

The Big Picture: Nationwide Drivers and Strategies for Water-Energy Savings



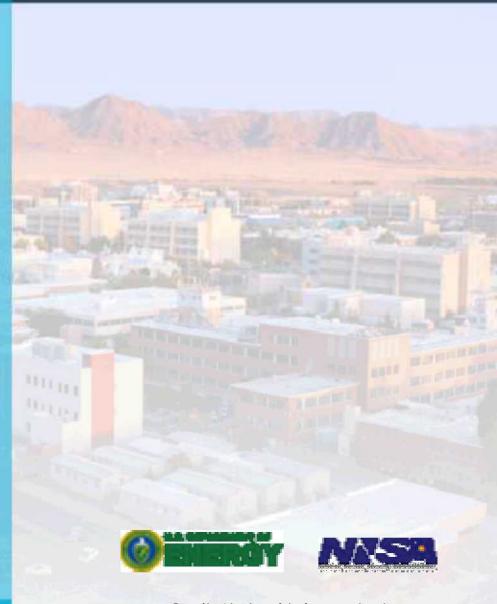
PRESENTED BY

Vincent Tidwell
Sandia National Laboratories

*National Governors Association
Water-Energy Nexus Learning Lab
September 1, 2020*



SAND2020-8974PE



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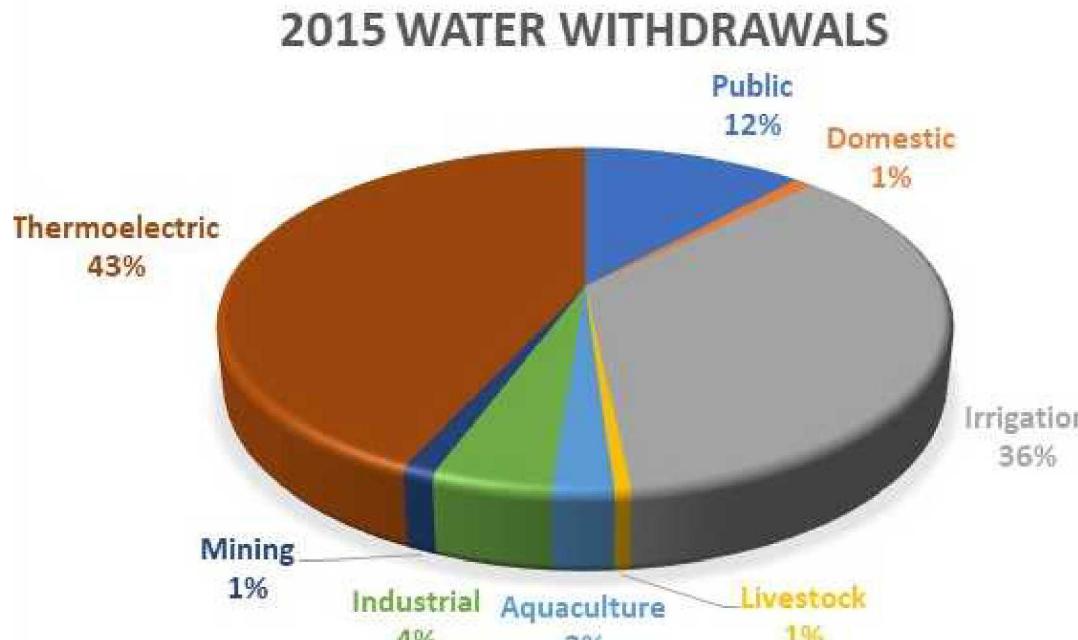
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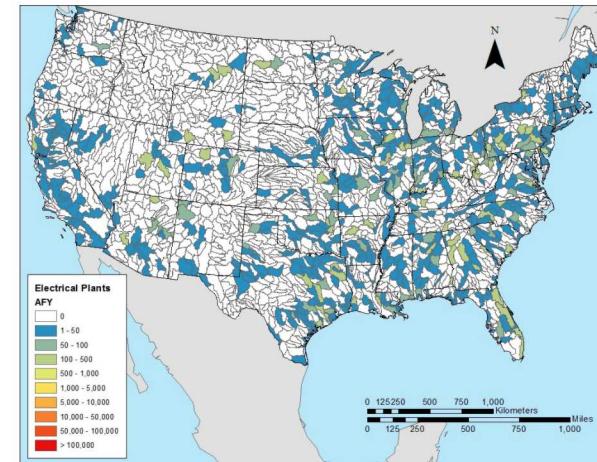
Water for Energy



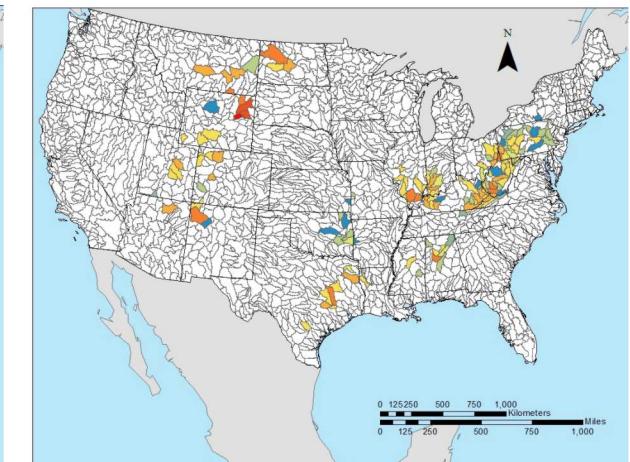
322 BGD Total Withdrawals
~7-8 BGD Total Consumption

Water Consumption by County

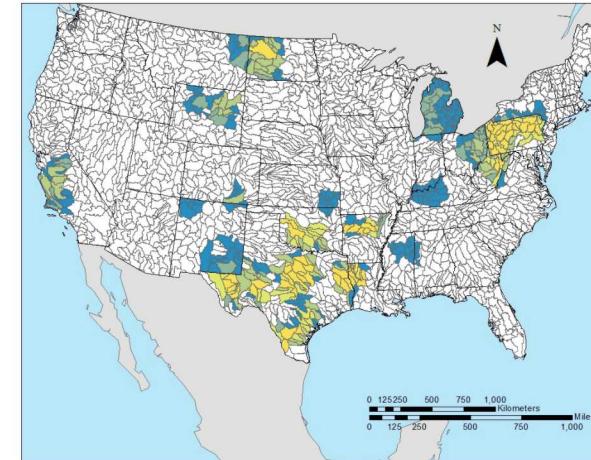
Thermoelectric



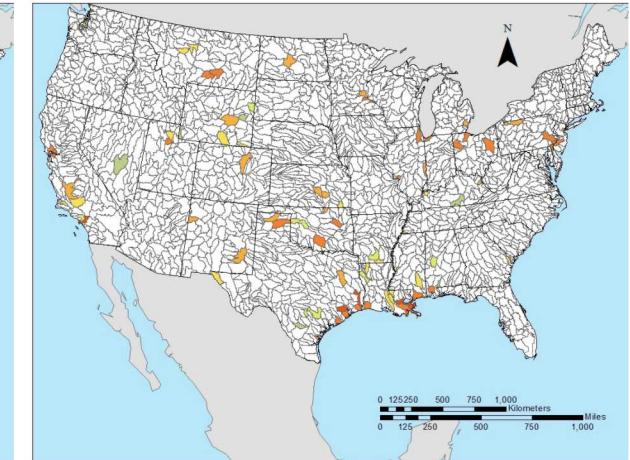
Coal



Unconventional Oil and Gas



Refineries



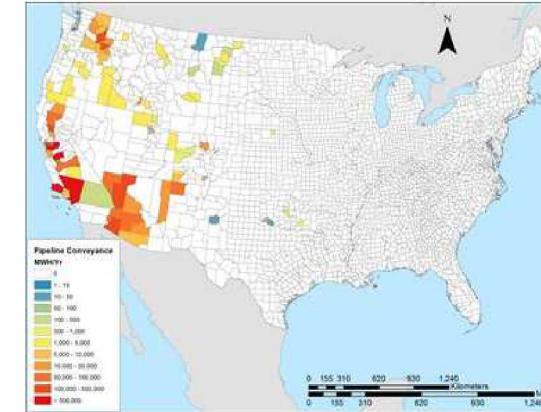
Source: Tidwell et al. 2016

Energy for Water

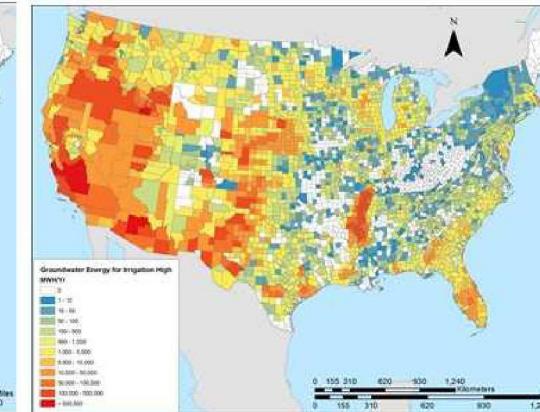
Water Sector
Consumes 4-8%
of Total U.S.
Energy
Production

Energy Consumption by County

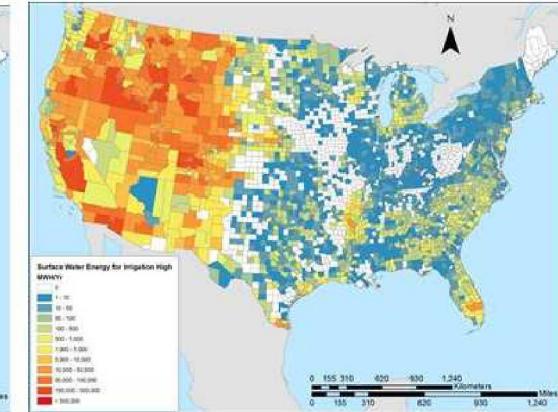
Large-Scale Conveyance



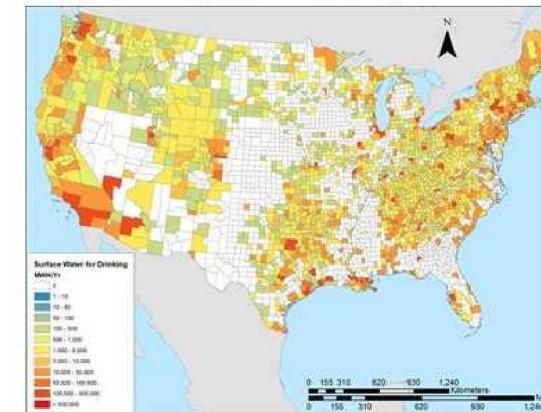
Agricultural Pumping
(Groundwater)



