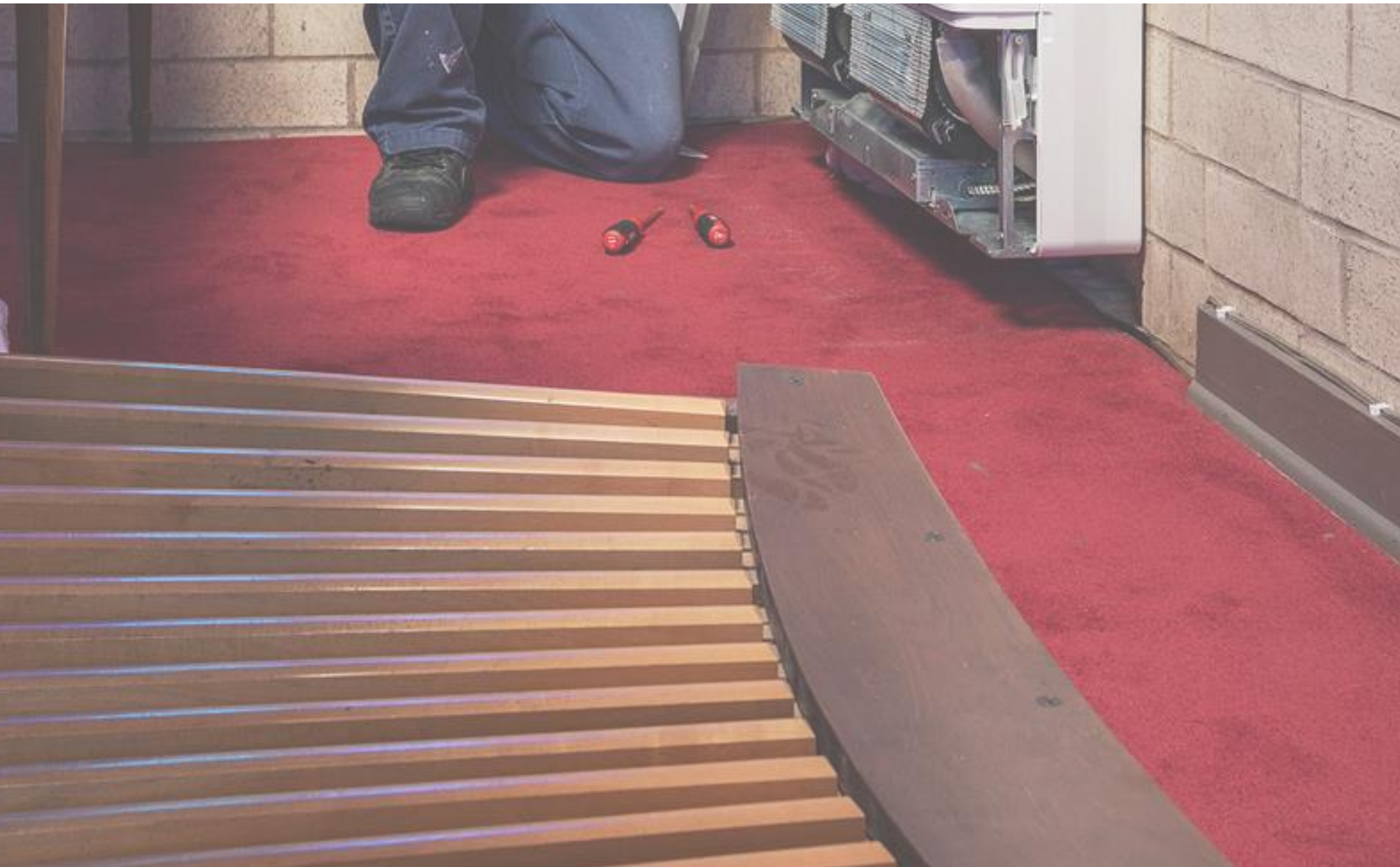
# Northeast/Mid-Atlantic Air-Source Heat Pump Market Strategies Report 2016 Update

January 2017



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## Acknowledgements

The combined efforts and expertise of many individuals brought about the Air Source Heat Pump Market Transformation Strategies Report. The 2013 report was originally authored by Robb Aldrich and Joanna Grab at Steven Winter Associates, Inc. and David Lis, Director of Market Strategies at Northeast Energy Efficiency Partnerships. Robb and David were both involved in the revisions for this update as were several NEEP staff including Claire Miziolek, Lisa Cascio and Chris Tanner. We would also like to recognize and thank several members of the Northeast/Mid-Atlantic ASHP Working Group for their review of the report and valuable input and guidance, including Richard Faesy, Energy Futures Group, Eric Dubin and Rick Nortz, Mitsubishi, Jeff Howard, Connecticut Department of Energy and Environmental Protection, and Robert Zogg, Navigant.

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## About NEEP

NEEP was founded in 1996 as a non-profit whose mission is to serve the Northeast and Mid-Atlantic to accelerate energy efficiency as an essential part of demand-side solutions that enable a sustainable regional energy system. Our vision is that the region will fully embrace next generation energy efficiency as a core strategy to meet energy needs in a carbon-constrained world.

**Disclaimer:** NEEP verified the data used for this white paper to the best of our ability. This paper reflects the opinion and judgments of the NEEP staff and does not necessarily reflect those of NEEP Board members, NEEP Sponsors, or project participants and funders.

## Executive Summary

Residential air-source heat pumps (ASHP) are a heating and air-conditioning technology that use electricity to provide a combination of space heating and, in most instances, cooling to homes. A new generation of ASHPs utilizing inverter-driven, variable-speed compressor has come to market over the past five years. These systems have demonstrated radically-improved heating performance under low temperature conditions (near or below 5°F), while continuing to offer highly efficient cooling. In the process, these systems have opened up vast new markets, including the Northeast and Mid-Atlantic regions and present exciting energy use, energy cost and greenhouse gas emission reduction potential.

