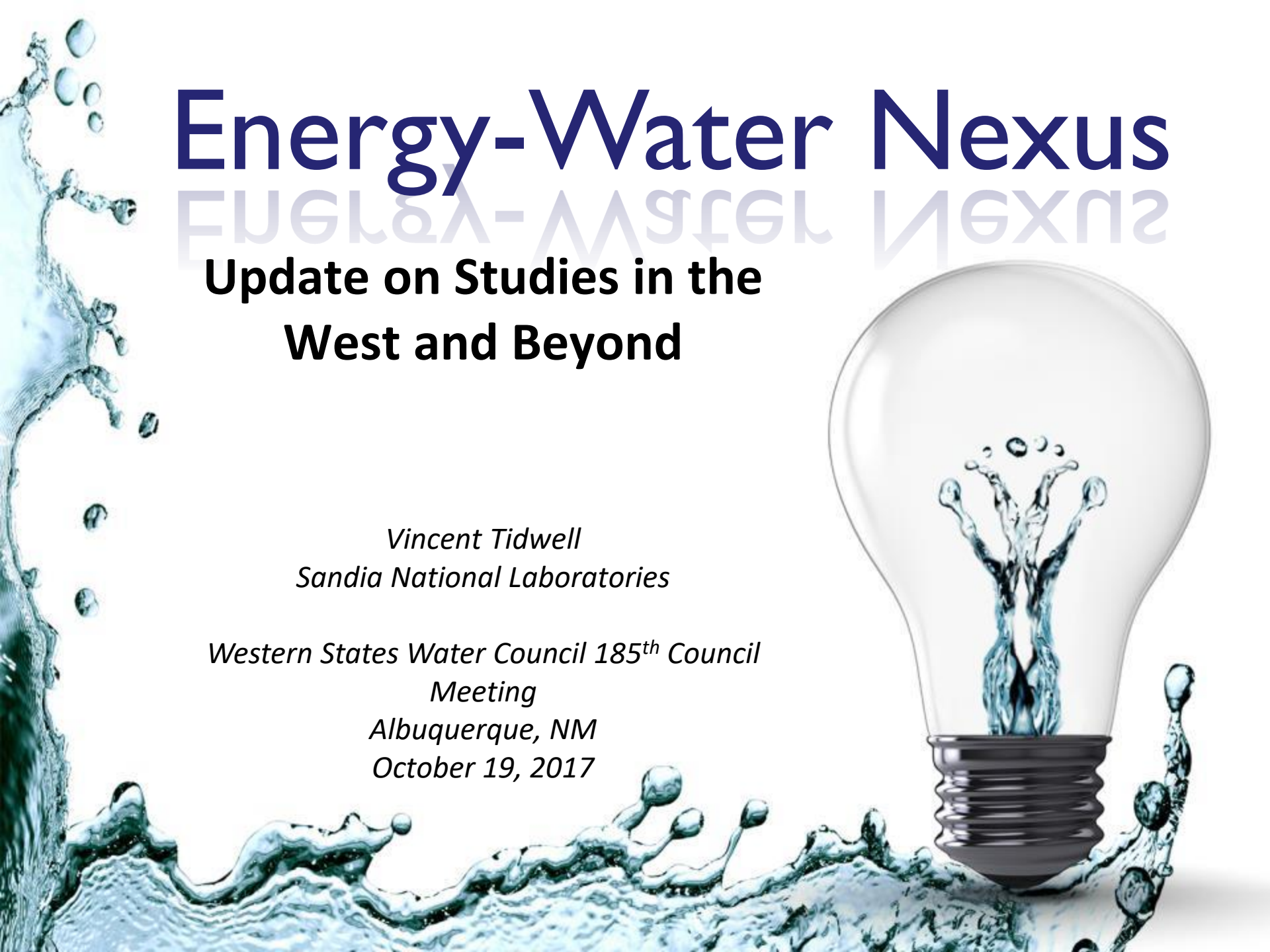
Energy-Water Nexus

Update on Studies in the West and Beyond



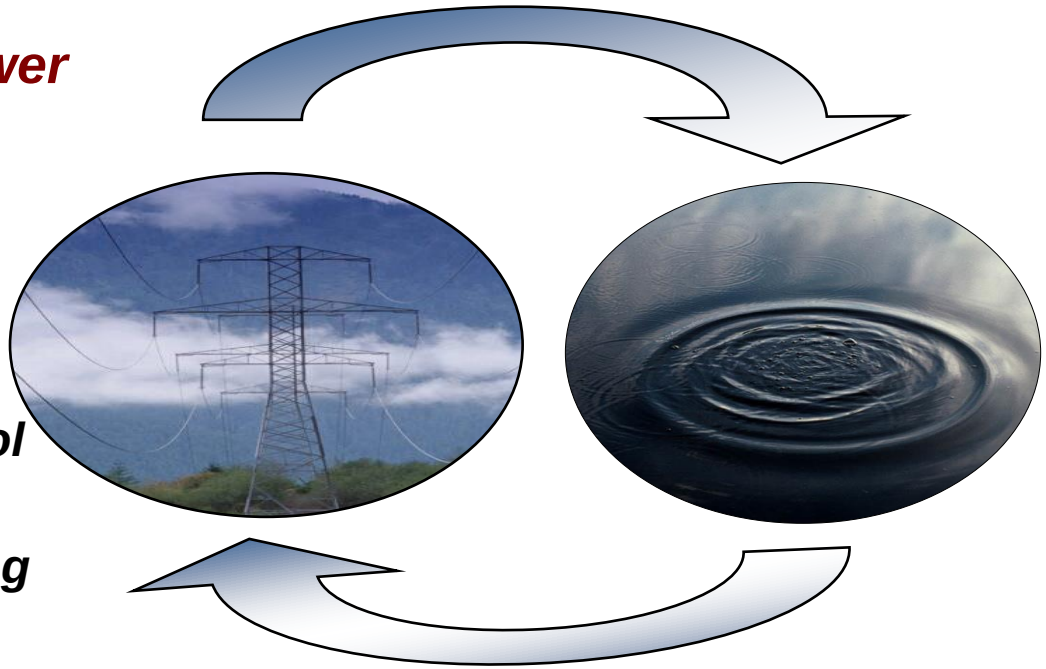
Vincent Tidwell
Sandia National Laboratories

Western States Water Council 185th Council Meeting
Albuquerque, NM
October 19, 2017

Energy-Water Nexus

Energy and power production requires water

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



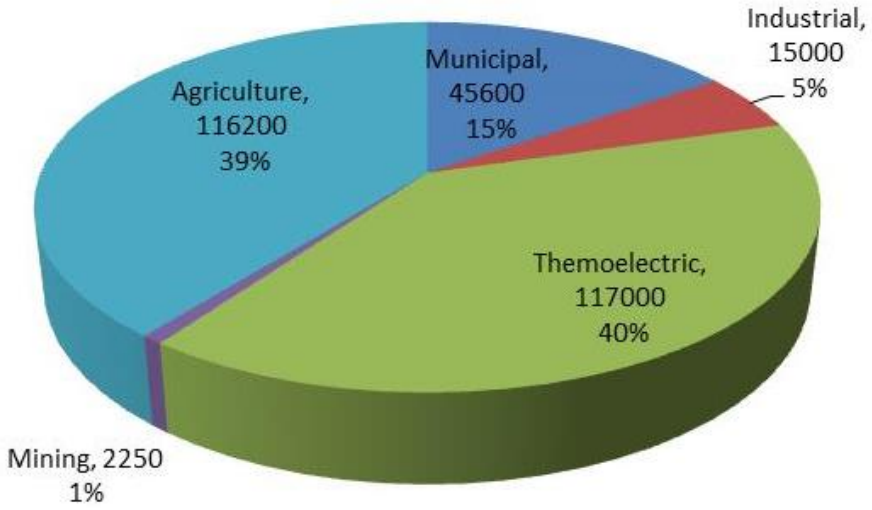
Water production requires energy

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

Water for Energy

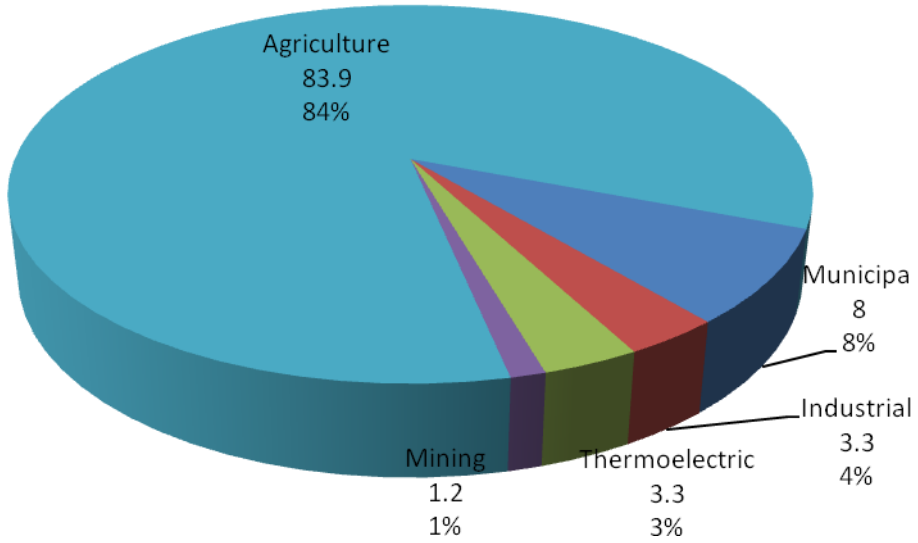
Water for Energy Today

Water Withdrawal (BGD) 2010



Source: USGS 1995, 2014

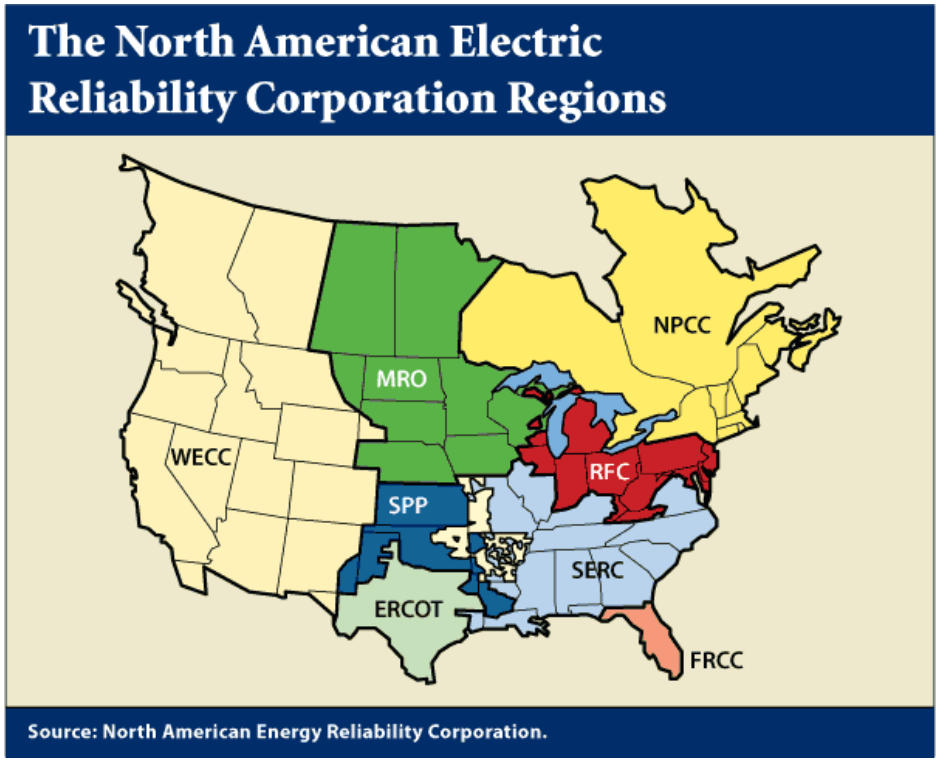
Water Consumption (BGD)1995



Estimated at ~2.6 BGD consumed in mining and fuel processing

Integrated Planning

- Integrate water related concerns into long-range transmission expansion planning (20 yrs.) of WECC:
  - Siting of new power plants
  - New transmission capacity



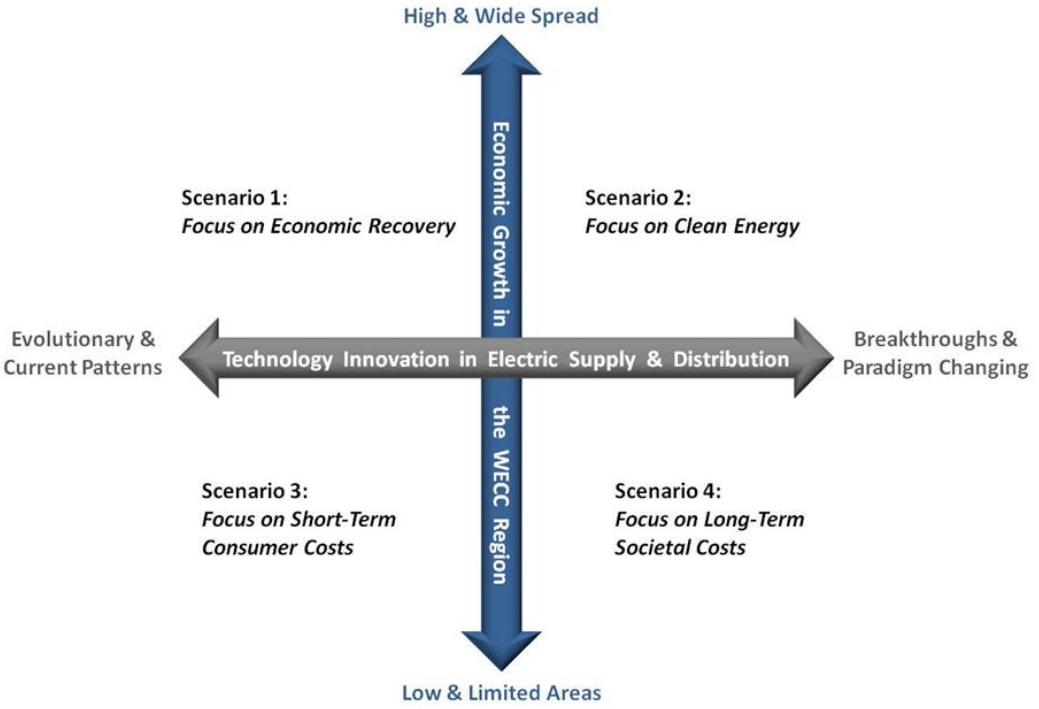
WESTERN GOVERNORS' ASSOCIATION
Serving the Governors of 19 States and 3 US-Flag Pacific Islands

WECC

WSWC
Western States Water Council

Methods: Scenario Development

- ***Reference Case:*** adopted trajectory of recent WECC planning information.
- ***Scenario One:*** favored continued trends in growing use of natural gas and renewables.
- ***Scenario Two:*** distinct shift toward renewables, energy efficiency and significant carbon tax.
- ***Scenario Three:*** reliance on traditional technologies while simply meeting current state renewable portfolio standards.
- ***Scenario Four:*** similar technology development and policies as in scenario two except limited by sluggish economic growth.