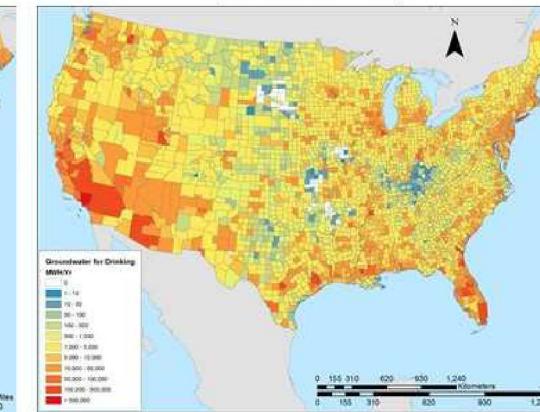
Agricultural Pumping
(Surface Water)



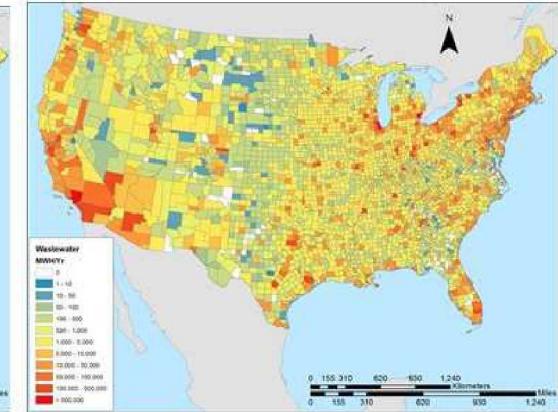
Drinking Water
(Surface Water)



Drinking Water
(Groundwater)

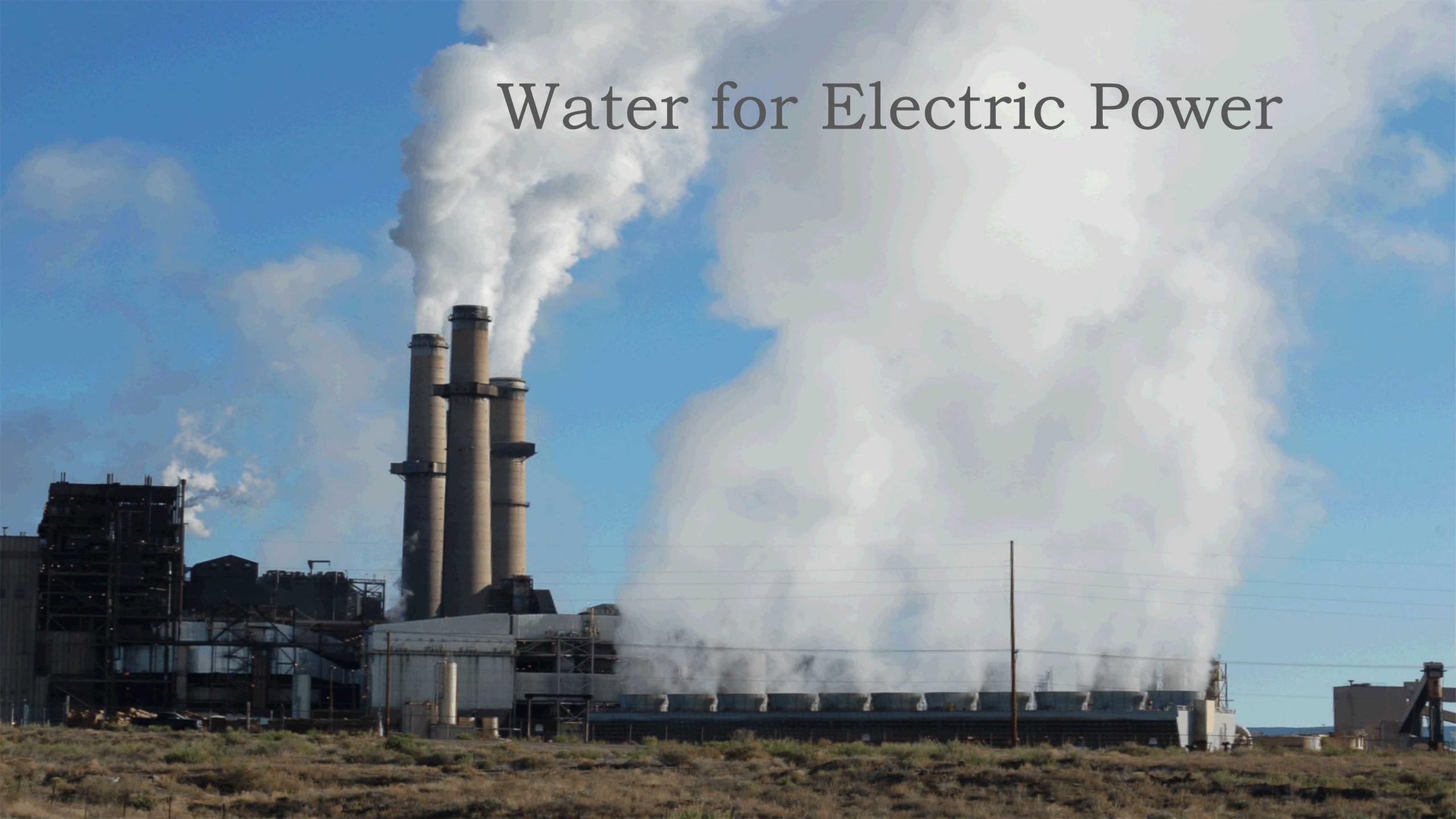


Municipal Wastewater



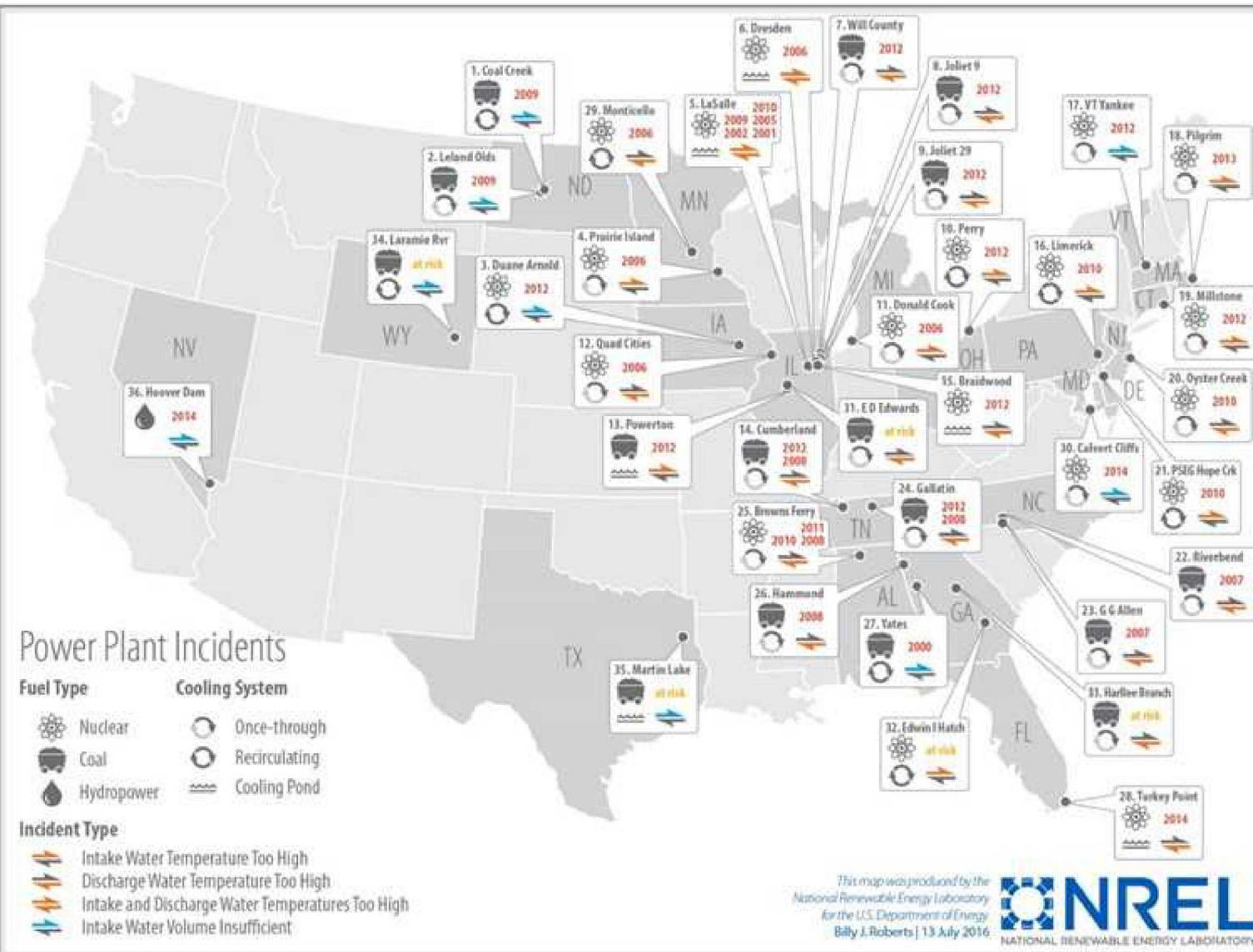
Source: Tidwell et al. 2014

Water for Electric Power



Current Impacts

Climate Extremes Impact Power Production



Water Scarcity Impacts Plant Siting



Idaho Places Moratorium on Coal-Fired Power Plants

May 24, 2006

The legislation was inspired in part by a controversial plan by California-based Sempra Energy to build a 600-megawatt plant in Jerome County, approximately 100 miles southeast of Boise. Following the Senate's passage of H. 791, Sempra announced that it would and efforts to construct the Jerome County project and a similar project in northern Nevada. Craig D. Rose, *Nevada, Idaho Projects Ran Into Stiff Opposition*, San Diego Union Tribune (March 30, 2006). In a letter to Idaho Governor Kempthorne, Sempra stated that it withdrew from the Idaho project because it was focusing on its natural gas related business. *Id.* Sempra plans on seeking buyers for the development it has already done at the site. *Id.*

Introduced by House Speaker Bruce Newcomb (R), H. 791 was passed by the Idaho House on a 65-1-1 vote on March 21, 2006, and by the Senate on a 30-5 vote eight days later. Rebecca Meany, *Power Plant Moratorium Bill on Governor's Desk*, Idaho Mountain Express (March 31, 2006). The Idaho Legislature found that it was "in the public interest to adopt an integrated energy plan... that provides for the state's power generation needs and protects the health and safety of the citizens of Idaho." *H. 791*. The Legislature also found that "certain coal-fired power plants may have a significant negative impact upon the health, safety and welfare of the population, the quality and financial security of existing agricultural business... and the environmental quality and natural resources of [the] state." *Id.*

H. 791 amends the Idaho Environmental Protection and Health Act, Idaho Code Ann. § 39-101, et seq. Under the act, as amended, municipalities, counties, and the Idaho Department of Environmental Quality are prohibited



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6/20/2019

State denies permit to Burrillville power plant

BURRILLVILLE — In a gripping decision that followed several days of debate, the state Energy Facility Siting Board today denied an application by a Chicago-based Invenergy to build an oil-and-gas-burning power plant on Wallum Lake Road.

The decision came after just a few hours of public debate during which members of the state board expressed doubt about the state's need for energy produced by the plant, a key argument made by representatives of the company.

