ISO New England Forecasts of Building Electrification

Energy Systems Integration Group (ESIG)

2023 Long-Term Load Forecasting Workshop

Session 5: Building Electrification

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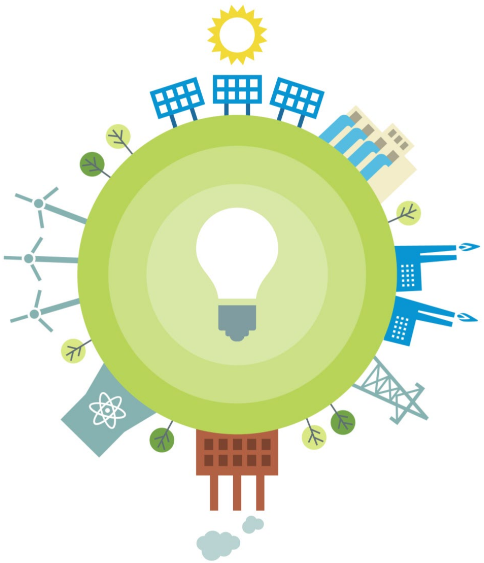
Overview of Presentation

- About ISO New England
- Introduction
- Methodology
- Forecast Results
- Closing Thoughts
- Appendix: Additional Information



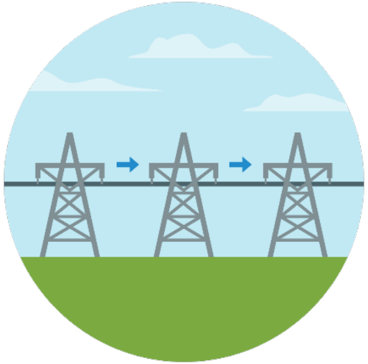
ISO New England (ISO) Has More Than Two Decades of Experience Overseeing the Region's Restructured Electric Power System

- **Regulated** by the Federal Energy Regulatory Commission
- **Reliability Coordinator** for New England under the North American Electric Reliability Corporation
- **Independent** of companies in the marketplace and **neutral** on technology

ISO New England Performs Three Critical Roles to Ensure Reliable Electricity at Competitive Prices

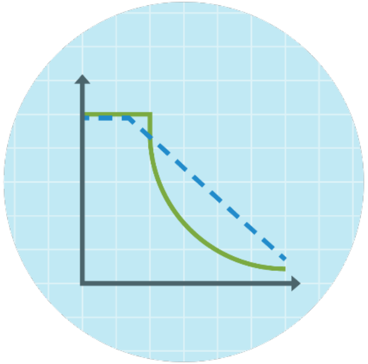
Grid Operation

Coordinate and direct the flow of electricity over the region's high-voltage transmission system



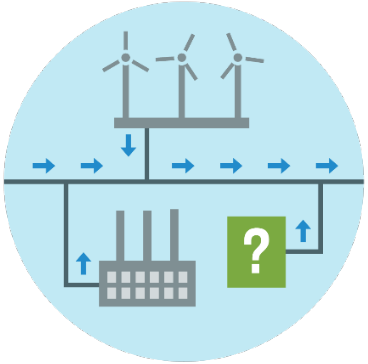
Market Administration

Design, run, and oversee the markets where wholesale electricity is bought and sold



Transmission System Planning

Study, analyze, and plan to ensure the transmission system will be reliable over the next 10 years



Things We Don't Do

Handle retail electricity —the power you buy from your local utility or electric supplier

Own, maintain, or repair power grid infrastructure, such as power plants, power lines, and substations

Plan or control the resource mix, or have a financial interest in the companies that own energy infrastructure

Have jurisdiction over fuel infrastructure

ISO New England's Building Electrification Forecast

Introduction

- Building electrification forecasting efforts focus on space and water heating (i.e., it's really a *heating* electrification forecast)
- Heating electrification is expected to play a pivotal role in the achievement of New England state greenhouse gas (GHG) reduction mandates and long-term decarbonization goals
  - See next slide
- Space heating is used throughout the remainder of the presentation to highlight methodological elements and related issues

State Laws Target Deep Reductions in CO_2 Emissions and Increases in Renewable and Clean Energy

≥80% by 2050	Five states mandate greenhouse gas reductions economy wide: MA, CT, ME, RI, and VT (mostly below 1990 levels)
Net-Zero by 2050 80% by 2050	MA emissions requirement MA clean energy standard
90% by 2050	VT renewable energy requirement
100% by 2050 Carbon-Neutral by 2045	ME renewable energy goal ME emissions requirement
100% by 2040	CT zero-carbon electricity requirement
100% by 2030	RI renewable energy requirement

