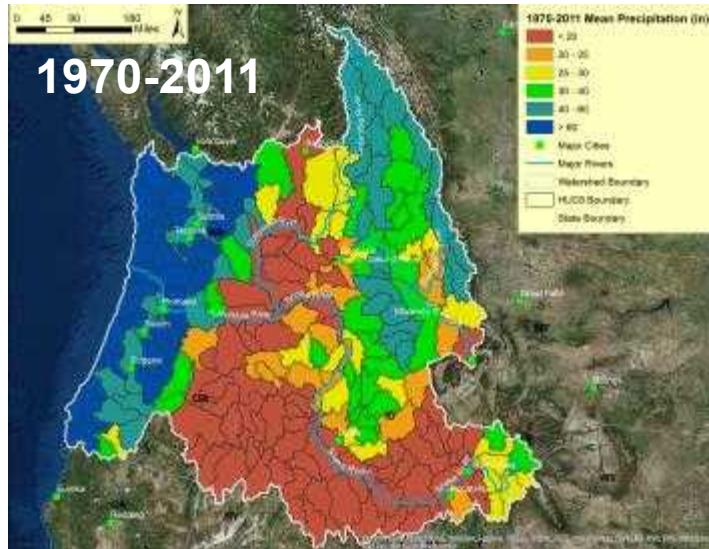
Fraction of Generation at Risk



Basin Map

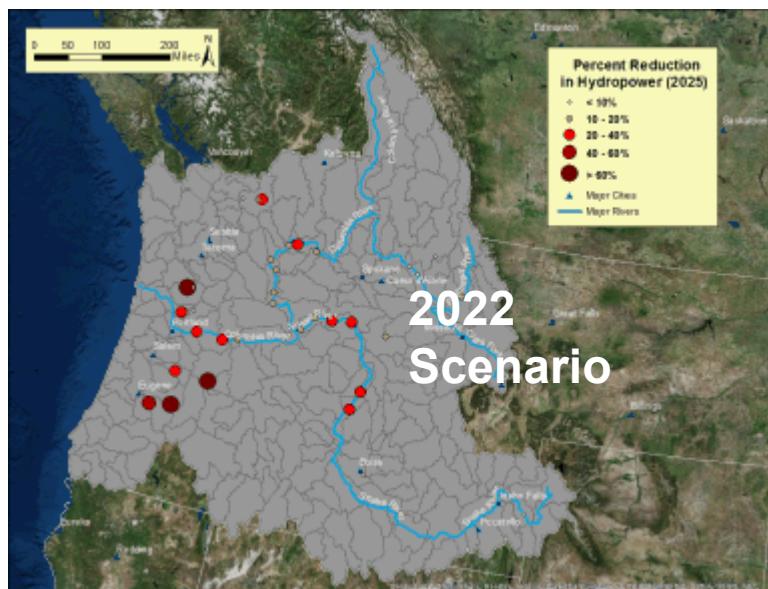
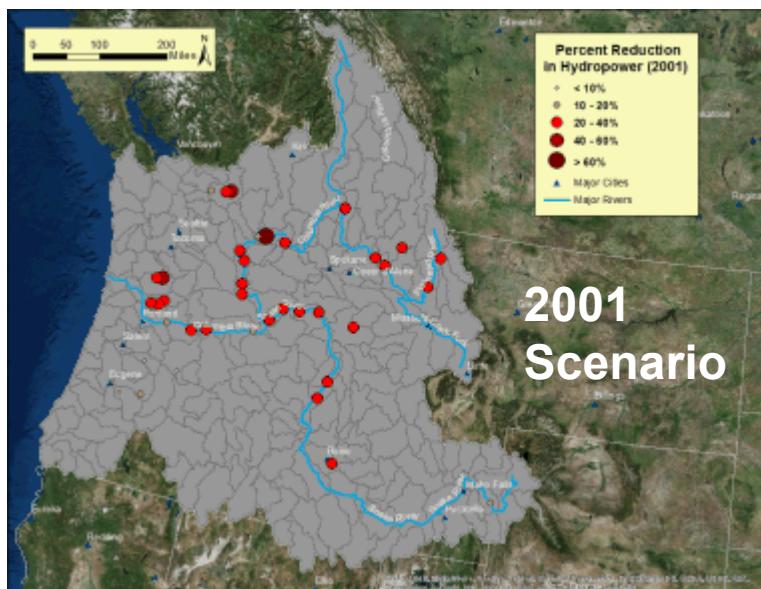
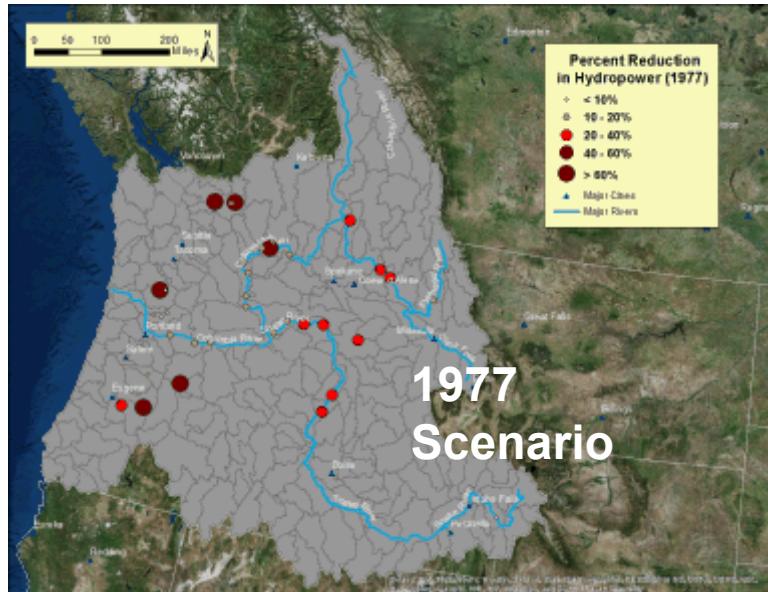
Source: ANL 2012