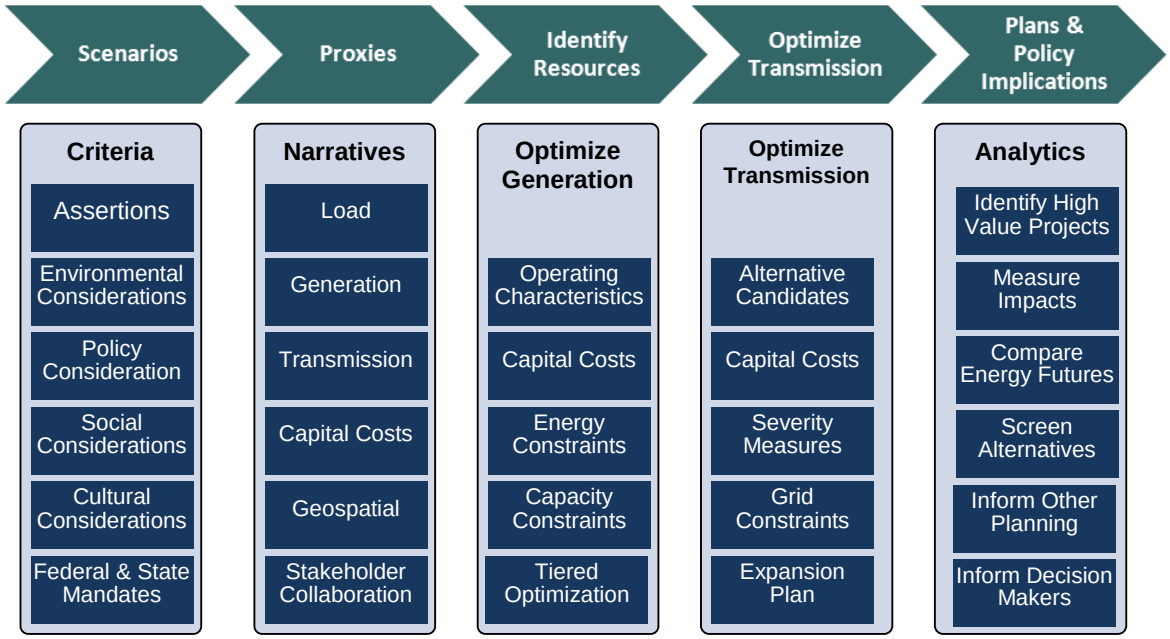


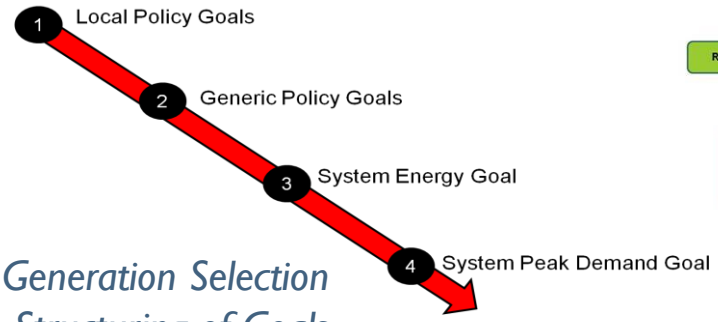
Source: WECC 2013

Methods: Capital Expansion

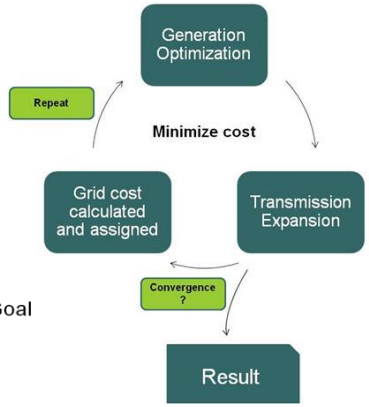
- Co-optimize generation and transmission additions.
- Least cost solution subject to goal related constraints:
  - Energy,
  - Policy,
  - Environmental, and
  - Societal conditions.
- Water is one of many considerations.

Source: WECC 2013





Generation Selection Structuring of Goals

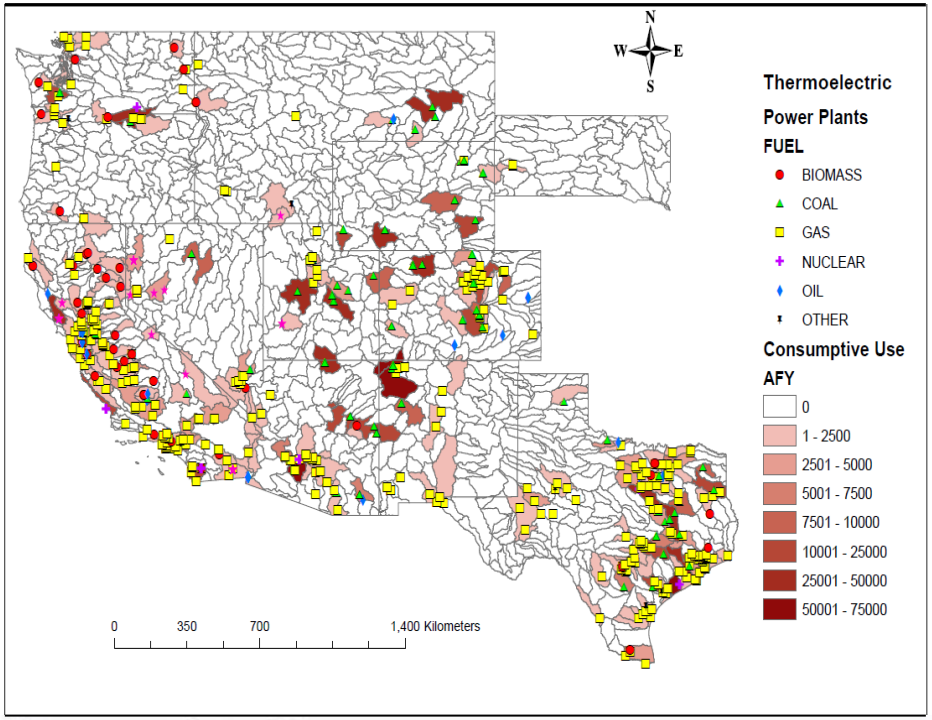


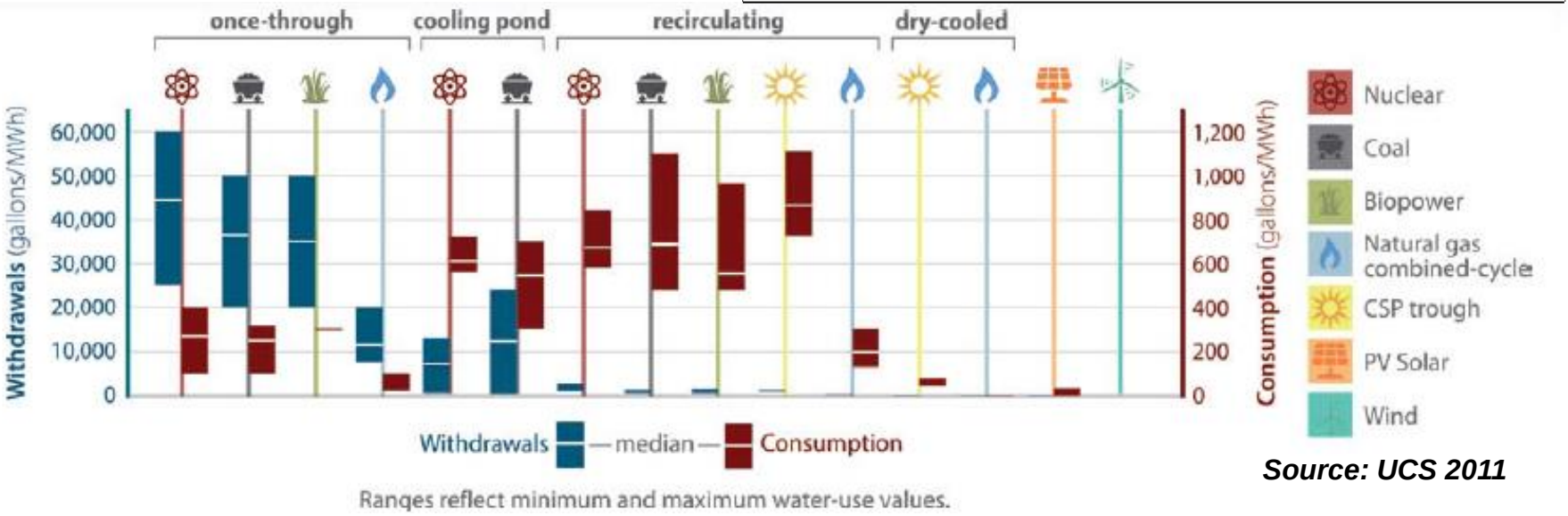
Optimization Iteration

Methods: Water for Thermoelectric Power

- Water withdrawal and consumption at existing power plants
- Water intensity of future thermoelectric power plants

