SAND2015-1323PE

Exceptional service in the national interest

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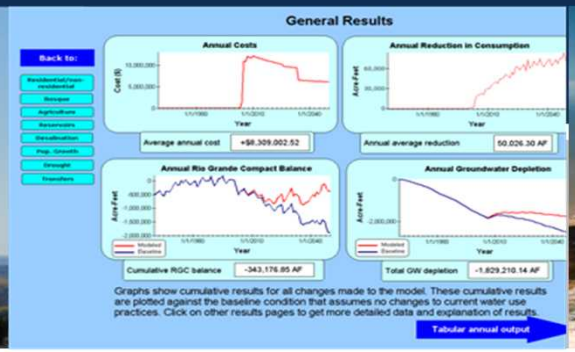

Energy-Water Nexus Past, Present and Future

Vincent Tidwell

Sandia National Laboratories

State of America's Water: Present and Future

February 10, 2015

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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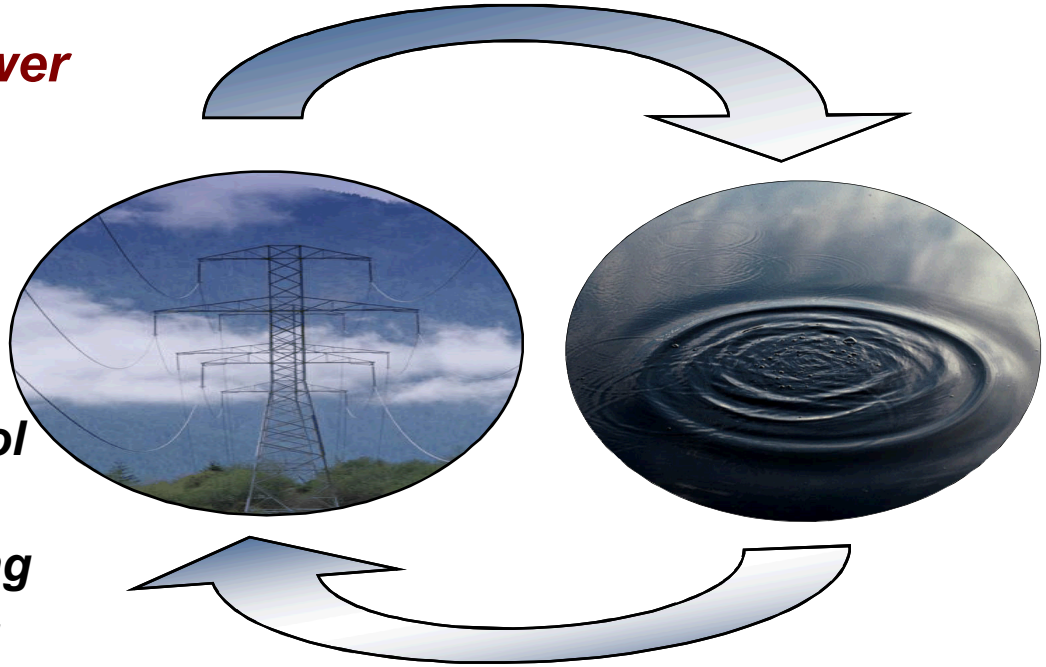
Energy-Water Nexus

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-Water Nexus Past

400 Years of Energy Use in the U.S.

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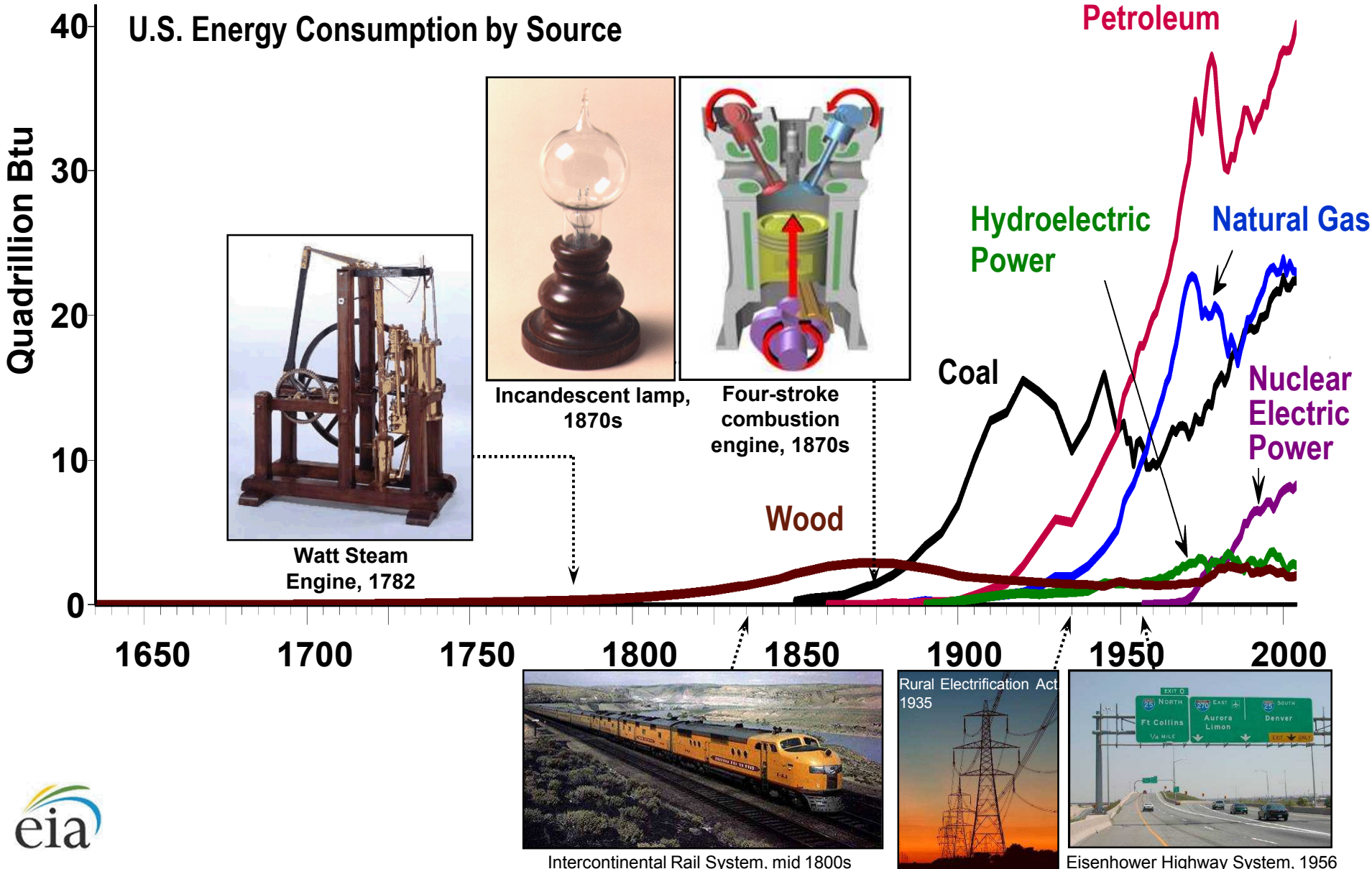

eia

High Fossil Fuel Use

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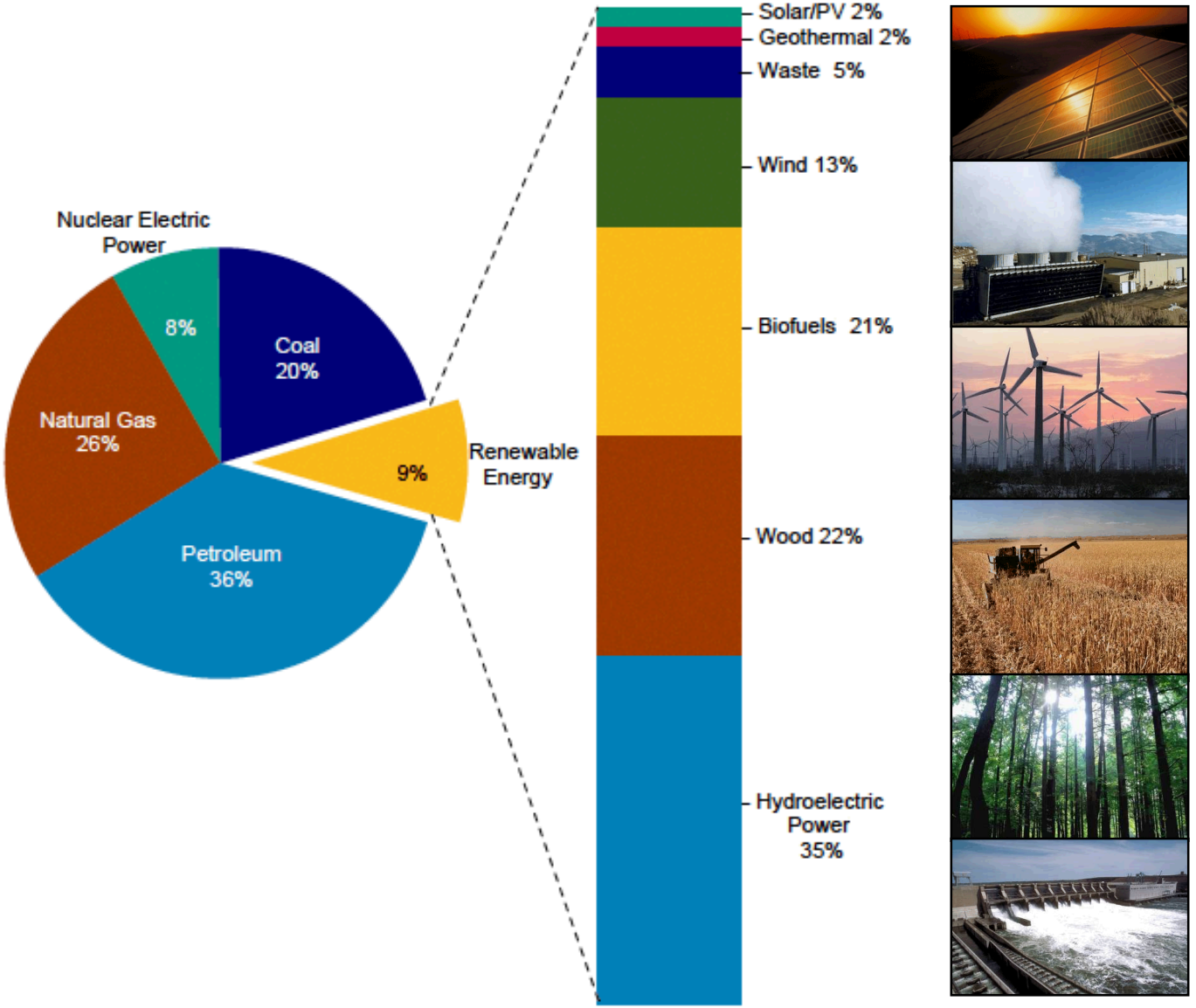
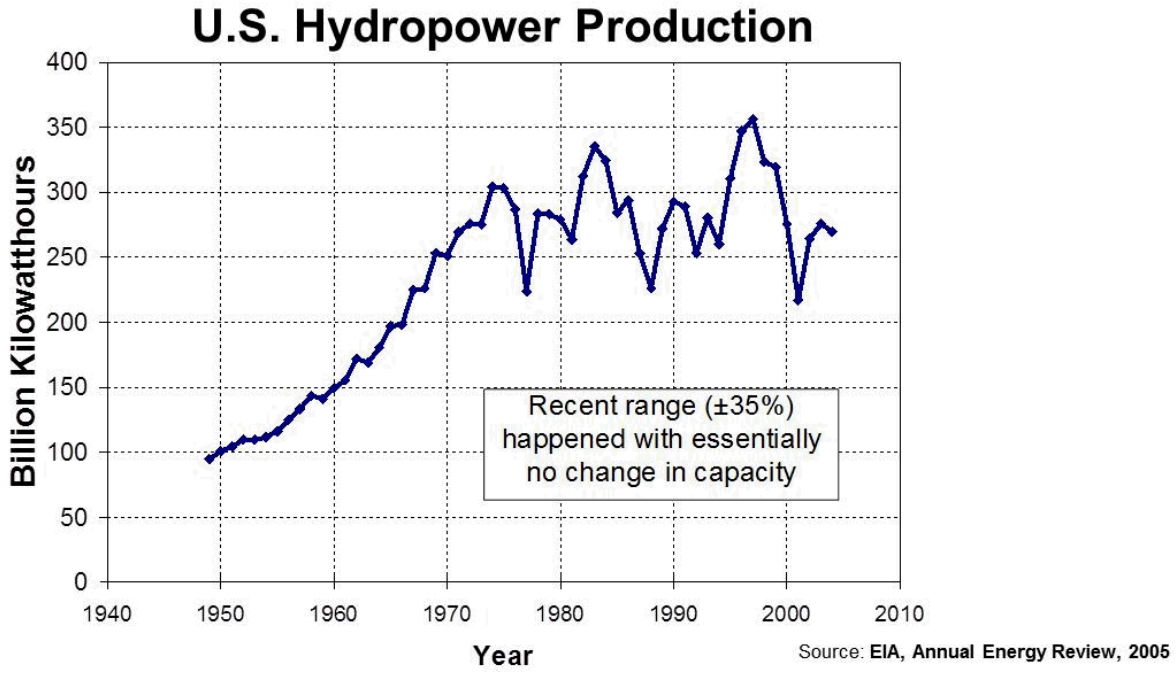


eia

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

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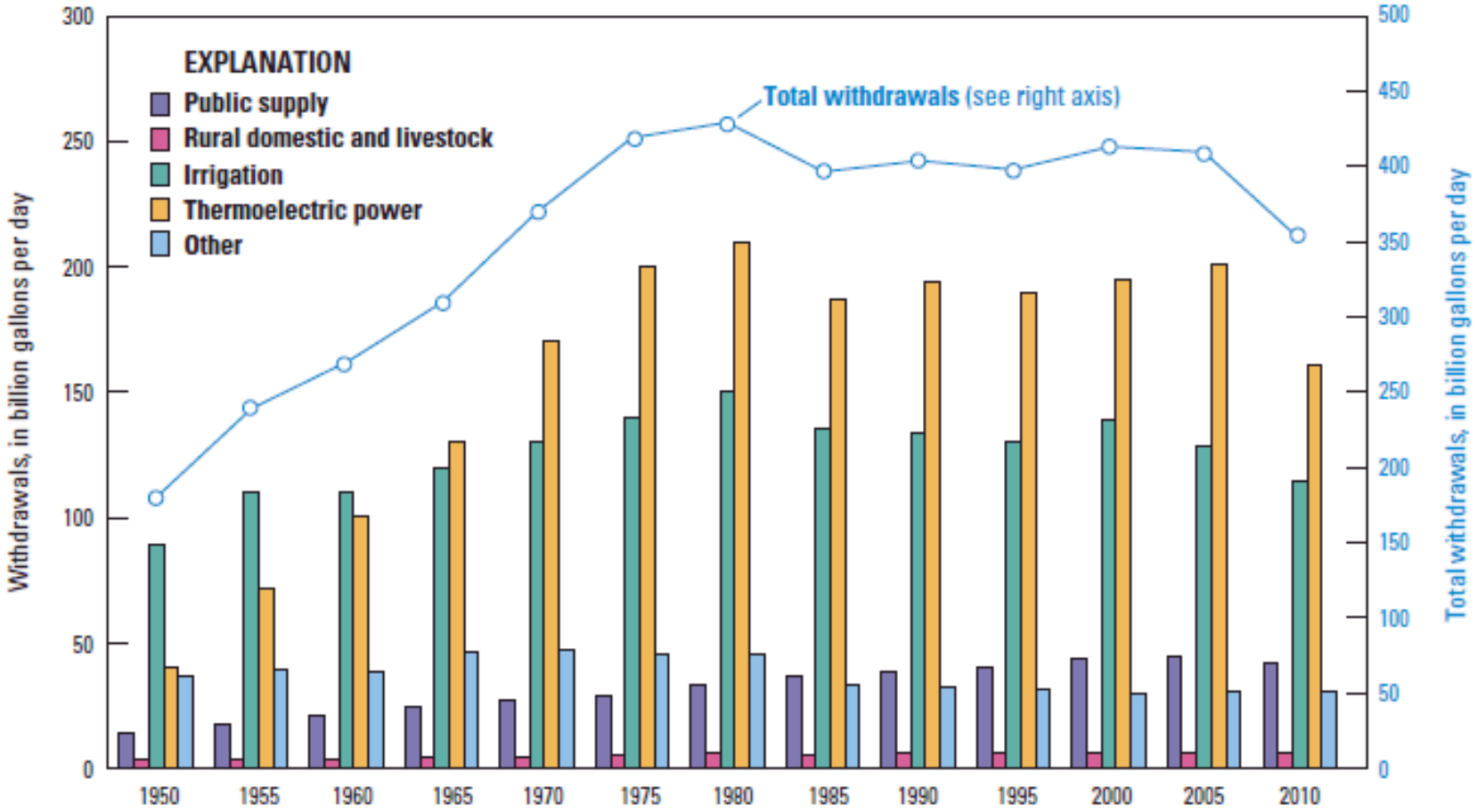
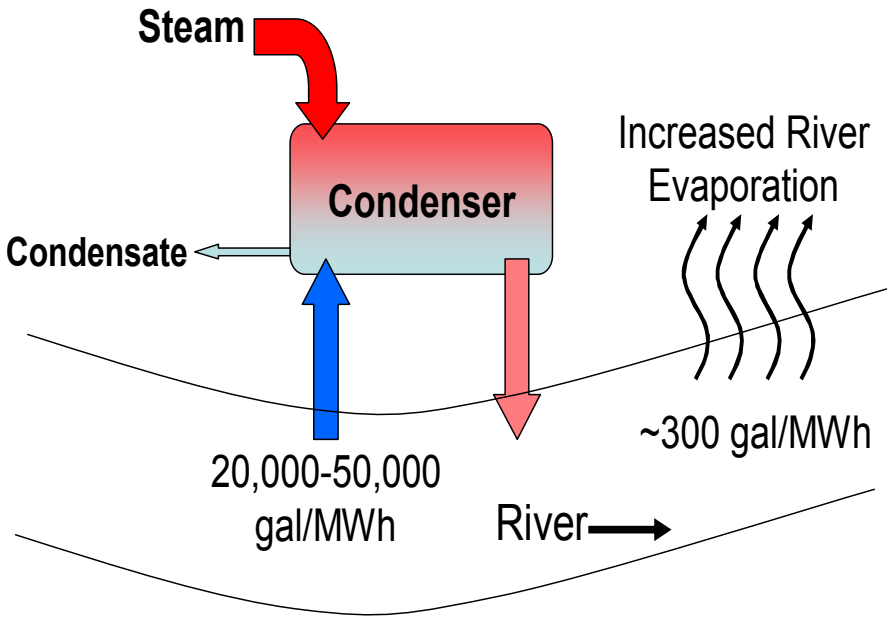
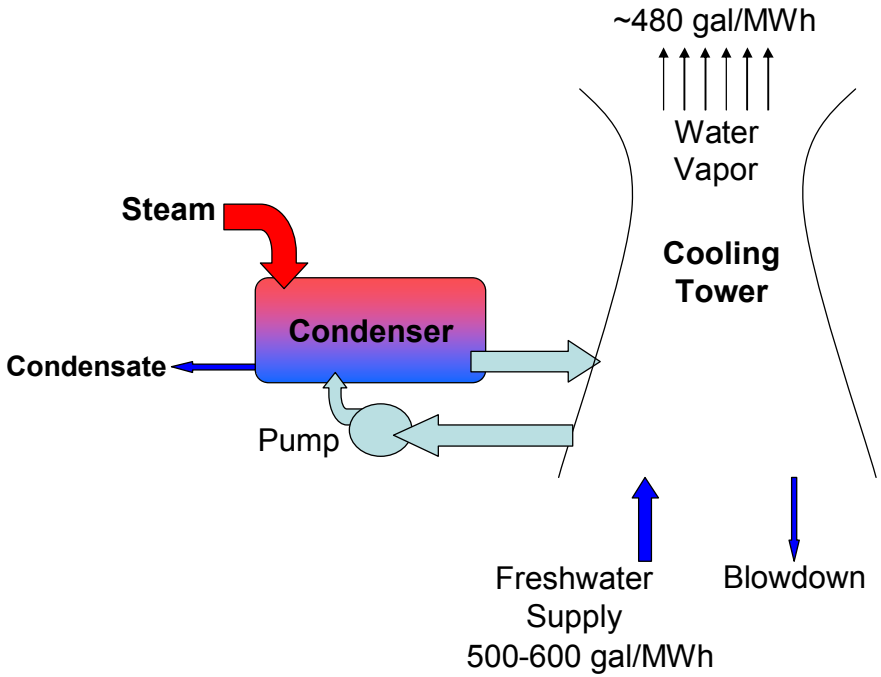


Source: USGS 2014

Power Plant Cooling Options



Open-loop “once-through” cooling cycle



Closed-loop cooling cycle

Source: EPRI 2002

Energy-Water Nexus

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"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."

