



Implications of sub-annual temperature dynamics on the power sector

December 5, 2019

Zarrar Khan, Gokul Iyer, Pralit Patel,

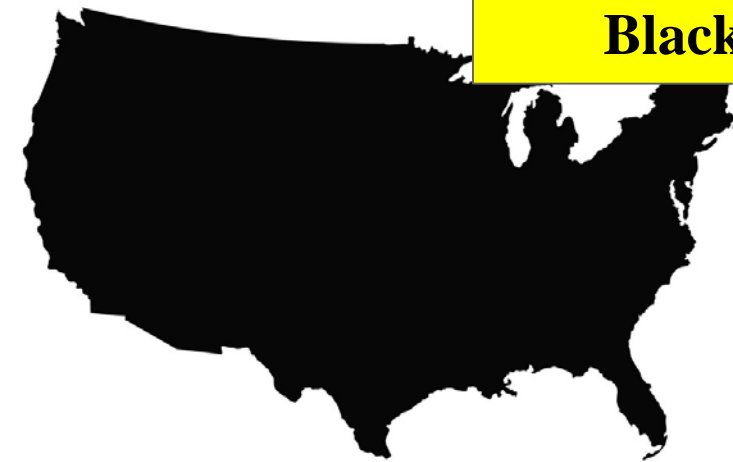
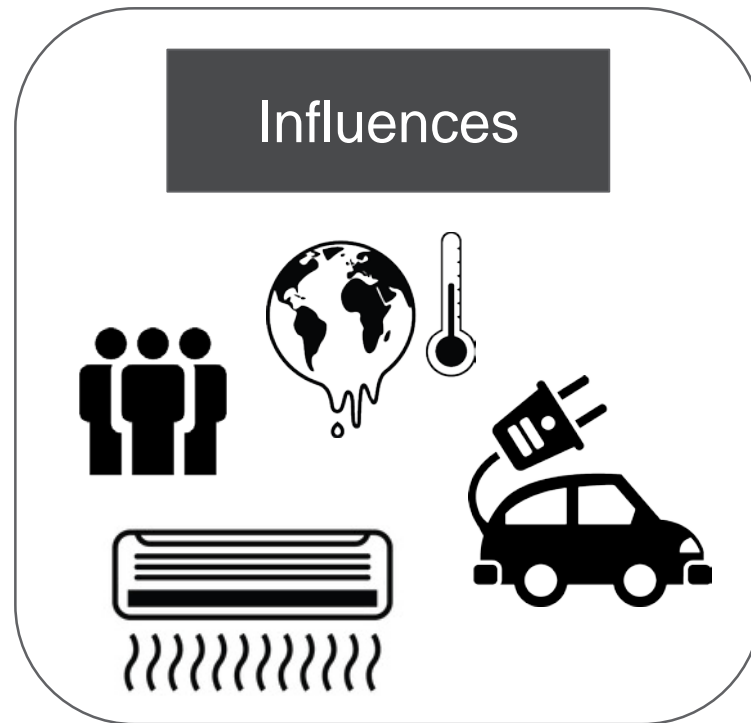
Marshall Wise, Sonny Kim

Mohamad Hejazi



PNNL is operated by Battelle for the U.S. Department of Energy

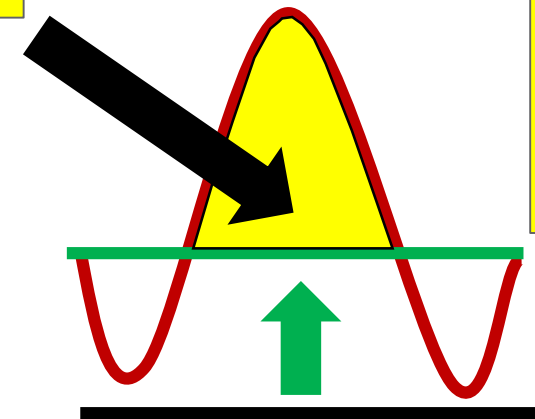




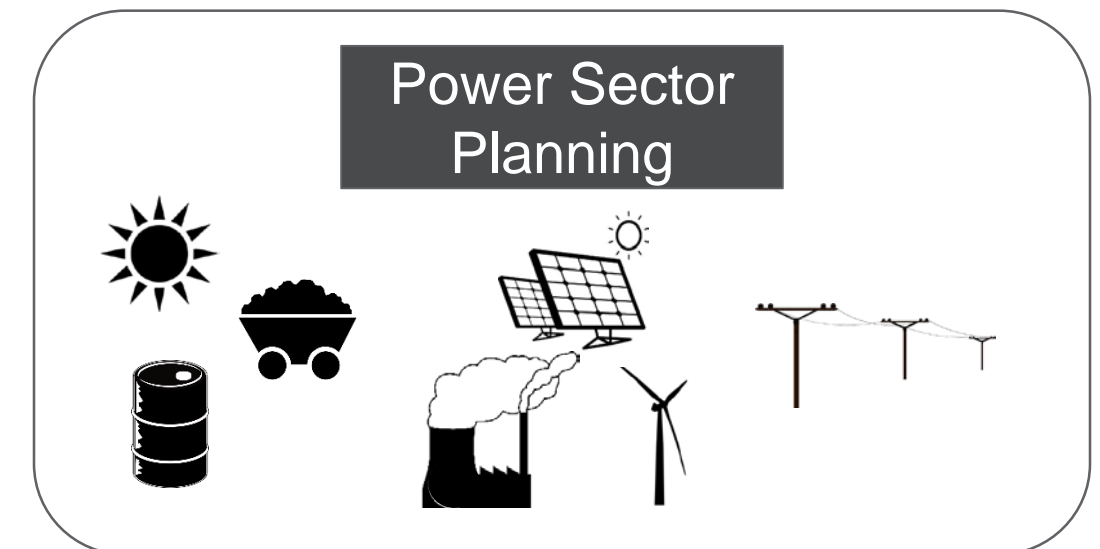
**Under-capacity
Reliability
Blackouts**

**Electricity
Demand**

**Hourly
Seasonal
Daily**



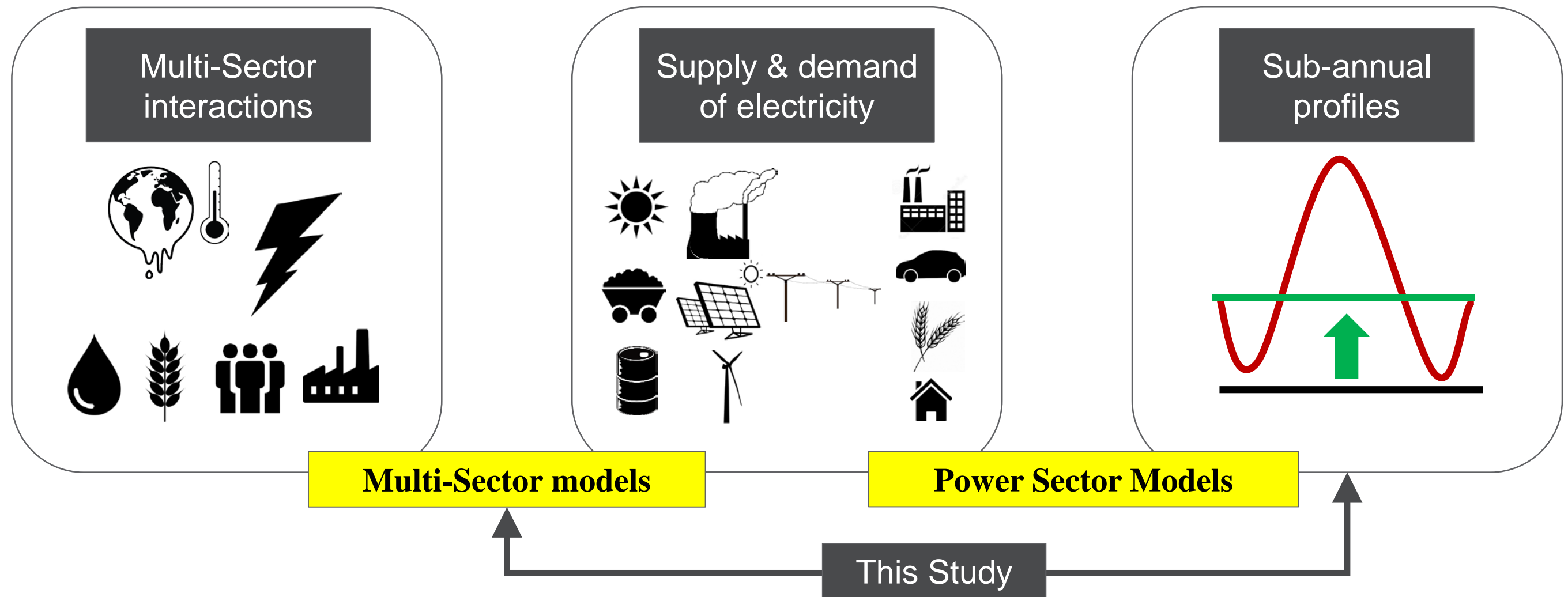
- Plan for **TOTAL** electricity demand
- Plan for **PEAK** electricity demand



