Exceptional service in the national interest

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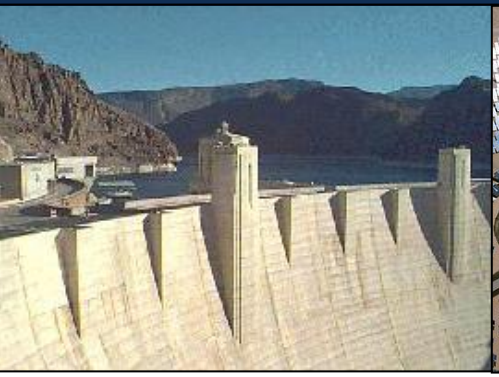


Water Availability and Power Generation

Vincent Tidwell

Sandia National Laboratories

Roundtable on Science and Technology for Sustainability

December 5, 2013

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Sandia National Laboratories

Argonne NATIONAL LABORATORY

EPRI ELECTRIC POWER RESEARCH INSTITUTE

NREL National Renewable Energy Laboratory

INL Idaho National Laboratory

THE UNIVERSITY OF TEXAS AT AUSTIN

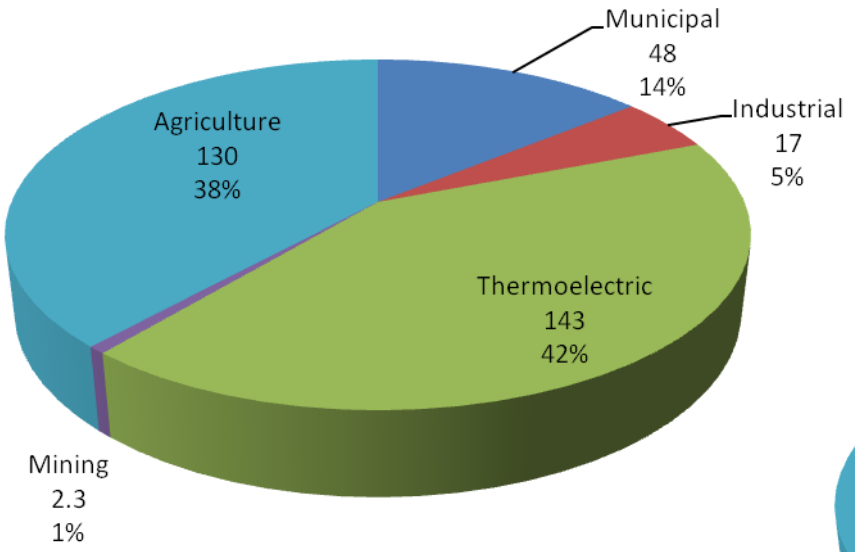
Pacific Northwest NATIONAL LABORATORY

Questions

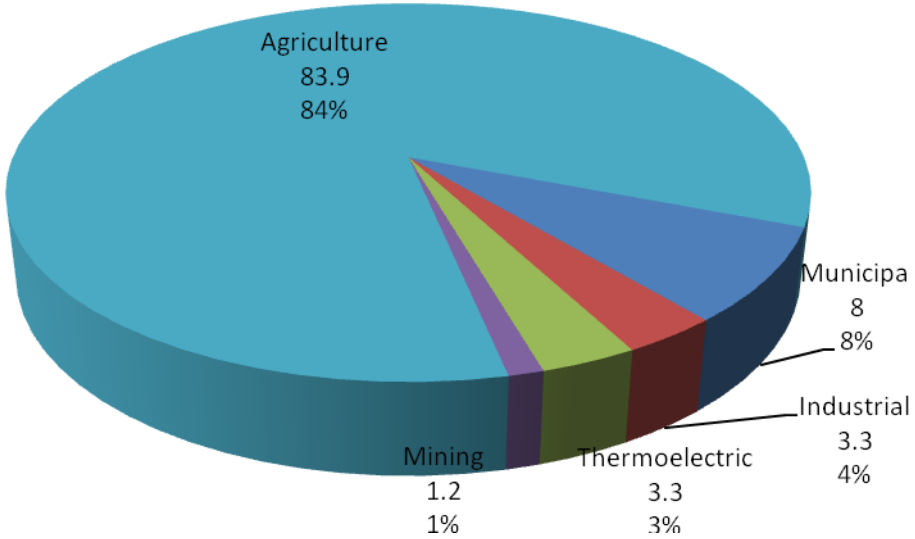
- Relationship between technology, water use and cost
- How to simplify national, state and local regulatory frameworks
- In context of future projections