Water Consumption for Existing Power Plants

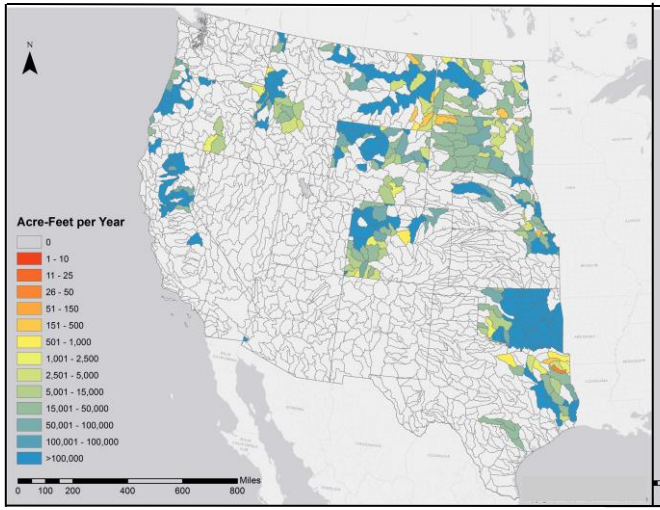




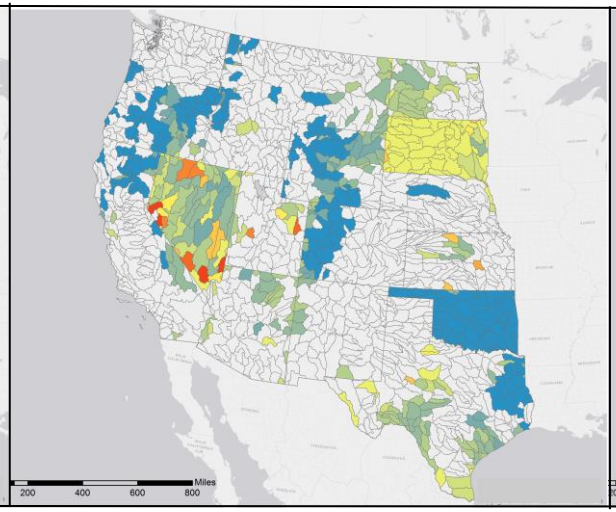
Source: UCS 2011

Results: Water Supply Availability

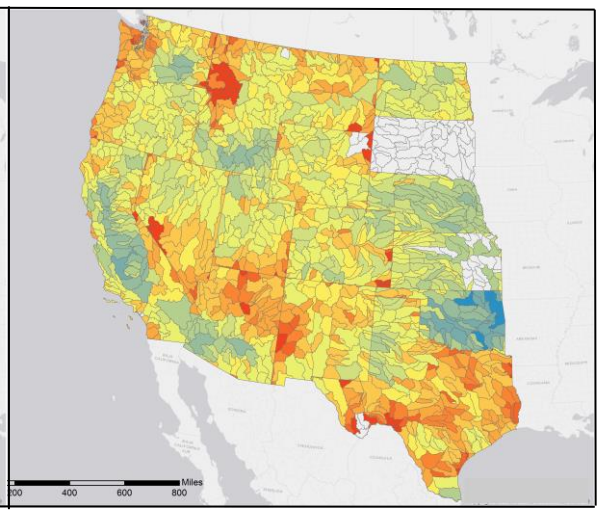
Unappropriated Surface Water



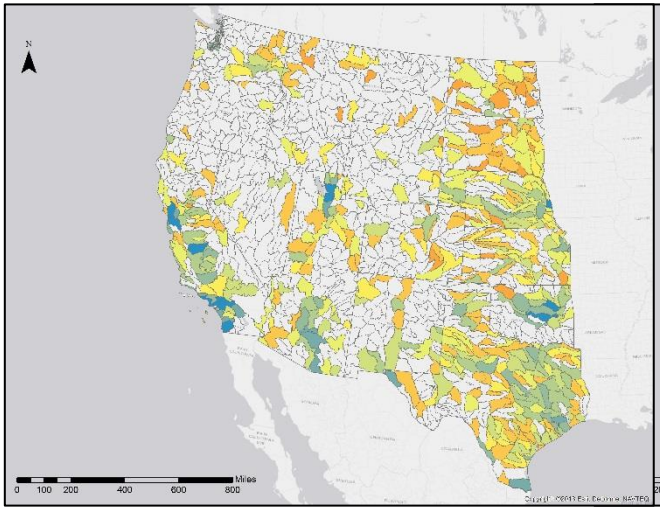
Unappropriated Groundwater



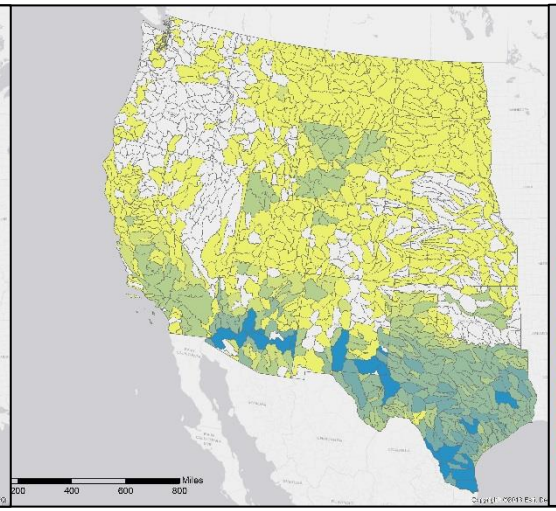
Appropriated Water



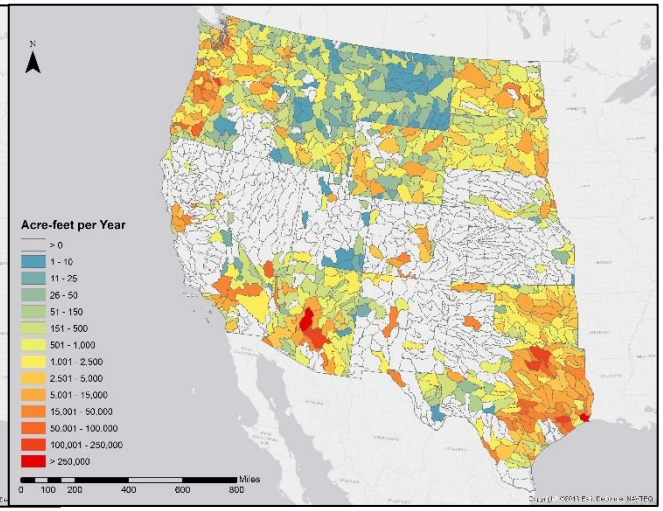
Municipal Wastewater



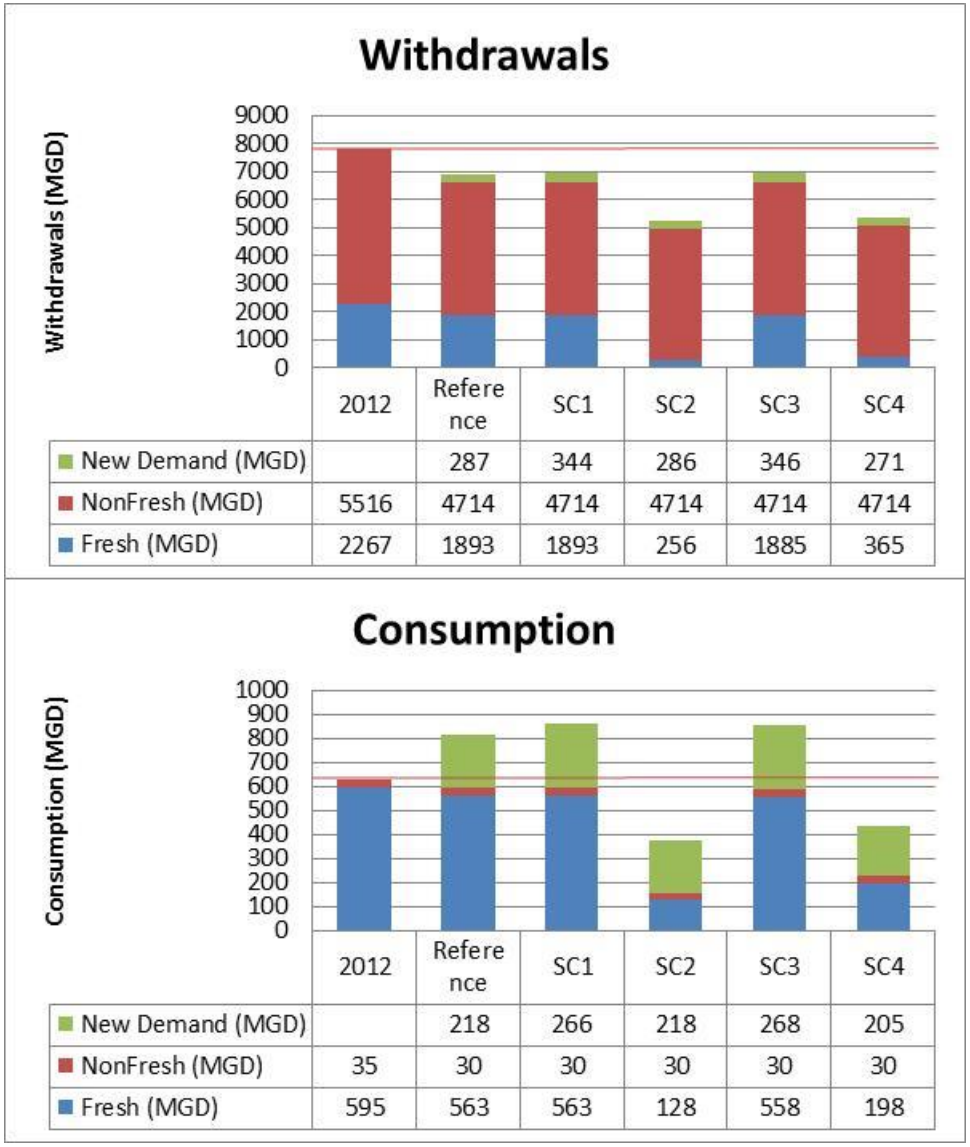
Brackish Groundwater



Consumptive Demand 2010-2030



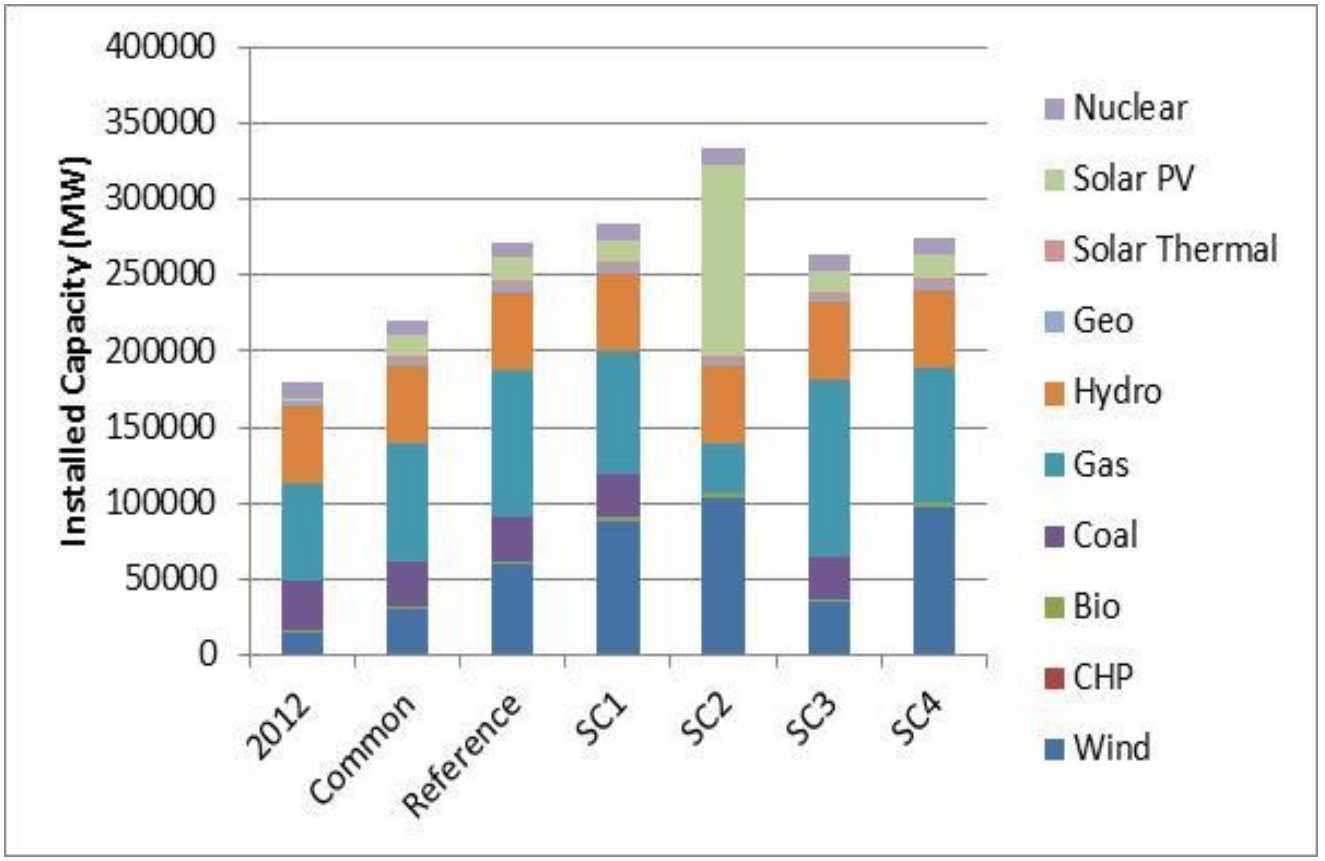
Results: Water Use



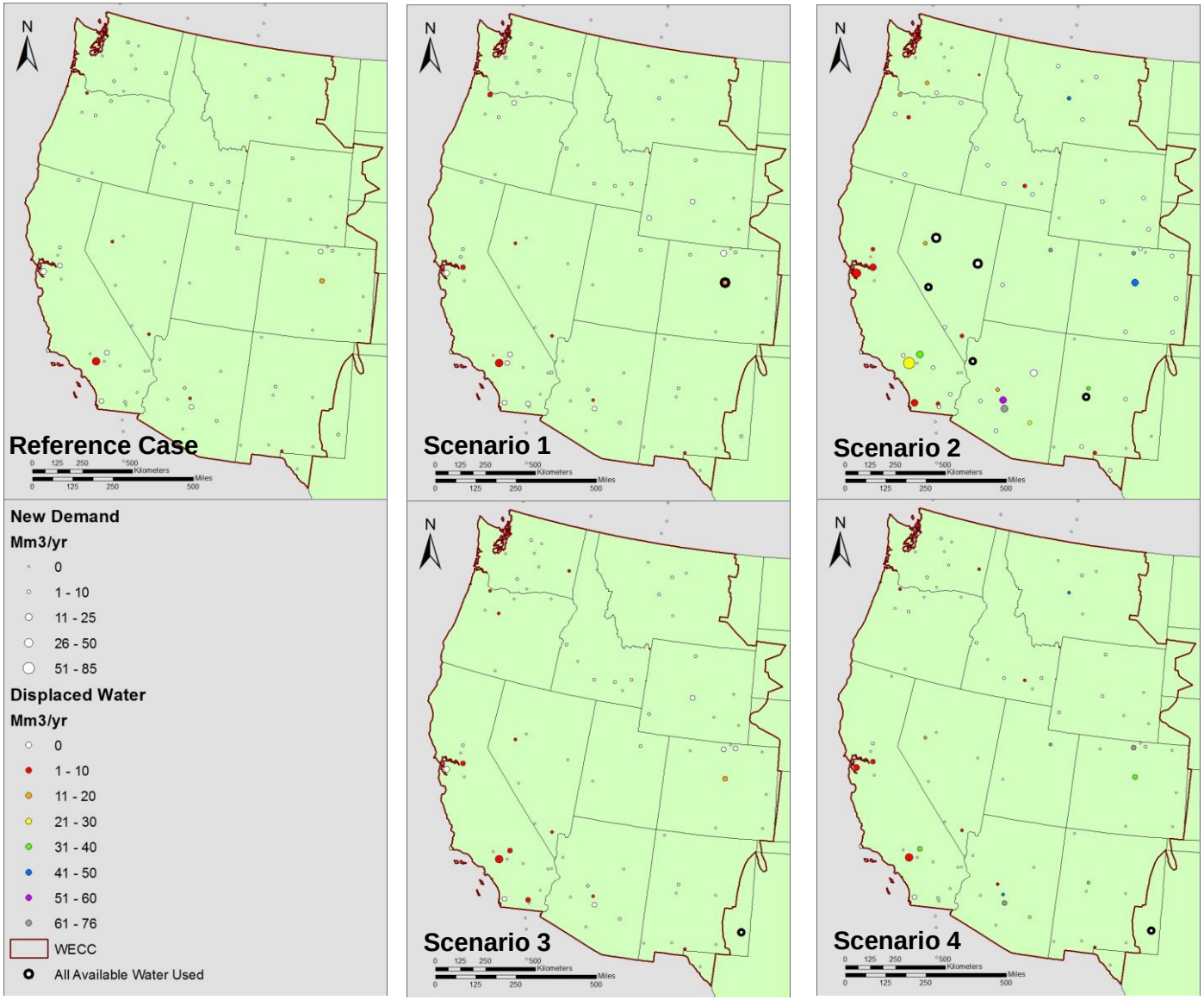
- Uniform reductions in withdrawals:
  - Similar additions across scenarios,
  - Retirements of 14% of seawater and 4 % freshwater withdrawals,
  - >70% displacement of freshwater withdrawal in scenarios 2 and 4
- Consumption varies by scenario:
  - Uniform additions,
  - >30% decrease for scenarios 2 and 4 (displaced coal)
  - >30% increase for other scenarios

Results: Generation Expansion

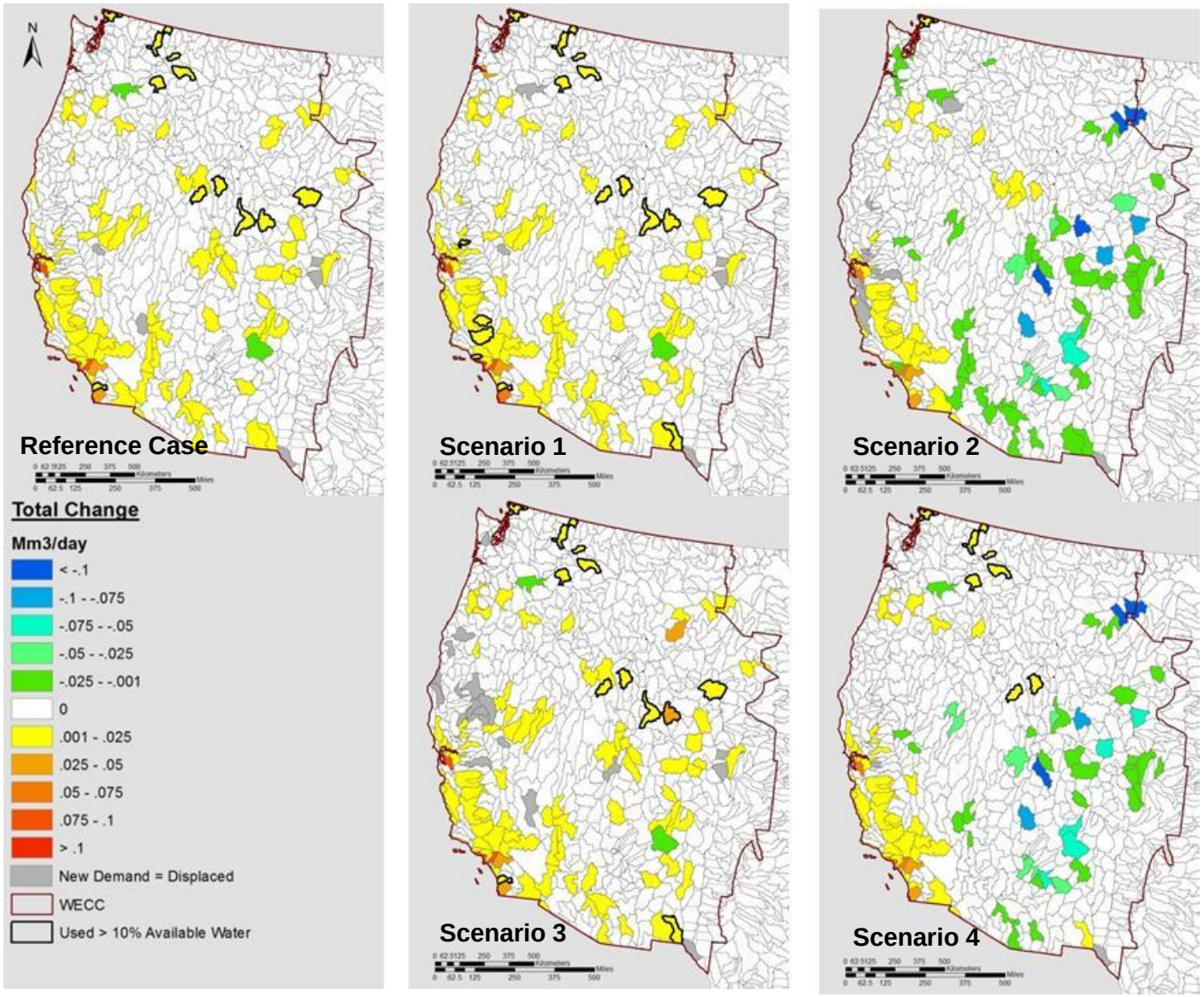
