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Heating Electrification Forecast Update

Load Forecast Committee

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Objectives

- Propose the methodology that will be used to forecast the impacts of heating electrification on regional energy and demand
- Discuss new data sources and background information that will be used to support key forecast inputs
- Obtain LFC feedback on proposed methodology

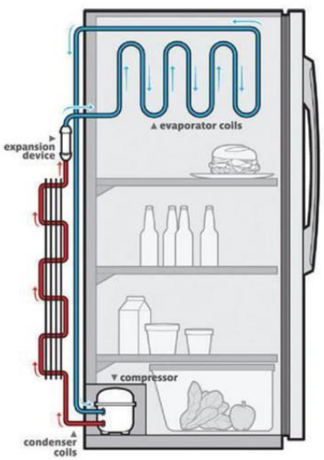
Introduction

- ISO discussed heating electrification at the July 27, 2018 LFC meeting
- Heating electrification initiatives are occurring as part of state-funded energy efficiency (EE) programs
- There is growing emphasis within EE programs on more holistic goals that focus on total energy savings across all sectors (e.g., electric, heating, transportation, etc.)
  - States may refer to such initiatives as “energy optimization” or “strategic electrification”
- These initiatives are driving the electrification of the heating sector across the region, which will result in an overall increase in electricity consumption during the heating season
- As part of the 2020 CELT forecast, ISO will include forecasted impacts of heating electrification on state and regional electric energy and demand
  - Forecast will focus on winter months only (January through April, and October through December
- ISO’s heating electrification forecasts will focus on consumer adoption of air-source heat pumps (ASHPs) across the region

ASHP Basics

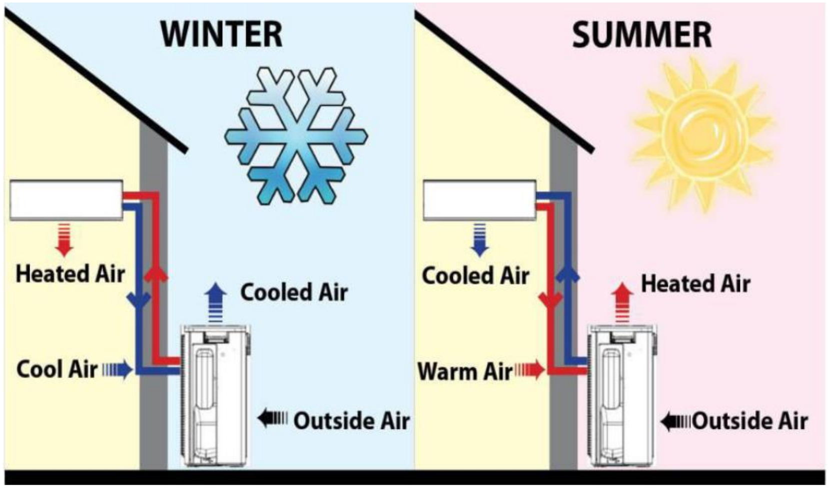
- ASHPs are similar to a typical refrigeration system
  - Components include a condenser, compressor, evaporator, and expansion device
- However, ASHPs (via a reversing valve component) can reverse the refrigeration cycle, enabling them to move heat in both directions, from indoors to outdoors (cooling mode) and from outdoors to indoors (heating mode)
- ASHPS that better provide heat at lower design temperatures are now commercially available
  - These are often referred to as “cold climate” ASPHs

Refrigerator



Both are refrigeration systems.

ASHP



Source: Eversource Energy, Exploring Climate Solutions, Renewable Thermal Technologies: Heat Pumps, April 2016

Types of ASHPs

- A variety of ASHP systems are commercially available
- Central ASHPs look similar to central air conditioners
- Single-headed ASHP (aka, "mini-split" or "single-split")
  - Has one outdoor compressor unit connected to a single indoor conditioning unit
  - Example shown in graphic to the right
- Multi-headed ASHP (aka, "multi-split")
  - Has one outdoor compressor unit connected to multiple indoor conditioning units
- Applications can be either ducted or ductless

Ductless single-headed ASHP

Source: Energy Star, https://www.energystar.gov/products/heating_cooling/ductless_heating_cooling

New England Residential Heating Sources

- The US Census Bureau collects data on heating fuel types used in occupied housing units
- Tabulated below are the shares of occupied residential homes heated by a variety of primary fuels according to most recent 5-year estimates
  - Carbon-based fuels account for more than 80% of residential heating

