Climate-Water Impacts on Interconnection-Scale Electricity System Planning

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Abstract

A growing literature emphasizes the importance of integrating climate change impacts into electricity system planning. Rising average temperatures can increase and shift electricity demand while reducing generator and transmission efficiency. Changes to water availability and quality can reduce the output of thermally cooled generators and hydropower. Electric power grids across the US and globally are undergoing transformational changes that present new opportunities and challenges to reliability assurance. However, electric utilities and system operators have limited internal capabilities to incorporate these effects into planning practices. This work addresses gaps in utility and system planner practices by integrating climate-water-electricity expertise from universities and U.S. Department of Energy National Laboratories with electricity system planners and stakeholders in the Western Electricity Coordinating Council (WECC). Using a highly collaborative approach, global climate model data, high-resolution hydrology models, and long-term electric sector capacity expansion tools are employed to analyze a range of climate outcomes for future electricity scenarios aligned with recent WECC planning studies. Doing so allows WECC to expand its climate-agnostic planning assessments to consider how future temperature and precipitation patterns could influence generation and transmission planning. We explore how changes to climate-water conditions can affect power plant investment and operation, system economics, and environmental impacts, providing an expanded perspective on interconnection-wide decision making under climate uncertainty.

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Background & Motivation

Stakeholder-Driven Modeling and Collaboration

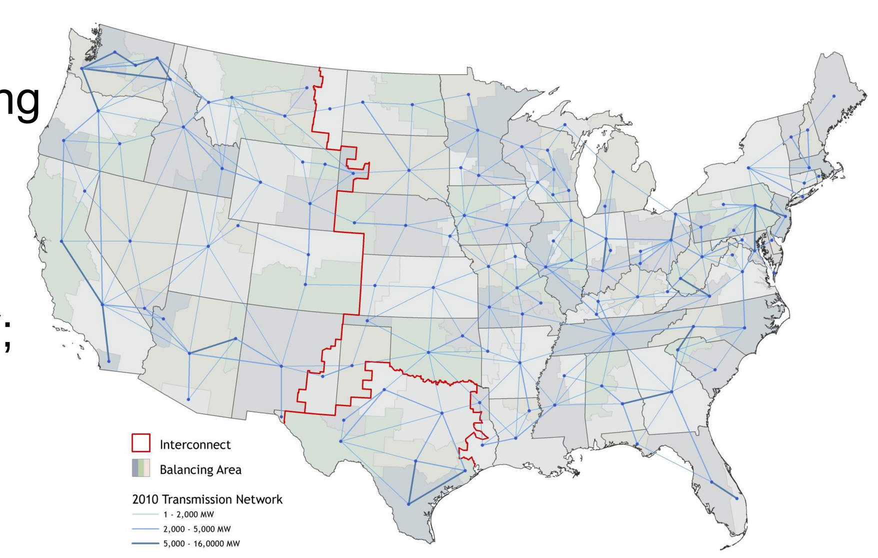
- U.S. Department of Energy National Laboratories have cutting-edge capabilities for studying climate-water-electricity interactions that can assist in answering questions that cannot be addressed with typical industry tools
- The Western Electricity Coordinating Council provides a practical perspective for power system decision-making and what is important to industry stakeholders

Research and Analysis Questions

1. How could future climate and water availability affect WECC investment decisions, dispatch decisions, and grid reliability?
2. How do climate and water impacts change under varying climate projections and electric system drivers?
3. How could the role of hydropower in the electricity system change under future climate and water conditions?

Methods

The Regional Energy Deployment System (ReEDS) with Climate-Water Impacts



- NREL's flagship model for simulating U.S. electricity generation and transmission investment and operation through 2050
- 134 regions for demand, water, PV; 356 regions for wind, CSP
- 17 intra-annual time-slices for seasonal and diurnal dispatch
- Temperature impacts on load, generator performance, and transmission capacity
- CUNY Water Balance Model converts precipitation projections to thermal cooling water and hydropower availability

Four Infrastructure Expansion Scenarios

1. REF: default ReEDS v2018 assumptions
2. LOW.VG.COST: NREL ATB 2018 Low Cost case for wind and solar
3. HIGH.VG.COST: NREL ATB 2018 High Cost case for wind and solar
4. ELEC: Transportation and building electrification increases electricity demand and adds demand flexibility

