

*Exceptional service in the national interest*



## Energy-Water Nexus in the U.S.

***Vincent Tidwell***

***Sandia National Laboratories***

***Ten year Framework for Energy and the Environment Cooperation***

***Washington, DC, March 2014***

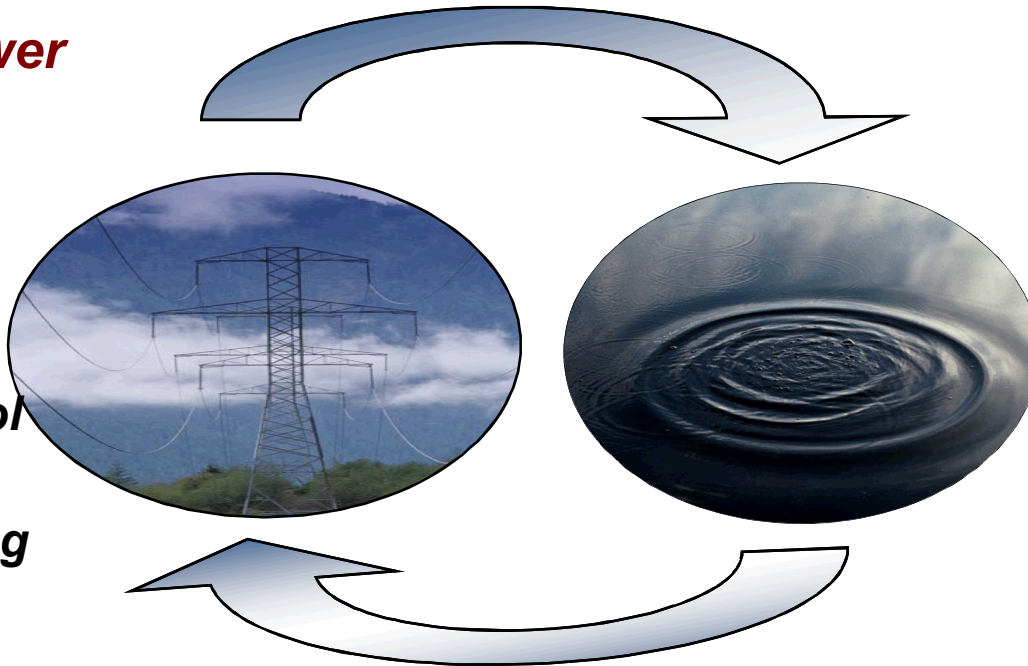


Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

# Energy-Water Nexus

## ***Energy and power production requires water***

- **Thermoelectric Cooling**
- **Emission Control**
- **Energy Minerals Extraction/Mining**
- **Fuel Processing (fossil fuels, H<sub>2</sub>, biofuels)**



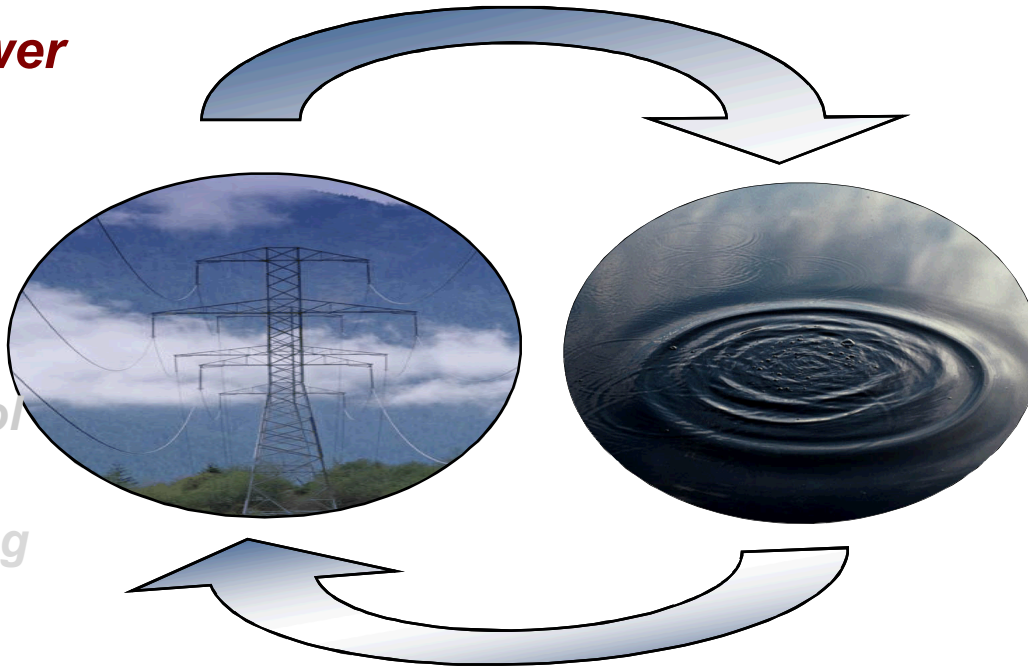
## ***Water production, processing, distribution, and end-use requires energy***

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

# Energy-Water Nexus

## **Energy and power production requires water**

- Thermoelectric Cooling
- Emission Control
- Energy Minerals Extraction/Mining
- Fuel Processing (fossil fuels, H<sub>2</sub>, biofuels)



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

- Pumping
- Conveyance
- Treatment
- Distribution
- Use Conditioning

# Water Utility Energy Use

- Drinking water accounts 1% of total electricity use in the U.S.
- Wastewater use 0.8%  
(EPRI 2013)



- Water and wastewater account for 35 percent of typical U.S. municipal energy budgets,
- 25–40 percent of the operating budgets for wastewater utilities
- 80 percent of drinking water processing and distribution costs  
(NYSERDA, 2008)



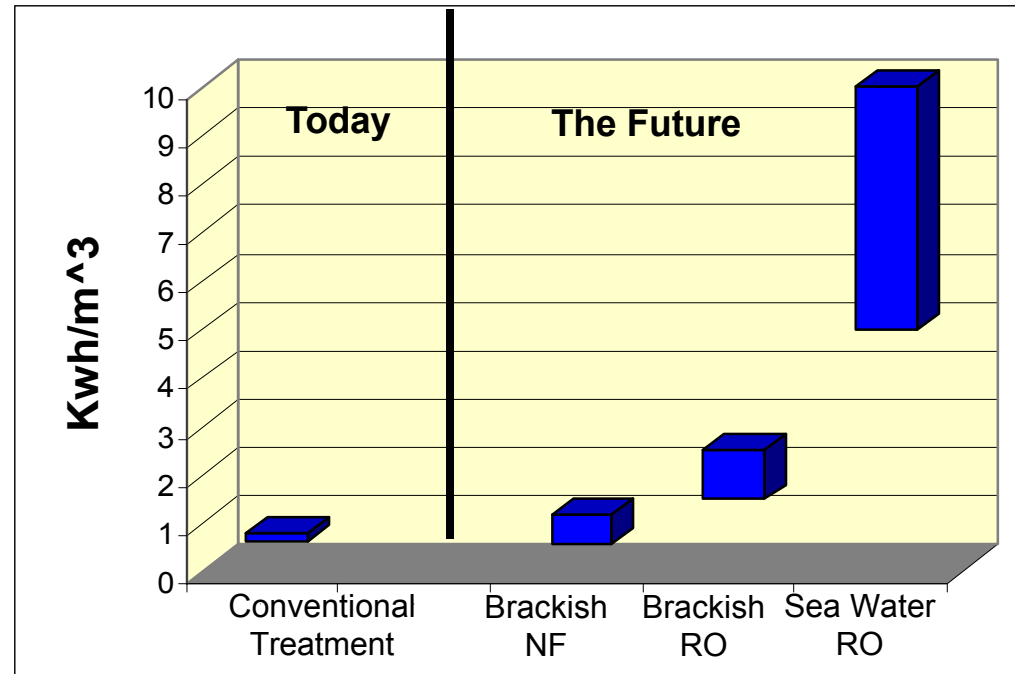
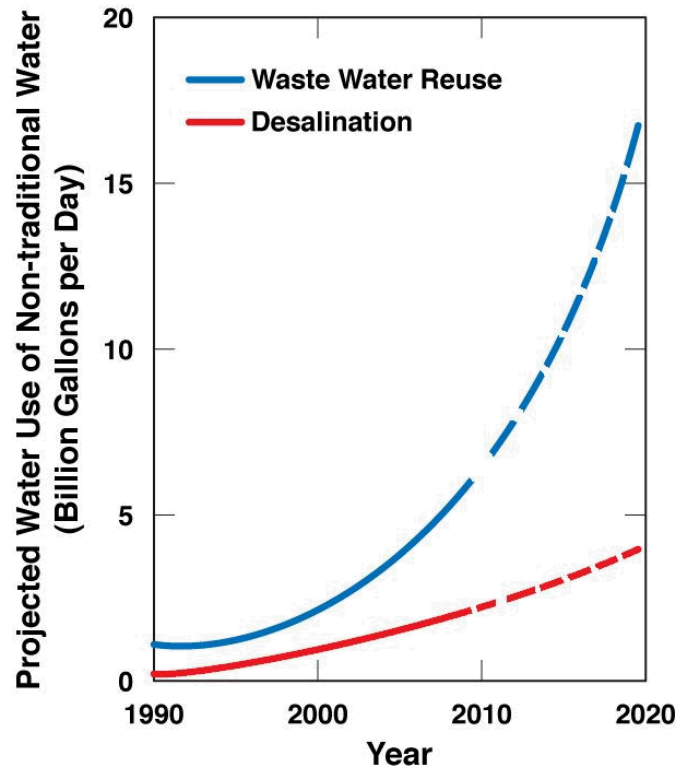
# Energy Management Opportunities

