The University of Texas at Austin
Operations Research and Industrial Engineering
Cockrell School of Engineering

U.S. Electricity Infrastructure Pathways Through 2050

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Project Overview

- This is one piece of the broader **Energy Infrastructure of the Future** study organized by the UT Austin **Energy Institute**.
  - Develop an extensive understanding of **existing** U.S. energy infrastructure.
  - Assess the economic and environmental impacts of alternative pathways along which U.S. energy infrastructure could evolve in the **future**.
  - Provide policymakers, industry strategists, other stakeholders, and the general public with energy data, interactive platforms, insights, analysis, and decision support tools.

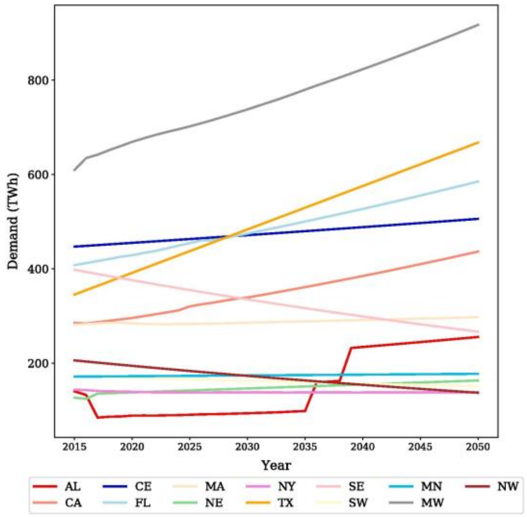
- We develop a **least-cost optimization model** to investigate alternative infrastructure pathways for the **U.S. electricity** sector through **2050**.
- Use an **open source** model (OSeMOSYS) parameterized only with data that are **public and free**.

Model

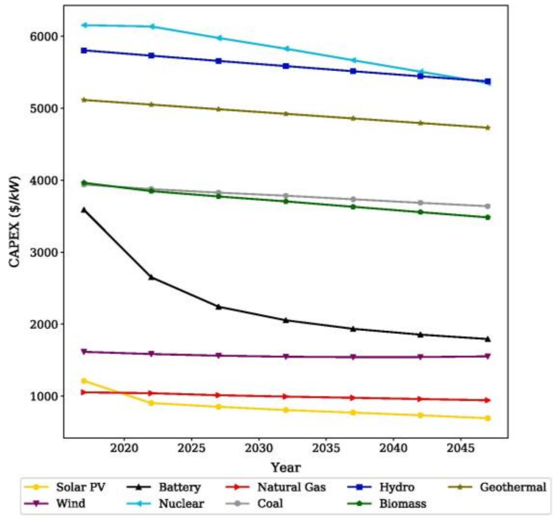
- Our model is a custom implementation of the Open Source Energy Modeling System (**OSeMOSYS**) in Python that is solved as a **large linear program** using the CPLEX solver.
- **Spatial** representation
  - Continental U.S. disaggregated into **13 regions**
- **Temporal** representation
  - Analysis timeframe: **2016–2050**
  - Investment decision time step: **5 years**
  - Dispatch resolution: **96 annual timeslices** (24-hour day in each season)
- Why the custom implementation?
  - **Transmission network** investment and flow balance constraints
  - Additional constraints to handle true **peak demands** plus reserve margins
  - Parallelize runs on **Texas Advanced Computing Center** supercomputer

Input Data Visualizations

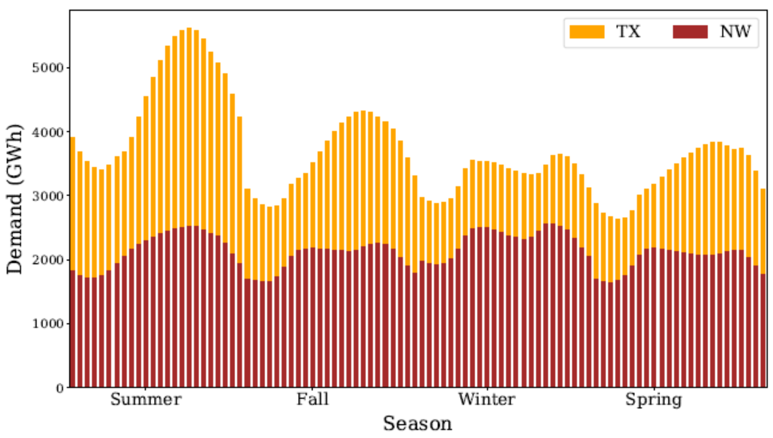
(a) Annual demand projection by region.



