Disentangling the Evolving Effects of Climate Change and Technology Diffusion on Building Electricity Demand

Mai Shi[a]*, Ziqi Wei[b], Flavio Lehner[c], Michael T. Craig[a,d]

a School for Environment and Sustainability, University of Michigan b Department of Civil and Environmental Engineering, MIT,
c Department of Earth and Atmospheric Sciences, Cornell University d Department of Industrial and Operations Engineering, University of Michigan
* Corresponding author: maish@umich.edu

SCHOOL FOR ENVIRONMENT & SUSTAINABILITY
UNIVERSITY OF MICHIGAN

ASSET LAB

I. Background & Research Question

Climate Change
- Changing hot & cold extremes
- **Internal variability**, climate-model uncertainty and scenario uncertainty

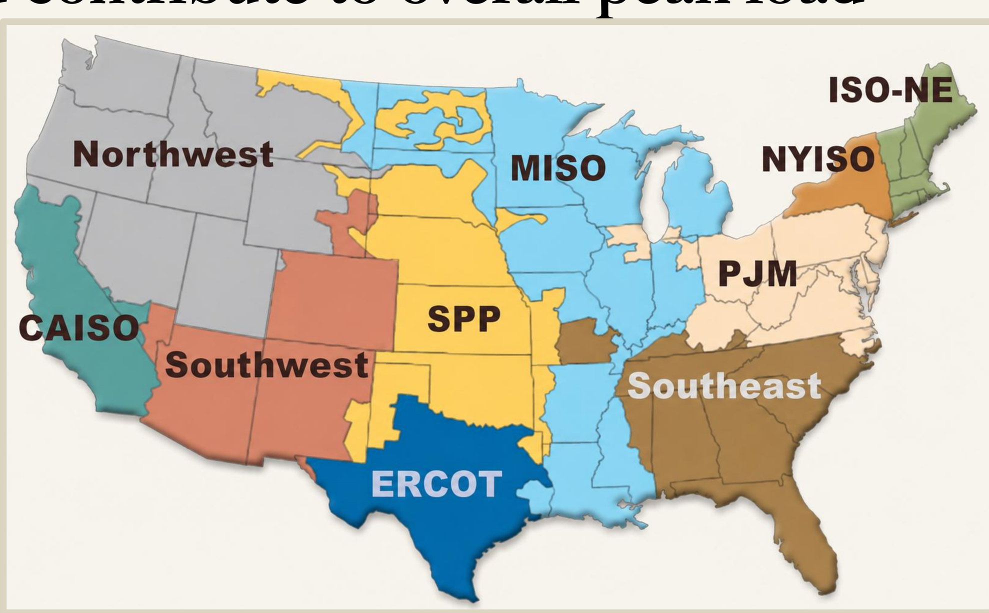
Technology diffusion
- Building electrification
- Insulation and efficiency upgrades
- Uncertainty in technology diffusion rates

Evolving Peak Demand Risk
Peak Extremes | Seasonality | Uncertainty

- **Q1 – Peak Demand Dynamics**
- How will climate change and technology diffusion **interact** to impact rates of peak extreme growth, differently from individual impacts?

- **Q2 – Peak Growth Uncertainty**
- How will uncertainty of climate change and technology diffusion **result in and contribute to overall peak load uncertainty**?

Map of 10 grid power regions for this research →



II. Methodology

Different future climate realizations

Raw LOCA2	→	Sampled-IV	→	Downscaling
• 6 km & Daily • 5-10 IV realizations		• 3 SSPs • 4 GCMs • 10 IV-realizations		• Hourly

Building demand model

- 2018 recorded weather → ML-demand regression
- 2018 Simulated hourly demand → ML-demand regression

ML-demand regression
- 74/32 Res/Com types
- 6 upgrades types
- 183 counties/10 regions
- ~209k ML models