Water for Thermoelectric Power Generation

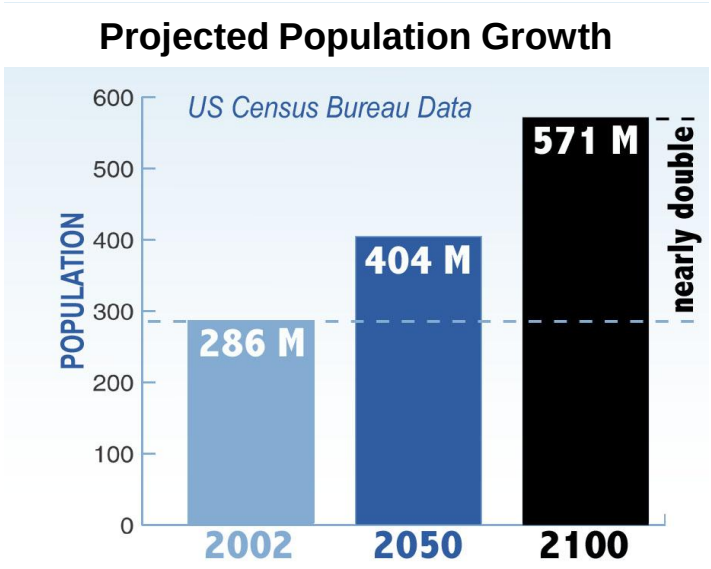
Water Withdrawal (BGD)
2005

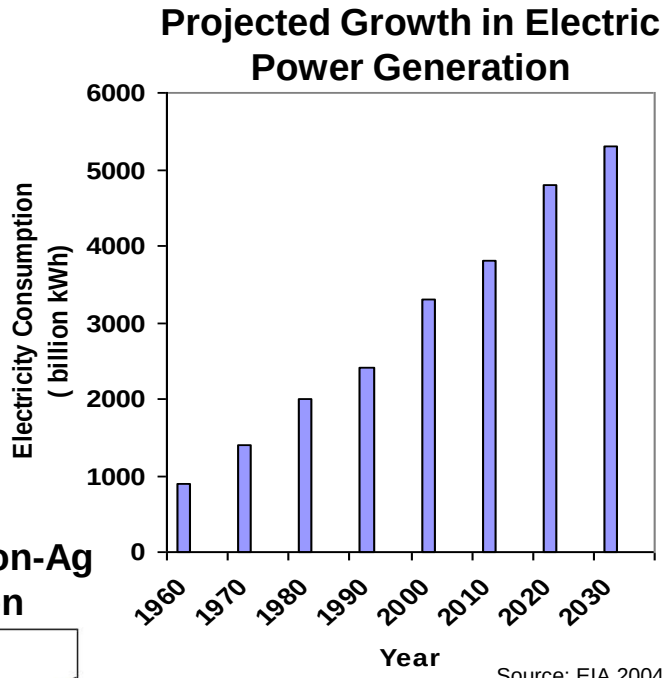


Water Consumption (BGD)
1995

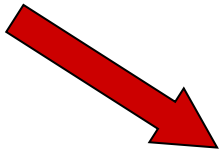


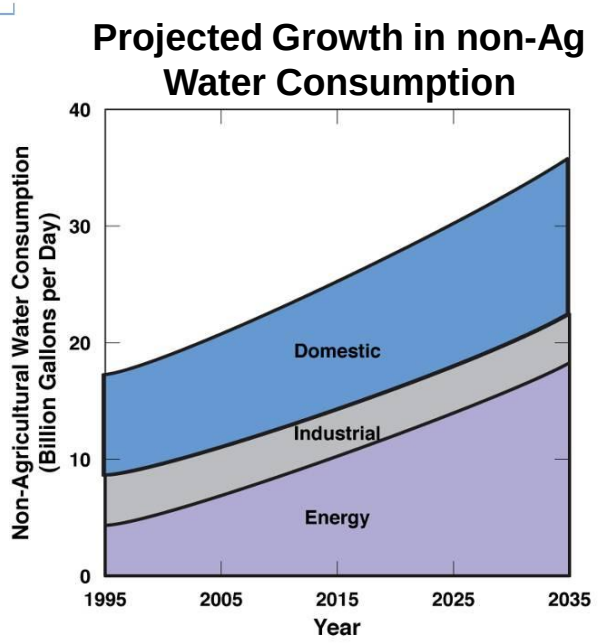
Energy-Water Tomorrow

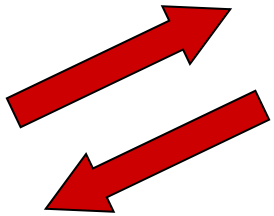




Source: EIA 2004

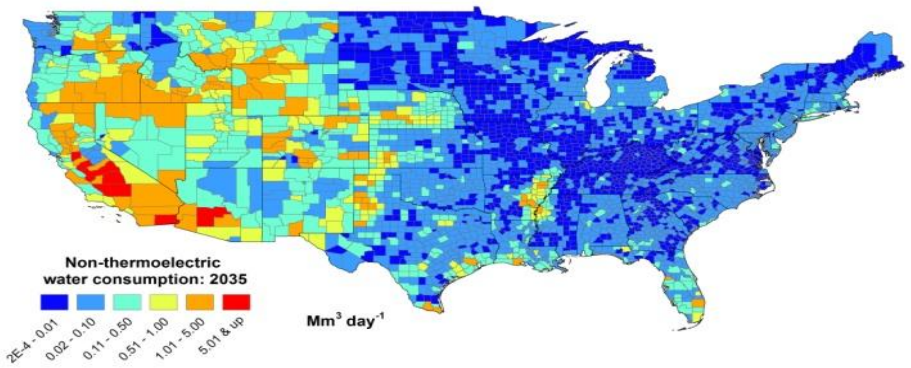




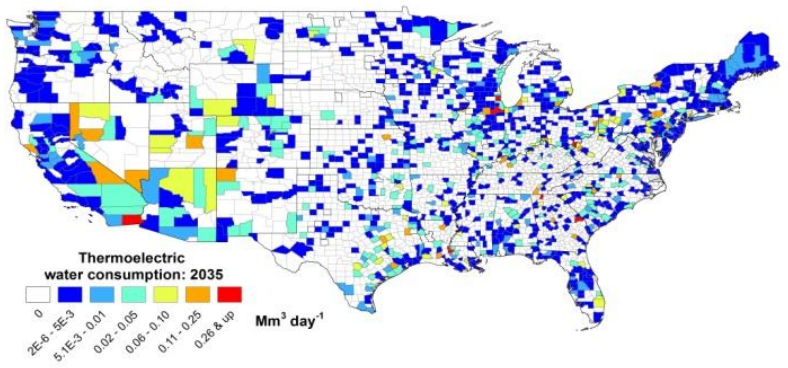


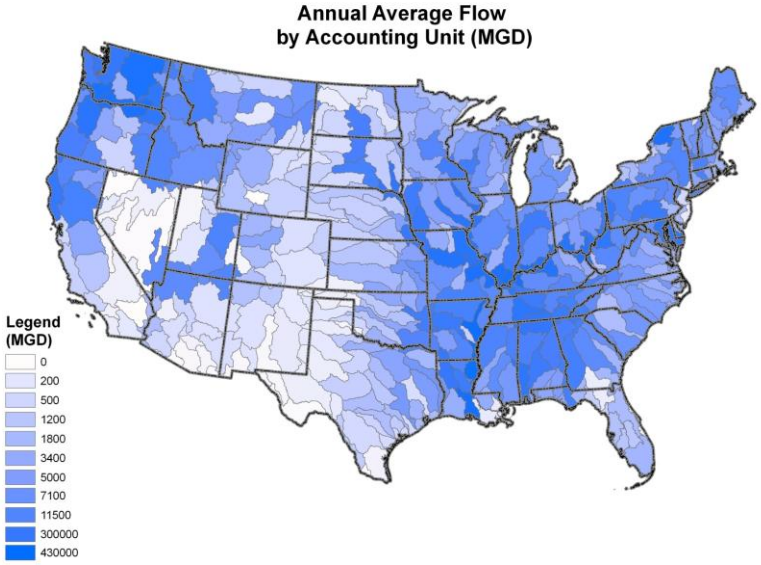
Place Matters

Non-Thermoelectric Consumption 2010



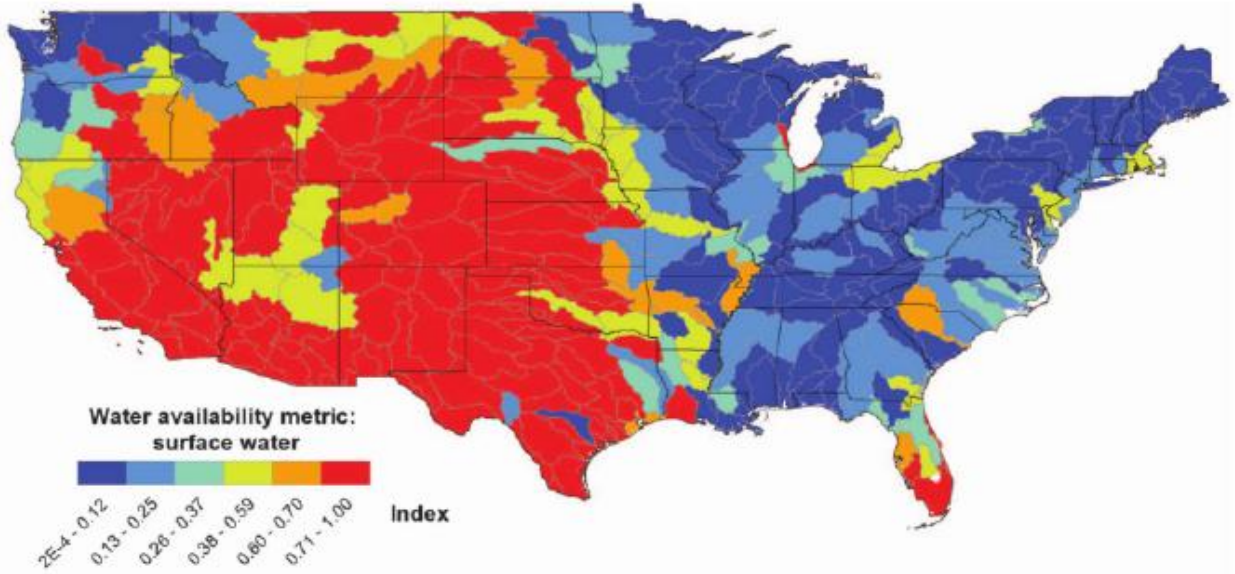
Thermoelectric Consumption 2010



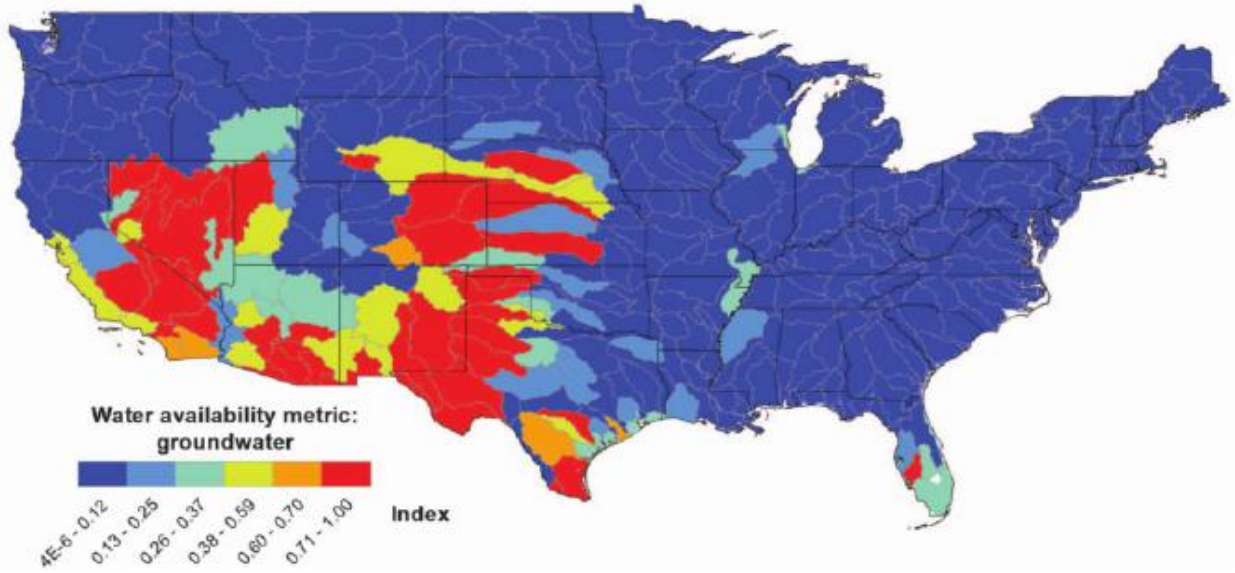


Water Limited Basins

Surface Water Availability



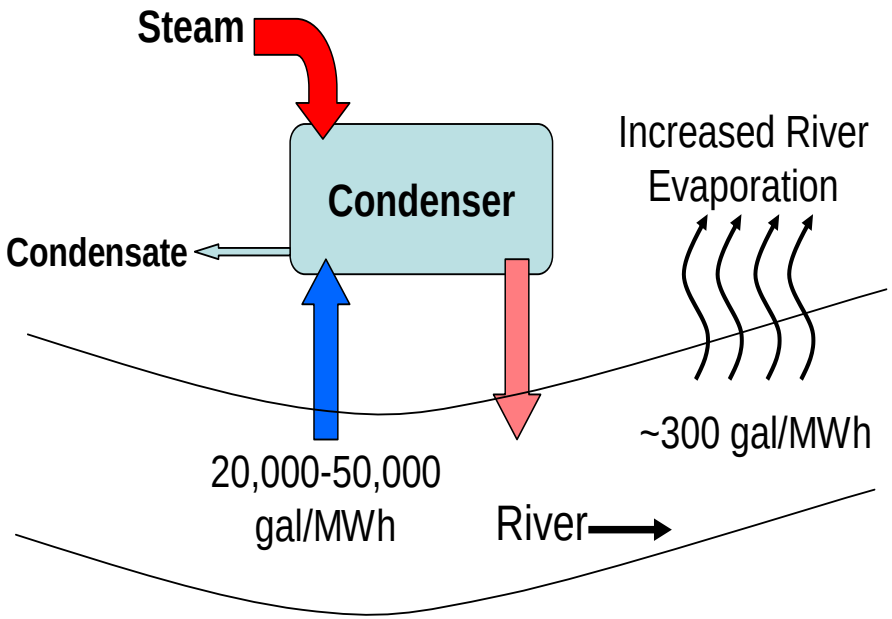
Groundwater Availability



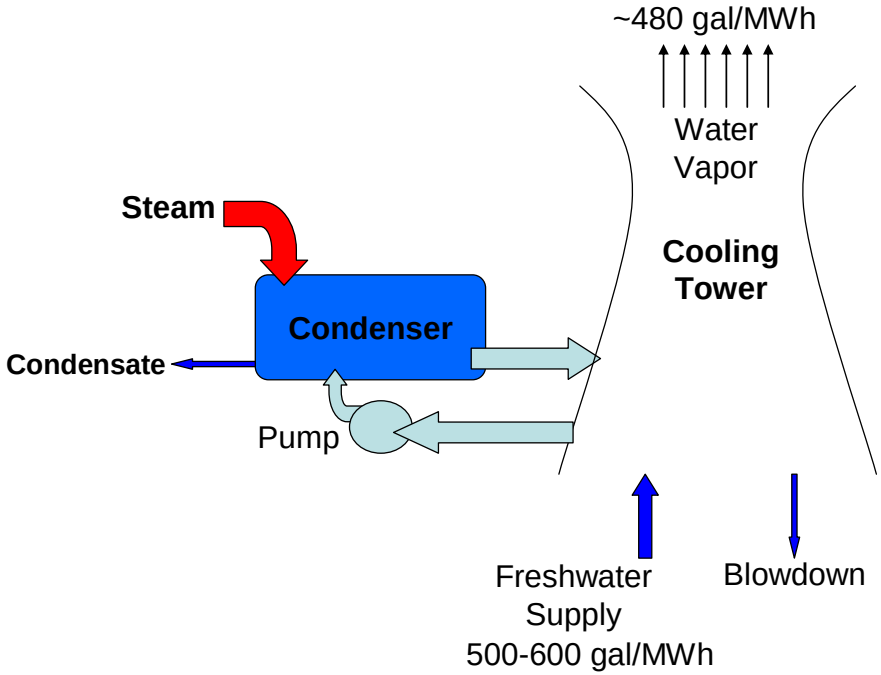
Power Plants Are Not Created Equal

- Water withdrawal and consumption dictated by:
  - Fuel type,
  - Cooling type,
  - Location,
  - Age,
  - Emission controls,
  - Other