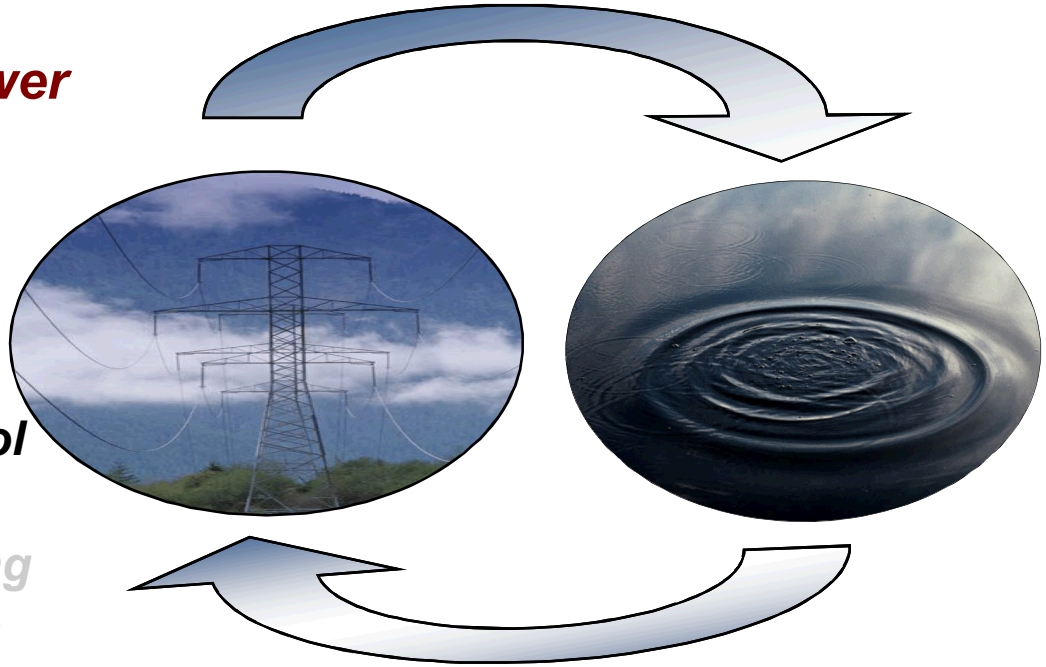
(DOE, 1980)

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, H_2,biofuels)*



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

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

Water for Thermoelectric Power Generation

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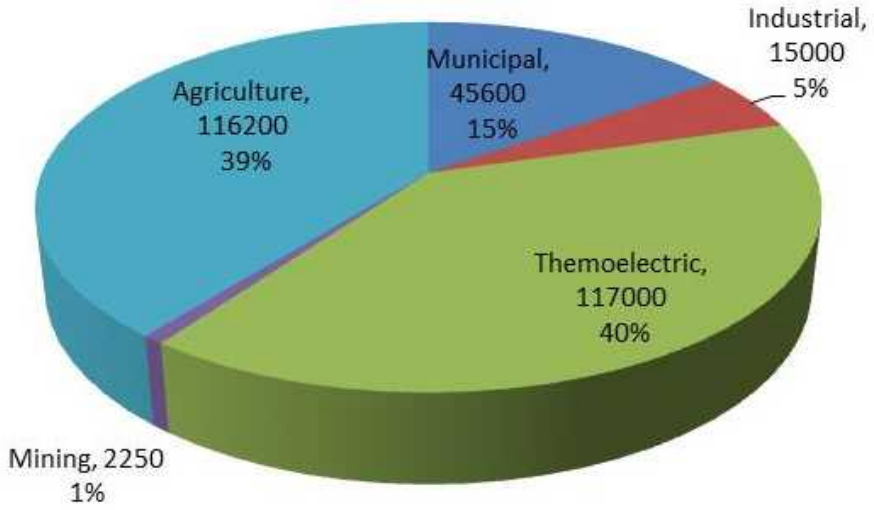
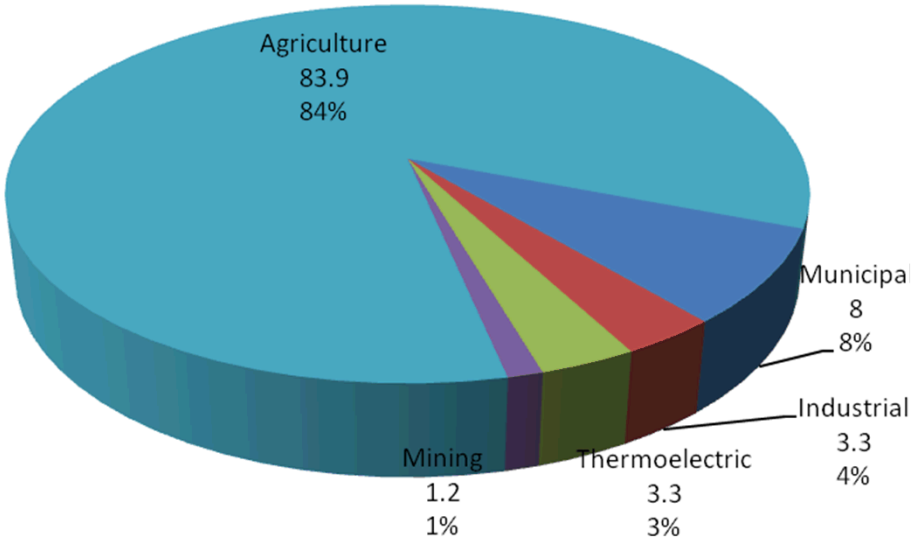
Water Withdrawal (BGD) 2010

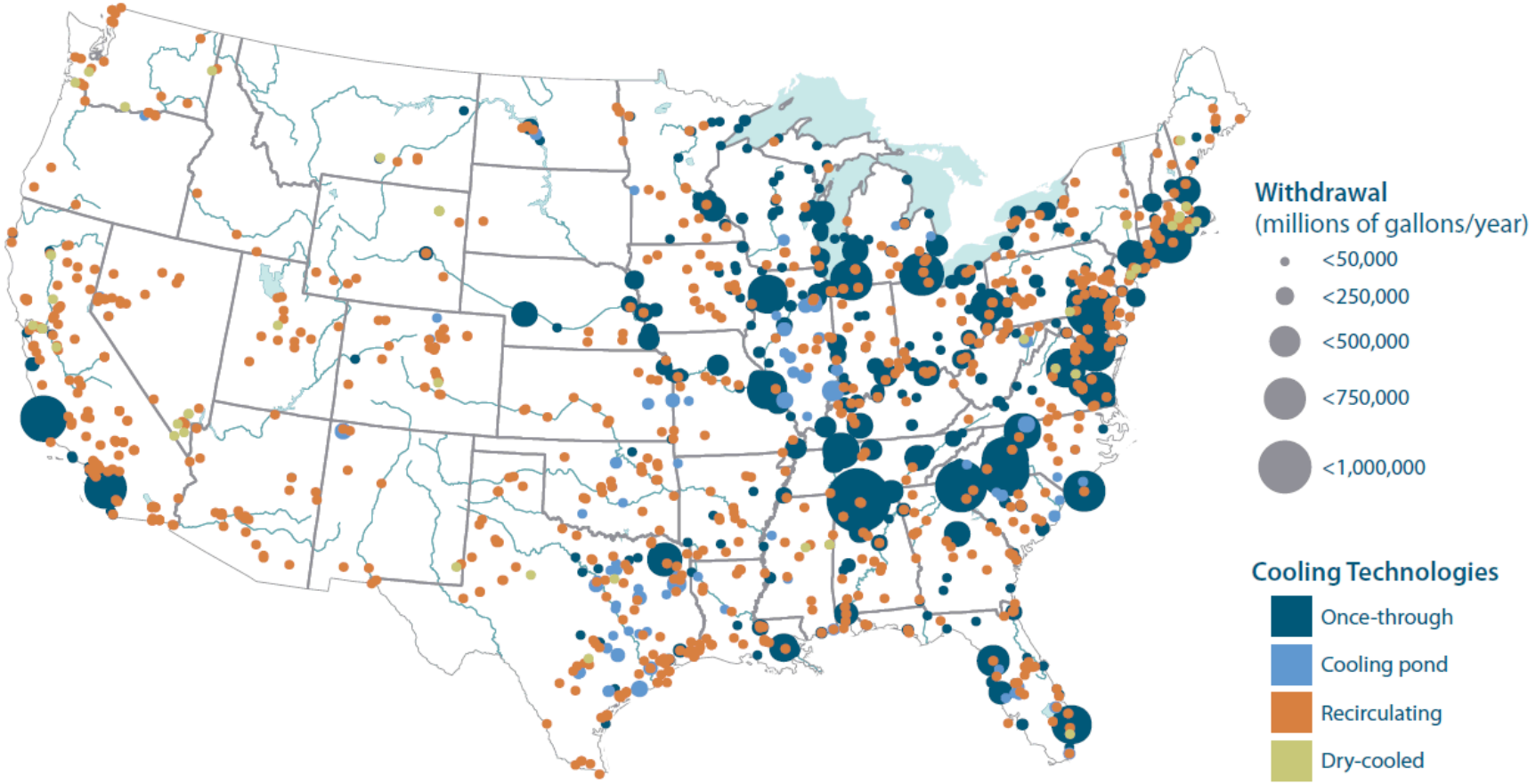


Water Consumption (BGD) 1995



Source: USGS 1995, 2014

Power Plant Water Withdrawals: 2008



Source: UCS 2011

Place Matters: Water Consumption

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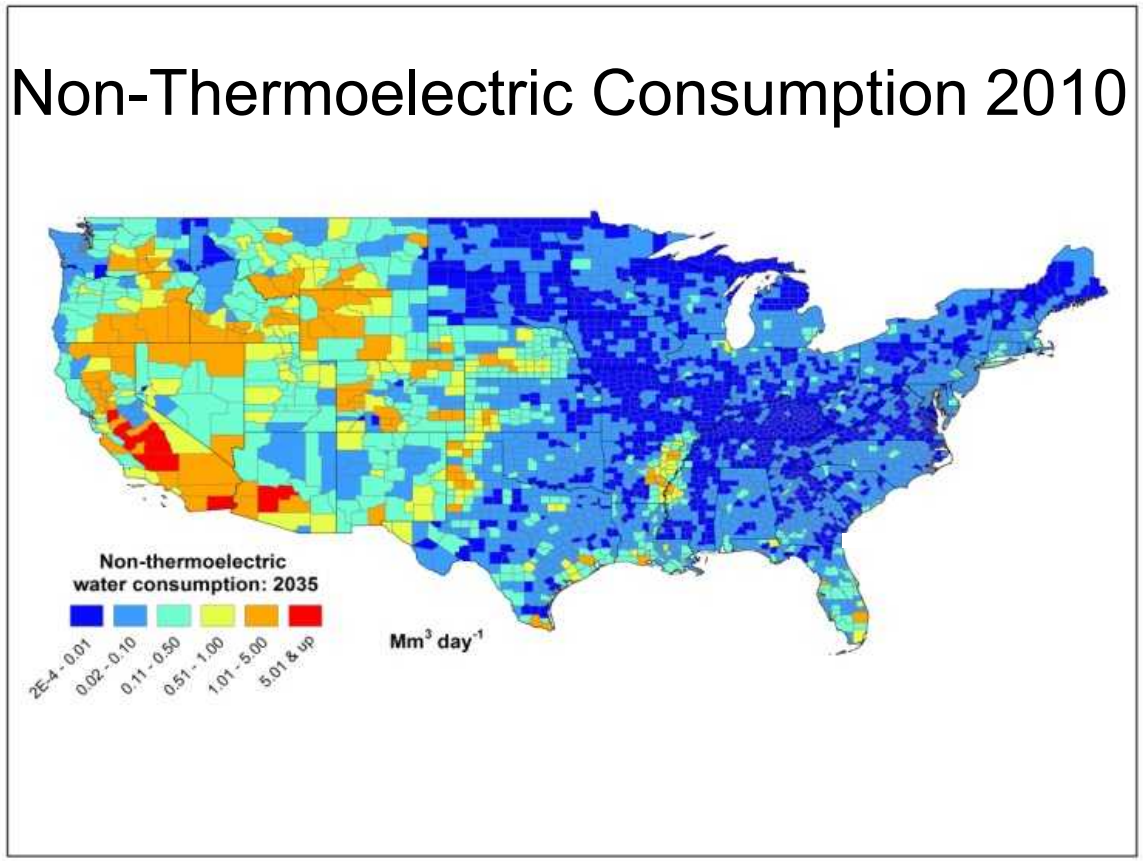
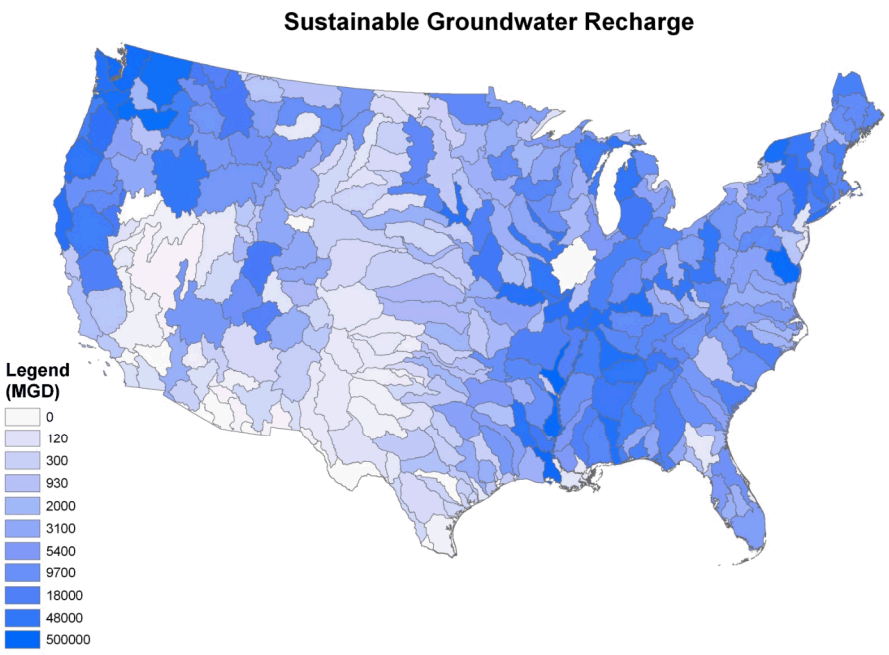
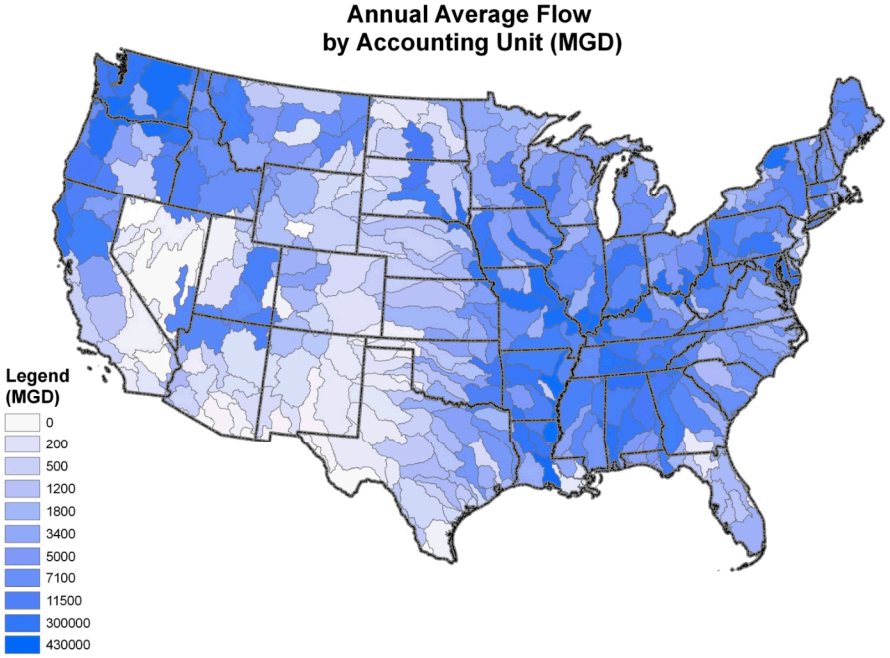


Place Matters: Water Supply

Sandia National Laboratories





Limited Water Basins

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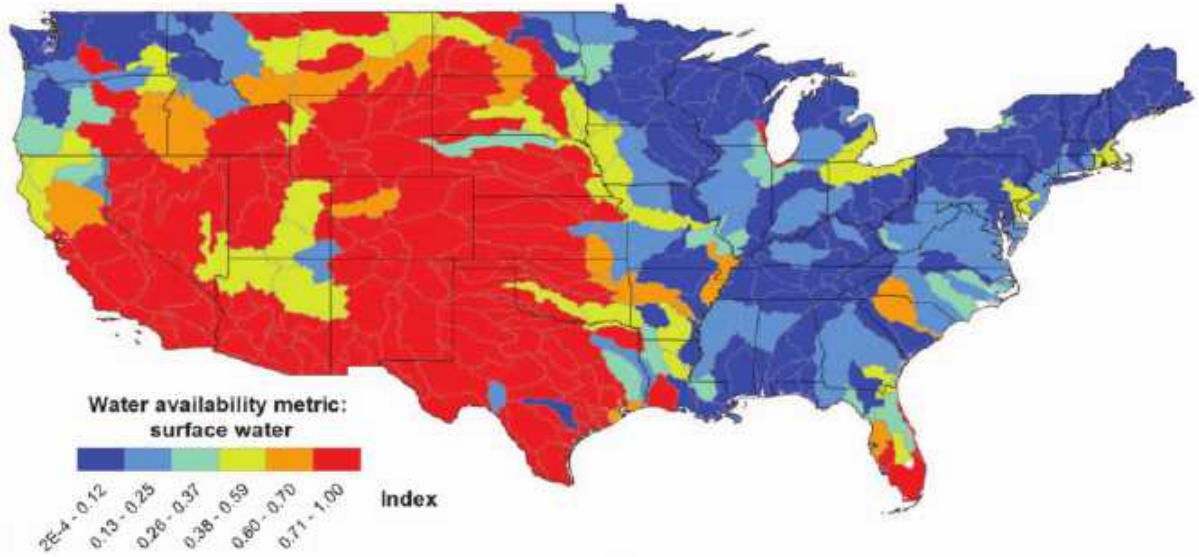
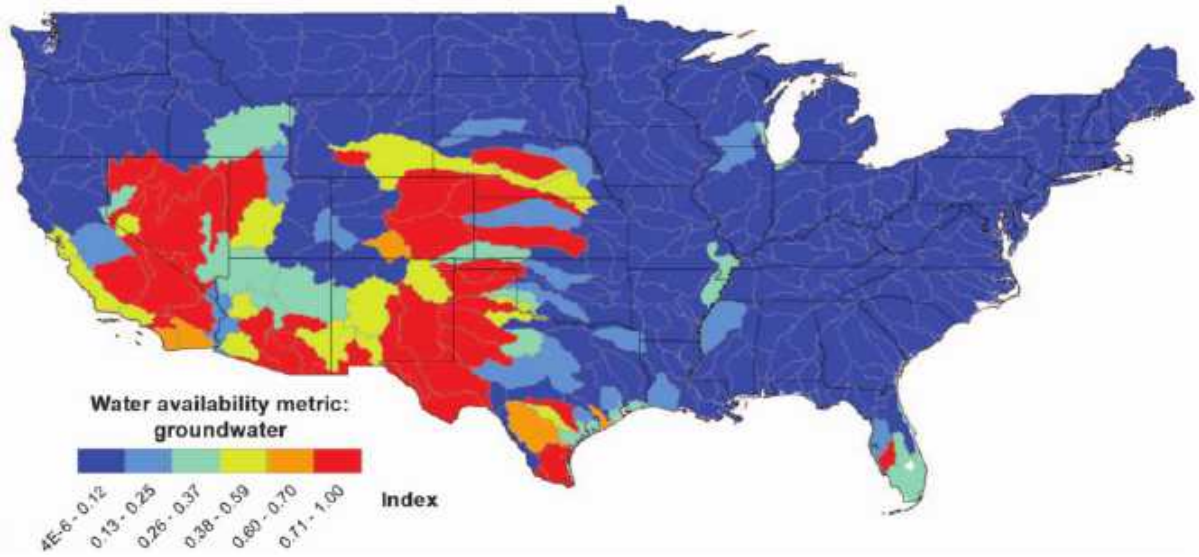
Limited Surface Water