Precipitation Pattern (Annual Mean)

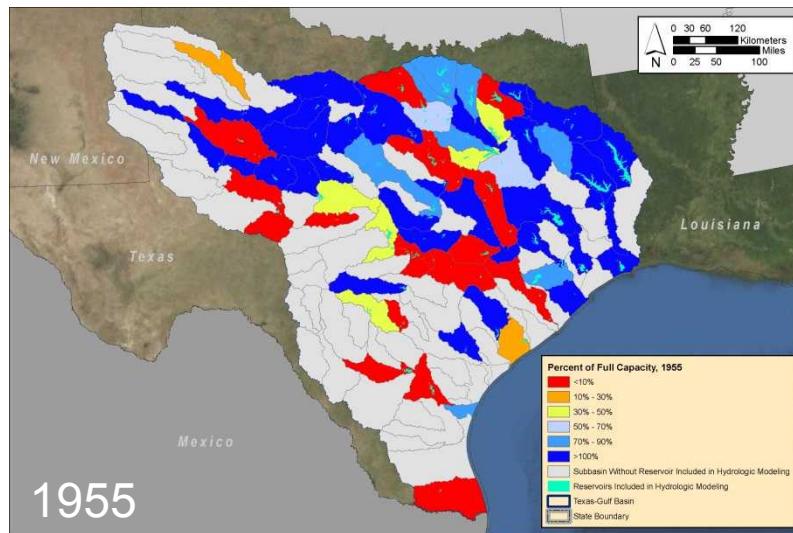
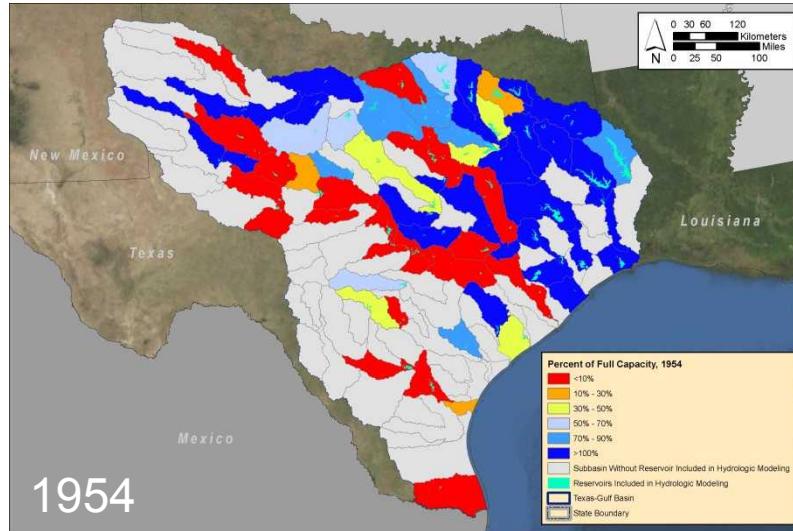