How does **temperature change** impact power sector investments and dispatch?

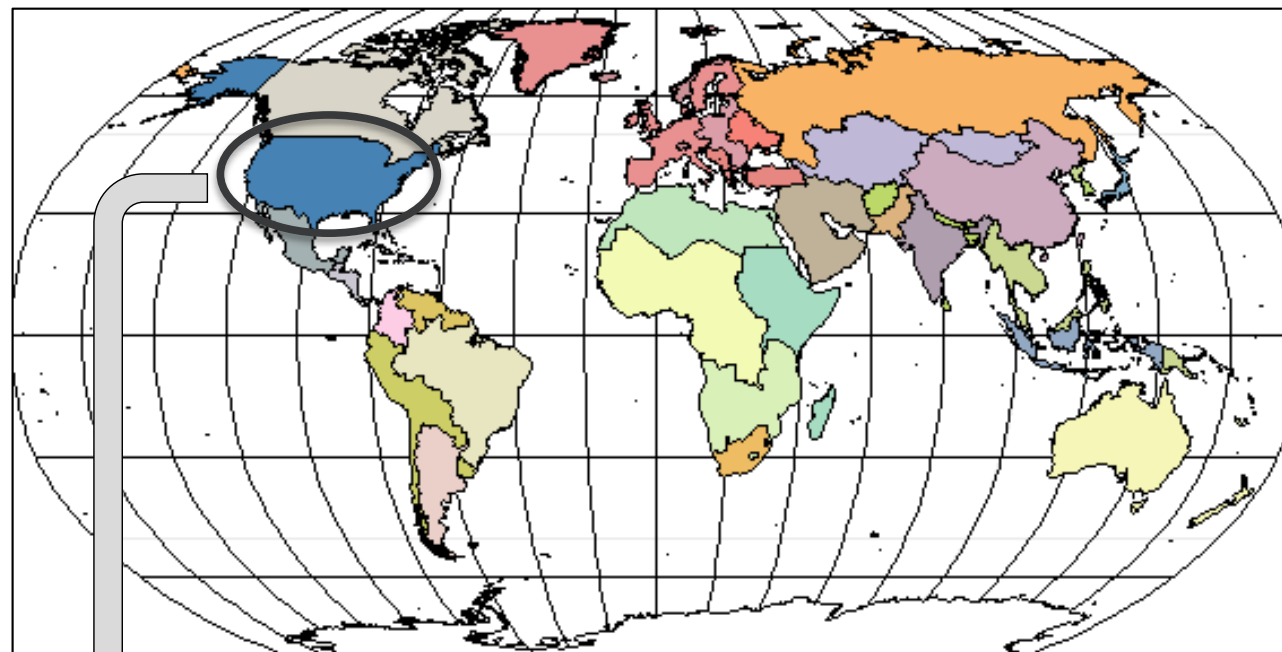
How do **sub-annual dynamics** influence these impacts?

The literature suggests three research needs to better capture climate impacts in the power sector

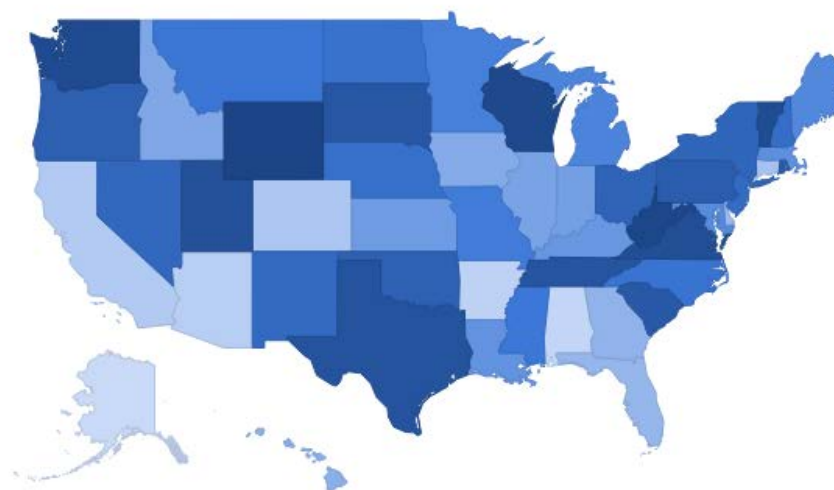


Methodology: GCAM USA

GCAM: 32 geopolitical regions

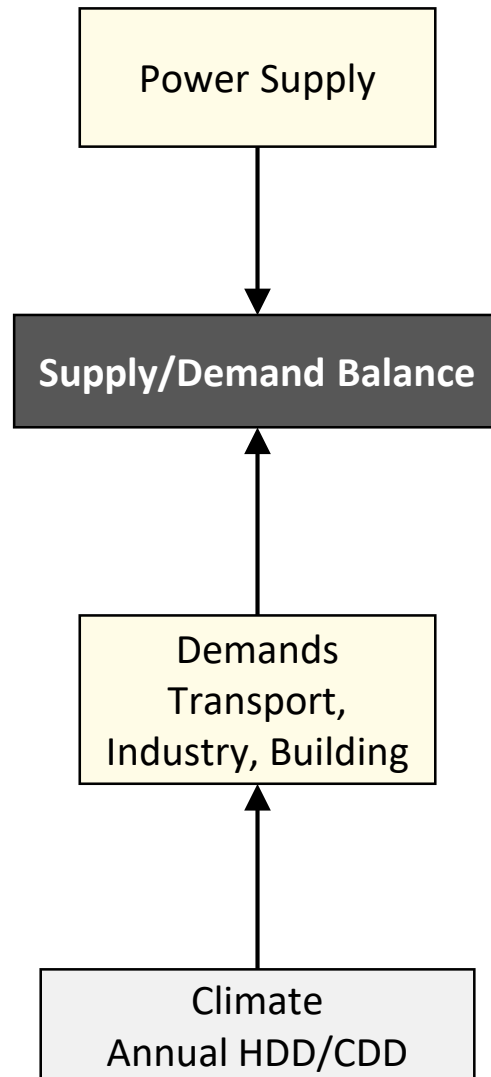


GCAM-USA: 50 states + D.C. in the U.S.