Limited Groundwater



Energy-Water Nexus

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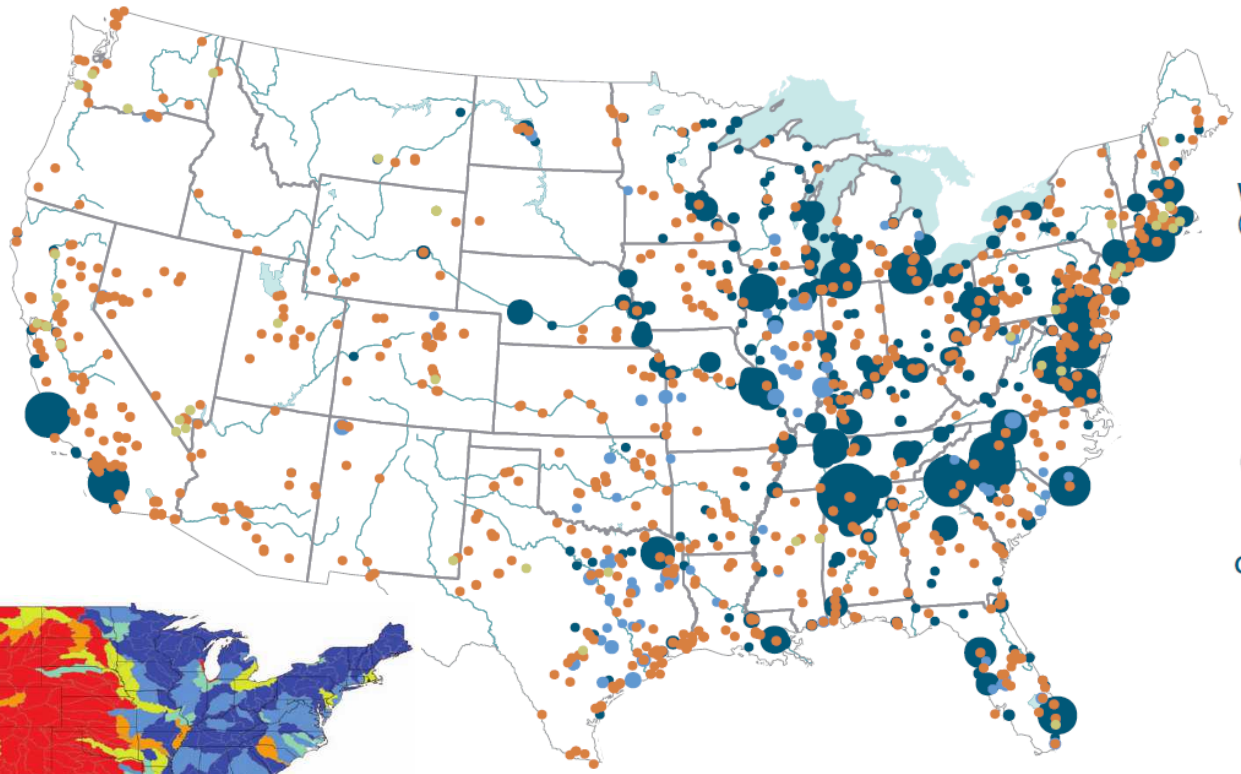
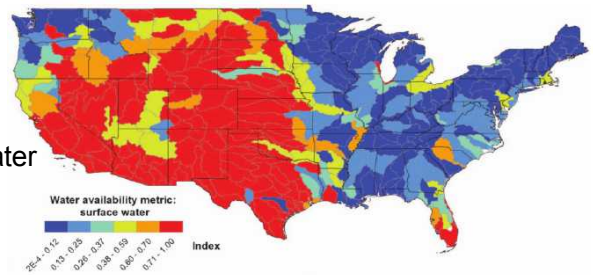
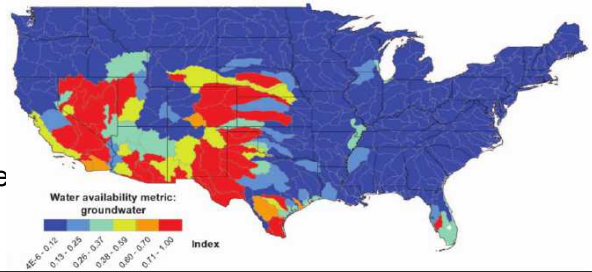


Source: UCS 2011

Surface Water Availability



Groundwate Availability



Energy-Water Nexus

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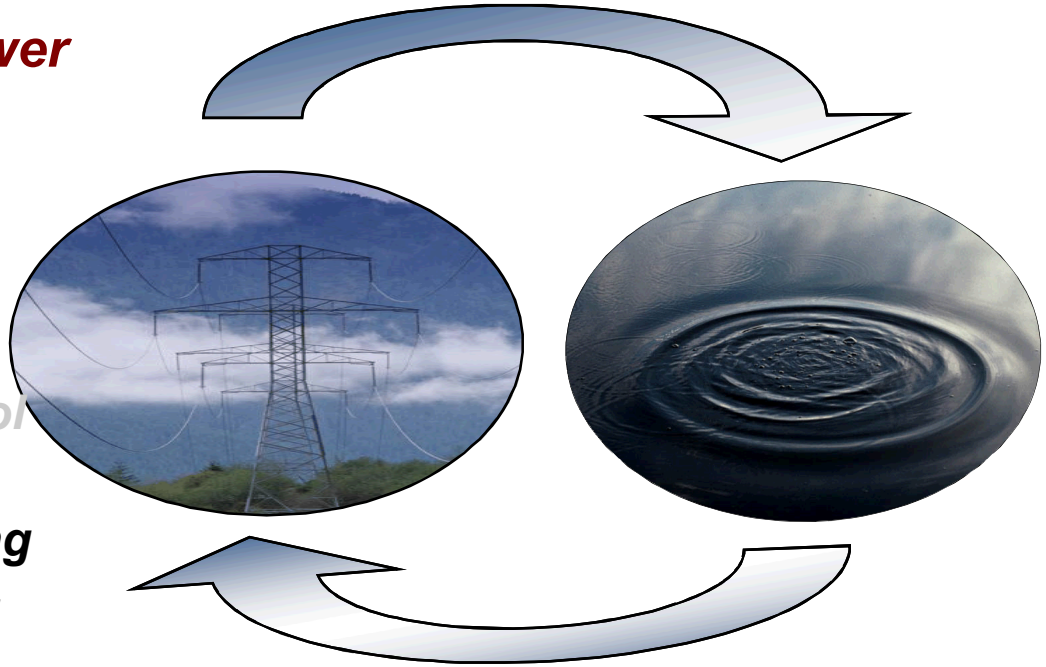

Water production, processing, distribution, and end-use requires energy

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- *Treatment*
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- *Use Conditioning*

Water for Mining and Fuel Processing

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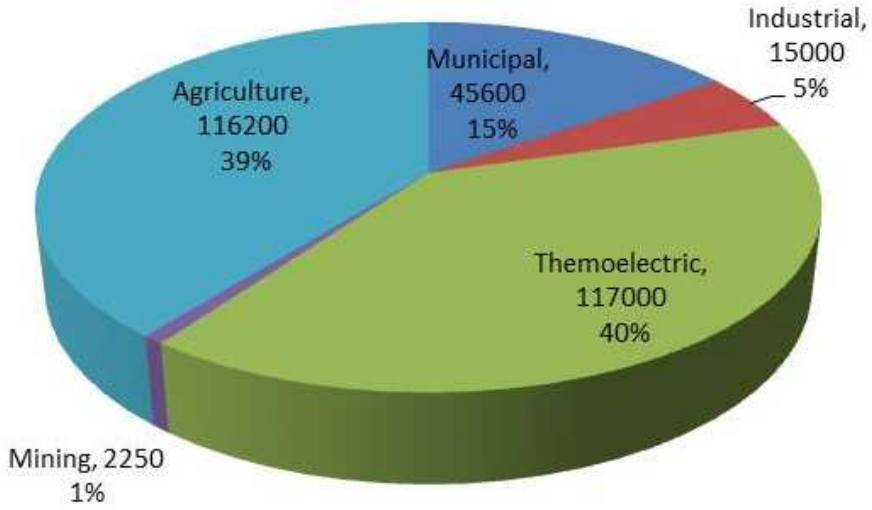
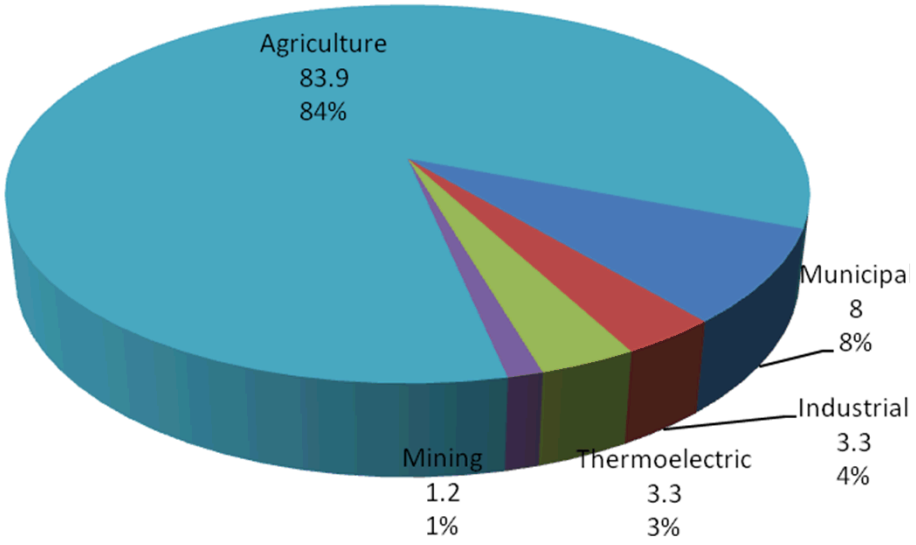
Water Withdrawal (BGD) 2010



Estimated at ~2.6 BGD consumed in mining and fuel processing

Water Consumption (BGD) 1995



Source: USGS 1995, 2014

Gas and Oil Shale Development

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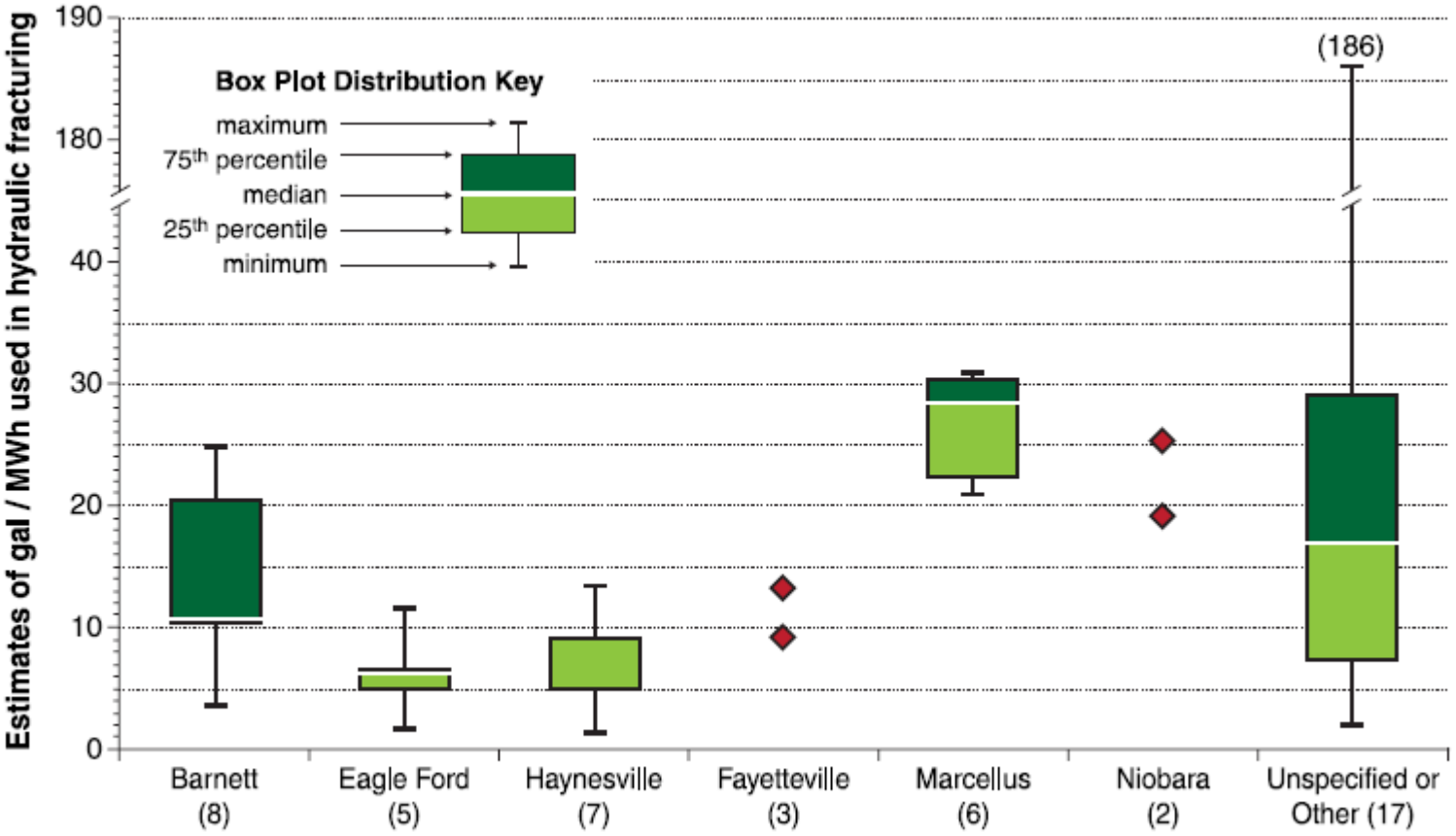
Water Use in Hydraulic Fracturing

Sandia National Laboratories



Source: Meldrum et al. 2013

Water for Fuel Extraction

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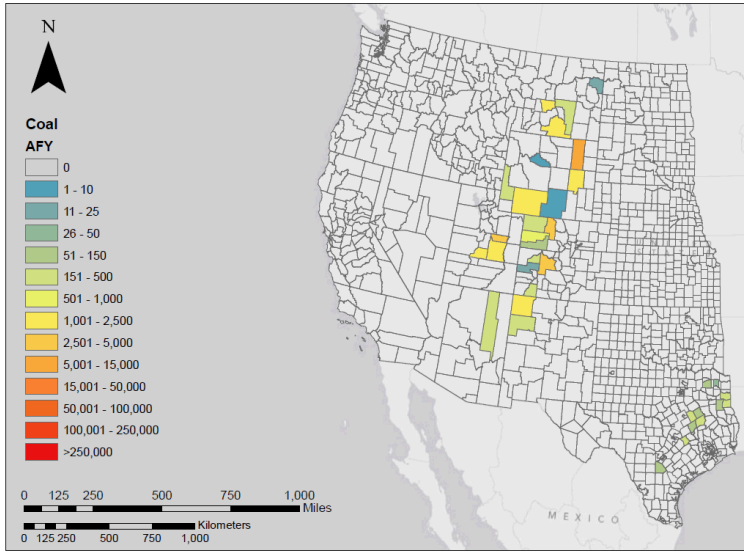
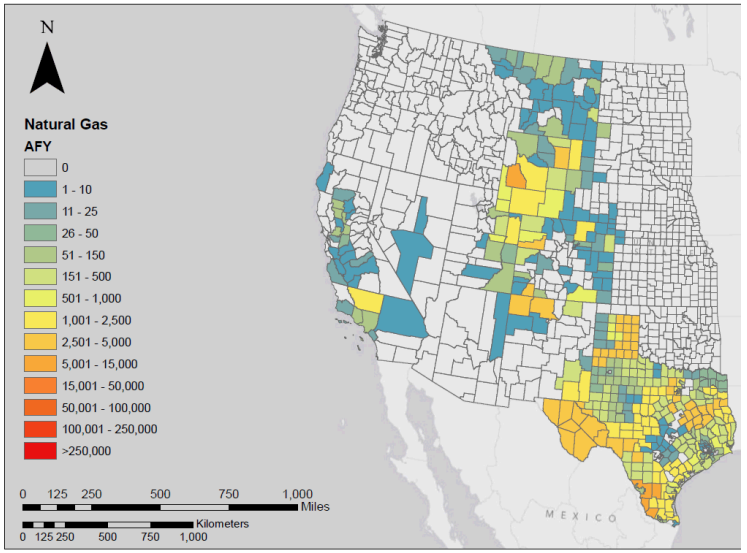
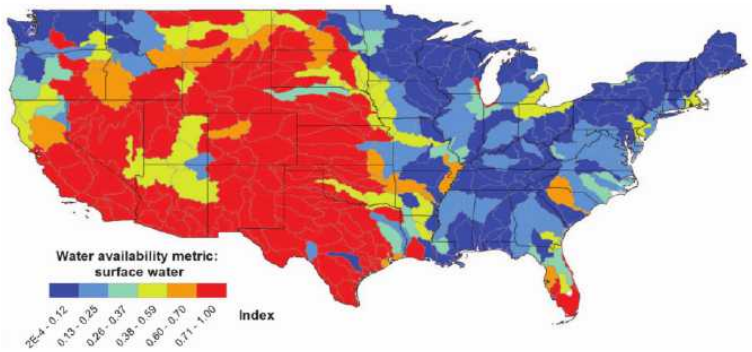
Water Use COAL