The decision was a victory for conservationists and local residents, many of

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Company's bid to use groundwater for nuclear plant denied

November 12, 2019

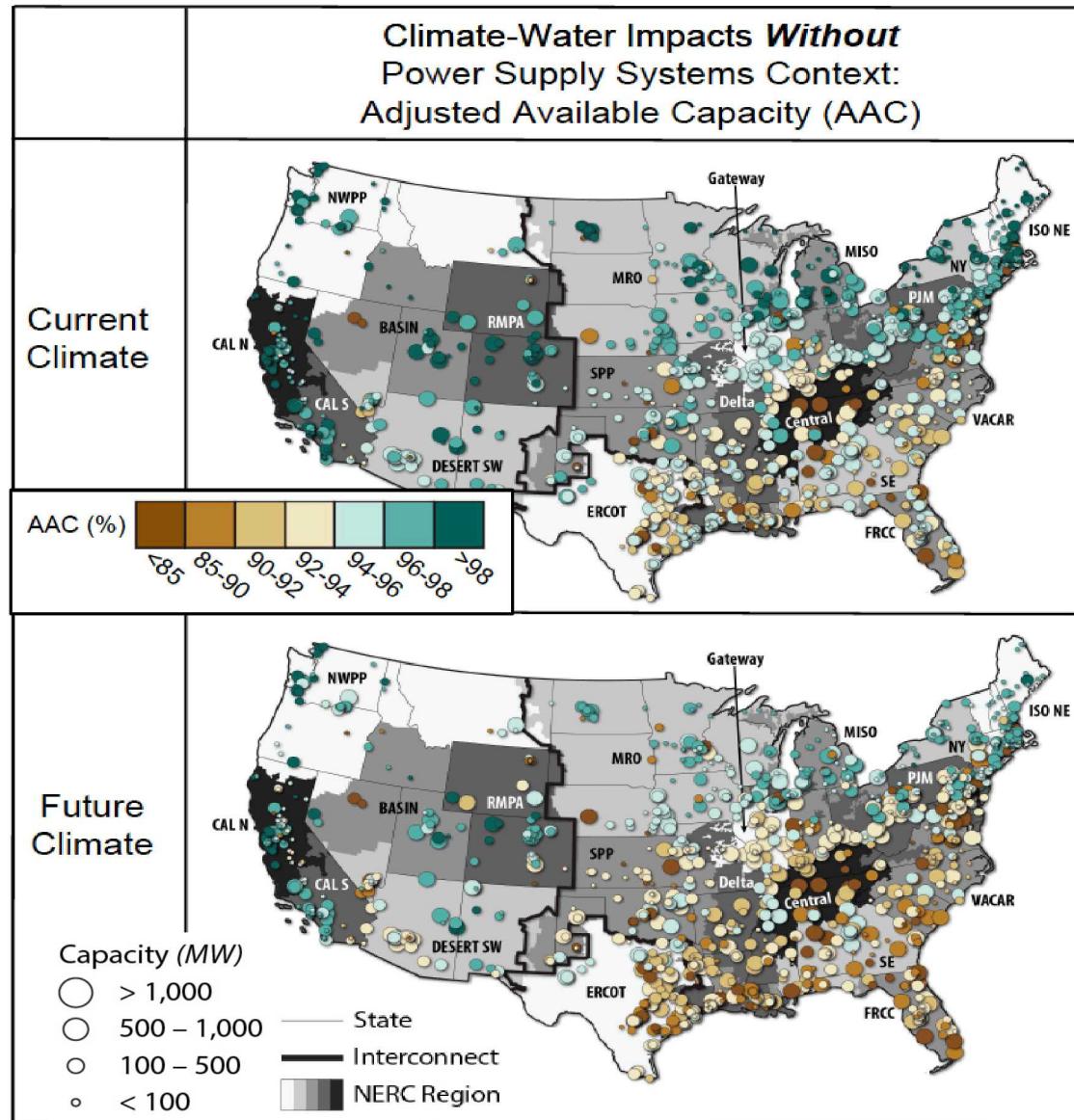
PHOENIX (AP) — Arizona water regulators have rejected an application by an electric utility to build a nuclear power plant west of Phoenix because the water is being used by nearby residents.

The state Department of Water Resources denied the request from Arizona Public Service to build the plant in the Buckeye area and study it as an alternative to expensive reclaimed water because it is Monday.

The permit requires water has no other beneficial use, state department officials said. "The Department finds that this groundwater is currently being used beneficially and deny the application," officials said in the rejection letter.



Intensifying Drought



- Power generation at risk from drought.
- Elevated water temperatures can necessitate plants to limit their generation.
- Shown is the potential impact on current generation capacity:
 - Under current climate, and
 - Under future climate conditions.

Source: Miara et al. 2017

Reduced Water Use

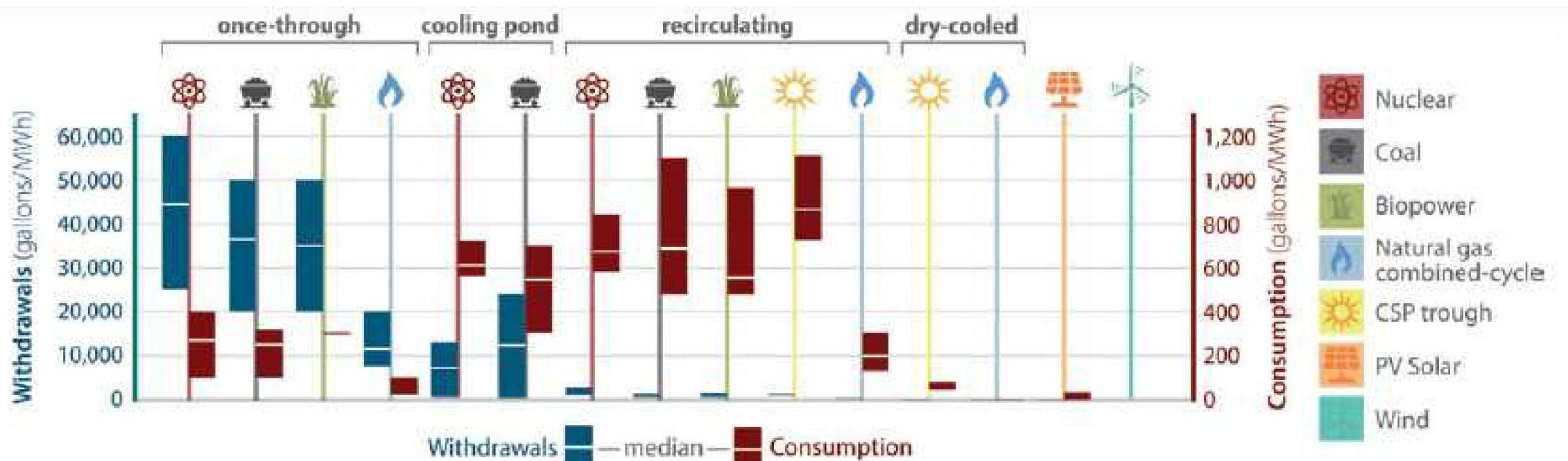
Systems are Moving to Less Water Intensive Forms of Generation

Current generation relies on high-water use technology:

- Coal
- Gas-Steam
- Nuclear

New capacity favors low-water use technology:

- Natural gas combined cycle
- Wind
- Solar PV



Ranges reflect minimum and maximum water-use values.

Source: UCS 2011

Reduced Withdrawals

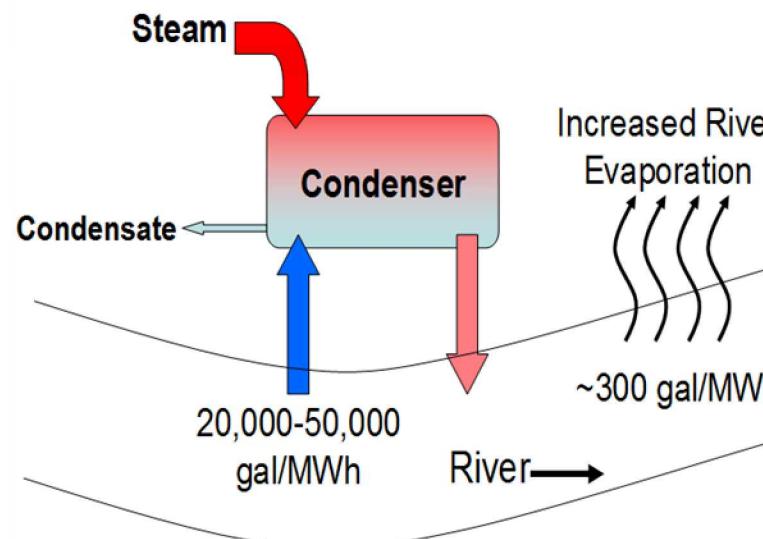
Systems are Moving to Less Water Intensive Forms of Cooling

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Home / Coal / EPA Issues Final Cooling Water Intake 316(b) Rule
EPA Issues Final Cooling Water Intake 316(b) Rule
05/19/2014 | Sonal Patel
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A final rule released by the Environmental Protection Agency (EPA) today will affect cooling water intake structures at 544 U.S. power plants and provide those plants with lower-cost compliance options than previously proposed to reduce fish impingement and entrainment.

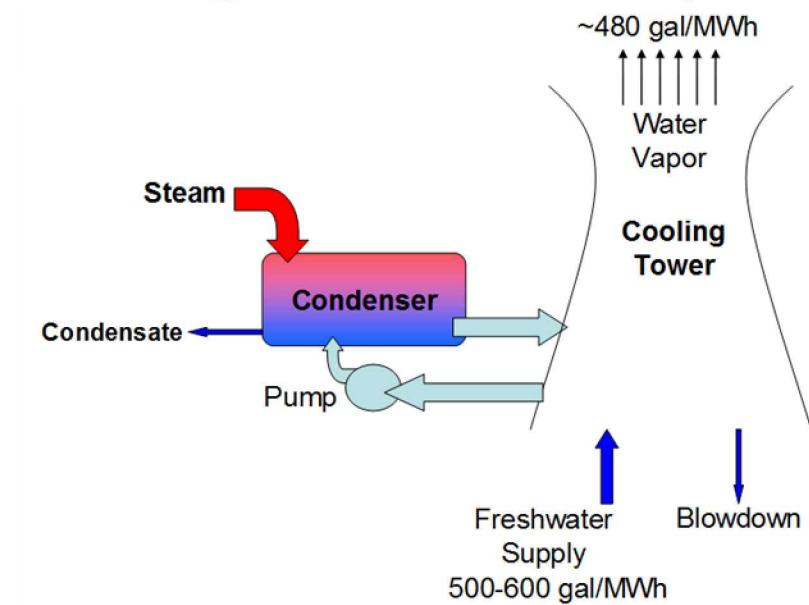
The final rule issued under Section 316(b) of the Clean Water Act applies to facilities that each withdraw at least two million gallons per day of cooling water from waters of the U.S. The national requirements, which will be implemented through National Pollutant Discharge Elimination System (NPDES) permits, "puts implementation analysis in the hands of the permit writers so requirements can be tailored to the particular facility," the EPA said today.