In 2013, NEEP launched a regional market transformation initiative to accelerate the market adoption of this technology in the region. The initiative collectively developed the Northeast/Mid-Atlantic ASHP Market Transformation Strategies Report to provide a "roadmap" of coordinated regional activities to effectively transform the market. The regional initiative and its working group have since advanced many of the key strategies, though there is still work to be done to transform this market. This report, which offers an update to the initiative's 2013 report, presents a series of updated and new market strategies that, if implemented by regional stakeholders, would result in the accelerated adoption of residential ASHPs in the Northeast/Mid-Atlantic Region.

The ASHP market has seen a number of evolutions since the 2013 report, prompting the need to revisit the regional strategies. A mix of market influencers have impacted this evolution, including a dramatic decrease in the cost of home heating oil, an expansion of ASHP system configurations to meet an ever diverse mix of application needs, a growth in state lead efforts to address greenhouse gas (GHG) reduction through "renewable" thermal technologies for which most have included ASHPs, and improved performance data for ASHP in-field performance. Along with technological and market changes, many stakeholders have conducted various forms of research around this technology to shed light on a number of issues.

In 2016, the initiative re-evaluated the key market barriers as well as potential opportunities to leverage. While most of the market barriers and opportunities remain in the market since 2013, several new barriers and opportunities have emerged. Based on our assessment of the regional ASHP market, it is clear that while ASHPs have established a viable and growing market, there remains a significant opportunity to further accelerate adoption of the technology and in the process achieve exciting energy, cost and carbon savings to the Northeast and Mid-Atlantic region.

With a strong understanding of the current market, including key barriers and opportunities to leverage, regional ASHP stakeholders worked collectively to develop updated strategies that will effectively overcome the barriers and leverage the market opportunities.

This effort established seven key regional market transformation strategies. While they are framed as recommendations to the broad community of regional stakeholders, the sub-strategies identify specific stakeholders for implementation.

## *List of Regional Market transformation strategies*

1. Increase consumer education and awareness
    a. Regional market actors should continue to deliver consumer-oriented educational messages promoting ASHP technology.
    b. Non-manufacturer market actors should develop and disseminate case studies and testimonials for different heat pump applications, including centrally ducted systems.
    c. Regional stakeholders should develop educational presentations or workshops for residential architects and mechanical designers as well as multifamily housing market actors.
2. Increase installer/builder awareness of, and confidence in, ASHP through expanded training and education
    a. Regional stakeholders, including manufacturers and program administrators, should develop educational contractor training materials on efficient, inverter-driven ASHP technology to increase contractor confidence in ASHPs.
    b. Manufacturers should develop consumer-oriented educational material to be disseminated by contractors directly or via the internet.
    c. Programs offering financial incentives for the installation of high performance ASHPs should require the installer to either have participated in some form of ASHP-specific training or complete some form of quality installation protocol.
    d. Regional stakeholders should work together to develop case studies for contractors and builders to highlight the benefits of installing efficient ASHPs versus other HVAC technologies.
3. Reduce upfront costs of installed systems through robust and aligned promotional programs and the support of alternative business models
    a. Energy efficiency and Renewable thermal programs should continue to offer downstream incentives and further explore upstream incentive opportunities; regional program should better align around high-performance and quality installation
    b. Encourage energy service companies to offer alternative business models that provide ASHPs to the market with no up-front installation cost.
    c. To increase concentrated installations and reduce installation cost, communities and/or state agencies should develop and implement community-based programs for ASHPs.
    d. Drive equipment and installation costs down through economies of scale.
4. Mobilize state and local policymakers to expand support for ASHPs
    a. Leverage existing policy interests in carbon reduction strategies to build general policy support for proactive ASHP deployment activities.
    b. Conduct further analysis to better describe regional impacts of broad ASHP deployment on energy usage across fuels, peak electricity demand, costs to consumers and utilities and associated emission impacts.
    c. States should develop/expand "renewable thermal" programs aimed at reducing carbon emissions through the increased adoption of qualifying

technologies, including ASHPs.
   d. State lawmakers should adopt state renewable/alternative portfolio standards and include ASHP as an eligible technology.

5. Promote advanced control technologies to allow automated coordination among multiple heating systems
   a. Regional stakeholders should encourage the manufacture and installation of low-cost integrated control systems that effectively manage the operation of multiple heating systems, with prioritization of ASHP operation.
   b. Installers must educate consumers on how to operate their ASHP in conjunction with other heating system(s).