Residential House Heating Fuel (ACS 2013-2017)*							
Fuel Type	**CT**	**ME**	**MA**	**NH**	**RI**	**VT**	**New England**
Utility gas	35%	7%	51%	20%	53%	18%	39%
Bottled, tank, or LP gas	4%	10%	3%	15%	3%	16%	6%
Electricity	16%	6%	15%	9%	10%	5%	13%
Fuel oil, kerosene, etc.	42%	62%	27%	45%	31%	43%	37%
Coal or coke	0%	0%	0%	0%	0%	0%	0%
Wood	2%	13%	2%	8%	2%	17%	4%
Solar energy	0%	0%	0%	0%	0%	0%	0%
Other fuel	1%	2%	1%	2%	1%	2%	1%
No fuel used	0%	0%	0%	1%	0%	0%	0%

** Source: U.S. Census Bureau, Selected Housing Characteristics, 2013-2017 American Community Survey 5-year Estimates.*

Accounting for ASHPs in Load Forecast

Seasonal Differences

- The vast majority of ASHPs are expected to be installed as part of EE programs, and for which all associated claimed demand savings data will be submitted to ISO by EE program administrators (PAs)
- Summer accounting
  - Since ASHPs provide an efficient cooling source, summer demand and energy savings are expected to mirror the savings calculations for efficient air conditioners
  - Consequently, the cooling implications of ASHP adoption are already treated appropriately through reported EE savings, and for which load is reconstituted
- Winter accounting
  - Despite an overall increase in winter electricity that results from the vast majority of ASHP installations (due to displaced fossil fuel sources of heat), winter savings related to ASHPs are often reported based on an assumed baseline of a lower efficiency ASHP or even resistance heat
    - Reporting practices vary widely across the region
    - This accounting will not work in the current load reconstitution process, in which EE savings are added back to historical loads
  - For this reason, ISO will be creating an exogenous heating electrification forecast, and plans to add the energy and demand implications of heating electrification to the gross load model forecasts to yield the final gross load forecast

ASHP Applications and Design Considerations

ASHP applications displace varying degrees of legacy heat utilization

Application	Description	Existing HVAC System	ASHP Sizing Strategy
Heating (or heating & cooling) displacement	Reduce heating (and/or cooling) cost for central area of home. Heating is supplemental when existing equipment has remaining life	**Left in place, provides heat only as needed.**	Place first zone where heat will cover most central living area; establish additional zones as appropriate.
Full heating system replacement	Best suited for homes with relatively small heating loads due to small size or existing weatherization	**Remove or disable**	Size to meet estimated heating and cooling loads; exact sizing depends on whether auxiliary heat source is used
Isolated zone	One room or zone that is otherwise thermally isolated from rest of home	**Left in place**	Size to meet both heating and cooling loads in zone
New construction or gut rehab	House is well insulated and relatively air tight	**ASHP will be only heating source other than possibly auxiliary heat**	Size to meet both heating and cooling loads

Source: Northeast Energy Efficiency Partnership, Guide to Sizing & Selecting Air-Source Heat Pumps in Cold Climates, December 2018.

Massachusetts ASHP Data

- The data below comes from residential ASHP projects that received a rebate from Massachusetts Clean Energy Center (MassCEC) between November 2014 and March 2019

Legacy Heating Fuel	Number of Projects	Number of Installed ASHPs	Share of Total
Electric	1,566	2,246	14.0%
Natural gas	4,379	5,591	34.8%
Oil	4,437	6,321	39.4%
Propane	519	723	4.5%
Other/Unknown	827	1172	7.3%
Total	**11,728**	**16,053**	**100%**

Source: Massachusetts Clean Energy Center, Cost of Residential Air-Source Heat Pumps, available at: https://www.masscec.com/cost-residential-air-source-heat-pumps

Using AMI Data for Insights

- ISO has licensed anonymized advanced metering infrastructure (AMI) and associated data from Sagewell, Inc. to help gain insights about changes to electricity consumption patterns due to the adoption of ASHP
- This dataset includes:
  - Building-level hourly interval energy consumption for both residential sites and commercial sites in northeastern MA
    - Includes data from more than 9,000 residential and almost 800 commercial sites
  - Building characteristics and end-use details that match each AMI point
    - Includes property type, square footage, heating distribution method & fuel
  - Interval energy consumption from more than 80 houses with CC-ASHPs installed
    - Associated metadata include heat pump installation month, system size, and type (i.e., ductless or ducted), legacy heating system and fuel type