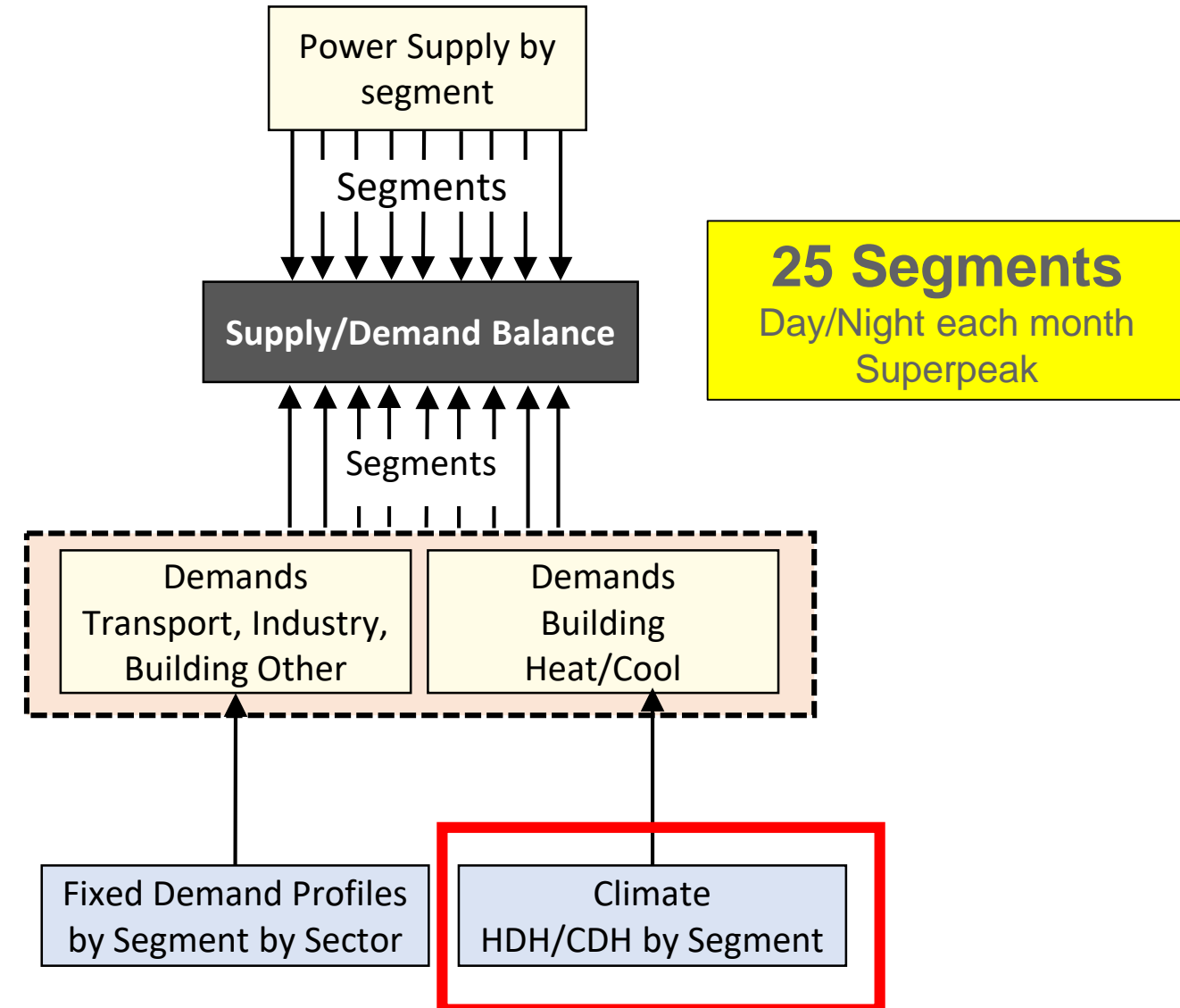


Methodology: Capturing Sub-Annual Dynamics

Annual



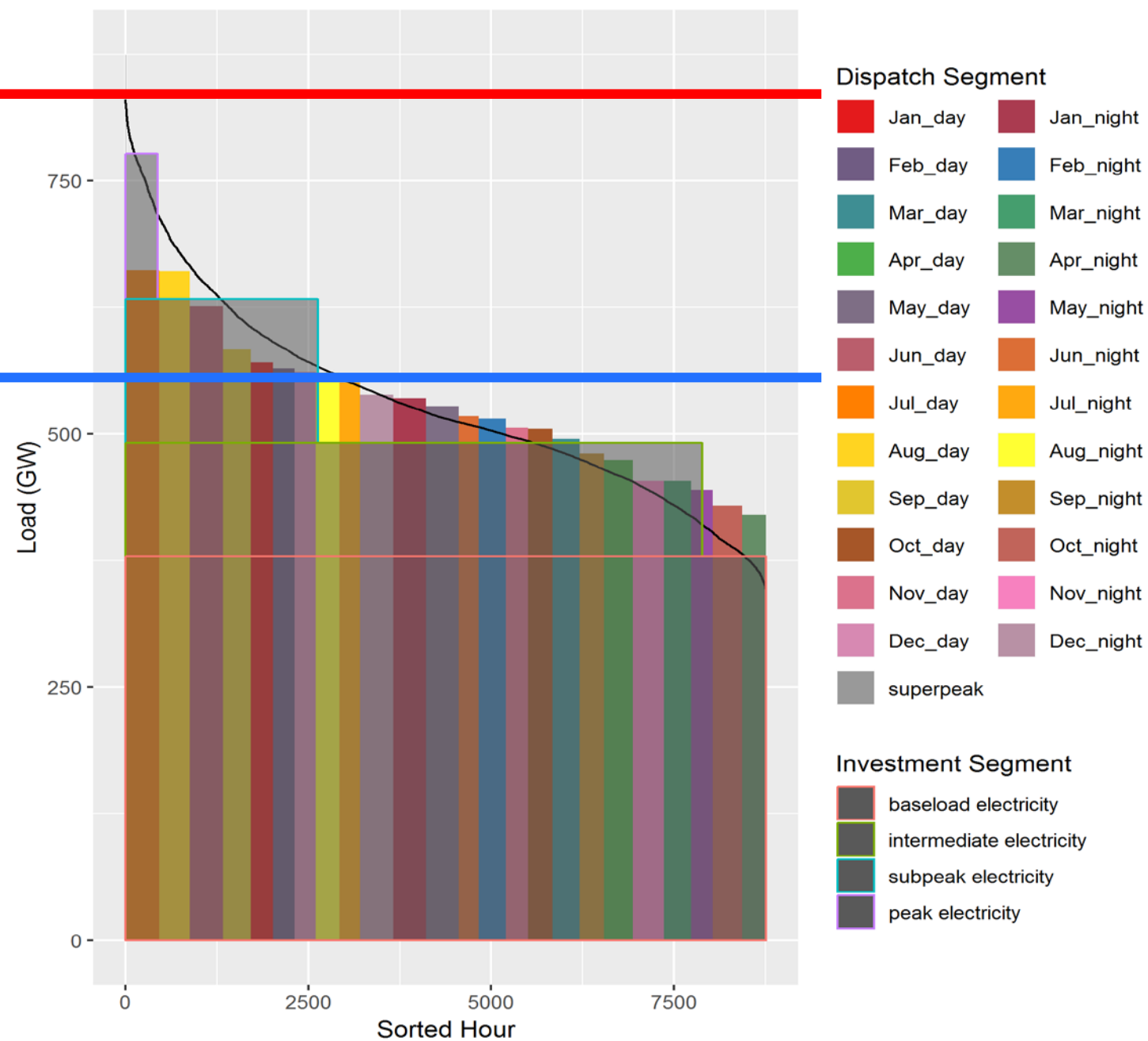
Sub-Annual



Methodology: Dispatch Segments & Investments

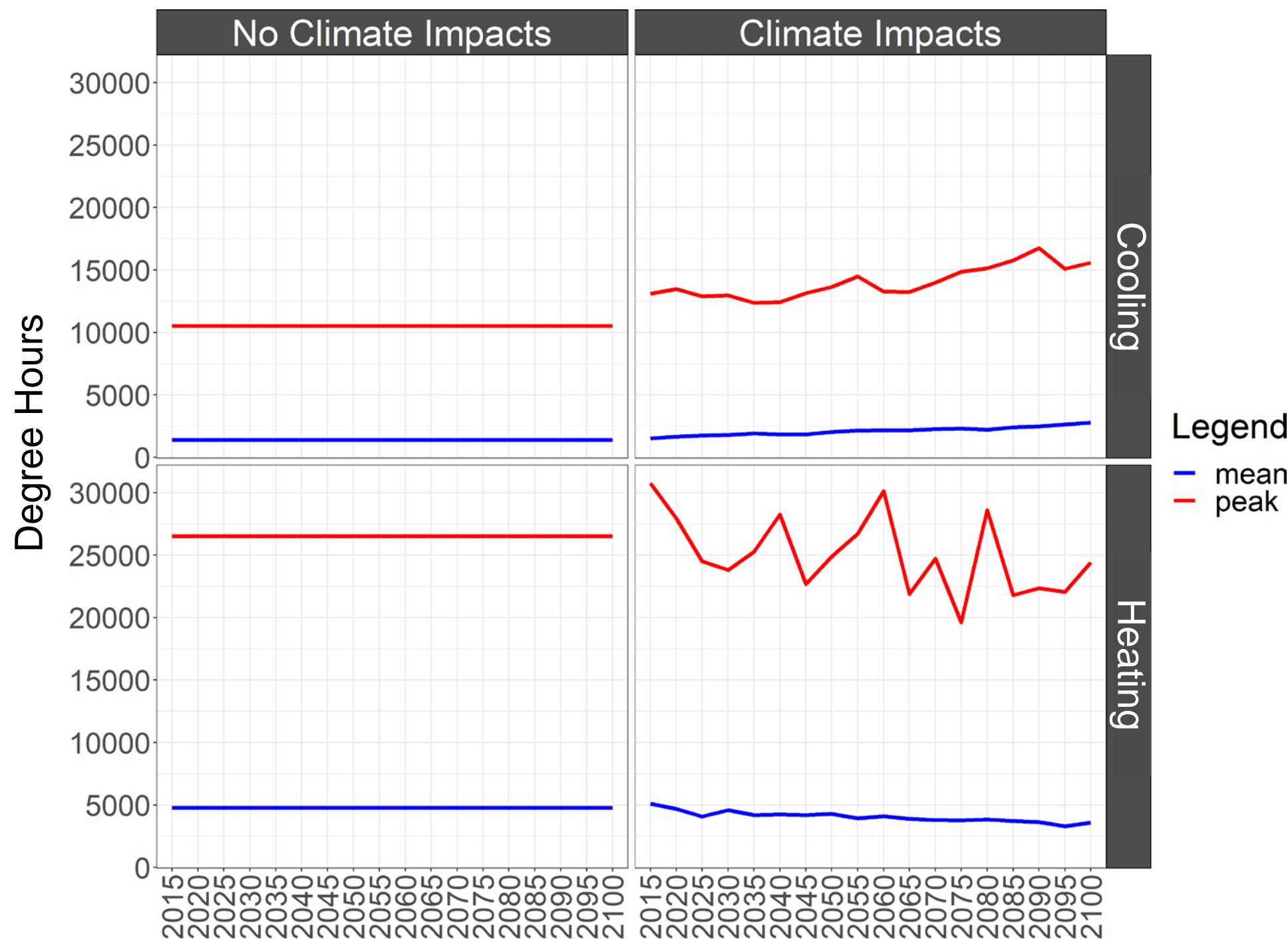
Peak

Mean



Exploring Two Scenarios: RCP 8.5 Without Climate Impacts and with Climate Impacts