Energy Efficiency, Load Management, and Demand Response	Emerging Technologies and Processes	Energy Recovery and Generation
<ul style="list-style-type: none"><li>• Strategic Energy Management Practices</li><li>• Data Monitoring and Process Control</li><li>• Water Conservation</li><li>• High-Efficiency Pumps and Motors</li><li>• Adjustable Speed Drives</li><li>• Pipeline Optimization</li><li>• Advanced Aeration</li><li>• Demand Response</li></ul>	<ul style="list-style-type: none"><li>• Odor Control</li><li>• Membrane Bioreactors</li><li>• Deammonification Sidestream Process</li><li>• Water Reuse</li><li>• Residuals Processing</li><li>• Microbial Fuel Cells</li><li>• LED UV Lamps</li></ul>	<ul style="list-style-type: none"><li>• Cogeneration Using Digester Biogas</li><li>• Use of Renewable Energy to Pump Water</li><li>• Recovery of Excess Line Pressure to Produce Electricity</li></ul>

EPRI 2013

# Energy for Water

## *Power Requirements For Treatment*



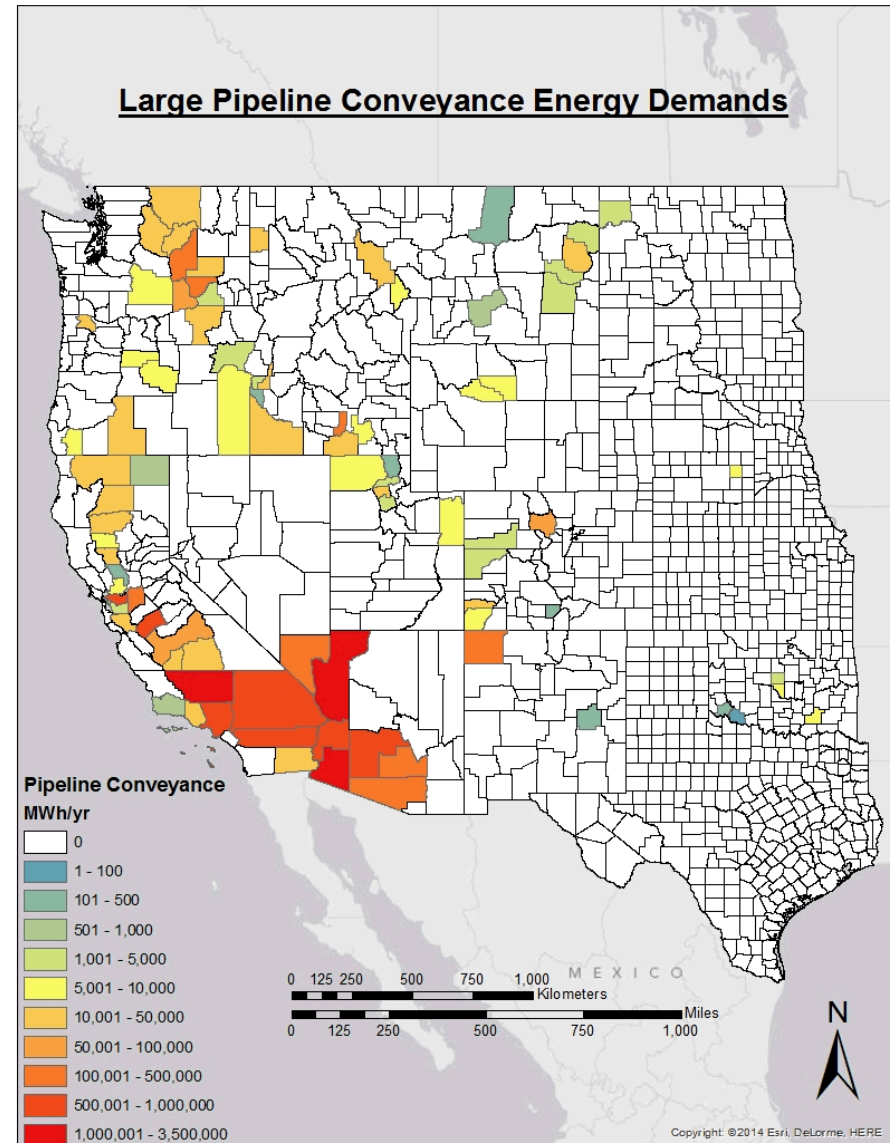
(Modified from Water Reuse 2007, EPA 2004, Mickley 2003)

(Einfeld 2007)

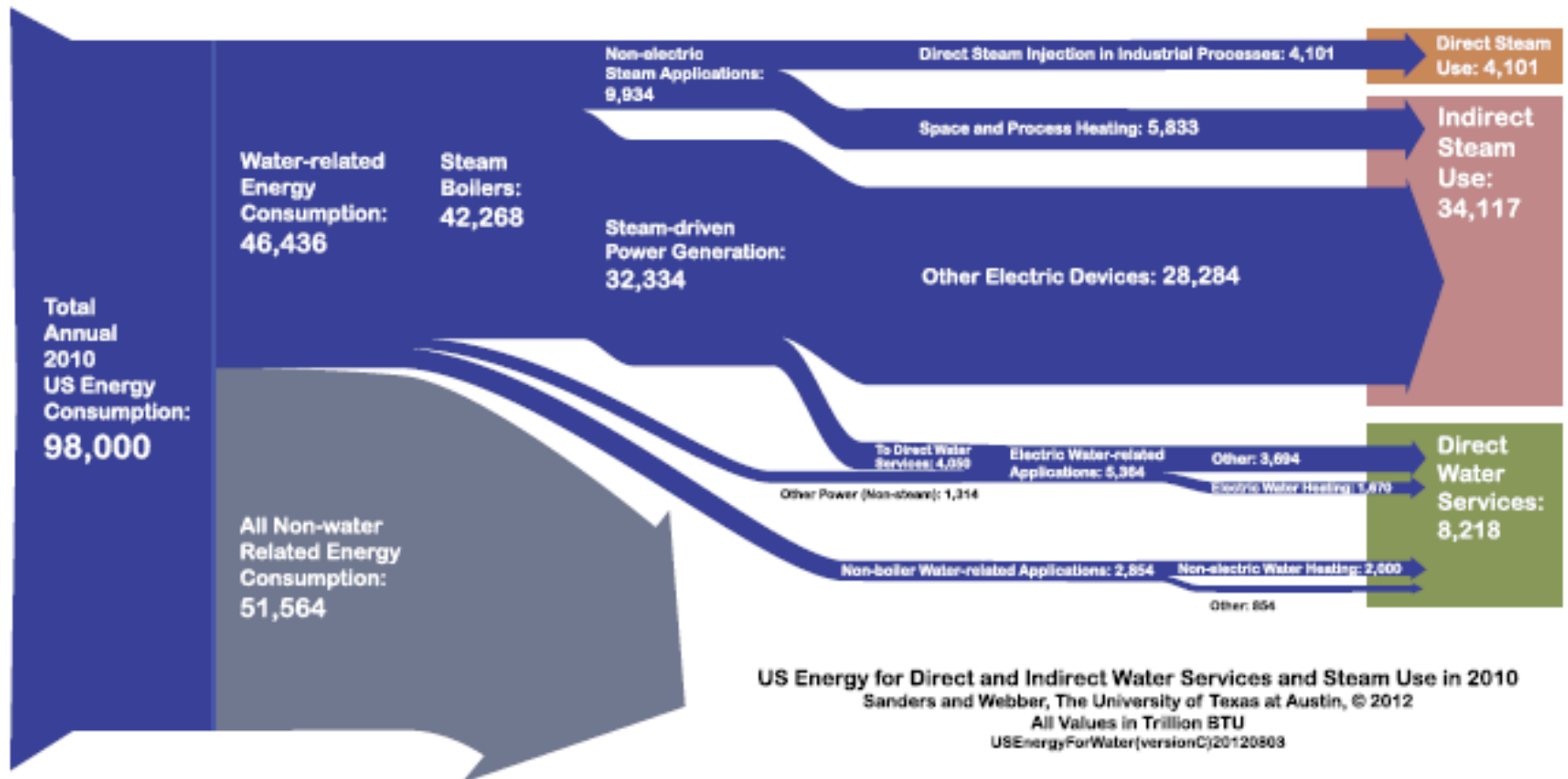
- Desal growing at 10% per year, waste water reuse at 15% per year
- Non-traditional water use is energy intensive

# Large-Scale Conveyance

- Inter-basin transfers account for 1.2% of West-wide electricity use.
  - 6% of Arizona electricity use, and
  - 3% of California electricity use.



# Energy for Water



- Water services account for 12.6% of energy consumption in U.S.
  - 8.2% for heating, chilling, treating, etc. water
  - 4.4% for direct steam applications



# Water and Energy Conservation

U.S. Government Federal law prohibits removal of this label before consumer purchase.

## ENERGYGUIDE

Clothes Washer  
Capacity: Standard

Sears Brands Management Corp.  
Model 796. 4118#31#  
796. 4128#31#

**Estimated Yearly Operating Cost**  
(when used with an electric water heater)

**\$14**

\$10 \$71


Cost Range of Similar Models


**130 kWh**  
Estimated Yearly Electricity Use

**\$10**  
Estimated Yearly Operating Cost  
(when used with a natural gas water heater)

Your cost will depend on your utility rates and use.

- Cost range based only on standard capacity models.
- Estimated operating cost based on eight wash loads a week and a 2007 national average electricity cost of 10.65 cents per kWh and natural gas cost of \$1.218 per therm.
- For more information, visit [www.ftc.gov/appliances](http://www.ftc.gov/appliances).