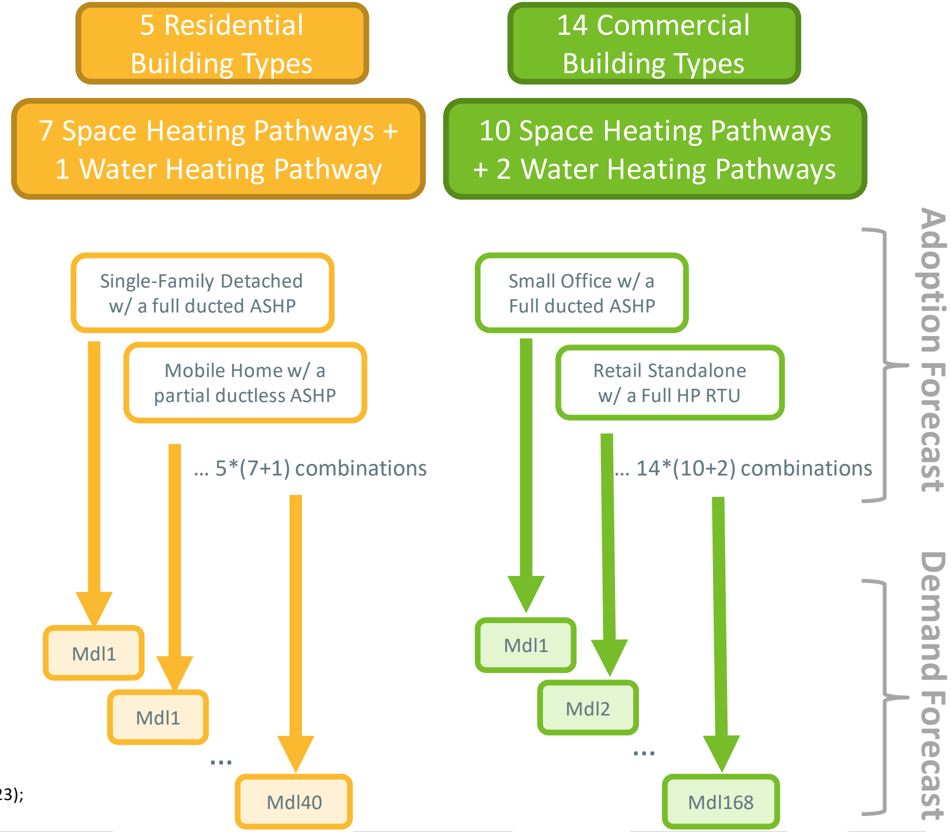
FORECASTING METHODOLOGY

Heating Electrification Forecast

Methodology Overview

Methodology leverages the National Renewable Energy Laboratory's ResStock and ComStock datasets, and is based on four sequential tasks:

1) New England building stock characterization
2) Development of "heating pathways"
3) Forecasting adoption along each pathway
4) Hourly demand modeling



Source: ISO New England 2023-2032 Forecast Report of Capacity, Energy, Loads, and Transmission (2023 CELT Report) (May 2023); and ISO New England Final 2023 Heating Electrification Forecast

Space Heating

Existing Fuel Sources

Residential

Starting Share of Housing Units, %

Space Heating Fuel	CT	MA	ME	NH	RI	VT	NE
Electricity	16.5	14.9	5.7	8.3	9.9	5.8	12.8
Fuel Oil	41.9	26.7	64.3	45.5	31.4	43.5	37.4
Natural Gas	35.4	53.3	6.2	19	55	17.7	38.9
None	0	0.2	0.1	0.5	0	0	0.1
Other Fuel	2.8	2.2	15.3	10.3	2.1	18	5.4
Propane	3.4	2.7	8.4	16.4	1.6	15.1	5.4

Commercial

Starting Share of Commercial SF, %

Space Heating Fuel	CT	MA	ME	NH	RI	VT	NE
DistrictHeating	2.3	2.2	1.4	3.5	2.2	1.9	2.2
Electricity	17.7	13	10.8	11.9	10.2	8.3	13.6
FuelOil	33.6	22.5	57.1	34.4	21.5	33.4	29.5
NaturalGas	26.6	43.6	2.7	15.6	50.5	19.6	33.2
NoHeating	12.8	14.4	11.6	12.5	12.4	8.8	13.3
Propane	7	4.2	16.3	22.1	3.3	28.1	8.1

Note: Sum of each column = 100%

Heating Electrification Pathways

Space Heating

Residential Space Heating

Heating Type	Technology Type	Heating Displacement
Space Heating	Ducted ASHP - Full	Full
	Ducted ASHP - Partial	Partial
	Ductless ASHP - Full	Full
	Ductless ASHP - Partial	Partial
	Ground Source Heat Pump	Full
	Air to Water Heat Pump	Full
	Packaged Terminal Heat Pump (PTHP)	Partial