High Water Withdrawal Low Water Consumption



Open-loop "once-through" cooling cycle

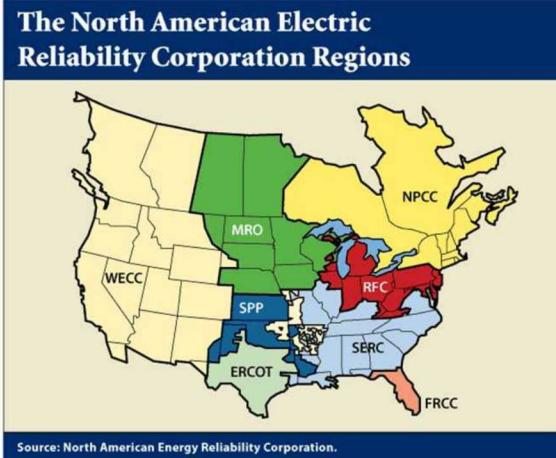
Low Water Withdrawal High Water Consumption



Closed-loop cooling cycle

Source: EPRI 2002

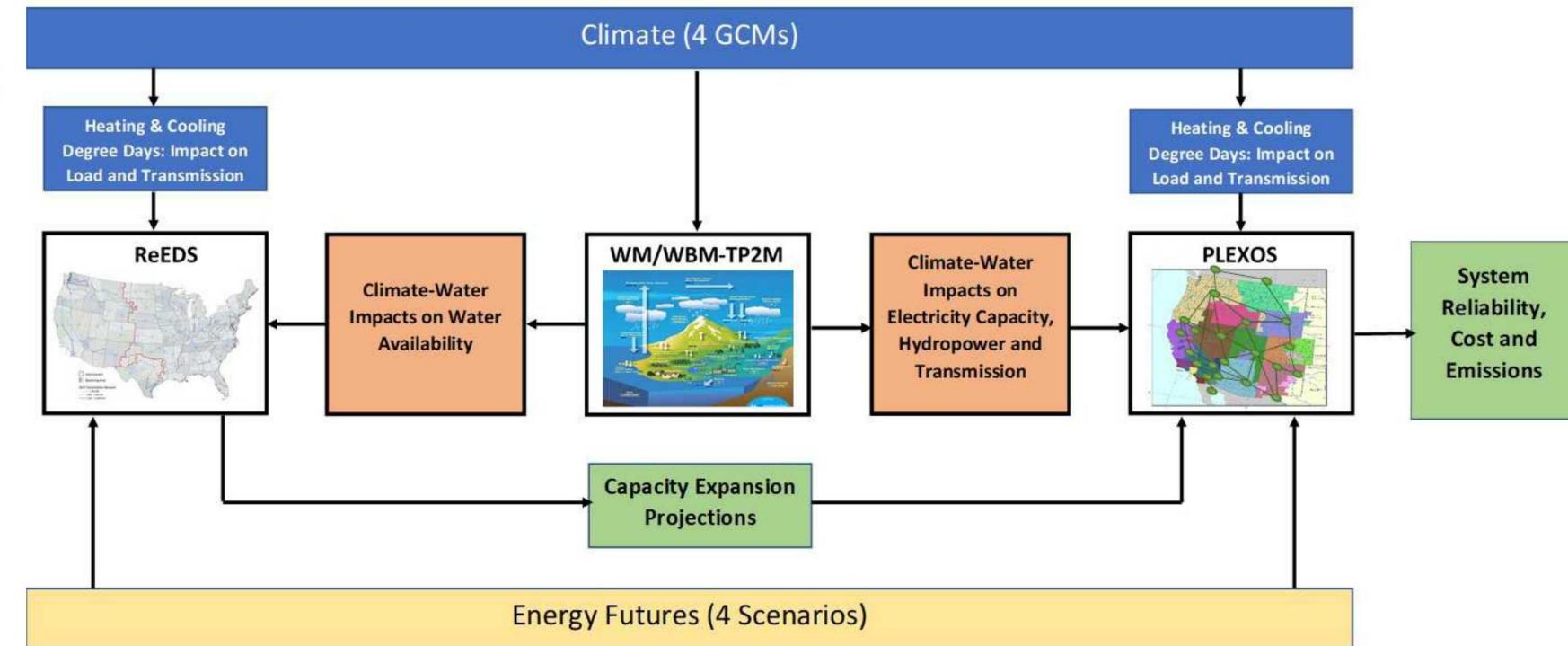
Integrated Planning



Analysis platform included:

- Hydrologic modeling,
- Capacity expansion modeling, and
- Production Cost Modeling

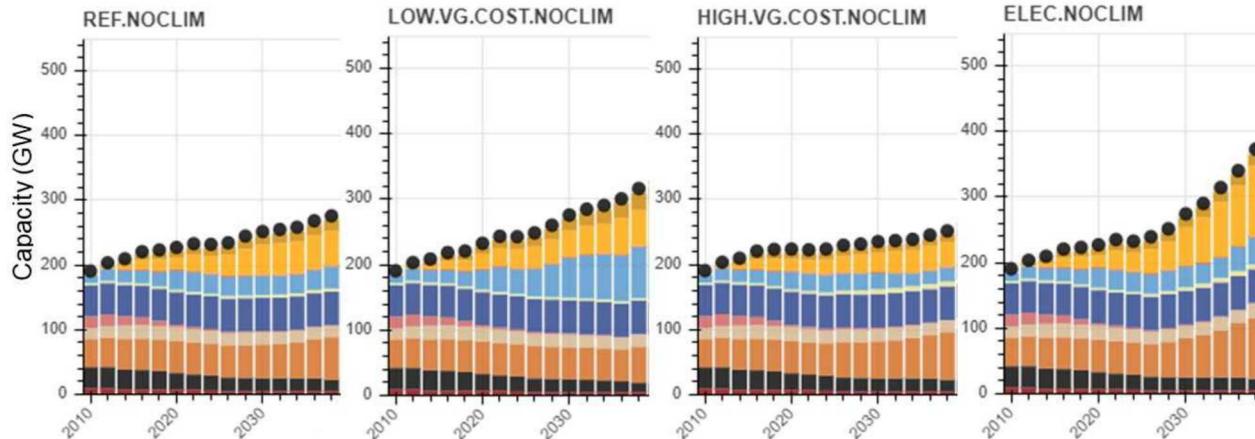
- Integrated climate into WECC's capacity expansion planning exercise
- Explored how water extremes influence planning decisions



Climate Impact on Planning



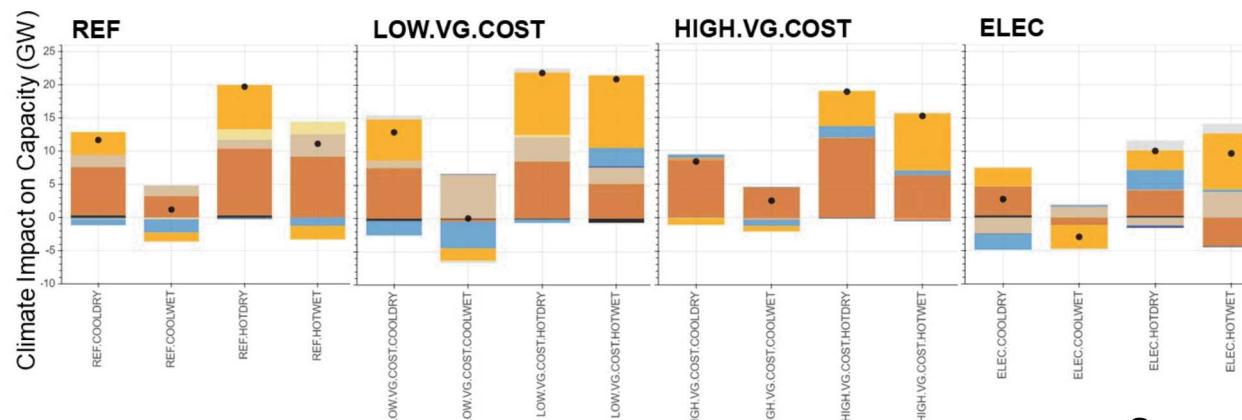
Generation Expansion Profiles



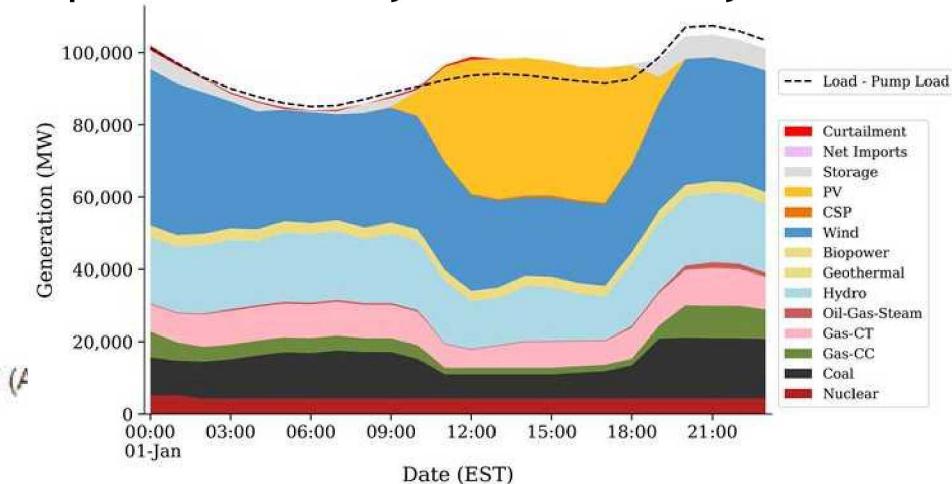
Legend:

- CAES
- Battery
- PSH
- Distributed PV (A)
- PV (AC)
- CSP
- Wind
- Landfill-gas
- Biopower
- Geothermal
- Hydro
- Oil-Gas-Steam
- Gas-CT
- Gas-CC
- Gas-CC-CCS
- Gas-CC
- Cofire
- Coal-IGCC
- Coal
- Nuclear

