GCAM-USA State Applications Community of Practice

Implications of climate change mitigation and socioeconomic development on the U.S. electric power sector

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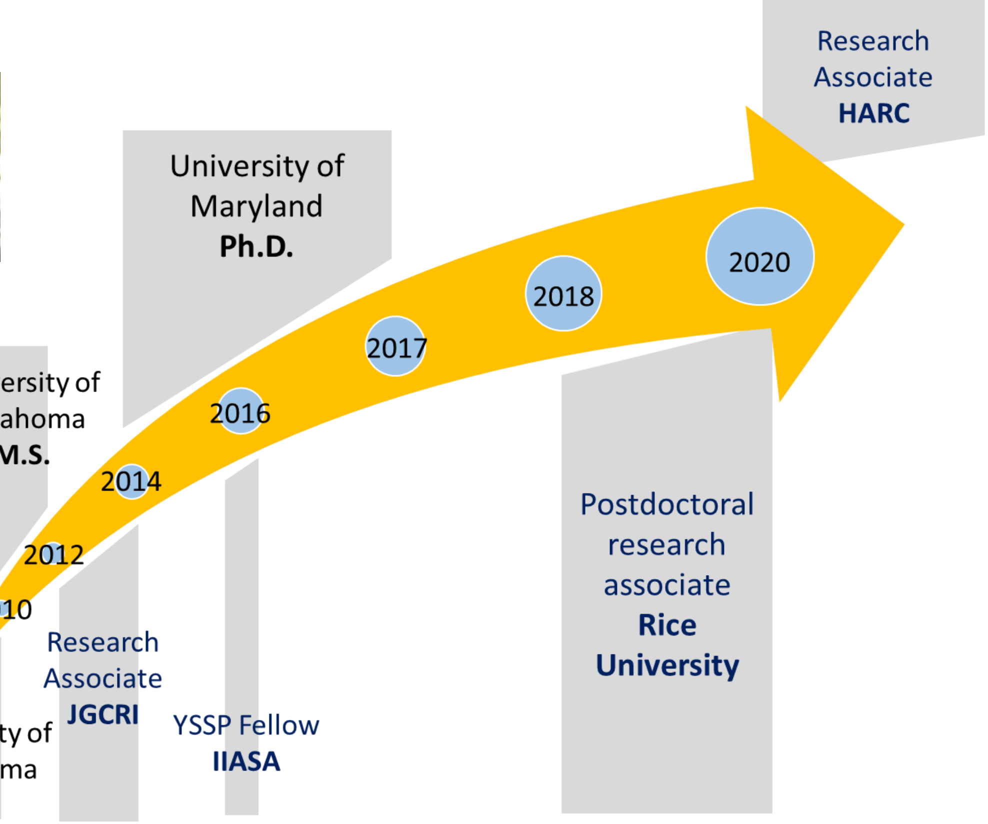
IOWA STATE UNIVERSITY

Academic Training



2021 Fall
Assistant Professor
CCEE

The Liu Group studies the interconnected fields of water, energy, and climate, focusing on sustainable resource management and planning through knowledge enhancement and decision-making tool development.

Photo taken in Fall 2023

Research Thrusts

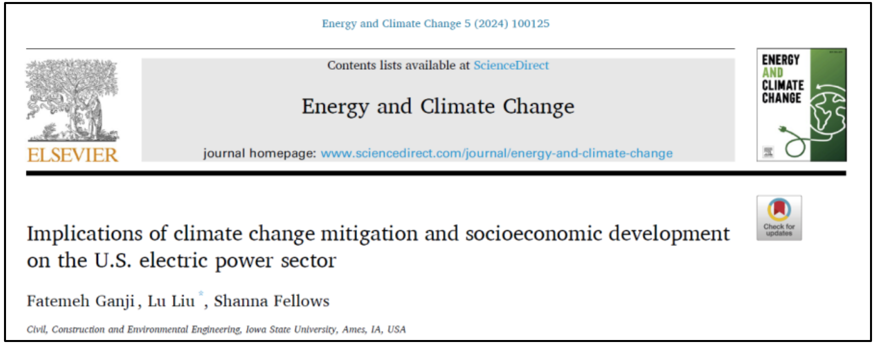
- Water-energy-climate nexus
- Urban water sustainability
- Equity and justice in the water sector

Net-zero emission by 2050 and 50-52% reduction by 2030 in the U.S.

Electric power sector accounts for 25% of GHG emissions in the U.S.

Success of achieving national targets relies on sub-national actions

Motivation: the need to develop sub-national strategies for the electric power sector in alignment with the national mitigation target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Implications of climate change mitigation and socioeconomic development on the U.S. electric power sector

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Implications of climate change mitigation and socioeconomic development on the U.S. electric power sector

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Research question: How do climate change mitigation and socioeconomic development interact in the U.S. electric power sector at the state level?

Objective:

Investigate how the RCP-SSP pathways on a global scale manifest as impacts on electricity sector at the sub-national level

- Electricity portfolio
- Environmental consequences (water, CO_2 emission)
- Economic impact

Combining RCPs and SSPs allows for the examination of barriers and opportunities for climate mitigation and adaptation across a wide range of plausible futures.

Integrated Assessment Models (IAMs) are great for evaluating the effectiveness of various mitigation strategies across scales.