ASHP = Air Source Heat Pump

Commercial Space Heating

Heating Type	Technology Type	Heating Displacement
Space Heating	District Heating via Geothermal Heat Pump	Full
	Dual Fuel Heat Pump RTU	Partial
	Heat Pump RTU	Full/Partial
	VRF system (air-source)	Full
	Air-to-Water Heat Pump	Full
	Ducted Air Source Heat Pump	Full
	Ducted Air Source Heat Pump	Partial
	Ductless Air Source Heat Pump	Full
	Ductless Air Source Heat Pump	Partial

RTU = Rooftop Unit; VRF = Variable Refrigerant Flow

Adoption Modeling

- Adoption modeling focuses exclusively on buildings with fossil fuel-based heating
- Adoption modeling considers potential pathways to space and water heating electrification based on existing building stock characteristics as well as state policy and economic considerations including:
  - Building type and sector
  - Existing heating fuels
  - Existing heating and cooling delivery systems (e.g. ducted, non-ducted)
  - Payback period for heating technology conversion
  - Level of state policy support, incentives, and goals regarding heating electrification
- Pathway adoption modeling is performed at the state level for both the residential and commercial sectors
- Bass diffusion model is used with input parameters guided by approximations of:
  1. Return on investment (ROI)
  2. Level of policy support
  3. Technical barriers to adoption
  4. Current levels of technology saturation

Space Heating Demand Modeling

Electric demand modeling methodology consists of three steps:

1) Development of hourly heating load relationships to outdoor temperature for all building types was based on heating usage profiles within NREL's ResStock and ComStock databases

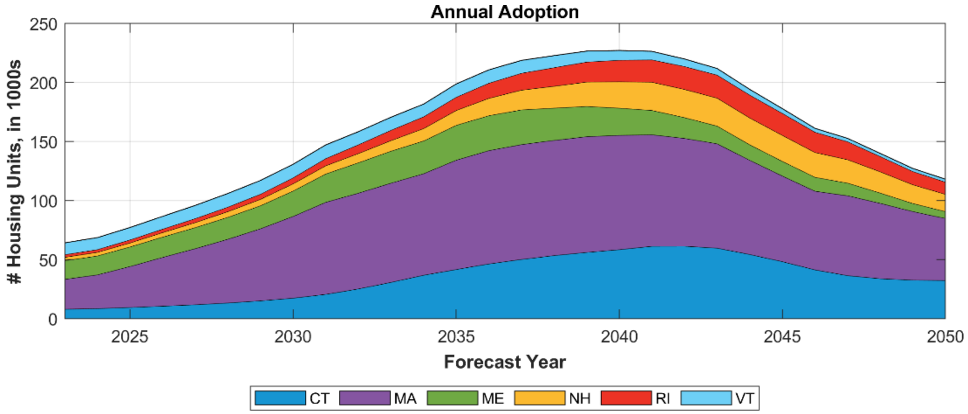
2) For each pathway, a reference make/model heat pump (HP) was selected, and its coefficient of performance ($COP = \frac{Heat\ Output}{Input\ Power}$) was used to convert hourly heating required to electricity demand
   - High performing HPs are used as reference under the assumption that performance will continue to improve over the forecast horizon

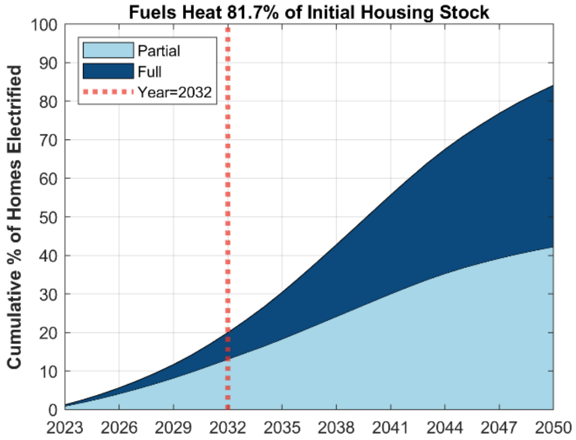
3) Development of models for HP electricity demand assumed
   - Heating demand is initiated when outside temperatures are below 62^{o}F
   - For partial heating pathways, all heating load needed when temperatures are below 20^{o}F is provided by a supplemental, non-electric heating system
   - For full heating pathways, electric resistance heat is used to meet any demand unmet by the HP (i.e., when temperatures are lower than the HP's minimum HP operating temperatures)
   - Resulting models for all combinations of building types and heating pathways include separate hourly parameters for both non-holiday weekdays and holidays/weekend days

FORECAST RESULTS

Residential Space Heating Adoption

- Annual adoption forecast for residential space heating (full + partial) is shown to the right
  - Adoption peaks by the late 2030s with annual installs equaling 3.5% of total households
- Forecast includes more than 4.4 million housing units with electrified space heating electrified by 2050