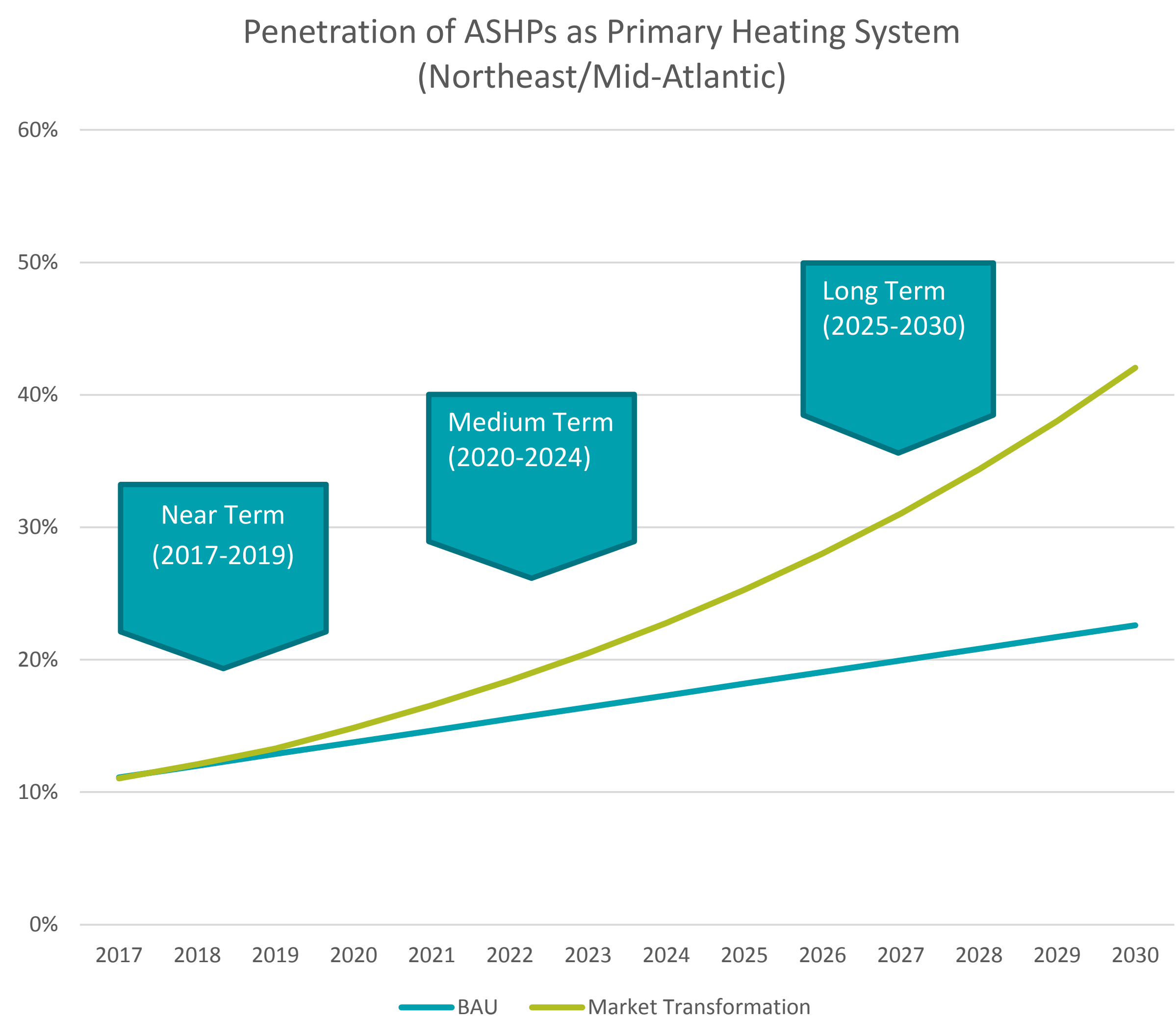
6. Enable the promotion of climate-appropriate ASHPs through improved performance metrics
   a. Energy Efficiency/Renewable Thermal programs throughout the region should leverage the publically-available ccASHP Specification for a variety of potential purposes.
   b. NEEP and the ccASHP Specification advisory committee should monitor and support development of the CSA heat pump testing procedures.
   c. Leverage increased program adoption of climate appropriate requirements to influence regional and national group to include more realistic test procedures as part of qualification to their ASHP programs.

7. Develop more accurate tools to predict energy, cost and GHG savings associated with ASHP installation through collection and analysis of real world performance data
   a. Regional energy efficiency program administrators should implement large-scale utility bill analysis study to evaluate changes in heating energy consumption after efficient ASHPs are installed.
   b. Regional energy efficiency and/or renewable thermal program administrators should continue to conduct focused monitoring studies on inverter-driven ASHPs in different applications.
   c. Regional stakeholders conducting in-field monitoring activities should be seeking coordination and consistency on methods and protocols used in ASHP evaluations with other researchers.
   d. Manufacturers and/or third party metering designers work to develop metering technology to incorporate into ASHPs for real-time performance evaluation and reporting.
   e. Regional stakeholders work with software providers to develop guidelines and/or to incorporate features that allow more accurate modeling of inverter-driven heat pumps.

NEEP projects that earnest implementation of these recommended market strategies will produce the necessary market conditions in order for accelerated and sustained uptake of ASHPs throughout the Northeast and Mid-Atlantic regions.

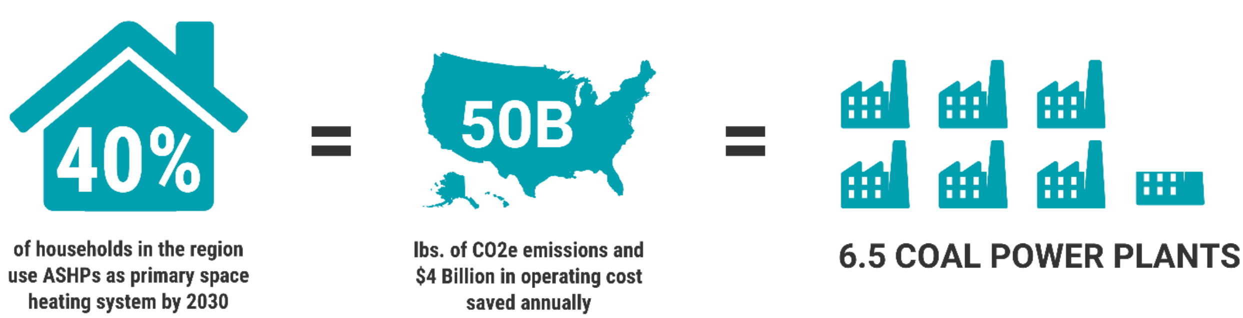
Figure ES 1 reflects the anticipated effects of successful implementation of the region strategies.

Figure ES 1: Market Transformation for ASHPs in the Northeast/Mid-Atlantic Region




Based on this long-term market trajectory, the initiative establishes a long-term market transformation goal and its associated impact on the region.

## NORTHEAST AND MID-ATLANTIC REGIONAL GOAL



NEEP projects that a sustained regional initiative can successfully transform the residential space heating market to a market where ASHPs are the most broadly utilized technology to heat homes.