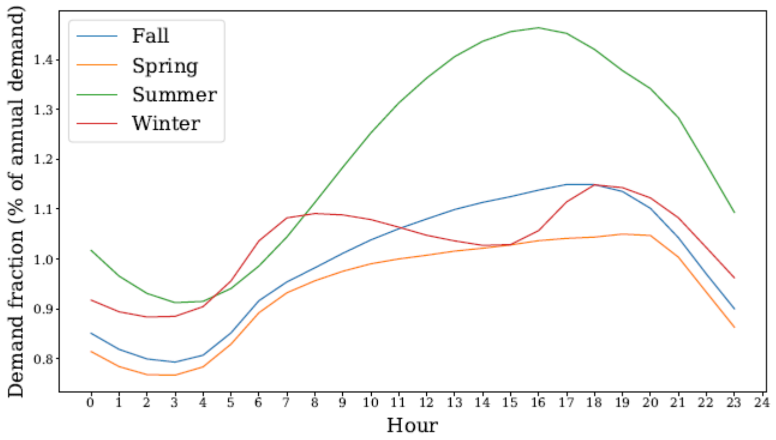
(b) Capital cost projection by technology.



(c) Hourly demand profiles for TX and NW.



(d) Aggregate U.S. demand profile by season.

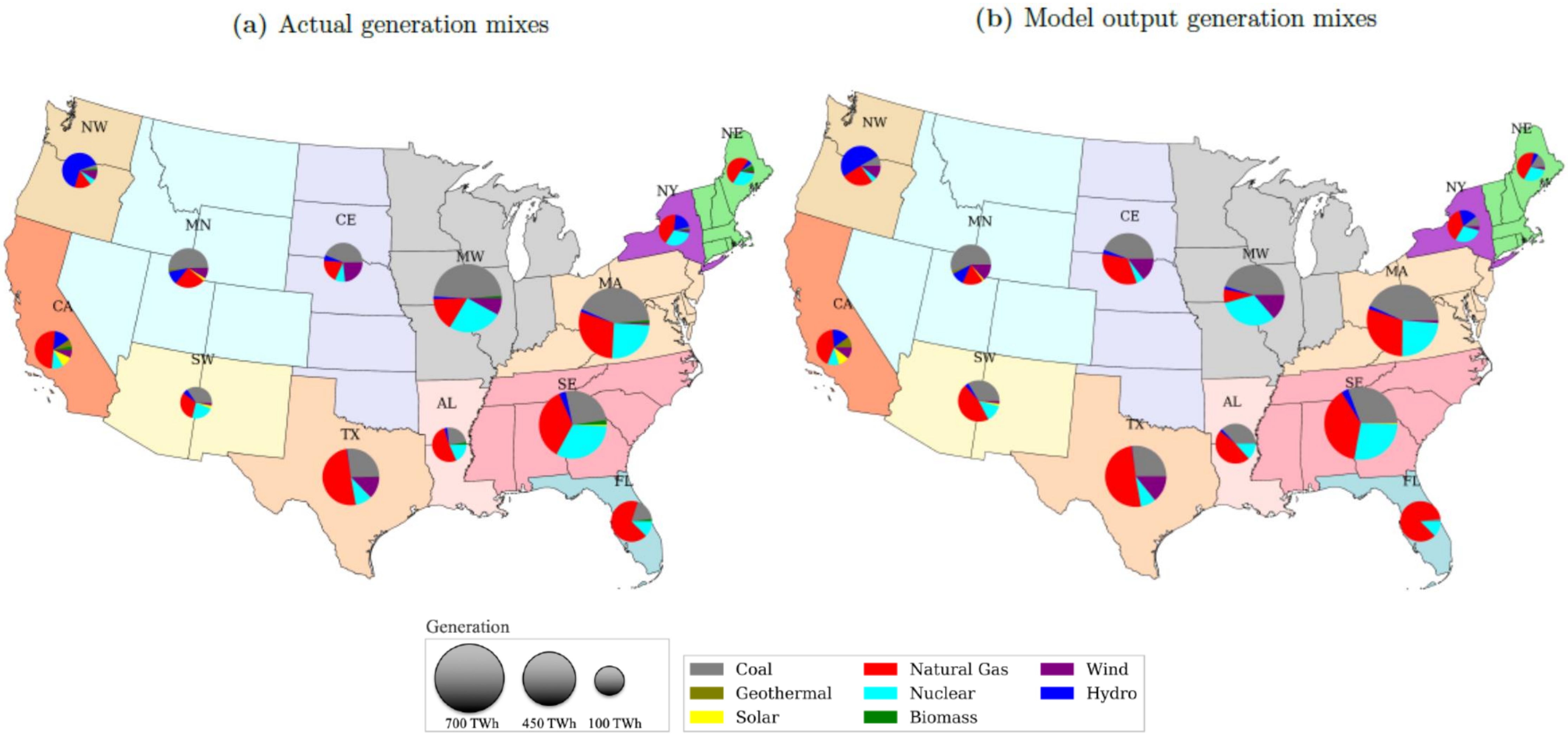


Scenarios

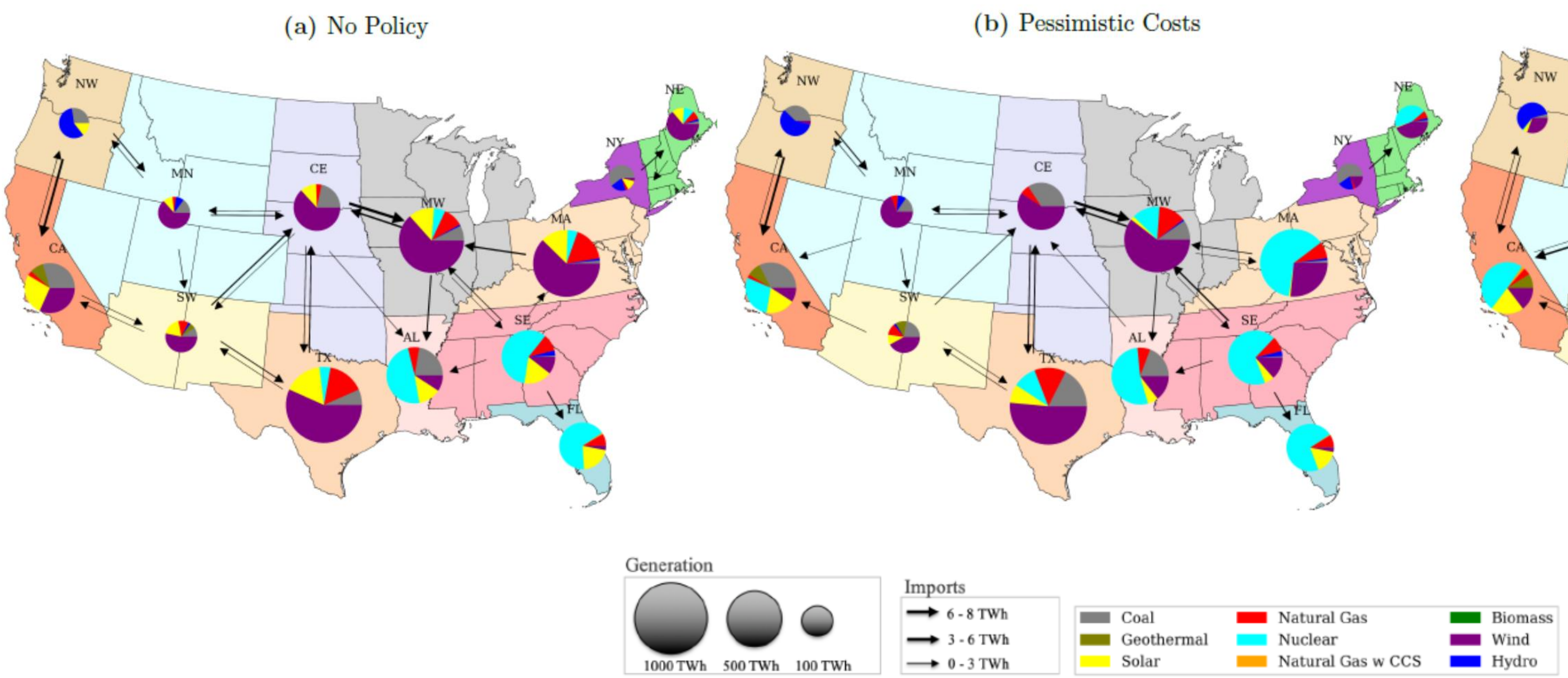
Scenario Name	Description
No Policy	• No policy constraints, incentives, or penalties. • Interpreted as a baseline development of the U.S. electricity system against which the other scenarios are compared.
No New Transmission	• Prohibits new investments in the inter-regional transmission network. • Used to quantify the value of new, long-distance transmission investments.
Pessimistic Costs	• Assumes only 20% of the future cost reductions for solar PV, wind turbine, and battery capital costs projected in the NREL Annual Technology Baseline. • Used to test the sensitivity of capacity investments, generation mixes, and total cost to uncertain future cost assumptions.
Carbon Tax	• Imposes a carbon tax that rises from \$20/tCO_2 in the base year to \$200/tCO_2 in 2050. • Used to assess how climate policy would affect capacity investments, generation mixes, CO_2 emissions, and total cost.