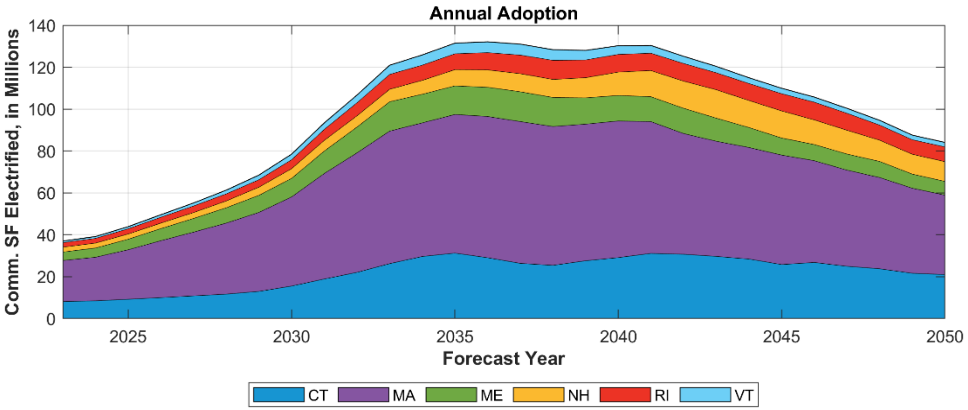


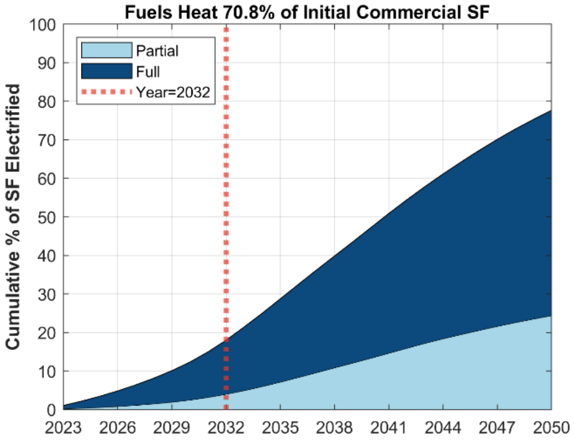


- Electrification of homes with legacy fossil fuel-based heating reaches ~84% by 2050
  - ~69% of total housing stock
- Roughly half are partial and half are full heating applications

Commercial Space Heating Adoption

- Annual adoption forecast for commercial space heating (full + partial) is shown to the right
  - Adoption peaks by the mid-2030s
- Forecast includes more than 2.7 billion square feet of commercial space with electrified heating by 2050





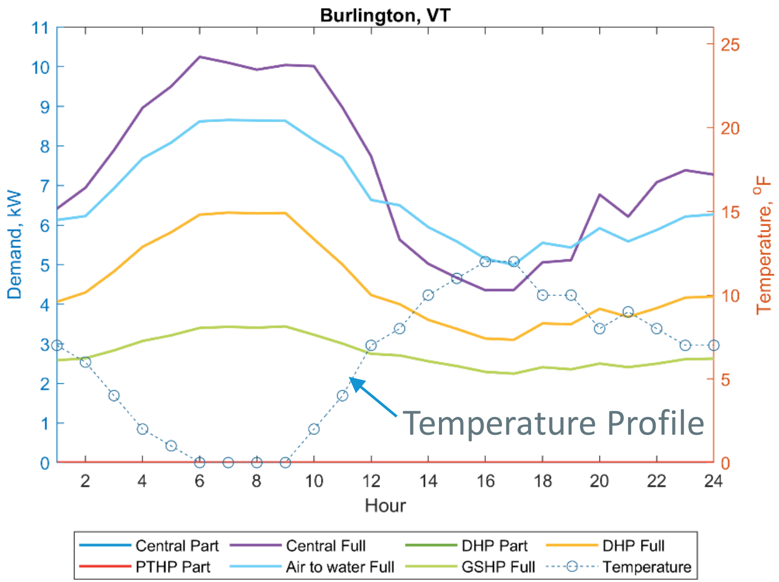
- Electrification of commercial buildings with legacy fossil fuel-based heating reaches ~78% of total heated floor space by 2050
- Roughly 30% are partial and 70% are full heating applications

