

# Implications of water constraints on electricity capacity expansion in the United States

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November 7<sup>th</sup>, 2017

## ▶ Water use restrictions in the US

- No use of freshwater for new thermoelectric development in California (California Water Code, 13550-13552)
- Statewide mandatory water reduction during California drought
- Restricted domestic water use in Austin, TX

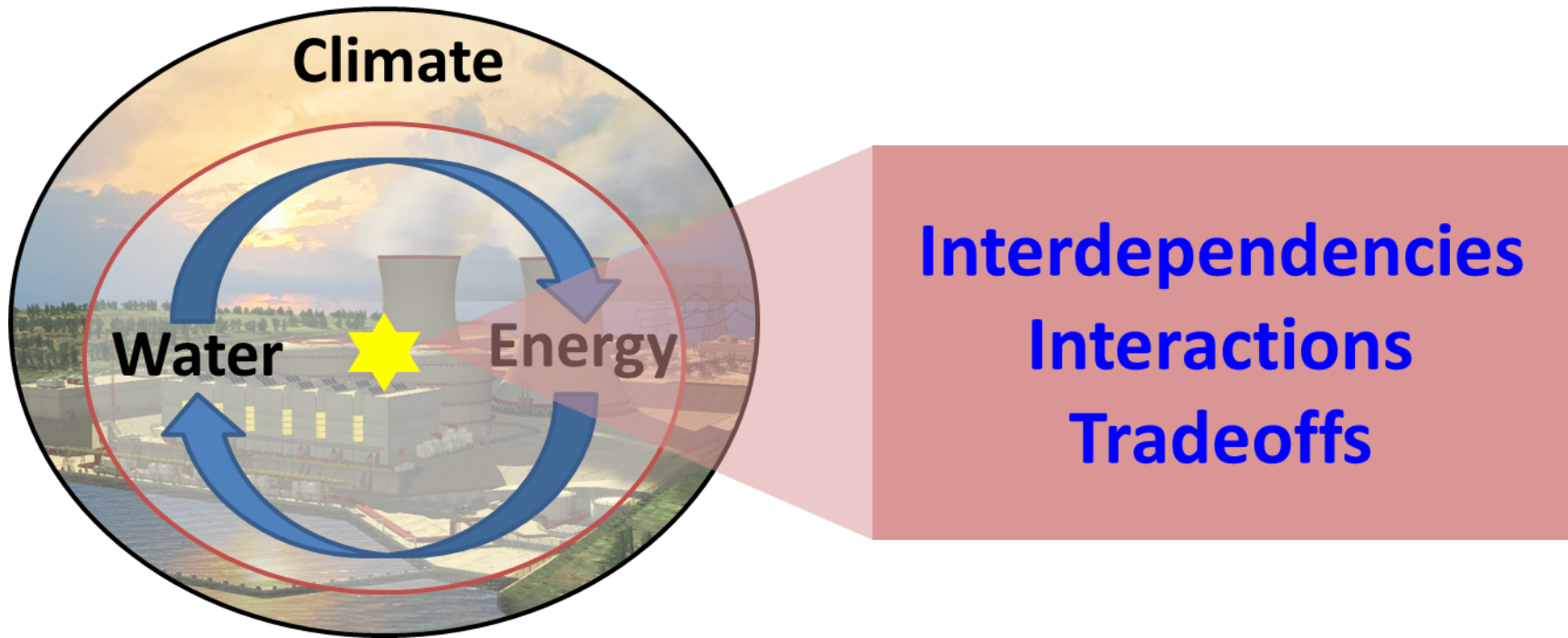


## ▶ Implications of water availability constraints on power sector

- Increased deployment of non-water intensive renewable energies in California
- Moratorium on coal-fired power plants in Idaho



# Research question



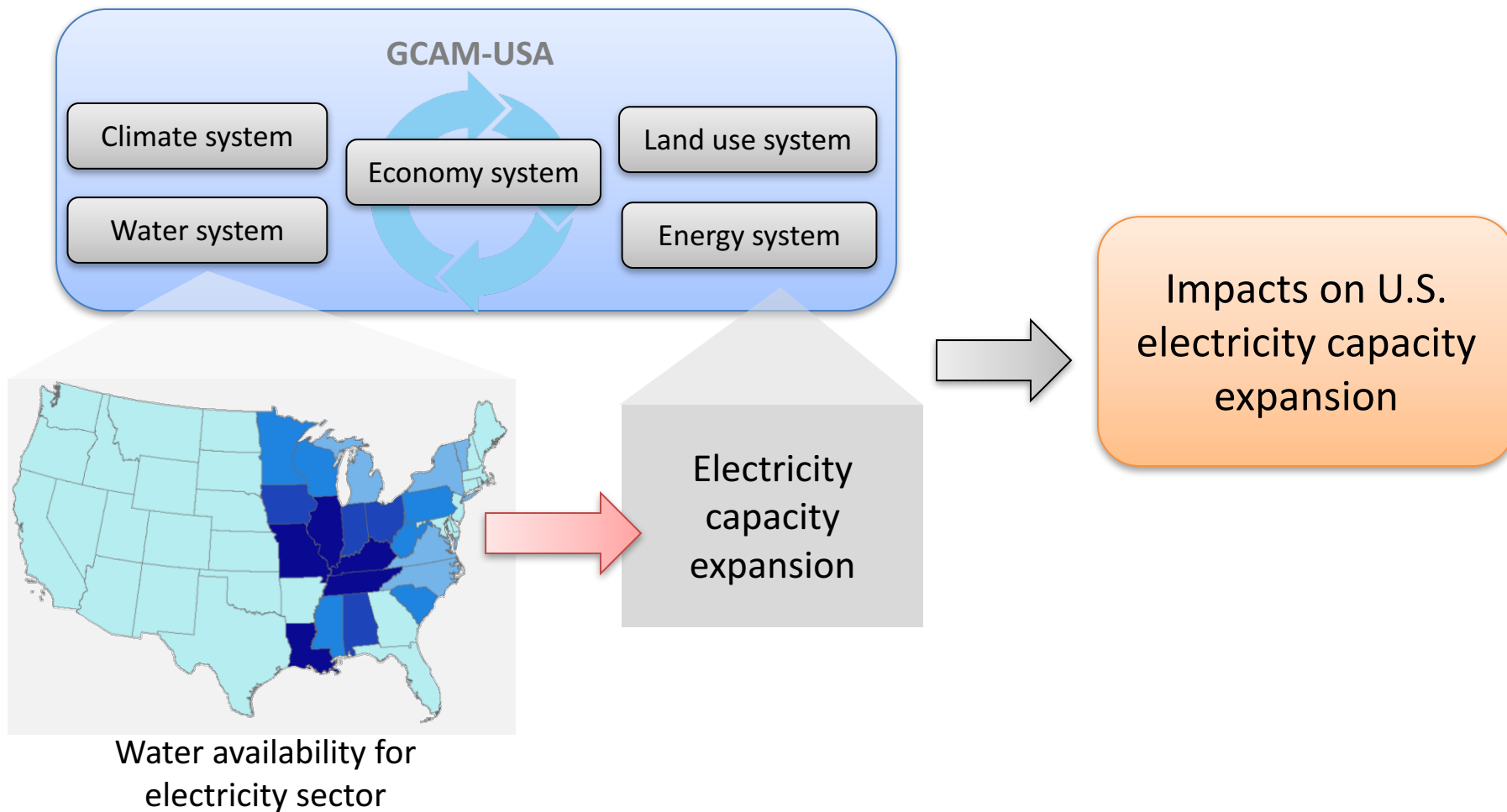
***How could US energy system adapt to water availability constraints?***