 ENERGY STAR

P/No.: MEZ64755653 

## Appliance Standards

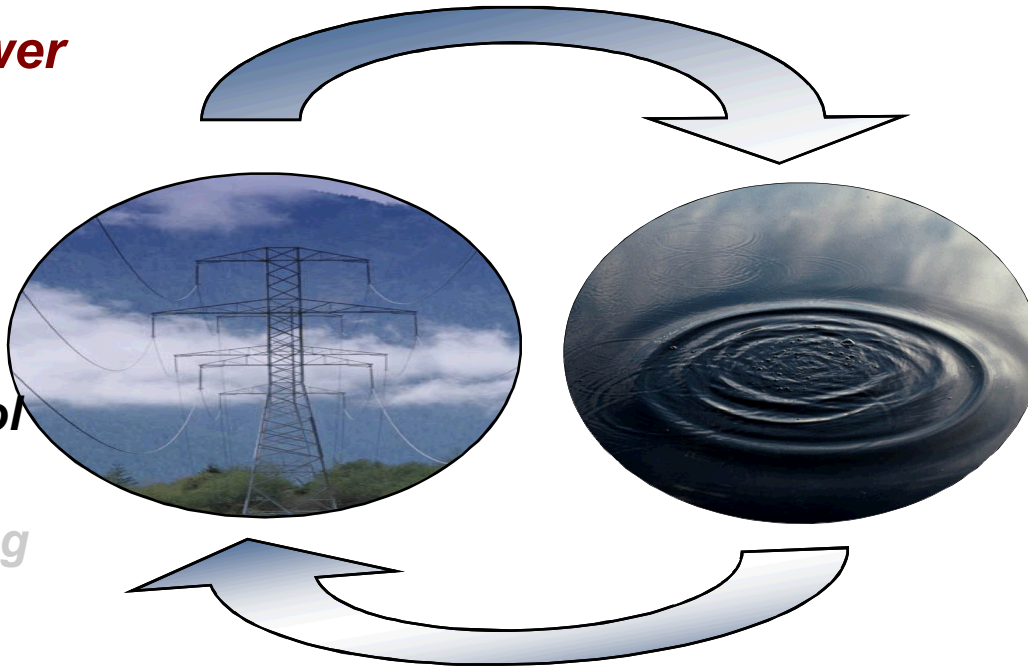


City of Denver Water Conservation Campaign

# Energy-Water Nexus

***Energy and power production requires water***

- ***Thermoelectric Cooling***
- ***Emission Control***
- *Energy Minerals Extraction/Mining*
- *Fuel Processing (fossil fuels, H<sub>2</sub>, biofuels)*

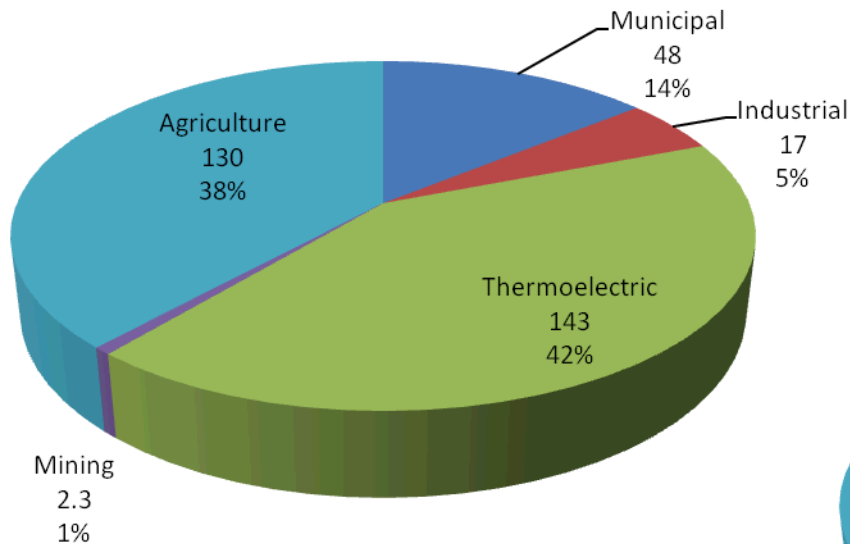


***Water production, processing, distribution, and end-use requires energy***

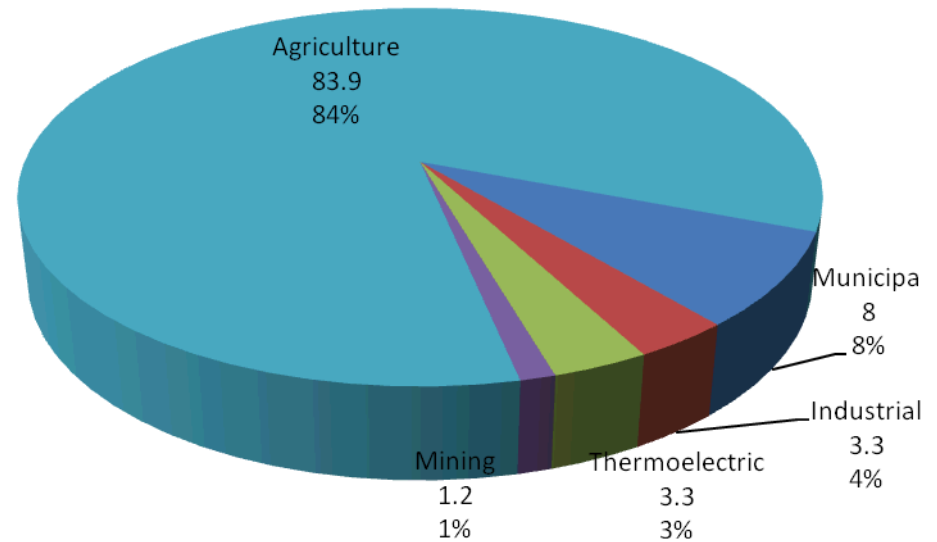
- *Pumping*
- *Conveyance*
- *Treatment*
- *Distribution*
- *Use Conditioning*

# Water for Thermoelectric Power Generation

## Water Withdrawal (BGD) 2005

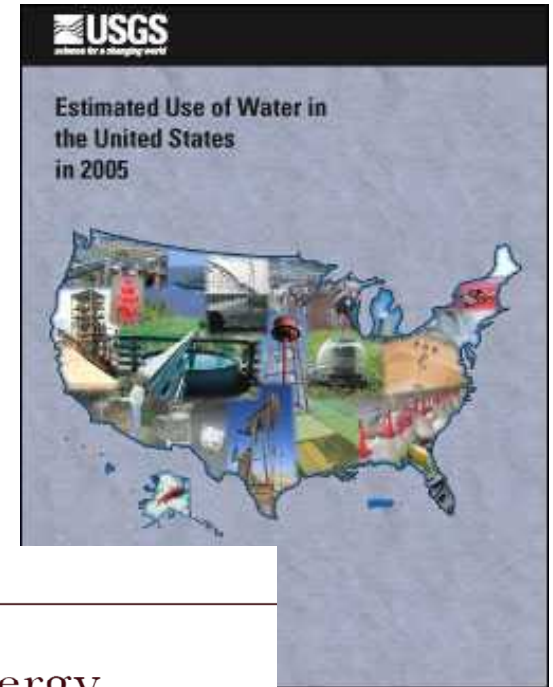


## Water Consumption (BGD) 1995



# Energy-Water Data

- Collaboration between:
  - U.S. Geological Survey
  - U.S. Energy Information Administration
- Expanded data collection
- Standardized procedures and definitions



DOE/EIA-0383(2013) | April 2013

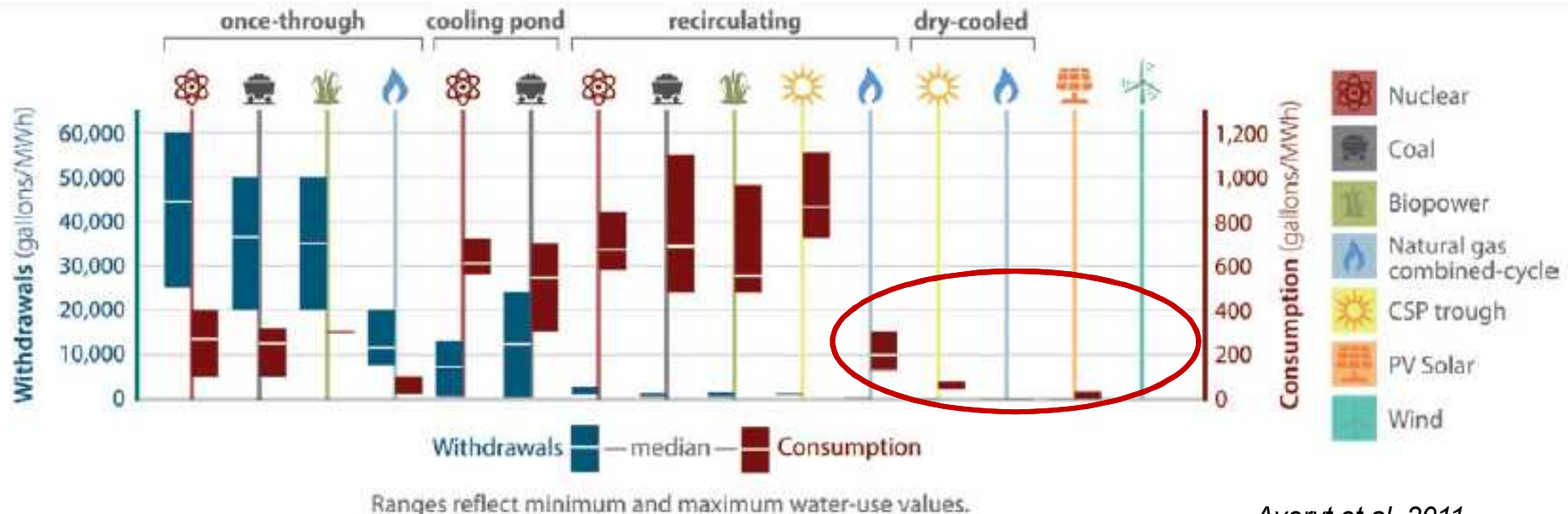
## Annual Energy Outlook 2013

with Projections to 2040



# Water for Thermoelectric Power

- Water use influenced by:
  - Fuel type,
  - Cooling type,
  - Emission controls,
  - Age, and
  - Location