Additional sensitivity analyses: capital cost of new transmission, CO_2 reduction target (%) for 2050

Model Calibration (2016 Base Year)

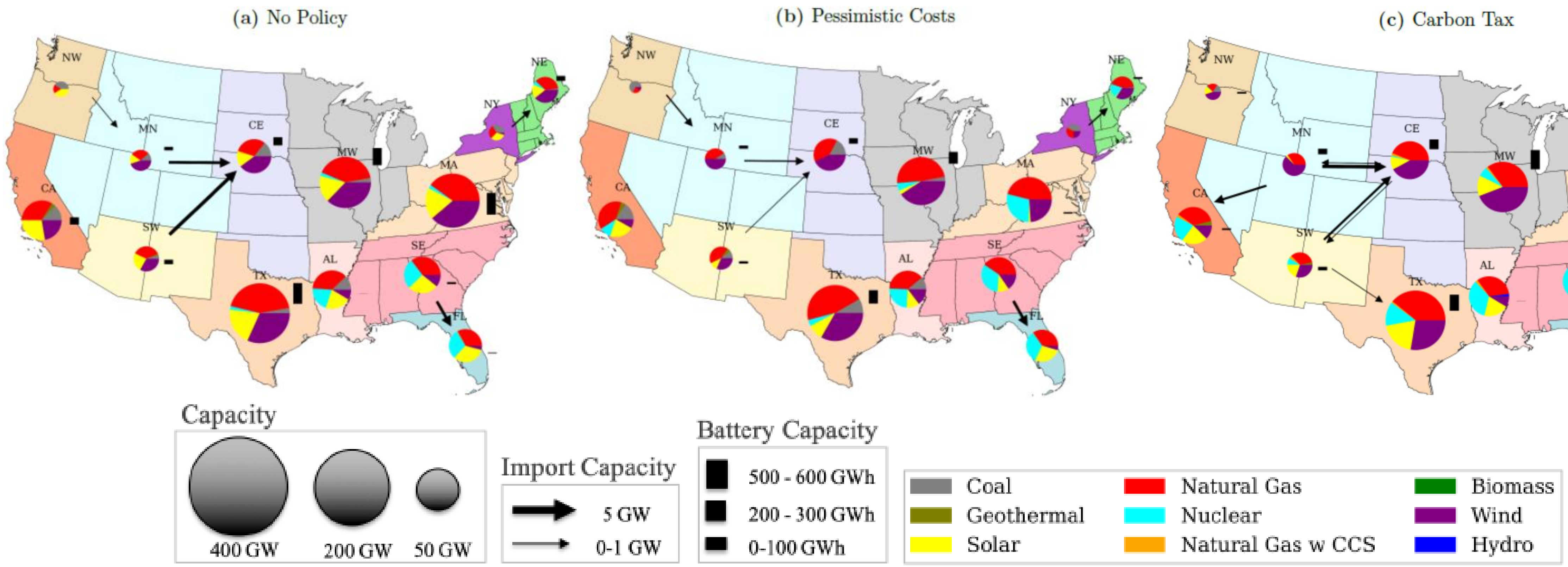


Results: Regional Generation Mixes in 2050



= True scale