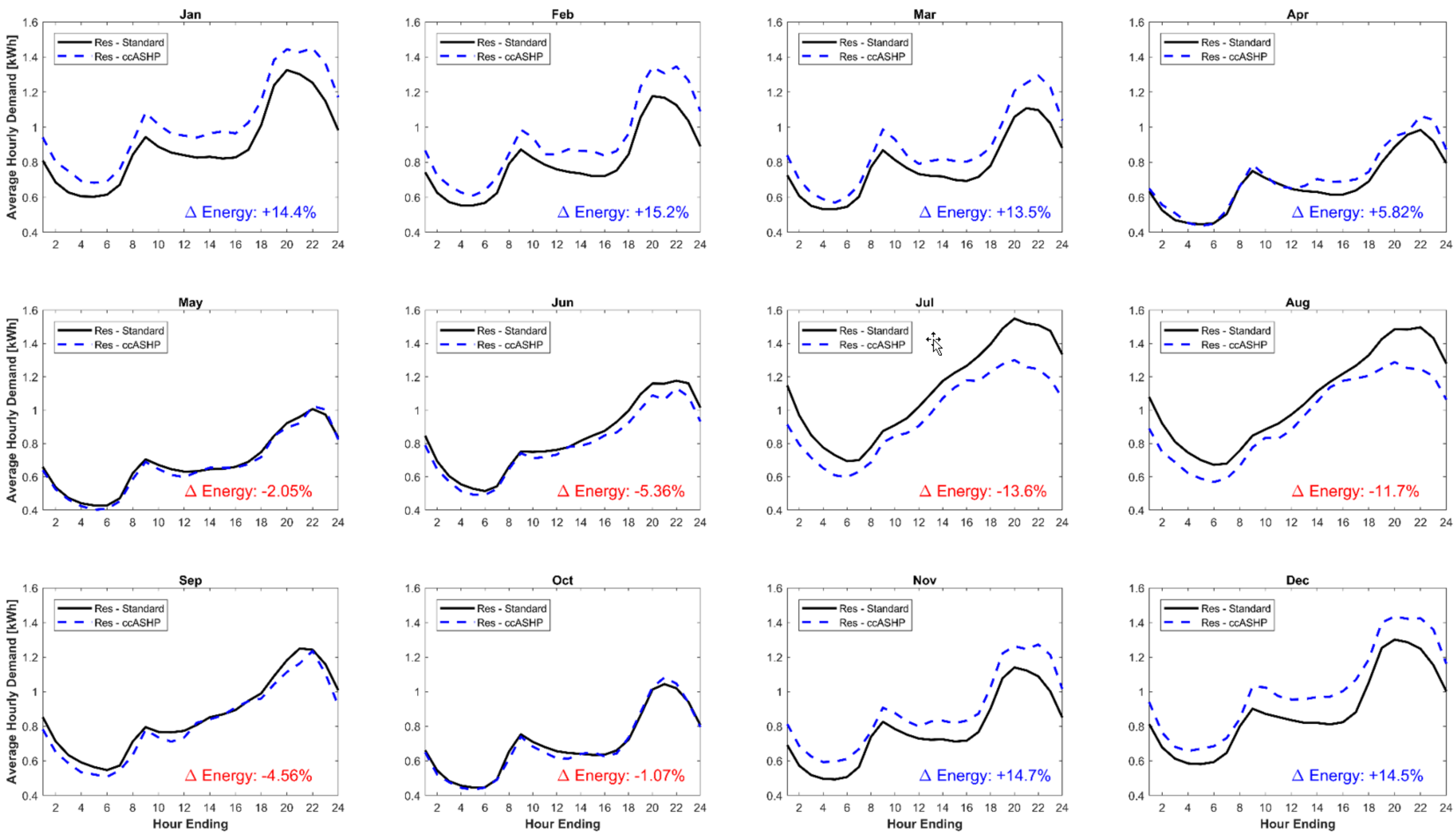
AMI Data Analysis

Initial Insights

- ISO has performed analysis on segmented subsets of the AMI dataset, including hourly average kWh profiles of:
  - Residential sites without ASHPs (Baseline)
    - More than 400 residential AMI points
  - Residential sites with ASHPs (ASHP)
    - Included 33 residential AMI points
- Analysis period included data between January 2017 and June 2019
- The plots on the next slide illustrate the monthly average profiles of both subsets of data described above
  - Solid black lines are the Baseline case ("Res-Standard")
  - Dashed blue lines are the ASHP case ("Res-ASHP")
- Observations about these monthly comparisons include:
  - The two profiles are very similar in months with little heating or cooling (May and October), which suggests the two subsets of data benchmark well to each other
  - Electricity consumption is higher for the ASHP sites during winter months
  - Electricity consumption is lower for the ASHP sites during summer months