ATB: NREL Annual Technology Baseline

Five Future Climate Conditions

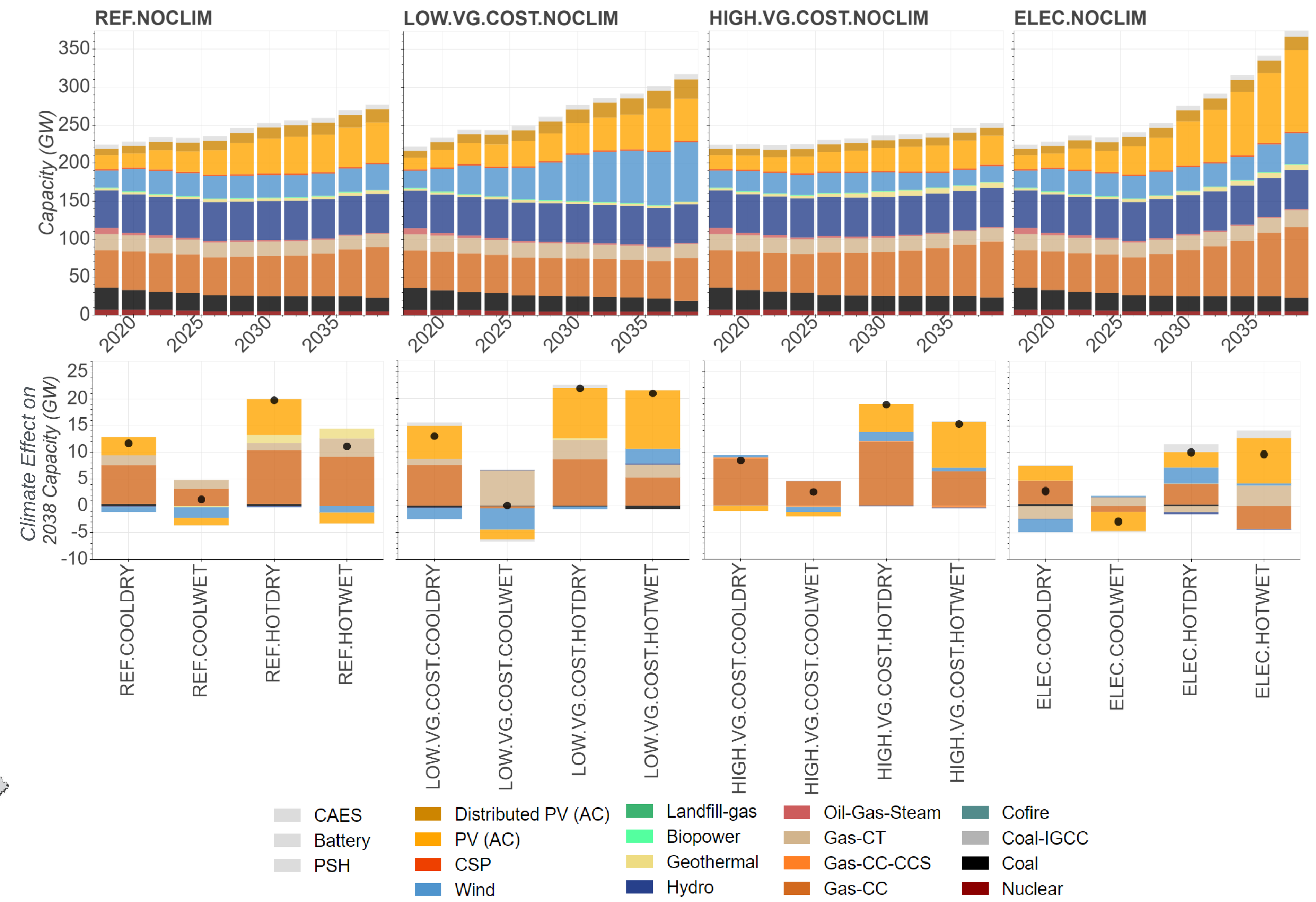
1. NOCLIM: Static climate conditions

\+ Four temperature/precipitation alternatives from climate model simulations