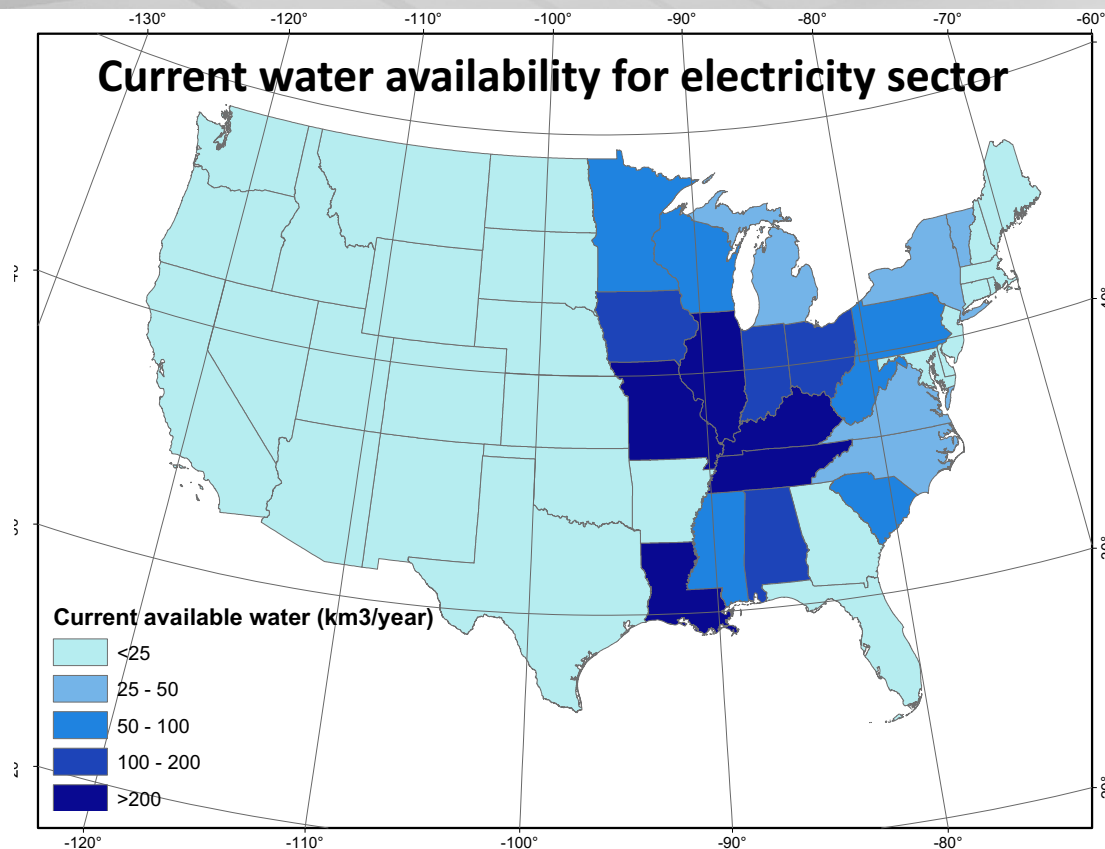
	Macknick et al. (2015)	Tidwell et al. (2016)	Webster et al. (2013)
Spatial scale and modeling year	US 2010-2050	Western US 2013-2032	The state of Texas 2050
Model	ReEDS	PCM and LTPT	Mixed Integer Linear Programming
Advantages	Resolved at Balancing Area (BA) level  Optimizes capacity and transmission investment	Resolved at transmission planning hub level	Incorporated load-duration curve for energy demand  Uncertainty analyses of future fuel cost and technology cost

## Areas of improvement

- Better representation of water availability constraint
- Dynamic modeling of electricity demand
- Inclusion of national and subnational energy strategies