**Exogenous
Input Data**

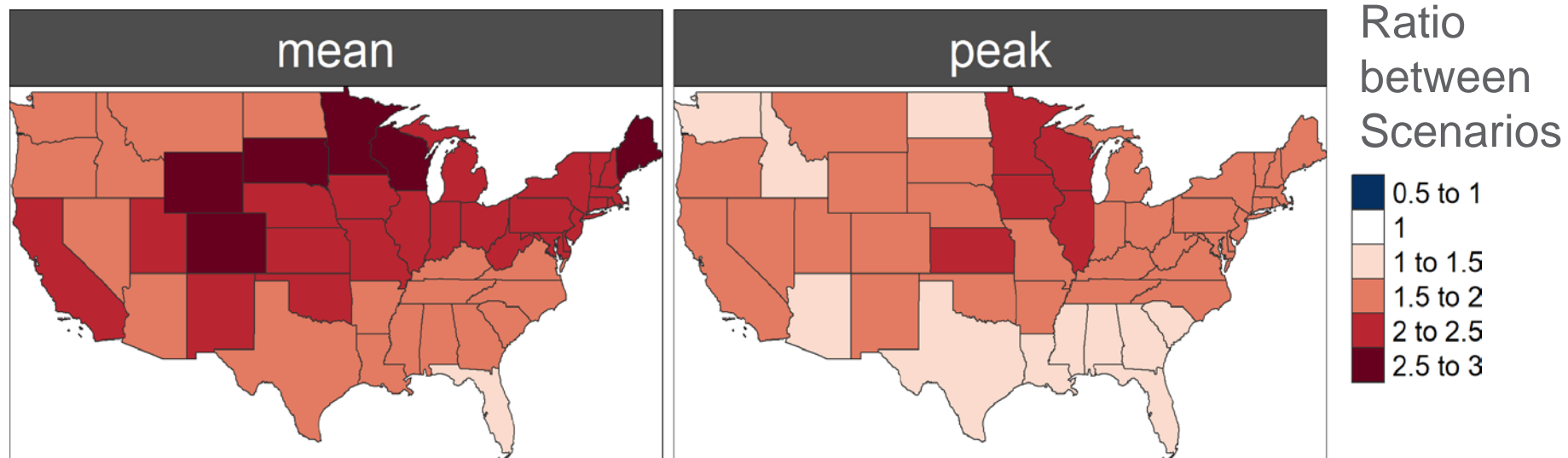


Source of Data:
PRIMA Project

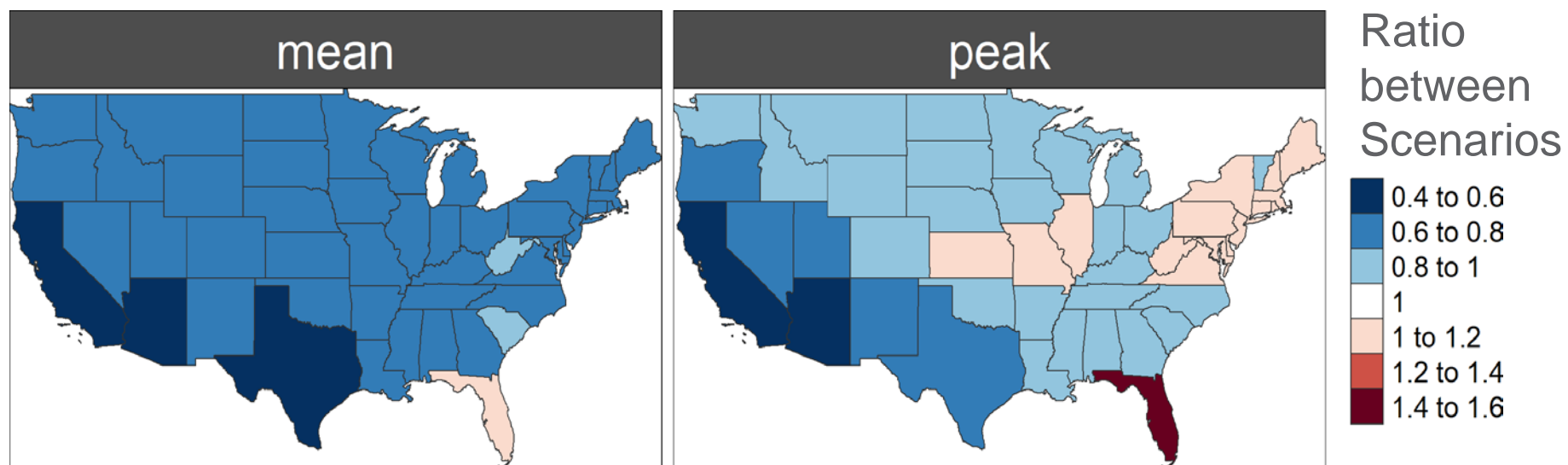
Future temperature change in RCP8.5 implies increase in cooling degree hours and decrease in heating degree hours across states