Averyt et al. 2011



# Technology Improvement

*Unique collaboration between industrial research institute and National Science Foundation*

## NSF/EPRI Collaboration on "Water for Energy"- Advanced Dry Cooling for Power Plants

### PROGRAM SOLICITATION NSF 13-564



National Science Foundation  
Directorate for Engineering  
Division of Chemical, Bioengineering, Environmental, and Transport Systems



Electric Power Research Institute

Full Proposal Deadline(s) (due by 5 p.m. proposer's local time):

August 19, 2013

### IMPORTANT INFORMATION AND REVISION NOTES

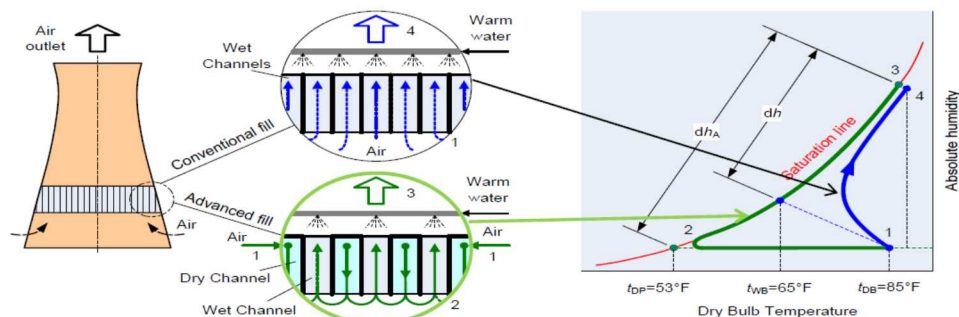
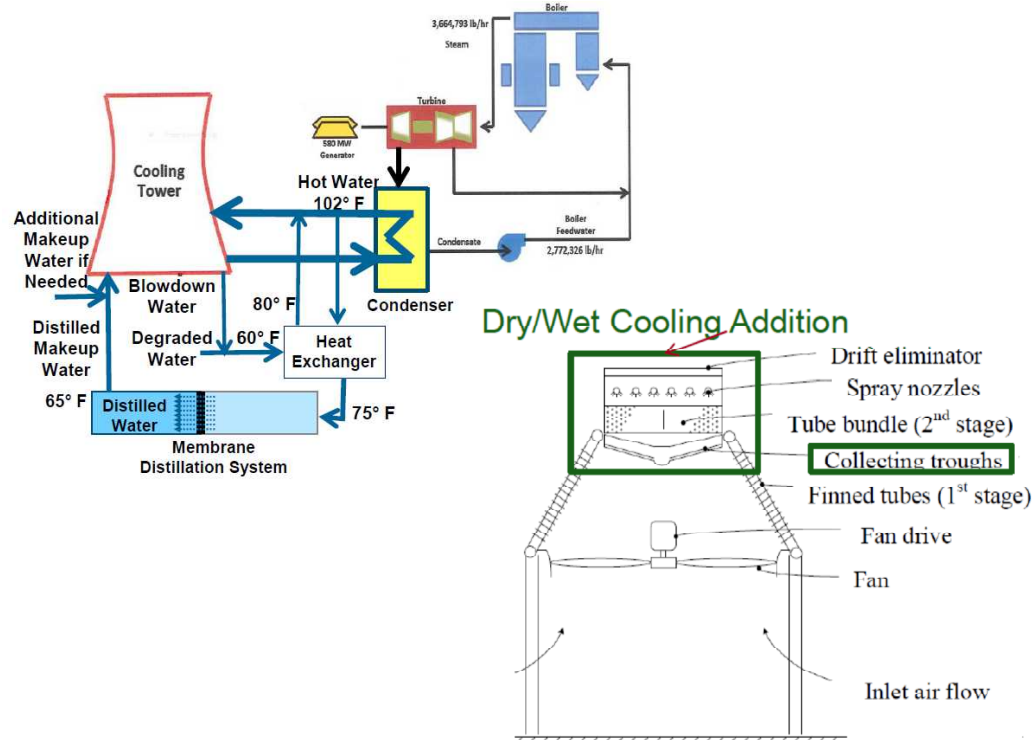
A revised version of the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG), *NSF 13-1*, was issued on October 4, 2012 and is effective for proposals submitted, or due, on or after January 14, 2013. Please be advised that the guidelines contained in *NSF 13-1* apply to proposals submitted in response to this funding opportunity. Proposers who opt to submit prior to January 14, 2013, must also follow the guidelines contained in *NSF 13-1*.

Please be aware that significant changes have been made to the PAPPG to implement revised merit review criteria based on the National Science Board (NSB) report, *National Science Foundation's Merit Review Criteria: Review and Revisions*. While the two merit review criteria remain unchanged (Intellectual Merit and Broader Impacts), guidance has been provided to clarify and improve the function of the criteria. Changes will affect the project summary and project description sections of proposals. Annual and final reports also will be affected.

A by-chapter summary of this and other significant changes is provided at the beginning of both the *Grant Proposal Guide* and the *Award & Administration Guide*.

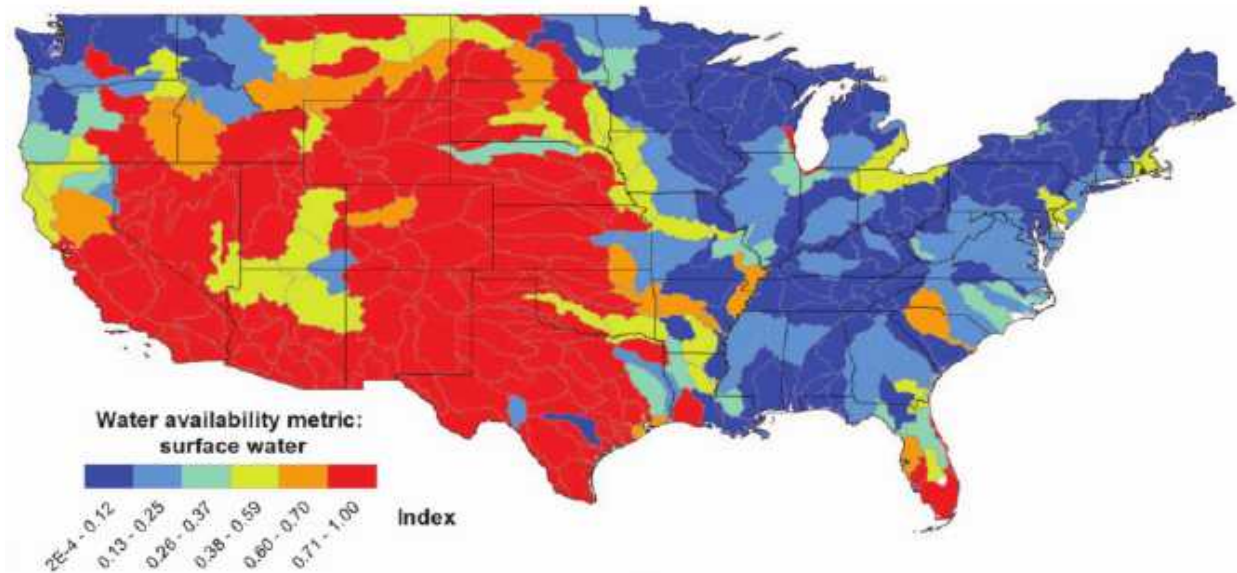
Please note that this program solicitation may contain supplemental proposal preparation guidance and/or guidance that deviates from the guidelines established in the *Grant Proposal Guide*.