## Built a response mechanism between water supply and energy supply





## Scenario configuration

- No water constraint
- Current water availability
- Severe water constraint  
– 50% of current water availability

Current water withdrawal for electricity generation (GCAM output)

Fraction of water withdrawal for electricity generation (USGS)

Untapped water (Tidwell et al., 2013 and 2017)

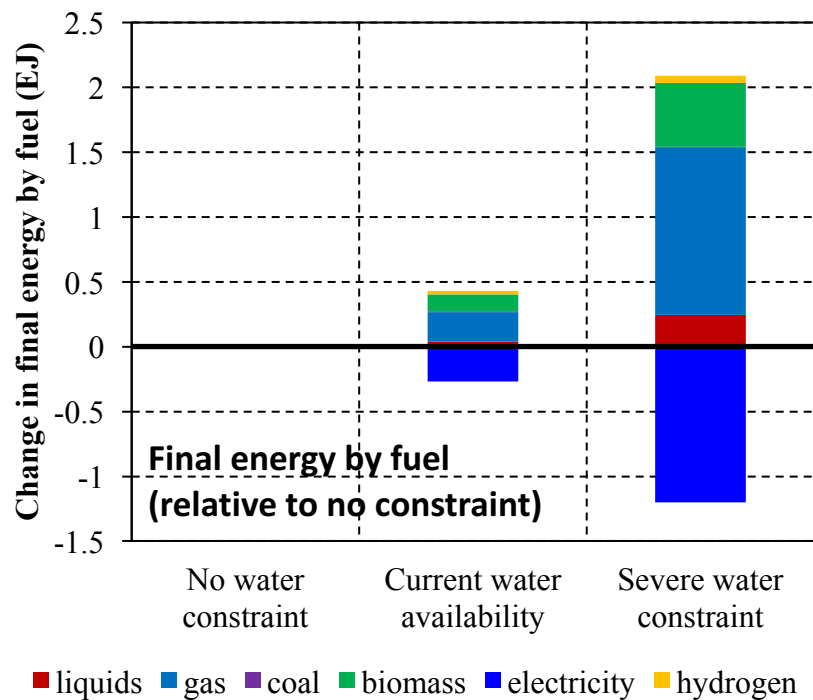
Current water availability

$$Q_{A,i} = Q_{2010W,i} + \alpha_i Q_{U,i}$$

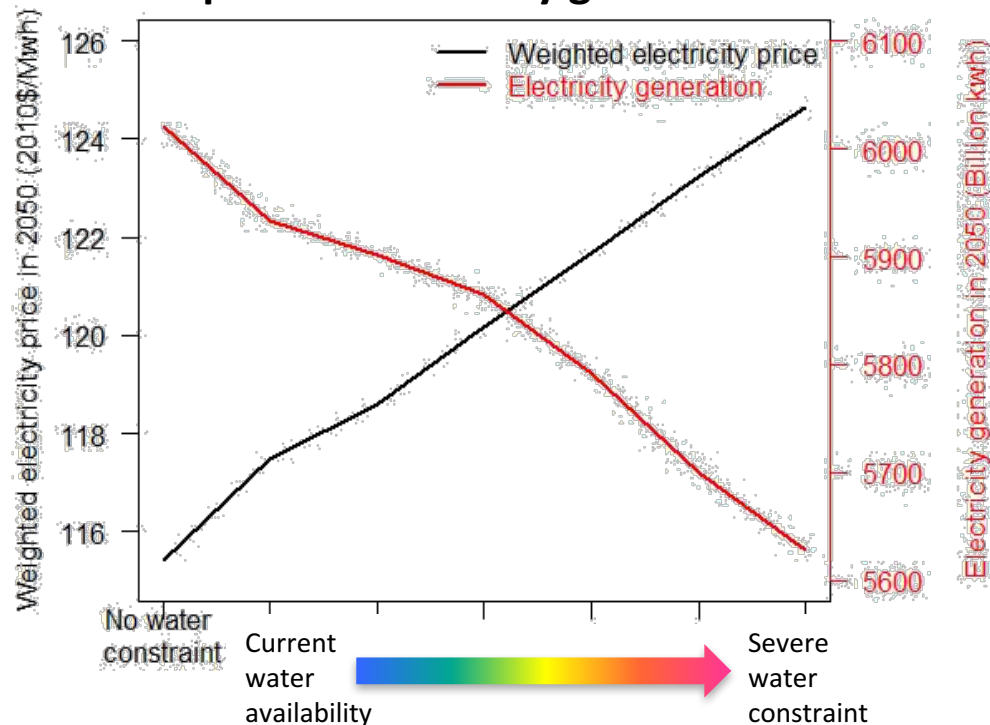
*i indicate each state*