Potential Impact of Drought on Hydropower Generation

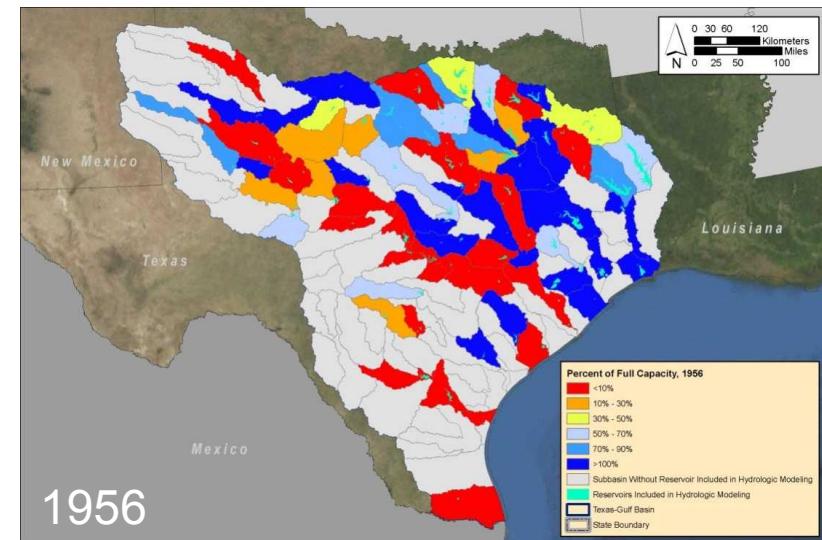
- Simulated reduction of hydropower
 - 1977 drought: 21% reduction
 - 2001 drought: 24% reduction
 - 2025 drought: 20 % reduction