- Uniform mix of additions across five scenarios:
  - Natural Gas Combined Cycle,
  - Wind, and
  - Solar PV.
- Coal generation displaced in Scenarios 2 and 4 due to emission policies.



Results: Water Constraint



Results: Watershed Impacts



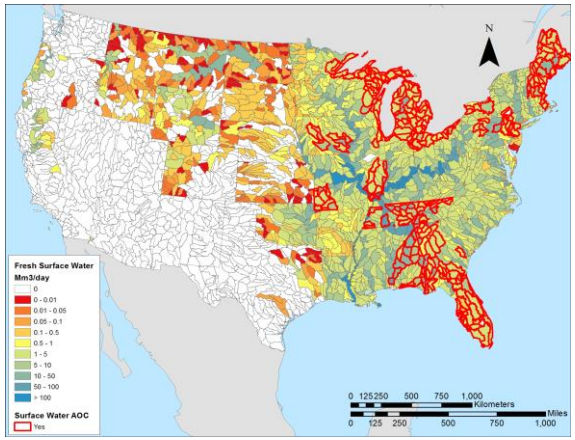
- Few instances where new demands exceed 10% of available water (outlined watersheds).
- Two scenarios free up considerable water (2 and 4).

Planning: Alternative Water

Scenario	Surface Water (%)	Groundwater (%)	Appropriated Water (%)	Wastewater (%)	Brackish Ground Water (%)
Reference Case	11	6	12	37	34
Scenario 1	16	6	10	35	33
Scenario 2	1	5	4	51	39
Scenario 3	16	7	12	31	34
Scenario 4	2	2	5	52	39

Water Supply Availability

Unappropriated Surface Water



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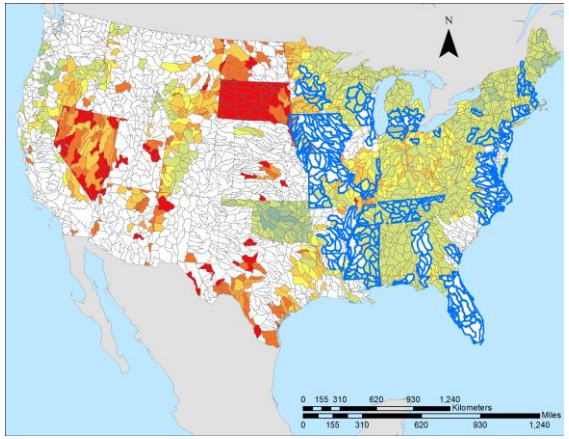
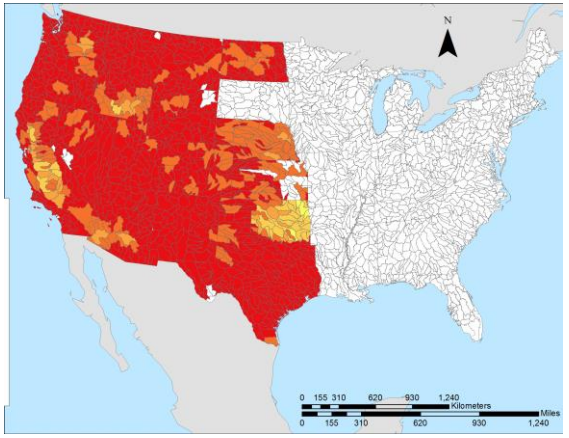
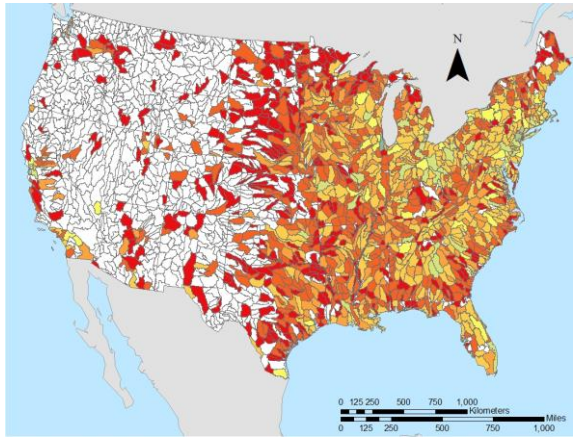


Appropriated Water



Municipal Wastewater



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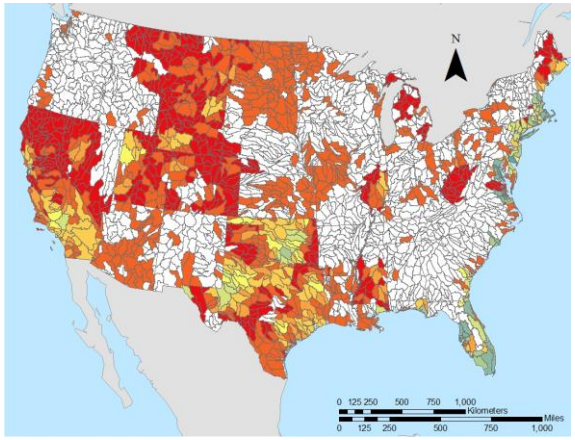