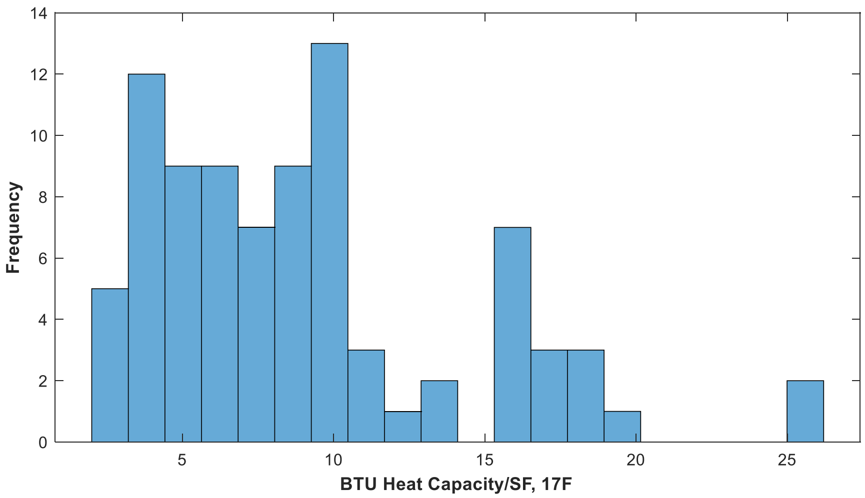
Monthly Average Household Profile

Baseline Residential versus Residential with ASHP



ASHP Design Characteristics

- Information concerning the specific application (refer to slide 8) of each ASHP in the AMI dataset is unknown but can be inferred based on site metadata
  - Total area of house, in square feet (SF)
  - Heat capacity of ASHP, provided in British thermal units (BTU) at 17 degrees Fahrenheit (F)
- A histogram of the BTU/SF of all ASHP applications in the AMI dataset is shown to the right
- Higher BTU/SF of heat capacity are associated with potential to displace a greater share of the legacy heating source, which is most often a carbon-based fuel



Cold Climate ASHP Design Loads

- Approximate ASHP design heating loads can help contextualize the BTU/SF values shown on previous slide
- ASHP design loads (in BTU/SF) for a design temperatures between -10°F and 5°F are tabulated to the right,
  - Relevant to New England cold climate ASHP applications

House Description	BTU/SF
No wall insulation	41
2x4 construction w/ insulation	22
2x6 construction w/ insulation	15
New construction (post 2012)	14

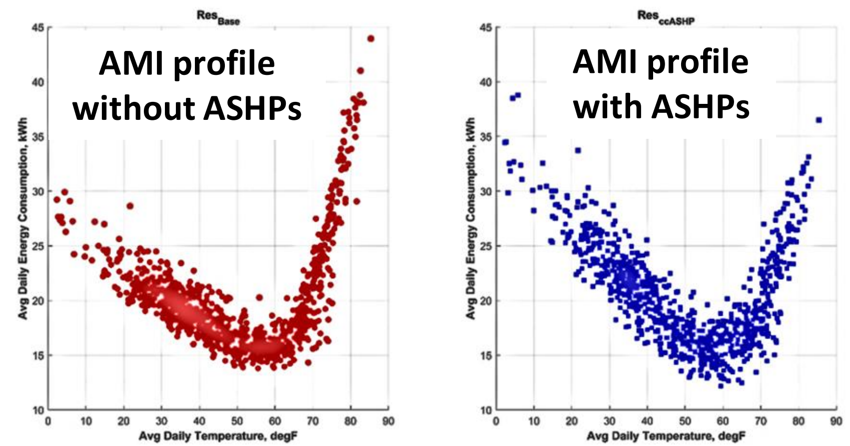
Source: Northwest Energy Efficiency Alliance (NEEA), available at: https://neea.org/img/documents/NEEA-Cold-Climate-DHP-Spec-and-Recommendations.pdf

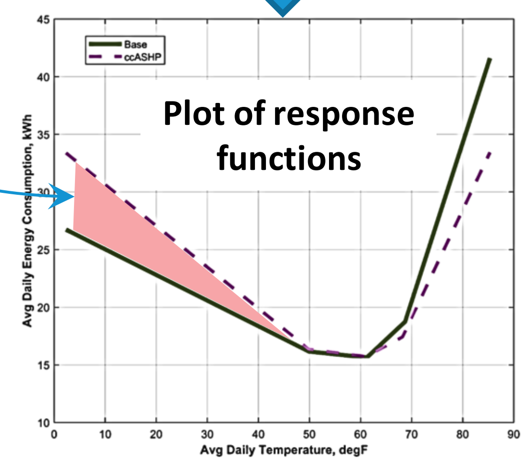
- These design values apply to the living area conditioned by a ductless ASHP, and include a typical 125% oversizing
- Most of the ASHPs in the AMI data are lower than the listed design heating loads, suggesting they are likely associated with relatively low overall heating displacement applications (i.e., isolated zone or low heating displacement applications)
  - Note that the BTU/SF data shown on the previous slide are based on performance at 17°F, and therefore would be somewhat lower at 5°F