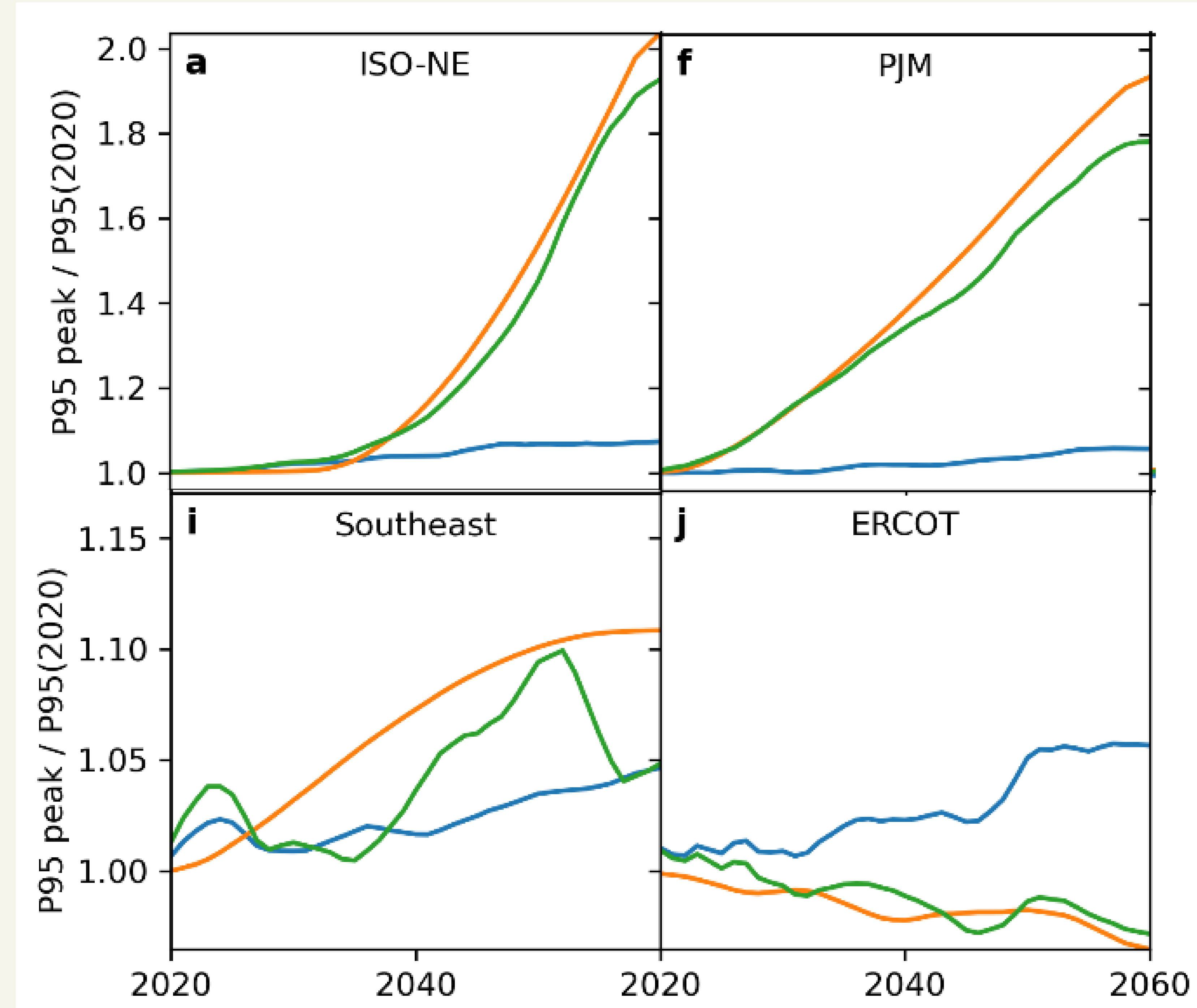
→ Current Building
→ Upgraded Building

Technology diffusion modelling

Logistic diffusion model
- Initial adoption ratio
- 18 historic-based rates
- Home AC as main scenario

→ Tech-diffusion dynamics
- Annual HP adoption
- Annual Insulation upgrades adoption