RCP: Representative Concentration Pathways
SSP: Shared Socioeconomic Pathways

Method

Run GCAM-USA (v5.4) under *four* future scenarios for the U.S. that are in line with the global RCPs and SSPs pathways

Scenarios		Socioeconomic Development	
		Low Population/GDP	High Population/GDP
Climate Change Mitigation	Reference	RCP6.0-SSP3 equivalent	RCP6.0-SSP5 equivalent
	Low emission	RCP2.6-SSP3 equivalent	RCP2.6-SSP5 equivalent

Scenarios		Socioeconomic Development	
		Low Population/GDP	High Population/GDP
Climate Change Mitigation	Reference	RCP6.0-SSP3 equivalent	RCP6.0-SSP5 equivalent
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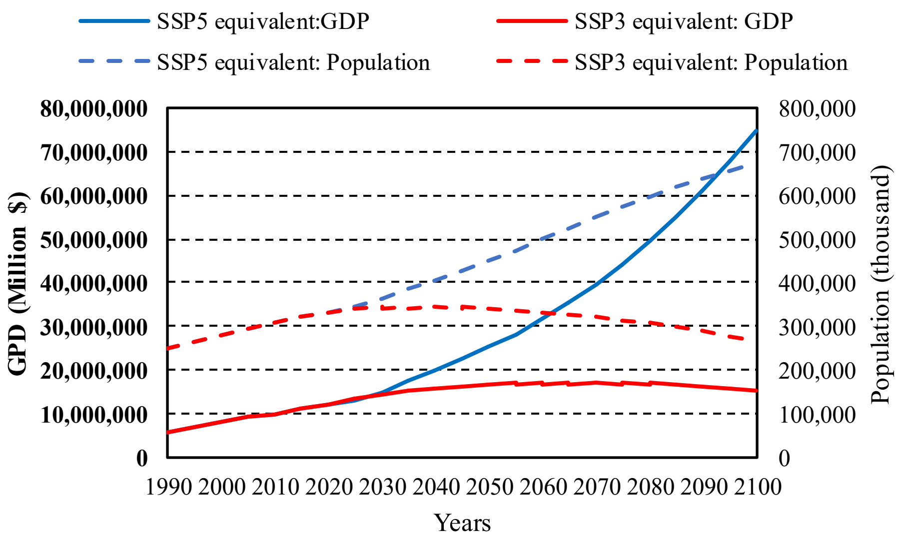
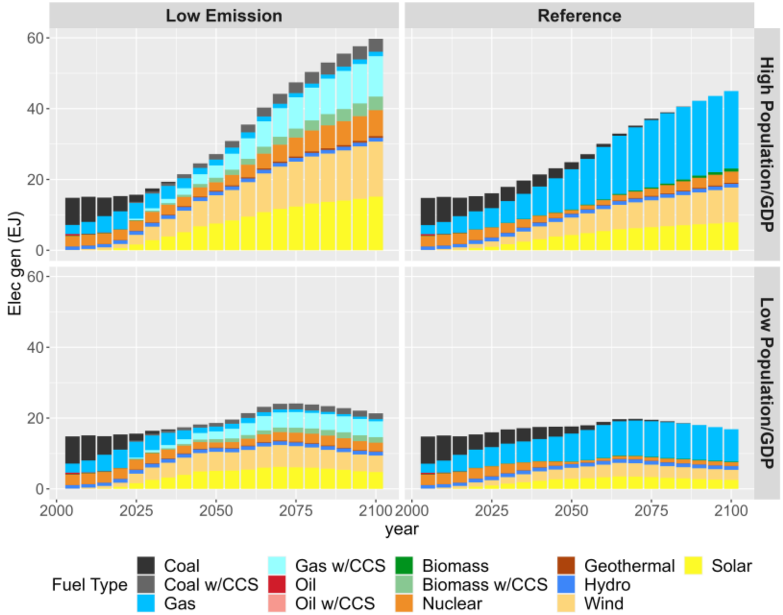
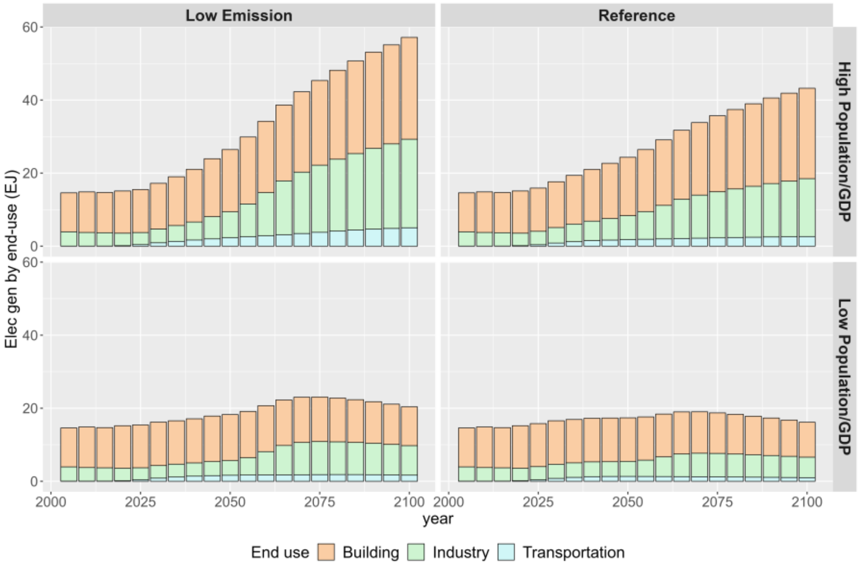


In the U.S. context

- RCP 2.6 equivalent – 58% of CO_2 emission reduction in 2050 relative to 2015 and net-zero emission around 2070.
- RCP 6.0 equivalent – continuous growth in CO_2 emissions with a peak around 2095.