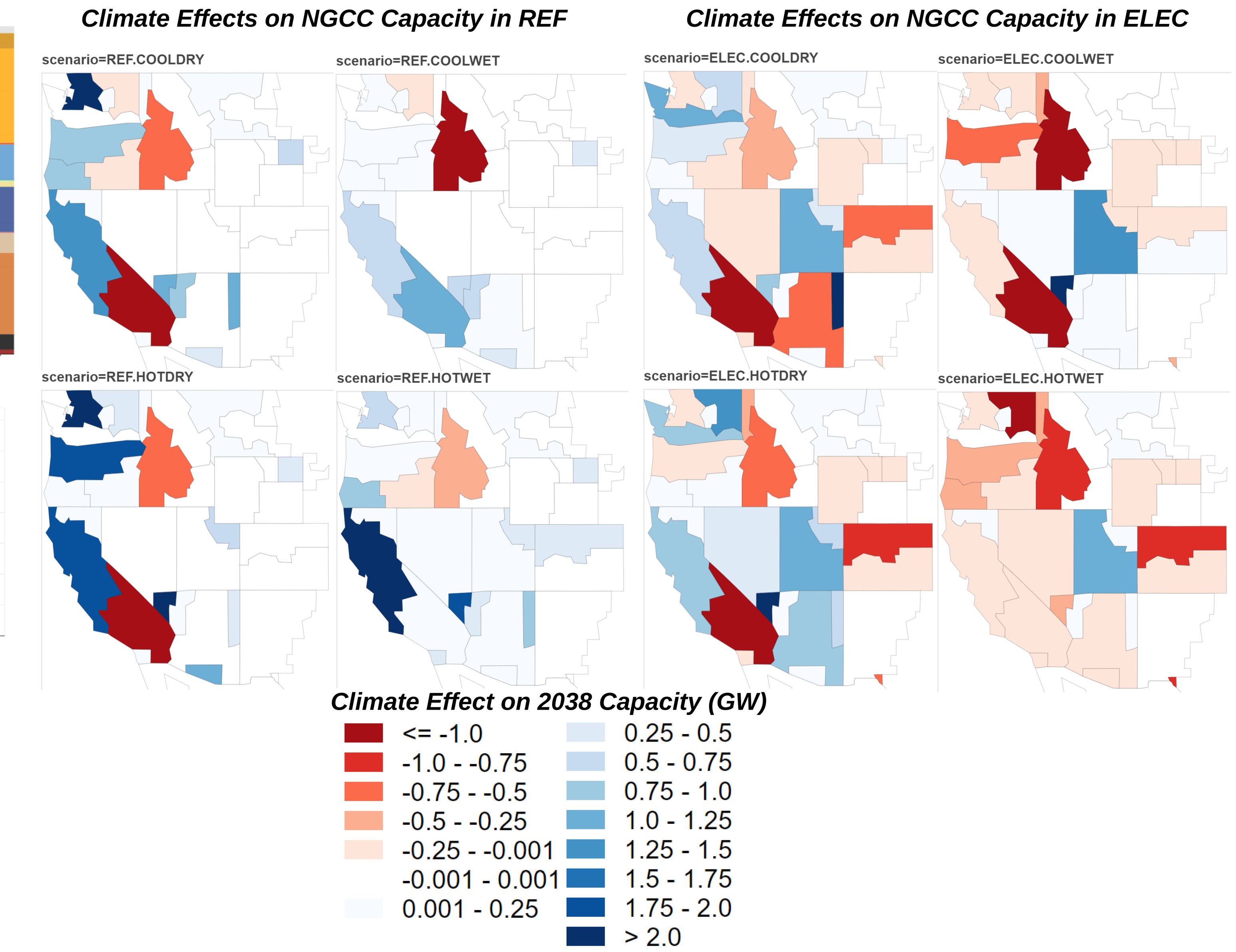
2. HOTDRY: IPSL-CM5A-LR RCP 8.5
3. HOTWET: MIROC-ESM-CHEM RCP 8.5
4. COOLDRY: IPSL-CM5A-LR RCP 4.5
5. COOLWET: GFDL-ESM2M RCP 4.5

