Future Energy Systems Center

April 26, 2023

Interim Project Update:

Evaluating the system demand impacts of residential heat electrification through bottom-up building energy models in New England

System impacts of decarbonization pathways for space heating in cold climates



Project Team

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Project motivation and objectives

Motivation

- Residential emissions are 26% of total in New England[1]
- Decarbonizing heat by electrification is essential
- State electrification plans are ambitious
- Stakeholder concerns for system impacts are high, especially in cold climates



Air-source heat pumps will be common method of electrification
(Leon Neal / Getty Images)

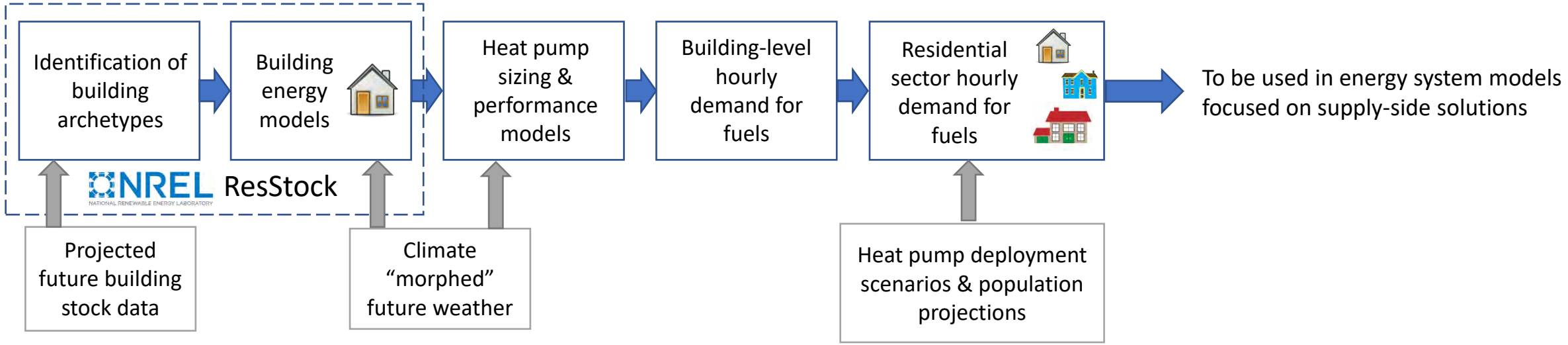
1. Calculated from EIA emissions data for 2019

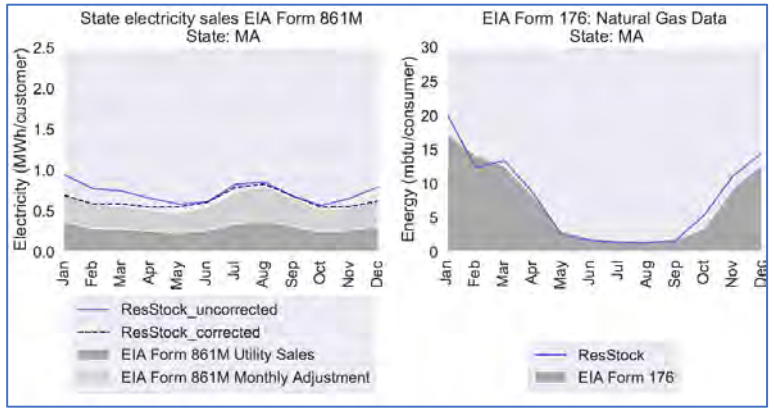
Objectives

- **What are regional demand-side effects of heat electrification under various penetration and technology adoption scenarios?**
- **How are these impacts sensitive to weather?**