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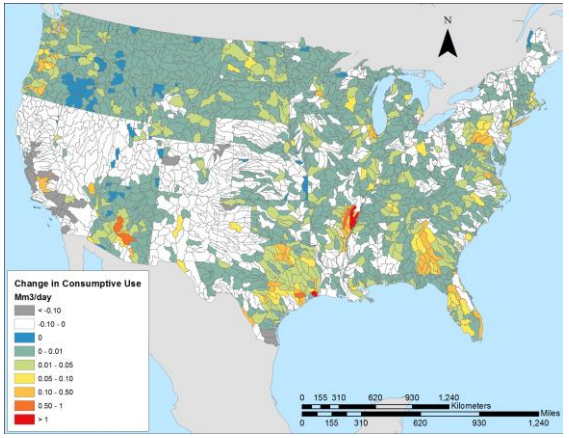
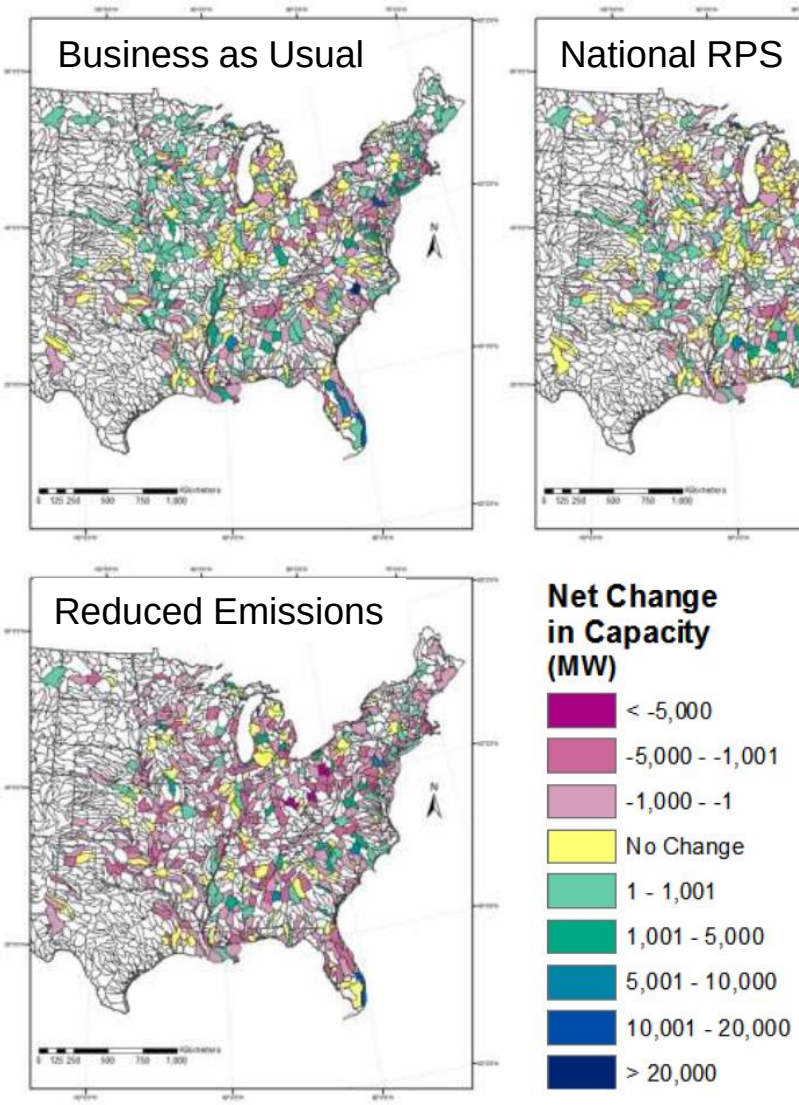
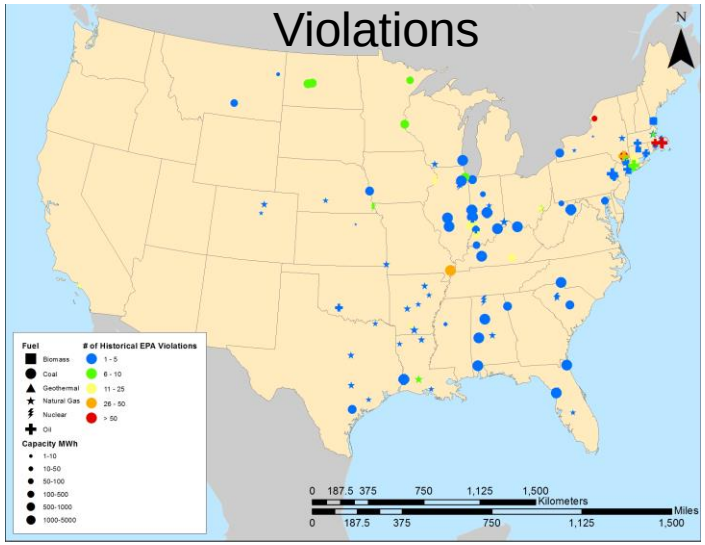


Transmission Planning in East

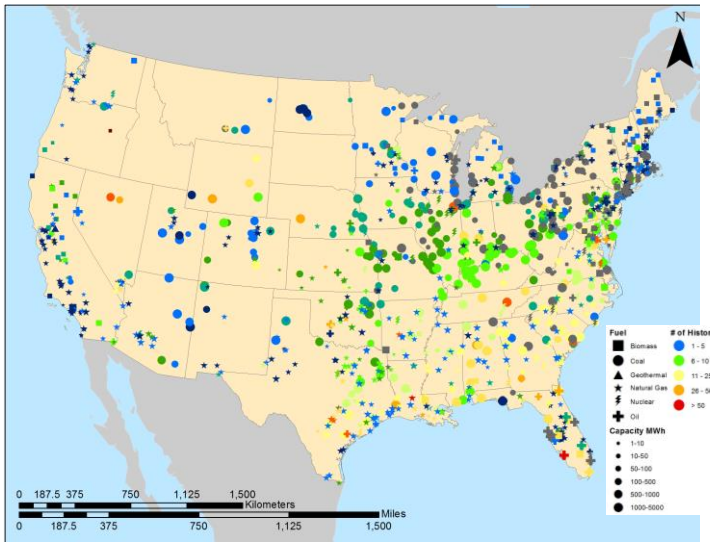


Current Generation at Risk

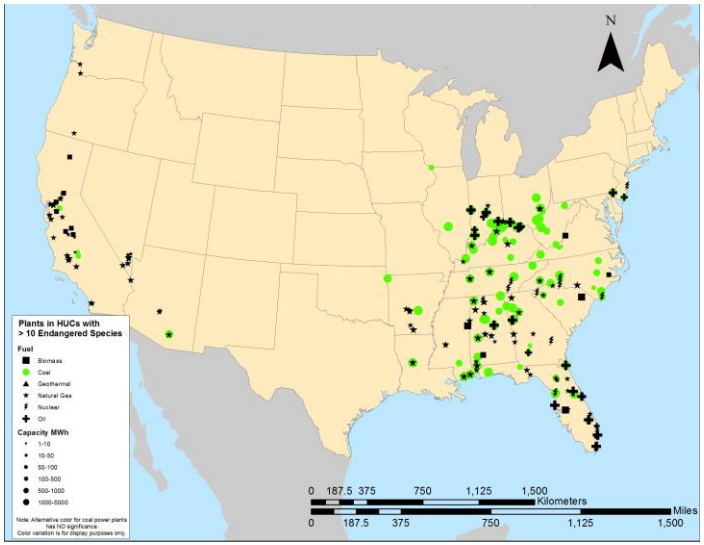
Historic Water Temperature Violations



Climate Vulnerability



Biological Vulnerability



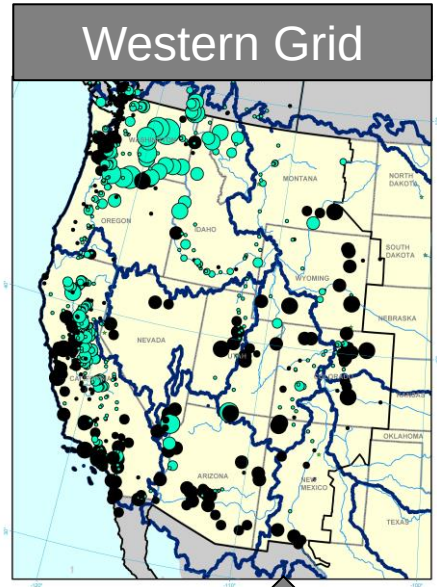
San Juan Basin

Four Corners Region

- Colorado River basin
- Snow melt dominated system
- Water Users
  - Native American
  - Irrigation
  - Multiple power plants and limited hydropower
  - Municipalities
  - Instream flows
  - Interbasin transfers

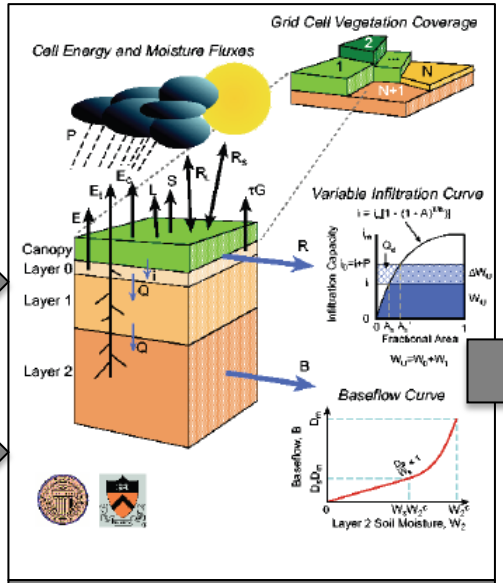
Asset-Level Energy-Water Nexus

- Framework that links natural and engineered systems to evaluate climate vulnerabilities and adaptive measures at the ***asset level***:
  - Multiple interacting sectors,
  - Multiple forcings, and
  - Multiple interacting scales.



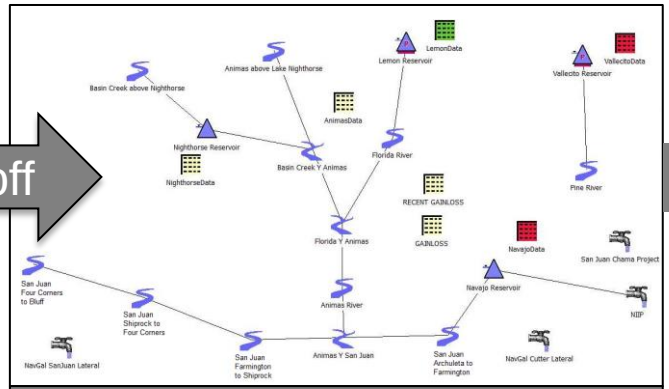
Climate

Growth



Natural System

Runoff



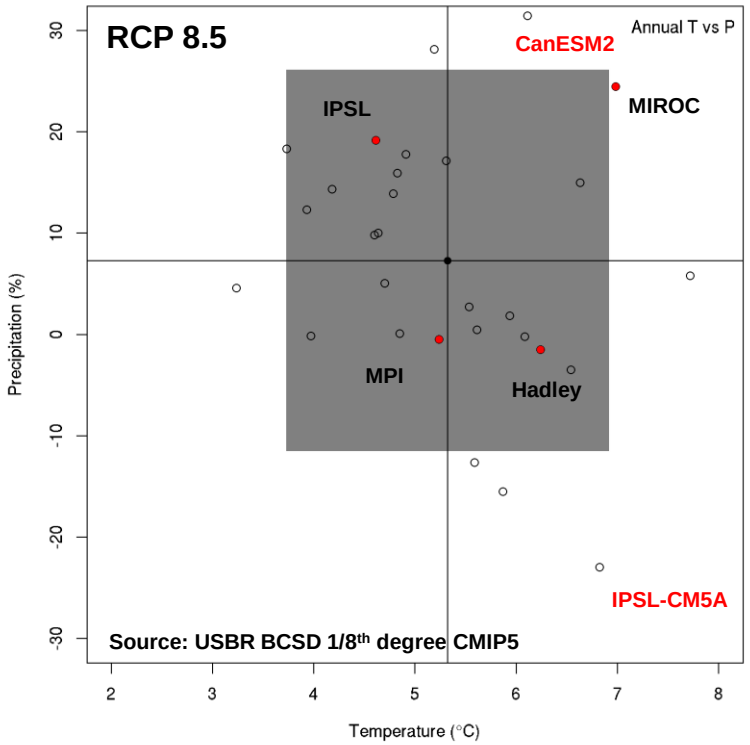
Engineered System

Deliveries

- Electric Power
- Agriculture
- Environment

Model Scenarios

1. Six CMIP5 global climate models using scenario RCP 8.5



2. Climate Driven Vegetation Change

3. Utilization of Settlement Waters

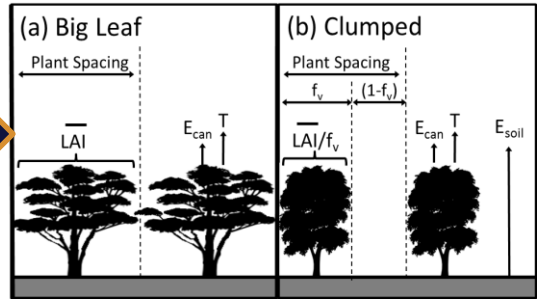
NAVAJO GALLUP WATER SUPPLY PROJECT

Navajo Indian Irrigation Project

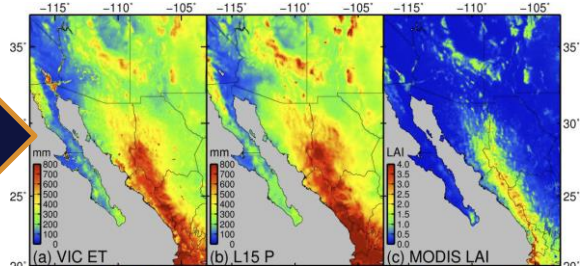
Methods: Hydrology

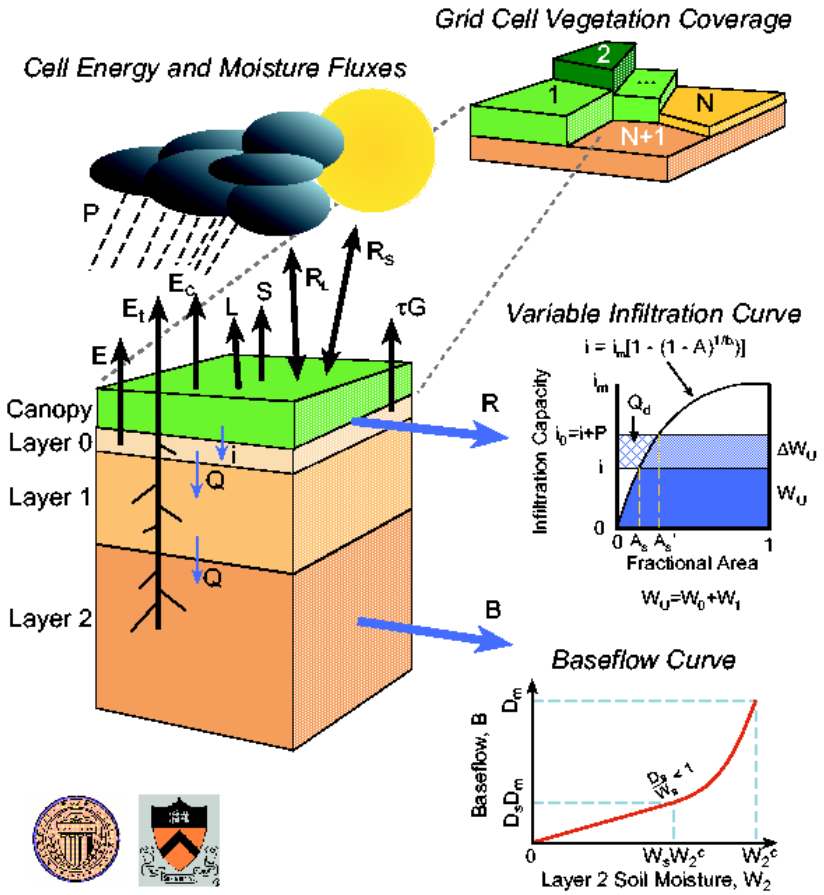
- Variable Infiltration Capacity (VIC) model at 1/16th degree
- New MODIS data, including time series for each grid cell for albedo, vegetation spacing and LAI
- Downscaling using Mutivariate Adaptive Constructive Analogues (MACA) data set (Abatzaglou and Brown, 2011)