We urge states, efficiency program administrators, industry and other market actors to work together to achieve thoughtful and coordinated implementation of the strategies presented herein to achieve the large potential for energy, costs and emission savings offered by the broad adoption of ASHP systems across the Northeast and Mid-Atlantic region. NEEP stands ready to lead such efforts to build regional-scale momentum through strategic regional coordination of these strategies with regular updates to this strategy to keep current with relevant product, market, program and policy developments.

## Introduction

Residential air-source heat pumps (ASHP) are an HVAC technology that use electricity to provide a combination of space heating and, in most instances, cooling to homes. ASHPs have been installed in homes for decades to provide efficient space heating and cooling, but they have primarily been used in warmer climates. During cold weather conditions, the capacity and efficiency of older, conventional ASHPs were quite poor resulting in heavy reliance on backup heating systems. A new generation of ASHPs utilizing inverter-driven, variable-speed compressors has come to market over the past five years. These systems have demonstrated radically improved heating performance under low temperature conditions (near or below 5°F), while continuing to offer highly efficient cooling. In the process, these systems have opened up vast new markets, including the Northeast and Mid-Atlantic regions.

The latest generation of ASHPs present the Northeast/Mid-Atlantic region with new and significant energy savings and greenhouse gas reduction opportunities. In fact, many believe that decarbonizing two key energy-use sectors - space heating and transportation - is necessary to meet long term carbon reduction goals established by Northeast and Mid-Atlantic states.[1] ASHPs can play a key role in the "strategic electrification" of the space heating sector. Additionally, ASHPs offer an effective solution for comprehensively meeting heating/cooling loads in low-load new construction (i.e. zero energy ready, zero energy homes). Such a long-term transition away from traditional heating systems and fuels (natural gas, oil, and propane) represents a major opportunity and challenge.

This report offers an update to NEEP's 2013 report, Northeast/Mid-Atlantic ASHP Market Transformation Strategies Report. The report's purpose is to present a series of key market strategies that, if implemented by regional stakeholders, would result in the accelerated adoption of residential ASHPs in the Northeast/Mid-Atlantic Region.

Once again, NEEP's approach to developing this strategy report update has been to utilize an involved stakeholder process to inform the market assessment and strategy development. Manufacturers, installers, energy efficiency and renewable thermal program administrators, industry experts, and state energy officials all provided important perspectives. NEEP utilized an in-person workshop in July of 2016 to begin the process of developing this update. That process has resulted in a revised set of strategies aimed at overcoming key market barriers and leveraging key market opportunities to drive accelerated adoption of high efficiency ASHPs.

The ASHP market has seen a number of evolutions since the 2013 report, prompting the need for a revisiting of regional strategies. A mix of market influencers has impacted this market evolution, including a dramatic decrease in the cost of home heating oil, an expansion of ASHP system configurations to meet an ever diverse mix of application needs, a growth in state lead efforts to grow markets for renewable thermal technologies for which most have included ASHPs, improved performance data for ASHP in-field performance. Along with technological and market changes, many stakeholders have conducted various forms of research around this technology to shed light on a number of issues. For instance, NEEP's Regional EM&V Forum completed a Meta-study of Ductless ASHP

[1] http://www.c2es.org/us-states-regions/policy-maps/emissions-targets

research in 2014. Results from these research activities are captured in the market assessment and are reflected by the updated strategies. In order to accelerate this market and put it on a path towards long term market transformation, are the original strategies still the most impactful? Are there new strategies we should be deploying to have more impact on the successful growth of this technology? We have answered these questions with this update.

While this technology has seen increasing market penetration in the Northeast/Mid-Atlantic over the past few years, it is believed that consumers have been more motivated by the cooling capabilities of the technology and have not been taking full advantage of the opportunities associated with the space-heating capabilities.

Even as recent regional experience with the latest generation of ASHP has demonstrated clear consumer benefits, questions concerning the impact of an extensive deployment of this technology on the electric grid and other fuel supplies are not as well understood.

To more fully assess the opportunities for this technology and inform efforts across the region to thoughtfully accelerate market adoption of these products, NEEP offers this document to continue to guide regional efforts with deliberate and coordinated strategies.

This report describes the new heat pump technologies, characterizes the performance advantages in NEEP's territory, identifies specific market barriers and opportunities, and provides a framework of strategies to address the key barriers moving forward.

NEEP brings a high level of experience in the area of developing regional market strategies for energy efficient technologies, especially those in the early stages of market introduction. In order to effectively accelerate the cold climate ASHP market, NEEP will continue to work across the spectrum of interested stakeholders in efforts to implement the regional strategies described in this report.

## Air-Source Heat Pump Technology

Residential air-source heat pumps (ASHPs) provide space heating and cooling to homes. An ASHP is a device that moves heat from outdoors to indoors (or vice versa) using a vapor compression cycle. In effect, it is an air conditioner that can run in reverse during cold weather. ASHPs have been installed in homes for decades, but they have primarily been used in warmer climates. In colder weather, the capacity and efficiency of older, conventional ASHPs was quite poor. Most of these heat pumps had backup resistance heating, and it was not uncommon for this resistance heating to be used frequently in cold climates.