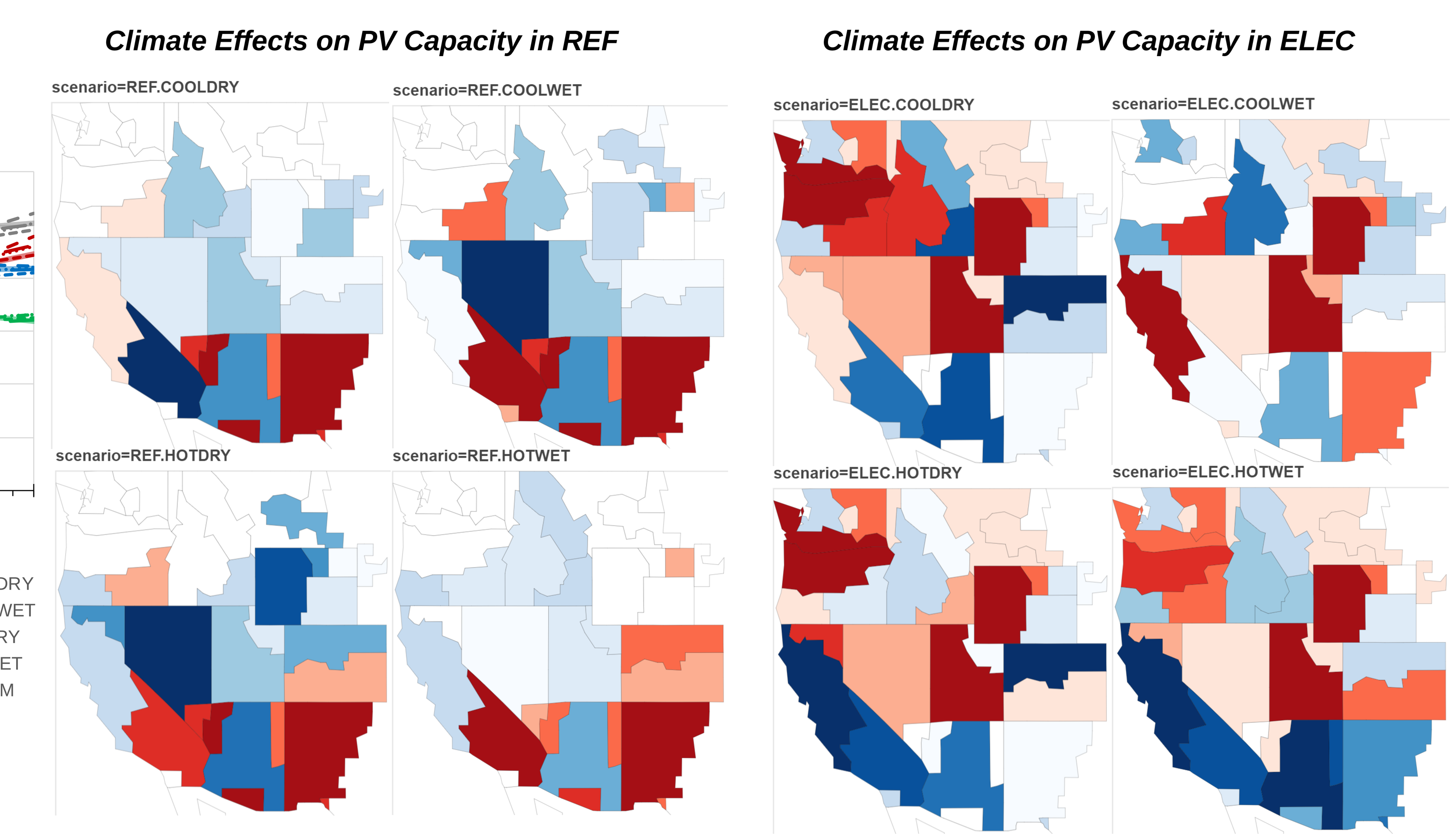
Results

WECC Power Capacity Investments

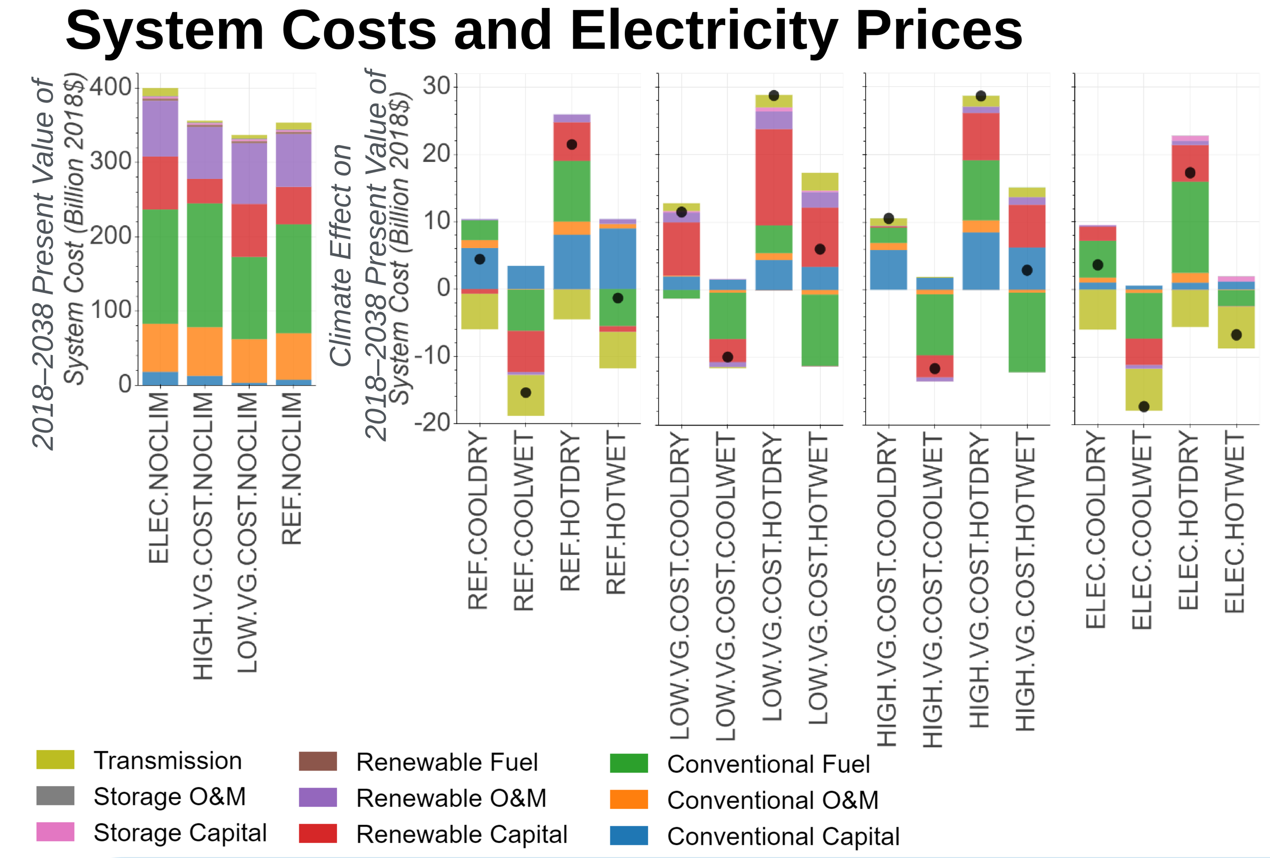


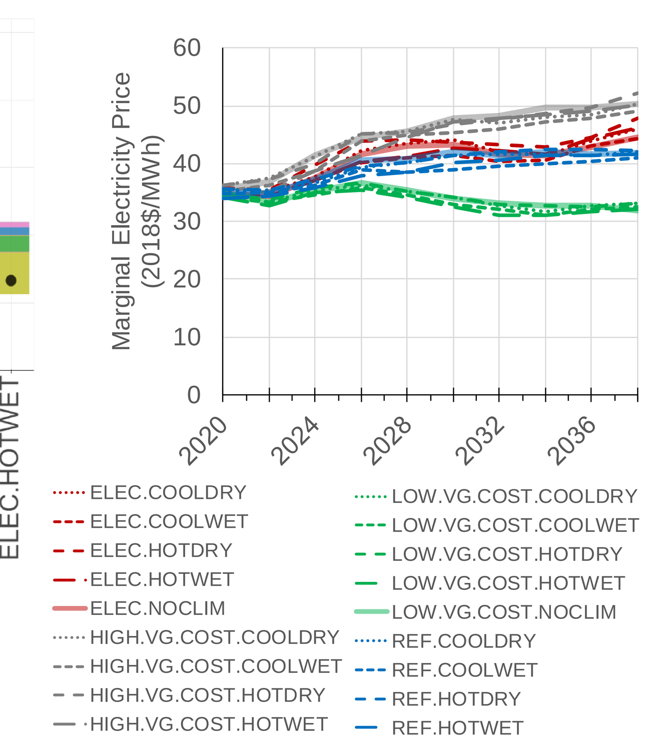
Regional Impacts on Power Capacity





System Costs and Electricity Prices





Key Takeaways

Regional and State-Level Capacity Expansion

1. Climate impacts on hydropower generation could affect future WECC capacity planning
2. Flexible and peaking capacity or flexible demand can help respond to temperature-induced load growth
3. State and sub-state impacts could depend on local resources and system configuration

System Economics

1. Heat-driven demand increases can lead to higher system costs, while increased hydropower generation can reduce system costs
2. Underlying technology costs and demand projections can influence total system costs as much as future climate conditions
3. Climate impacts on electricity prices appear small compared to the influence of technology assumptions

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