# Key results – US

## Impact on final energy demand



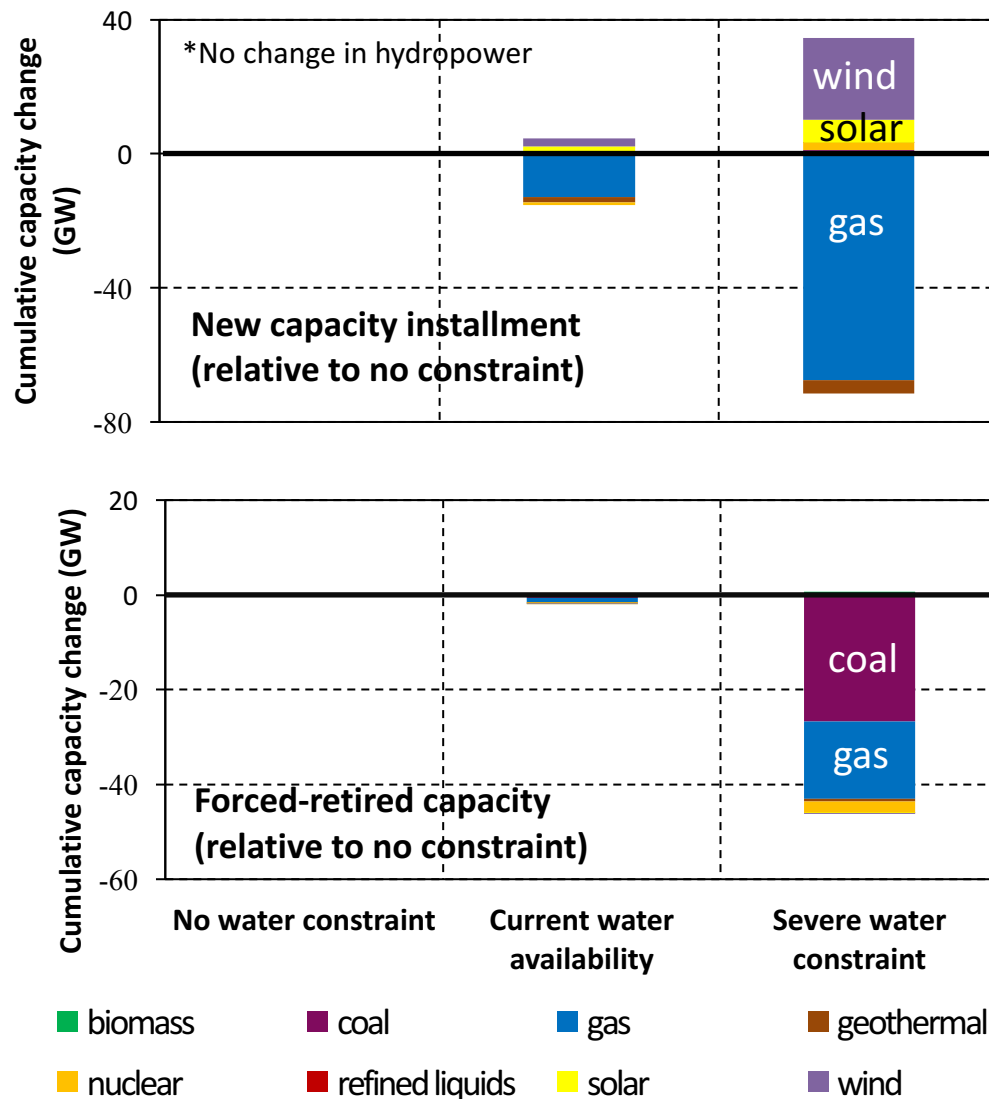
## Impact on electricity generation



## Key observations:

- ↑ water constraint stringency leads to ↑ electricity cost, thus ↓ total electricity generation

# Key results – US

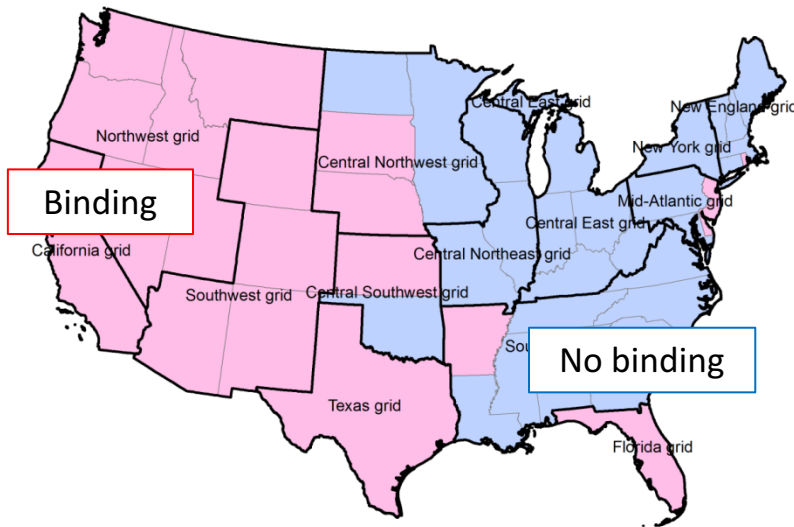


## Key observations:

- Increased investment in less water dependent technologies (i.e., wind and solar)
- Reduce investment in water intensive technologies (i.e., coal- and gas-fired)
- Forced retirement of conventional gas- and coal-fired technologies before the end of their designed life time