Example of Demand Forecast Process for a Day in VT

Residential Space Heating, Building Type = Single-Family Detached

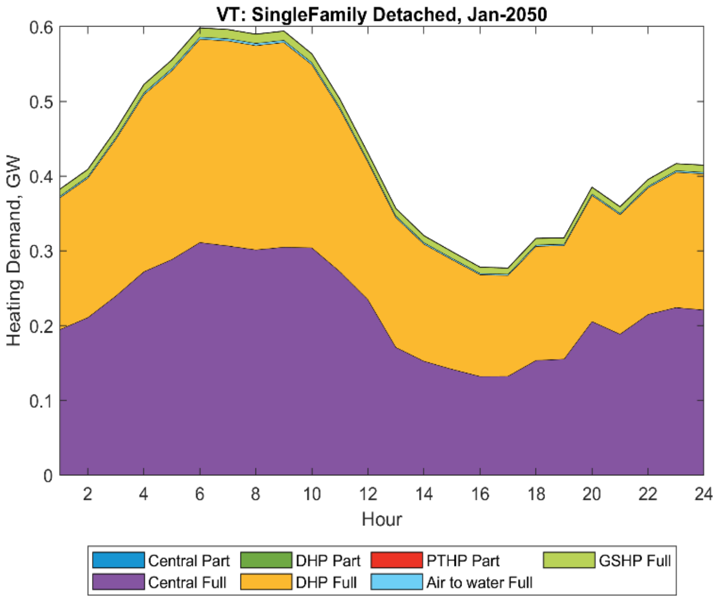
Note: Demand is from full heating pathways only since temperatures are below 20 degrees F