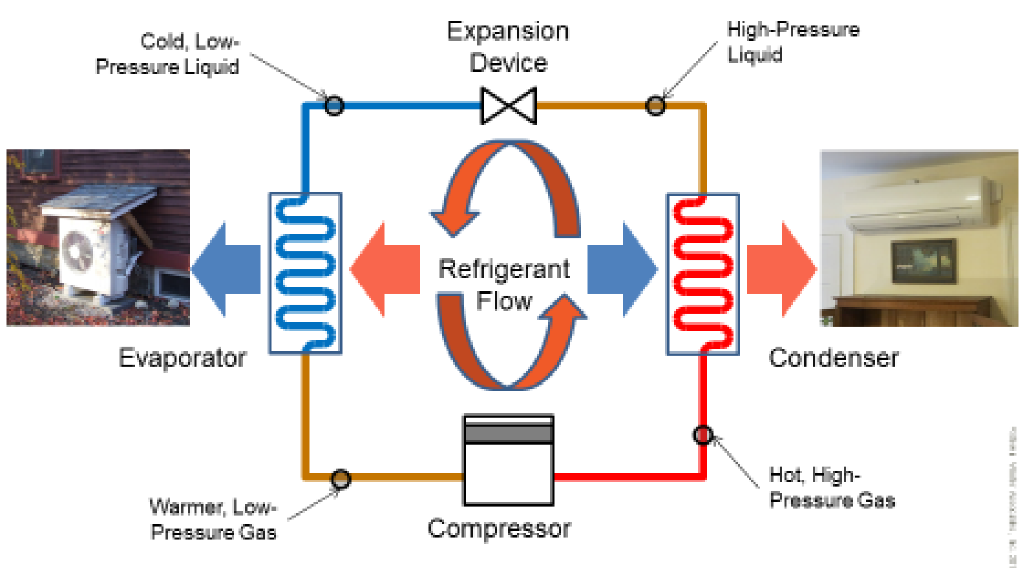
Over the past decade, many new ASHPs have been introduced to the United States market. Many of these systems use variable-speed compressors which allow for much higher efficiencies. Some of these systems also offer good performance at low outdoor temperatures (below 17°F). In many parts of the world – especially in Asia – variable-speed "ductless" or "mini-split" systems are the standard for residential space heating.

### *How ASHPs Work*

ASHPs make use of a vapor compression cycle to move heat from indoors to outdoors (during summer) and from outdoors to indoors (during winter). The principle is very similar to that of a refrigerator/freezer which moves heat from the freezer into the kitchen. The core components include:

- an outdoor unit, similar to the outdoor condensing unit with central air conditioners;
- one or more indoor fan coils;
- refrigerant piping connecting the two;
- wiring and controls

**Figure 1: Air-Source Heat Pump vapor compression cycle schematic (heating mode) (Steven Winters Associates)**



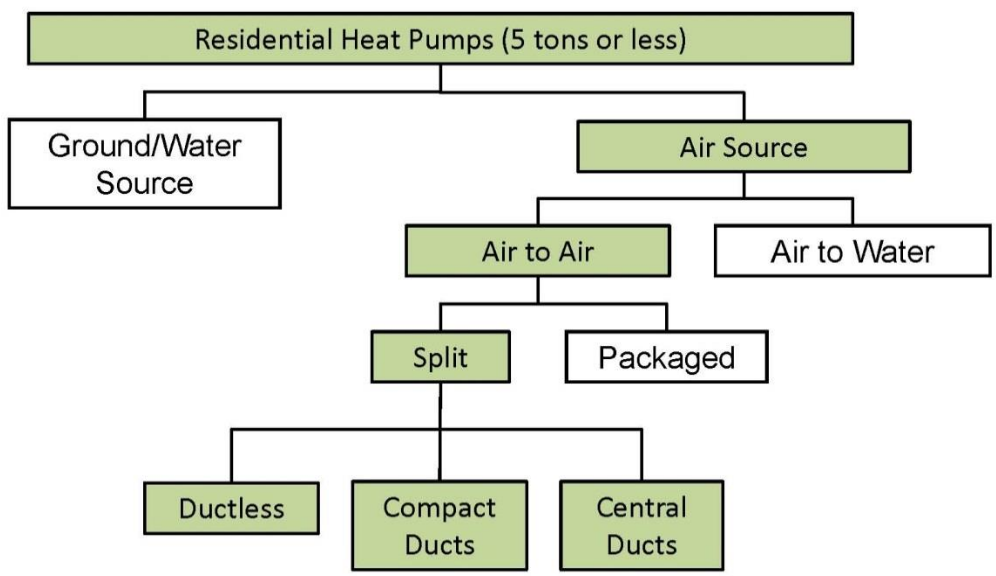

During heating season, the compressor (located in the outdoor unit) compresses the refrigerant and sends this hot gas to the indoor unit. Here the refrigerant releases heat to the home, condenses, and is piped back outdoors. Refrigerant then runs through an expansion device and absorbs heat from outdoors as it evaporates. Refrigerant returns to the compressor where the cycle continues. Condensate (moisture that condenses out of the ambient air when it comes in contact with a cool surface) from the fan coils is piped to an appropriate location or drain.

During cooling operation, this cycle is reversed. Warm air is delivered to the home via fan coils. The simplest systems are ductless; these fan coils are usually wall-mounted and provide direct conditioning to a single space. Other systems make use of fan coils that connect to duct systems that carry the warm (or cool) air to different parts of the home.

## *Terminology and Scope of the Report*

Figure 2 presents basic heat pump terminology. As previously described, an **air-source** heat pump (ASHP) is a device which uses a vapor compression cycle to transfer heat between outdoor air and indoor air or water.

**Figure 2: Categorizing Heat Pumps (Scope of report includes products highlighted in green)**




**Ground-source heat pumps (GSHPs)** have been used in homes for decades. These typically involve pumping water (or antifreeze) to underground loops or wells. During heating season, the heat pump extracts heat from the pumped water and delivers it to the home. These systems are not within the scope of this study.

**Air-to-air** heat pumps are the most prevalent and the focus of this report. **Air-to-water** systems have been in the U.S. market but in very small numbers. As the name implies, instead of heating or cooling indoor air, these systems move energy into (or from) water. In the winter, this warm water can be used to heat homes hydronically. It can also meet domestic hot water needs.