U.S. electricity generation portfolio

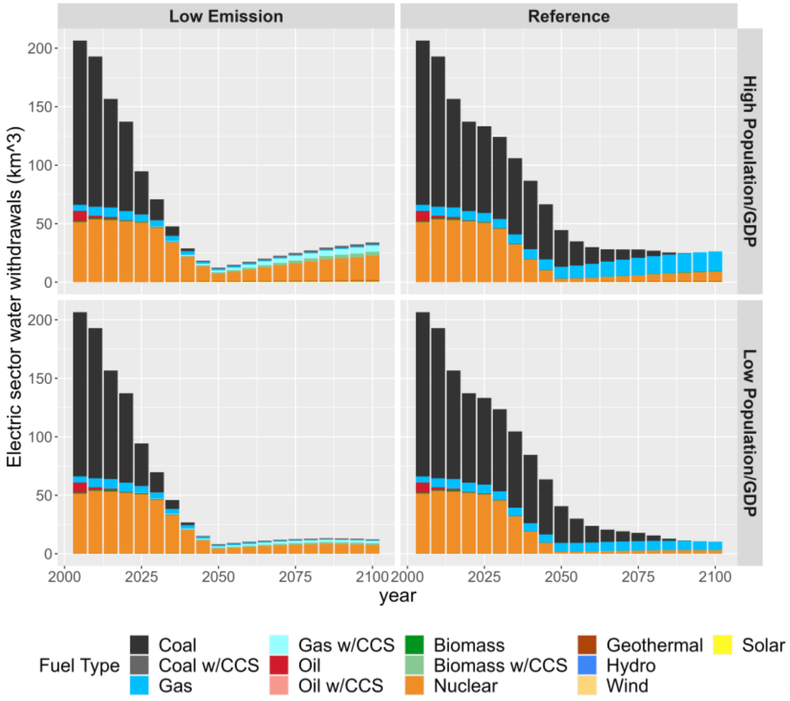


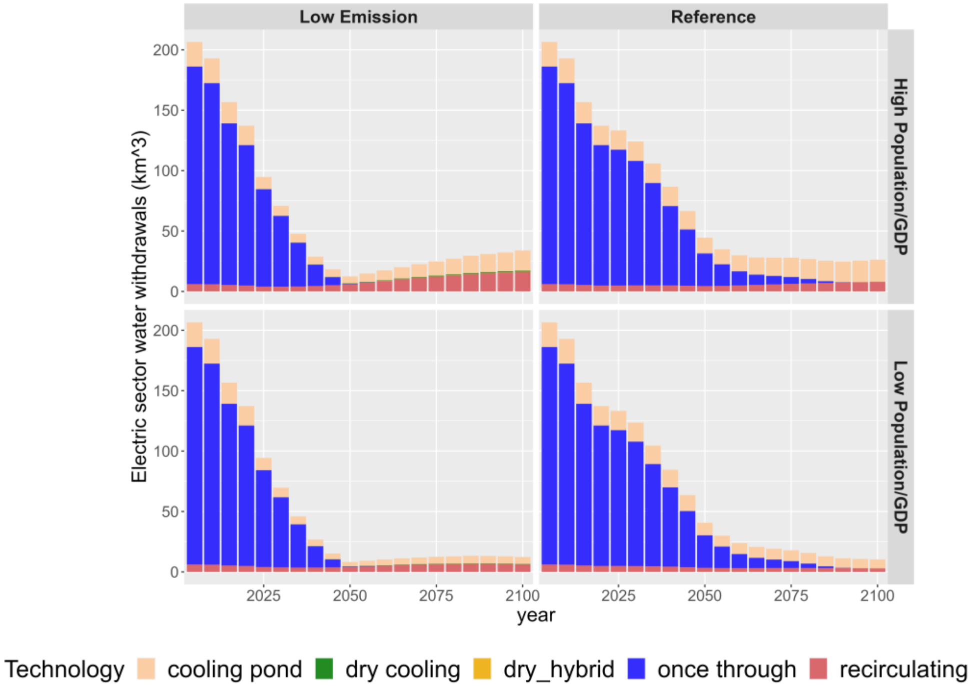


Greater increases of electricity demand under High population/GDP and low emission scenarios

Mitigation leads to more end-use electrification, particularly in the industry sector