### SUMMARY OF PROGRAM REQUIREMENTS

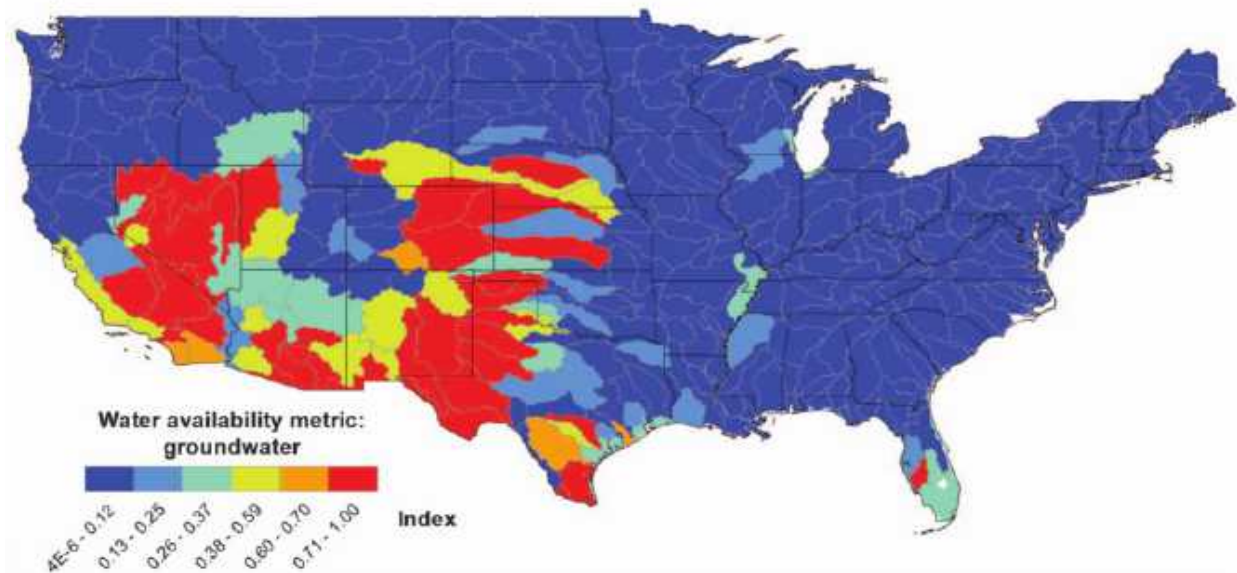


# Water Limited Basins

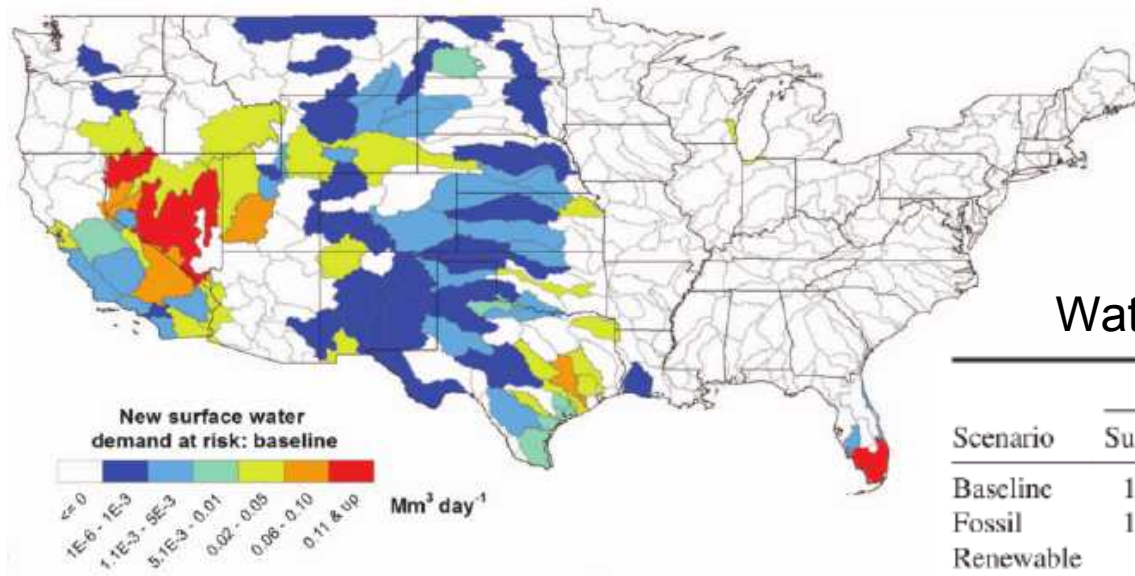
Surface Water  
Availability



Groundwater  
Availability

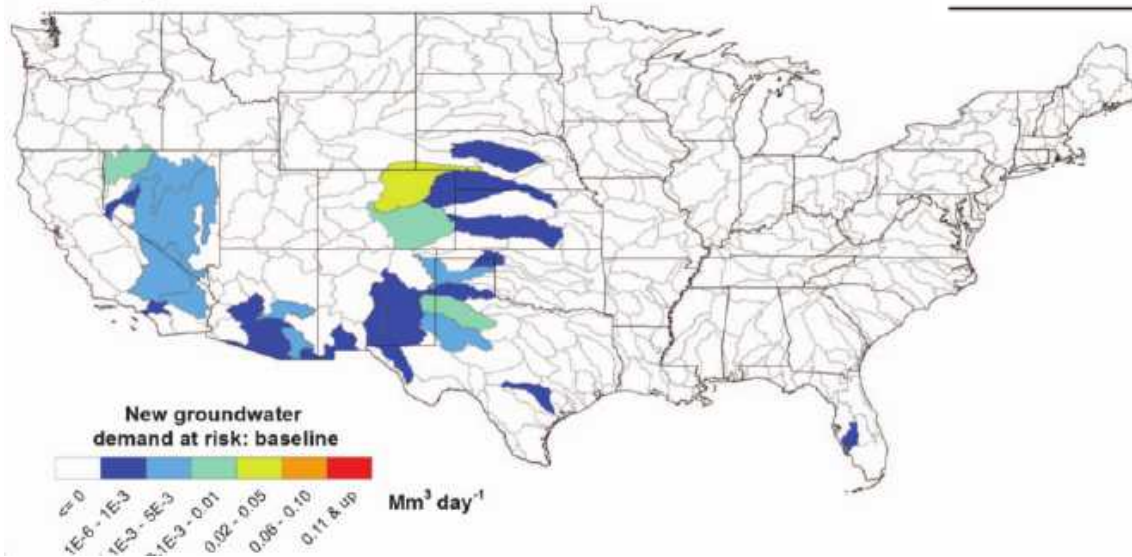


# Thermoelectric Development in Water Limited Basins



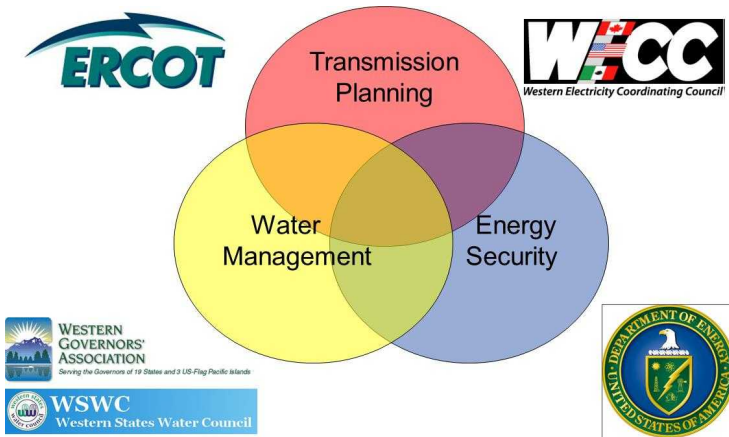
## Water and Power at Siting Risk

Scenario	Power (MMWh)		Water (Mm <sup>3</sup> /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%)