Preliminary results - do not disclose or distribute

Bottom-up modeling enables simulation of demand effects

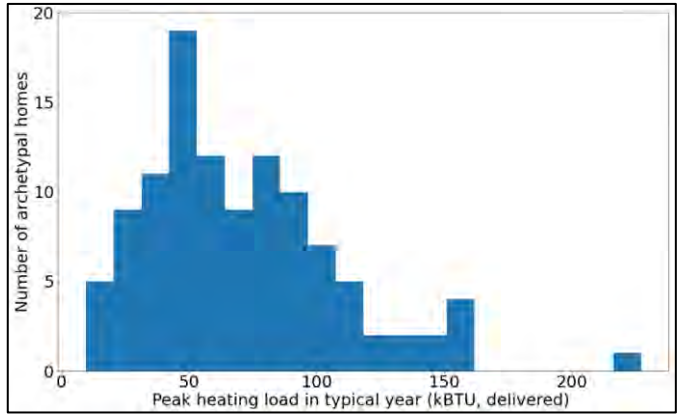




ResStock model is calibrated to real-world stock & meter data

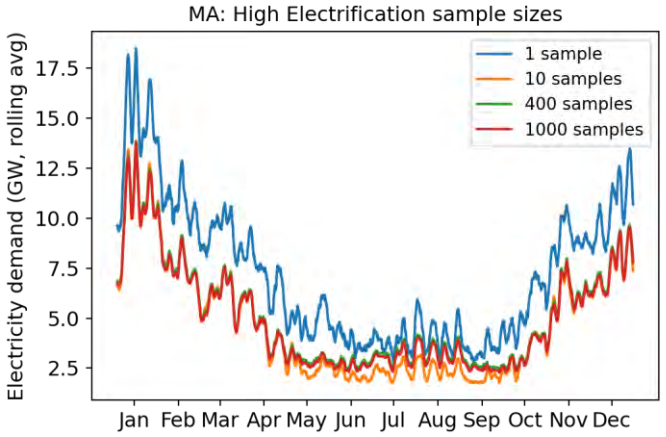
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Merits of the bottom-up approach



Archetype-based approach captures heterogeneity of housing stock and demand patterns

Ability to model heat pump sizing (winter vs. summer) and its impacts on hour-to-hour demand