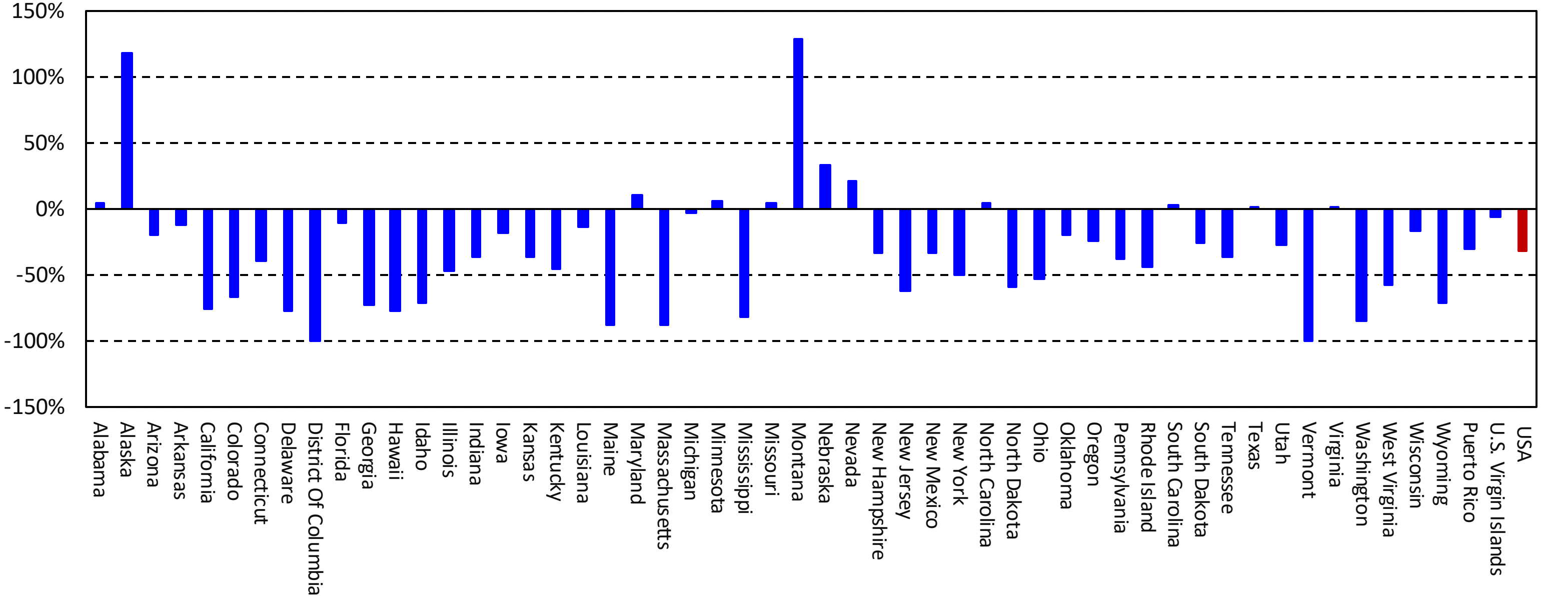
Impacts on electricity water withdrawal





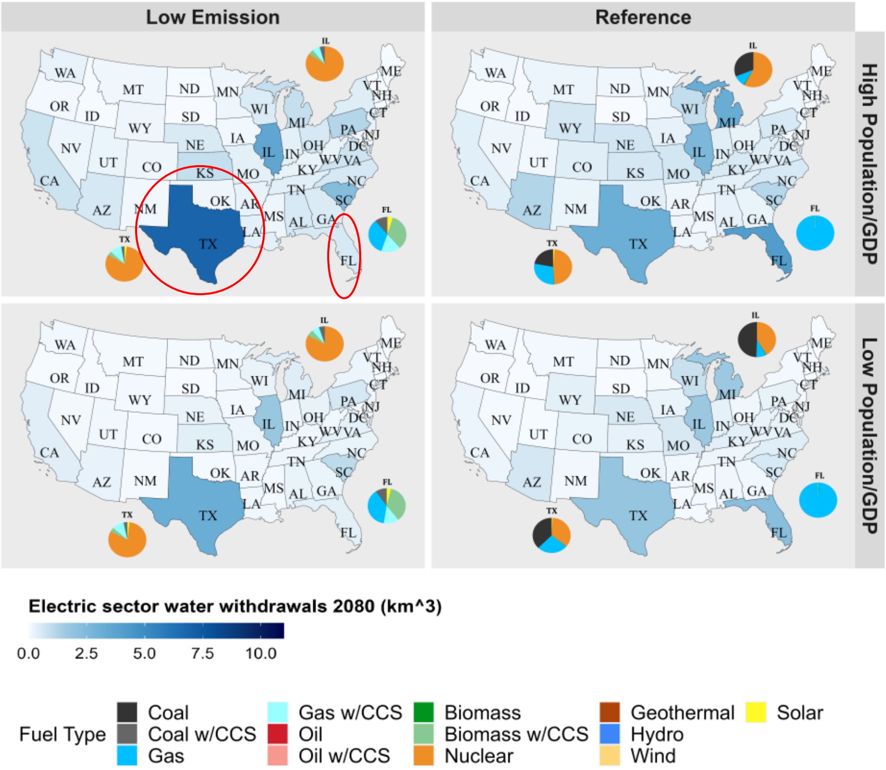
Retirement of coal power plants and shifts in cooling technologies contribute to the decline in water withdrawal.