Power Plant Cooling Options



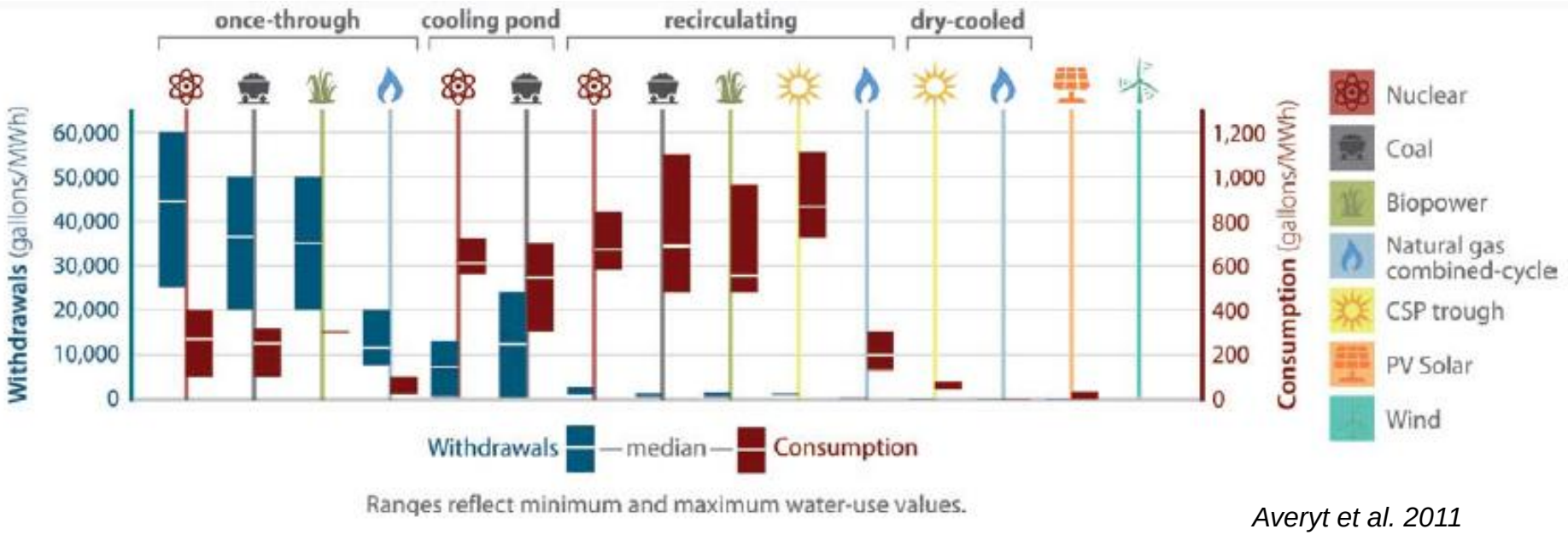
Open-loop “once-through” cooling cycle



Closed-loop cooling cycle

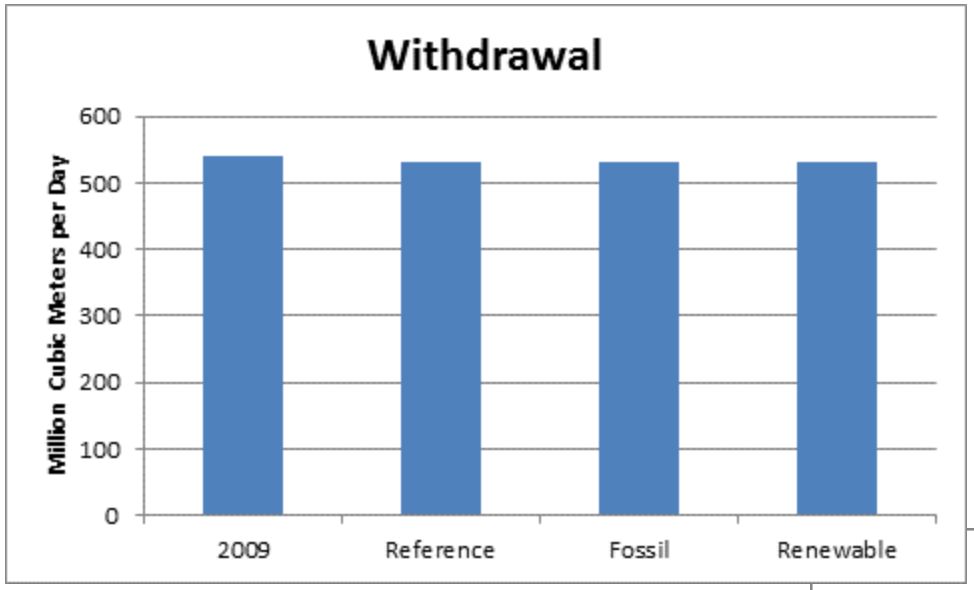
Source: EPRI, 2002

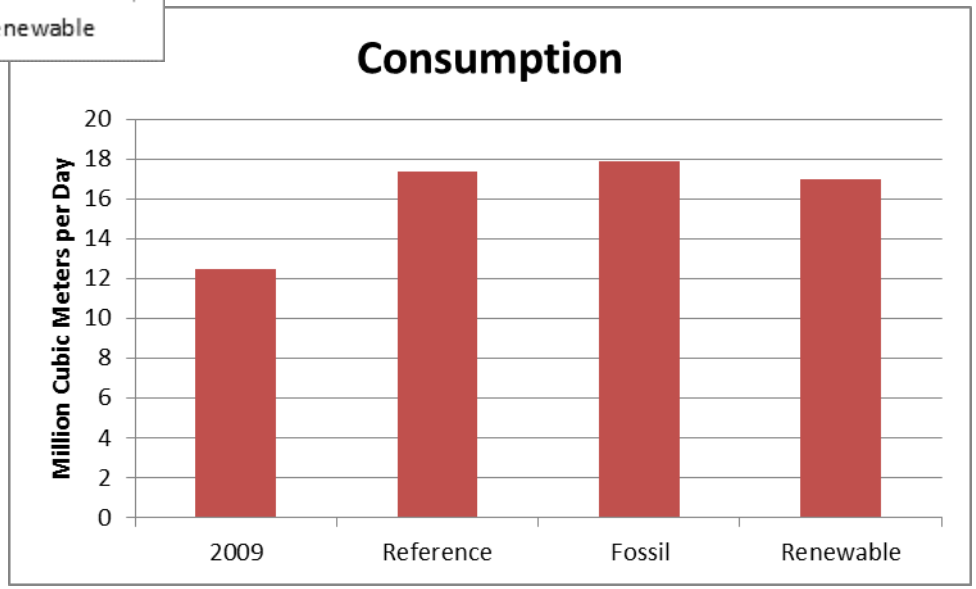
Water for Thermoelectric Power



Averyt et al. 2011

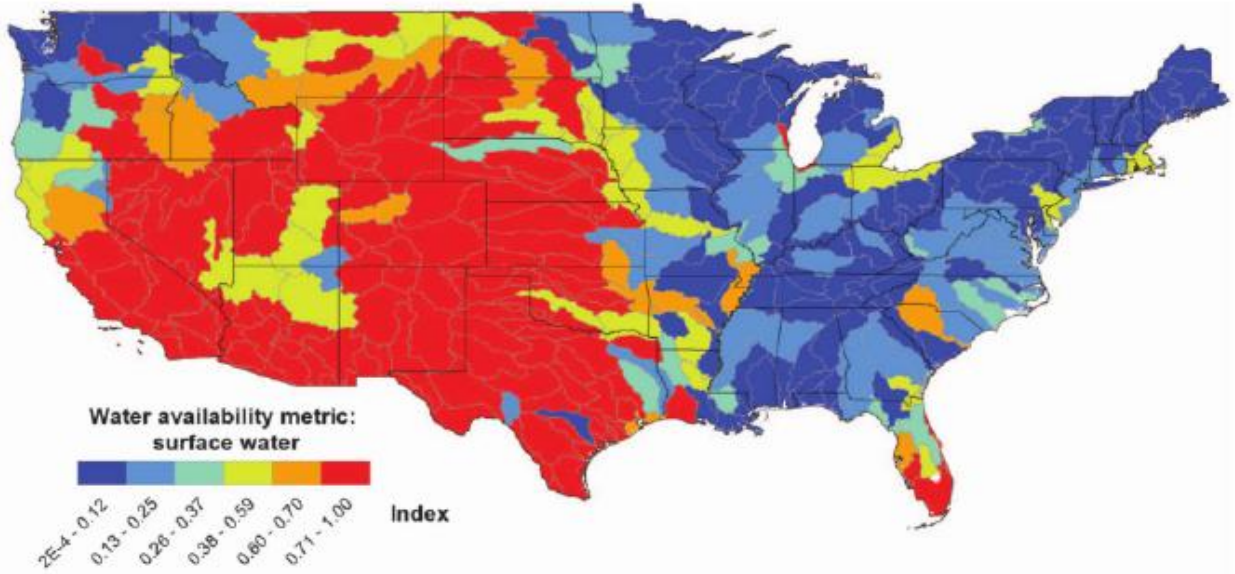
Projected Changes in Demand to 2035



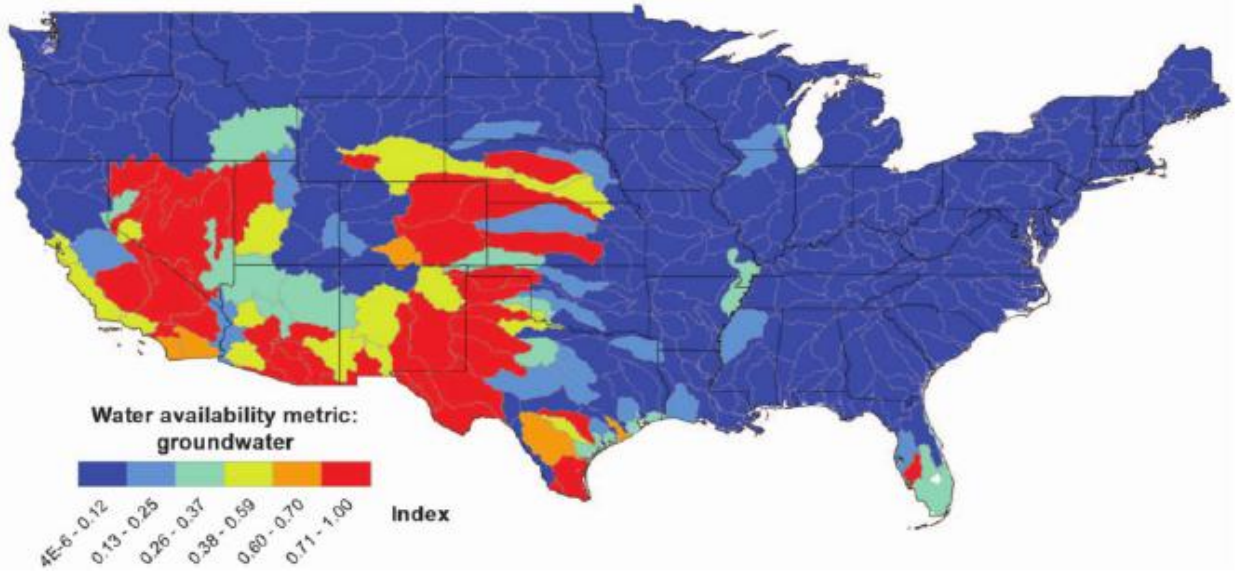


Water Limited Basins

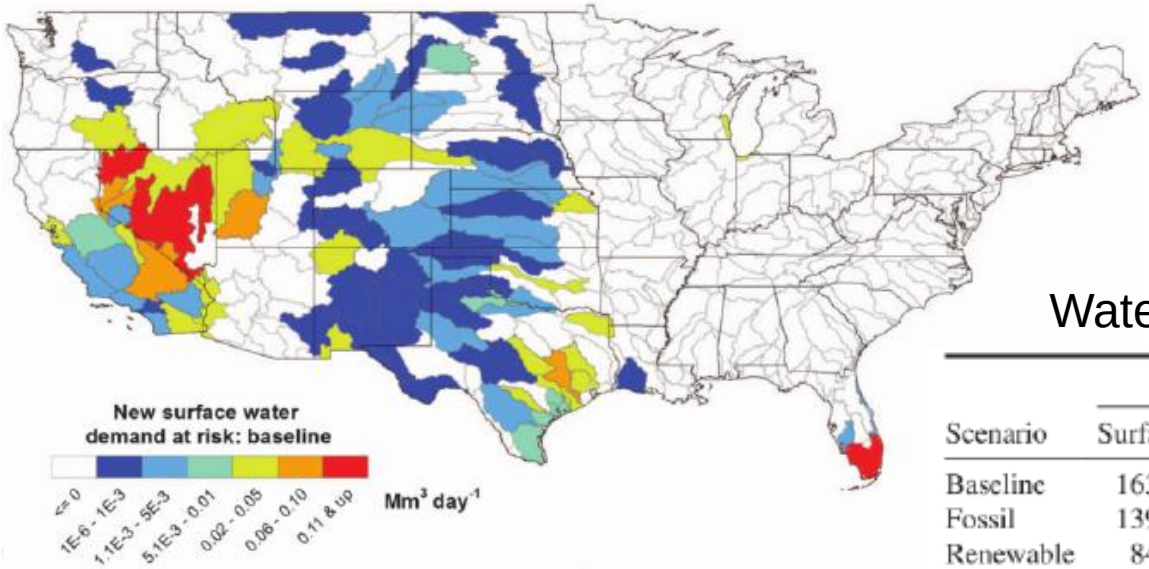
Surface Water Availability