Difference with and without Water Constraint



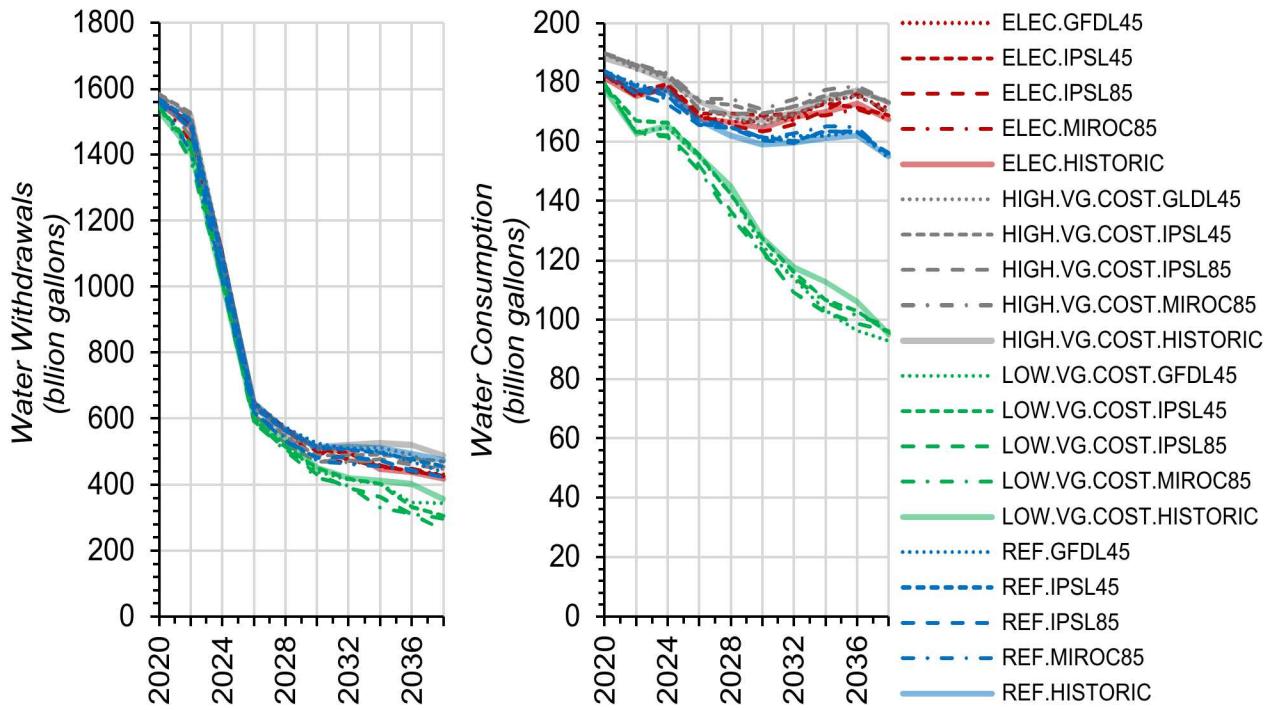
Implications for System Reliability and Cost



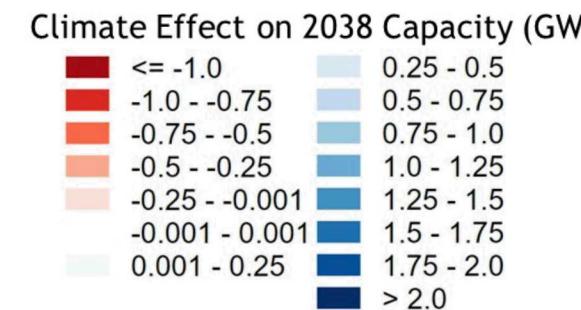
- Additional capacity needed to meet peak load.
- Hydropower production is key uncertainty.
- Considerable adaptive capacity available in the grid.

Climate Impact on Planning

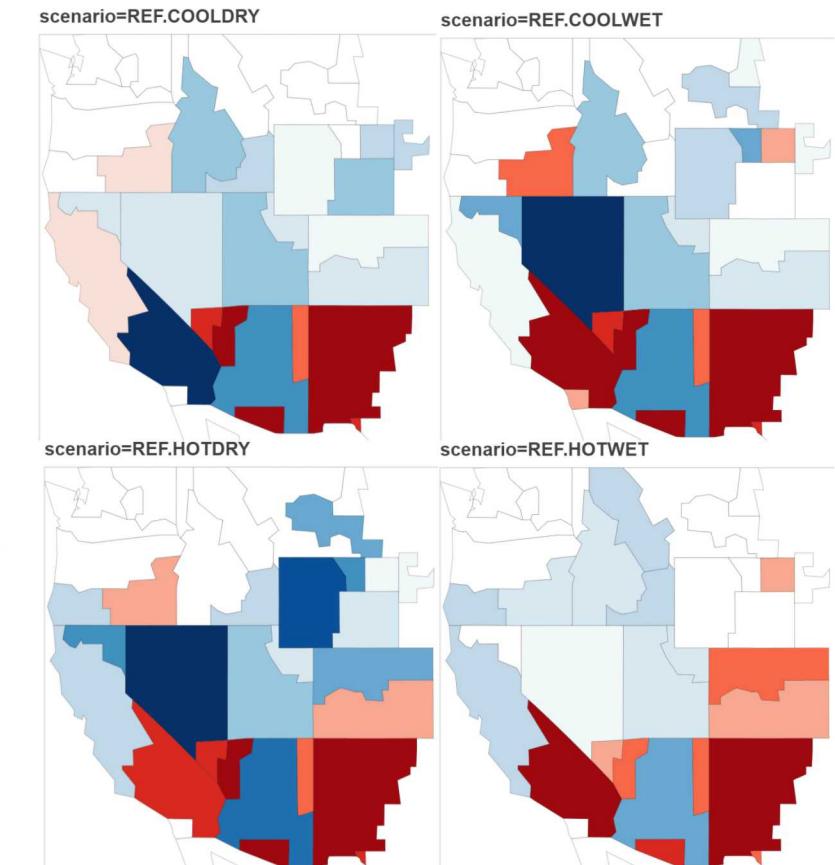
Implications for Future Water Use



Source: Tidwell et al 2020



Combined influence of climate and water availability influence siting decisions



Integrated Plant-Level Planning

Techno-economic assessment of water options for the Palo Verde Nuclear Power Plant, Phoenix, AZ



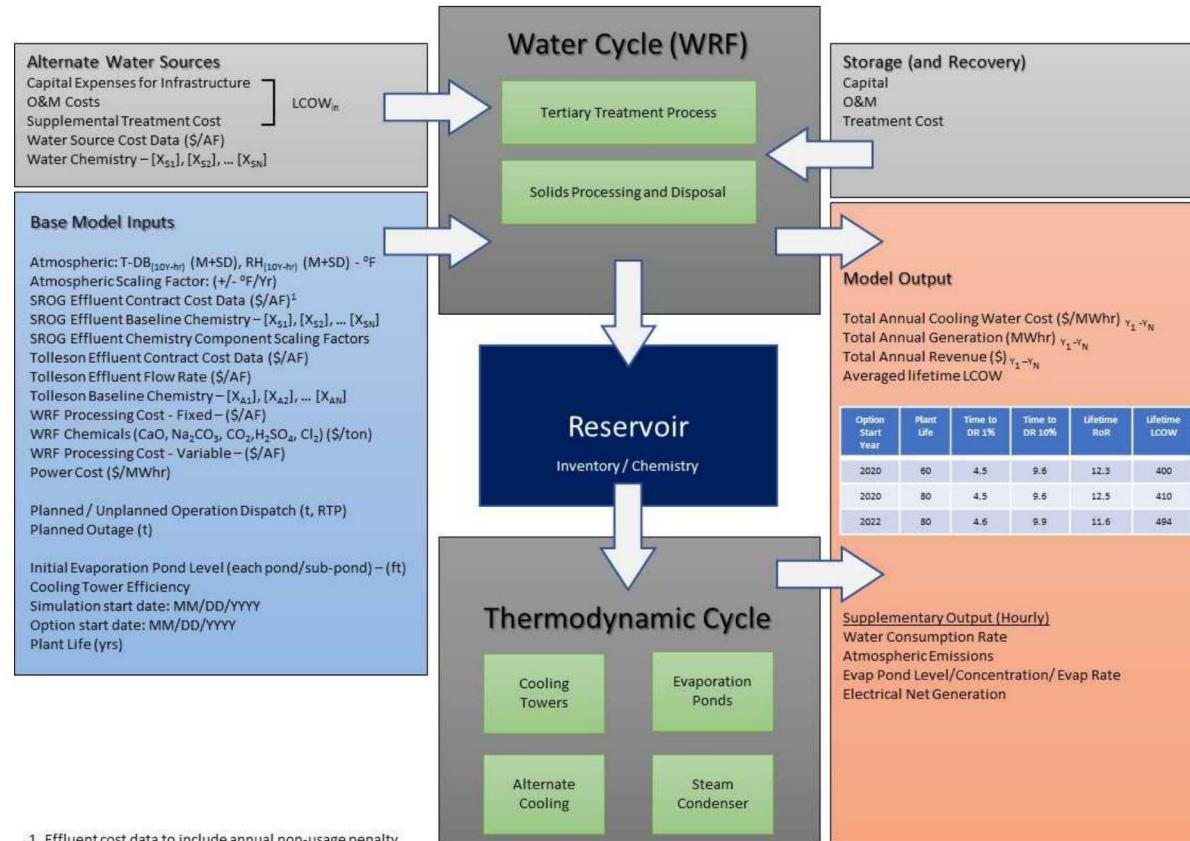
Source: Middleton and Brady 2020

There are many dimensions to a power plant's water footprint:

- Water supply reliability and cost.
- Variable/changing chemistry of water supply.
- Changing cost of cooling and water treatment technology.
- Wastewater management options and costs.

Integrated Plant-Level Planning

Interactive Decision Platform to Support Water Planning



1. Effluent cost data to include annual non-use penalty

Source: Middleton and Brady 2020

Presents tradeoffs in plant economics due to:

- Alternative cooling technologies,
- Water usage and treatment,
- Water disposal options, and
- Influent water chemistry

The screenshot shows the 'ECONOMIC MODEL HOME PAGE' interface. It features a 'Runtime Settings' section with fields for Start Time (1/1/2019), End Time (1/1/2020), and Timestep [hrs] (02:00). It also includes checkboxes for 50-Year Plant Life, 80-Year Plant Life, Custom, Non-Iterative, and Iterative. Below this are buttons for Play, Pause, and Reset. To the right, there are several tabs and sections: 'Water Resources Tertiary Inputs', 'Financial Inputs', 'Power Plant and Unit Status', 'Circulating Water System & Cooling Towers', 'Evaporation Pond Settings', and 'Options and Reference Run Settings'. The bottom of the page includes a 'RESULTS' section, a navigation bar with 'HOME', 'PROJECT DESCRIPTION', 'USER MANUAL', 'ECONOMIC MODEL' (which is highlighted in blue), and 'OPTIMIZATION', and logos for 'Palo Verde' and 'Sands Material Technologies'.

