Decarbonization of Heat Study: project update

Dharik S. Mallapragada

December 14, 2021

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

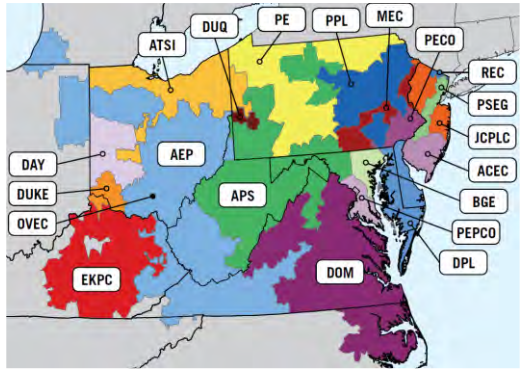
Key questions

- What are demand-side effects of heat electrification under various penetration and technology adoption scenarios?
- How does heat electrification affect 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 do we 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





DER = distributed energy resources

Project activities to date

Key questions

- What are demand-side effects of heat electrification under various penetration and technology adoption scenarios?
- How does heat electrification affect 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 do we 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

- **Key project activities to date**
- April 26, 2021: kick-off meeting with sponsors
- May – Sept 2021:
  - Progressed research on task 3 (distribution network analysis)
  - Refined project scope through sponsor engagement and finalize staffing
  - Discussion with sponsors on data request for task 1 (demand-side analysis)
- Sept - Dec 2021:
  - Completed project staffing and initiated research on all activities
  - Established data usage agreement with 3 sponsors and initiated data transfer

Research team



Prof. Christopher Knittel, Sloan School



Dr. Dharik Mallapragada, MITEI



Dr. Raanan Miller, MITEI



Dr. Pablo Duenas-Martinez, MITEI



Dr. Karen Tapia-Ahumada, MITEI



Prof. Saurabh Amin, Civil & Environmental Eng.



Prof. Les Norford Architecture



Dr. Audun Botterud, LIDS



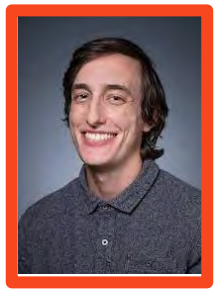
Dr. Rahman Khorramfar, postdoc, MITEI, CEE



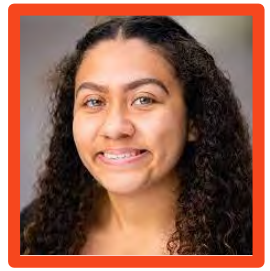
Tony Lee, Grad. student, IDSS/MITEI



Jameson McBride, Grad. student, IDSS/ MITEI



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



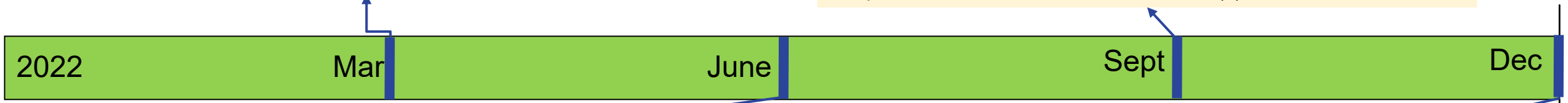
Lelia Marie Hampton Grad. student, Computer Science

Research tasks and tentative timeline going forward

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 (electricity, gas, H2) energy system modeling and resilience

- Deterministic gas-electricity system model for New England (NE) (4)
- Preliminary data-driven demand side model (1)

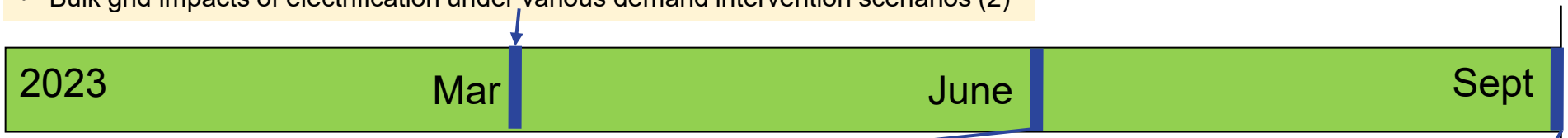
- Preliminary bottom-up demand assessment+ reconciliation with data-driven modeling (1, 2)
- Updated data-driven demand-side model (1)



- Deterministic multi-vector energy system model for NE + Discuss and determine resiliency scenarios of interest (4)
- Distribution network impacts of heat electrification w/o demand-side interventions (3)
- Analysis of economic heat-pump adoption under different rate designs (3,2)

- Alternative demand scenarios based on demand interventions, electrification and future climate scenarios (1,2)
- Distribution network analysis with demand side interventions and retail tariff design (3)