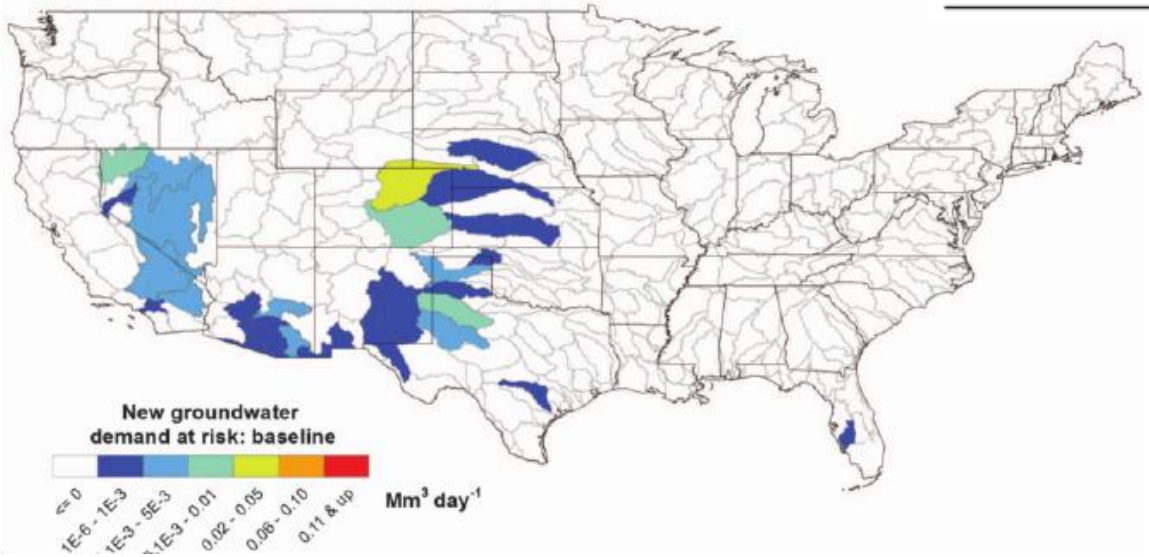


Groundwater Availability



Thermoelectric Development in Water Limited Basins



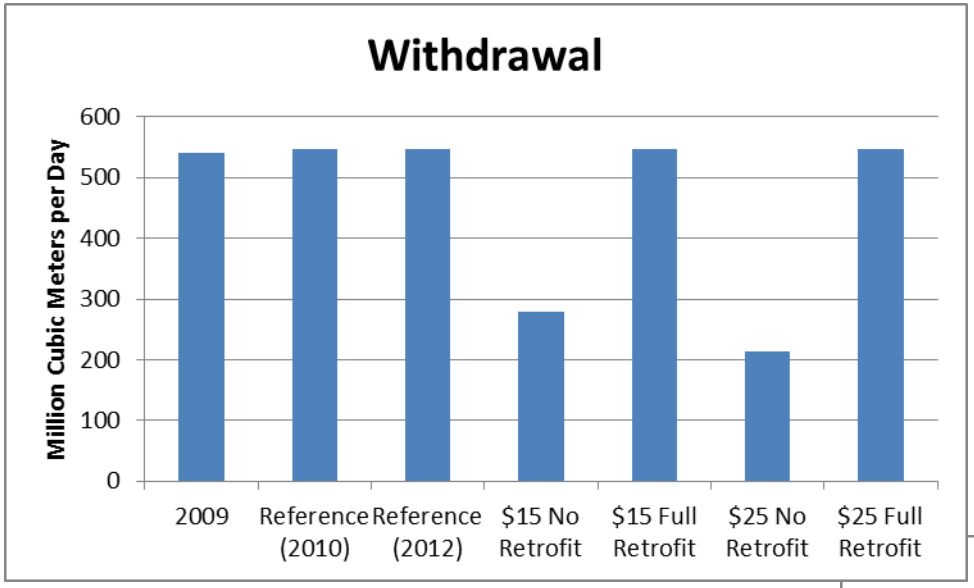


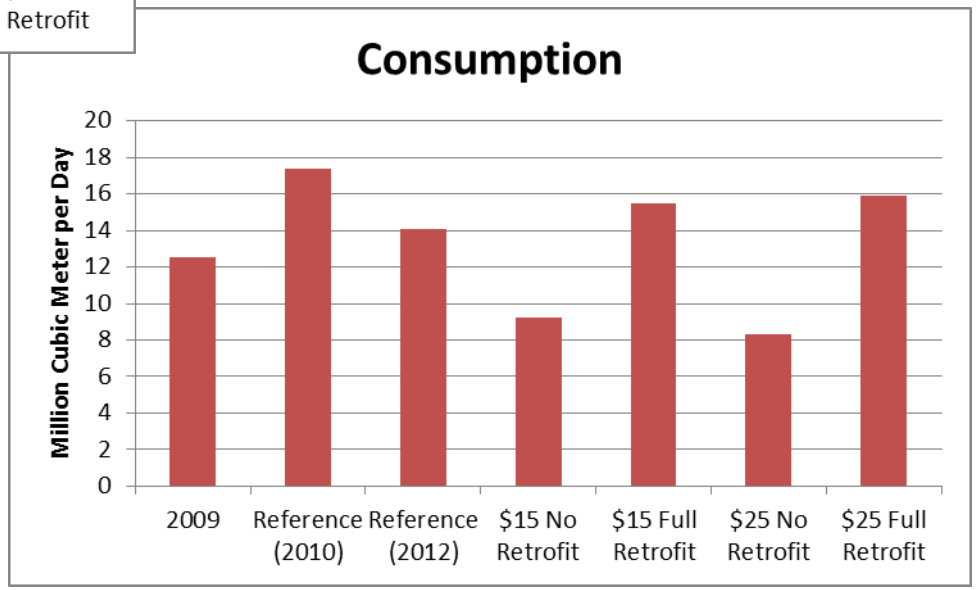
Water and Power at Siting Risk

	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%)

Tidwell et al. 2012

Projected Changes in Demand to 2035





Role of Carbon Capture and Sequestration

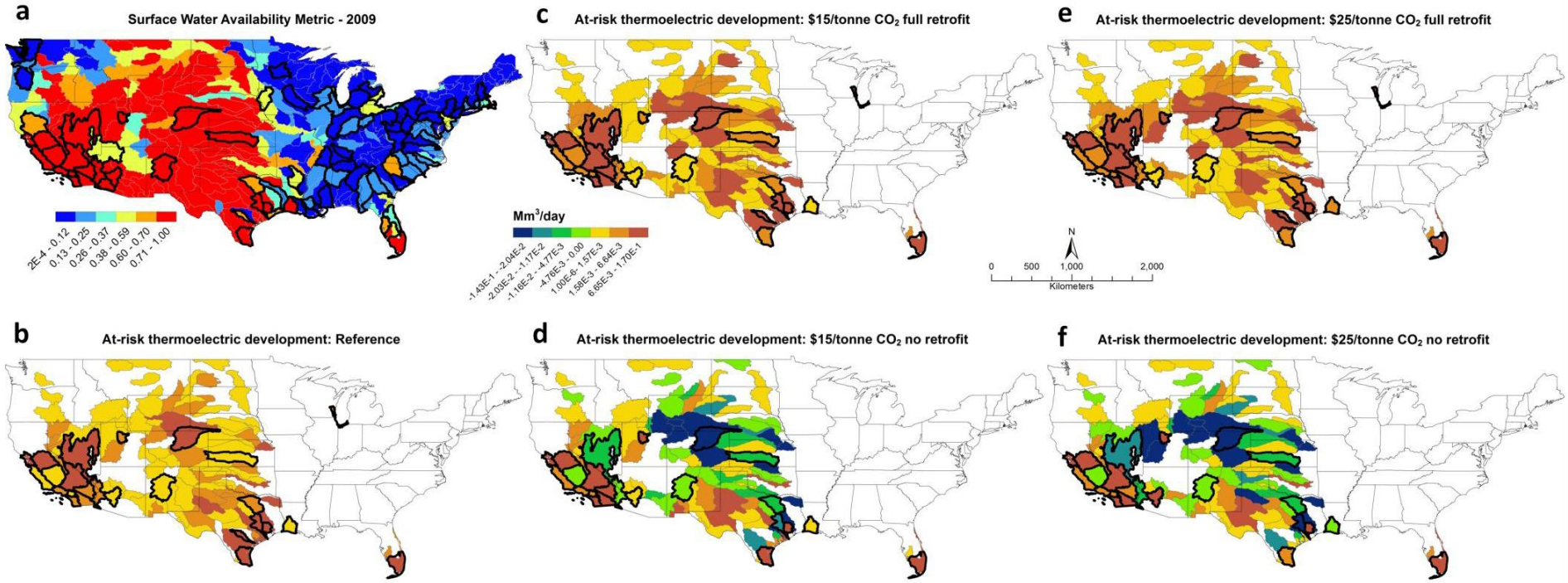
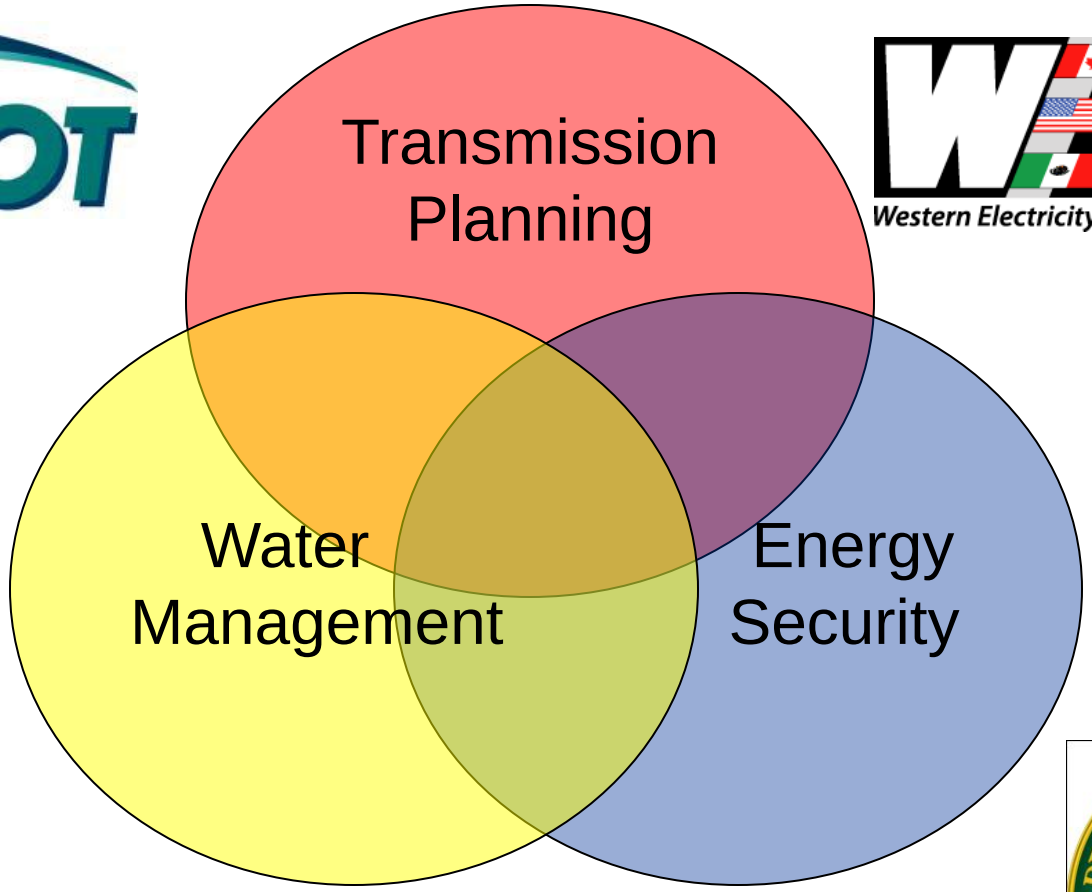


