Decarbonization of Heat Study: project update

Dharik S. Mallapragada

Future Energy Systems Center Advisory Committee Meeting

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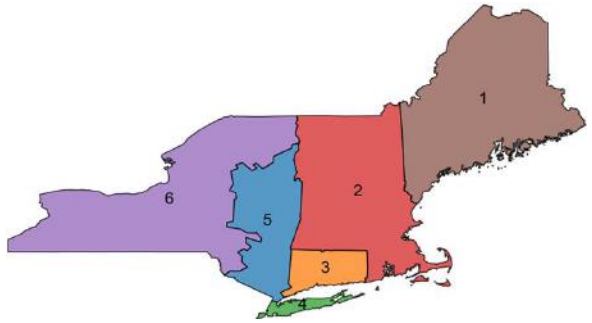
Study focus: Assess energy system impacts of decarbonization pathways (including electrification) for space heating in cold climates

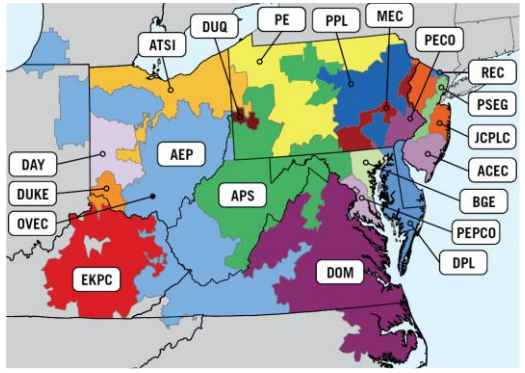
Key questions

- What are demand-side effects of heat electrification under various penetration and technology adoption scenarios?
- How does heat electrification impact distribution network operation and planning, and what are the implications of tariff design and DER deployment?
- What are the bulk system impacts of electrification vs. other approaches for decarbonization of space heating (e.g. gas with negative emissions offset, synthetic gas, H_2)
- How to account for system resiliency in energy system planning and what does it imply about the cost of alternative decarbonization pathways?

Major study activities

1. Data-driven modeling of space heating energy demand
2. Bottom-up demand analysis using building energy models + bulk power system assessment
3. Distribution network impacts of heat electrification and implications for tariff design
4. Multi-vector (electricity, gas, H2) energy system modeling and resilience analysis





Project timeline: 24 months (Sept 2021 – Sept 2023)

DER = distributed energy resources

Task 1: High-resolution heating demand estimation using novel Machine Learning methods

	Hourly	Monthly
Consumer-level	Not Metered	Metered
Zip code-level	Not Metered	Metered
City gate-level	Metered	Metered



Stephen Lee, Grad. student, Computer Science

- **The problem:**
  - High-spatial and temporal resolution heating demand estimates are needed for planning future energy systems.
  - Utilities do not meter consumer-level gas consumption at hourly frequencies.
- **What are we doing?**
  - Developing novel machine learning models for scalable high-resolution demand estimation.
    - Learning from metered data at lower spatial and temporal resolutions.
    - Physics-based constraints: relating heating demand with outdoor temperature and building size, etc.
- **What we need**: Gas consumption data at all resolutions.
- **Contact:** Prof. Christopher R. Knittel (knittel@mit.edu) and Stephen J. Lee (leesj@mit.edu)

Gas consumption data received as of May 10th to be used to inform data-driven heating demand model

	Monthly consumer-level	Hourly gate station-level
Company 1	sample received*	✓
Company 2		✓
Company 3	**	***

- We are iterating with contacts to ensure that the data meets modelling requirements.
- Customer location data is requested to match consumer-level data with building size, urbanization, economic activity, and other generalizable features of interest.
- Shapefiles for gate stations service territories are requested for matching consumer-level and gate station-level datasets.

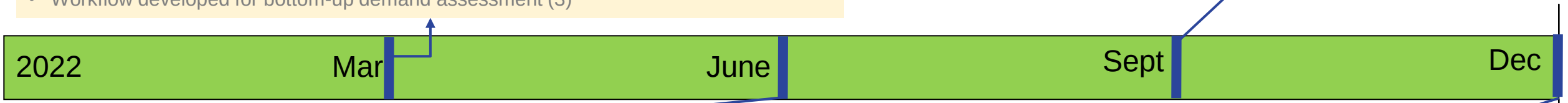
*Additional data was made available but analyst data access issues remain.
**Monthly zip-code level data was sent but we are seeking clarification.
***Daily operating totals were sent but we are seeking clarification.