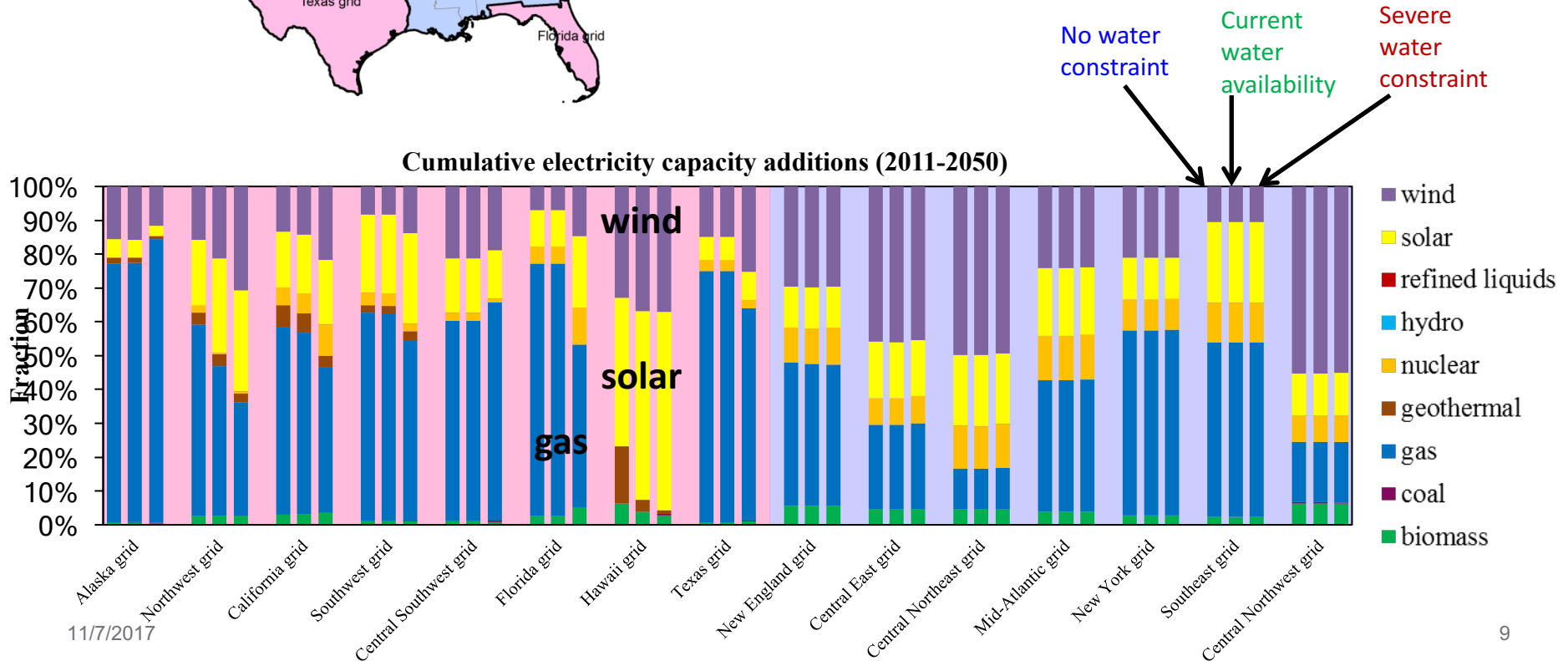


# Key results - States

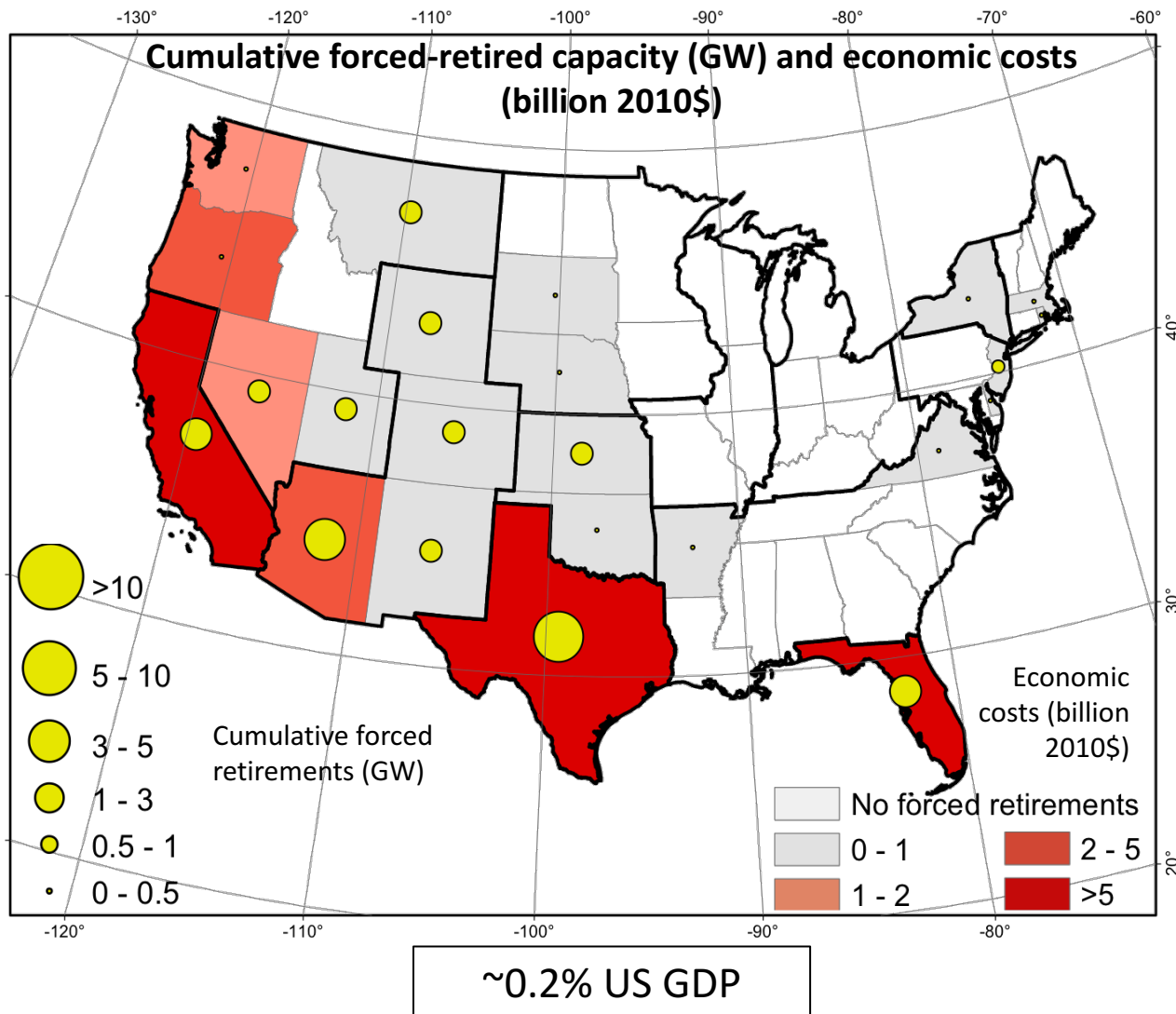


## Key observations:

- Substantial capital stock turnover, particularly in water stressed western regions