Table 3. Thermoelectric Power Production and Associated Freshwater Consumption at Siting Risk Due to Limited Water Availability.

	electricity (TWh)	water consumption (Mm^3/d)
reference	154	0.55 (0.53, 0.57)
\$15 CO_2 no retrofit	135	0.47 (0.44, 0.51)
\$15 CO_2 full retrofit	146	0.96 (0.93, 1.0)
\$25 CO_2 no retrofit	113	0.44 (0.41, 0.48)
\$25 CO_2 full retrofit	127	0.95 (0.92, 0.99)

Tidwell et al. 2013

Integrated Planning



ERCOT

WECC
Western Electricity Coordinating Council

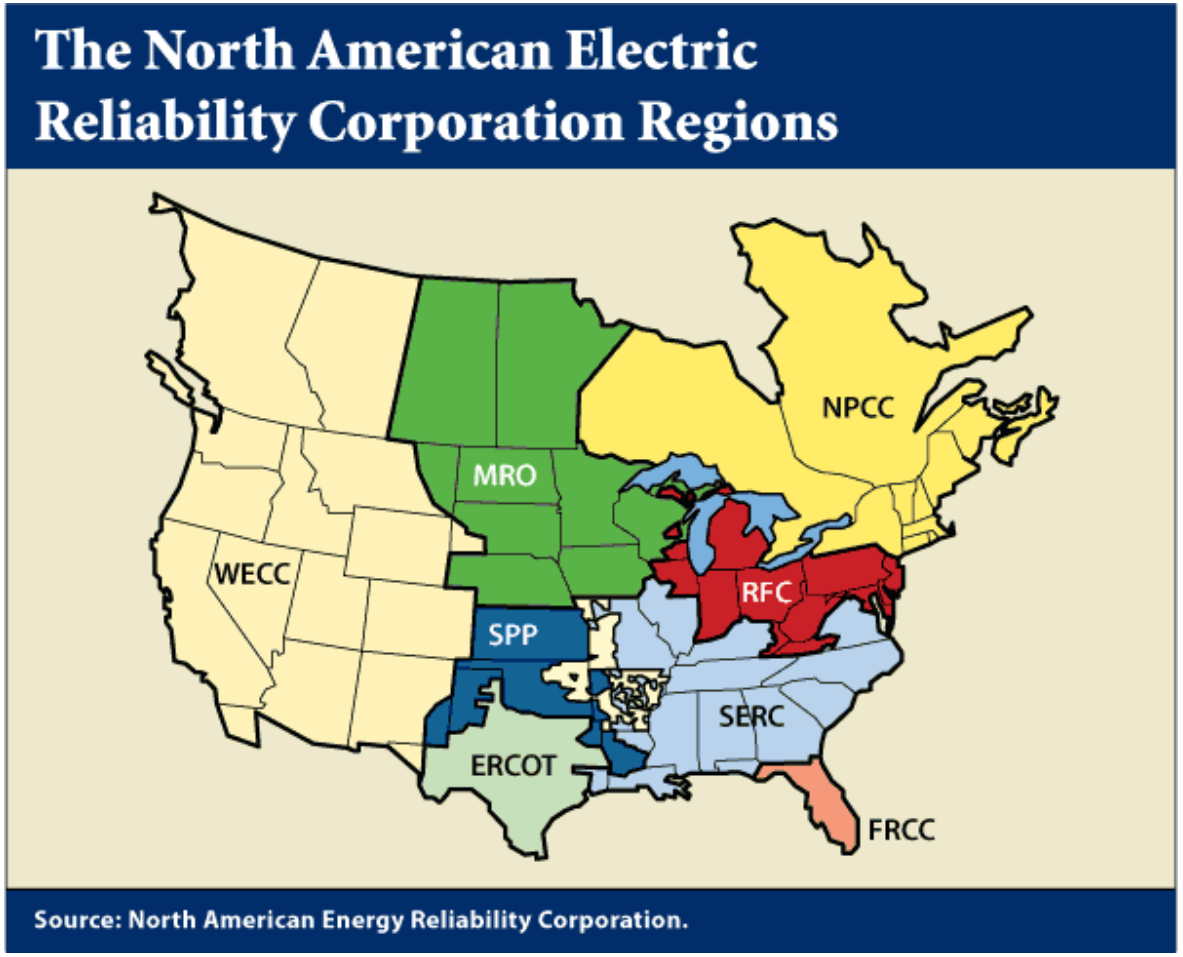
Western Governors' Association
Serving the Governors of 19 States and 3 US-Flag Pacific Islands