Electricity water withdrawal has already declined for most states



Electricity water withdrawals changes between 1990-2015

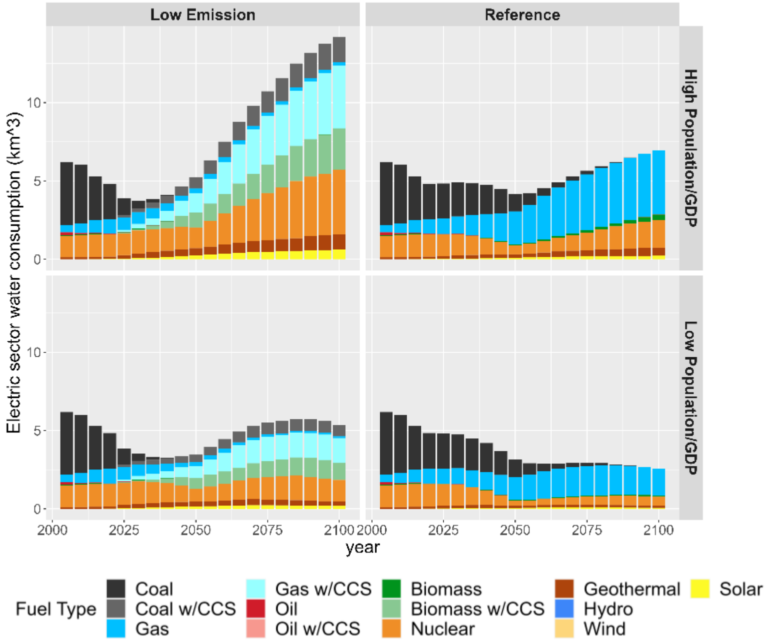
Heterogenous impacts at the state level

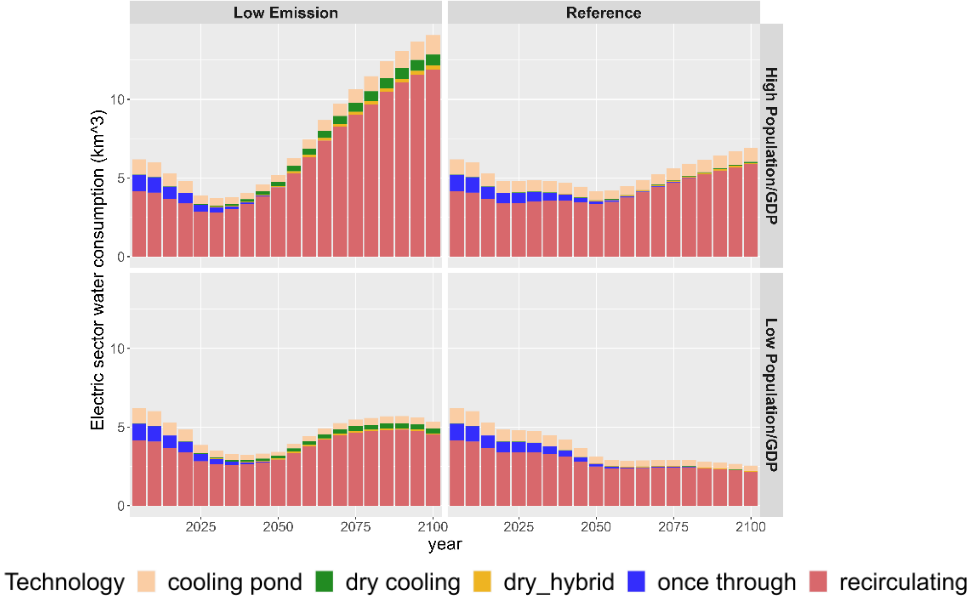


Decarbonizing the electricity sector leads to increased/decreased water withdrawal in Texas/Florida

- Nuclear and CCS in Texas
- Diversified energy mix in Florida

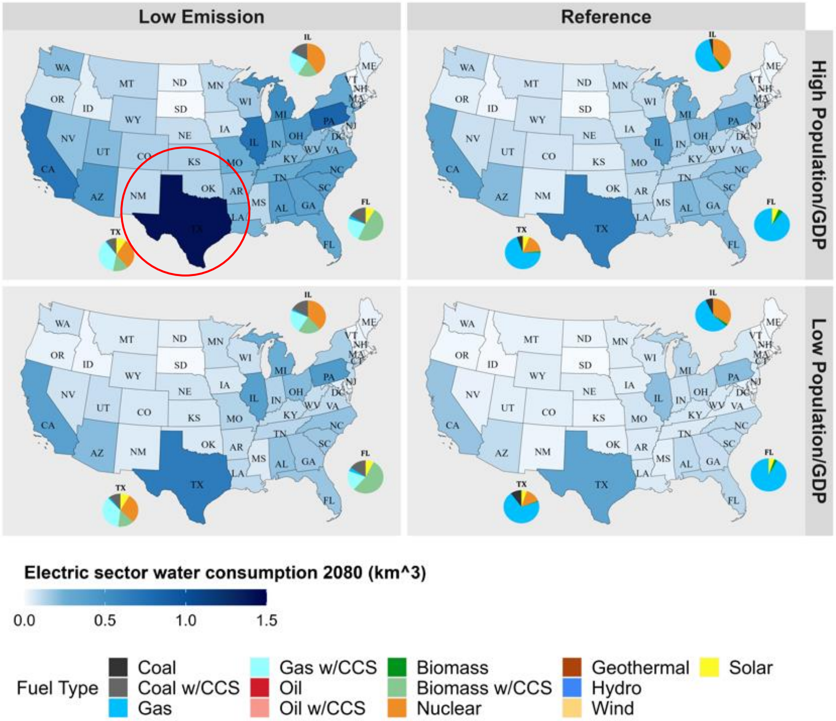
Impacts on electricity water consumption