**Exogenous
Input Data**

Cooling Degree Hours

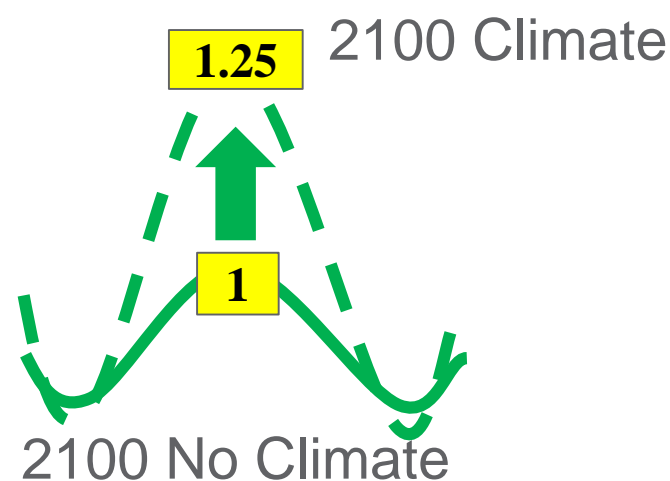
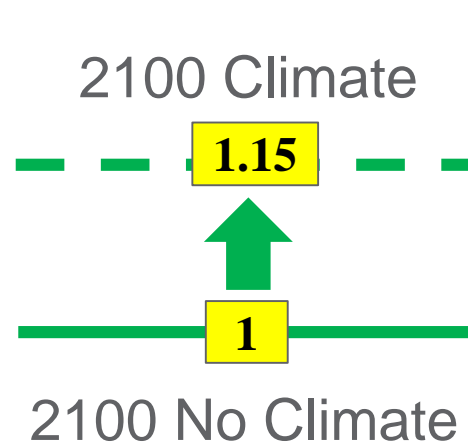
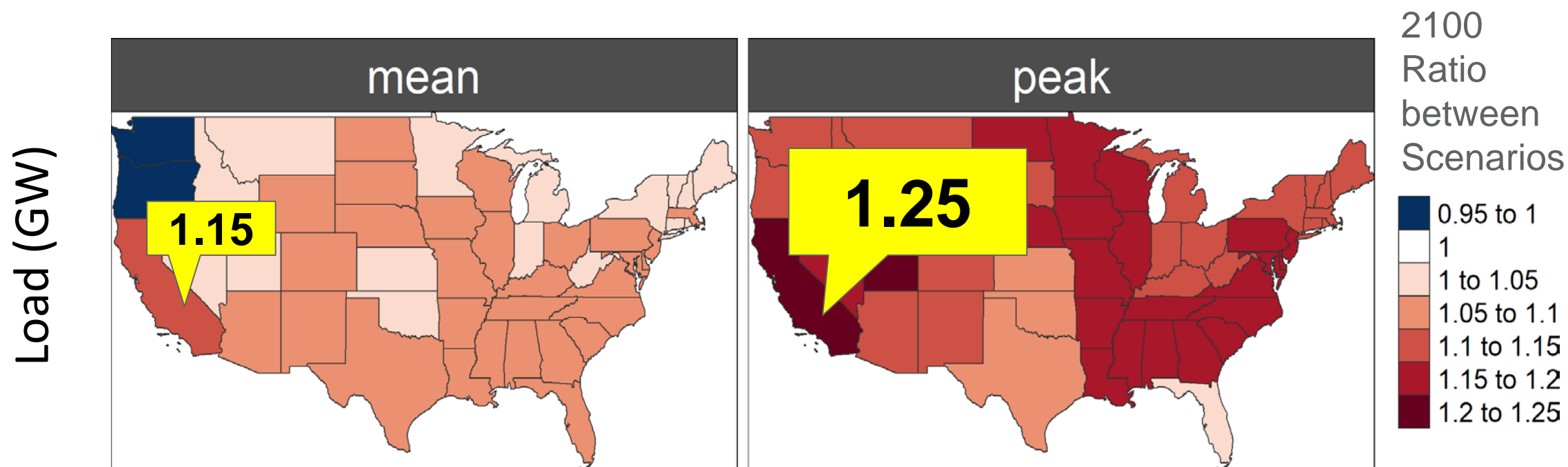


Heating Degree Hours

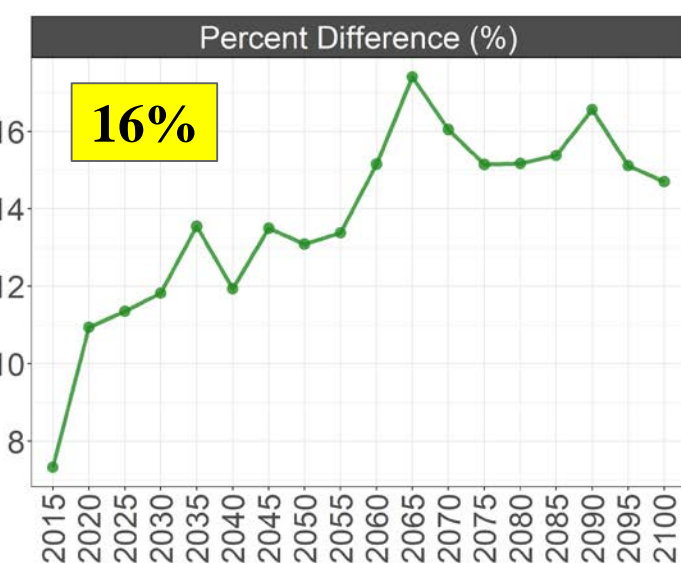
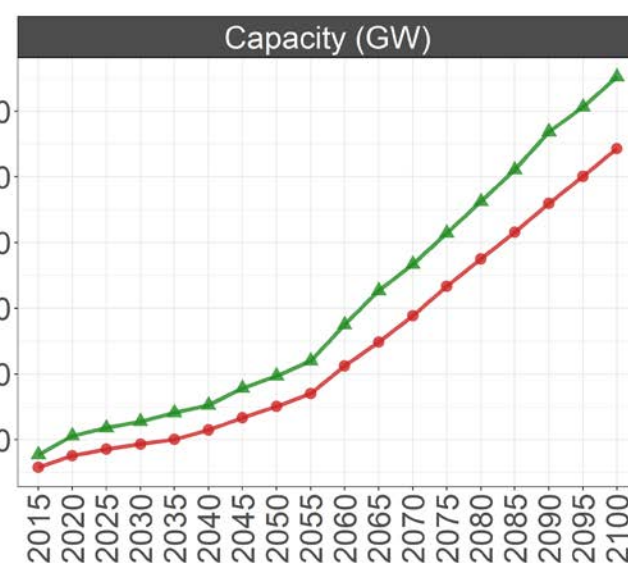
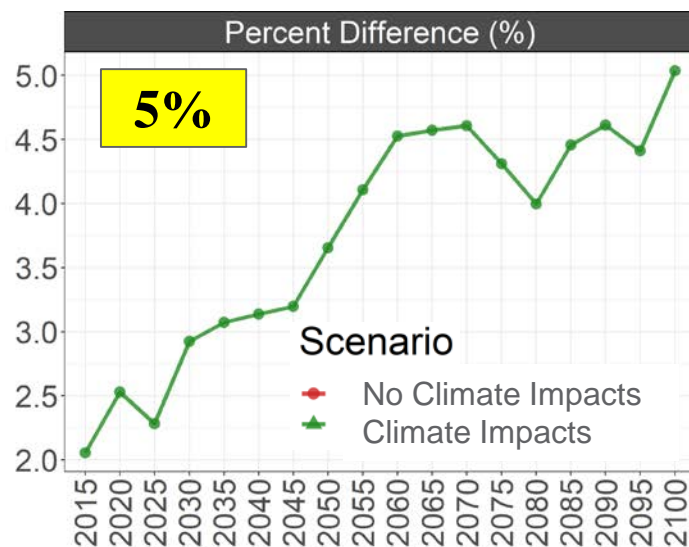
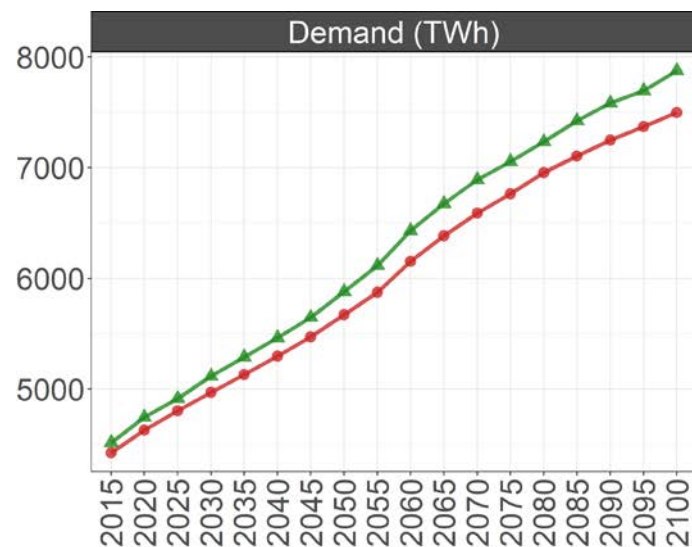