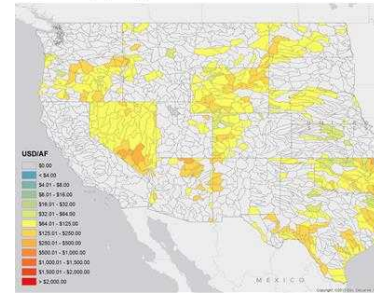


# Integrated Energy-Water Planning

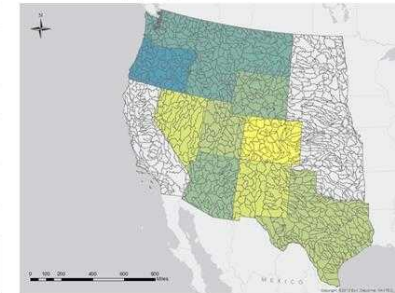


## Water Cost Metrics

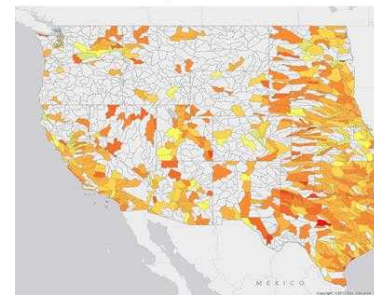
Unappropriated Groundwater



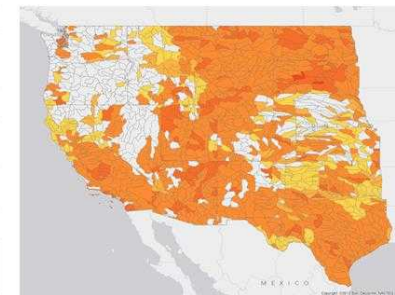
Appropriated Water



Municipal Wastewater

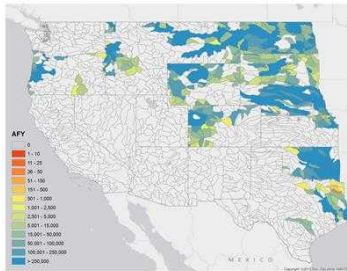


Brackish Groundwater

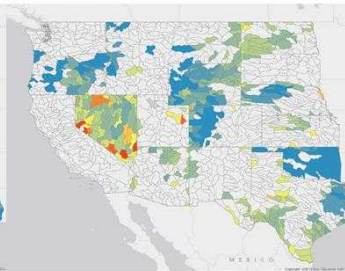


## Water Availability Metrics

Unappropriated Surface Water

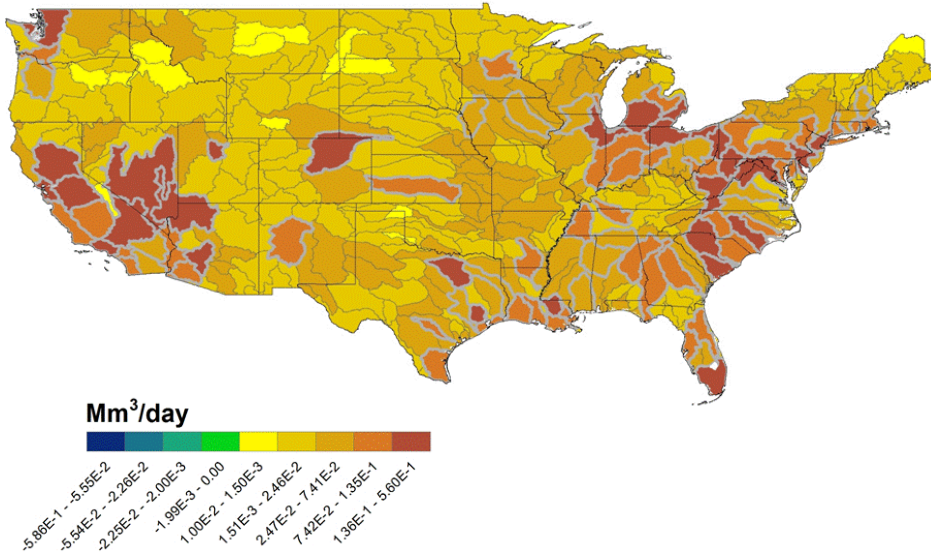


Unappropriated Groundwater



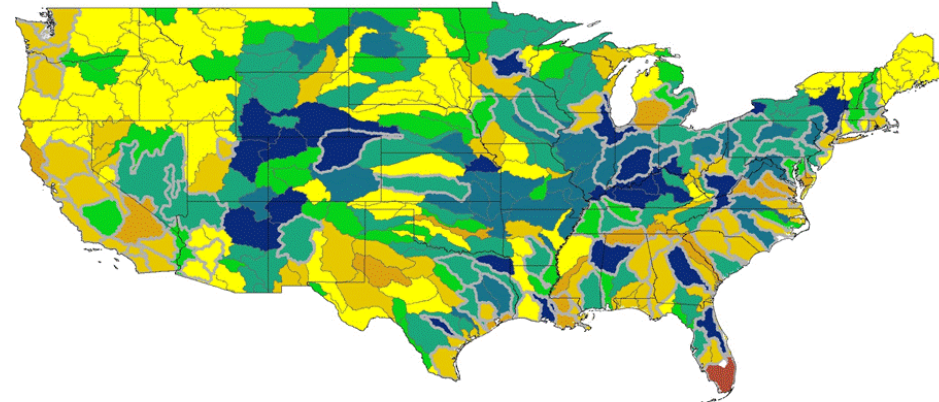
# Water from Retiring Plants

Change in non-thermoelectric water use 2009-2035



- New capacity in U.S. is largely renewables and natural gas
- Retirement or de-rating of older plants result in net water savings

Change in thermoelectric water use: \$15/tonne CO<sub>2</sub> no retrofit



**Table 3. Thermoelectric Power Production and Associated Freshwater Consumption at Siting Risk Due to Limited Water Availability. T<sup>a</sup>**

	electricity (TWh)	water consumption (Mm <sup>3</sup> /d)
reference	154	0.55 (0.53, 0.57)
\$15 CO <sub>2</sub> no retrofit	135	0.47 (0.44, 0.51)
\$15 CO <sub>2</sub> full retrofit	146	0.96 (0.93, 1.0)
\$25 CO <sub>2</sub> no retrofit	113	0.44 (0.41, 0.48)
\$25 CO <sub>2</sub> full retrofit	127	0.95 (0.92, 0.99)



# 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 wastewater
- Brackish groundwater

## **Costs:**

Capital

Operating and Maintenance (O&M) costs

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

Treatment

Parasitic energy losses

## **Availability:**

Municipal wastewater: within 50 miles

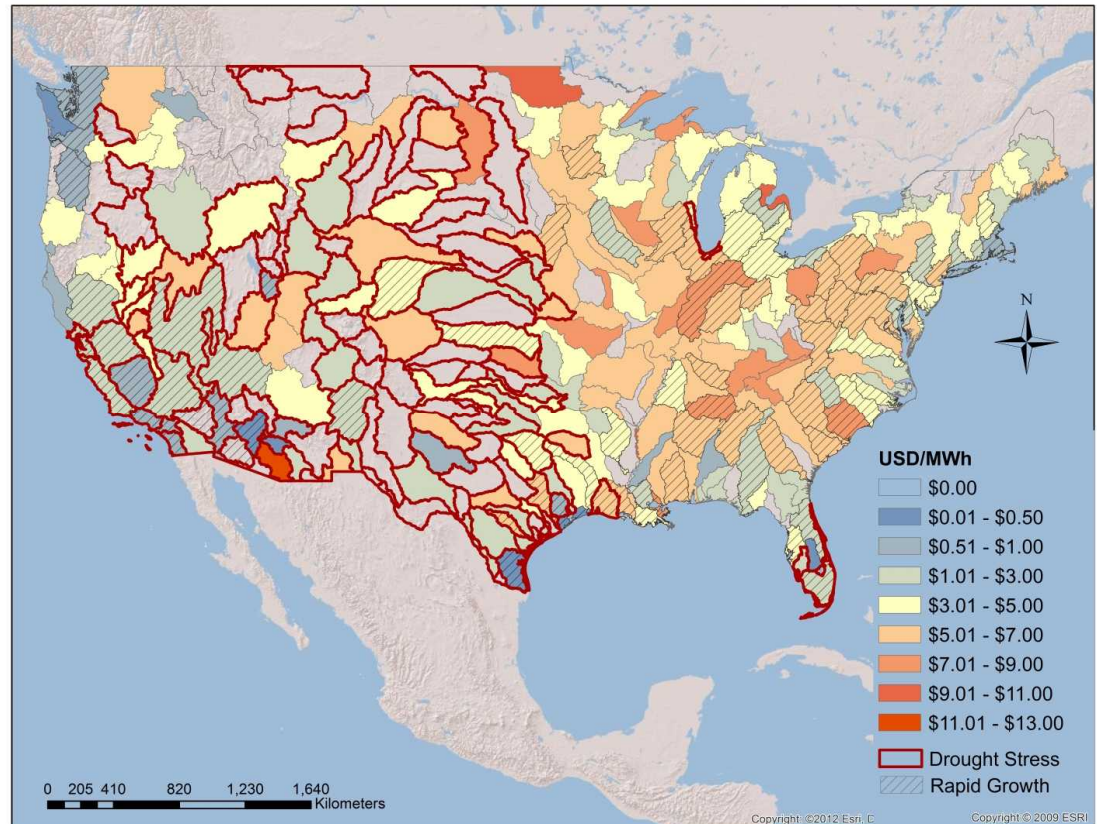
Brackish water: <2500 ft deep, salinities >10,000 TDS

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

# Cost Associated with Retrofit

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

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



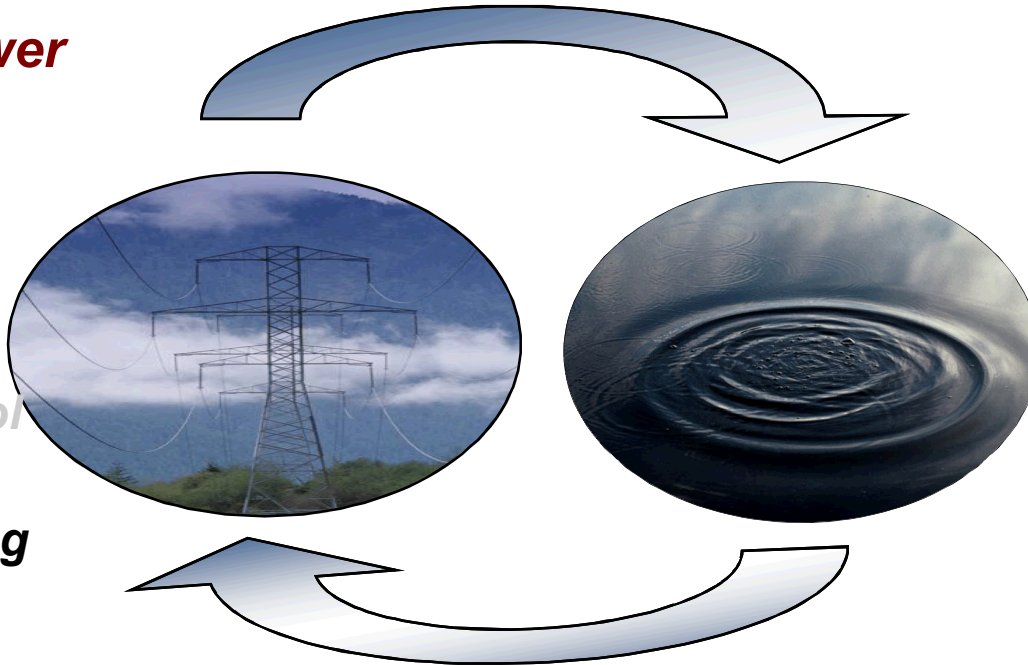
*With wholesale cost of electricity about \$40/MWh\*, many retrofits could be accomplished at levels that would add less than 10% to current power plant generation expenses.*

\*average 2012 wholesale cost over 3 US trading hub regions

# Energy-Water Nexus

## **Energy and power production requires water**

- **Thermoelectric Cooling**
- **Emission Control**
- **Energy Minerals Extraction/Mining**
- **Fuel Processing (fossil fuels, H<sub>2</sub>, biofuels)**