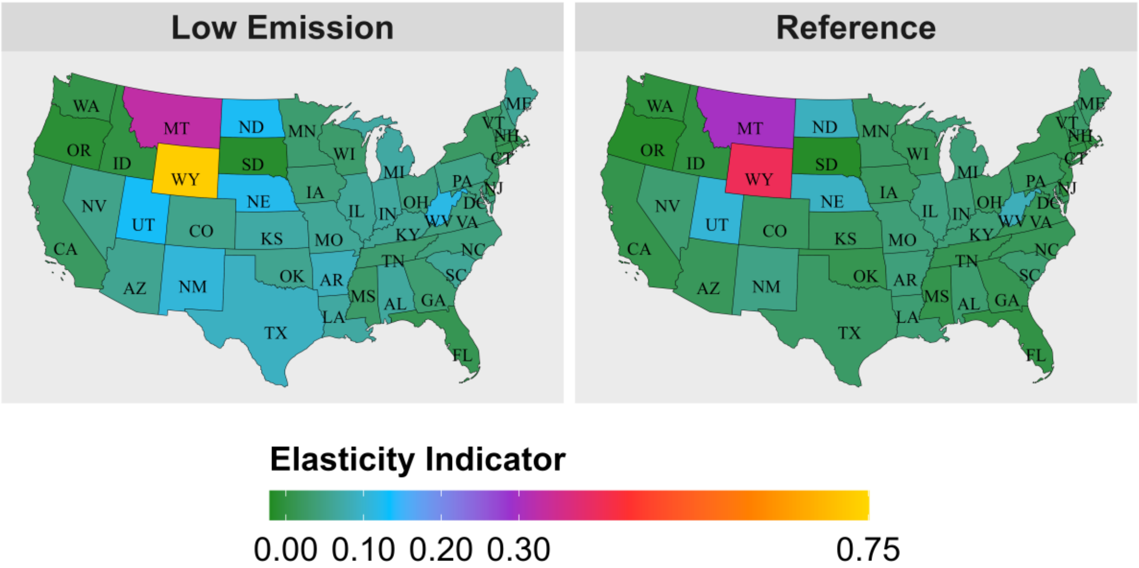
- Retirement of coal power plants and the uptake of less water-dependent cooling technologies are the main drivers behind the reduction before the 2030s.
- The rate of electricity generation growth to meet the demand outpaces the rate of decline from capital turnover.

Heterogenous impacts at the state level



Texas has the most substantial water consumption in low emission scenarios

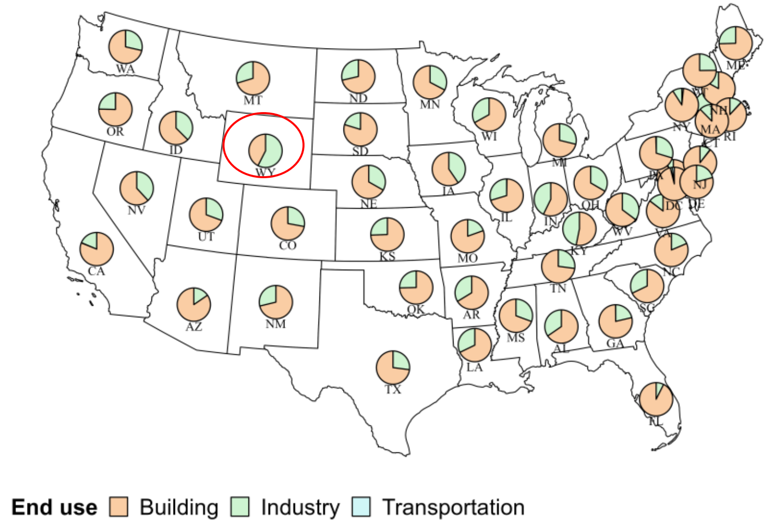
Population growth dictates increases in electricity generation in most states



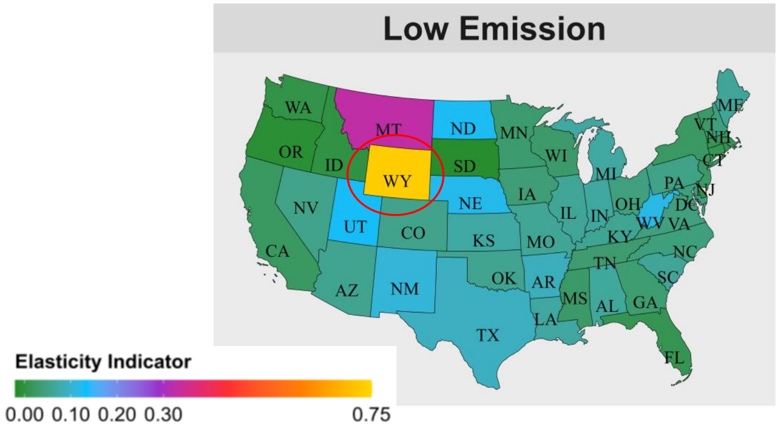
A low value close to zero (whether positive or negative) indicates population growth being the primary driver behind increases in electricity generation.

$$\mathit{Elasticity\ indicator} = \frac{\Delta \mathit{Electricity\ generation}}{\Delta \mathit{Population\ change}} - \mathit{Per\ capita\ electricity\ generation}(2015)$$