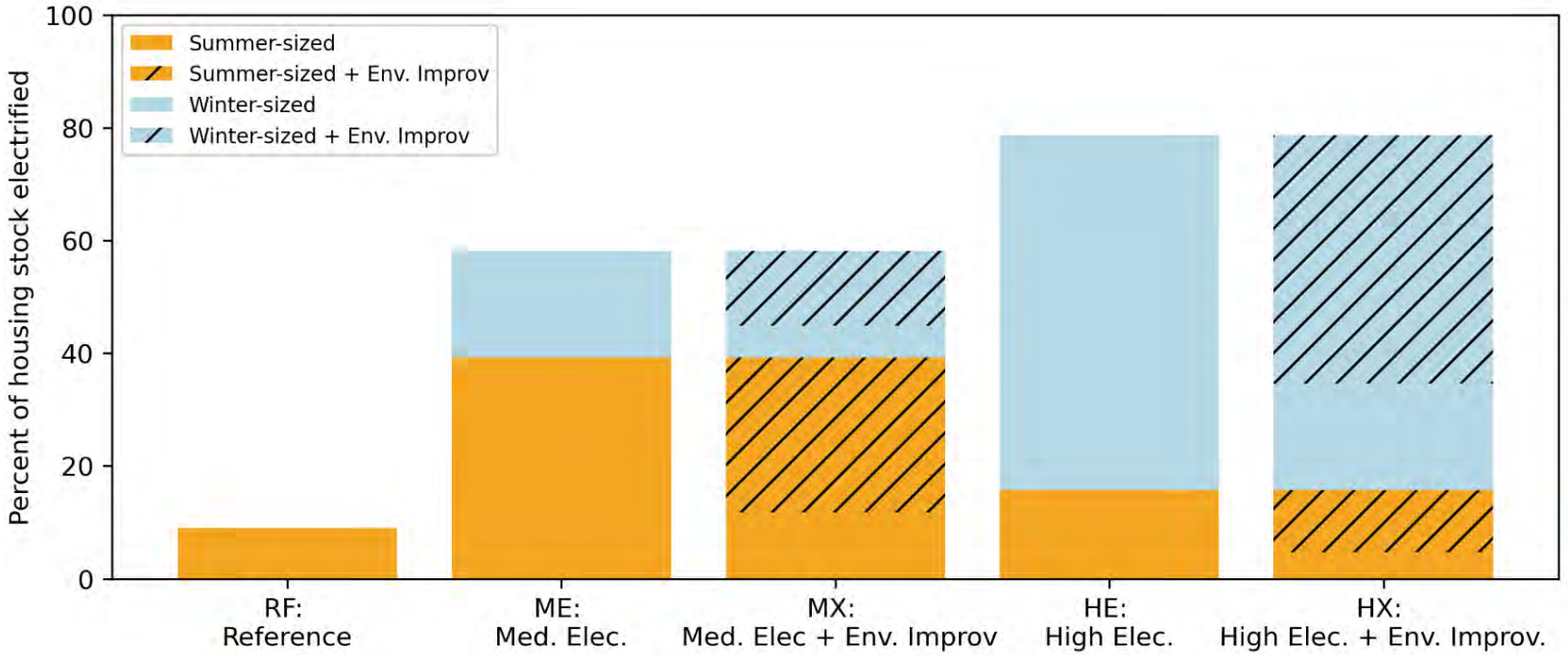


Selections of large enough number of samples leads to convergence of hourly demand

Method is easily transferred to other geographic regions and different assumptions about pace of electrification

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Residential heat pump deployment scenarios for 2050



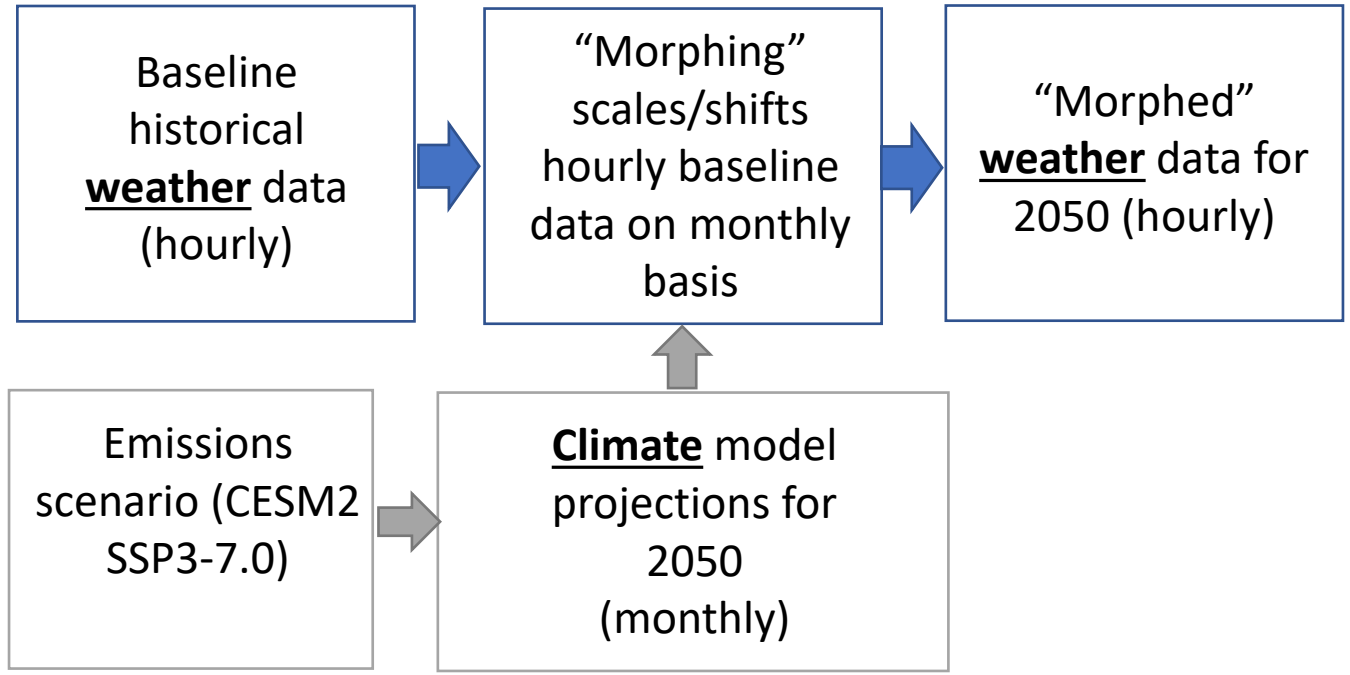
- "Reference" scenario based on NREL Electrification Futures Study
- Electrification scenarios based on Massachusetts Clean Energy & Climate Plan