Key project activities over last 6 months and updated timeline

1. Data-driven modeling of space heating energy demand
2. Bottom-up demand assessment using building energy models + bulk power system assessment
3. Distribution network impacts of heat electrification and implications for tariff design
4. Multi-vector energy system modeling and resilience

- Deterministic gas-electricity system model for New England (NE) (4)
- Detailed review of installed costs for heat pump and their variability (4)
- Review all data received, identify gaps, iterate on requirements, and begin data review meetings (1)
- Workflow developed for bottom-up demand assessment (3)

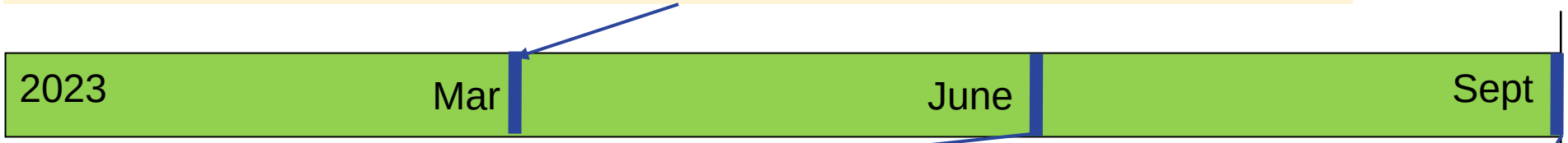
- Preliminary data-driven demand-side model (1)
- Scale the optimization model to include scenarios of interest + Update gas-electric system model including demand-side variables (4)



- Define scenarios of interest to model reliability and resiliency considerations (4)
- Distribution network impacts of heat electrification w/o demand-side interventions (3)
- Analysis of economic heat-pump adoption under different rate designs (3)
- Receive input data in finalized formats necessary for modeling (1)

- Reconciliation b/w data-driven and bottom-demand modeling (1, 2)
- Updated data-driven demand-side model (1)
- Updated distribution network analysis with demand side interventions and retail tariff design (3)

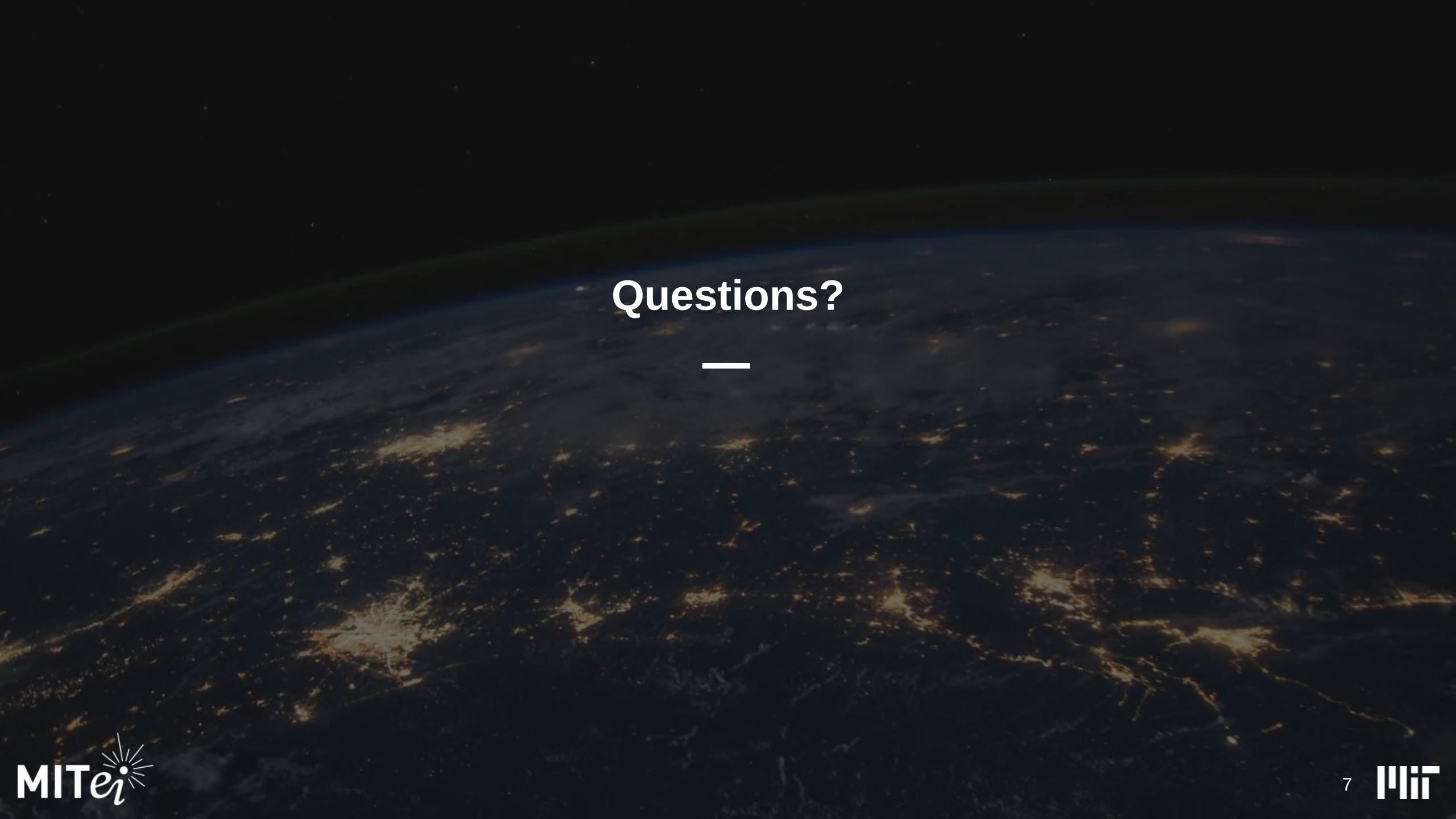
- Alternative demand scenarios based on demand interventions, electrification and future climate scenarios (1,2)
- Insights on multi-vector energy system modeling w/ resilience (4)
- Bulk grid impacts of electrification under various demand intervention scenarios (2)