Heterogeneous responses at the state-level

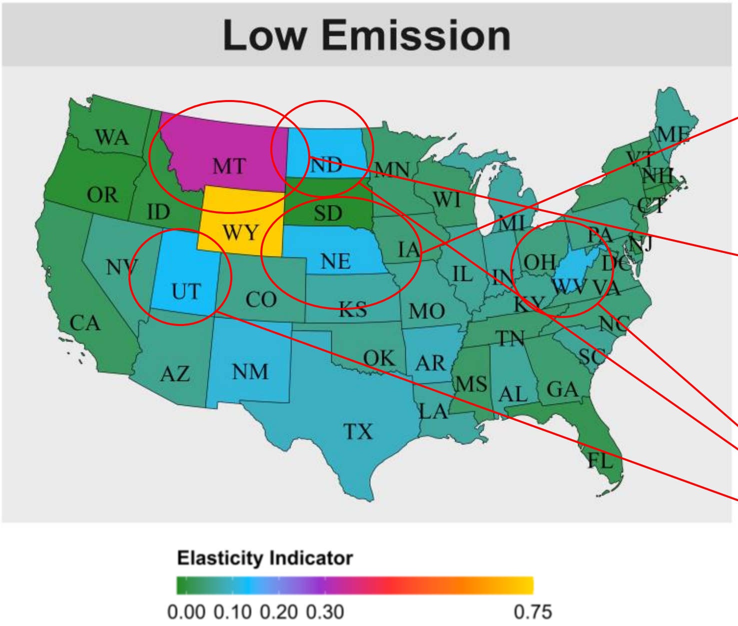


Building sector is the largest electricity user is in most states, a direct reflection of population.



- End-use electrification of the industry sector leads to the increase in electricity generation in WY, a pattern not notably swayed by the state's population dynamics.
- Net electricity exporter

Heterogeneous responses at the state-level



- Energy intensive industrial sector (food processing)

- Highest number of vehicles per person
- Transportation electrification
- Net power exporter

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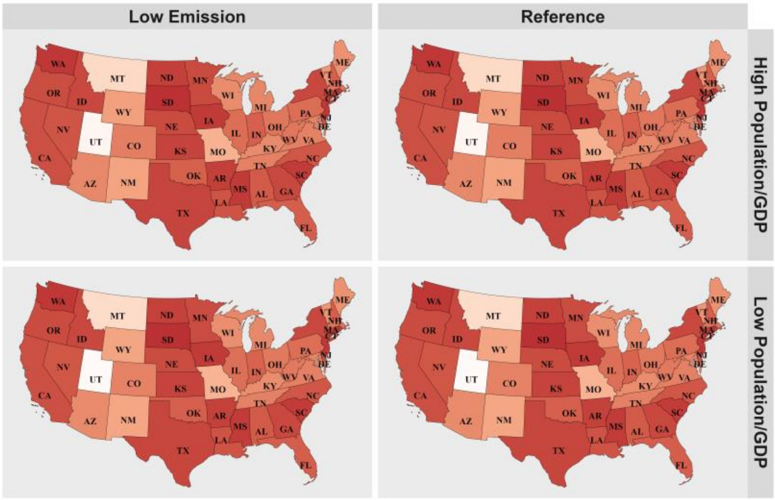
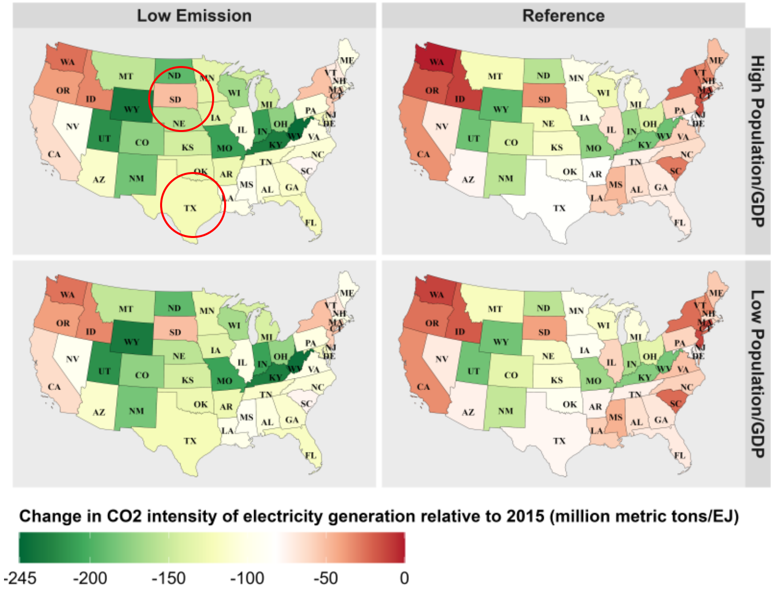
  - 2/3 of electricity generated in ND goes to other states and Canada