Model Results

Larger change in Peak loads leads to greater impact on capacity than generation/demand

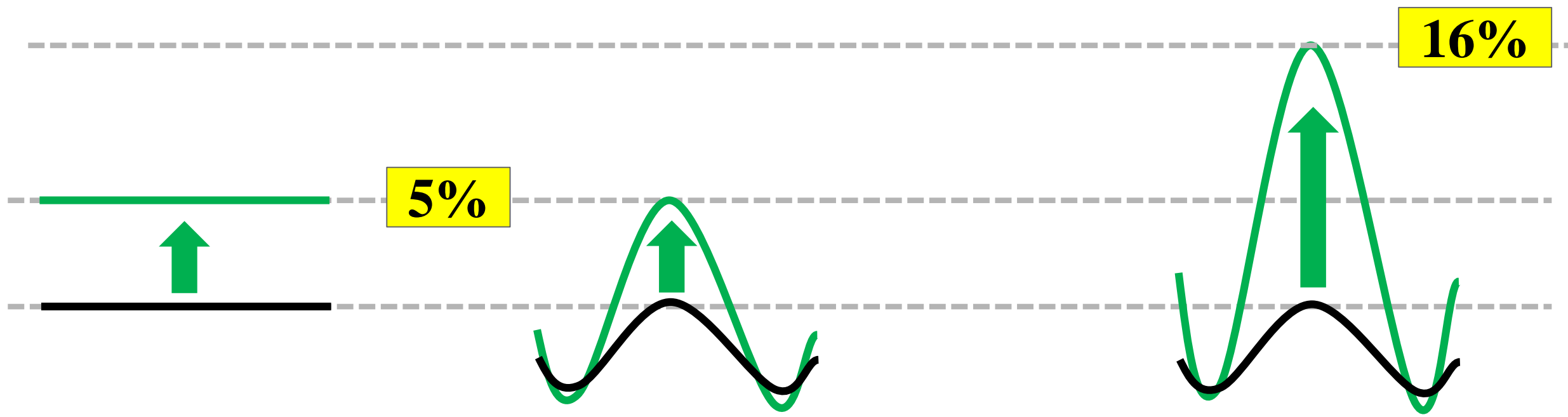


Larger change in Peak loads leads to additional demand for Capacity



Existing GCAM-USA

Improved GCAM-USA



1. How does **temperature change** impact power sector investments and dispatch?

- Temperature has a direct impact on electricity demands and capacity requirements
- Impacts vary spatially across the US

2. How do **sub-annual dynamics** influence these impacts?

- Peak load impacts can be significantly different than mean load impacts
- This has direct and important implications for Capacity Planning

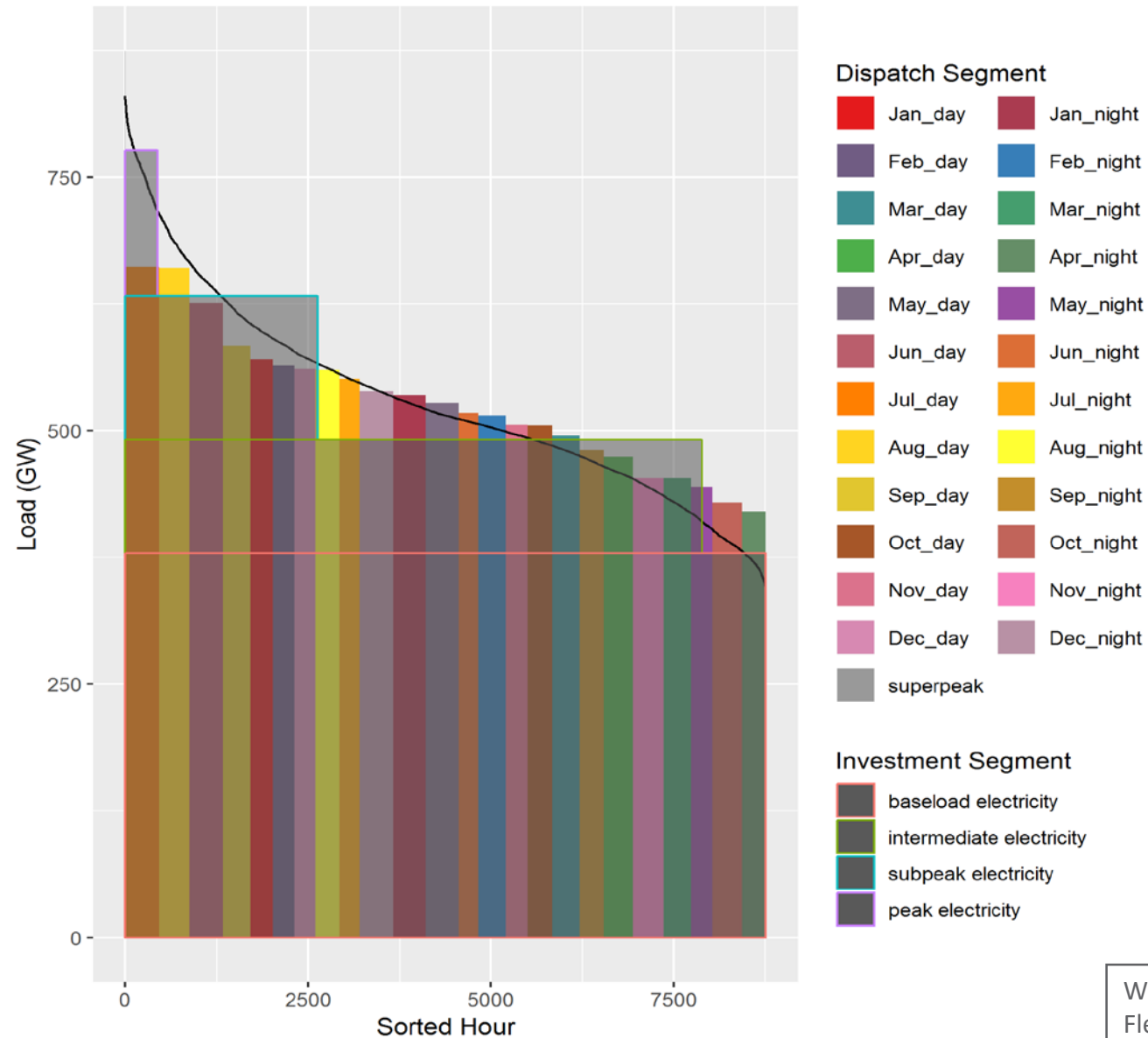
- Detailed supply-side dynamics (e.g. capacity expansion fuel mix)
- Impacts of electric vehicle deployment on load curve shapes
- Impacts of droughts and other environmental influences.