VIC Version 4.2x



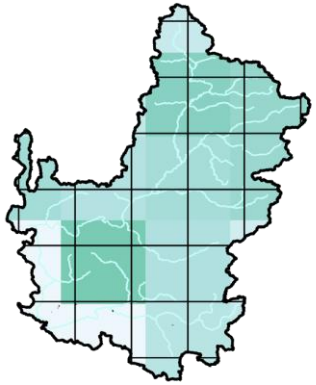
MODIS Veg; Livneh et al. 2015

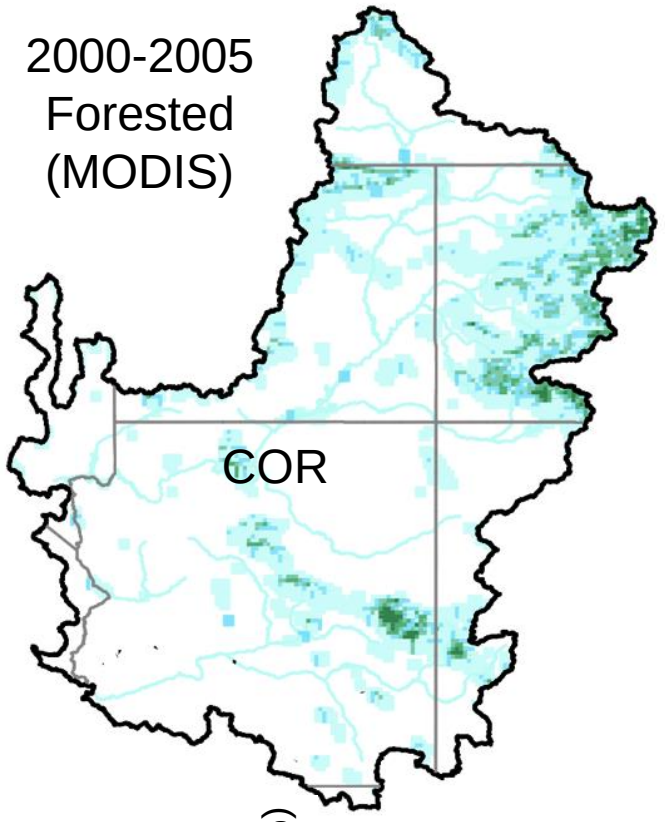


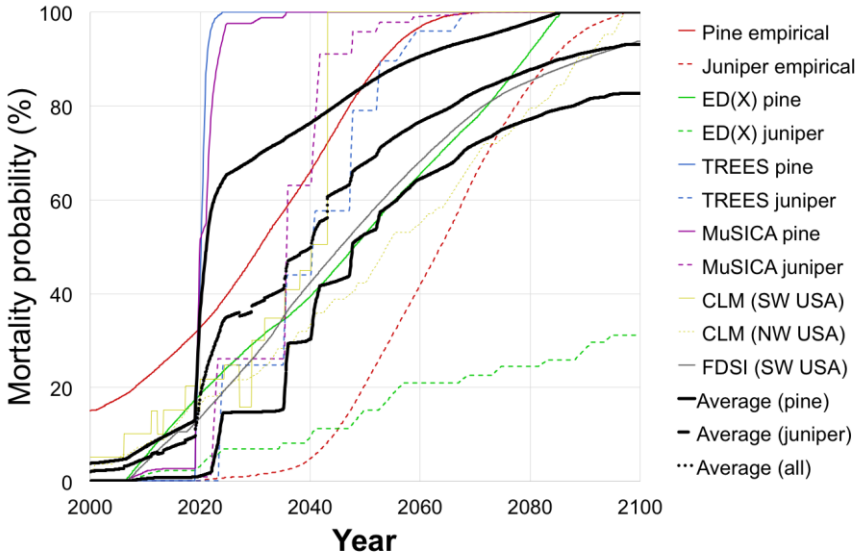


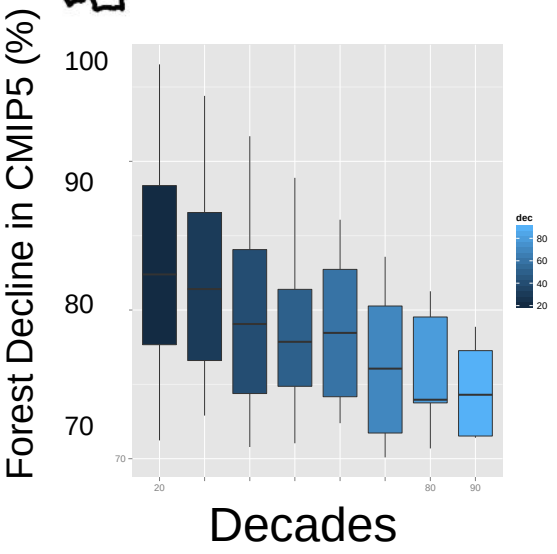
Bohn and Vivoni, 2015

Methods: Vegetation





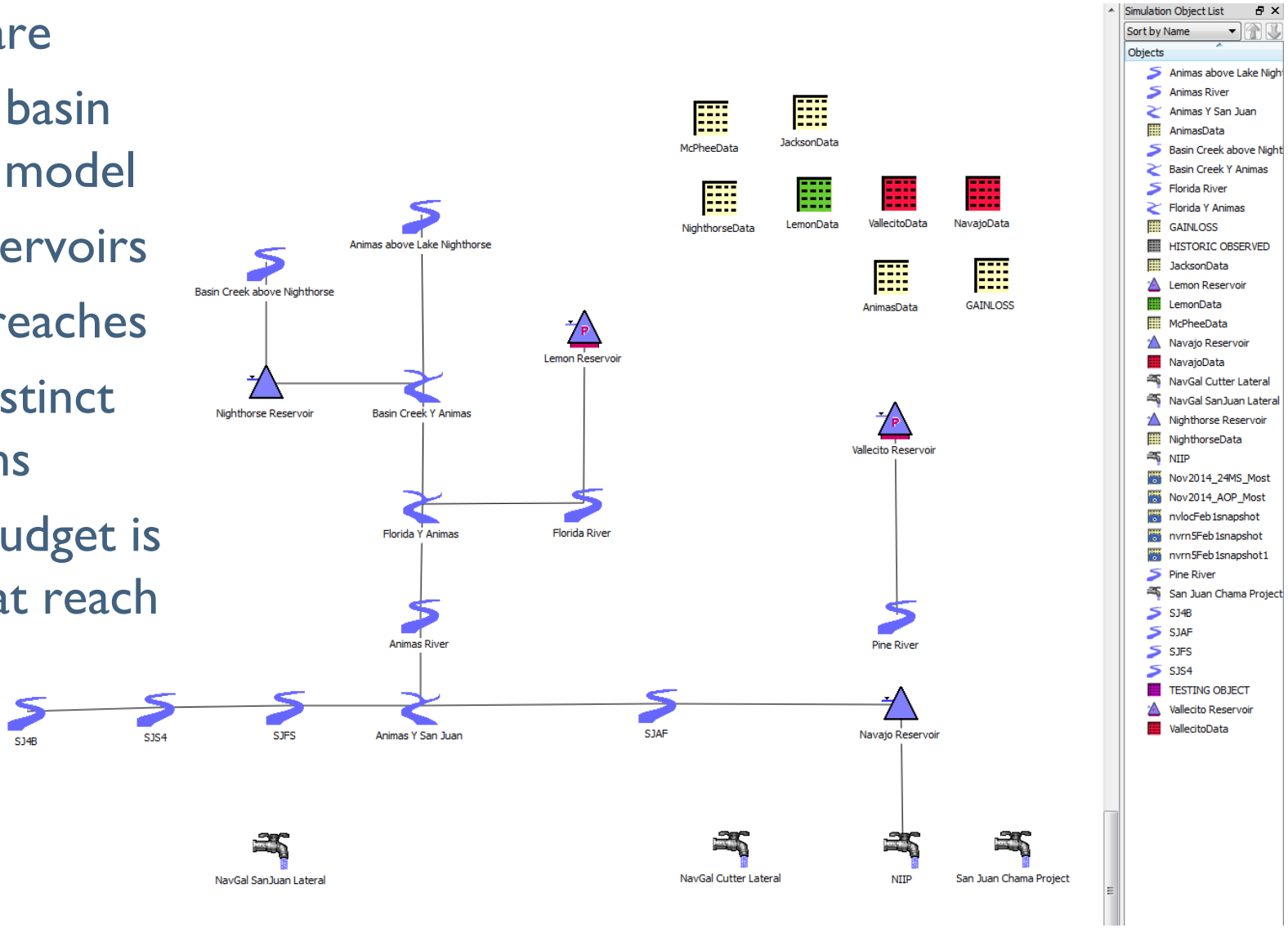




McDowell et al. Convergent predictions of massive conifer mortality due to chronic temperature rise. *Nature Climate Change.* 2015.

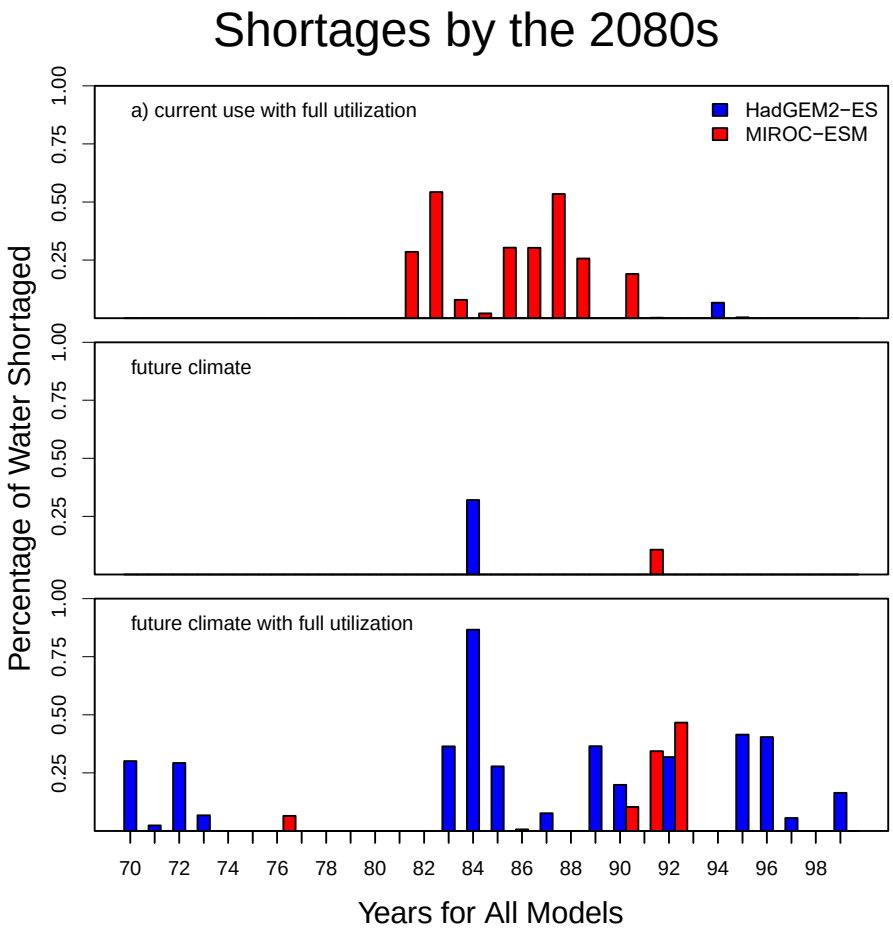
Methods: Reservoir Routing

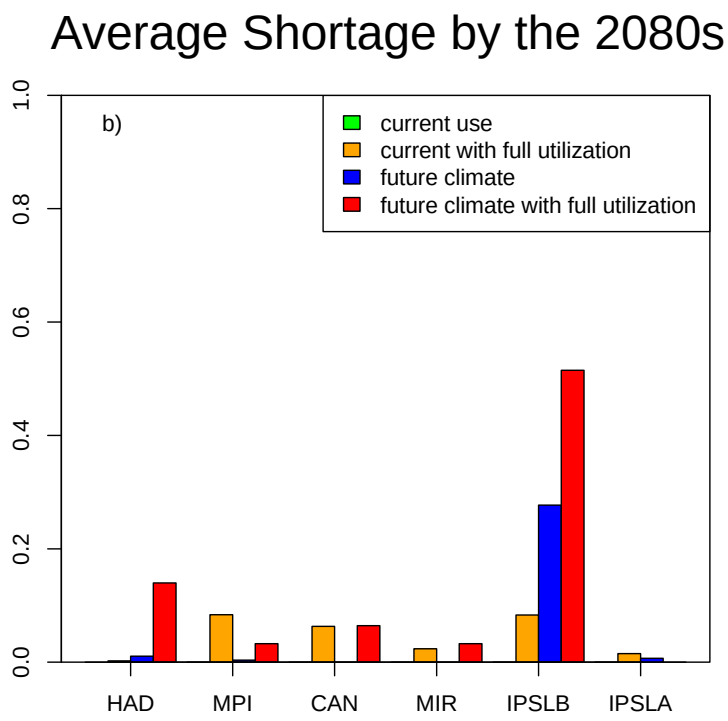
- RiverWare
- Current basin planning model
- Four reservoirs
- Twelve reaches
- Three distinct diversions
- Water budget is lumped at reach level