III. Technology diffusion turns gradual climate effects into nonlinear peak growth



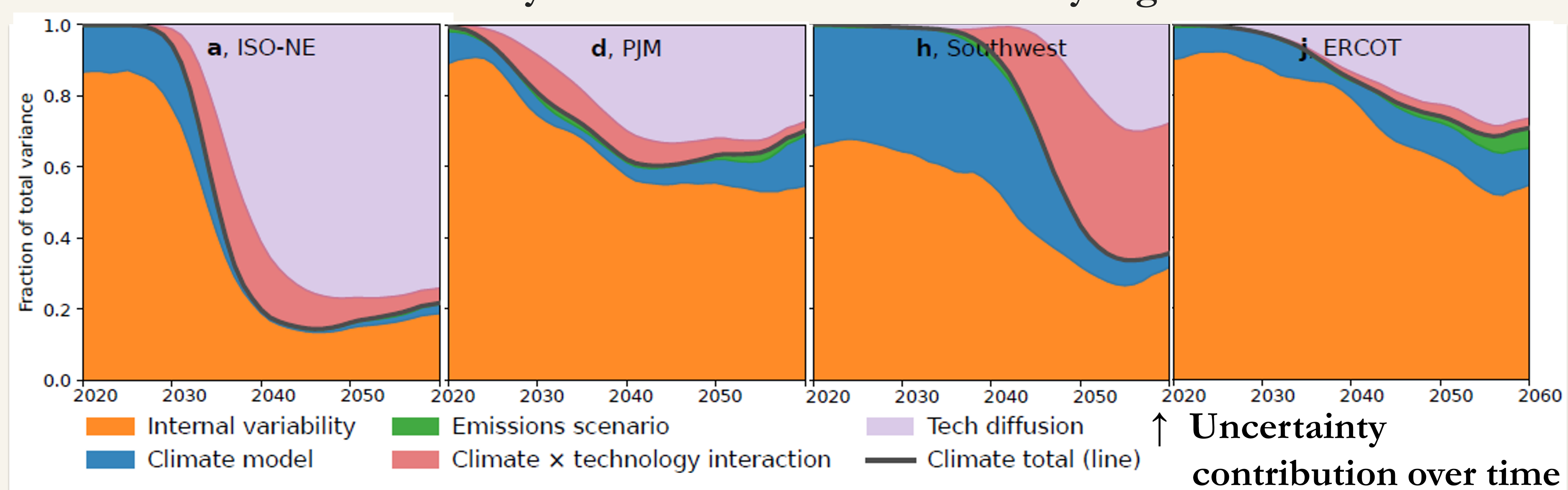
← **Five-year centered 95th PTL annual peak across all climates under SSP-370, normalized to 2020**

Climate-only: Most gradual changes; peak extreme demand (95th PTL peak across all climates under SSP 370) +3-9% across regions

Technology diffusion-only: Heat pump diffusion drives non-linear peak growth in cold regions and can reduce existing summer peaks in CAISO/ERCOT

Combined effects: Warmer winter partially offsets diffusion-driven peak growth; but cold regions still rise +48-93%; hot-regions remain heterogenous.

IV. The dominant uncertainty shifts over time and differs by region



↑ **Uncertainty contribution over time**

WHEN - Climate dominates near-term uncertainty
WHERE - The shift is strongly regional
WHY - Seasonal transitions create interaction uncertainty

Within climate-related uncertainty, IV dominates (>70%), while scenario remains below 10%.

V. Discussion and Conclusion

- **1. Co-model climate and technology.** Their joint response is non-additive and regionally heterogeneous.
- **2. Plan the transition, not only 2060.** The late 2030s–2040s are a critical window for seasonal peak transitions.
- **3. Target the uncertainty planners can manage.** Adoption programs, efficiency, storage, and firm winter capacity can reduce diffusion-driven risk.

VI. Acknowledgements

This work was supported by the U.S. National Science Foundation under Award Number 2142421, and the University of Michigan Graham Sustainability Institute.

Exploring faculty and postdoctoral opportunities beginning in 2027!

Scan for CV↓