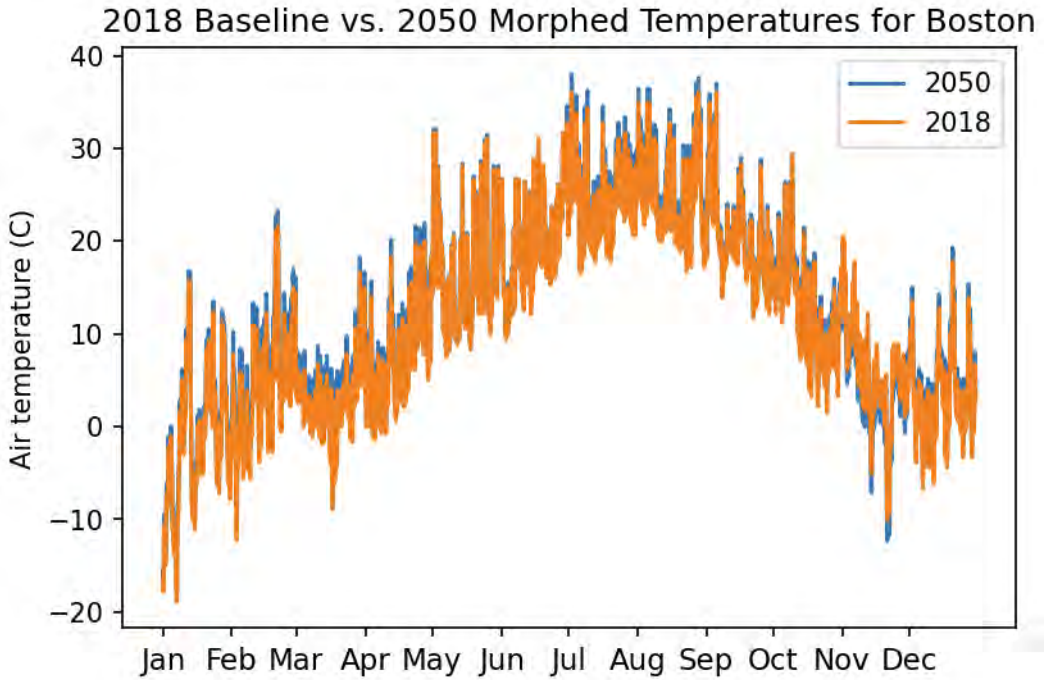
- "Winter-sized" -> whole-home ASHP heating
- "Summer-sized" -> partial-home ASHP heating w/ existing system kept as backup
- Successful deployment & operation will rely on effective incentives, rate structures, & other policies

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Example “Morphing” for Obtaining 2050 Weather Data

- Climate model projections generally do not include all hourly variables needed for building simulations
- “Morphing” method is oft-used in the building model literature to estimate hourly variables from monthly predictions