- Finalize results on multi-vector energy modeling, grid modeling (2,4)
- Finalize findings on distribution network analysis (3)

Finalize key findings and summary report

Demand-side interventions include: improved end-use efficiency (e.g. building envelope), flexibility (e.g. thermal storage) and DER adoption


Questions?

Research team



Prof. Christopher Knittel, Sloan School



Dr. Dharik Mallapragada, MITEI



Dr. Raanan Miller, MITEI



Dr. Pablo Duenas-Martinez, MITEI



Prof. Saurabh Amin, Civil & Environmental Eng.



Prof. Les Norford Architecture



Dr. Audun Botterud, LIDS



Dr. Rahman Khorramfar, postdoc, MITEI, CEE



Tony Lee, Grad. student, IDSS/MITEI



Jameson McBride, Grad. student, IDSS/ MITEI



Morgan Santoni-Colvin, Grad. student, IDSS/ MITEI

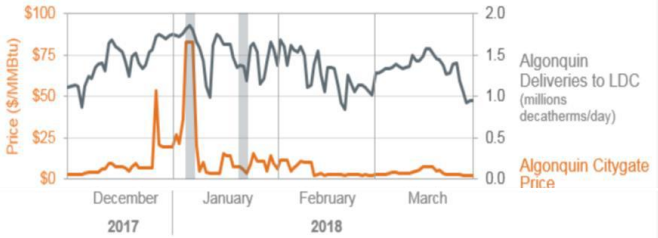


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Further details on requested data inputs

	Data type	Data units/ description	Time-scale and coverage	Spatial resolution	Notes
1	Historical gas withdrawal rates from transmission system at gate stations	Million BTU per hour	Hourly resolution spanning last 10 years (or what is available)	For each gate station serving region	
2	Monthly natural gas consumption by customer class and location	Million Btu	Monthly or bi-weekly resolution spanning last 5-10 years (or what is available)	For each census zipcode and aggregated by customer class (residential, commercial)	If residential data can be broken down into further sub-classes (e.g. single family, multi-family) that will be helpful.
3	DER, EV, Heat pump adoption by customer class and location	% of households	As of 2019 or 2020		
4	Service rate and supply cost option for different customer class and location	a) Fixed and variable component of tariffs; b) % of households on each tariff type	As of 2019 or 2020		

Example format for data # 1 (picture source: ref 1)



1. Speake et al., Residential Natural Gas Demand Response Potential during Extreme Cold Events in Electricity-Gas Coupled Energy Systems, Energies, 2020