WSWC
Western States Water Council

Department of Energy · United States of America ·

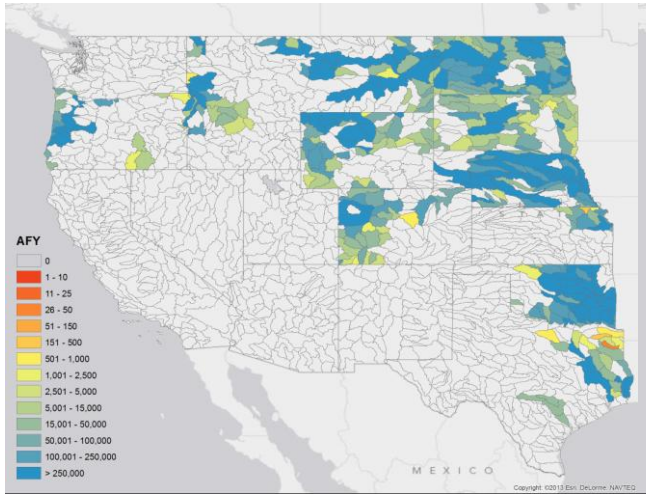
Transmission Planning

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

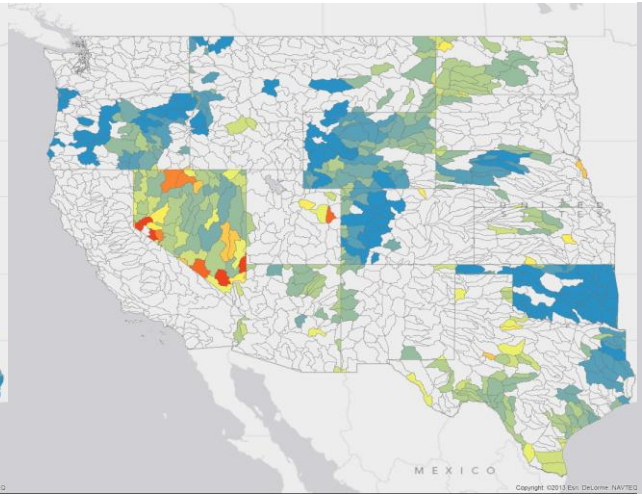


Water Availability

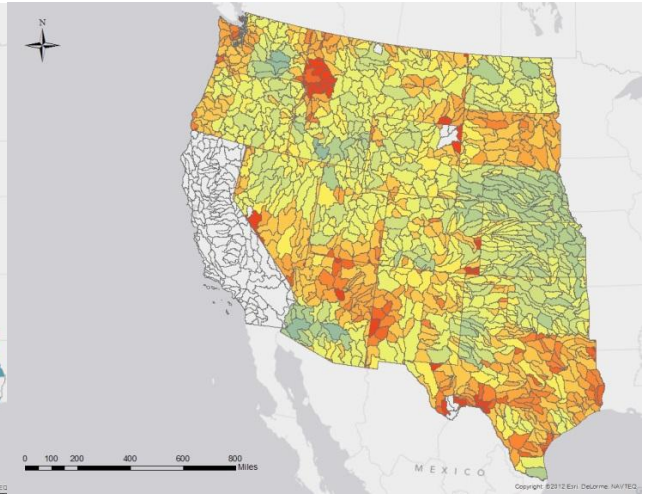
Unappropriated Surface Water



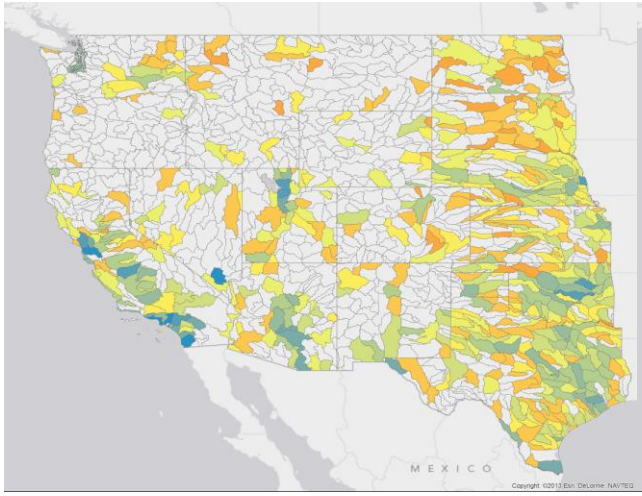
Unappropriated Groundwater



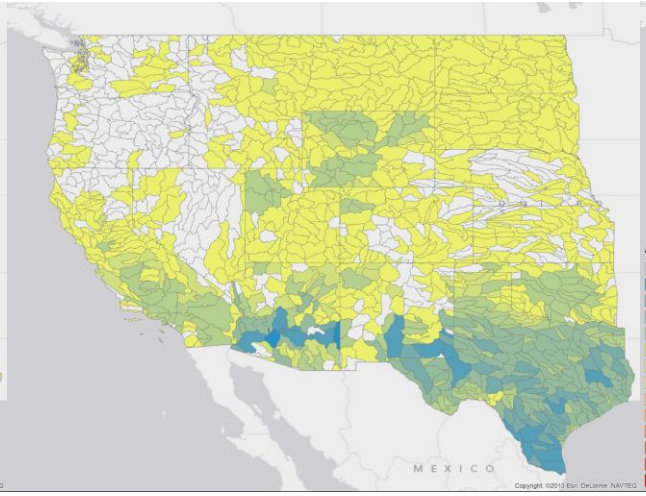
Appropriated Water



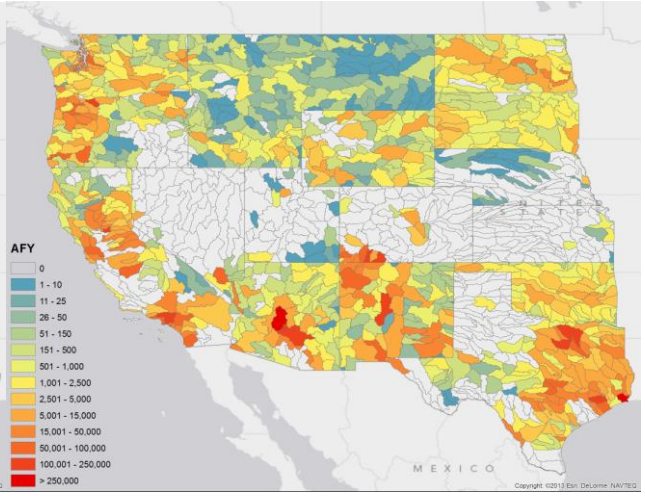
Municipal Wastewater



Brackish Groundwater

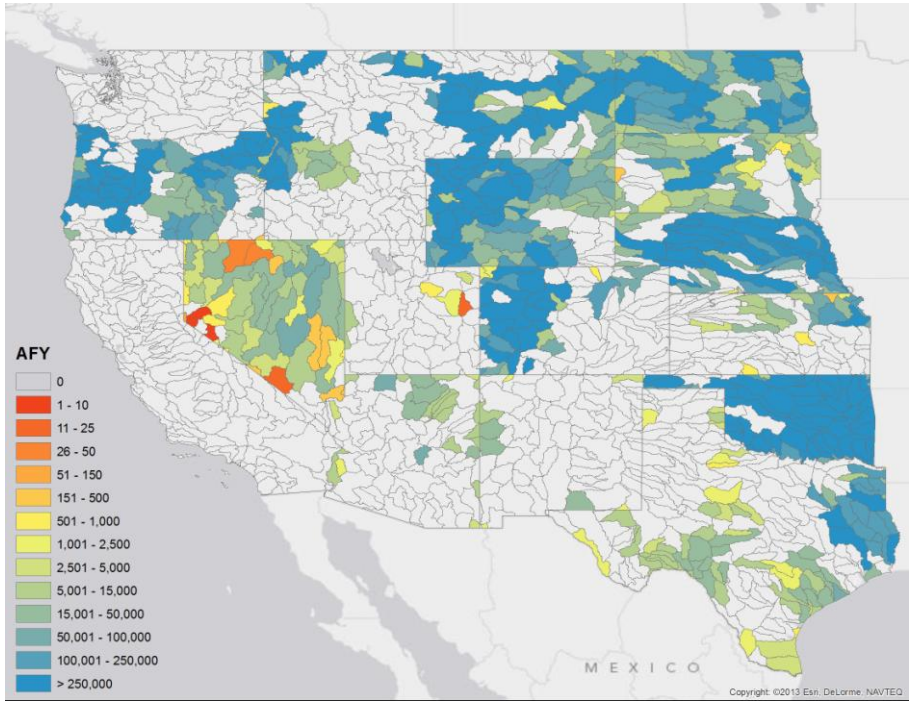


Consumptive Demand 2010-2030

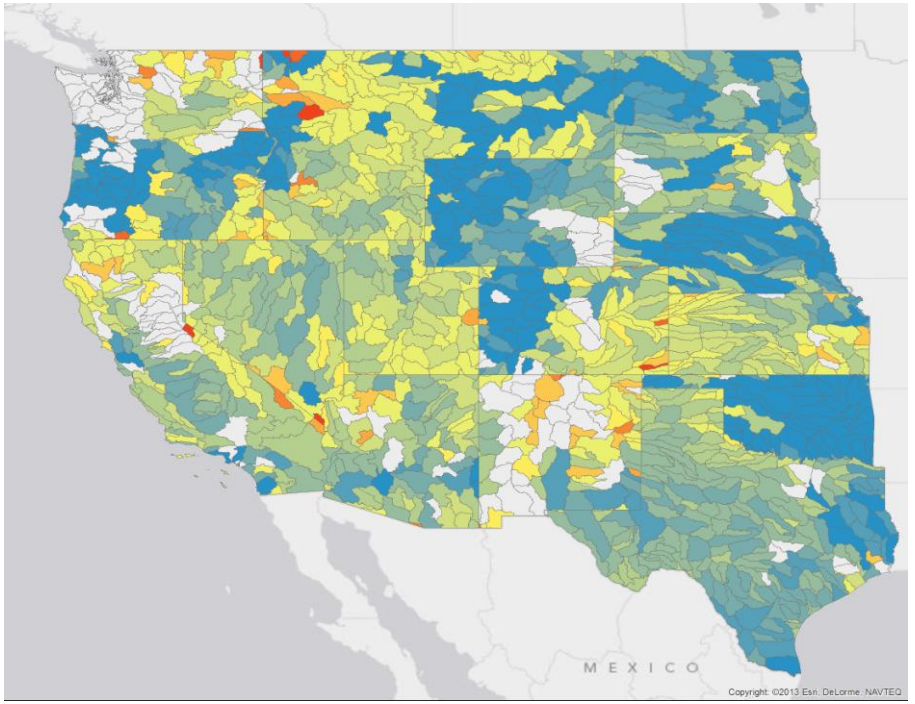


Water for Development

Unappropriated Water Sources – Change in Demand 2030

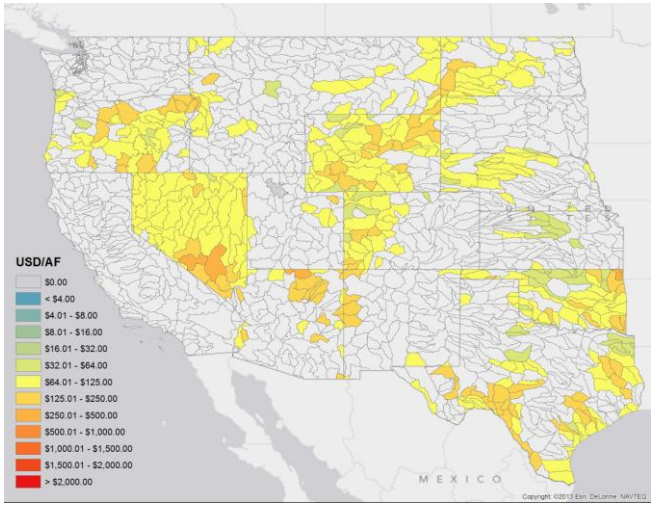


All Water Sources – Change in Demand 2030

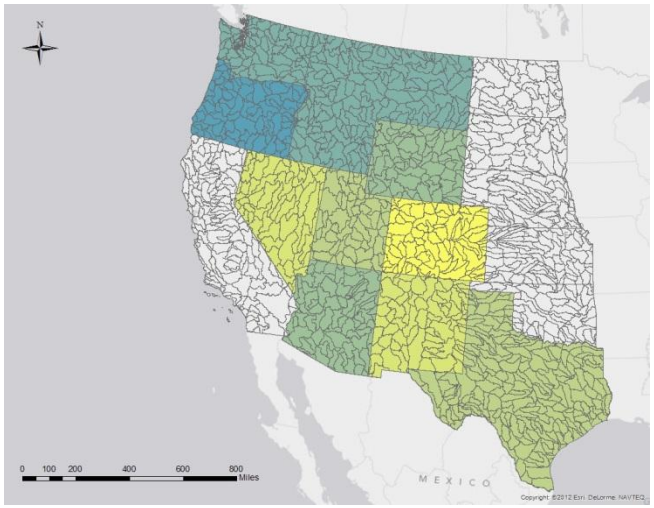


Relative Cost of Water

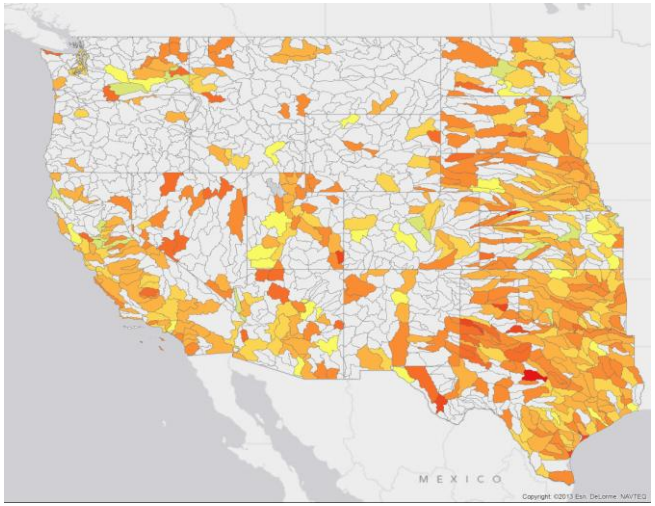