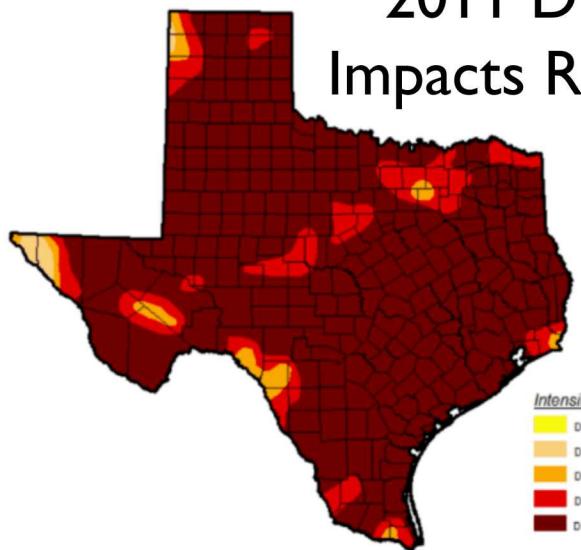
Water for Oil and Gas Production



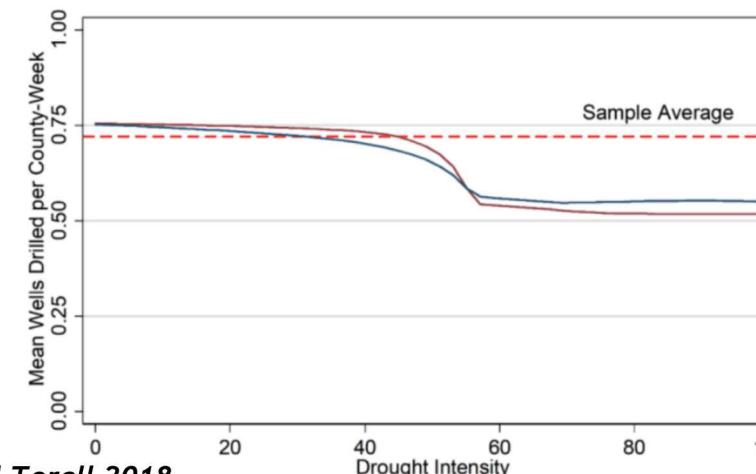
Current Impacts

Water extremes impact oil and gas production:

- Water policy,
- Water cost.



2011 Drought Impacts Rig Count



Disruptions Caused by Drought and Storm Damage



CNN Money

Companies Markets Tech Media

Drought strains U.S. oil production

By Steve Hargreaves @CNNMoney July 31, 2012: 4:55 AM ET

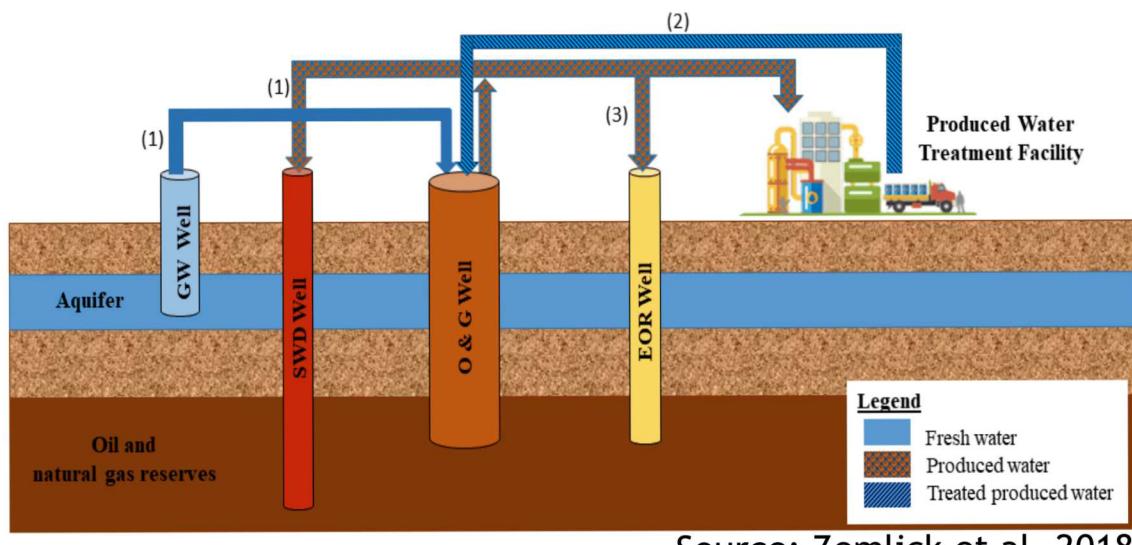
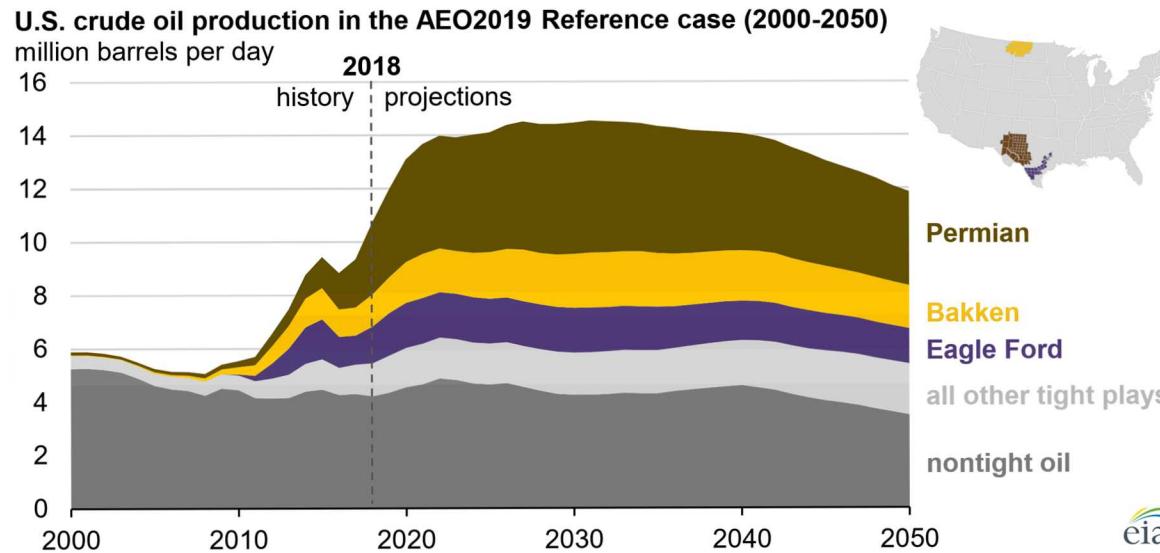


PHOTO: BLAKE ELLIS/CNNMONEY

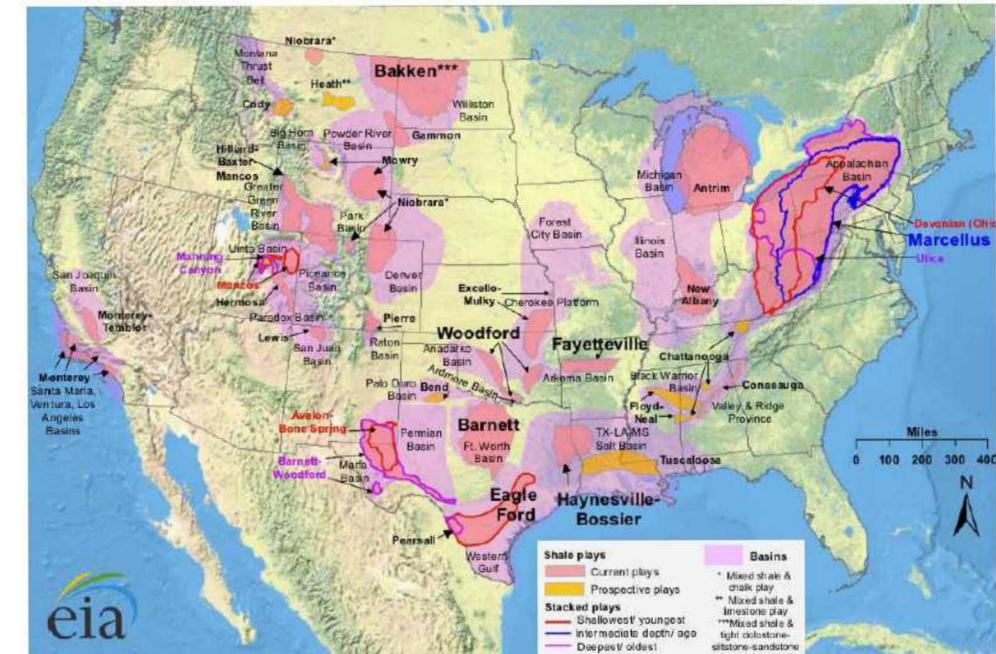
Excavators prepare water for the oil industry in Kansas. The drought is restricting water available for fracking, which could harm U.S. oil production.

Intensifying Demands

Projected Increases in Production



Much of Production in Water-Limited Regions



Water choices are complicated:

- Alternative water sources,
- Water disposal options,
- Intensity of production, and
- Produced water use options.

Produced Water Solutions

Recycle produced water



Source: American Oil and Gas Reporter 2020

- 25BG of water used in unconventional oil production each year
- Over one trillion gallons of produced water generated in 2012
- \$40B in annual disposal costs