Weather-Based HP Demand Profiles



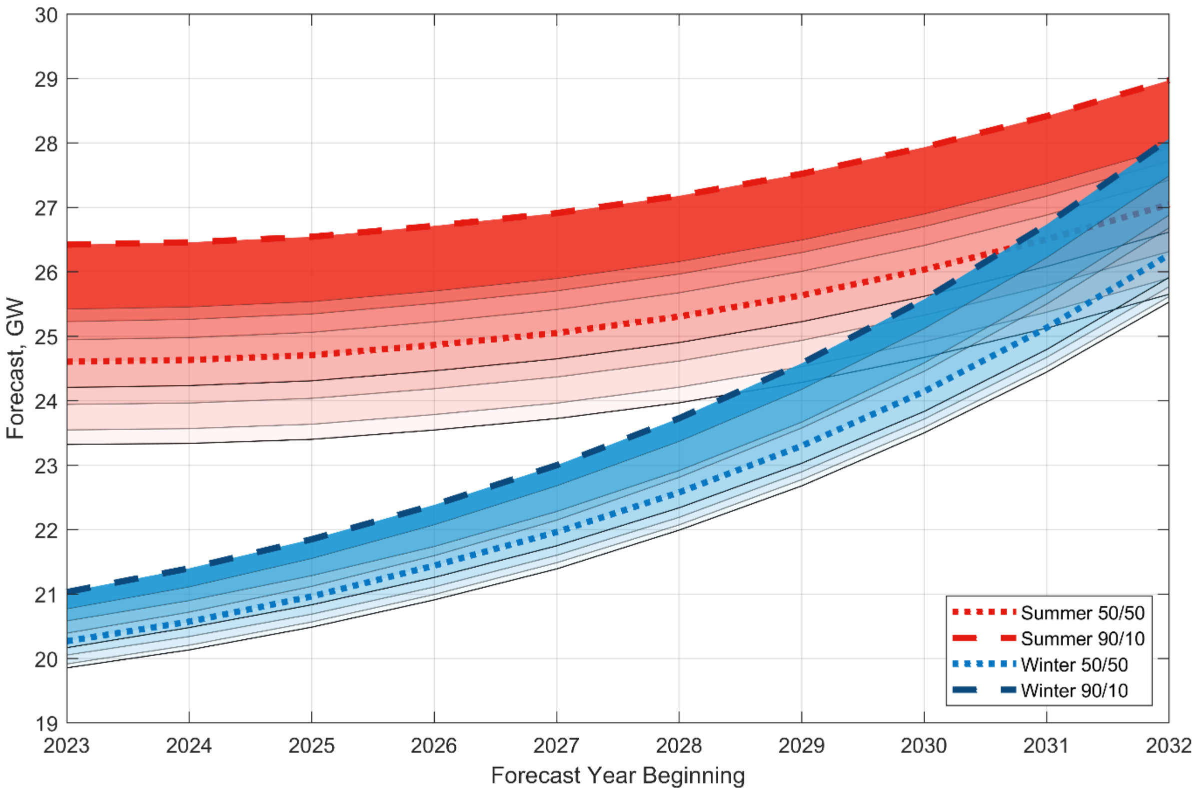
January 2050 HP Adoption Forecast

Demand Forecast



Winter and Summer Peak Convergence

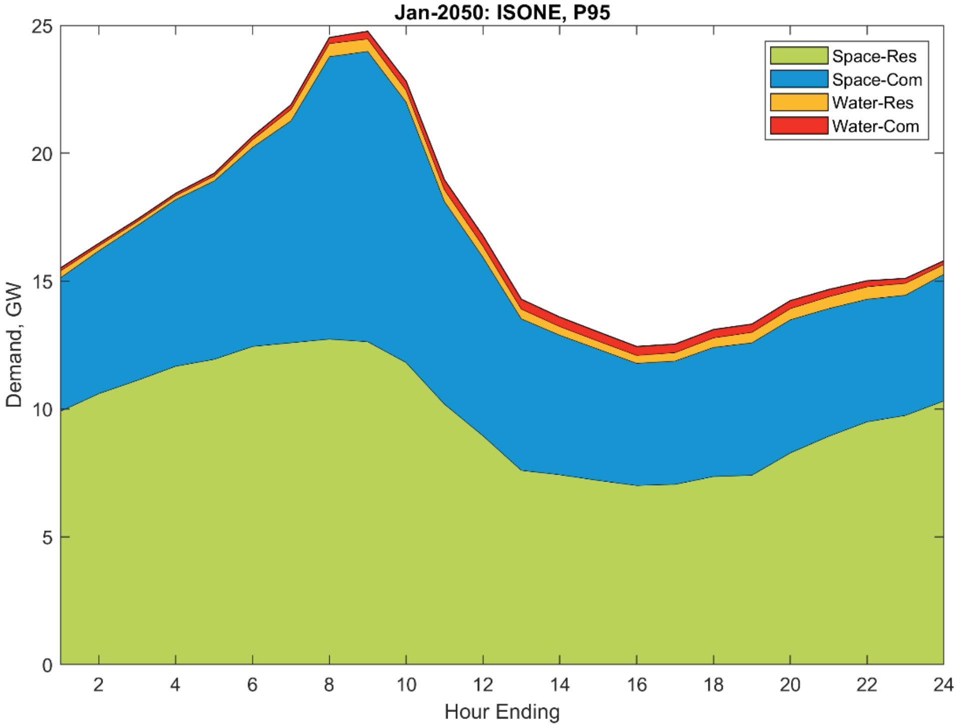
- Plot shows "peak" portion of probabilistic net load forecast distribution for both winter and summer
  - Forecasts include impacts of both heating and transportation electrification
- By 2031, the 90/10 net winter demand forecast exceeds the 50/50 net summer demand forecast
- Beyond the forecast horizon, by the mid-2030s, electrification will cause winter peak demand to become the typical, prevailing peak season



Heating Electrification and Future Winter Peaks

January 2050

- Plot shows the composition of heating electrification impacts on a "typical" winter peak day in January 2050
  - Residential space heating ("Space-Res")
  - Commercial space heating ("Space-Com")
  - Residential water heating ("Water-Res")
  - Commercial water heating ("Water-Com")
- Demand during morning peak hours is significantly higher than during typical ISO-NE coincident winter peak hour(s) (hours 18-19) that exist today
- As New England evolves towards a winter peaking system (again!), the timing of the winter peak will likely also start to occur in the morning, rather than its current evening timing



Closing Thoughts

- We need to forecast the electric energy and demand implications of trends that are yet-to-emerge and highly uncertain
  - Forecasts inform key investments, planning studies, and decision-making that will literally “shape the future” of the grid
  - Goal is to begin by painting a picture (even if a bit blurry) of a likely future, and refine it over time

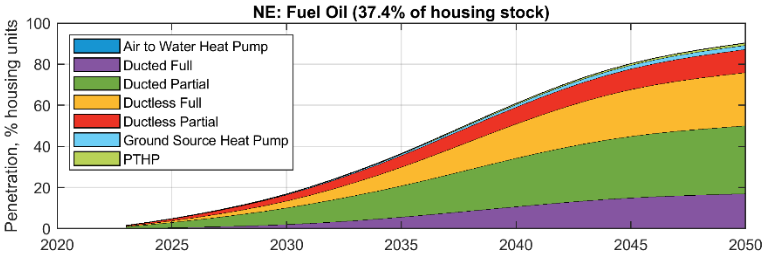
- **Sources of uncertainty include:**
  - Rates of adoption by sector
  - Equipment mix and its performance over time
    - HP sizing practices
    - Relative need for backup heating (resistance-based or other)
    - Hybrid systems with integrated controls
  - Impacts of building envelope improvements
  - Behavioral shifts in technology adoption
    - Lower heating rates relative to fossil fuel-based heating
    - Utilization of HPs for cooling
  - Geographical distribution of adoption and its impacts
    - How to disaggregate impacts to substations or network buses