**Packaged Systems** heat pumps have all components (compressor, condenser and evaporator coils, fans, etc.) in a single appliance. Packaged terminal heat pumps are often used in hotels and apartments. They are installed through a wall and deliver heating and cooling directly to the space.

**Split Systems**, for the purpose of this report, are **split** systems where the outdoor unit and indoor fan coils are separated; refrigerant piping and wiring connect the two. Within the split-system categories, there are several ways to deliver or distribute conditioned air to the space:

- **Central ducted** systems make use of conventional air duct systems – where a single air handler moves air through ducts that deliver air to the entire home (larger homes may have more than one). The use of centrally ducted heat pumps is far more common in the milder Mid-Atlantic region than the hasher Northeast region.
- A **ductless** heat pump (DHP) delivers conditioned air to a home without use of air ducts. Very narrow piping carries refrigerant to localized indoor units where the heat or cool is delivered directly to the space. Ductless fan coils in homes are most often wall mounted. (Figure 3**Error! Reference source not found.**)
- **Compact, ducted** systems typically make use of short, low-friction duct runs to deliver air to a few (1-3) rooms. These are sometimes referred to as "ducted mini-splits".

**Figure 3: A ductless heat pump fan coil**

Much of the ductless and compact-ducted equipment is imported from Asia where this type of HVAC is the norm. These two types of systems are very similar; often the same outdoor unit can be used with either ductless or compact ducted fan coils. These systems typically have two configurations:

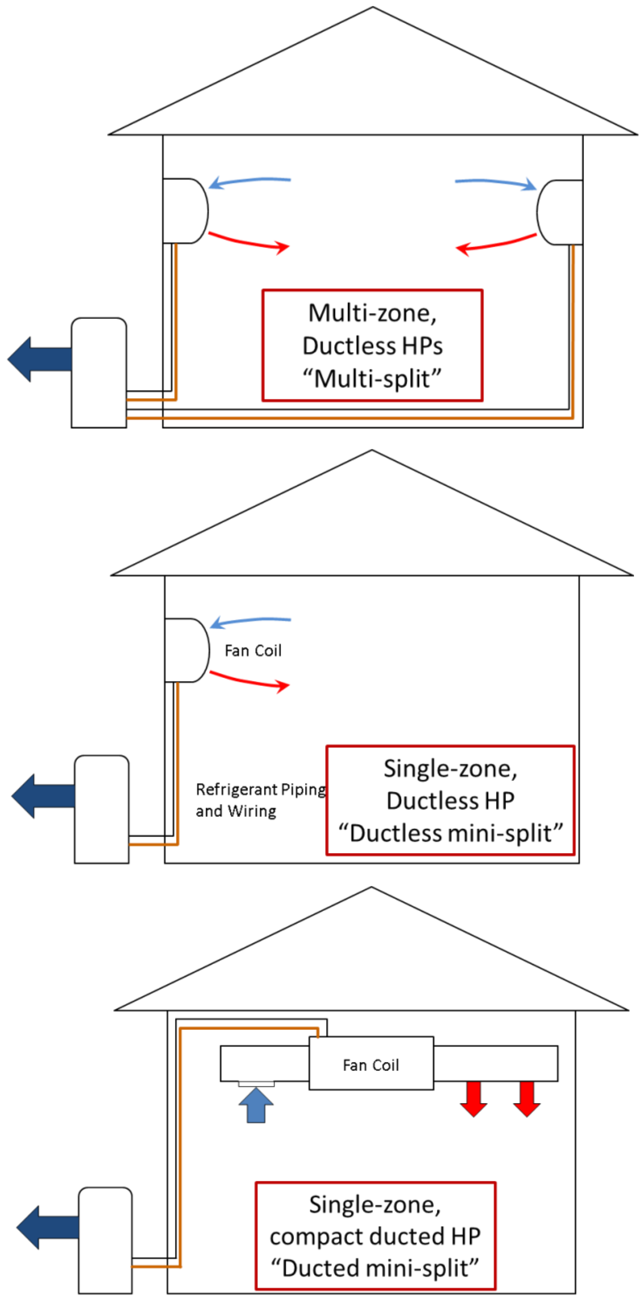
- **Single-zone** or "one-to-one" systems where one outdoor unit serves a single fan coil (which can be either ducted or ductless). See bottom two illustrations in Figure 4 below. Single-zone systems are sometimes referred to as **mini-split** systems.
- **Multi-zone** systems feature multiple fan coils and are served from a single outdoor unit. See top illustration in Figure 4 below. Multi-zone ductless heat pumps are also sometimes referred to as **multi-split** systems**.**

In residential multi-split systems, refrigerant lines from most fan coils run all the way back to the outdoor unit ("home run" configuration), however some residential systems utilize branch boxes and manifolds. Residential systems that use branch boxes have the expansion valve at the branch box, not the outdoor unit.

In larger commercial variable refrigerant flow (VRF) systems, refrigerant lines often have branches and manifolds within the building. Another key difference between residential multi-split and commercial

VRF systems is the location of the expansion device(s): a multi-split system typically has the expansion device at the outdoor unit, a VRF system has expansion devices at each indoor fan coil.

**Figure 4: Example schematics of several ductless air-source heat pump configurations**




**Inverter-driven** heat pumps have variable-speed compressors. This feature allows heat pumps to operate much more efficiently by varying capacity with building loads. The variable-speed compressors allow for **variable refrigerant flow**. The term VRF typically refers to larger heat pumps (over five tons) that serve larger buildings with many fan coils. These are becoming more common in larger commercial, institutional, and multifamily buildings in the U.S. For the purposes of this report, systems referred to as mini-split or multi-split are for residential use, and systems referred to as VRF are for commercial use.

## Performance Metrics, Ratings, and Standards

ASHP manufacturers test and rate equipment per AHRI Standard 210/240: *Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment* (AHRI 2008). These test procedures are also specified by the U.S. Department of Energy's (US DOE) minimum efficiency standards program at 10 CFR 430.23(m).