Shortage Sharing

- Shortage sharing used to prioritize deliveries: all share equally in times of water shortage



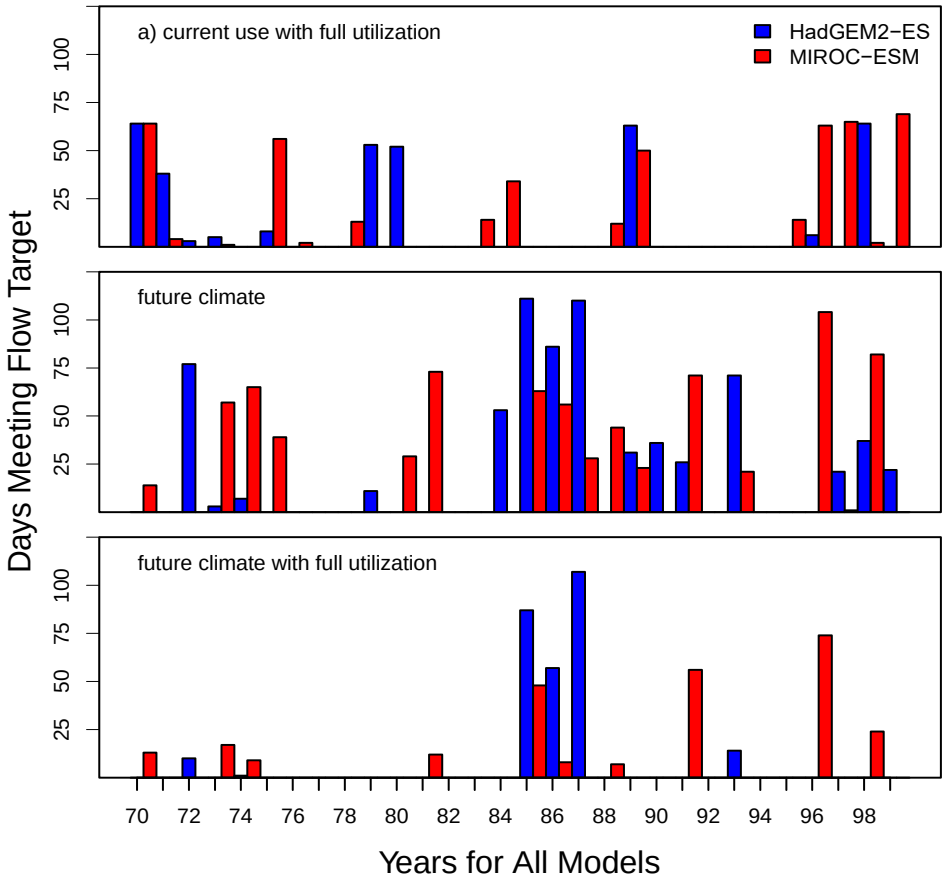


Targeted Spring Flows

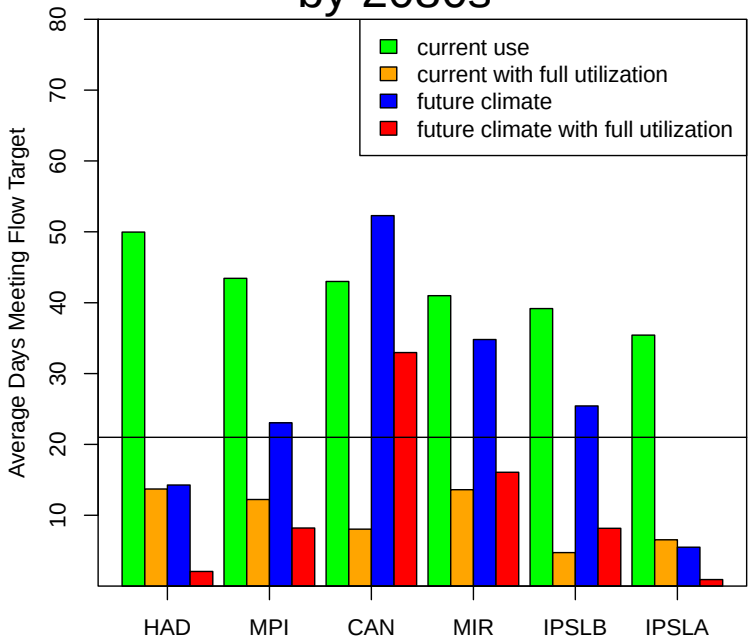
Days above 5000 cfs: March-July

Target is 21 days per year

Days Meeting Target by 2080s

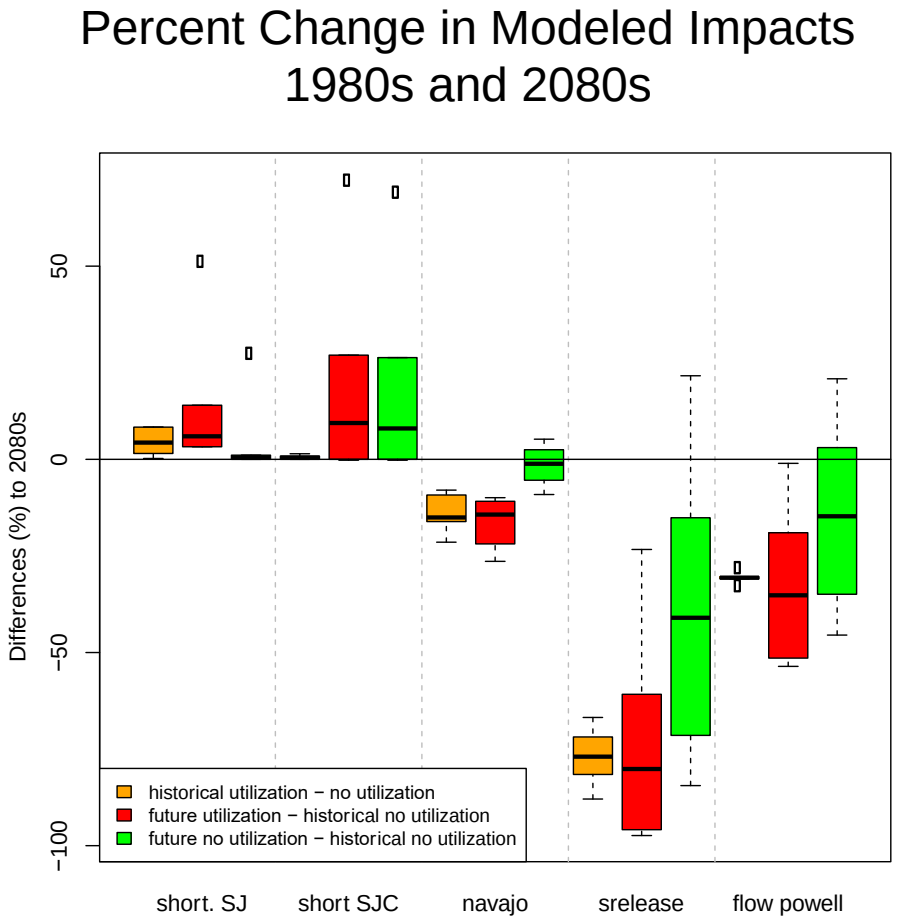


Average Days Meeting Target by 2080s



Uncertainty and Variability

- Big spread in climate model impacts as well as direction of change
- Different metrics respond differently
- Little uncertainty in effects of full utilization



Energy for Water

Energy for Water Today

Source: Wisconsin Department of Natural Resources 2014

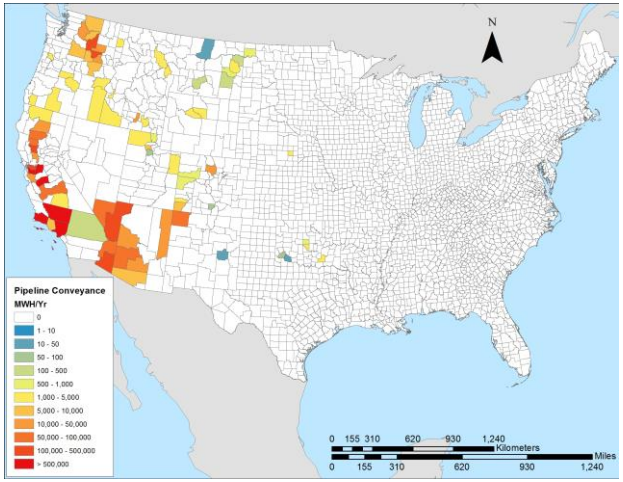
Source: Green Prophet 2014

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

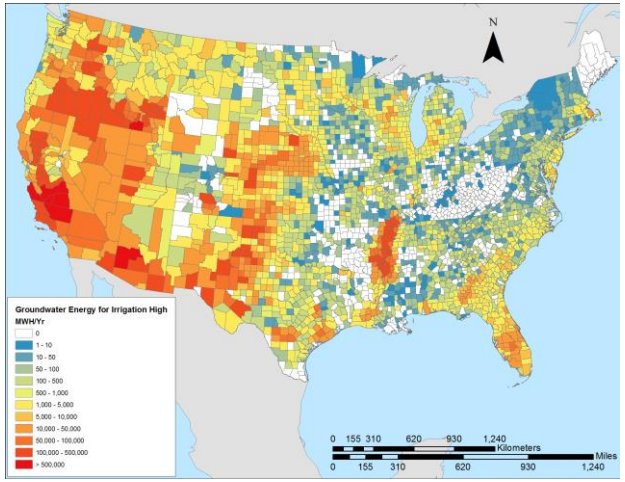
Source: Circle of Blue 2015

Varies by Sector and Location

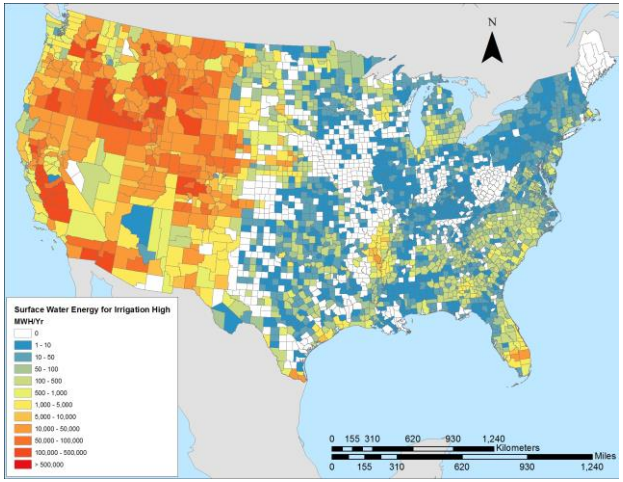
Large-Scale Conveyance



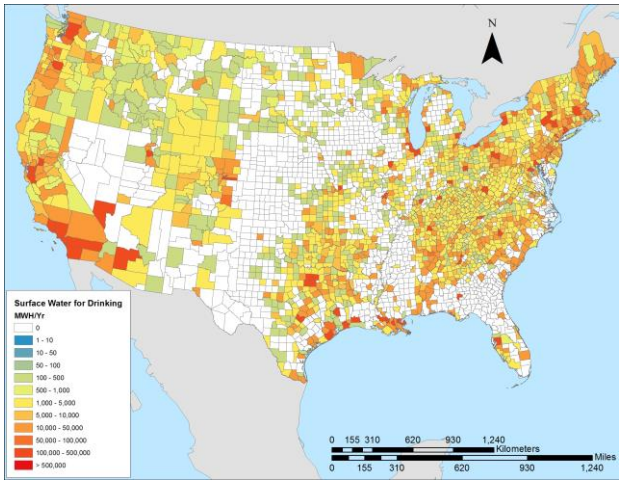
Agricultural Pumping (Groundwater)