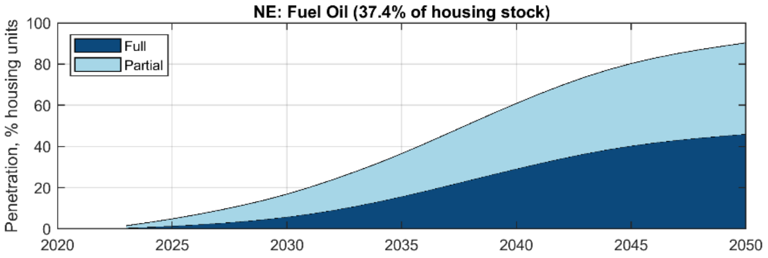
Questions

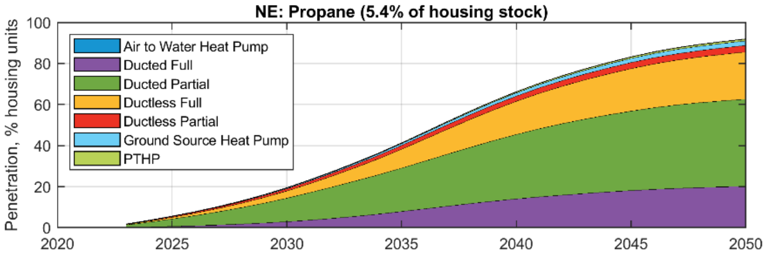
APPENDIX: ADDITIONAL INFORMATION

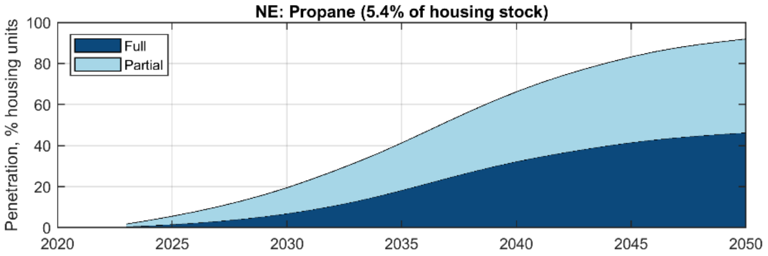
Adoption By Legacy Residential Space Heating Fuel