Unappropriated Groundwater



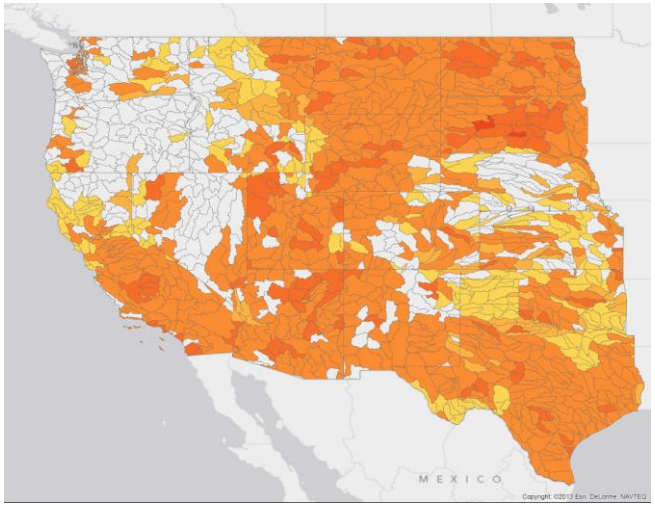
Appropriated Water



Municipal Wastewater

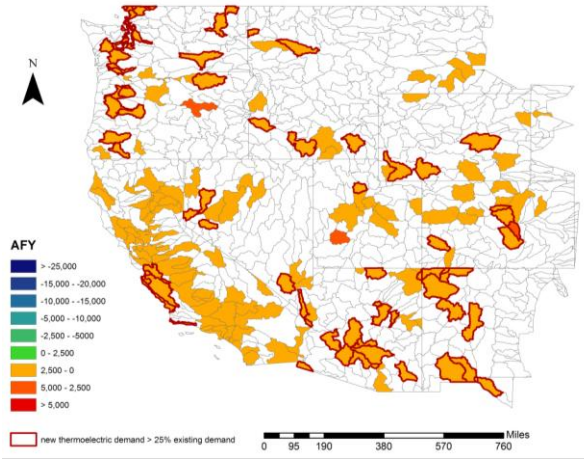


Brackish Groundwater

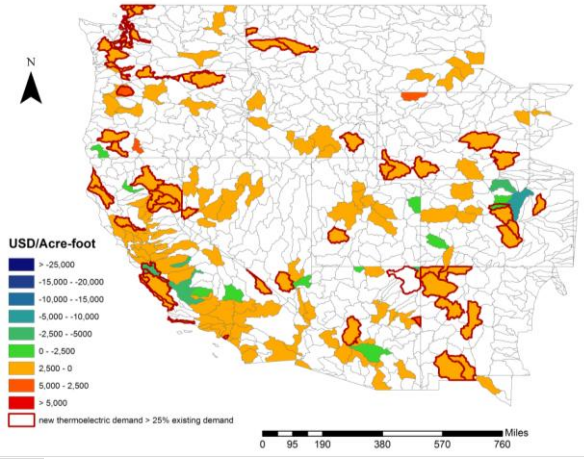


Long Range Planning Results

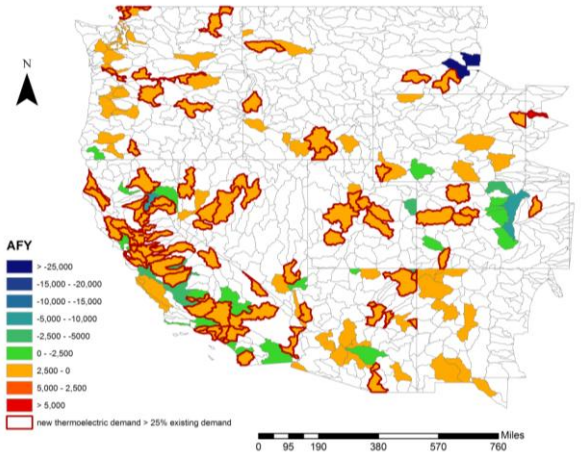
Reference Case



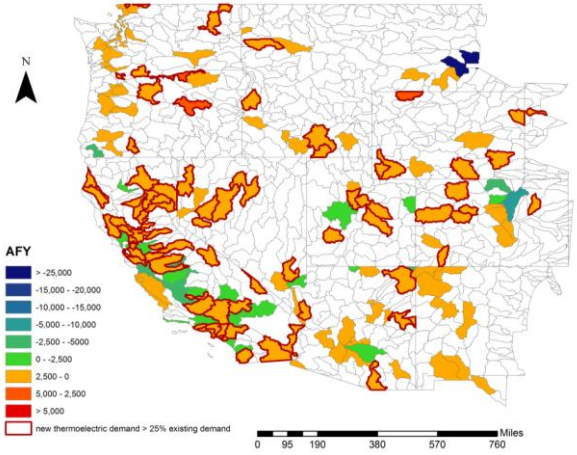
Scenario 1: Focus on Economic Recovery



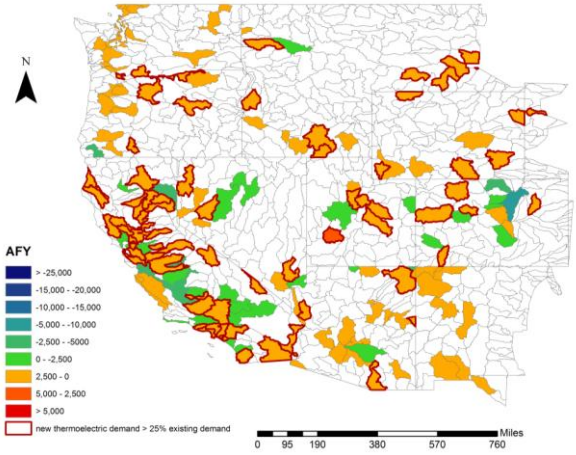
Scenario 2 - Focus on Clean Energy



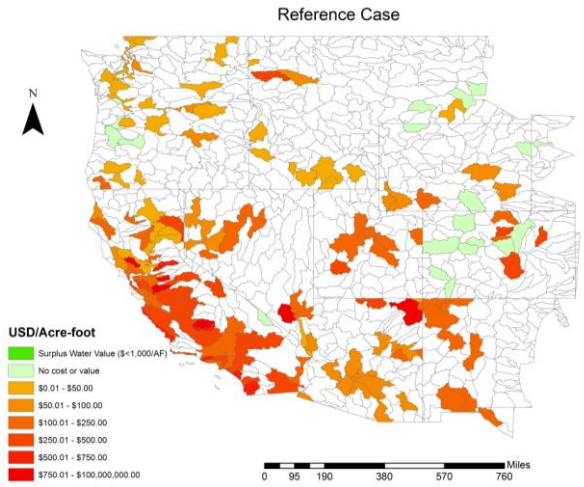
Scenario 3 - Focus on Short-Term Consumer Costs

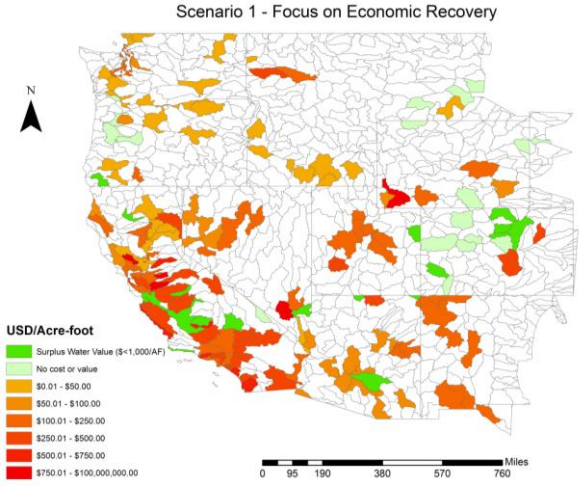


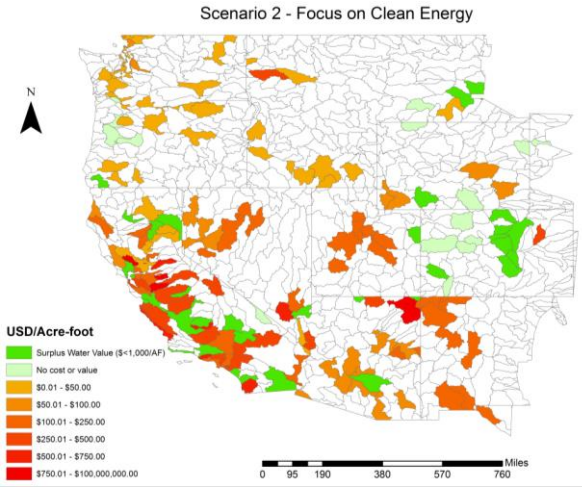
Scenario 4 - Focus on Long-Term Societal Costs

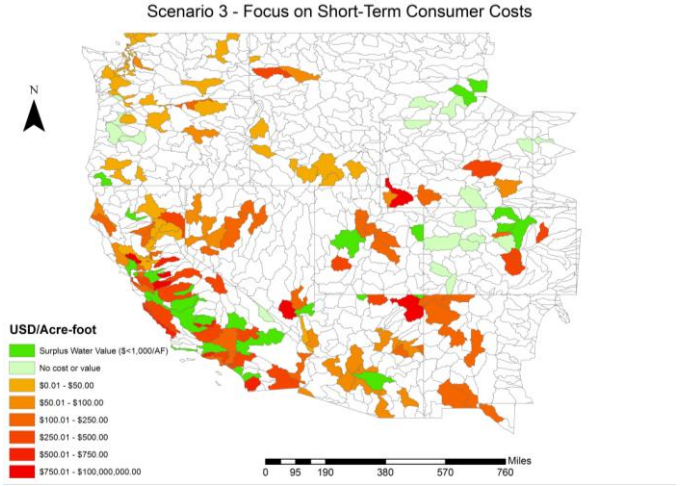


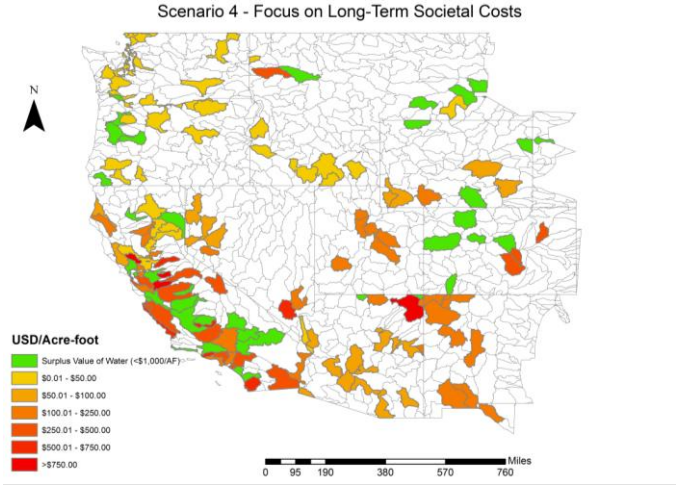
Long Range Planning Results



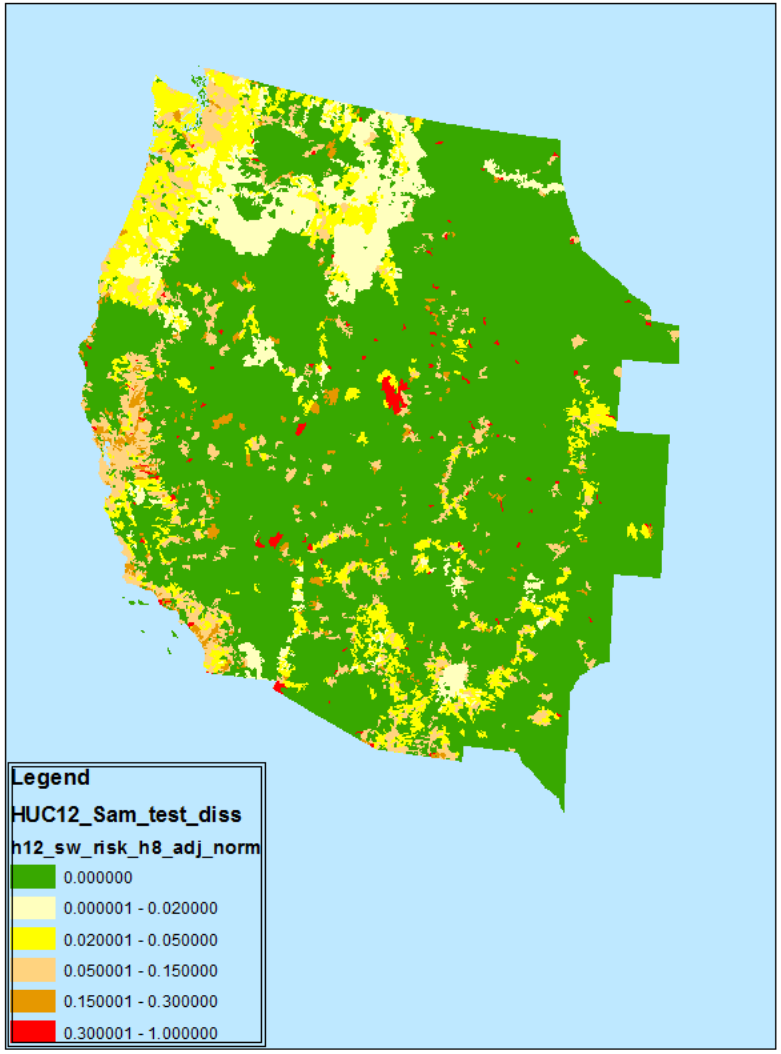




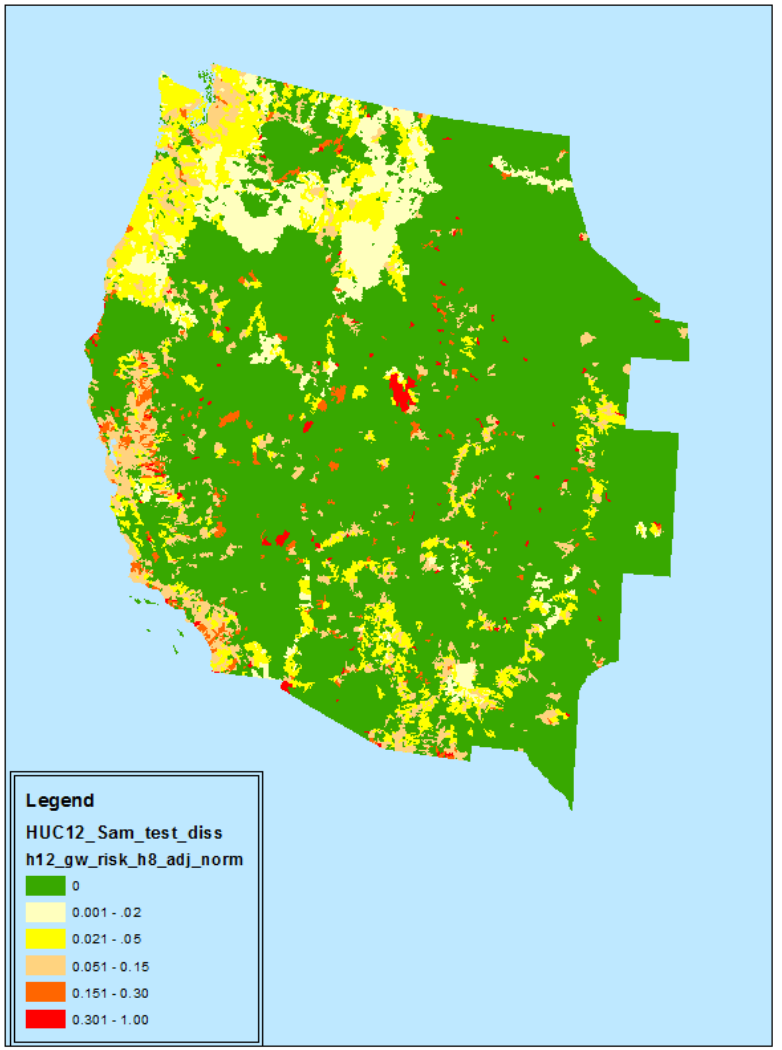




HUC-12 Risk Map (From Surface Withdrawals)