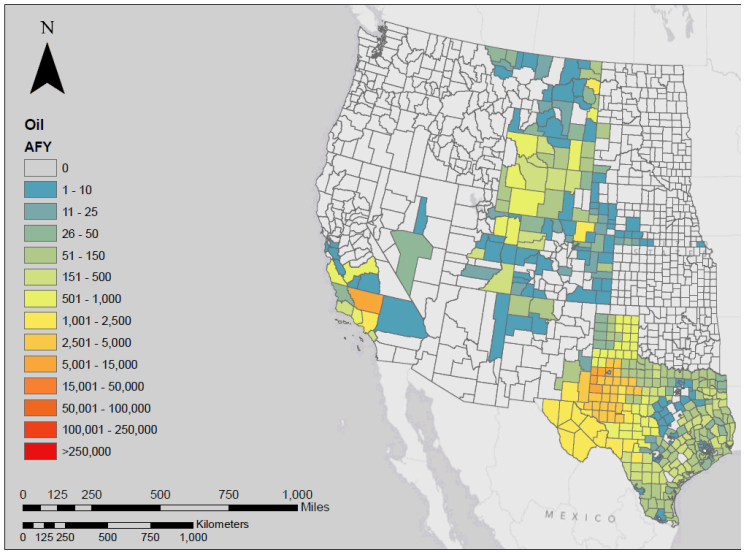
Water Use NATURAL GAS



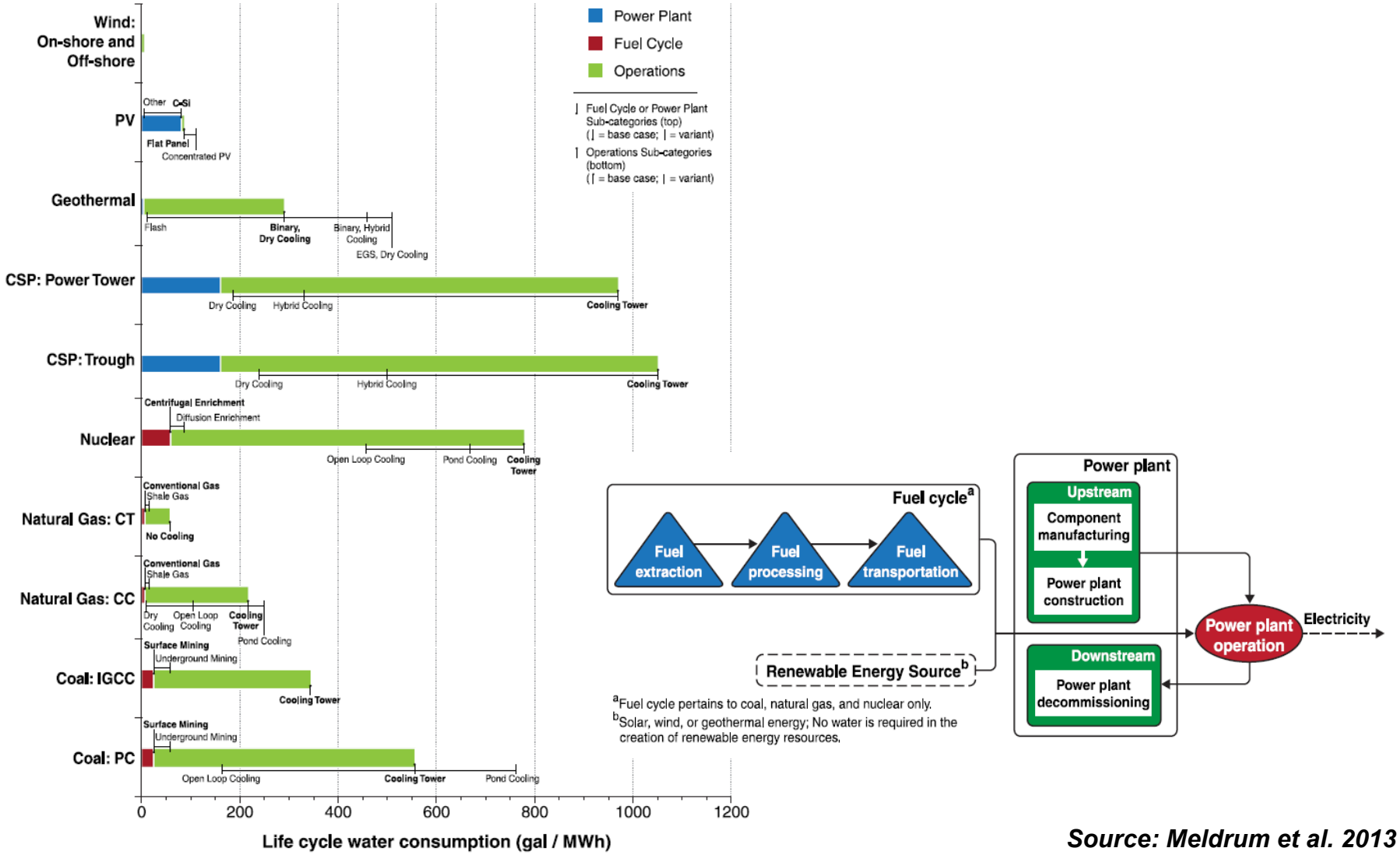
Limited Surface Water



Water Use OIL



Life Cycle Water Use



Source: Meldrum et al. 2013

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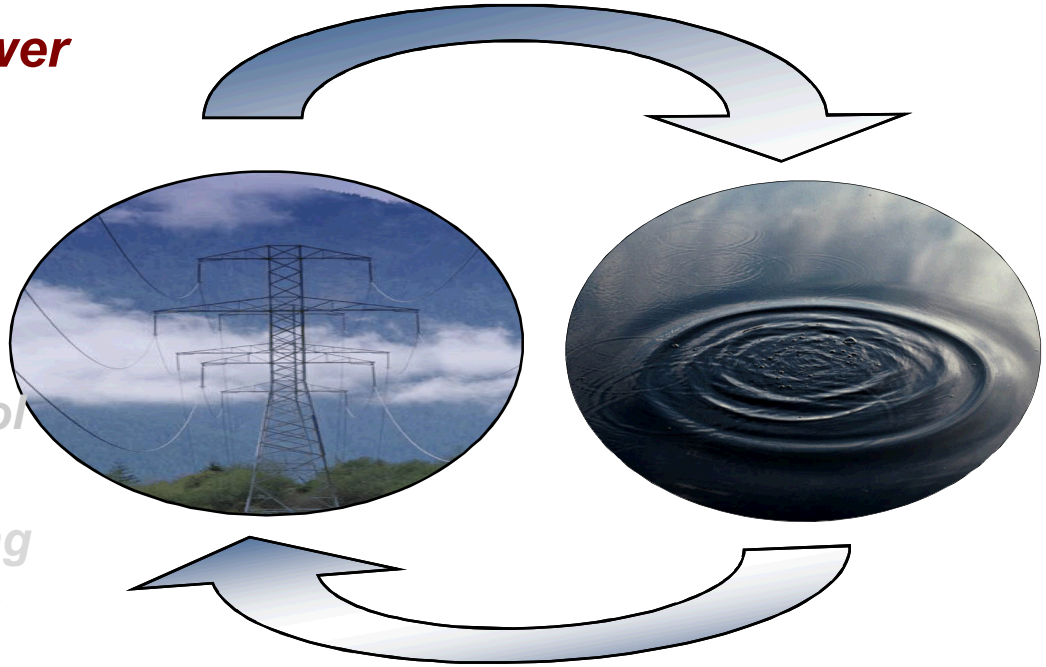

Water production, processing, distribution, and end-use requires energy

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

Energy for Water

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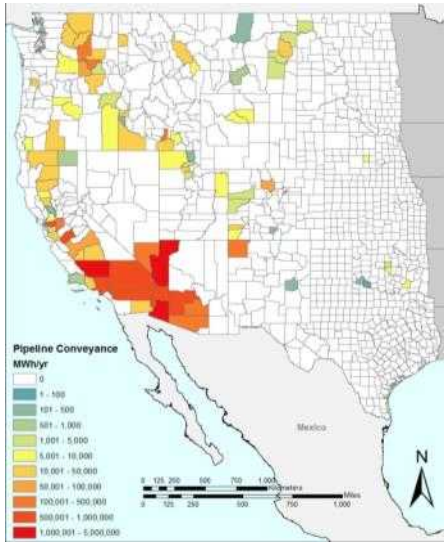
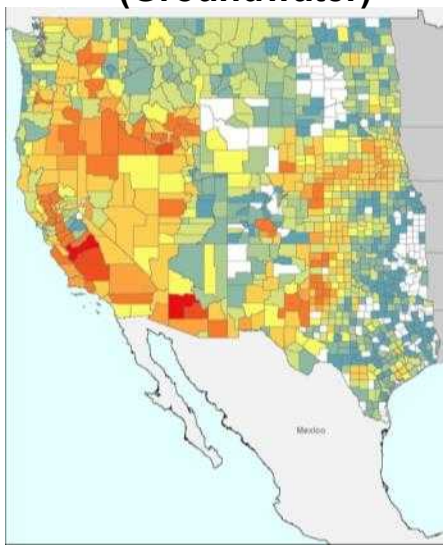
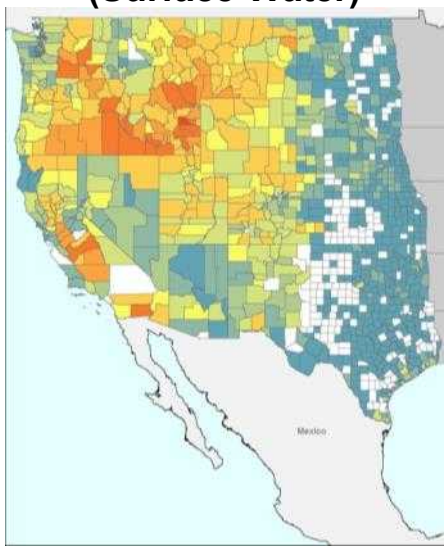
Large-Scale Conveyance



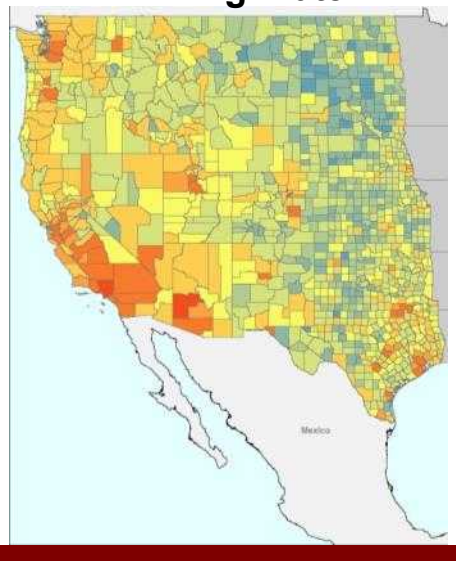
Agricultural Pumping (Groundwater)



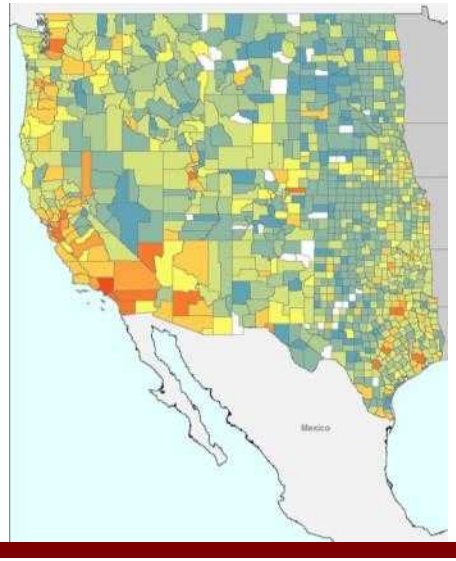
Agricultural Pumping (Surface Water)



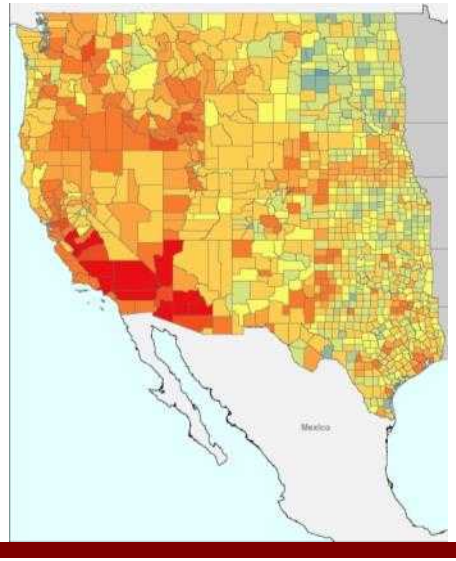
Drinking Water



Municipal Wastewater



All Water Services



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

Source: Tidwell et al. 2014

Energy-Water Nexus

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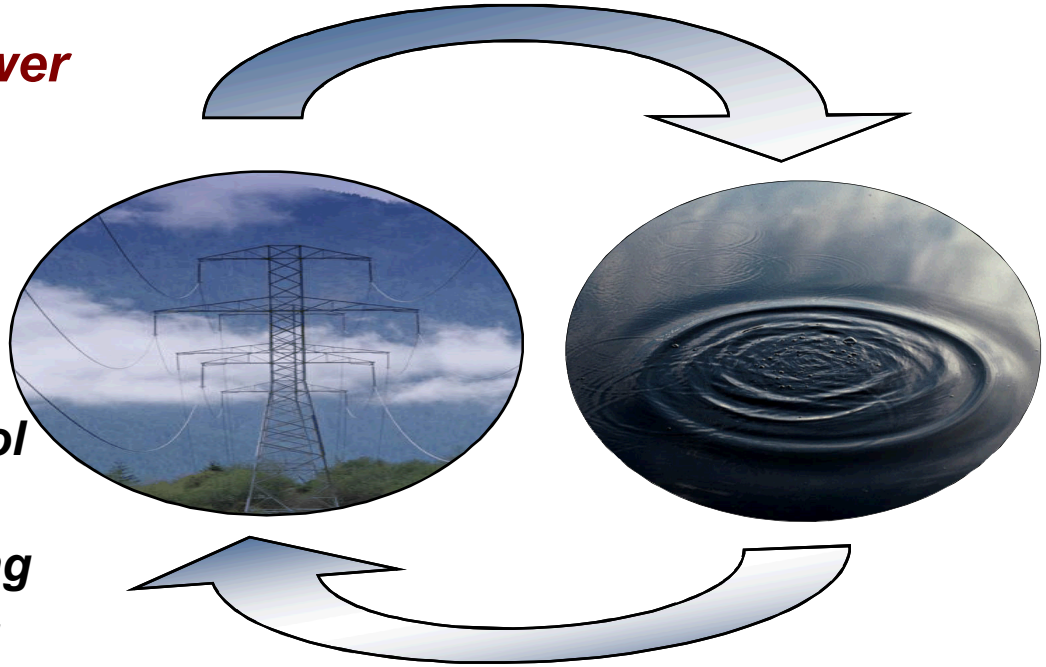
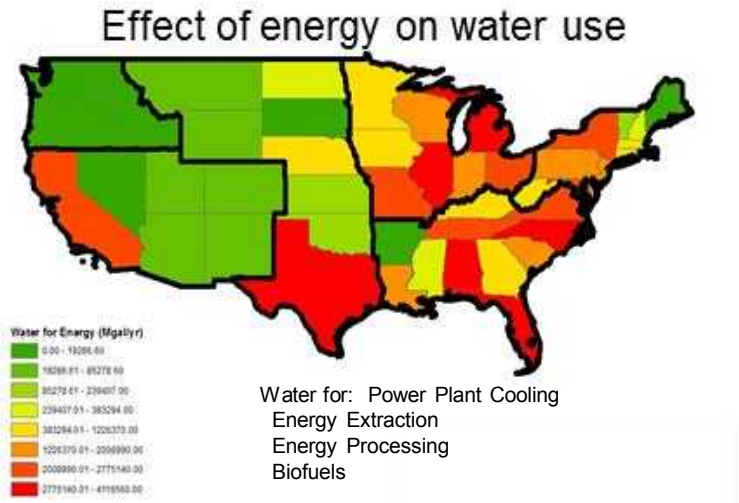
- ***Energy Minerals Extraction/Mining***
- ***Fuel Processing (fossil fuels, H_2,biofuels)***



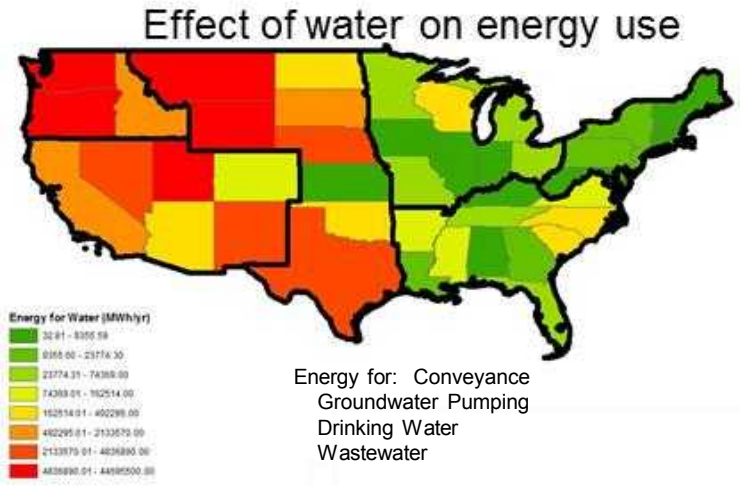
Water production, processing, distribution, and end-use requires energy

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

Regional Challenge



Water for: Power Plant Cooling
Energy Extraction
Energy Processing
Biofuels



Energy for: Conveyance
Groundwater Pumping
Drinking Water
Wastewater

Regional Challenges

West Coast: Seawater desalination and interbasin transfers

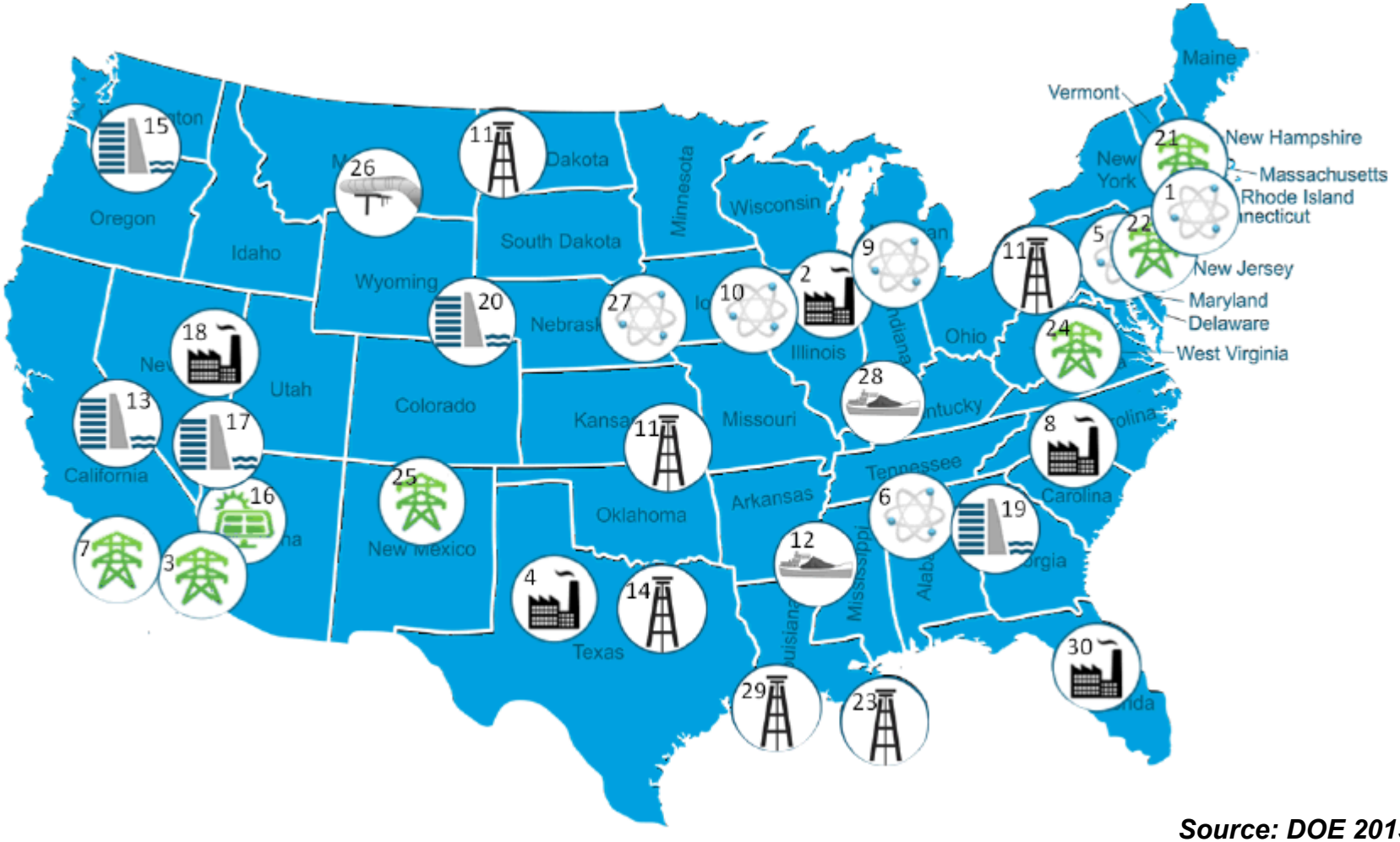
Rocky Mountain/Southwest: Brackish desalination, alternative water resources, unconventional oil & gas, thermoelectric cooling