CO_2 intensity decreases heterogeneously across states

2020

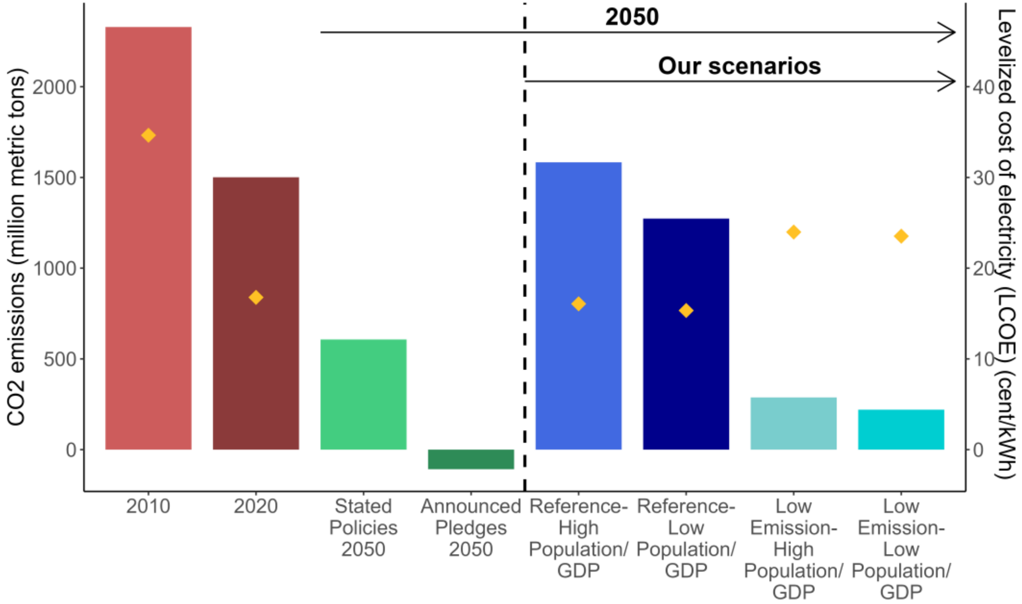


2080



- SD already has 90% of its electricity from renewables (constrained potential for enhancing CO_2 intensity)
- TX sees substantial reduction in CO_2 intensity, but faces notable increase in water use

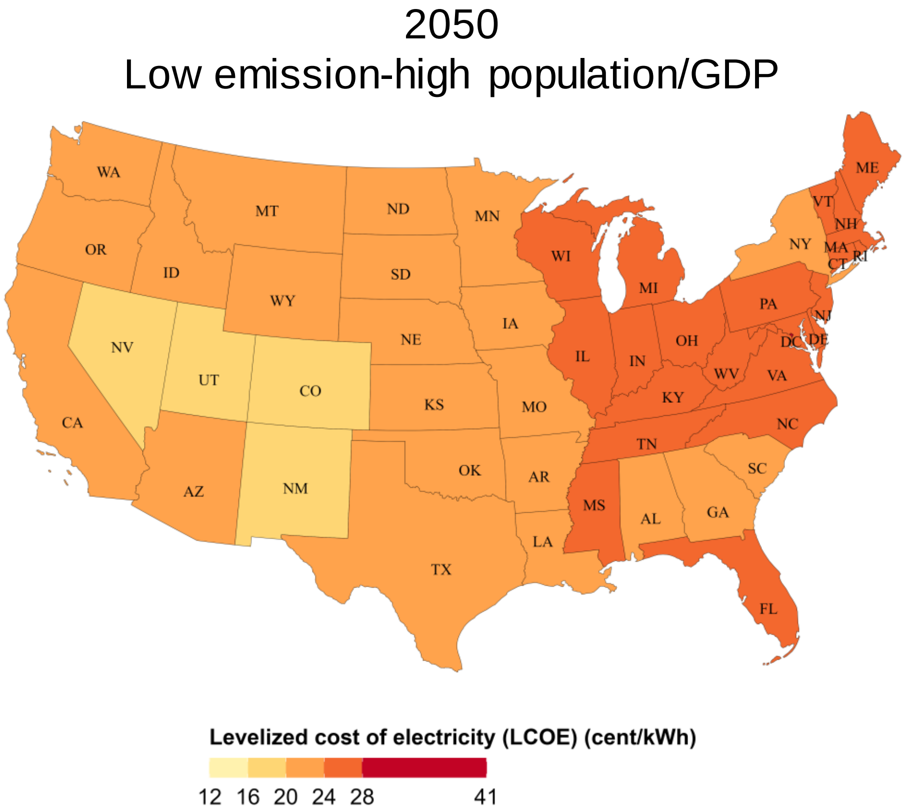
Comparison of emissions and costs with other mitigation pathways



Stated Policies: current policies and implementing measures will continue without additional efforts.
Announced Pledges: successful implementation of NDCs and net zero goals.

- Levelized cost of electricity (LCOE) is stable when there are no mitigations.
- Mitigation drive up lifetime costs for electricity generation.
- Low emission scenarios has a more assertive stance than the "Stated Policies", but less ambitious than the "Announced Pledges".
  - Attainment of net-zero emissions by 2050 is not feasible even with low population growth

LCOEs are higher for eastern states



Trade-offs associated with mitigation

Analyzed how climate change mitigation and socioeconomic development interact in the U.S. electric power sector at the state level

Key takeaways

- Population growth predominantly shapes electricity generation, unique state-level electrification potential yields indirect population-electricity dynamics.
- Low emission scenario analysis suggests shifting to natural gas and renewables can reduce CO_2 emissions but raise lifetime costs, especially in the eastern states.
- Mitigation efforts cut water withdrawal but raise water consumption, with state-level variations.

Implications

- Underscores the complexity of reconciling climate mitigation objectives with local electricity demand and resource constraints.
- Highlights the need for nuanced, state-specific strategies that balance emissions reduction, electricity demand, and water usage.
- Serves as a reminder that while pursuing aggressive emissions reductions is crucial, it's equally important to weigh the economic feasibility and consumer impact.

Great research comes from great teams!

Acknowledgement

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