Results: Regional Cumulative New Capacity Additions



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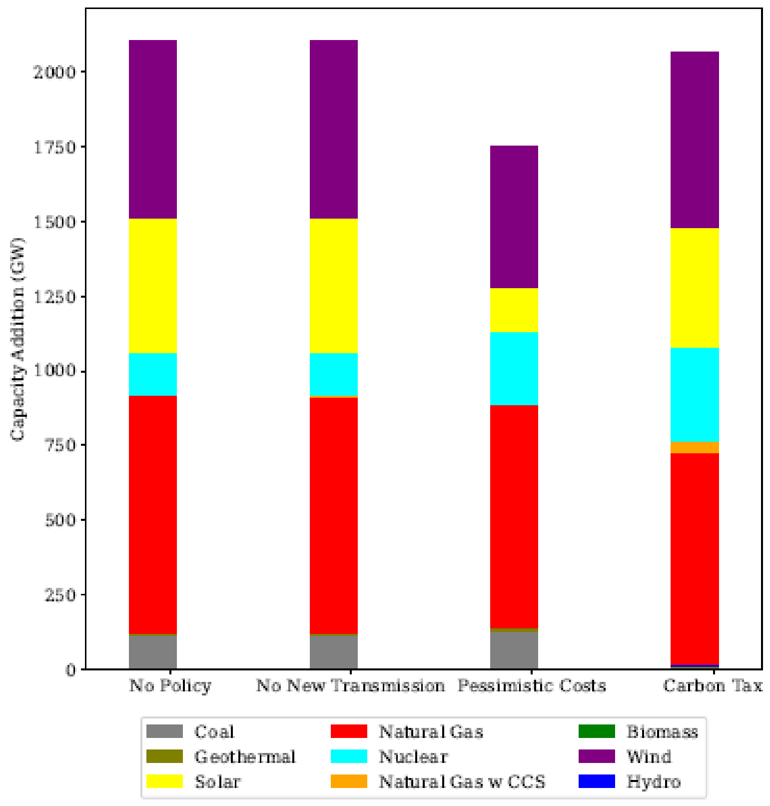
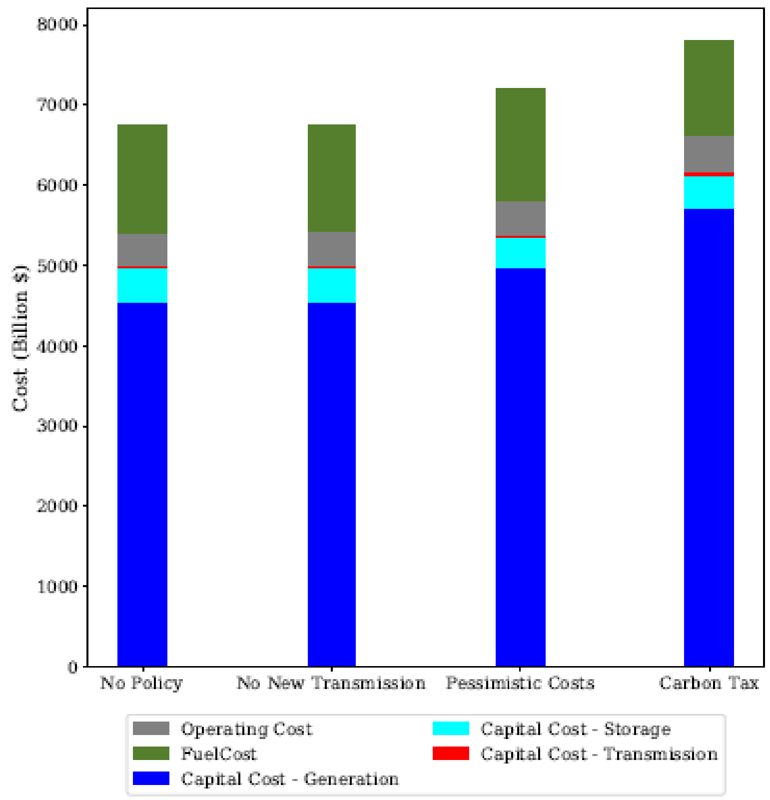
Results: Capacity Investments and Cost Breakdown