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

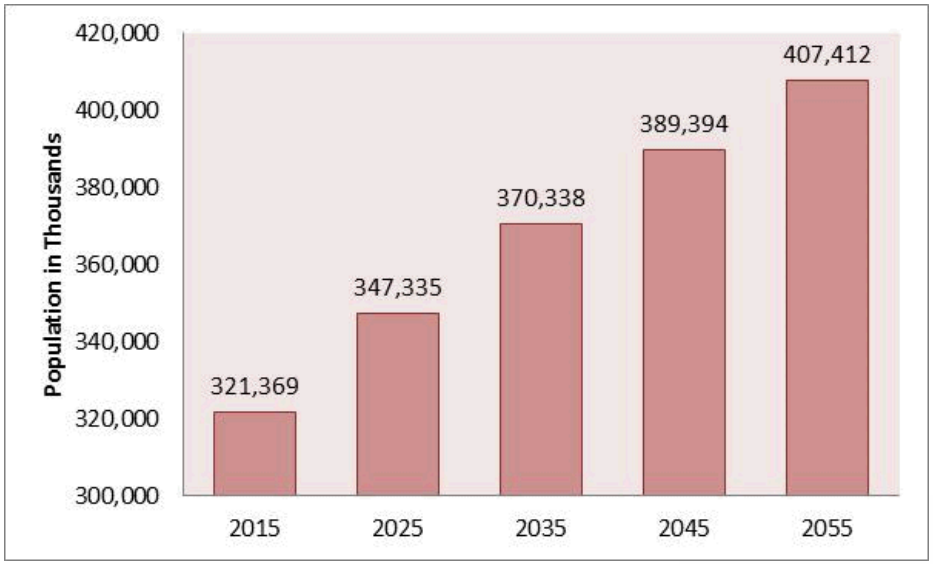


Source: DOE 2013

Energy-Water Nexus Future

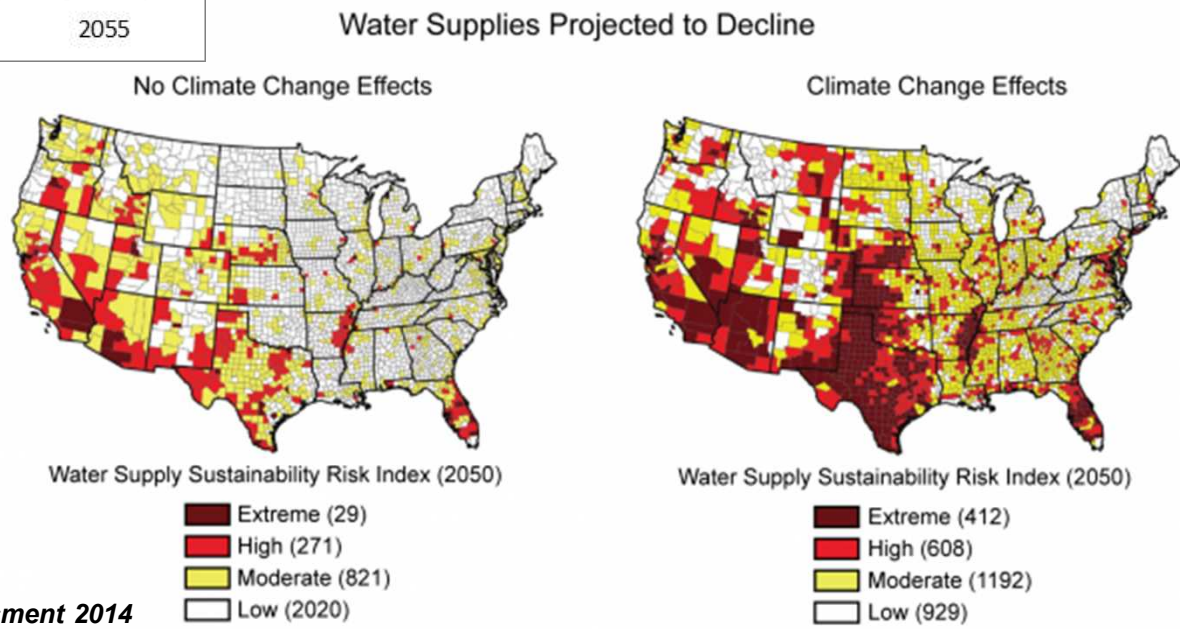
Growth and Change

Sandia National Laboratories



Source: U.S. Census Bureau 2014

Growing Population & Climate Change

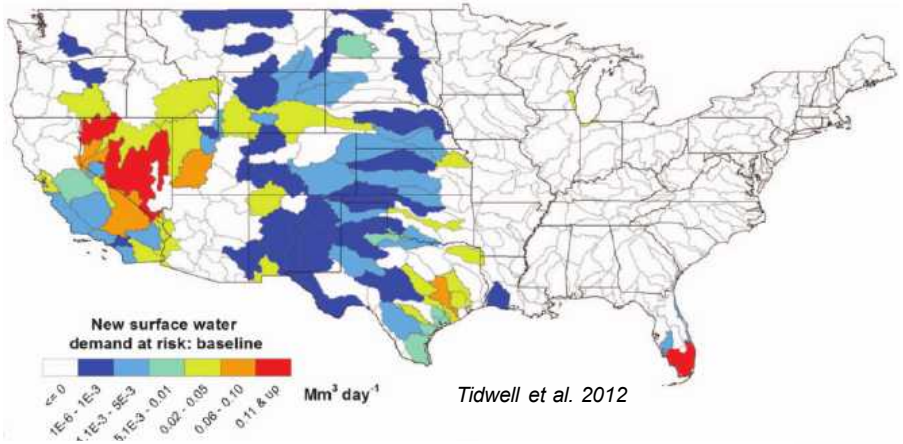


Source: National Climate Assessment 2014

Growing Demands

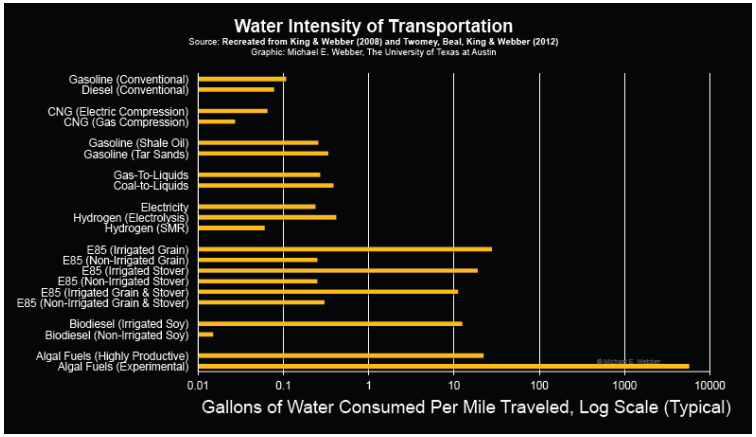
Sandia National Laboratories

Thermoelectric Demands for Water



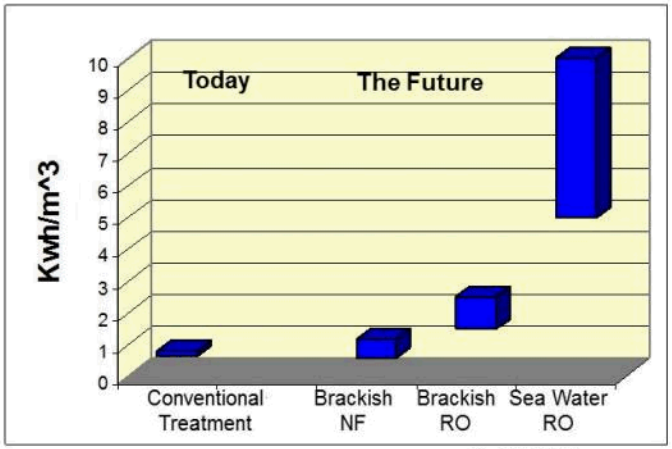
Tidwell et al. 2012

Liquid Fuels Demand for Water



Shale Gas/Oil Demands for Water

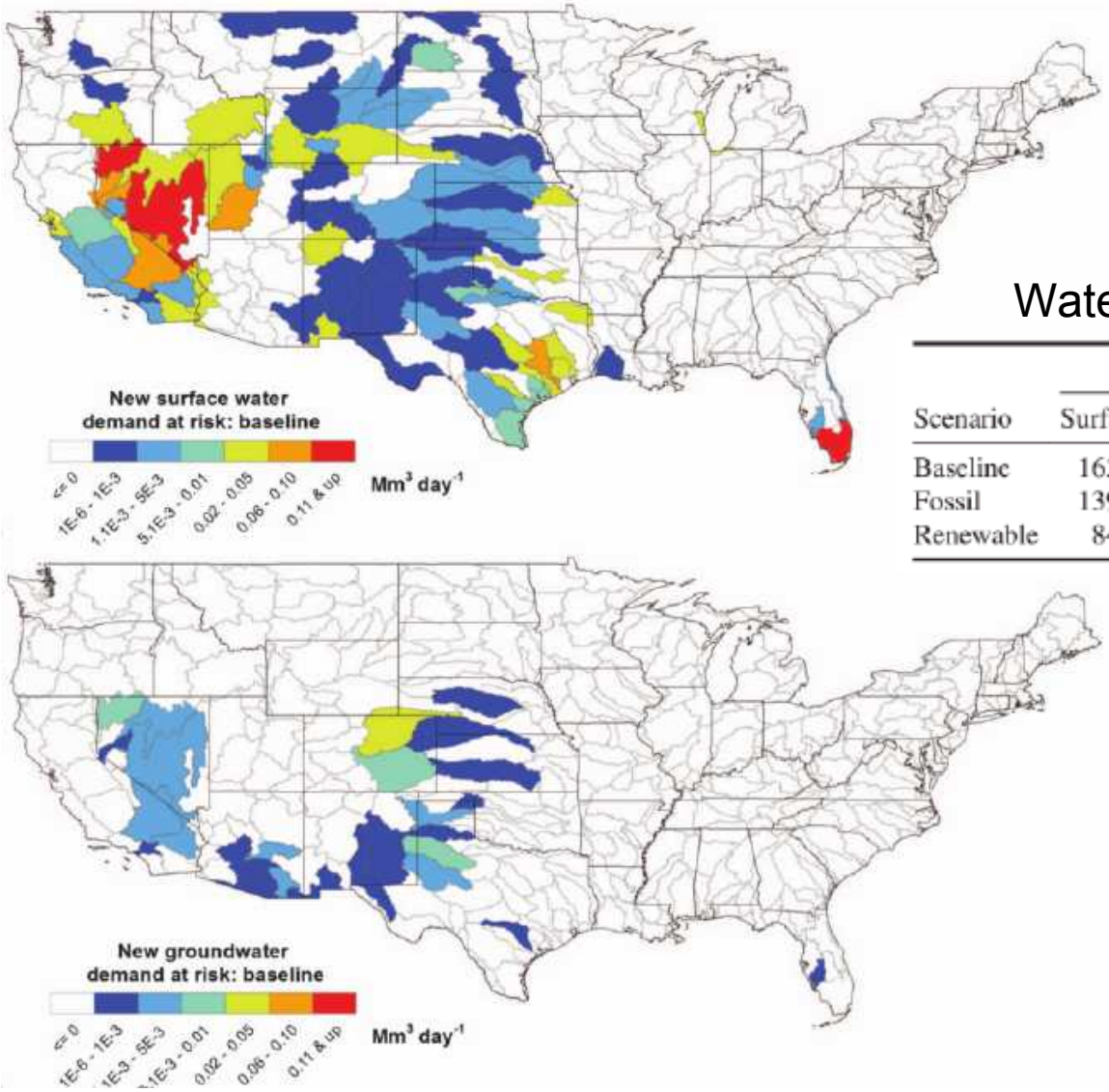
Energy Demands for Water Treatment



Einfeld 2007

Thermoelectric Development in Water Limited Basins

Sandia National Laboratories



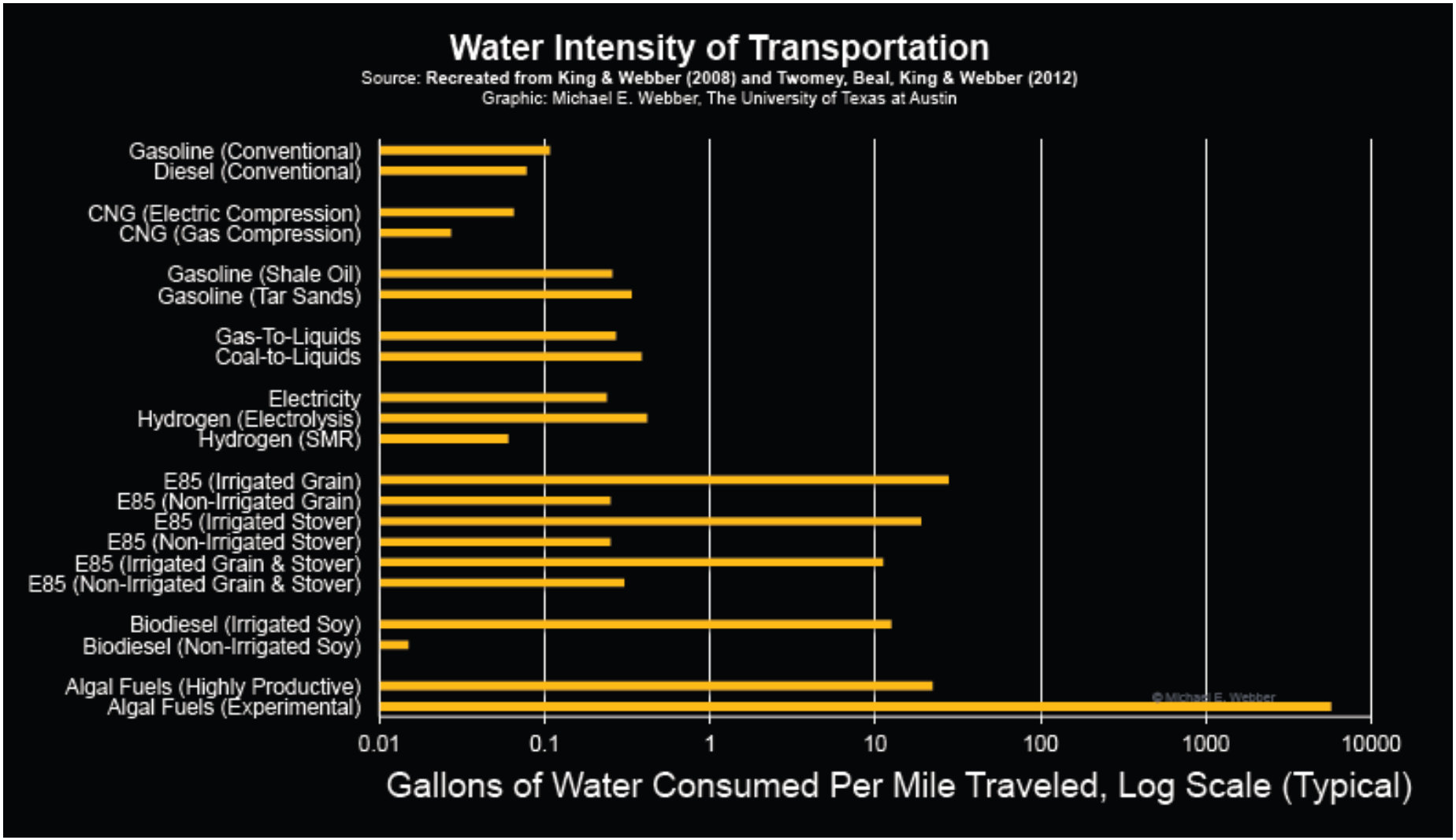
Water and Power at Siting Risk

	Power (MMWh)		Water (Mm^3/day)	
Scenario	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

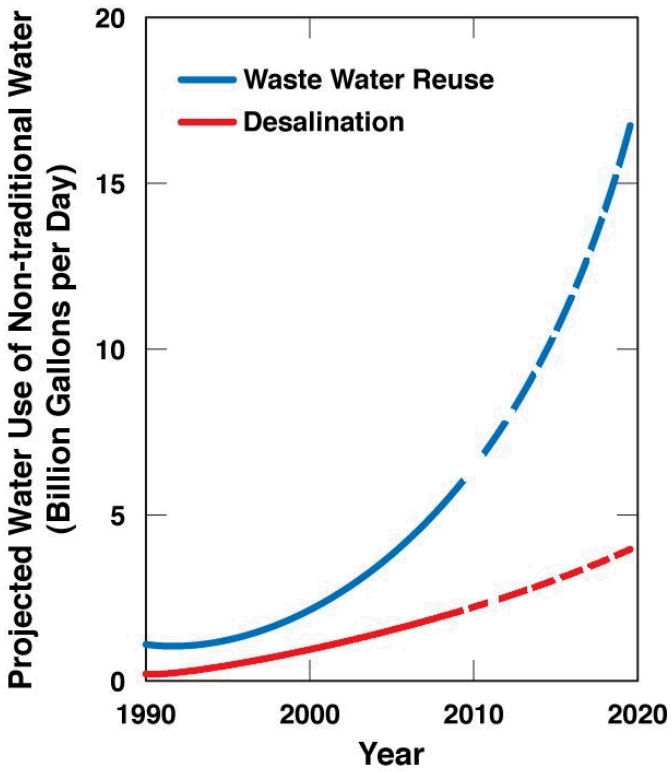
Water for Transportation Fuels

Sandia National Laboratories

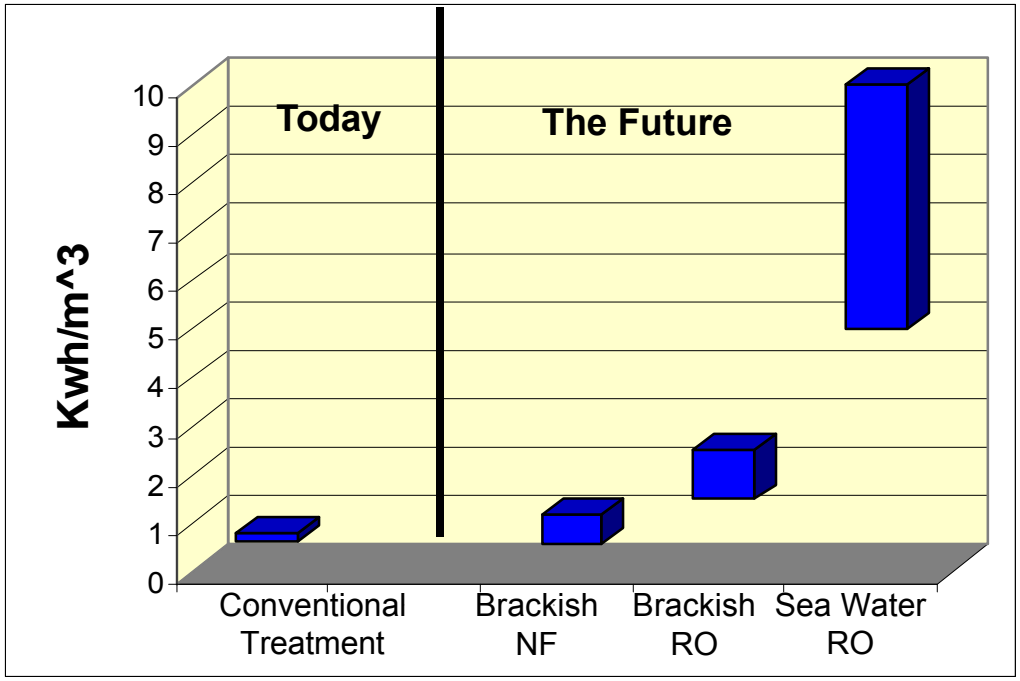


Energy for Water

Power Requirements For Treatment



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



(Einfeld 2007)

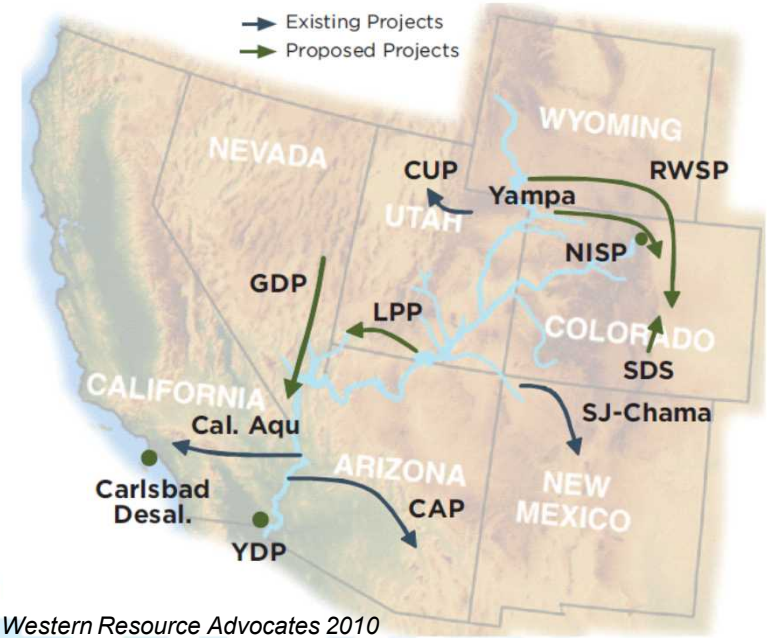
- Desal growing at 10% per year, waste water reuse at 15% per year
- Non-traditional water use is energy intensive

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.