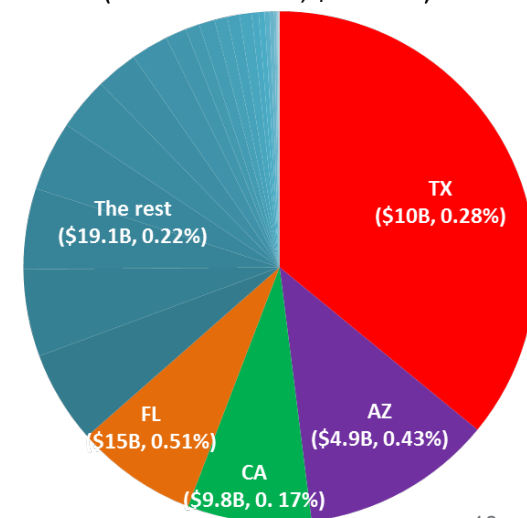
# Key results - States



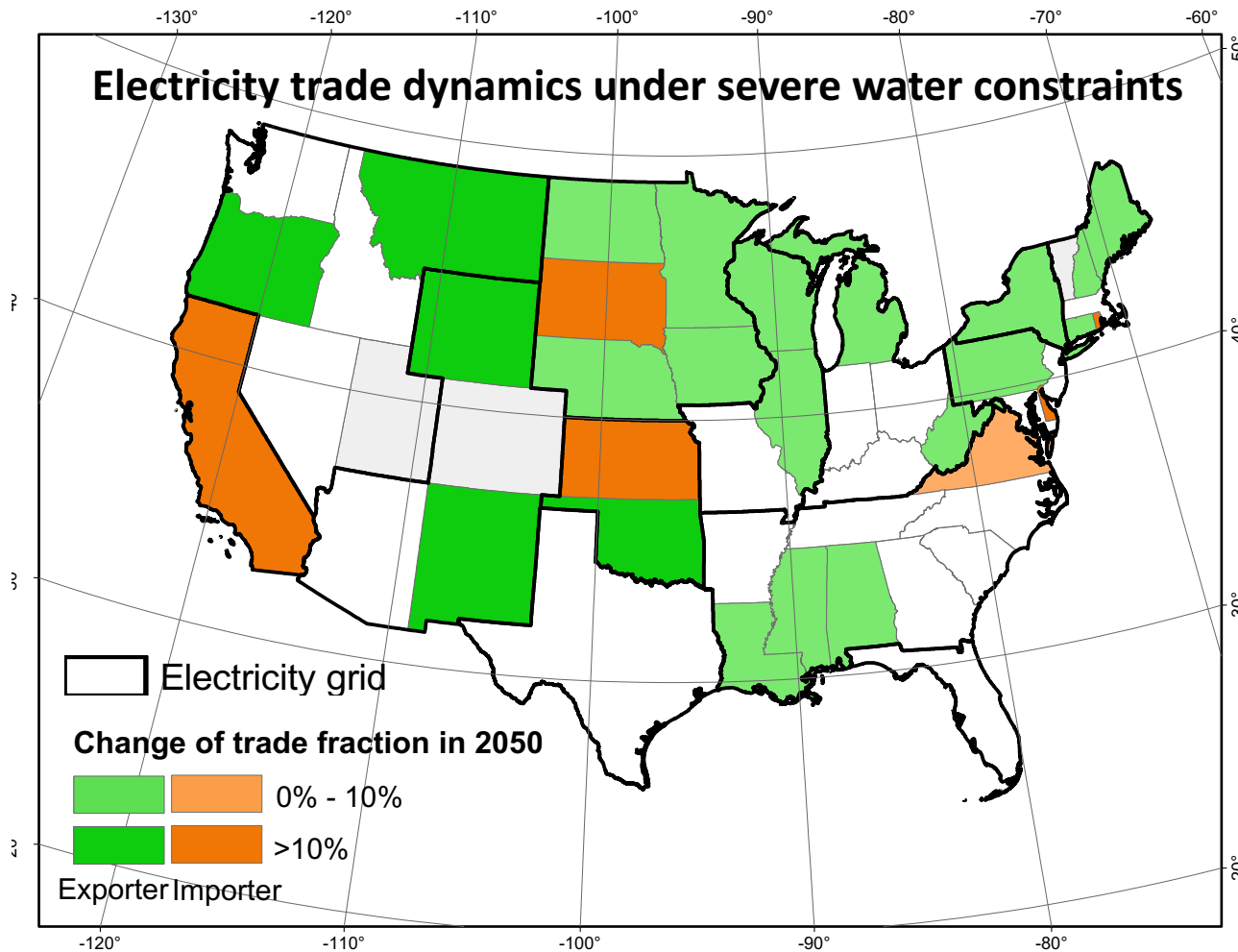
## Key observations:

- Forced retirements mostly occur in the western regions
- Economic costs associated with adapting to water constraint are non-trivial

Cumulative forced-retired capacities (2011-2050) by state (economic costs, \$ of GDP)