(a) Cumulative capacity investment

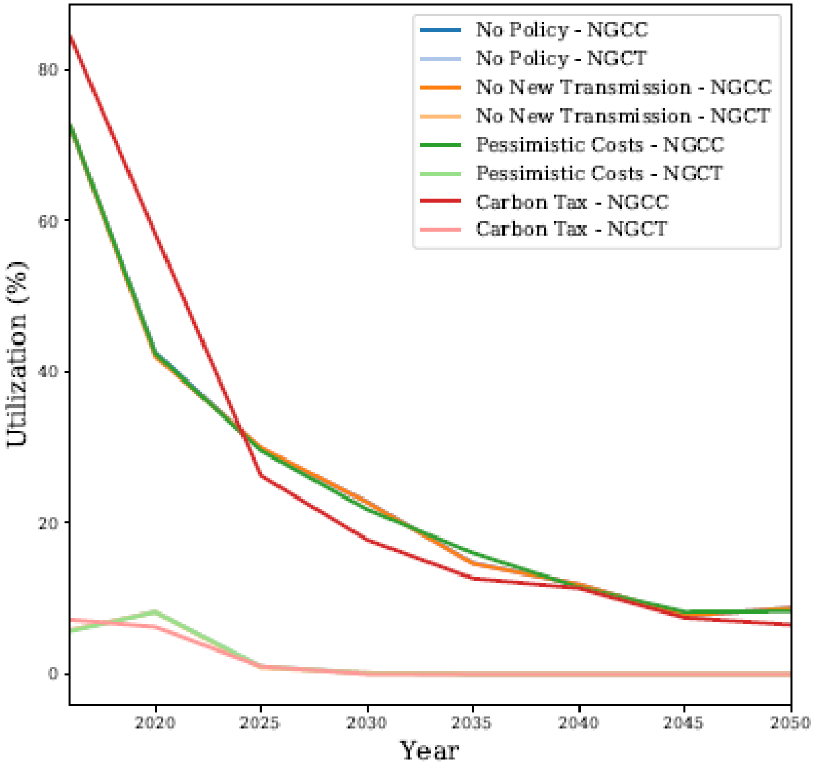


(b) Cost breakdown

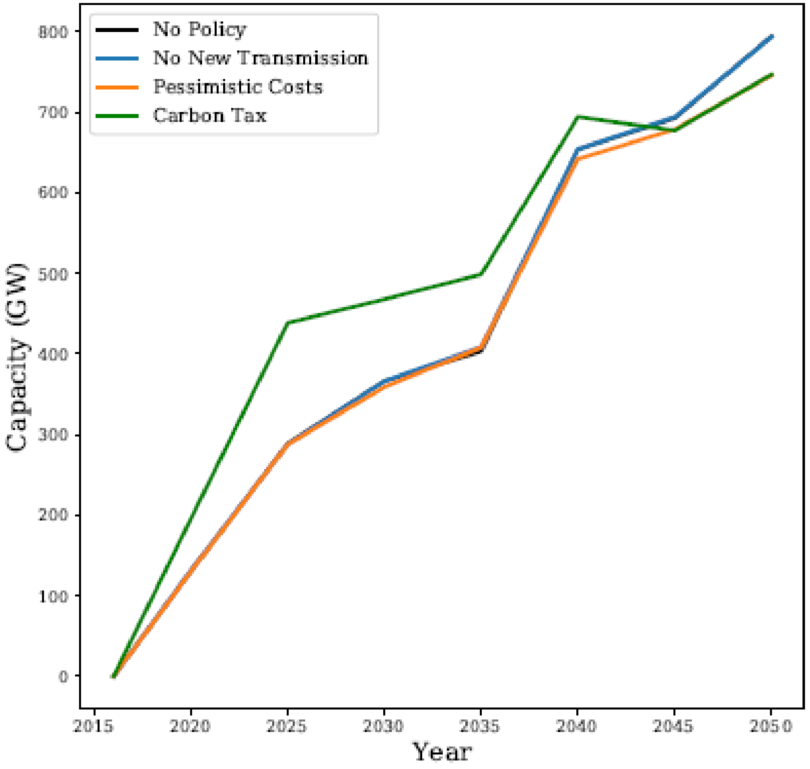