The AHRI/DOE test procedures define two efficiency metrics for ASHPs:

- **Heating Seasonal Performance Factor (HSPF):** The total space heating required during the space heating season, expressed in Btu's, divided by the total electrical energy consumed by the heat pump system during the same season, expressed in watt-hours (Wh). HSPF has units of Btu/Wh; higher numbers indicate better efficiencies. To determine heating capacity and HSPF of ASHPs, systems must be tested at outdoor dry bulbs of 17°F, 35°F, 47°F, and 62°F (210/240 Table 10). AHRI provides coefficients for calculating HSPF in six US climate regions. Note that these regions are NOT the same as DOE climate zones referenced in many codes (e.g. 2012 IECC, ICC 2011). The standard HSPF published on equipment literature, and reference in the standards below, is for climate region IV. HSPF is related to the non-dimensional **Coefficient of Performance** for a heat pump, which measures the ratio of heat energy delivered to electrical energy supplied, independently of the units used to measure energy. The HSPF can be converted to a seasonally-averaged COP by converting both the Btu heat output and the electrical input to a common energy unit (e.g. joules). Since 1 BTU = 1055.056 J, and 1 watt-hour = 3600 J, the seasonally-averaged COP is given by: Average COP = 0.293 HSPF.

$$\textbf{HSPF} = \frac{\text{total space heating required during the space heating season } (Btu)}{\text{total electrical energy consumed by the heat pump system during the same season } (Watt\text{–}hours)}$$

- **Seasonal Energy Efficiency Ratio (SEER)** The total heat removed from the conditioned space during the annual cooling season, expressed in Btu's, divided by the total electrical energy consumed by the air conditioner or heat pump during the same season, expressed in watt-hours. SEER has units of Btu/Wh; higher numbers indicate better efficiencies. To determine cooling capacity and SEER of variable speed heat pumps, manufacturers are required to test performance at four different outdoor temperature conditions: 67°F, 82°F, 87°F, and 95°F (210/240 Table 9).

$$\textbf{SEER} = \frac{\text{total heat removed from the conditioned space during the annual cooling season } (Btu)}{\text{total electrical energy consumed by the heat pump during the same season } (Watt\text{–}hours)}$$

**Other common performance metrics for ASHPs-**

- **Energy efficiency Ratio (EER)** The energy efficiency ratio at the most extreme cooling condition outlined in AHRI 210/240 – i.e. 95°F outdoor dry bulb. Like SEER and HSPF, EER has units of Btu/Wh.

$$\textbf{EER} = \frac{\text{total heat removed from the conditioned space during } 95^{\circ}\ F \text{ test } (Btu)}{\text{total electrical energy consumed by the heat pump during the } 95^{\circ}\ F \text{ test } (Watt\text{–}hours)}$$

- **Coefficient of Performance (COP)**. For heating, COP is calculated as the **heating capacity** (i.e. the amount of thermal energy delivered in Btu/h or Watts) divided by the electric power consumption. COP can be calculated or measured under many different conditions, and a seasonal average COP can also describe overall efficiency of a system. COP is a dimensionless ratio.

$$\textbf{COP} = \frac{total\ heating\ capacity\ delivered\ (Watts)}{total\ electric\ power\ consumption(Watts)}$$

US DOE has been active over the past few years to reconsider both test procedures and minimum efficiency standard levels for ASHPs.

On the test procedure side, US DOE published several proposals in a November 2015 supplemental notice of proposed rulemaking (SNOPR). US DOE finalized some of the amendments in a June 2016 final rule. US DOE published a *Federal Register* notice of final rule and technical correction pertaining to test procedures for central air conditioners and heat pumps. 81FR55111 (August 18, 2016) which included corrections of several editorial errors. US DOE has since published a *Federal Register* supplemental notice of proposed rulemaking pertaining to test procedures for central air conditioners and heat pumps 81 FR 58164 (August 24, 2016) to develop additional updates. This SNOPR proposes additional revisions to the central air conditioner and heat pump test procedures, mainly in Appendix M1, and also clarifies other aspects of the test procedure. The updates would take effect in two phases and impact Appendices M/M1 at different stages. Update to Appendix M will become effective in 2018 while more substantive changes will impact M1 in 2023. DOE is expected to publish new final rules for test procedures for ASHPs by January, 2017.

## *Federal Regulations: Minimum Efficiencies*

ASHPs are covered under US DOE's Appliance and Equipment Standards Program. Current US DOE conservation standards for residential air-source heat pumps (effective on January 1, 2015 and specified in the Code of Federal Regulations at CFR 430.32(c)(3)) include these minimum efficiencies:

**HSPF: 8.2**

**SEER: 14**

In addition, current federal standards require that systems installed in several states in the southwest have minimum EER values (11.7-12.2 depending on capacity, US DOE 2012).

US DOE launched a regulatory negotiation process in 2015 through the Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC), charging a volunteer working group with negotiating new efficiency levels and proposed changes to the test procedure. An agreement was reached in January 2016 between industry and energy efficiency advocates to increase the efficiency of ASHPs (and air-conditioners). The ASRAC approved the agreement. US DOE is expected to publish new Final Rules Efficiency standards for ASHPs by January 2017.

The ASRAC process developed a term sheet that specified recommendations for new standards to be effective in 2023. It is expected that US DOE formalizes these updates in a direct final rule by January 2017. Efficiency levels included in the ASRAC recommendations:

**HSPF: 8.8**

**SEER: 15**

### *ENERGY STAR and CEE Requirements*

While US DOE sets minimum system efficiencies, the Environmental Protection Agency (EPA) manages the ENERGY STAR™ program for appliances, including ASHPs. ENERGY STAR is a voluntary labeling program that differentiates high-efficiency products from minimally compliant products. The current minimum values for split-system air-source heat pumps are outlined below:

**HSPF: 8.5**

**SEER: 15**

**EER: 12.5**

The ENERGY STAR website also lists criteria for the "most efficient" heat pumps available in 2016. To attain the "most efficient" designation, ASHPs (ducted and ductless) must meet these criteria:

| Central (or Ducted) ASHPs | Ductless Heat Pumps |
|---|---|
| HSPF: 9.6 | HSPF: 10 |
| SEER: 18 | SEER: 20 |
| EER: 12.5 | EER: 12.5 |

The "most efficient" designation also has requirements pertaining to controls, communication, and automated fault detection.