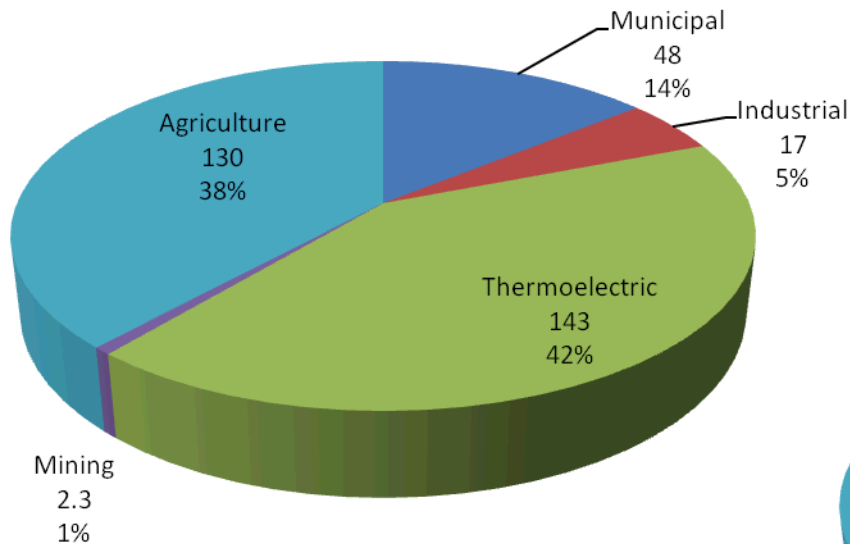


## **Water production, processing, distribution, and end-use requires energy**

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

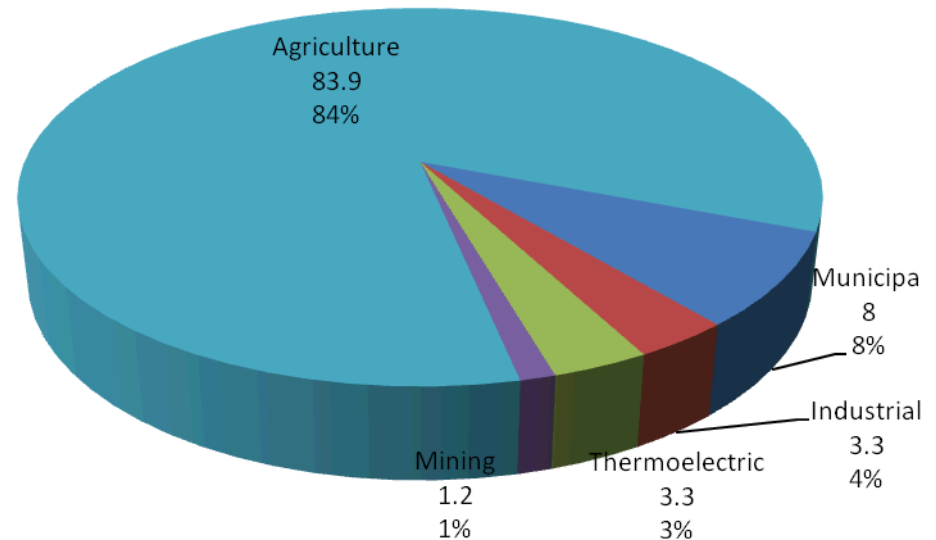
# Water for Fuel Extraction and Processing

## Water Withdrawal (BGD) 2005



*Estimated at ~1 BGD consumed  
in mining and fuel processing*

## Water Consumption (BGD) 1995



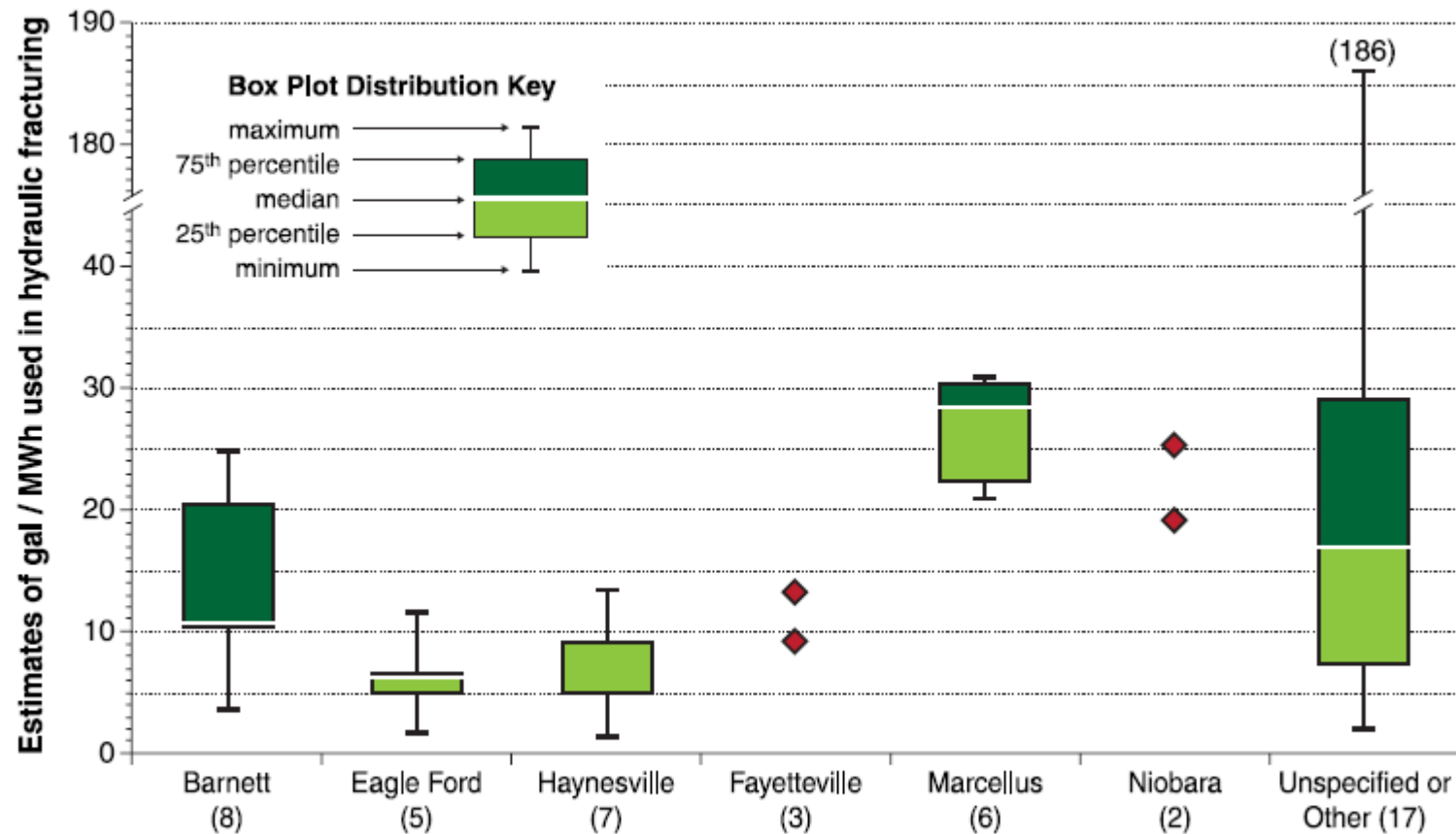


# Gas and Oil Shale Development





# Water Use in Hydraulic Fracturing



# Reducing Water Impacts

- Re-use of produced water
- Use of brackish water
- Protection of fresh water resources



**EPA** United States Environmental Protection Agency


Español | 中文: 繁體版 | 中文: 简体版 | Tiếng Việt | 한국어

Learn the Issues | Science & Technology | Laws & Regulations | About EPA

Search EPA.gov


Contact Us | Share

## 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 \(SAB\)](#)

[Contact Us](#) to ask a question, provide feedback, or report a problem.


EPA Home | Privacy and Security Notice | Contact Us

News by E-mail | Widgets | News Feeds | Podcasts | EPA Blog

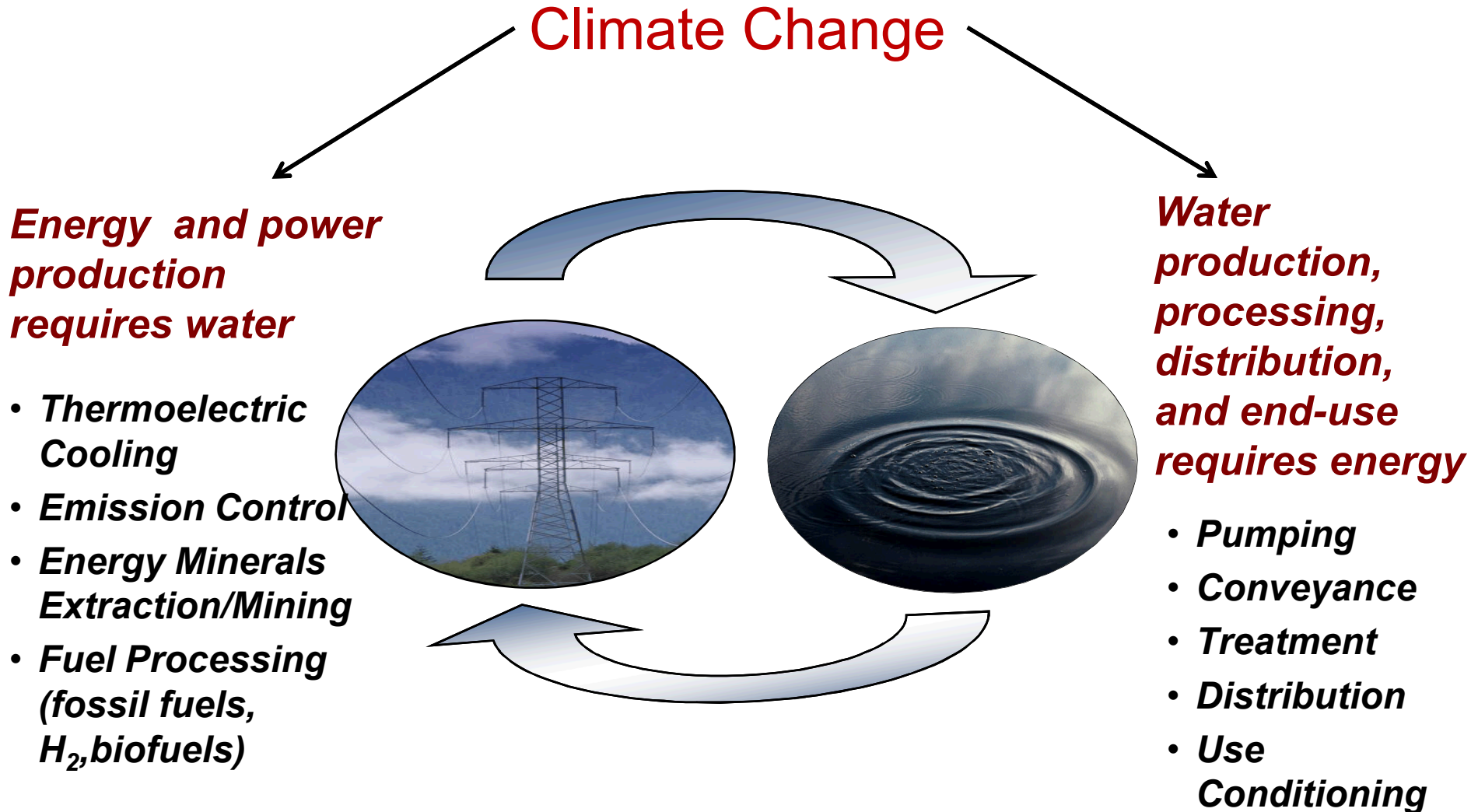
Last updated on February 3, 2014

Social sites:     