Thank you

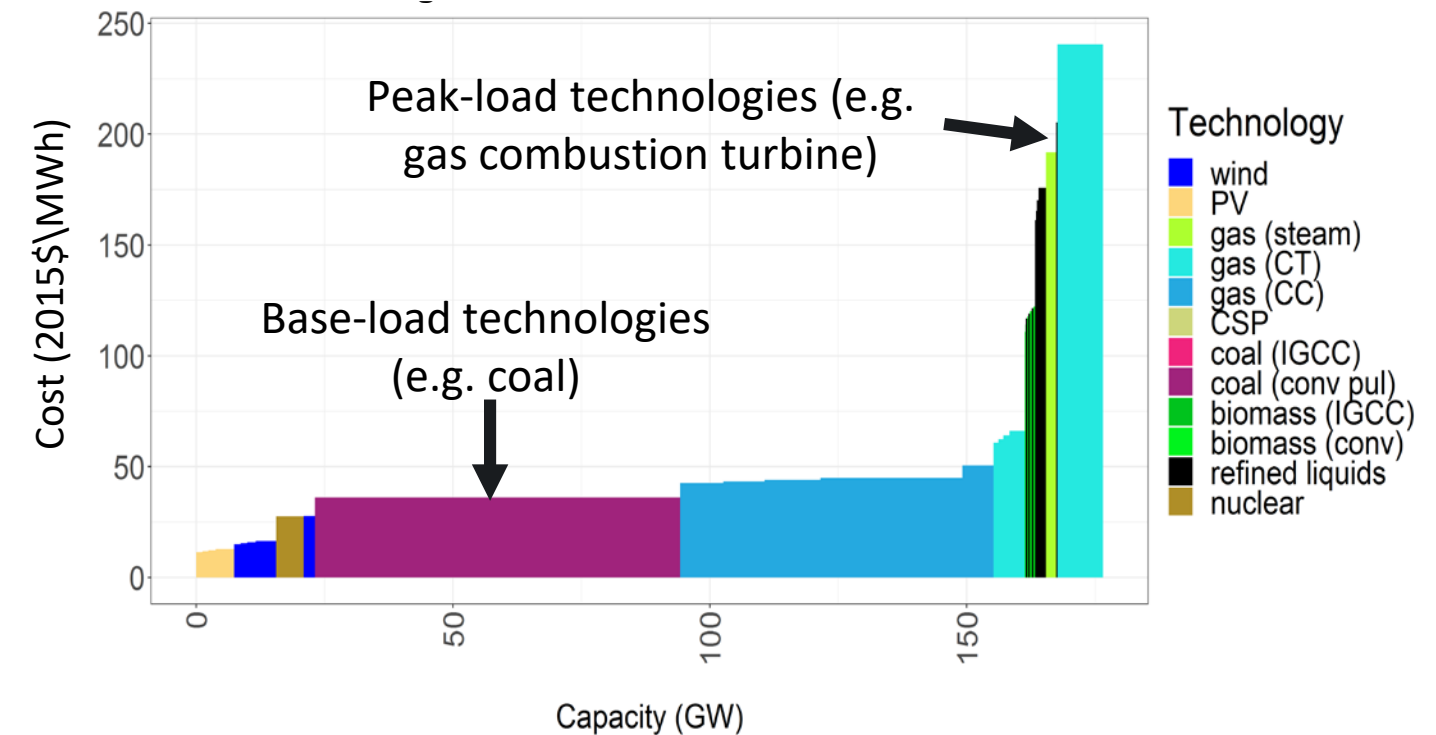


Methodology: Dispatch Segments & Investments

Dispatch & Investment Segments



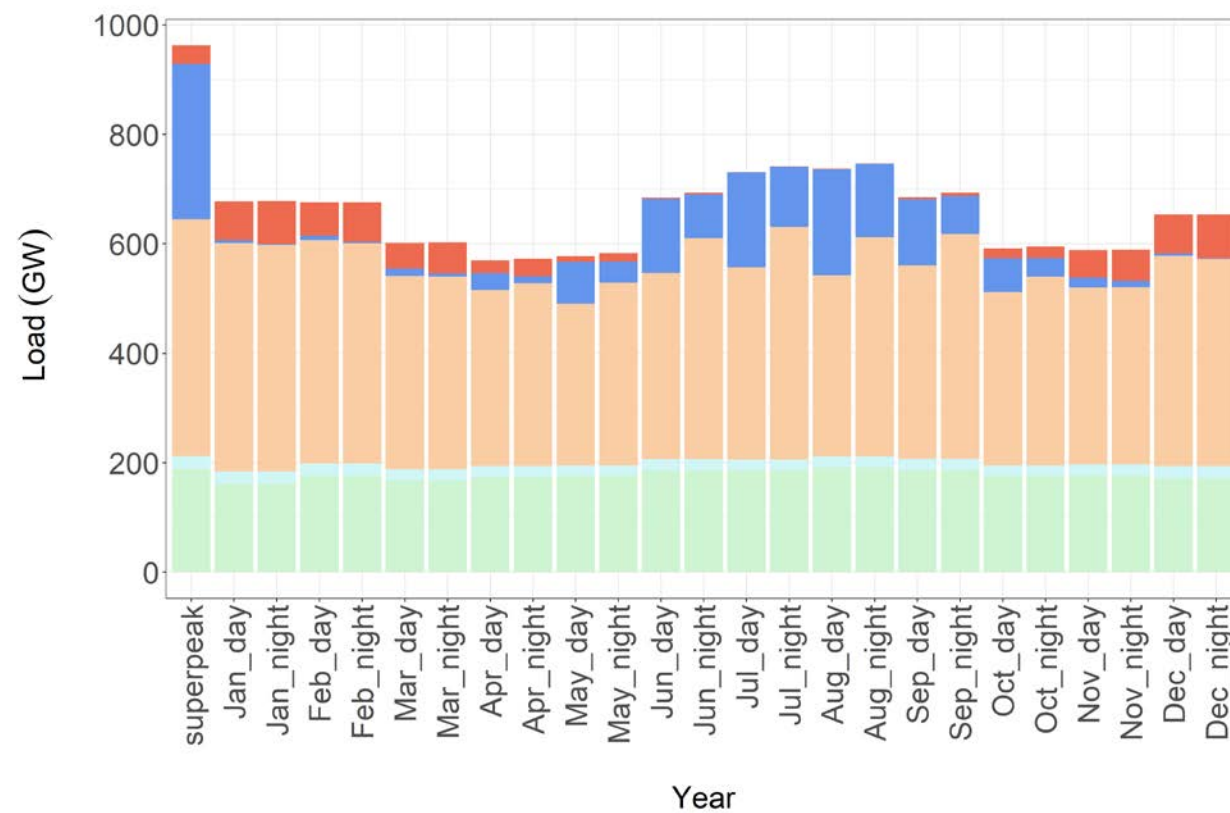
Merit Order Dispatch



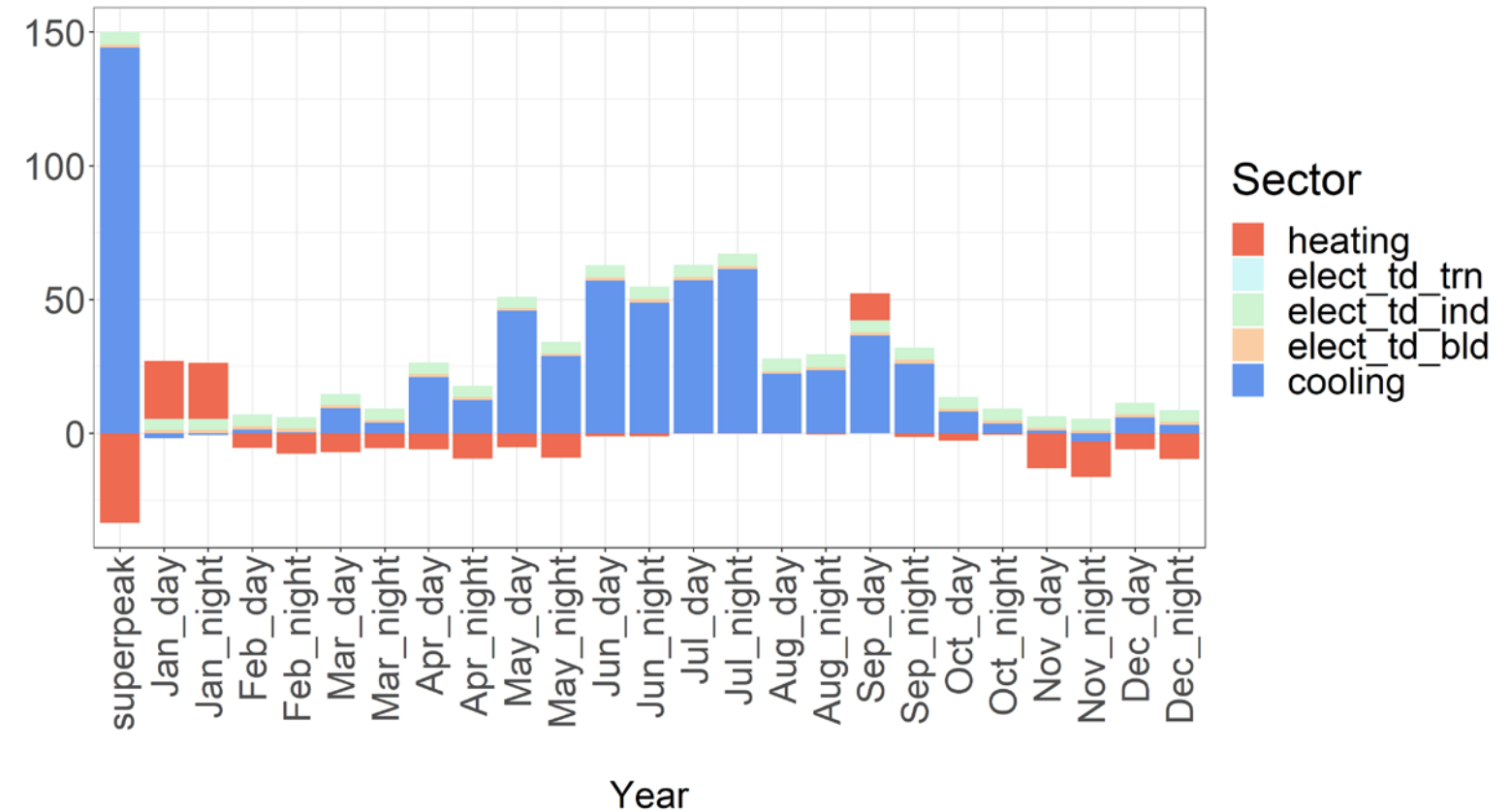
Wise M.A., P.L. Patel, Z. Khan, S.H. Kim, M.I. Hejazi, and G.C. Iyer. 2019. "Representing Power Sector Detail and Flexibility in a Multi-sector Model" *Energy Strategy Reviews*. <https://doi.org/10.1016/j.esr.2019.100411>

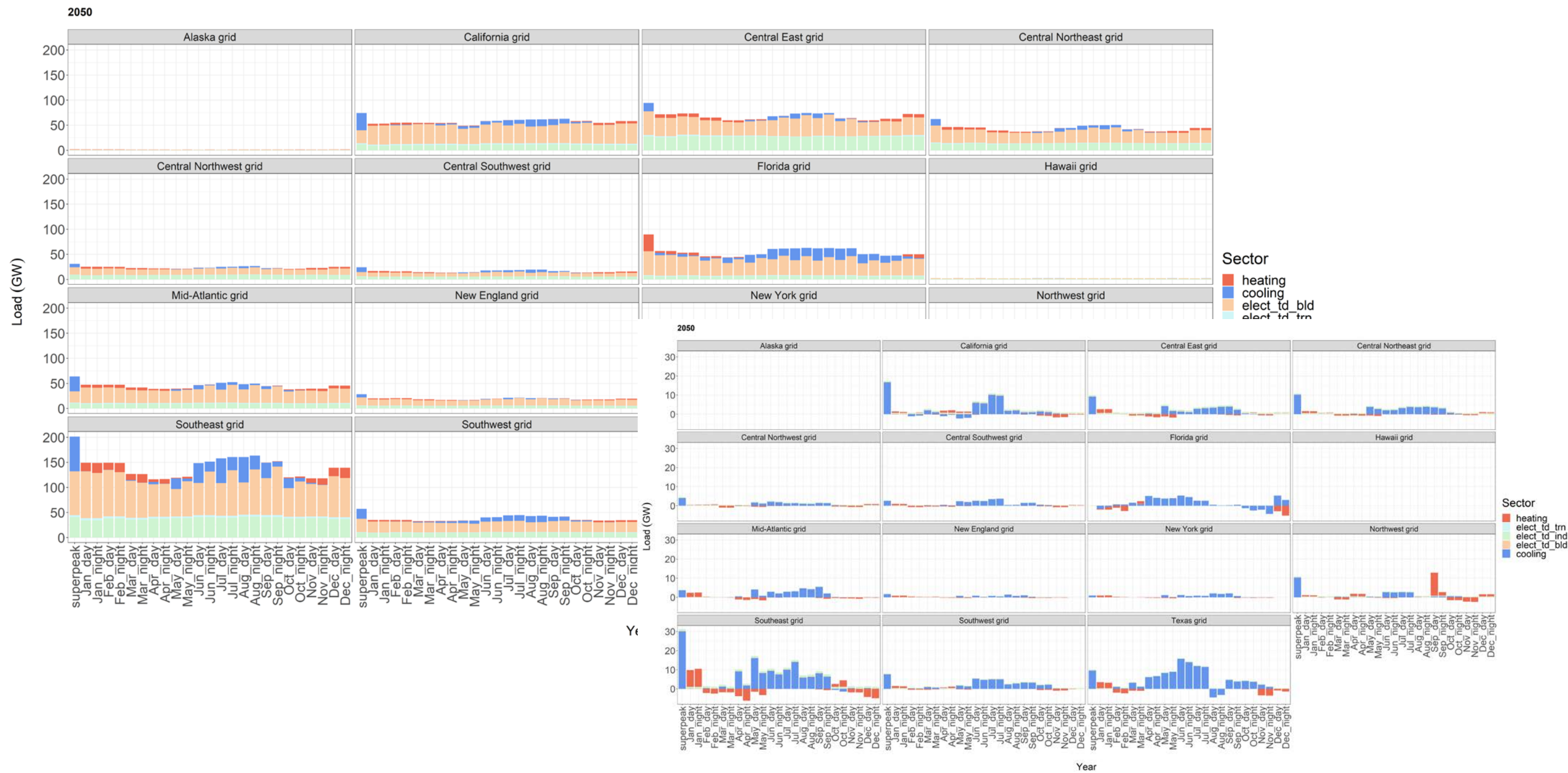
Change in Load results from heating, cooling and other sector demands

No Climate Impacts



Difference with Climate Impacts





- Craig, Michael T., Stuart Cohen, Jordan Macknick, Caroline Draxl, Omar J. Guerra, Manajit Sengupta, Sue Ellen Haupt, Bri-Mathias Hodge, and Carlo Brancucci. “A Review of the Potential Impacts of Climate Change on Bulk Power System Planning and Operations in the United States.” *Renewable and Sustainable Energy Reviews* 98 (December 1, 2018): 255–67. <https://doi.org/10.1016/j.rser.2018.09.022>.
- Cronin, Jennifer, Gabriel Anandarajah, and Olivier Dessens. “Climate Change Impacts on the Energy System: A Review of Trends and Gaps.” *Climatic Change* 151, no. 2 (November 1, 2018): 79–93. <https://doi.org/10.1007/s10584-018-2265-4>.
- Chandramowli, Shankar N., and Frank A. Felder. “Impact of Climate Change on Electricity Systems and Markets – A Review of Models and Forecasts.” *Sustainable Energy Technologies and Assessments* 5 (March 1, 2014): 62–74. <https://doi.org/10.1016/j.seta.2013.11.003>.