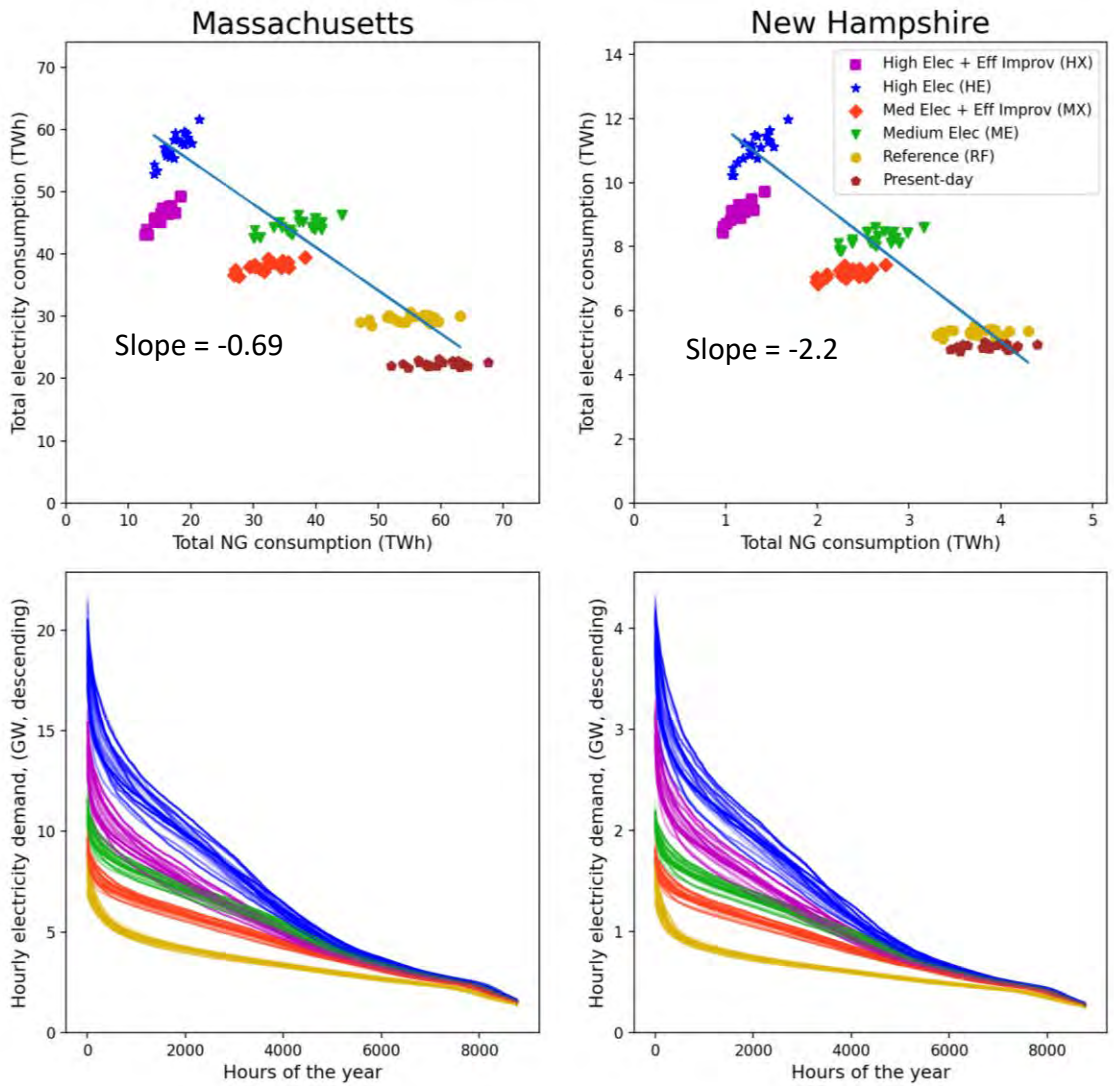




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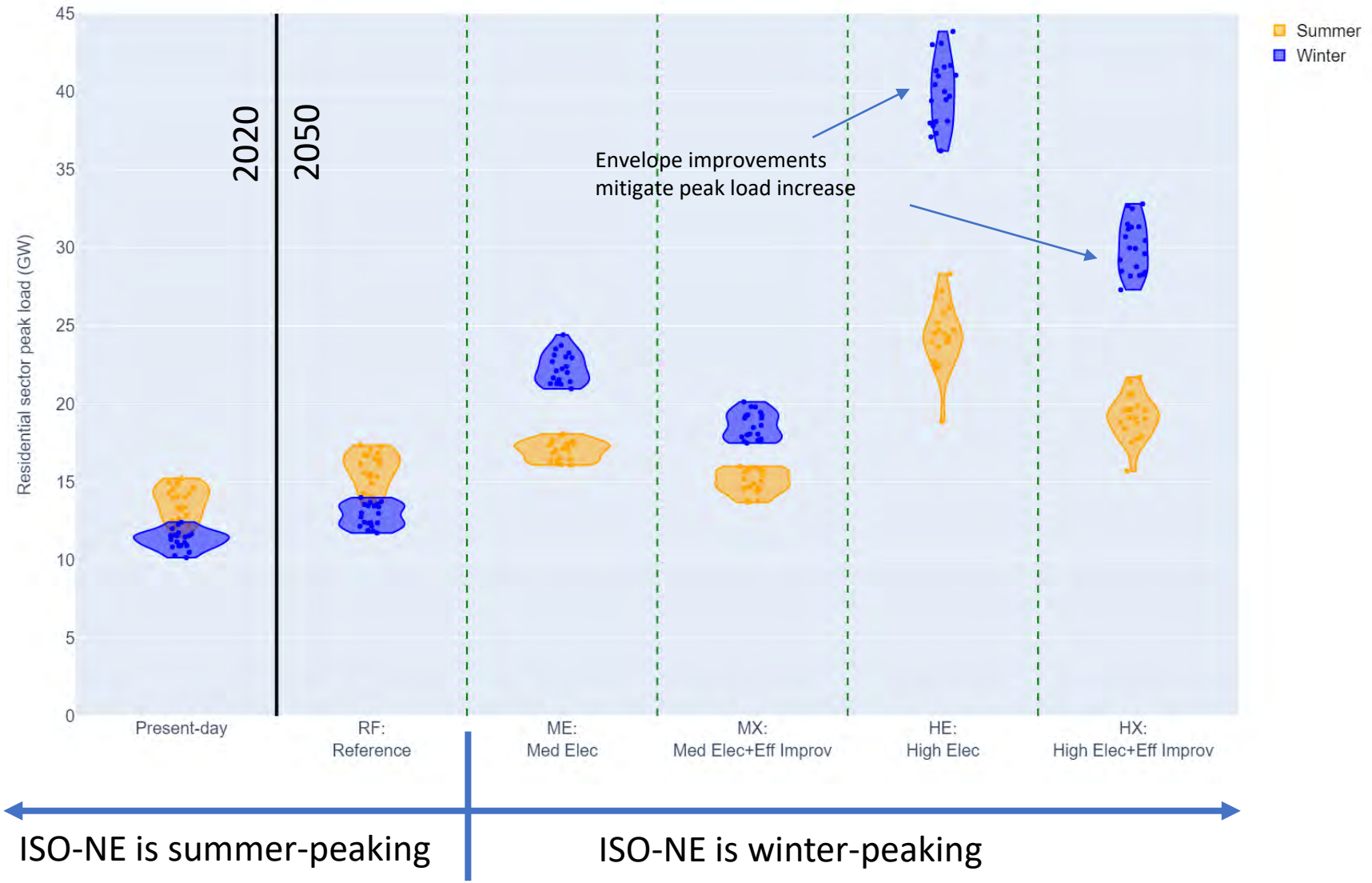
Results: State-level demand characteristics for 2050

- Simulated for 20 climate-adjusted weather years (2001-2020)
  - Our study is first to account for interannual variation
- Tradeoff between reduction in NG usage and increase in electricity demand
  - Ratio is dependent on fuel mix in initial stock
- More ambitious electrification results in higher variation in hourly demand



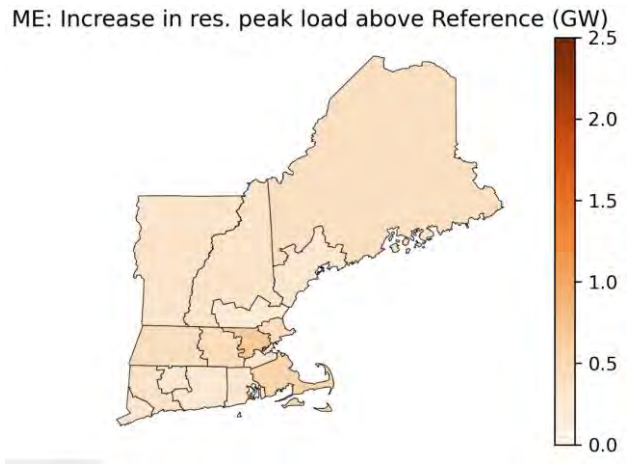
Changes in residential ISO-NE peak loads