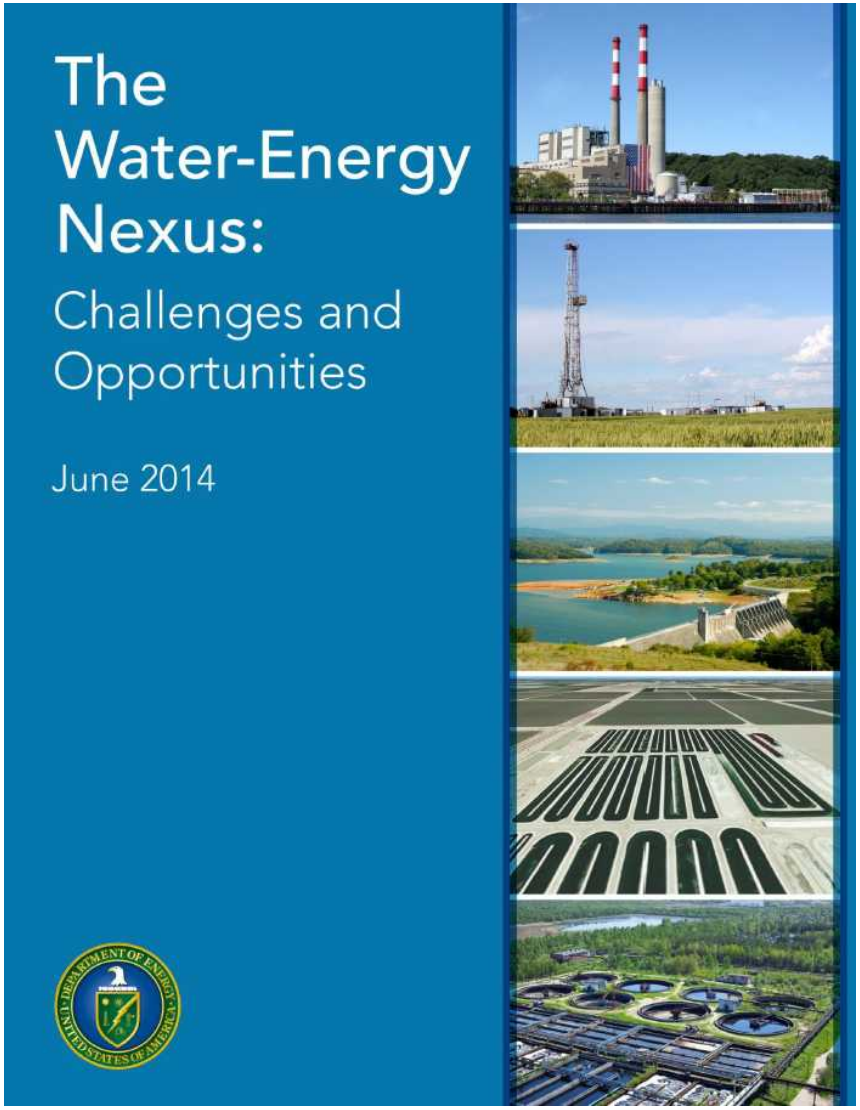
Source: detoxifynow.com

Existing and Proposed Western Water Supply Projects



Western Resource Advocates 2010

Water-Energy Nexus Report

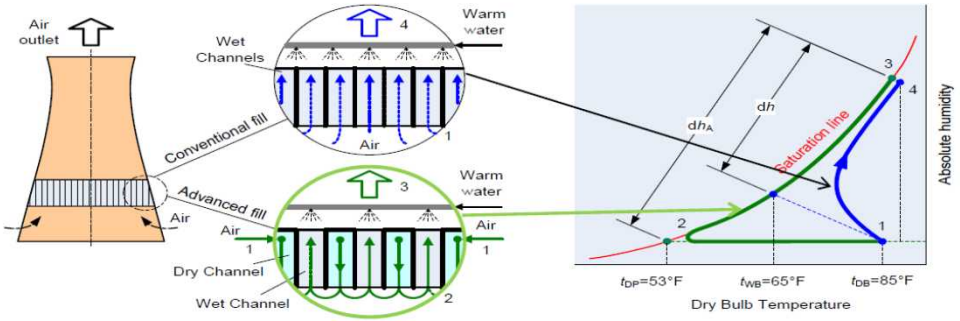


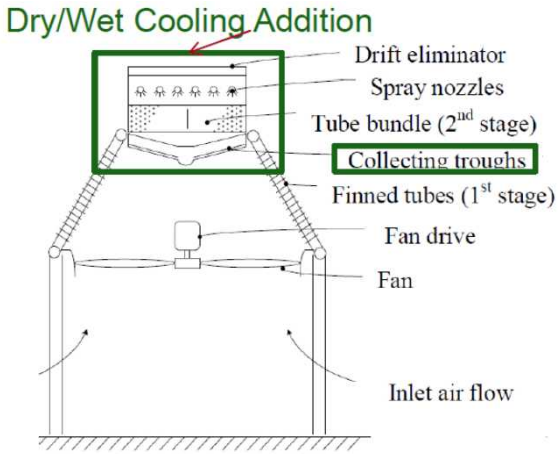
- Prepared by the Department of Energy
- Released June 2014
- Purpose:
  - Provides a foundation for future DOE action,
  - Provide data and analysis to frame opportunities, and
  - Broadly engage others in the dialogue.

Six Strategic Pillars to Address Water-Energy Nexus

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

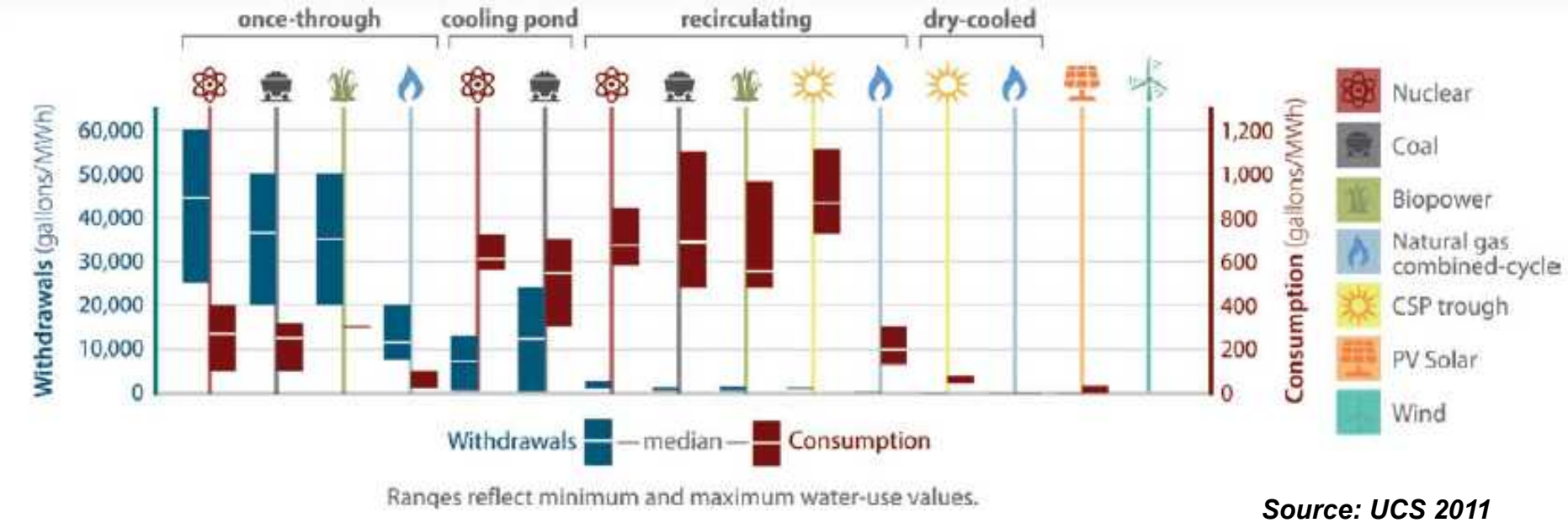
Enhanced Wet and Dry Cooling Systems





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:

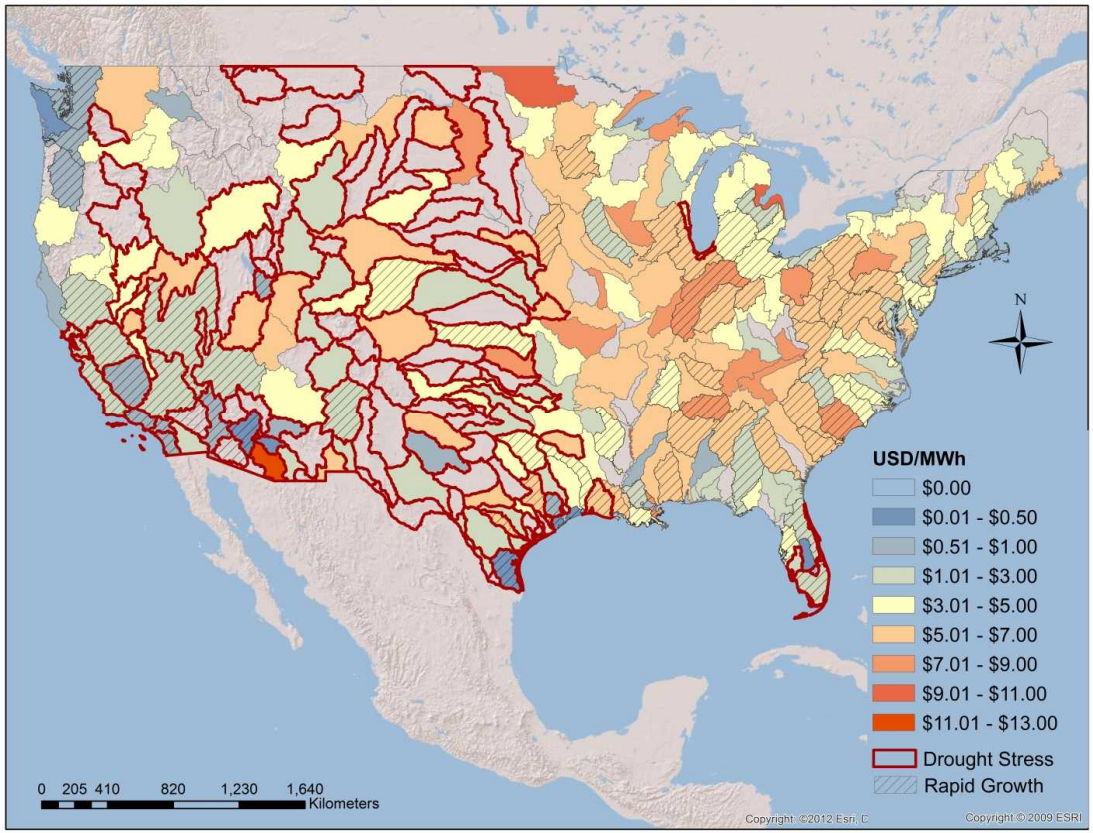
Municipal waste water: within 50 miles
Brackish water: <2500 ft deep, salinities>10,000 TDS

* 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: ΔLCOEs 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.*

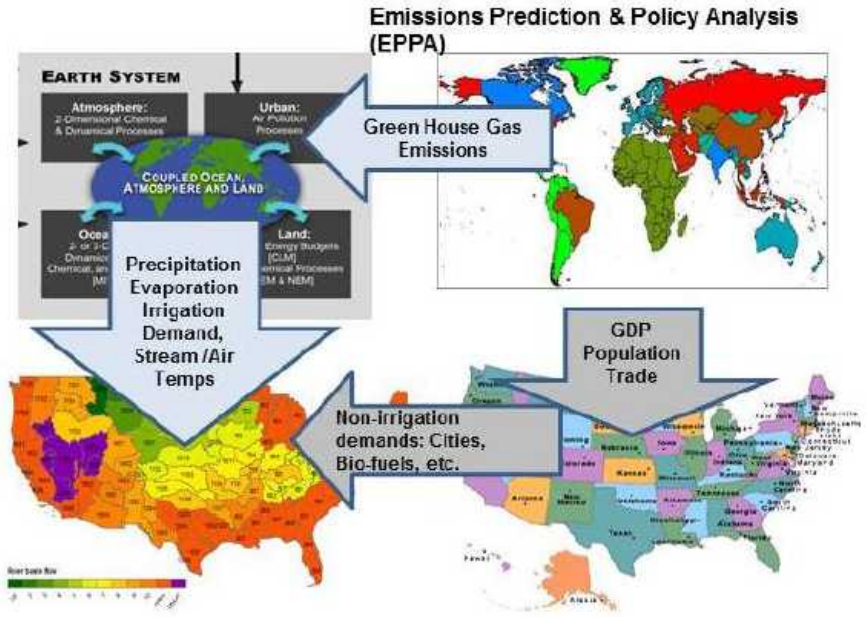
*average 2012 wholesale cost over 3 US trading hub regions

Six Strategic Pillars to Address Water-Energy Nexus

Sandia National Laboratories

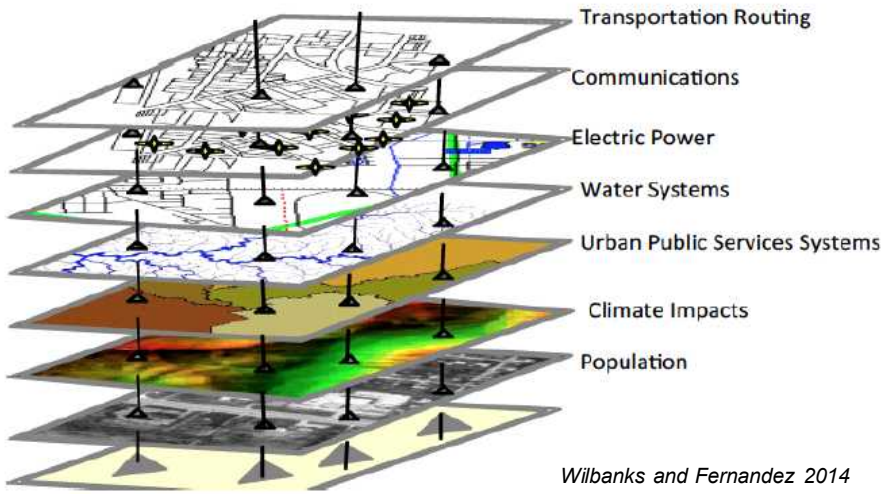
- Enhance the reliability and resilience of energy and water systems.

Integrated Modeling



Schlosser et al. 2014

Infrastructure Risk Analysis



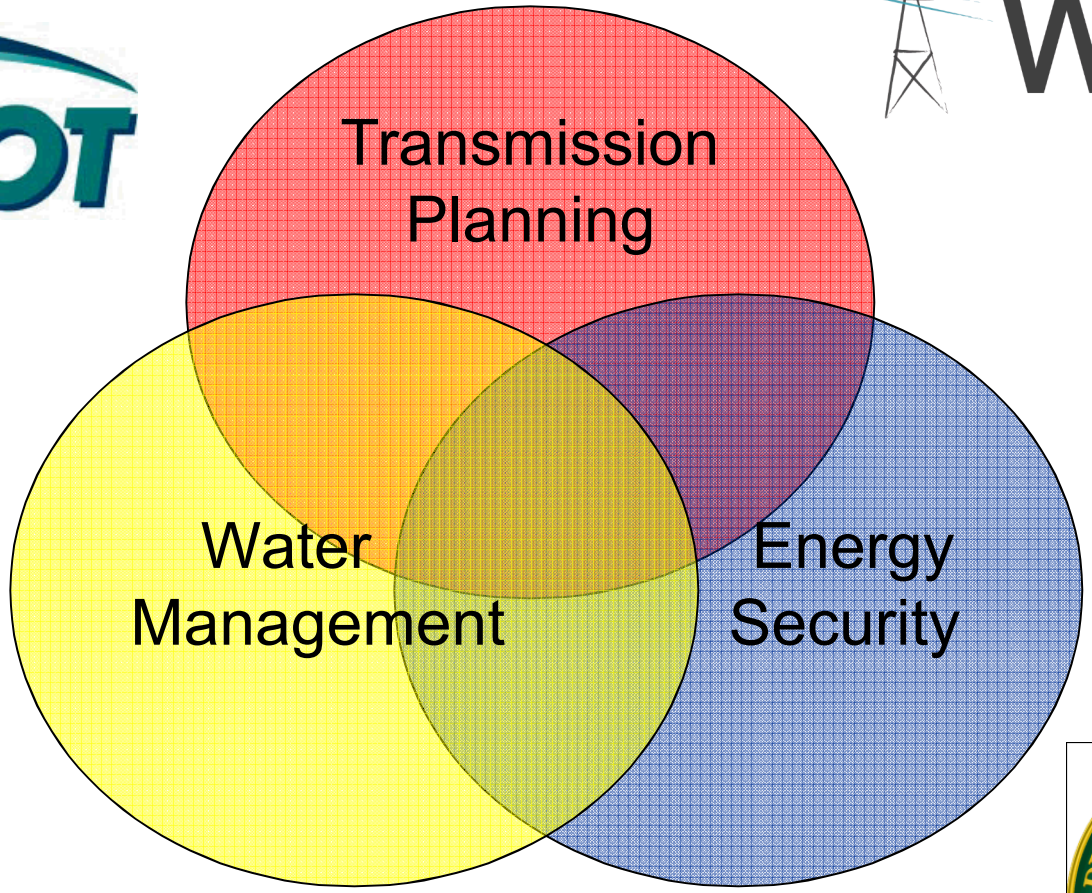
Wilbanks and Fernandez 2014

Integrated Planning

Sandia National Laboratories

ERCOT

WECC



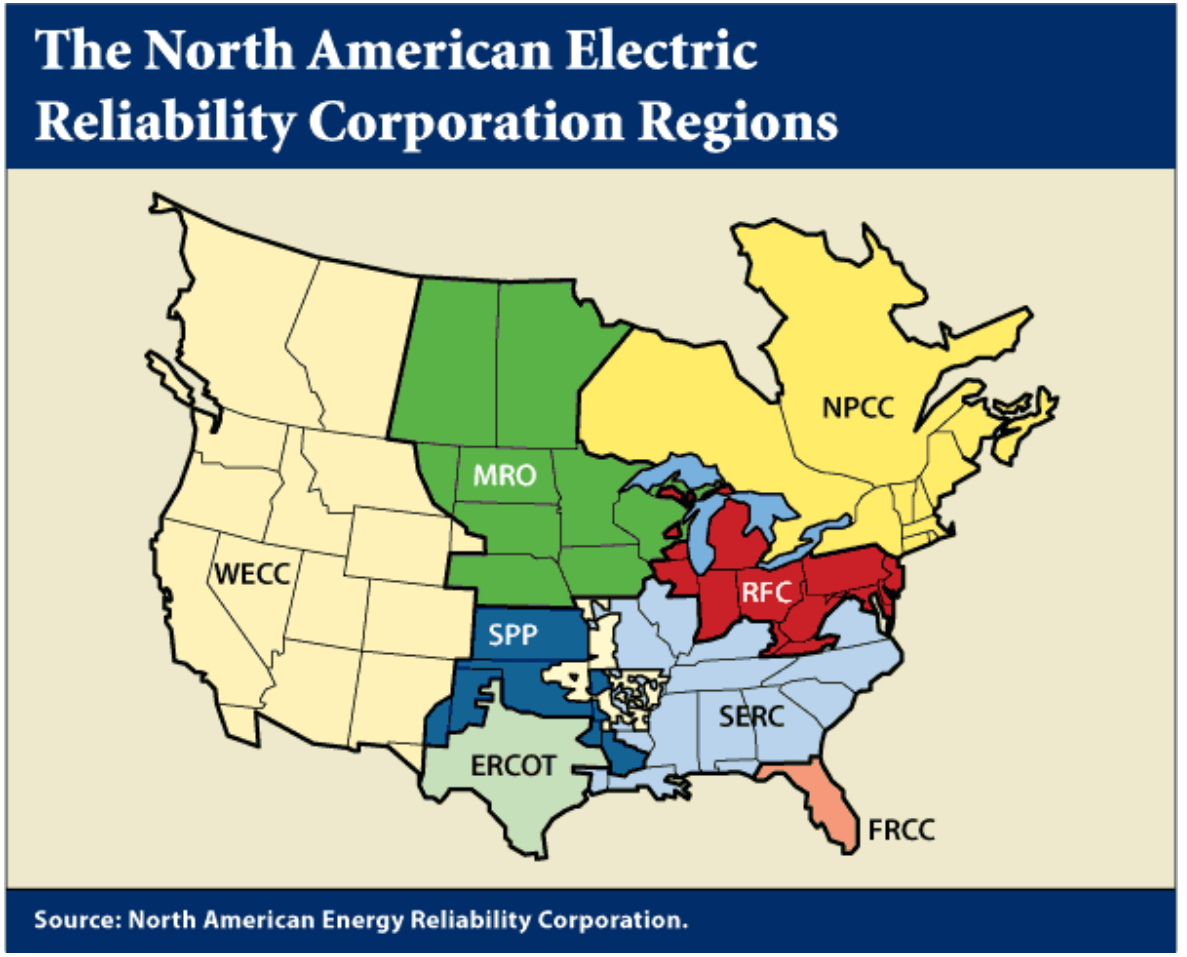
Western Governors' Association
Serving the Governors of 19 States and 3 US-Flag Pacific Islands