Results: Natural Gas Capacity and Utilization

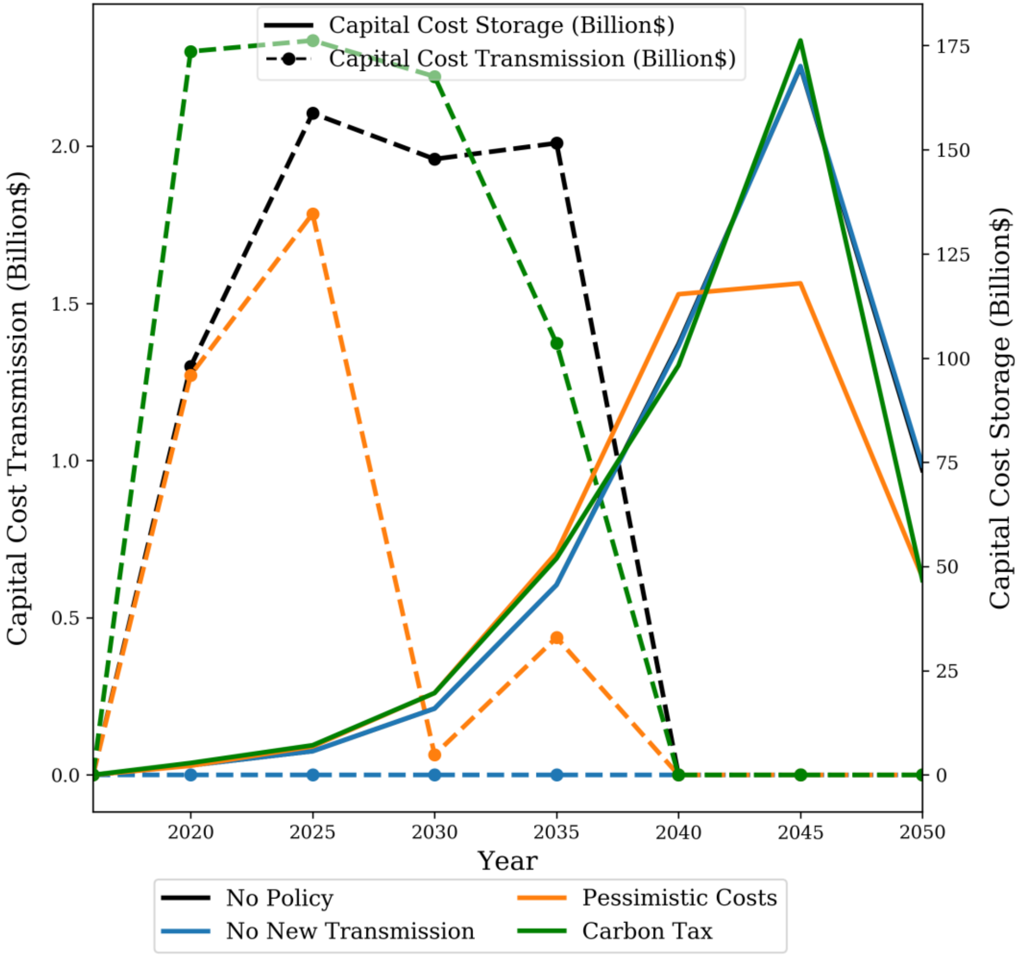
(a) Annual average gas capacity utilization