Climate Impacts on the Hydrology



- Projected reservoir storage in HUC-8 basins under 1950-1957 drought scenario

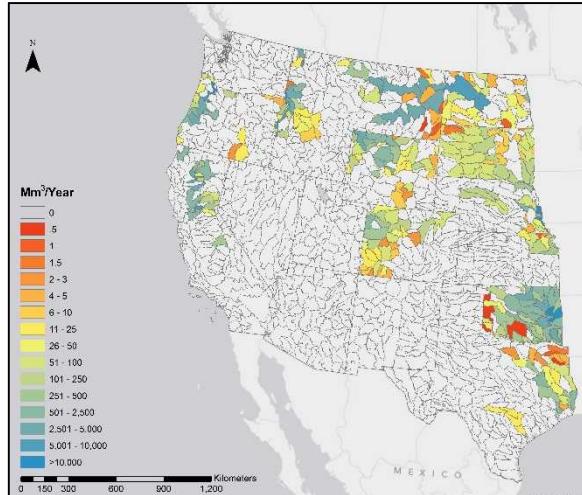


Source: ANL 2013

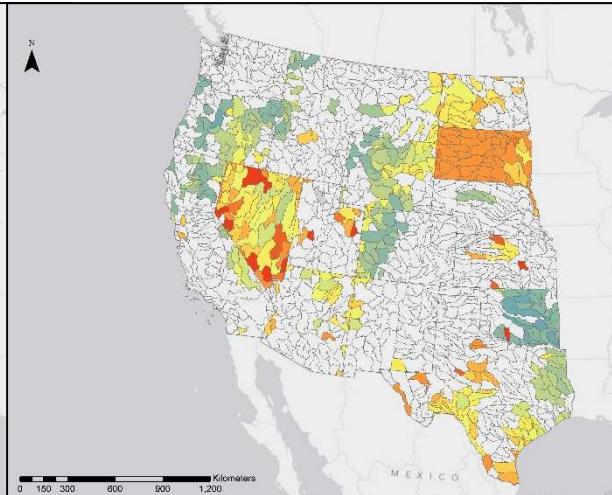
Water Availability and Future Demand



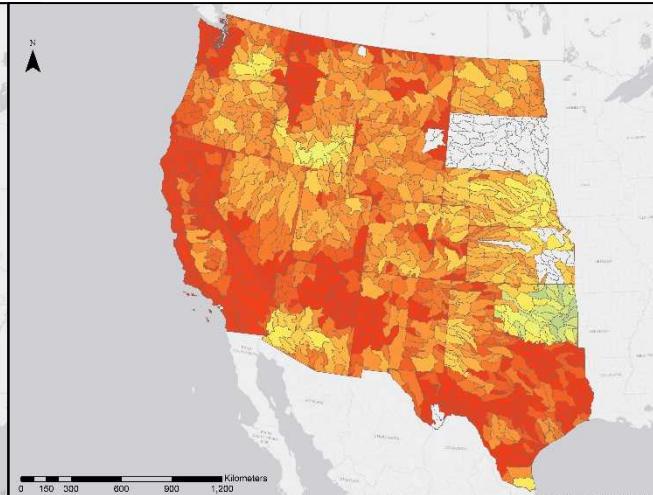
Unappropriated Surface Water



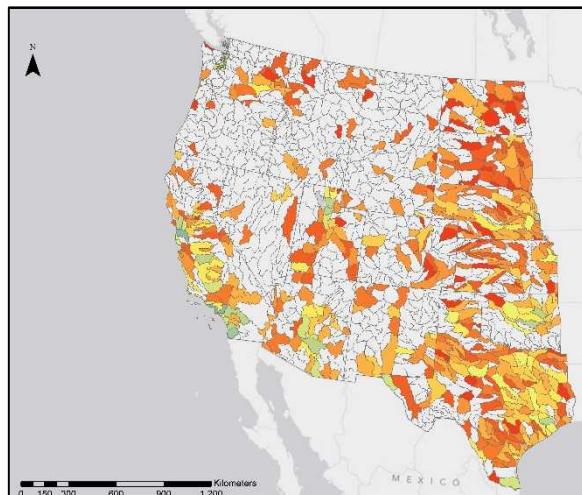
Unappropriated Groundwater



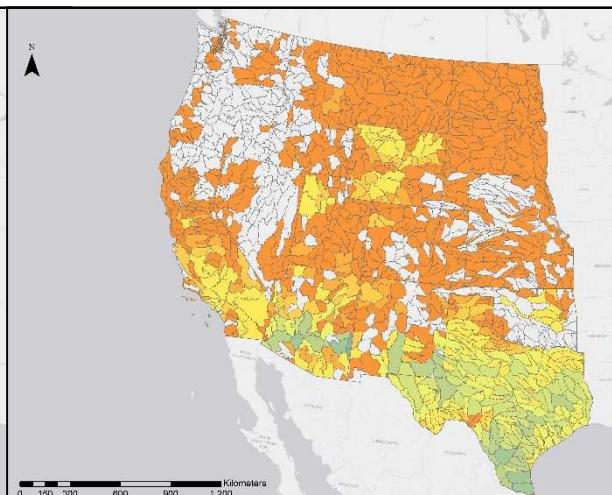
Appropriated Water



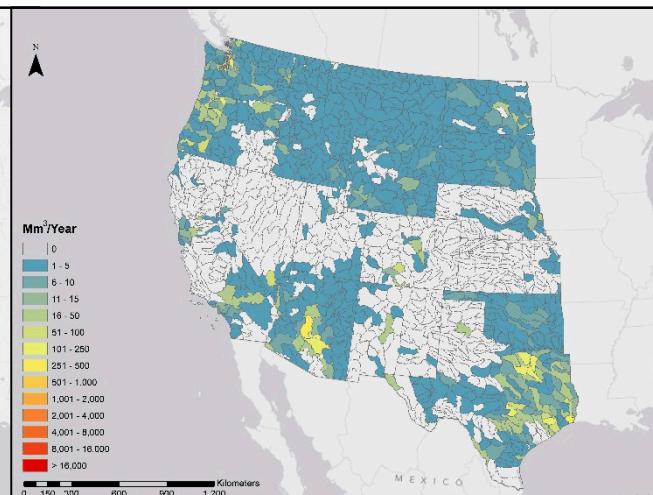
Municipal Wastewater



Brackish Groundwater

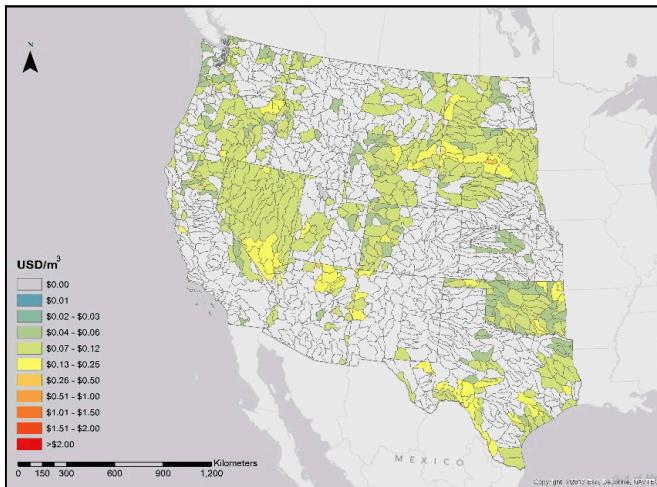


Consumptive Demand 2010-2030

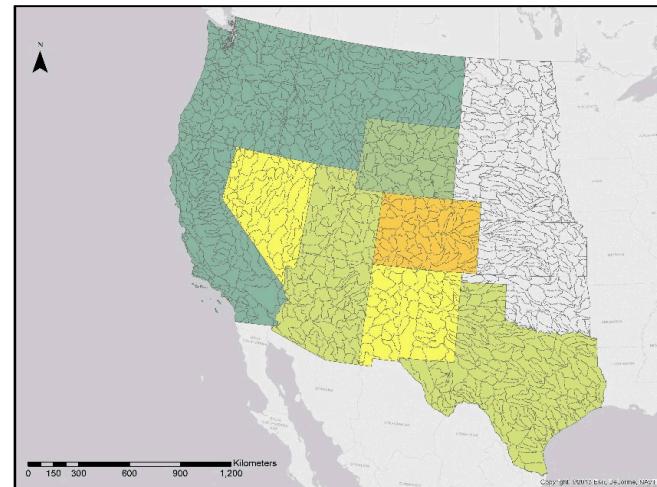


Relative Cost of Water

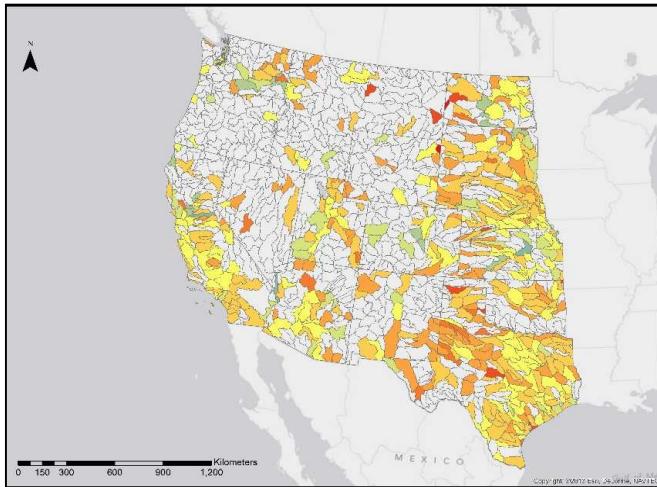
Unappropriated Groundwater



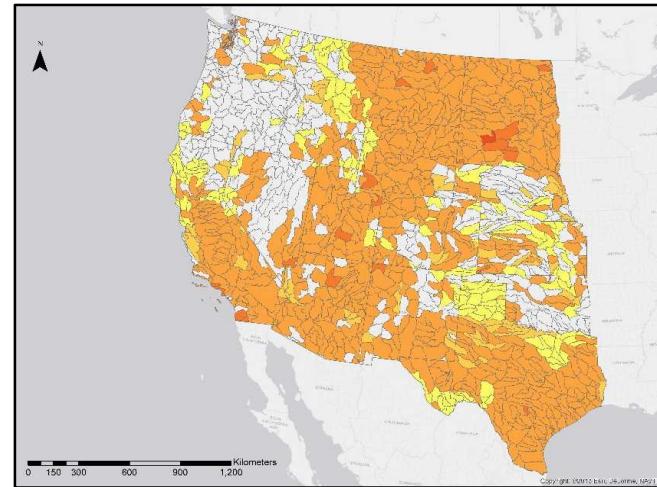
Appropriated Water



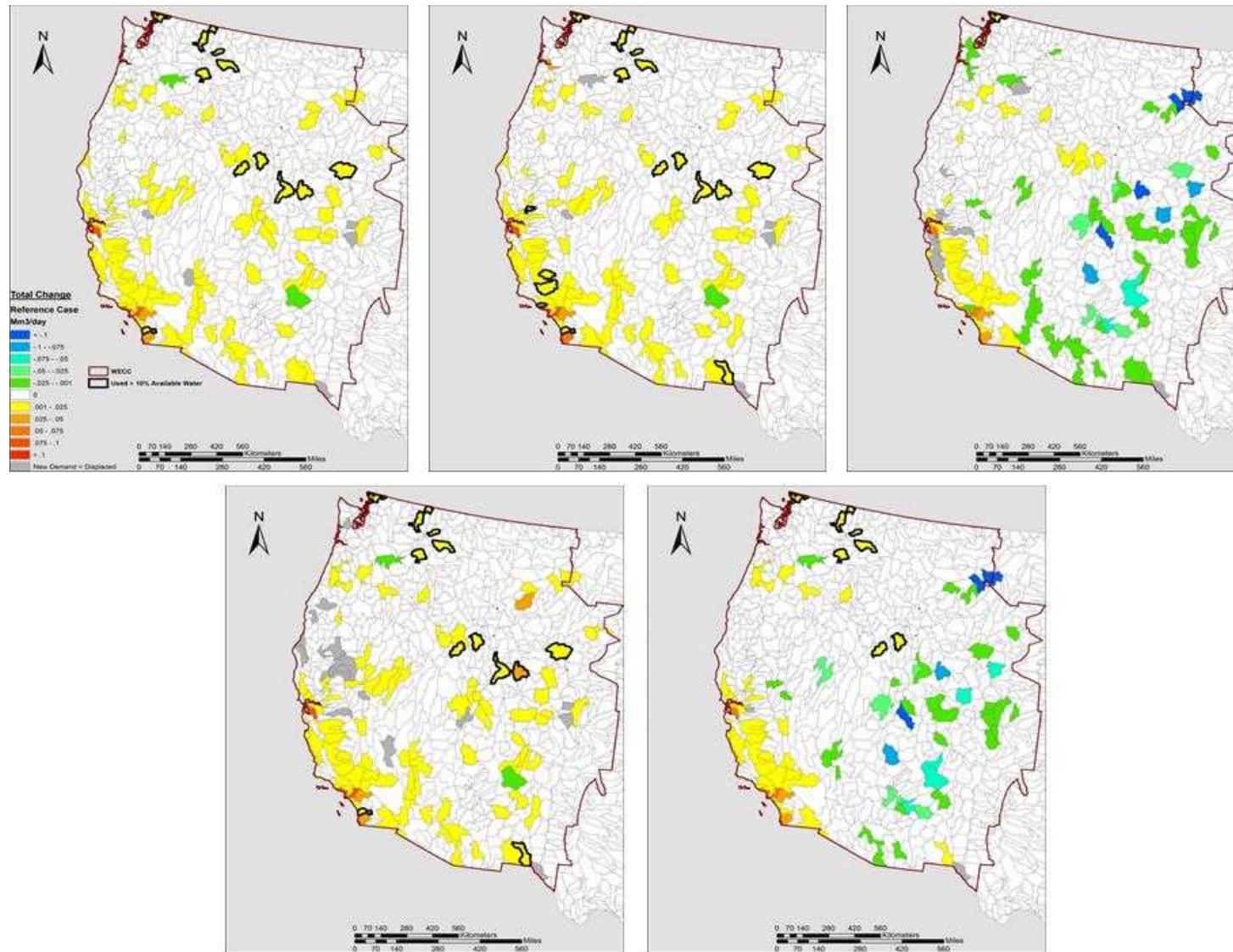
Municipal Wastewater



Brackish Groundwater



Change in Thermoelectric Water Use



Six Strategic Pillars to Address Water-Energy Nexus

- Optimize the energy efficiency of water management, treatment, distribution and end use system.



Drinking Water Systems



Appliance Standards



Wastewater Systems

Six Strategic Pillars to Address Water-Energy Nexus

- Increase safe and productive use of nontraditional water sources.