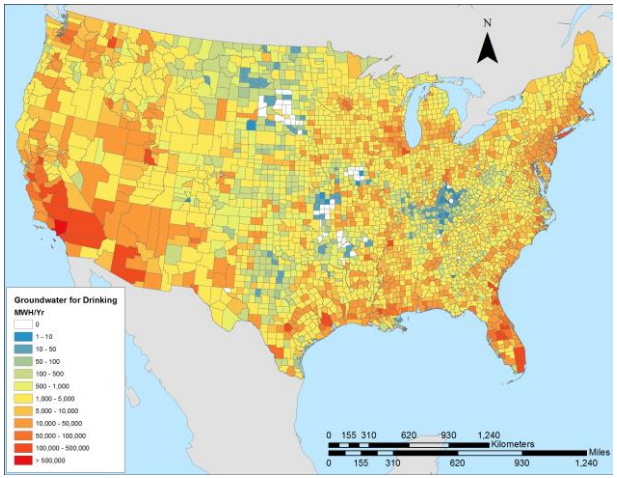
Agricultural Pumping (Surface Water)



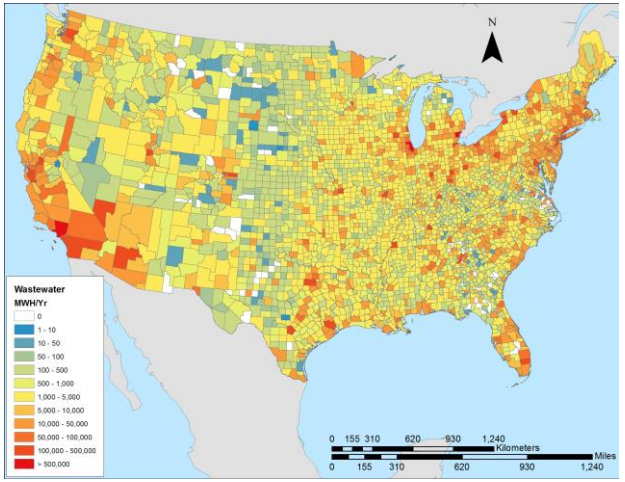
Drinking Water (Surface Water)



Drinking Water (Groundwater)



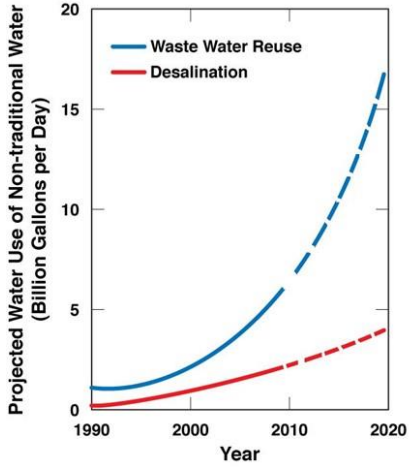
Municipal Wastewater



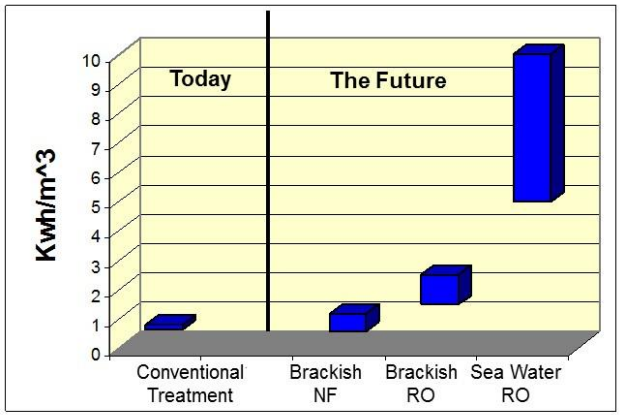
Source: Tidwell et al. 2014

Demands Likely To Increase

Power Requirements For Treatment



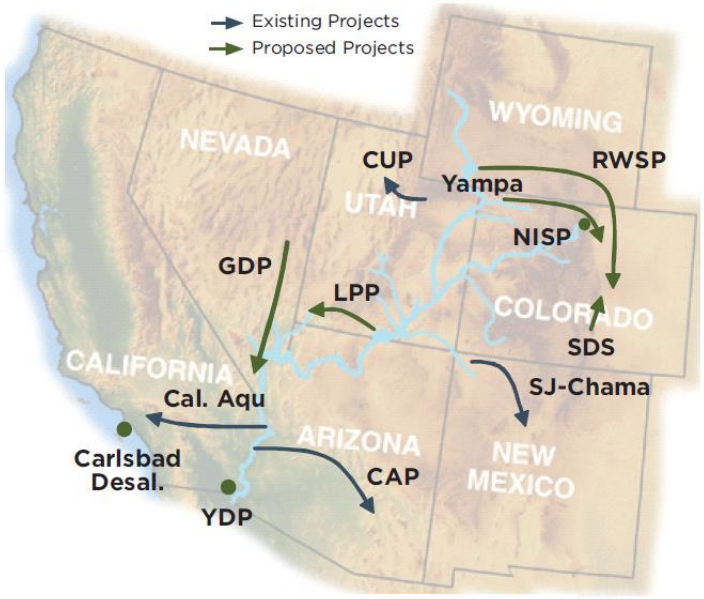
Modified from Water Reuse 2007, EPA 2004, Mickley 2003



Source: Einfeld 2007

Source: detoxifynow.com

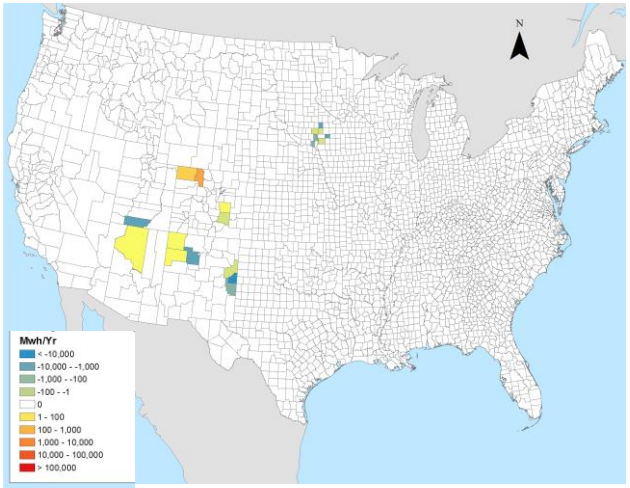
Existing and Proposed Western Water Supply Projects



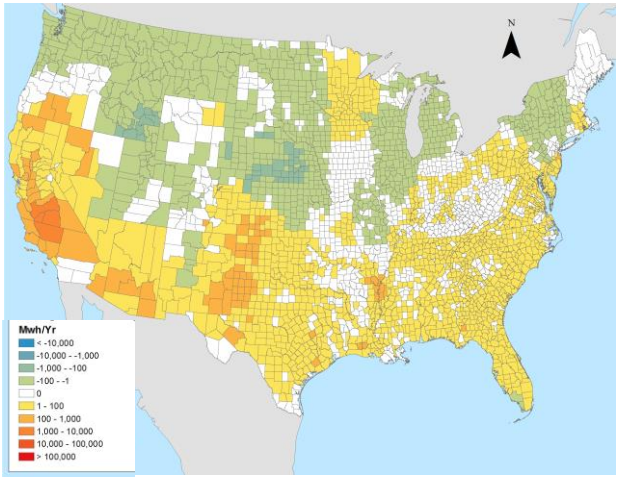
Source: Western Resource Advocates 2010

Projected Changes to 2030

Large-Scale Conveyance

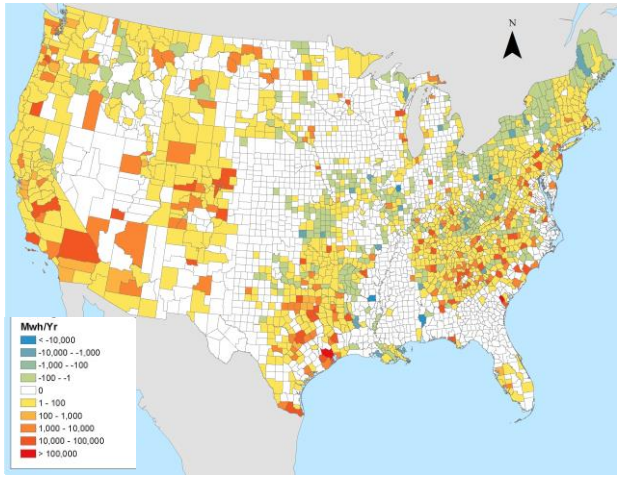


Agricultural Pumping (Groundwater)

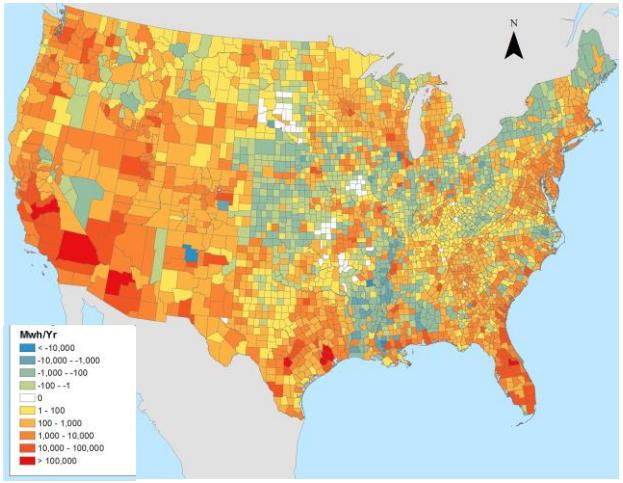


- Projected growth of ~10%
- Heterogeneously distributed

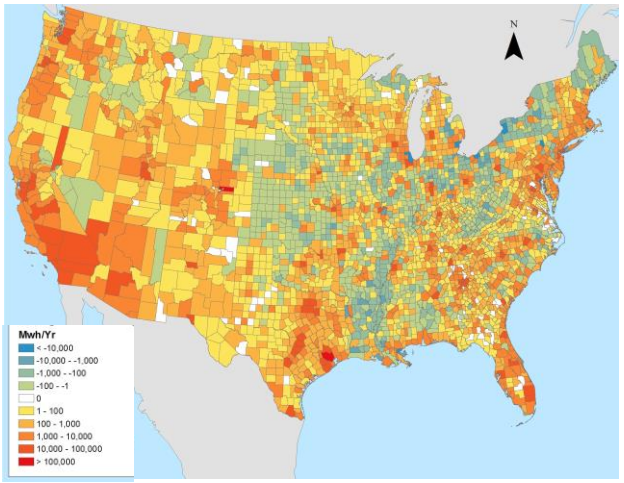
Drinking Water (Surface Water)



Drinking Water (Groundwater)



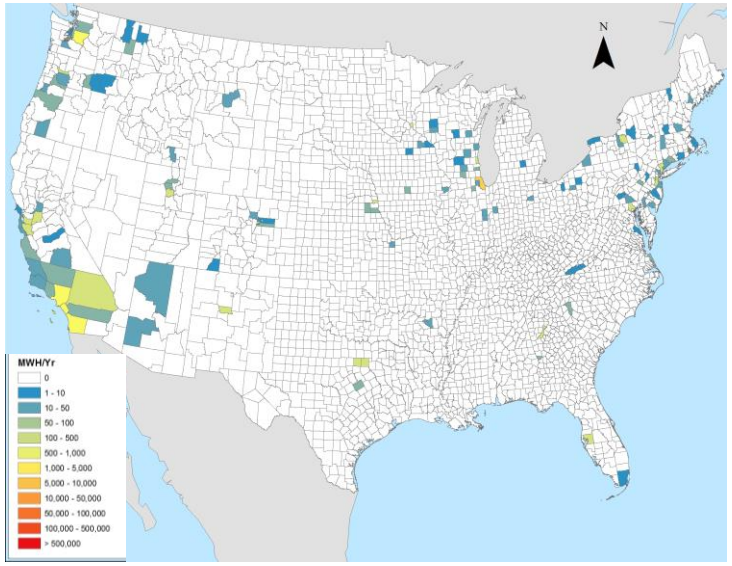
Municipal Wastewater



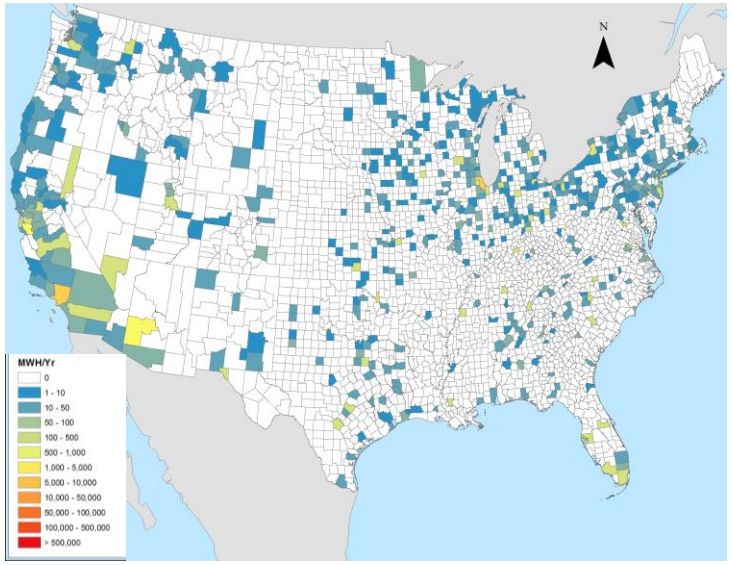
Opportunities

Newtown Creek Wastewater Treatment Plant serving New York City

Current Electricity from Biogas



Potential for Electricity from Biogas: 2030



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