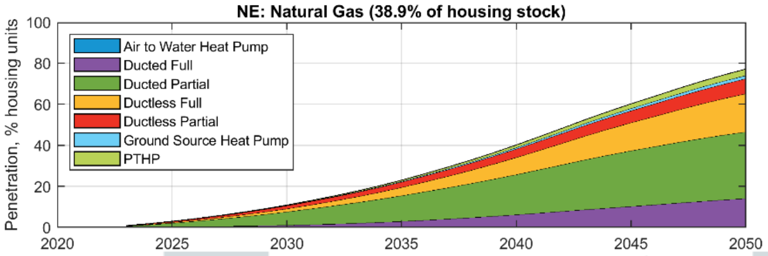
New England

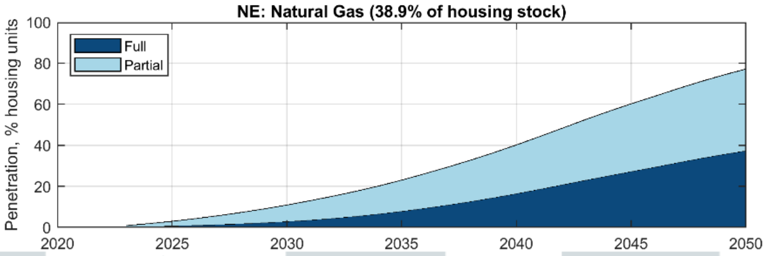






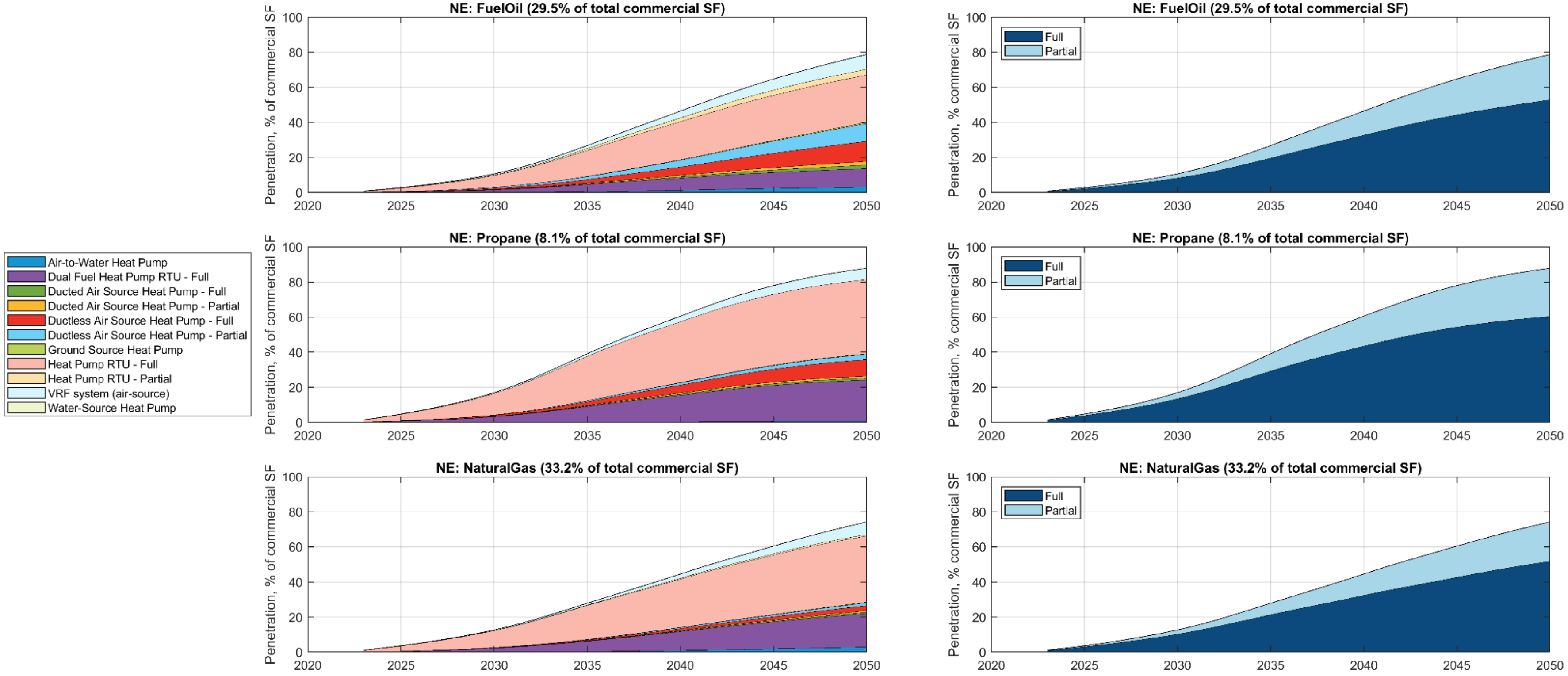






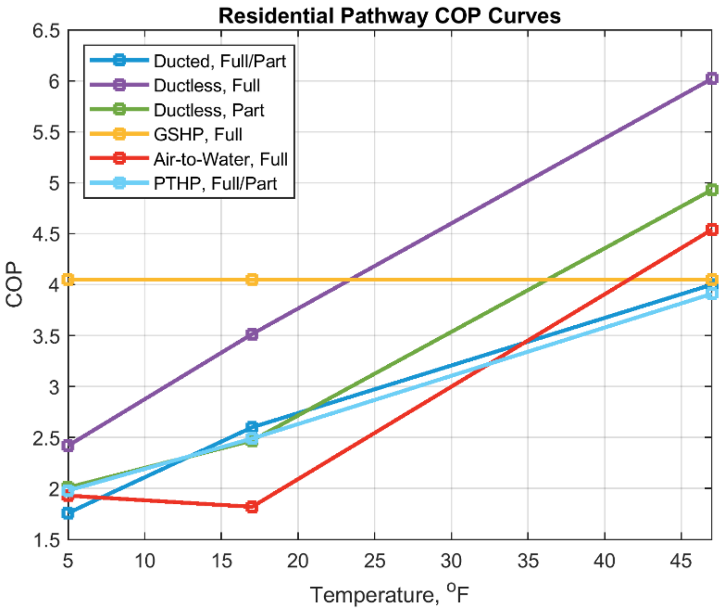
Adoption By Legacy Commercial Space Heating Fuel

New England



Residential Space Heating Pathway Assumptions

Pathway	Share of Adoption (%)		Min. Operating Temp (F)	Approx. Seasonal Heating Supplied (%)	Reference HP
	2032	2050			
Air-to-Water	0.2	0.2	-5	100	Taco Comfort System M
Ducted Full	12.6	18.6	5	100	Lennox Central Heat Pump
Ducted Partial	50.9	39.7	5	63-74	
Ductless Full	19.2	26.4	-13	100	Mitsubishi M-Series
Ductless Partial	14.5	10.5	-13	65-76	Daikin DZ6VS
Ground Source Heat Pump (GSHP)	1.5	2.1	-20	100	Energy Star rated models
Packaged Terminal Heat Pump (PTHP)	1.1	2.4	5	81	ICE-AIR HP



Commercial Space Heating Pathway Assumptions

Pathway	Share of Adoption (%)		Min. Operating Temp. (F)	Approx. Seasonal Heating Supplied (%)	Reference HP
	2032	2050			
Air-to-Water	1.4	3.7	0	100	Trane ACX
Dual Fuel Heat Pump Rooftop Unit (RTU)	17.4	20.6	0	81	Rheem Renaissance Packaged Heat Pump
Ducted Full	0.7	1.8	5	100	Lennox Central Heat Pump
Ducted Partial	0.7	1.7	5	61-74	
Ductless Full	3.8	9.3	-13	100	Mitsubishi M-Series
Ductless Partial	2.5	6.8	5	63-76	Daikin DZ6VS
Ground Source Heat Pump	0.2	0.6	-20	100	Energy Star rated models
Rooftop Unit (RTU) – Full	68.0	43.5	0	100	Rheem Renaissance Packaged Heat Pump
RTU - Partial	1.5	2.3	0	81	
Variable Refrigerant Flow (VRF)	3.8	9.7	-13	100	Mitsubishi M-Series