WSWC
Western States Water Council

Department of Energy · United States of America

Transmission Planning

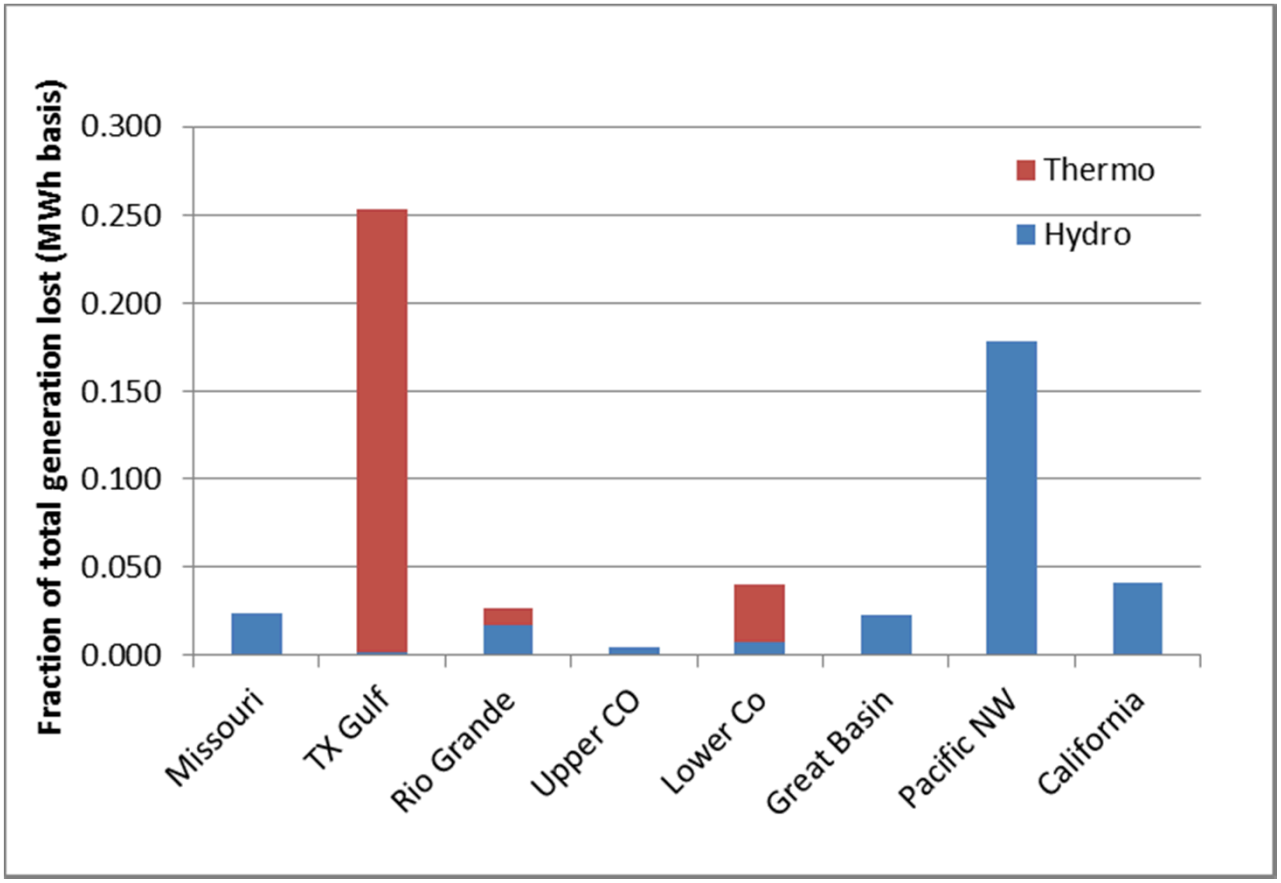
- WECC and ERCOT are conducting long-range transmission planning (20 yrs.) to direct:
  - Siting of new power plants
  - New transmission capacity



Climate Impact on Existing Plants

Sandia National Laboratories

Fraction of Generation at Risk

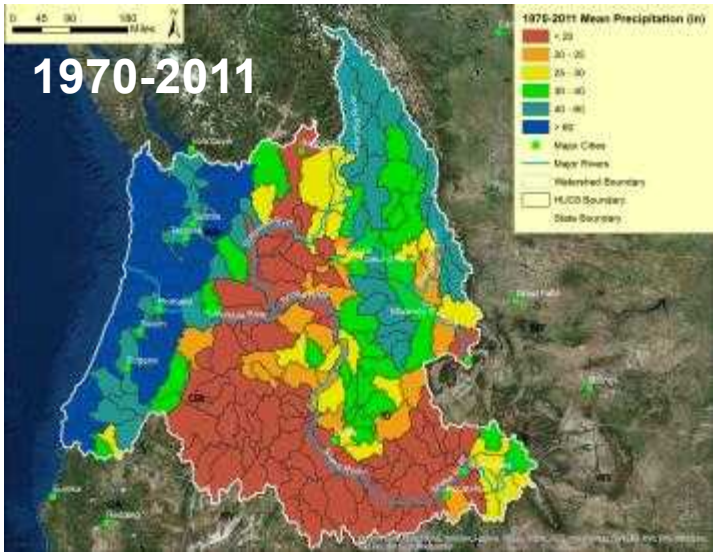


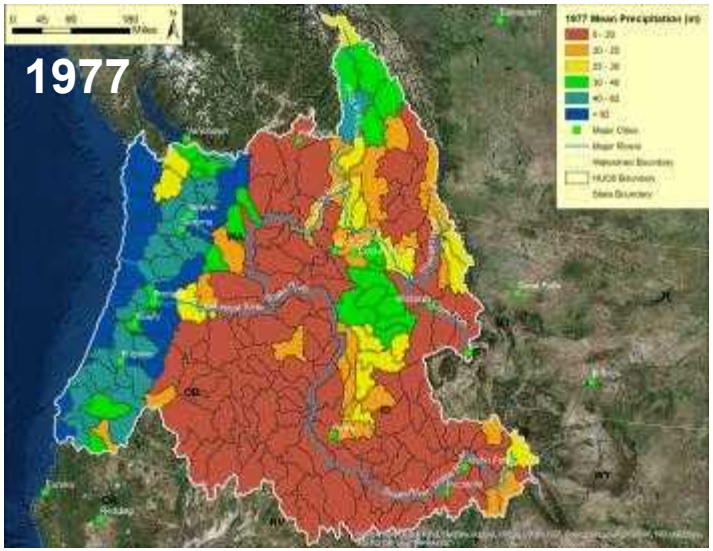
Basin Map

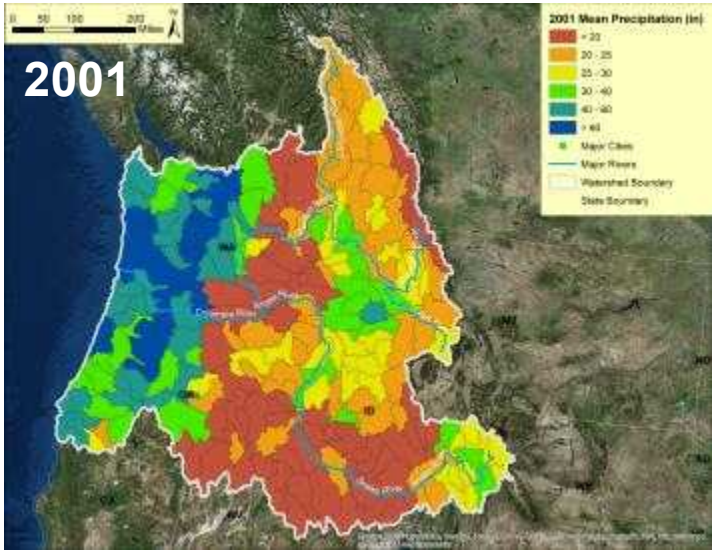
Source: ANL 2012

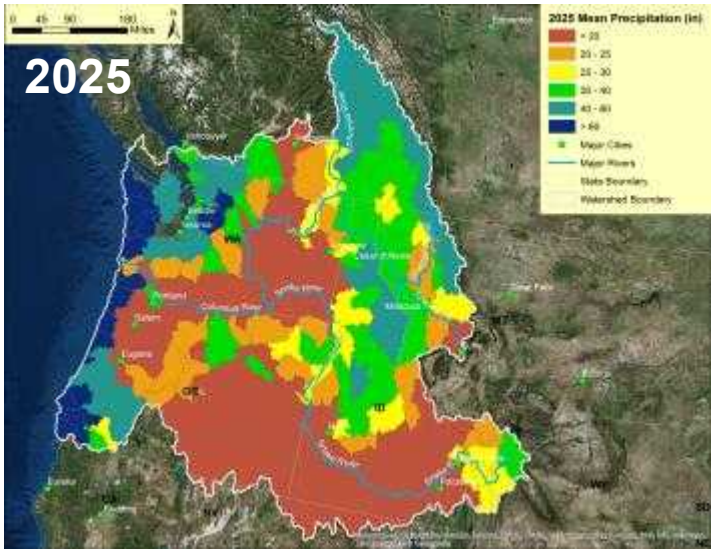
Precipitation Pattern (Annual Mean)

Sandia National Laboratories



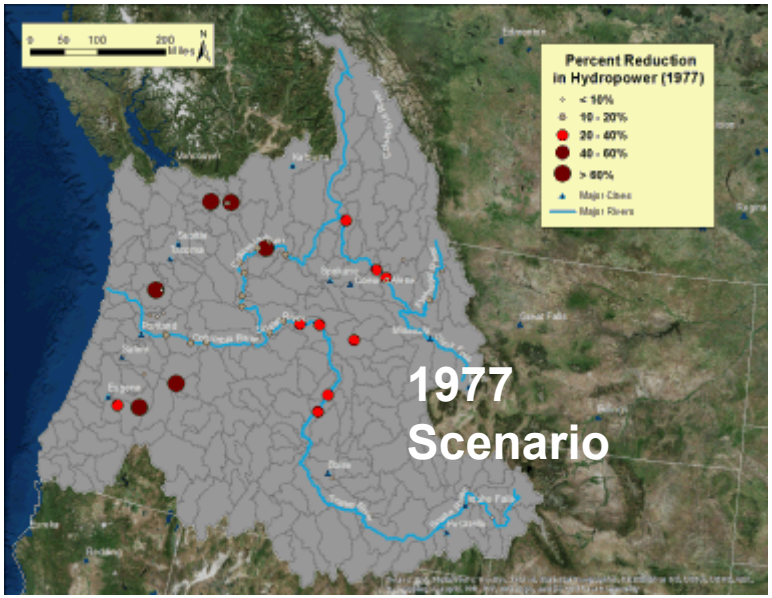


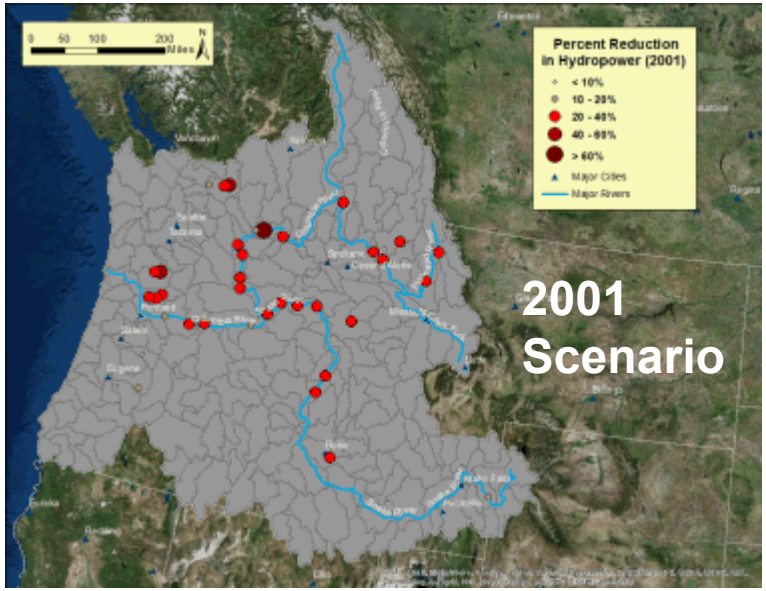


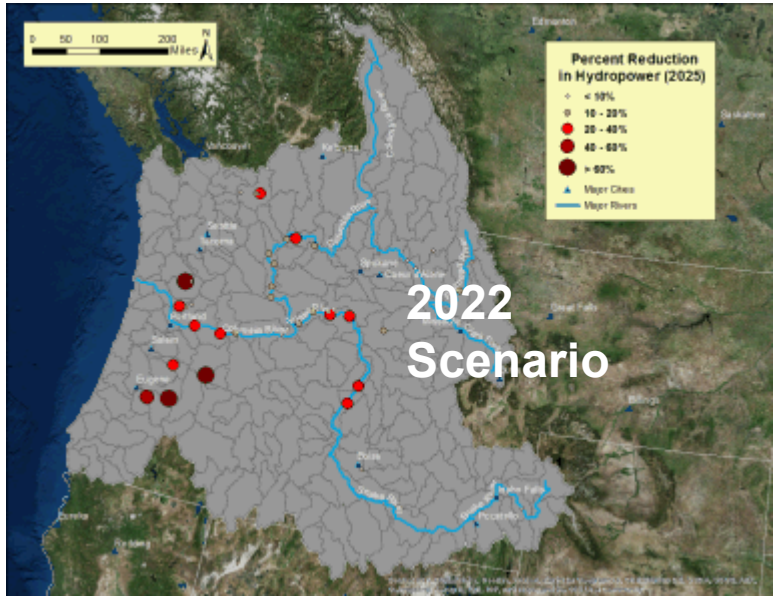


Potential Impact of Drought on Hydropower Generation

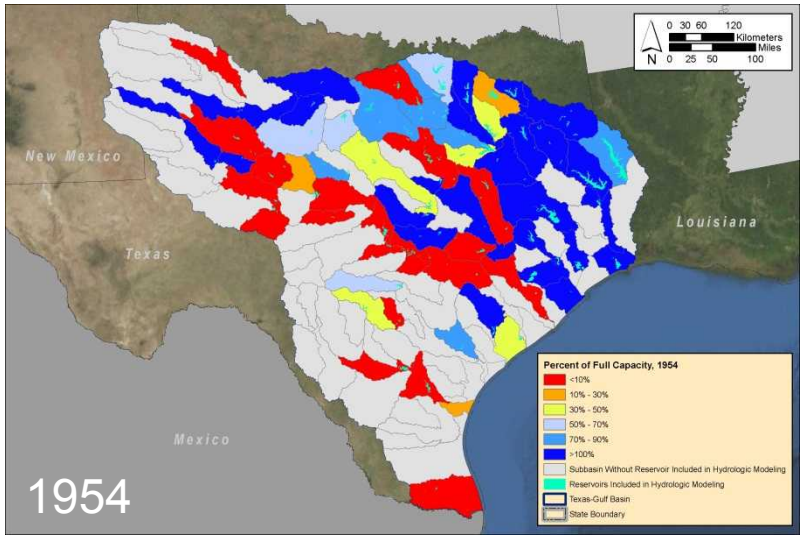
- Simulated reduction of hydropower
  - 1977 drought: 21% reduction
  - 2001 drought: 24% reduction
  - 2025 drought: 20 % reduction