# Key results - States



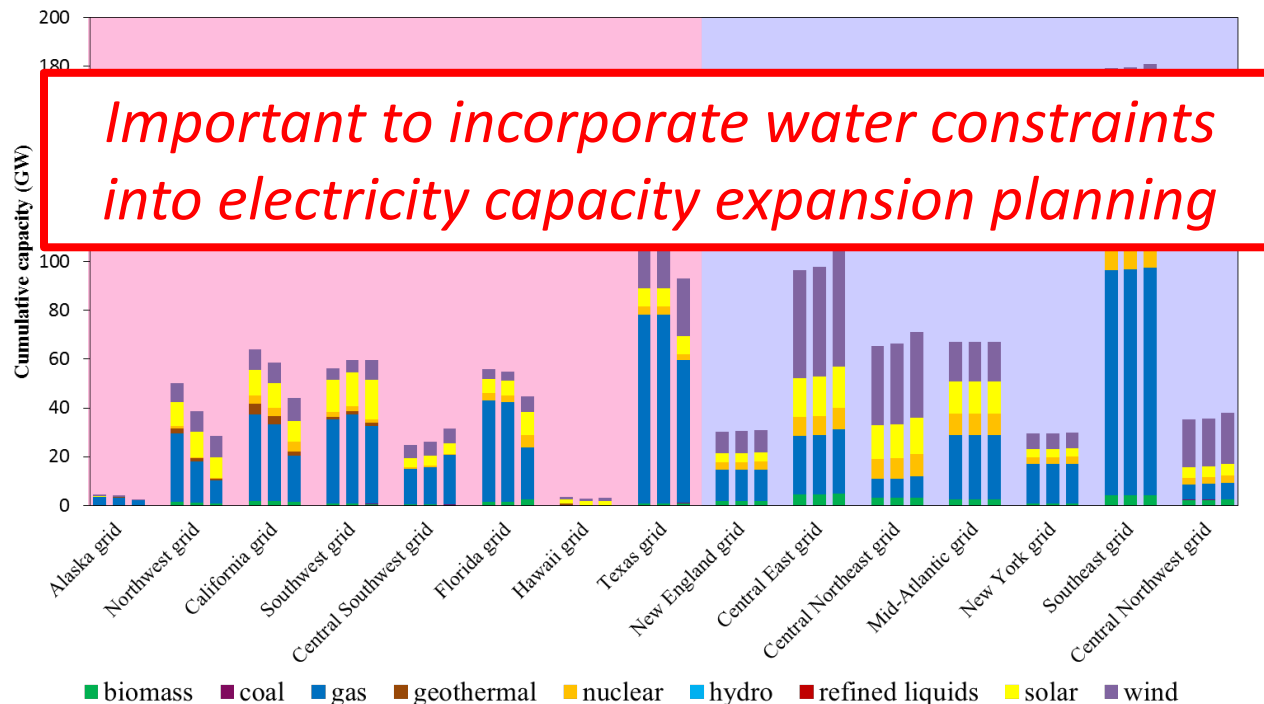
## Key observations:

- Intensified electricity trade within and between grids
- More stress on electricity transmission system

$$\Delta \text{Trade fraction} = \begin{cases} \frac{\text{Trade}_2}{\text{Gen}_2} - \frac{\text{Trade}_1}{\text{Gen}_1} & \text{Net exporter} \\ \frac{\text{Trade}_2}{\text{Gen}_2 + \text{Trade}_2} - \frac{\text{Trade}_1}{\text{Gen}_1 + \text{Trade}_1} & \text{Net importer} \end{cases}$$

# Main conclusions

- Substantial capital stock turnover, particularly in the West
- Associated non-negligible economic costs
- More stress on current transmission system



## 1 Implications of water constraints on electricity capacity expansion in the 2 United States

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*(Under review by Nature Sustainability)*

- ▶ Water use competitions with other sectors
- ▶ Policy incentives
- ▶ Other adaptive alternatives

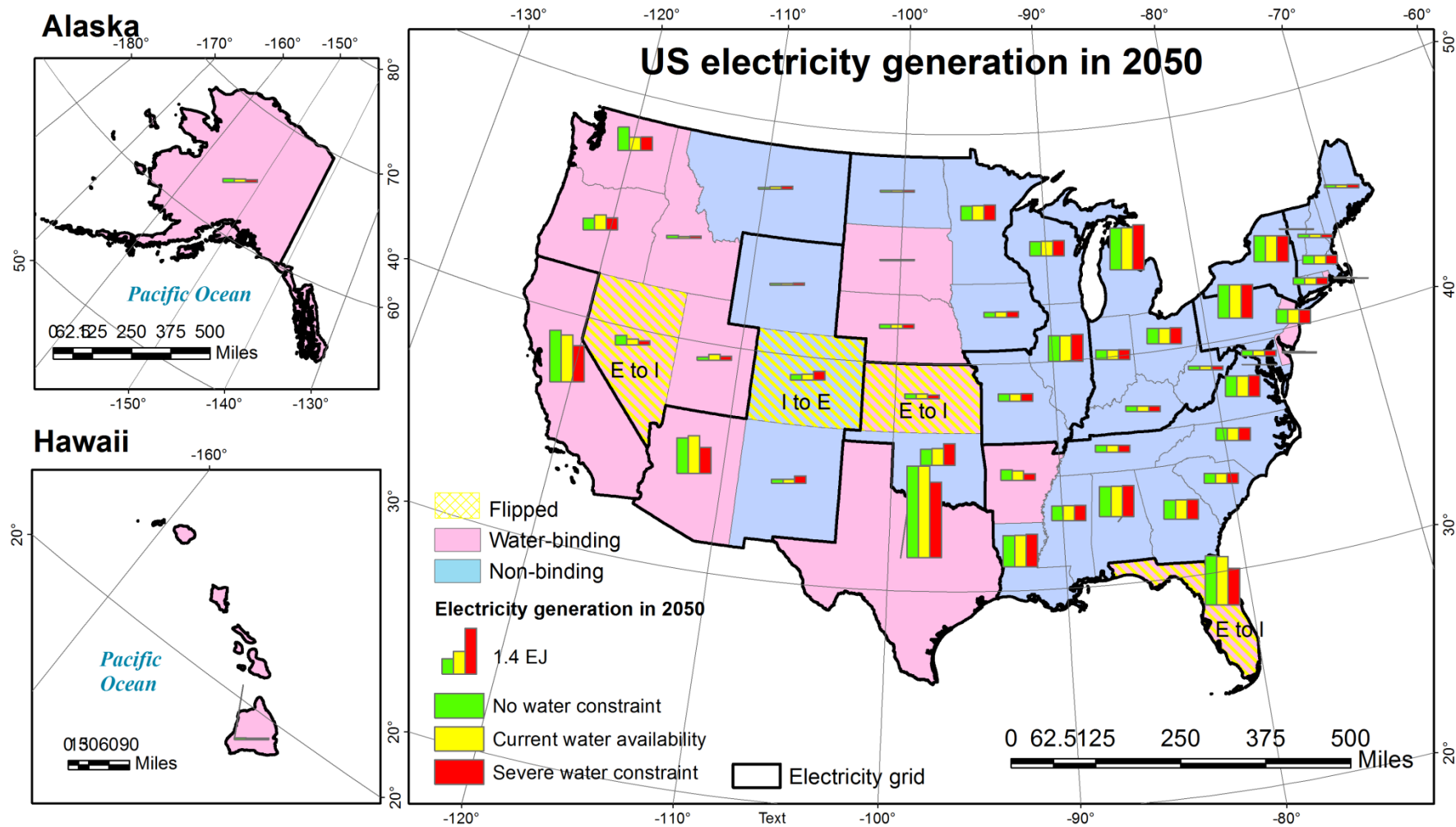
- Office of Science of the U.S. Department of Energy through the Integrated Assessment Research Program
- Dr. Vincent Tidwell for providing water availability data for the U.S.