Fit-for-use treatment: Reclaiming well pads



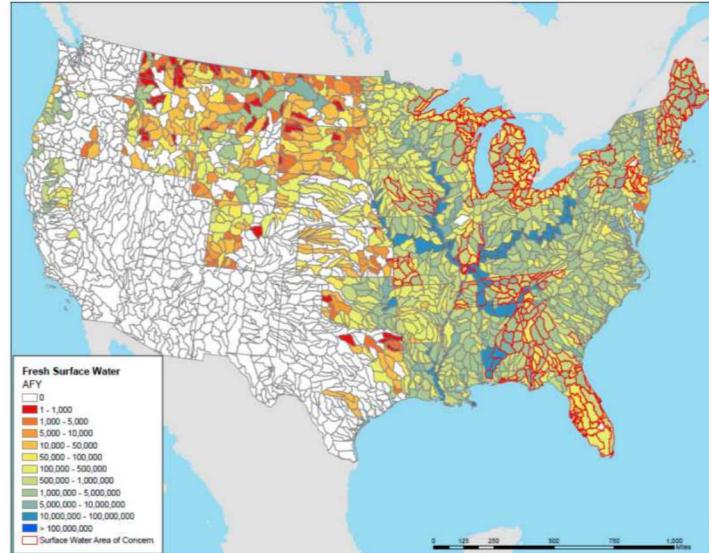
Source: Dwyer and McDonald 2016



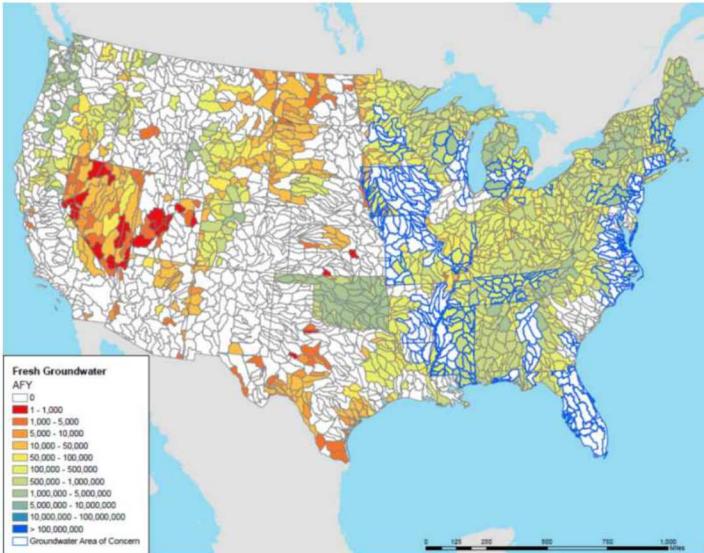
Energy for Water

Supply and Demand

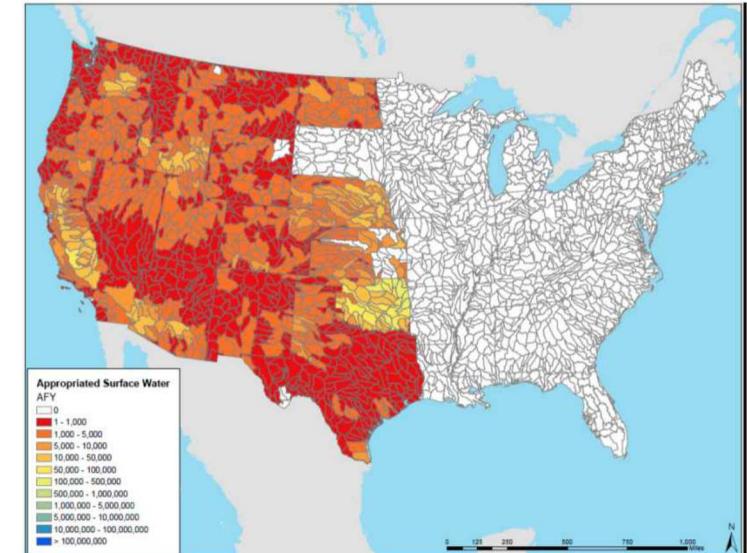
Fresh Surface Water



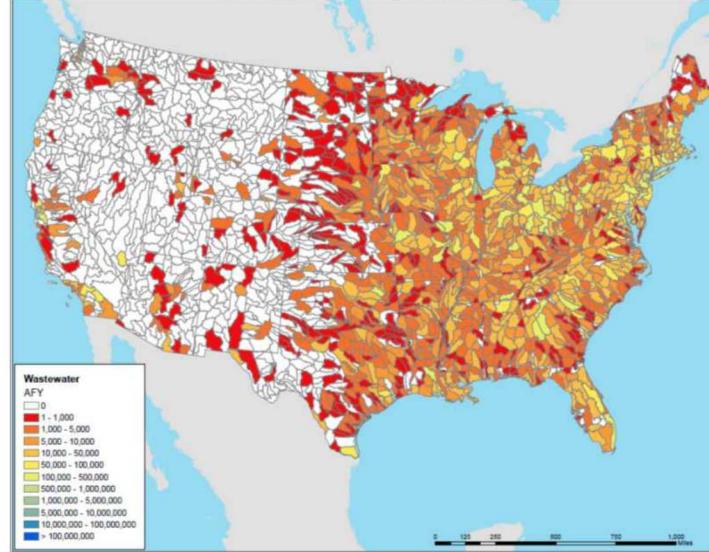
Fresh Groundwater



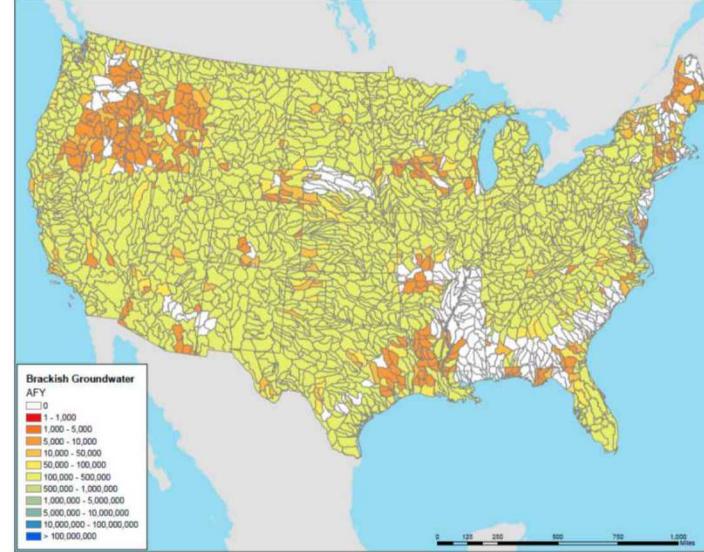
Appropriated Water



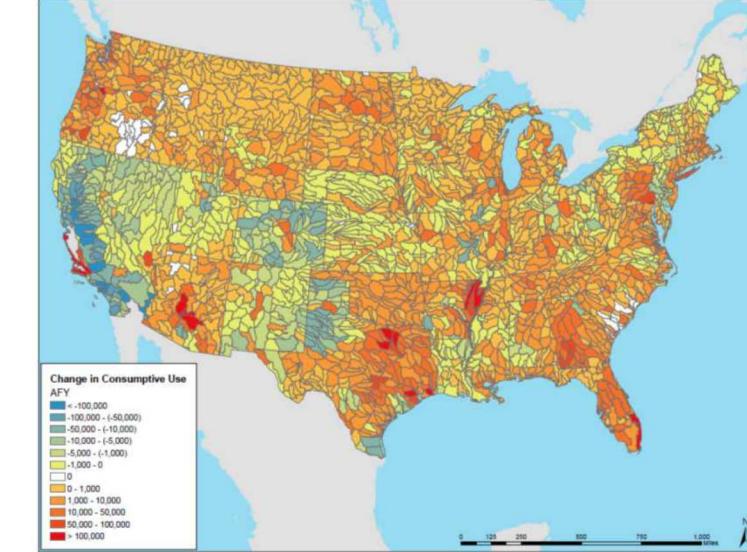
Wastewater



Brackish Water



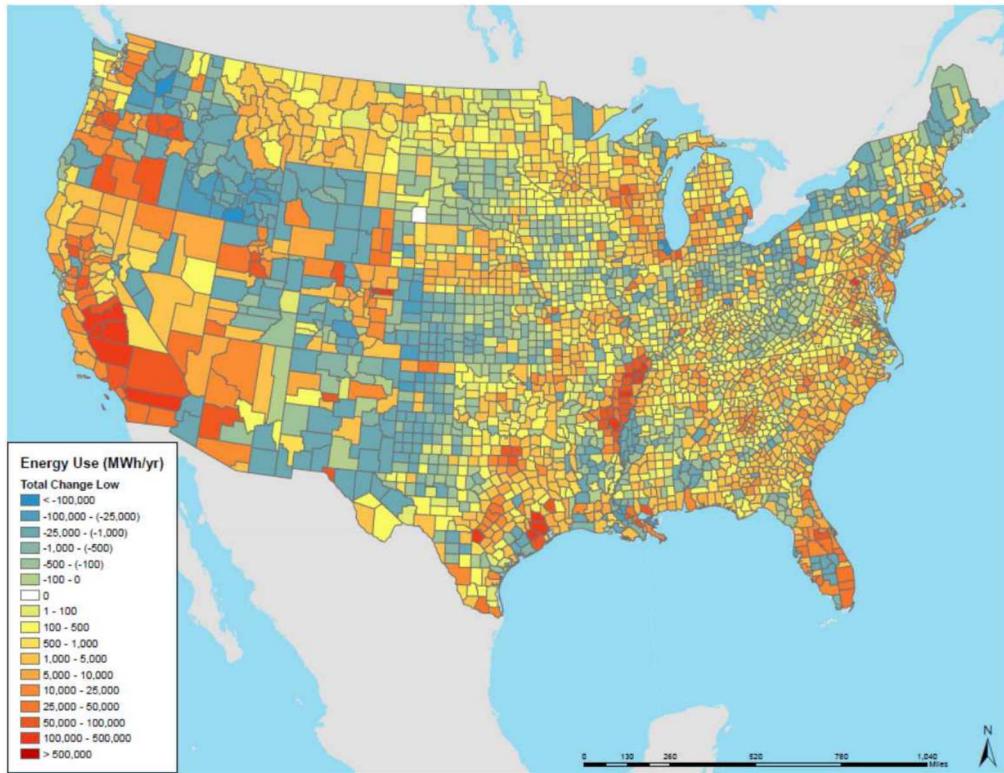
Growth in Demand 2015-2035



Source: Tidwell et al. 2018

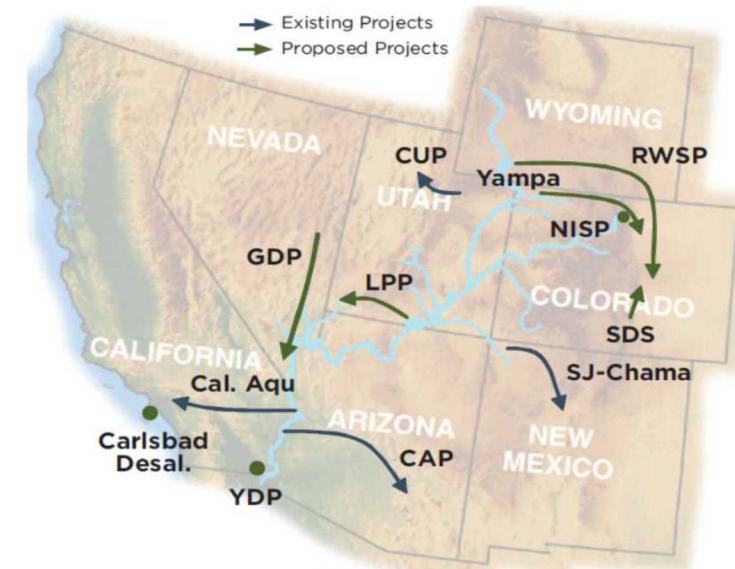
Intensifying Demands

Projected Change in Energy Demand for Water Services 2015-2030

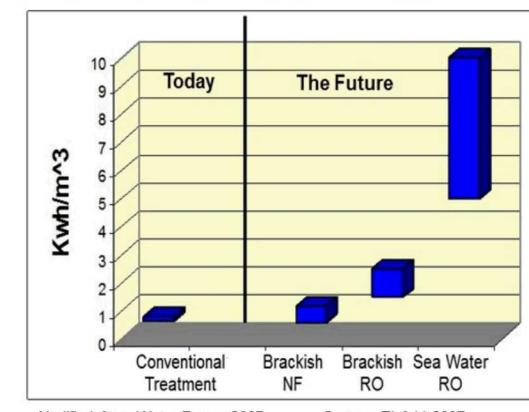
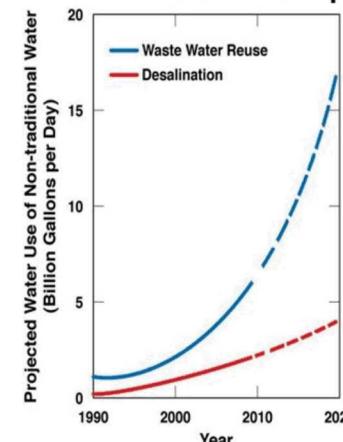


7-13% increase projected over 15 yrs.