HUC-12 Risk Map (From Underground Withdrawals)



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

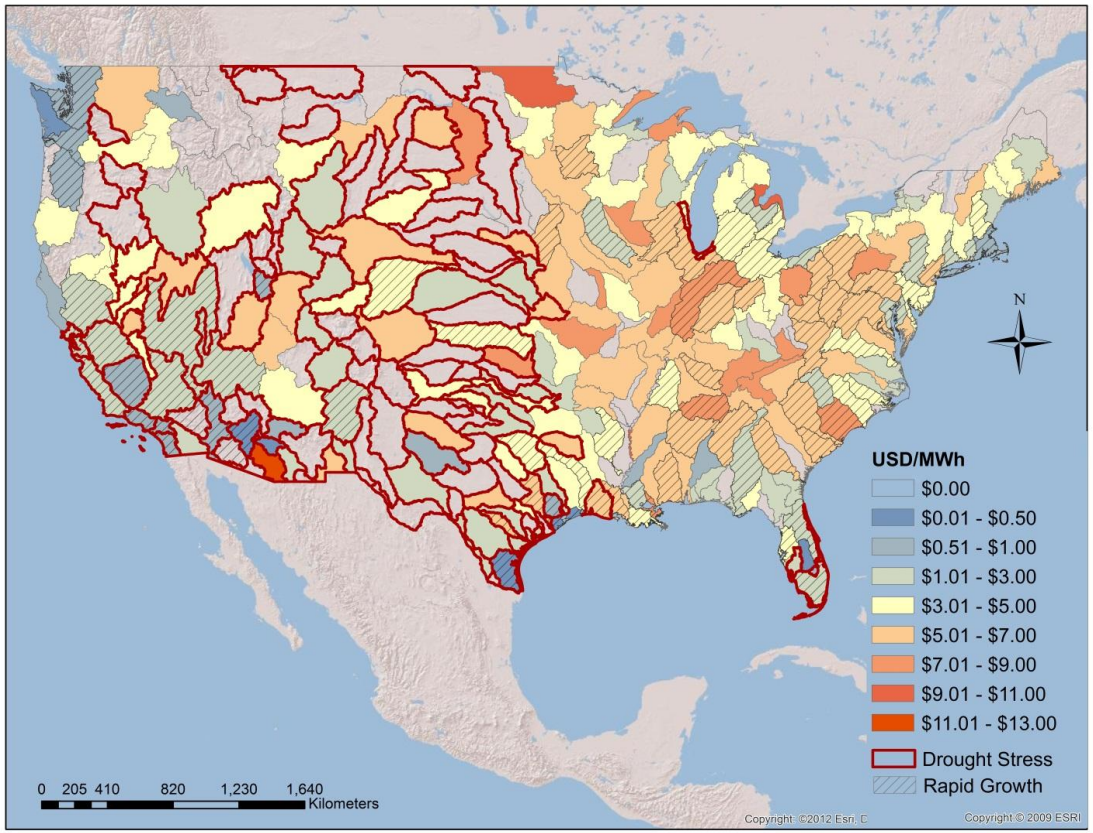
Brackish water: <2500 ft deep, salinities>10,000 TDS

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

ΔLCOE Associated with 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

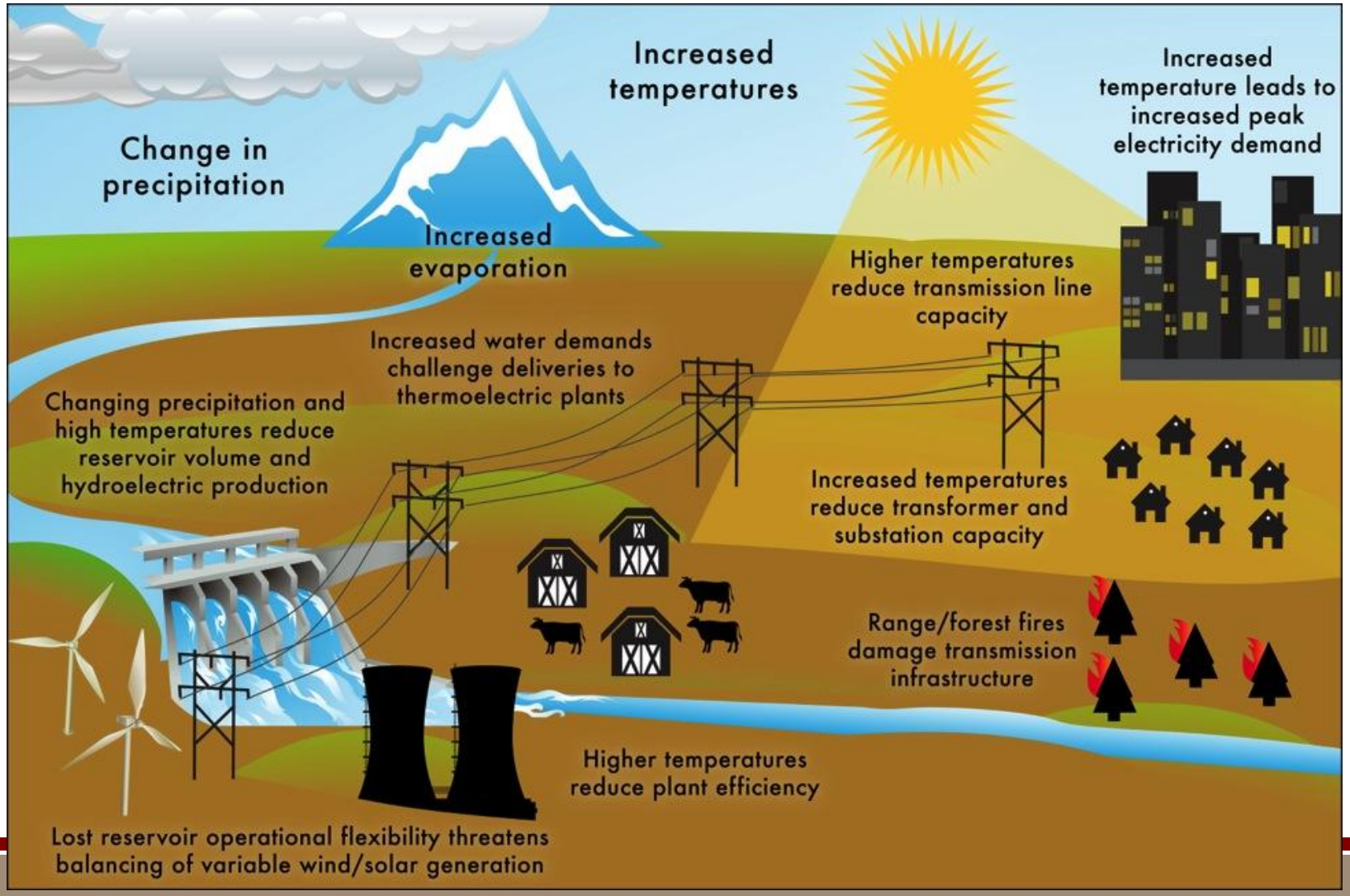


With wholesale cost of electricity about $40/MWh, many retrofits could be accomplished at levels that would add less than 10% to current power plant generation expenses.*

*average 2012 wholesale cost over 3 US trading hub regions

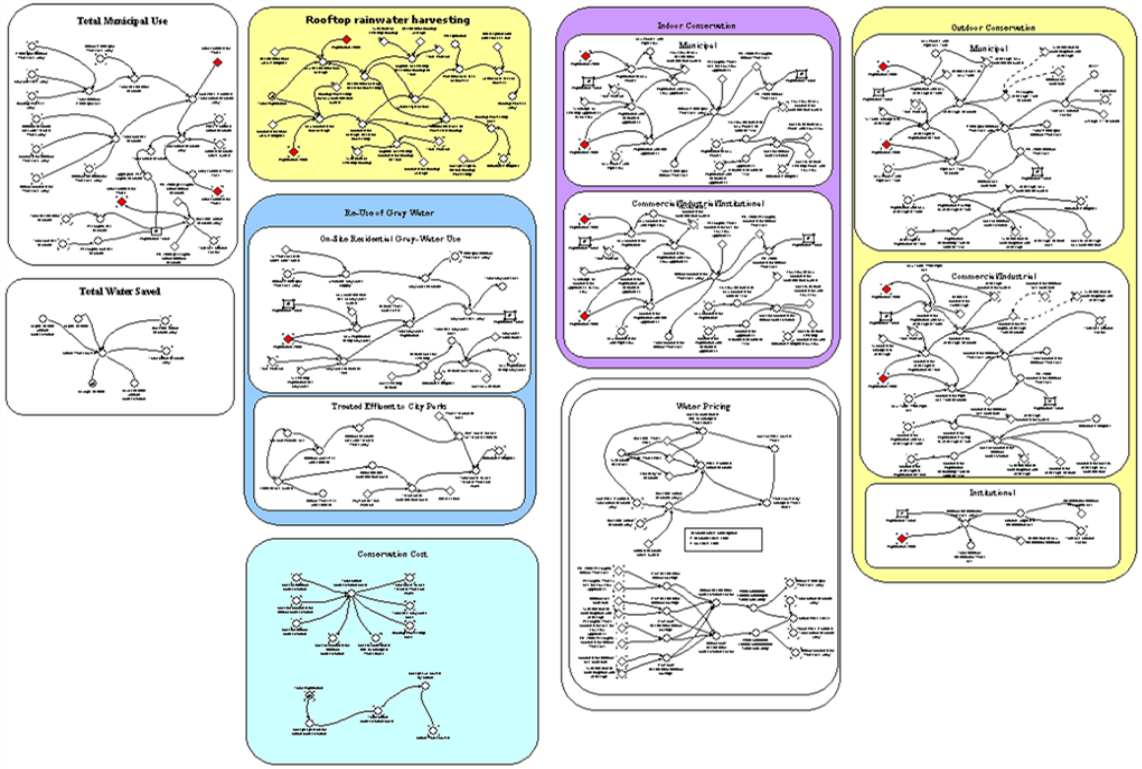
Cascading Impacts of Climate Change

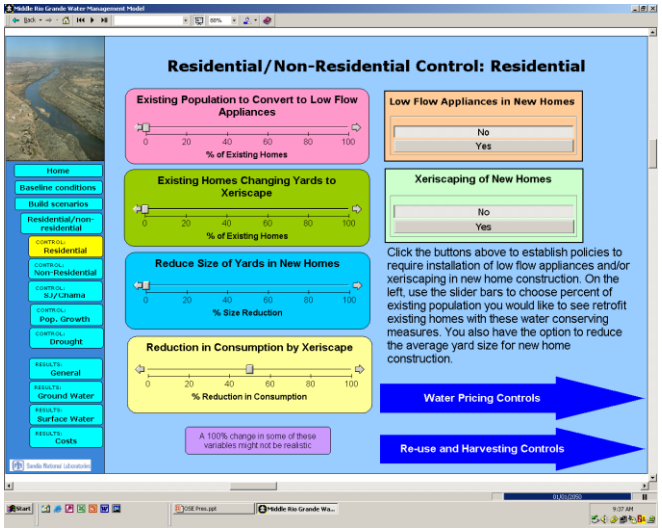
Delivery of electricity may become more vulnerable to disruption due to climate-induced impacts



Summary

- Although thermoelectric generation accounts for only 3-4% of current national water consumption it is of critical concern because:
  - Its growing demand (need for “new water”)
  - Place matters
- Important technology shifts/opportunities
  - Open loop cooling
  - Gas revolution
  - Emission controls/retirements
  - Retrofitting to zero freshwater use
- Need for integrated planning between water and energy planners/managers





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