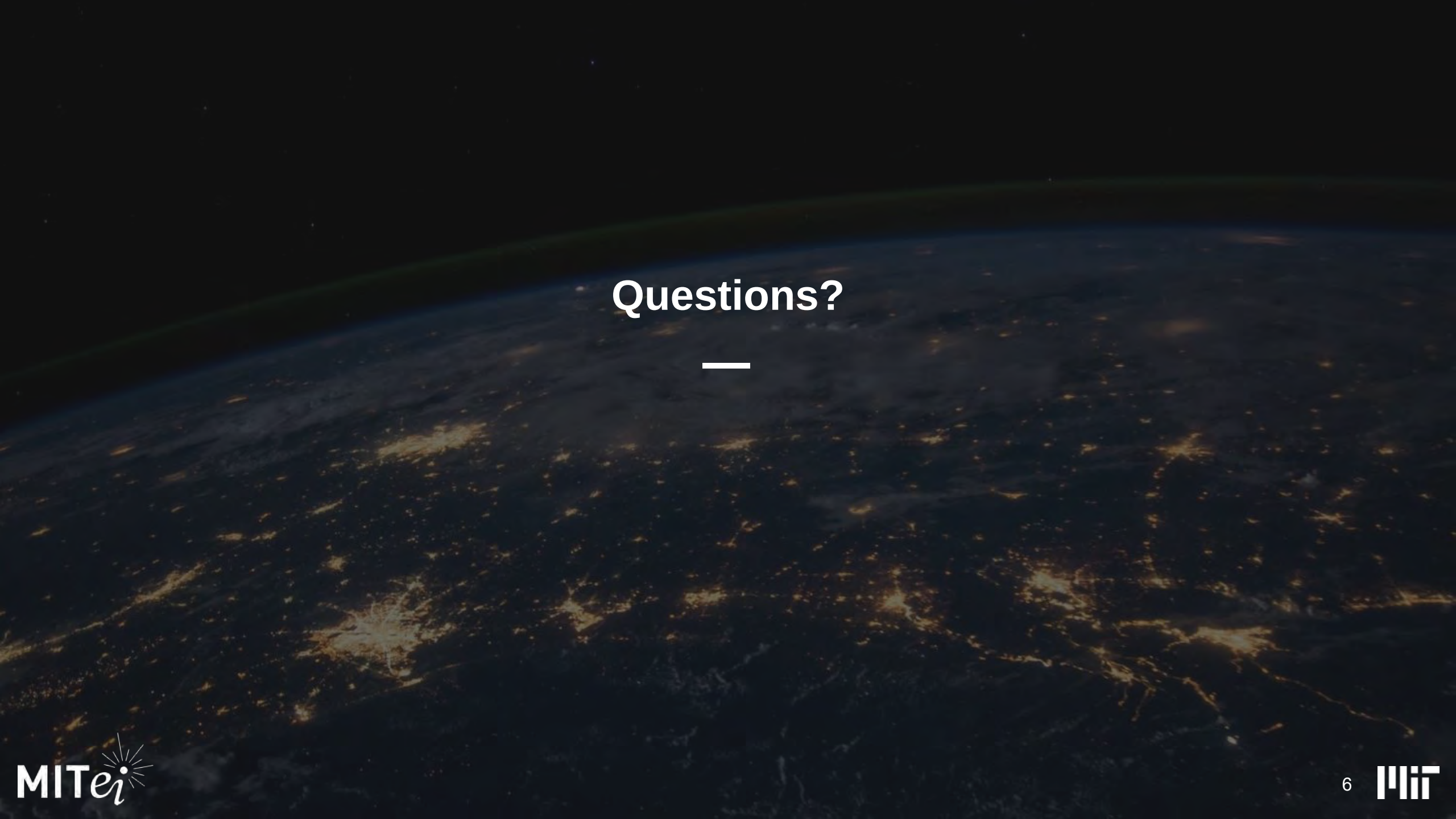
- Insights on multi-vector energy system modeling w/ resilience (4)
- Bulk grid impacts of electrification under various demand intervention scenarios (2)



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

Finalize key findings and summary report

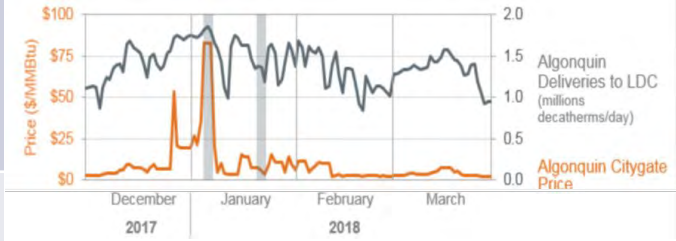
Demand-side interventions include: improved end-use efficiency (e.g. building envelope), flexibility (e.g. thermal storage) and DER adoption


Questions?

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