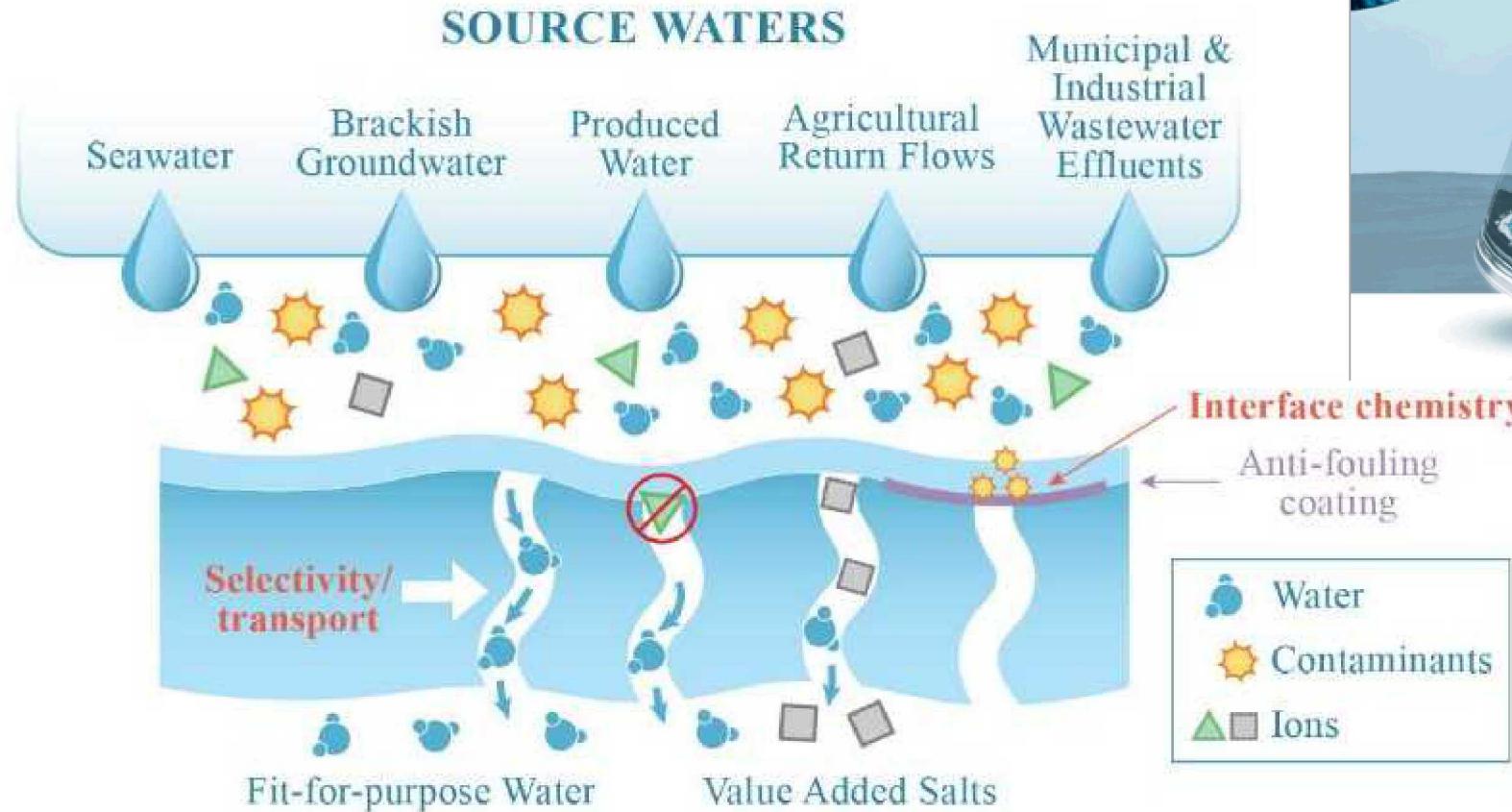
Existing and Proposed Western Water Supply Projects



Power Requirements For Treatment



Treatment Paradigm



DOE Water Security Grand Challenge

- **Goal 1: Desalination**
- **Goal 2: Produced Water**
- **Goal 3: Cooling Water**
- **Goal 4: Energy Recovery**
- **Goal 5: Modular Systems**

Municipal Supply

Manufacturing

Thermoelectric
Cooling

Agriculture

Oil & Gas

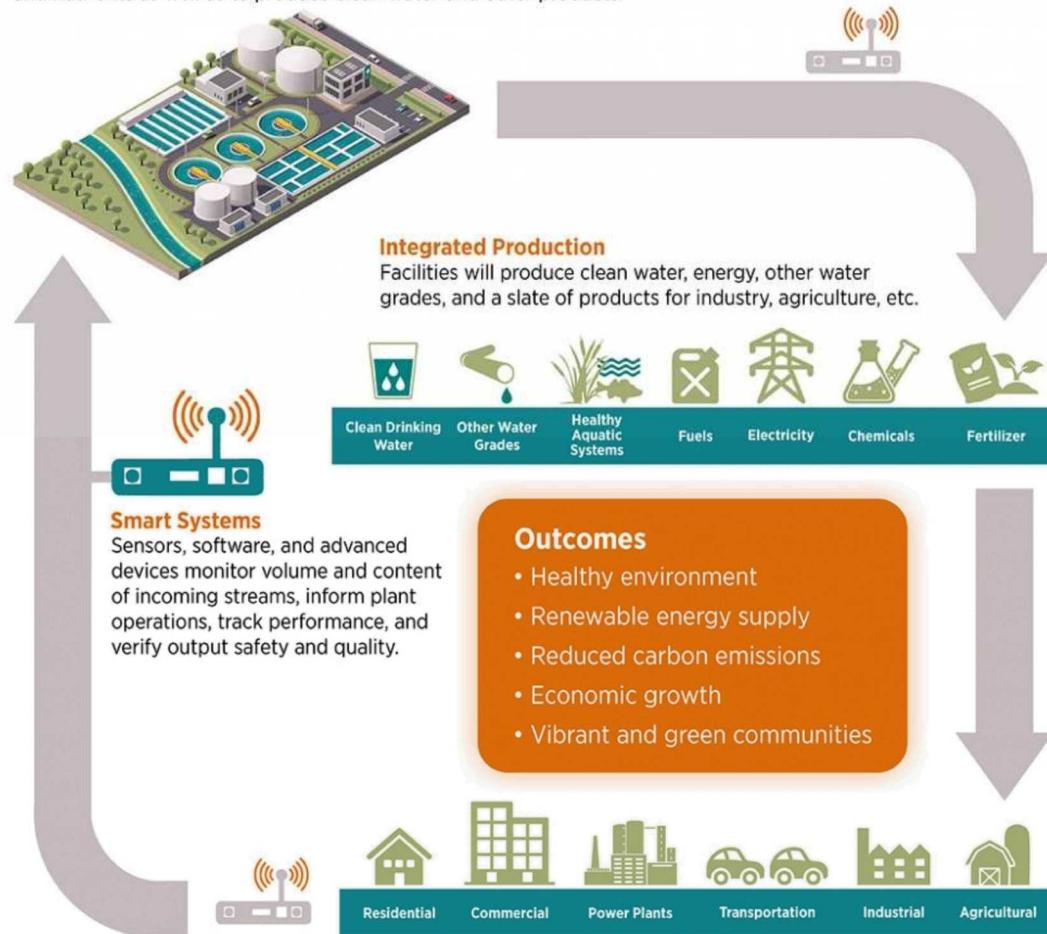
Resource Recovery

Water Resource Recovery Facility of the Future

Energy Positive and Beyond: The Vision for Transforming Wastewater Treatment

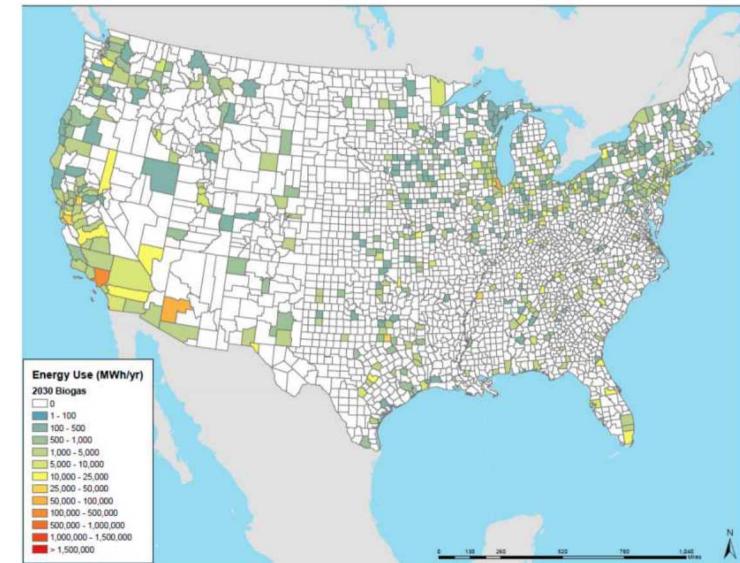
Energy Efficiency and Resource Recovery

Facilities will use energy-efficient operations to recover water, energy, and nutrients as well as to produce clean water and other products.



Source: DOE 2015

Biogas Potential



Source: Tidwell and Moreland 2020

- \$2 billion of electricity each year.
- \$200 billion in future capital investment.
- Wastewater treatment plants can account for a third or more of municipal energy bills.
- Recoverable resources include:
 - Energy,
 - Nutrients for fertilizer, and
 - Clean water.

1. Energy-Water-Climate issues are affecting energy and water production today.
2. Without attention these issues will intensify.
3. Changes in the energy and water sectors are mitigating some climate vulnerabilities.
4. Options are available to adapt to a changing and uncertain future.

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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

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
- Thermolectric 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:

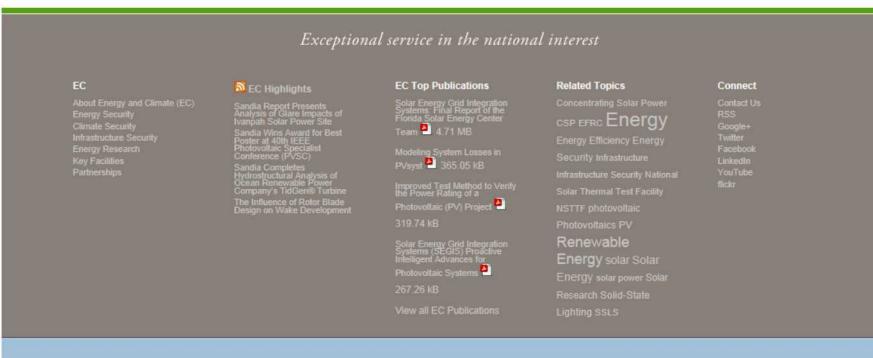
- Limitations of surface-water storage capacity
- Increasing depletion and degradation of ground water supplies
- Increasing demands for the use of surface water for in-stream ecological and environmental uses
- Uncertainty about the impact of climate variability on future water fresh surface and ground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

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