**Thank you for your attention**  
**Any questions?**

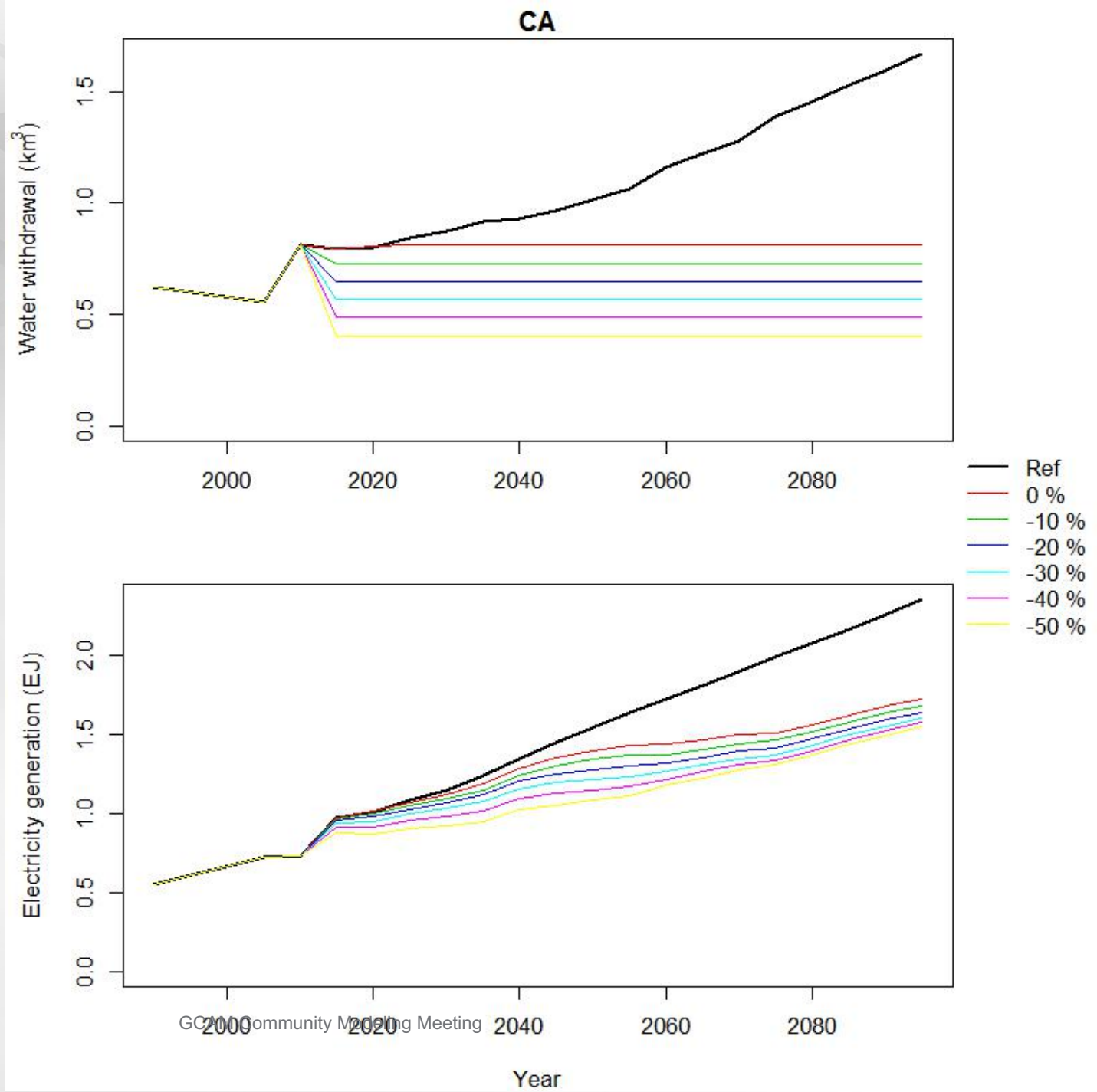
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## Additional slides







Shadow price: the marginal cost of strengthening the constraint