Proposed Forecast Framework

Response Functions to Estimate Energy & Demand Impacts

- ISO will develop a regression-based approach to leverage AMI and weather data to derive response functions
  - Response functions will show ASHP impacts as a function of weather
- Regression models will be developed based on two subsets of AMI data:
  - 1) aggregate profile of homes without ASHPs, and
  - 2) aggregate profile of homes with ASHPs
- *Model differences* reveal the incremental increase in electric energy as a function of weather due to ASHP adoption
  - Focus on heating only
- Graphics illustrate an example process for developing a response function for daily energy
  - Same process can be followed for demand

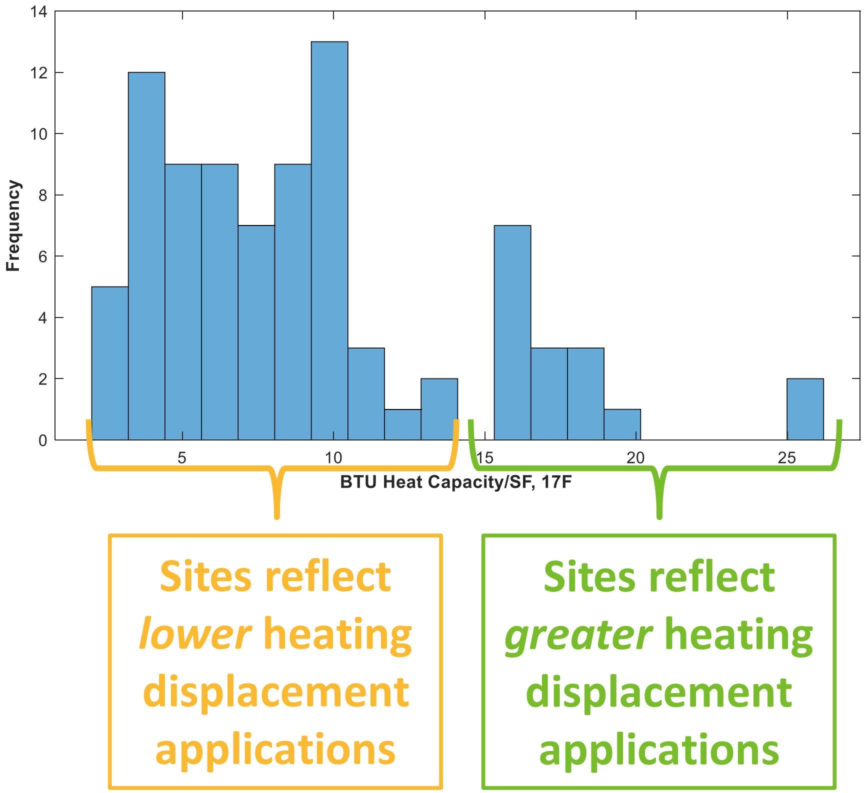




Proposed Forecast Framework

Need For Clustering ASHP Source Data

- As ASHP adoption grows across the region, an increasing share of ASHP installations is expected in greater heating displacement applications, which will have greater energy and demand impacts
- As illustrated to the right, clustering of the ASHP AMI sites can be performed based on the BTU/SF site characteristics
- Aggregate energy and demand profile characteristics of each cluster can be used to estimate shifts in ASHP heating displacement trends over time



Proposed Forecast Framework

Forecast ASHP Adoption and Energy & Demand Impacts

- ISO will develop projections of ASHP adoption for each state using available data
  - Recent ASHP installations
  - EE program data and state EE plans
- Given that ASHP adoption is expected to play a pivotal role in meeting state GHG reduction mandates and goals, ISO will assume:
  - Increasing trends in ASHP adoption over time
  - Increasing tendency for ASHP applications that induce greater displacement of carbon-based sources of heating over time horizon (i.e., increasing shares of higher BTU/SF applications)
- The ASHP adoption forecast will be interacted with the relevant response functions to yield the forecasted energy and demand impacts

Next Steps

- ISO will present a draft heating electrification for the region and states at the November 18, 2019 LFC meeting
- A finalized heating electrification forecast will be included in the 2020 CELT gross load forecast

Questions