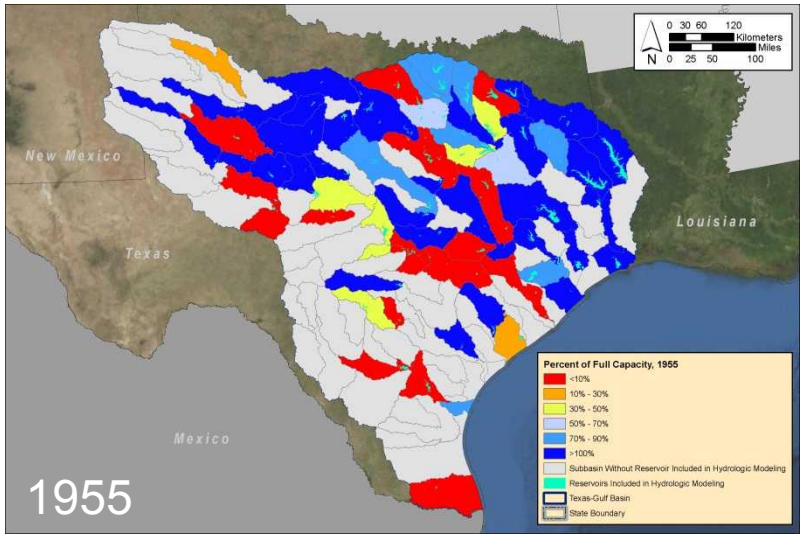




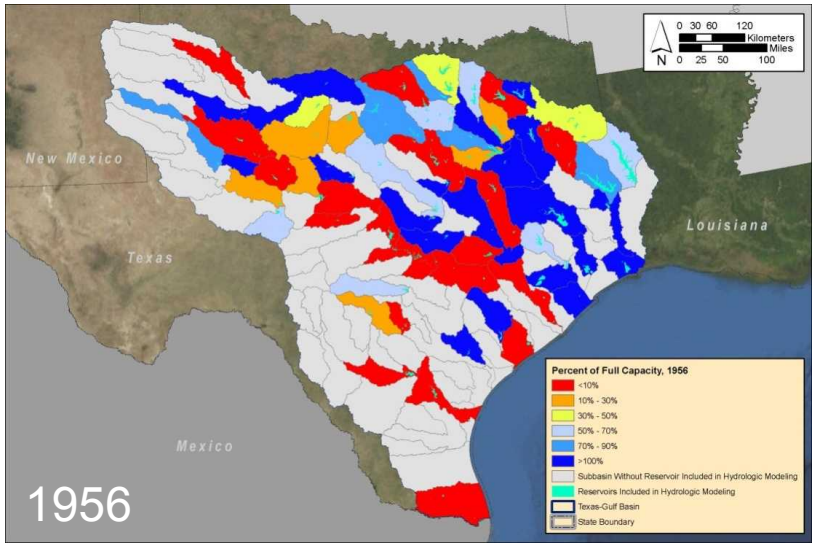


Climate Impacts on the Hydrology





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

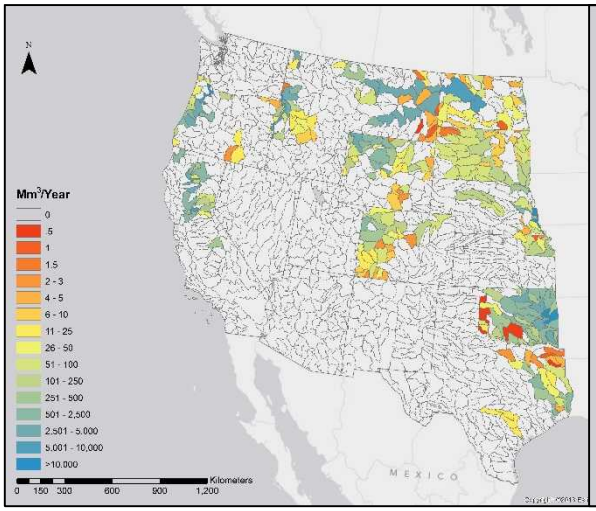


Source: ANL 2013

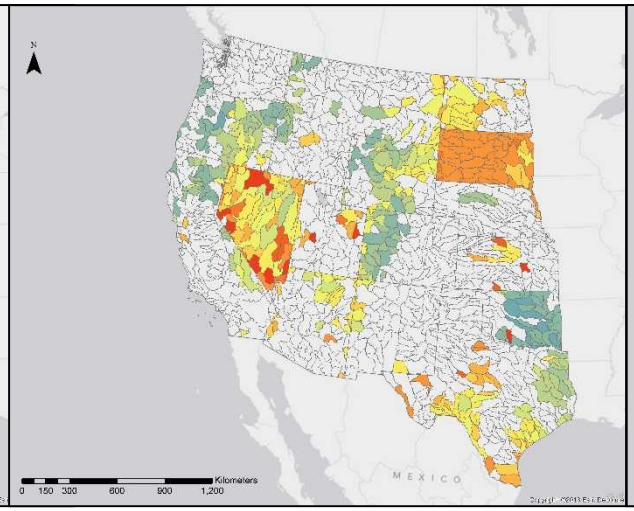
Water Availability and Future Demand

Sandia National Laboratories

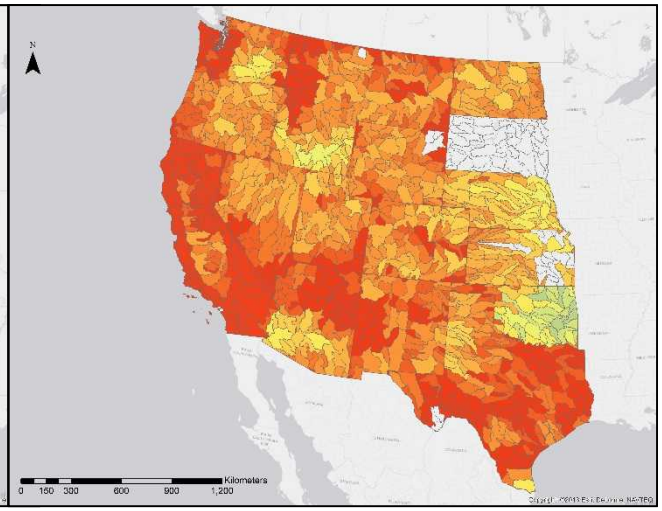
Unappropriated Surface Water



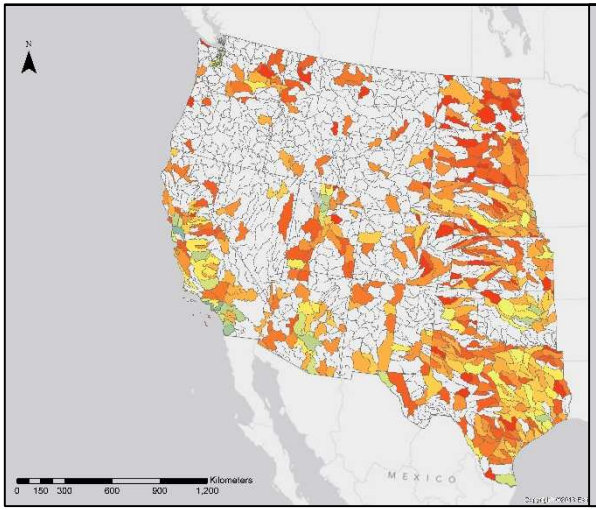
Unappropriated Groundwater



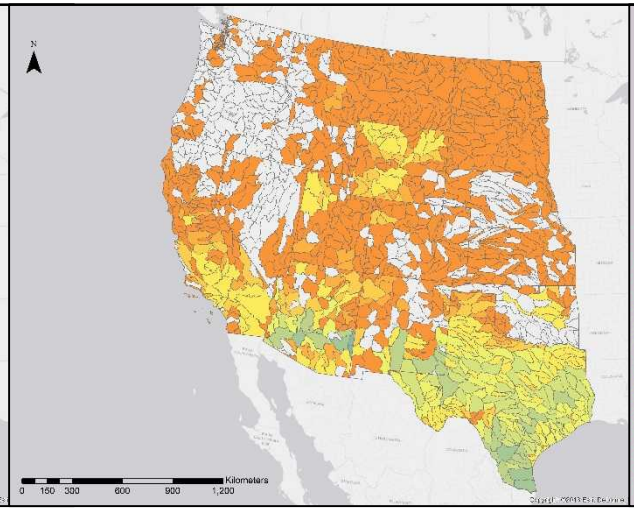
Appropriated Water



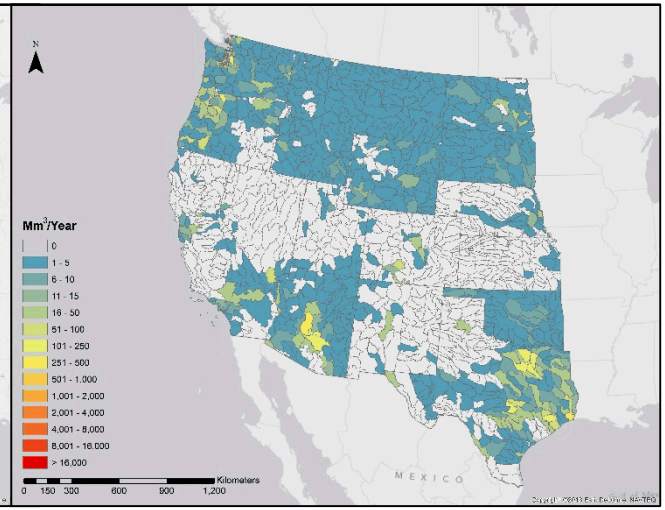
Municipal Wastewater



Brackish Groundwater



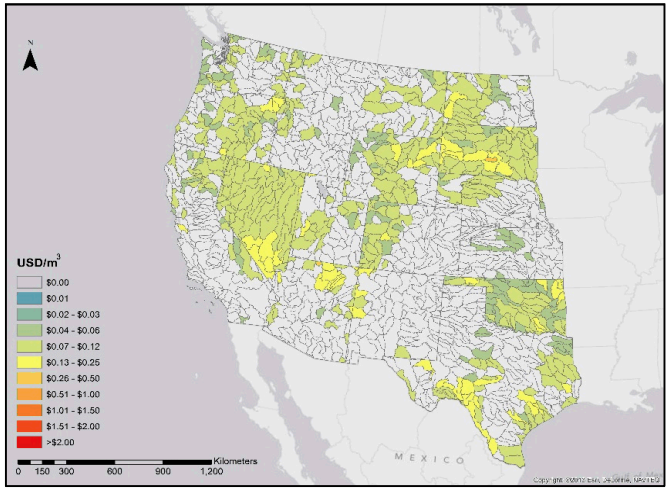
Consumptive Demand 2010-2030



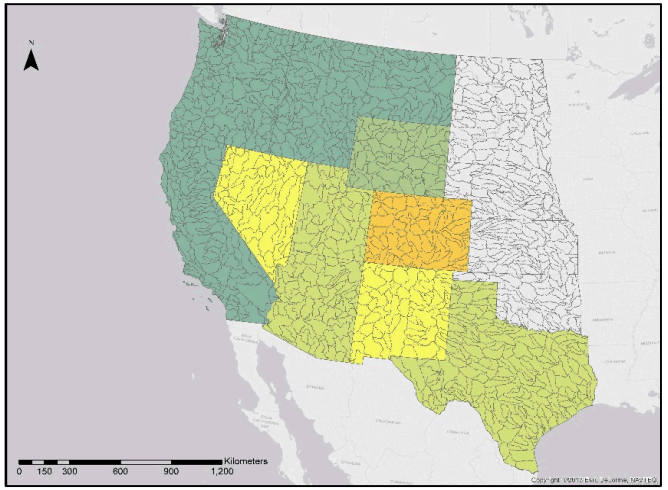
Relative Cost of Water

Sandia National Laboratories

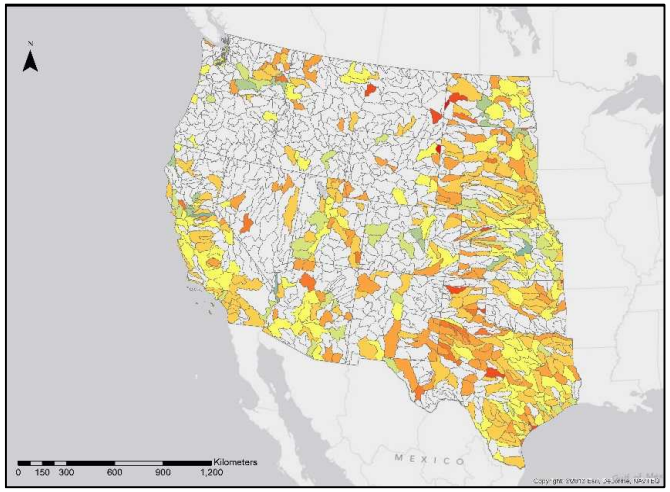
Unappropriated Groundwater



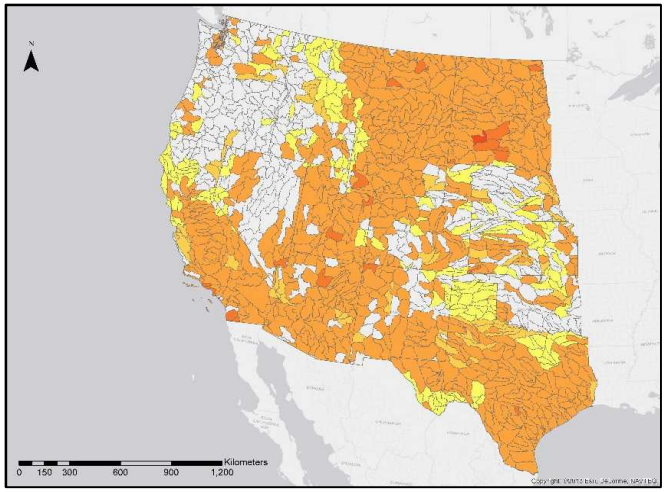
Appropriated Water



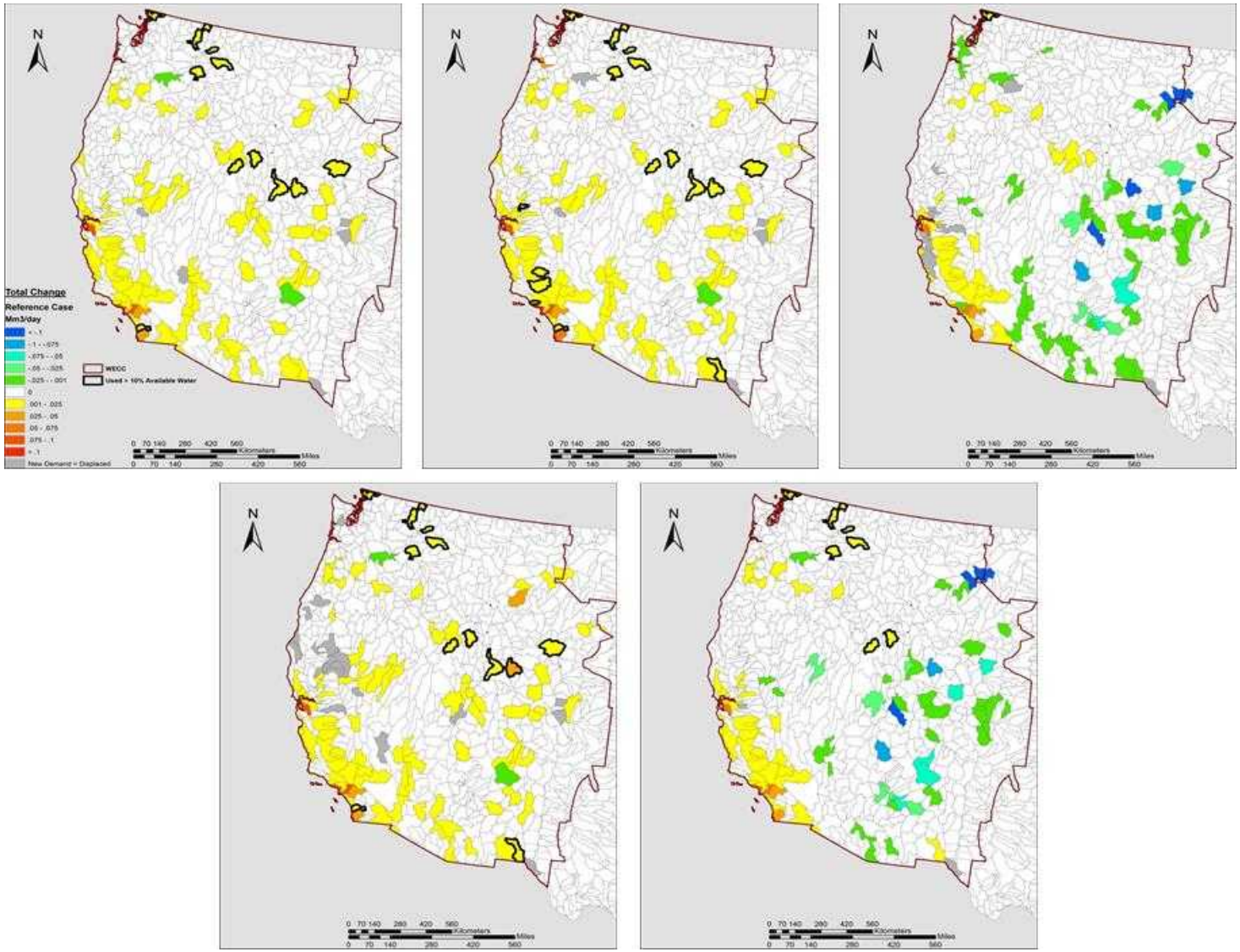
Municipal Wastewater



Brackish Groundwater

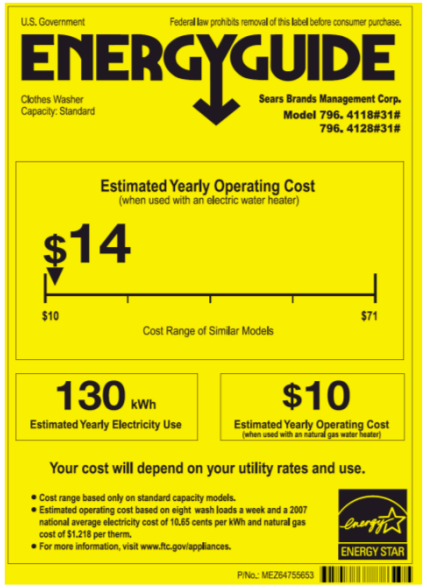


Change in Thermoelectric Water Use



Six Strategic Pillars to Address Water-Energy Nexus

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



Appliance Standards

Drinking Water Systems

Wastewater Systems

Six Strategic Pillars to Address Water-Energy Nexus

Sandia National Laboratories

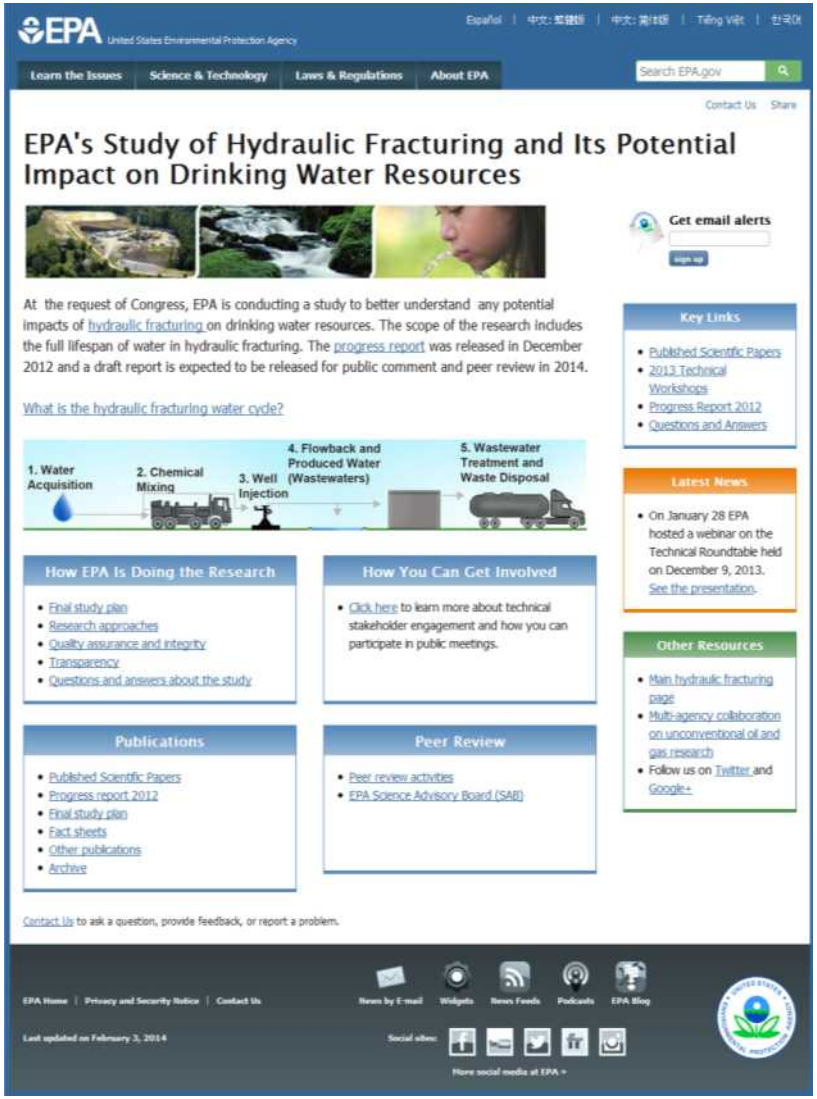
- Increase safe and productive use of nontraditional water sources.

Use of Produced Water in Shale Gas/Oil Extraction

Wilbanks and Fernandez 2014

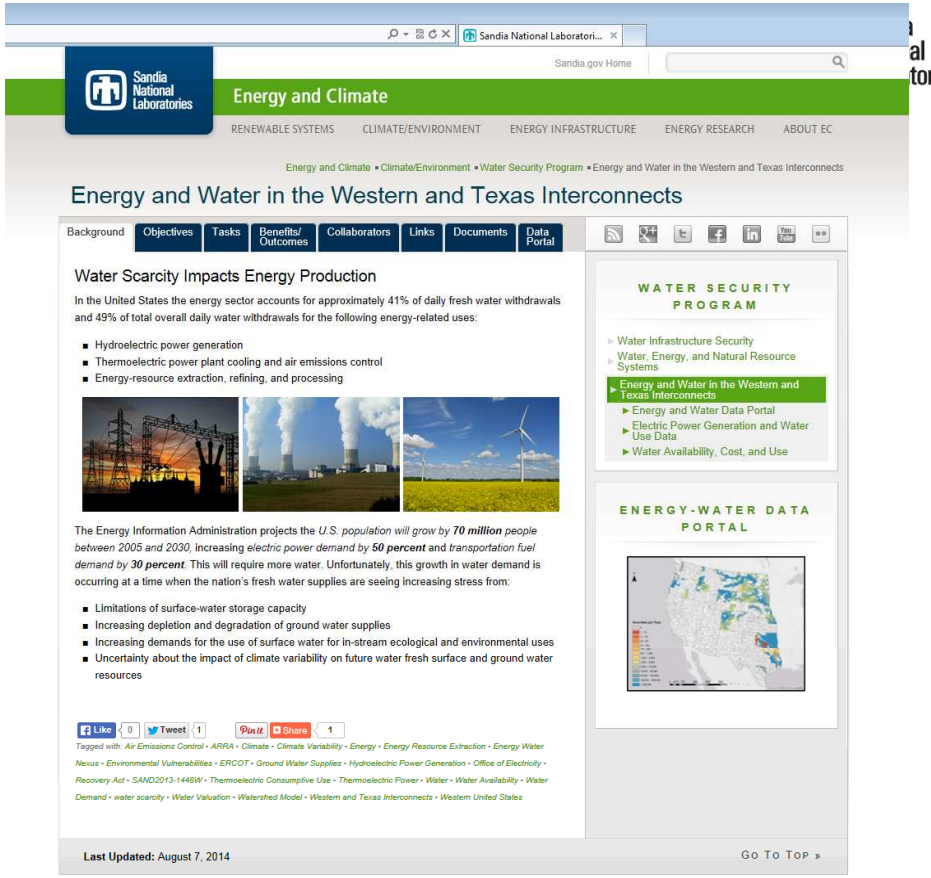
Six Strategic Pillars to Address Water-Energy Nexus

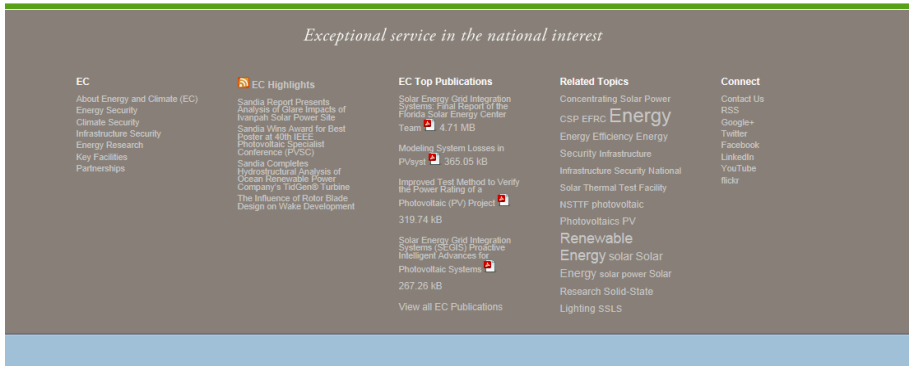
- Promote responsible energy operations with respect to water quality, ecosystem, and seismic impacts.
- Exploit productive synergies among water and energy systems



- Project data available at:

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





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