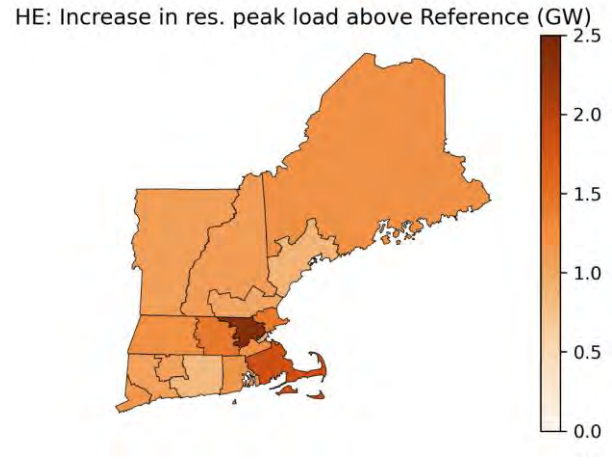
- Weather-related uncertainty in peak load increases with deeper electrification
- Increases in peak load highlight importance of peak-shaving and -shifting measures

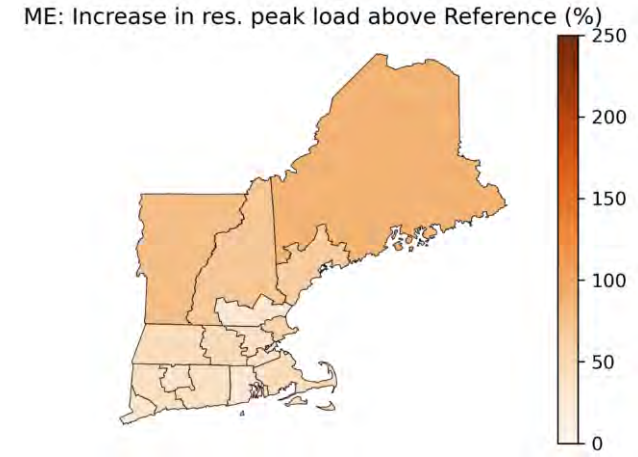


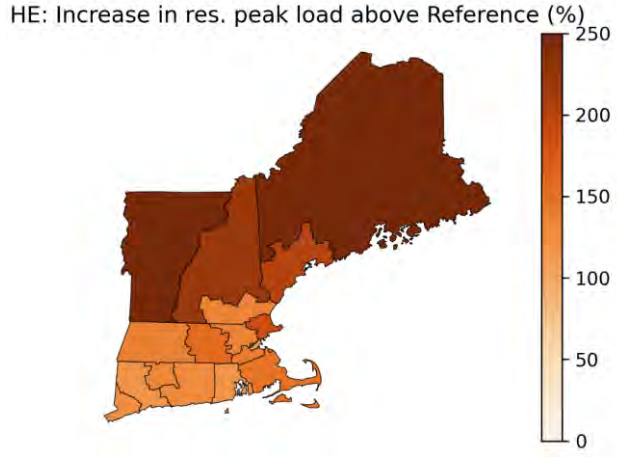
Changes in peak load are spatially heterogeneous

- Vermont, Maine, and rural NH experience greatest increases in peak load relative to reference case
  - Especially cold
  - Very little existing electric heating









Interim conclusions

- More aggressive electrification presents tradeoff between electricity and NG demands
- Hourly and peak electricity demand will become more weather-variant
- High electrification results in new significant winter peak
  - Resiliency implications
- Policy is needed to facilitate high electrification
  - Cost-effective investment in efficiency improvements
  - Promoting technology advancement in ASHPs and storage
  - Rates, incentives, and programs to shift load

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Remaining project activities

- Through 9/1:
  - Collaborative journal article submission for this work + integrated power-gas planning
  - Repeat this analysis for PJM
  - Commercial sector modeling
- Hopeful follow-on work:
  - Assessment of value of demand flexibility

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Q&A and Project Discussions