(b) Cumulative additions of gas capacity

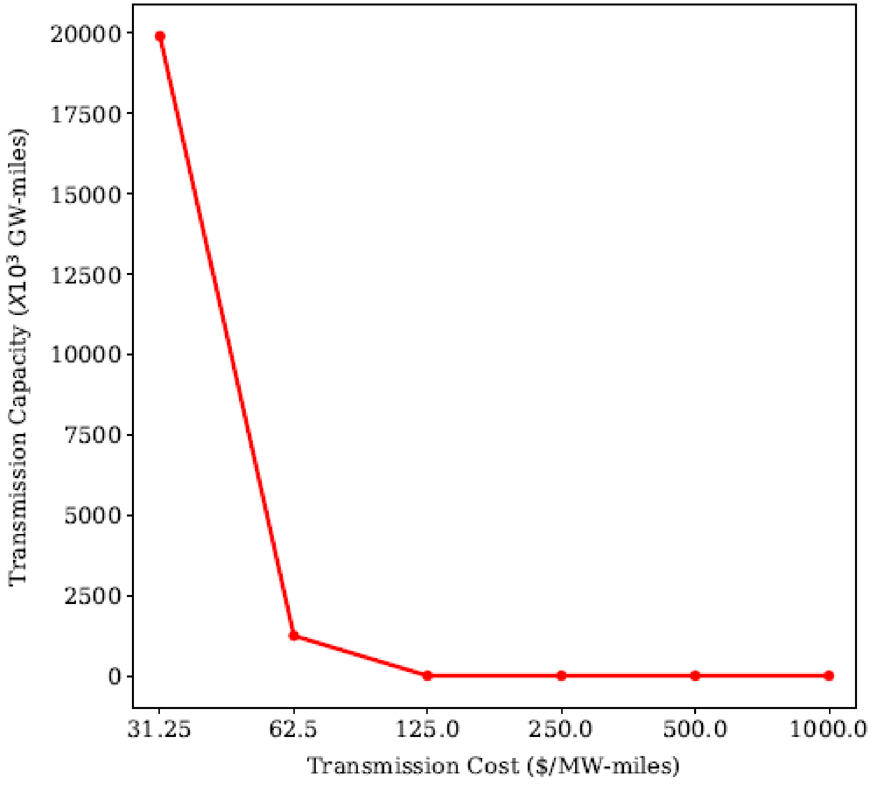


Results: Annual Transmission and Storage Investments

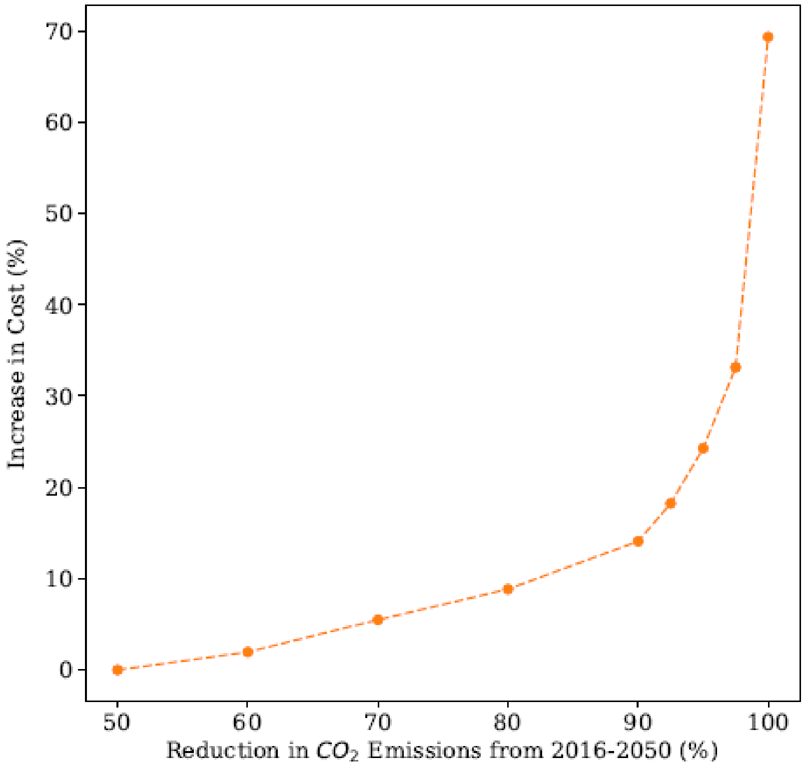


Results: Sensitivity to Transmission Cost and CO_2 Target

(a) Sensitivity of total transmission capacity additions to transmission capital cost



(b) Sensitivity of total cost to targeted % reduction in 2050 CO_2 emissions



Five Key Takeaways

1. U.S. electricity can be substantially decarbonized at modest cost, but complete **decarbonization** is very costly.
2. Significant expansion of **solar and wind** to combine for at least 40% of the national generation mix by 2050 is fairly certain, although solar and storage are more sensitive to assumptions than wind.
3. Investments in long-distance **transmission** are very limited, and investments in **storage** are much greater, under a wide range of assumptions.
4. Optimal solutions include large investments in **natural gas** capacity, but its utilization rates decline steadily and significantly.
5. **Cost structures** shift away from operating expenditures and toward capital expenditures, especially under climate policy.

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