Wilbanks and Fernandez 2014

Use of Produced Water in Shale Gas/Oil Extraction

Six Strategic Pillars to Address Water-Energy Nexus

- Promote responsible energy operations with respect to water quality, ecosystem, and seismic impacts.
- Exploit productive synergies among water and energy systems

EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources

At the request of Congress, EPA is conducting a study to better understand any potential impacts of [hydraulic fracturing](#) on drinking water resources. The scope of the research includes the full lifespan of water in hydraulic fracturing. The [progress report](#) was released in December 2012 and a draft report is expected to be released for public comment and peer review in 2014.

[What is the hydraulic fracturing water cycle?](#)

How EPA Is Doing the Research

- Final study plan
- Research approaches
- Quality assurance and integrity
- Transparency
- Questions and answers about the study

How You Can Get Involved

- [Click here](#) to learn more about technical stakeholder engagement and how you can participate in public meetings.

Publications

- Published Scientific Papers
- Progress report 2012
- Final study plan
- Fact sheets
- Other publications
- Archive

Peer Review

- Peer review activities
- EPA Science Advisory Board (SAB)

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- Project data available at:

http://energy.sandia.gov/?page_id=1741

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Energy and Climate

RENEWABLE SYSTEMS CLIMATE/ENVIRONMENT ENERGY INFRASTRUCTURE ENERGY RESEARCH ABOUT EC

Energy and Climate • Climate/Environment • Water Security Program • Energy and Water in the Western and Texas Interconnects

Energy and Water in the Western and Texas Interconnects

Background Objectives Tasks Benefits/Outcomes Collaborators Links Documents Data Portal

Water Scarcity Impacts Energy Production

In the United States the energy sector accounts for approximately 41% of daily fresh water withdrawals and 49% of total overall daily water withdrawals for the following energy-related uses:

- Hydroelectric power generation
- Thermoelectric power plant cooling and air emissions control
- Energy-resource extraction, refining, and processing



The Energy Information Administration projects the U.S. population will grow by **70 million people** between 2005 and 2030, increasing electric power demand by **50 percent** and transportation fuel demand by **30 percent**. This will require more water. Unfortunately, this growth in water demand is occurring at a time when the nation's fresh water supplies are seeing increasing stress from:

- Limitations of surface-water storage capacity
- Increasing depletion and degradation of ground water supplies
- Increasing demands for the use of surface water for in-stream ecological and environmental uses
- Uncertainty about the impact of climate variability on future water fresh surface and ground water resources



Tagged with: Air Emissions Control • ARRA • Climate • Climate Variability • Energy • Energy Resource Extraction • Energy Water Nexus • Environmental Vulnerabilities • ERCOT • Ground Water Supplies • Hydroelectric Power Generation • Office of Electricity • Recovery Act • SAND2013-148W • Thermoelectric Consumptive Use • Thermoelectric Power • Water • Water Availability • Water Demand • water scarcity • Water Valuation • Watershed Model • Western and Texas Interconnects • Western United States

Last Updated: August 7, 2014

WATER SECURITY PROGRAM

- Water Infrastructure Security
- Water, Energy, and Natural Resource Systems
- Energy and Water in the Western and Texas Interconnects
 - Energy and Water Data Portal
 - Electric Power Generation and Water Use Data
 - Water Availability, Cost, and Use

ENERGY-WATER DATA PORTAL



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