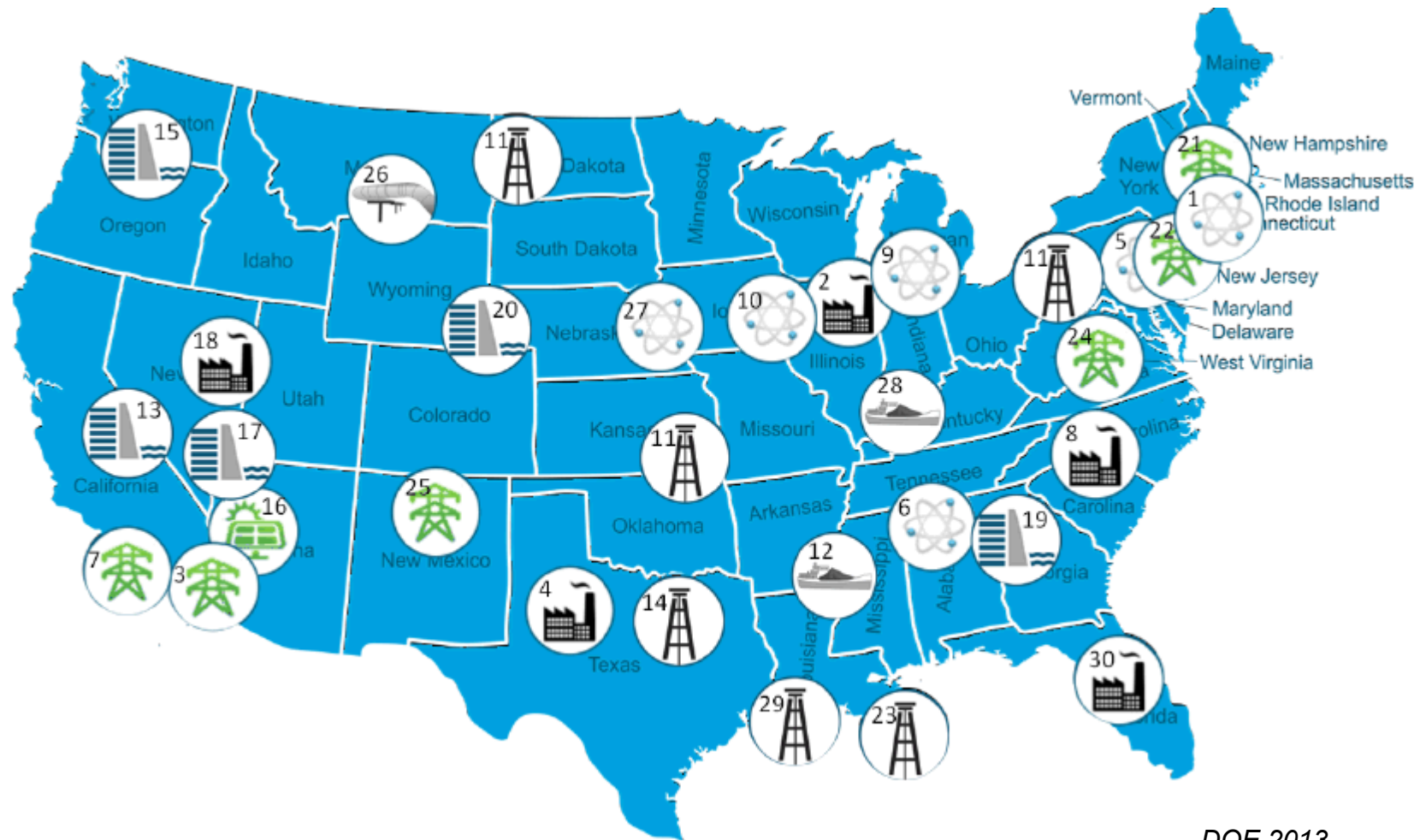
More social media at EPA »



# Energy-Water-Climate Nexus



# Energy-Water-Climate Nexus in the News

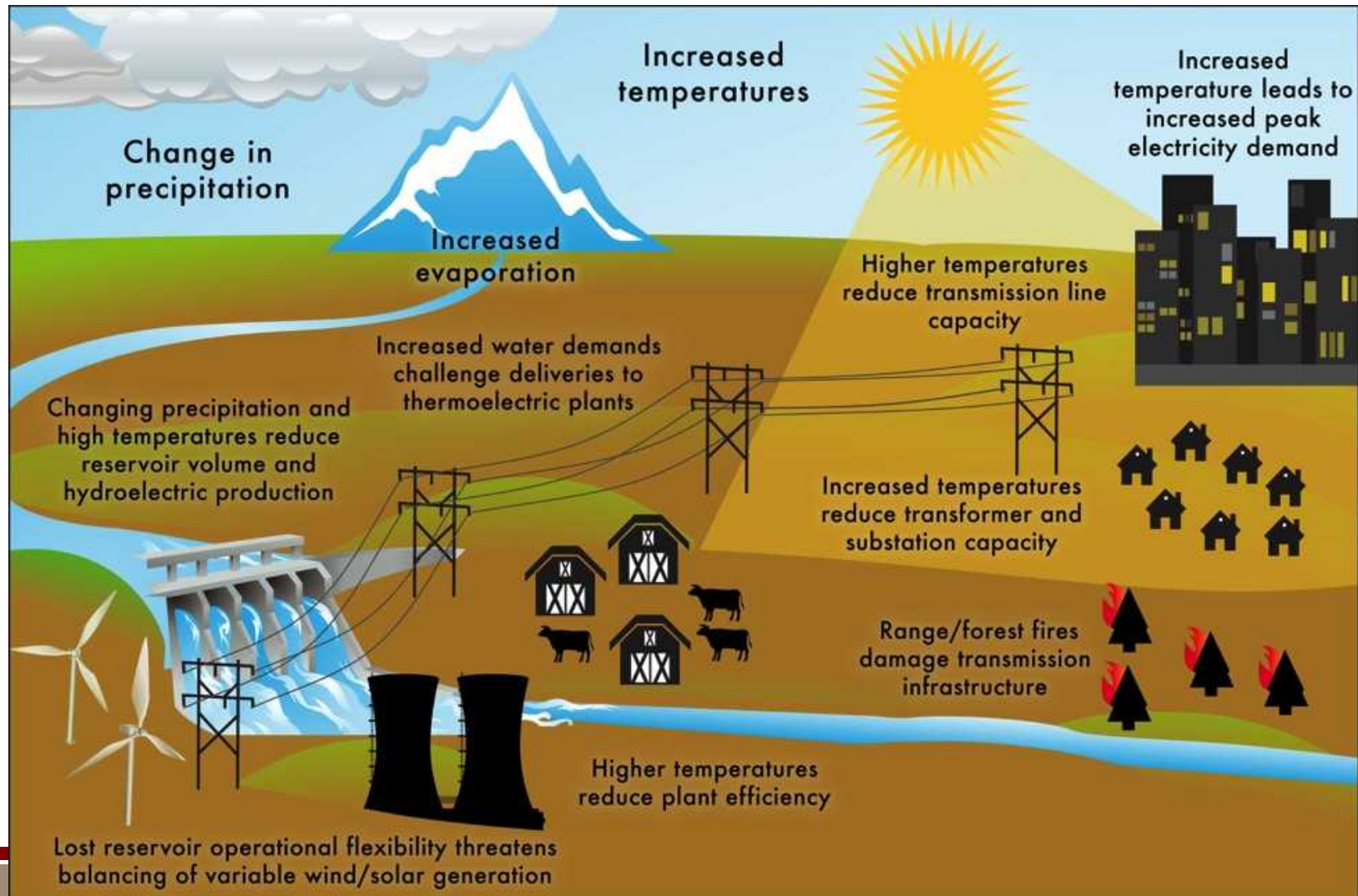


DOE 2013



# Cascading Impacts of Climate Change

*Delivery of electricity may become more vulnerable to disruption due to climate-induced impacts*





# Energy-Water Nexus



- A challenge that we both share
- We are not that different
  - Share similar climates
  - Use similar energy and water technologies
  - Share similar opportunities to manage the energy-water nexus
  - Share similar concerns over the impacts of climate change
- Many benefits to be realized if we work together

# Points of Coordination

- Department of Energy: Water-Energy Technical Team
- Environmental Protection Agency:
  - Water/Wastewater
  - Energy/Water efficiency
- Electric Power Research Institute: Industry Partner