Consortium for Energy Efficiency (CEE) also has established energy efficiency tiers for ASHPs (apply to both ducted and ductless ASHP)

| CEE Tier | HSPF | SEER | EER |
|---|---|---|---|
| 0 | ≥ 8.5 | ≥ 14.5 | ≥ 12 |
| 1 | ≥ 8.5 | ≥ 15 | ≥ 12.5 |
| 2 | ≥ 9 | ≥ 16 | ≥ 13 |
| 3 | ≥ 10 | ≥ 18 | ≥ 13 |

In partnership with the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), CEE maintains a CEE Directory of Efficiency Equipment. This directory of HVAC equipment can be used to search for the most efficient residential and small commercial equipment on the market. Manufacturers work with

AHRI to verify that their equipment meets the criteria established by the federal ENERGY STAR® program and by CEE. This directory leverages the AHRI Directory of Certified Product Performance along standing source of performance certified heating, ventilation, air-conditioning, and commercial refrigeration equipment and components.

### *Heating Performance Metrics in Cold Climates*

At a minimum, ASHP manufacturers have historically provided the following information to characterize heating performance via the AHRI Directory:

- HSPF (region IV)
- Heating capacity at 47°F outdoor (dry bulb)
- Heating capacity at 17°F outdoor (dry bulb)

AHRI Standard 210/240 provides specific guidance for testing and reporting these values, but these values alone do not adequately characterize performance for many applications. In most of the Northeast, temperatures routinely fall below 17°F during the winter. Knowing capacity and efficiency at colder temperatures is very important, especially when the ASHP is the sole or primary source of heat in a home, some manufacturers do provide more information than required by 210/240 such as:

- Heating capacities at several temperatures, including outdoor temperatures well below 17°F;
- Power consumption and/or efficiencies at many conditions;
- Capacities and power consumption at various part-load ratios.

One challenge with this additional information from manufacturers, however, is that testing and reporting procedures are not standardized. Different manufacturers provide capacities and efficiencies at different temperatures and at different part loads. This makes comparisons of various ASHPs challenging.

Determining HSPF per AHRI Standard 210/240 involves calculating a theoretical design building load based on heat pump capacity. In a cold climate (such as region IV), this building load is much larger than the heat pump's capacity at cold temperatures. In HSPF calculations, therefore, the heat pump often cannot meet the building load. HSPF calculations assume that electric resistance provides the balance of heat needed to meet the load.

While this may accurately represent how many older, conventional heat pumps operated, it is very different from how ASHPs are sized and operated today. The large majority of inverter-driven ASHP installations do not include the addition of resistance heat, rather they are often sized to provide a large part (or all) of the heating load of a space at very cold conditions. One key reason that ASHPs can be very efficient is their variable capacity. They can modulate capacities over a wide range, and they are extremely efficient at part load. If a heat pump operates at full capacity any time outdoor temperatures drop below 25-30°F (as HSPF calculations assume), the benefit of modulation is dramatically reduced.

Since the first version of this report was published in January 2014, NEEP spearheaded a working group to develop new performance metrics for ASHPs, with a focus on low temperature capabilities. From that group, the Cold Climate Air Source Heat Pump Specification was created. The specification includes a set of criteria that ASHPs must meet to be considered suitable for cold climates, and NEEP maintains an online database of products that meet these criteria. This resource has been useful to many stakeholders as it allows a more level comparison of efficiencies and capacities of different products under similar operating conditions. The specification also requires manufacturers to provide performance values at outdoor air temperatures well below those required by US DOE or AHRI. In the spring of 2016, the specification n working group developed a Version 2.0 to become effective in January 2017.

High-level analysis of listed products (as of the end of October, 2016);

- 210 products in total;
- 52 are central/ducted systems and 158 are ductless systems;
- Of the 158 ductless systems, 123 are single-zone and 35 are multi-zone systems;
- Systems from 15 different manufacturers;
- Average rated heating capacity (47°F) of listed ductless single-zone systems; 15,000 Btu/hr;
- Average rated heating capacity (47°F) of listed ductless multi-zone systems- 30,000 Btu/hr;
- Average rated heating capacity (47°F) of listed ducted systems- 33,000 Btu/hr.

Several states and utilities in the region have leveraged the specification for a variety of different uses. The Massachusetts Clean Energy Center (MassCEC) requires that among other items, products be listed on the specification to qualify for their incentives. Efficiency Vermont asks for similar performance data that is in the specification and encourages manufacturers who want to participate in their rebate programs to simply have their products listed on the cold climate ASHP specification. NYSERDA will soon be launching a demonstration project for ASHPs and as part of the solicitation to participate, it requires all systems to be tested appear on the specification.

While the specification provides far greater information and transparency around ASHP performance, there are weaknesses as well. The most glaring - and one that the working group is most keen on addressing - is that there are no industry standard test procedures for ASHPs below 17°F, including the performance at 5°F. The performance data collected in the specification at 5°F is self-reported. The working group is encouraged by the work of the CSA Group (formerly the Canadian Standards Association; CSA) in Canada who began work on new test procedures for ASHPs in the fall of 2015. The working group intends on track progress and consider leveraging these testing protocols to update the specification and the underlying test procedures from which the performance data is developed.

**CSA Variable-capacity Heat Pump Test Procedure Development**

The CSA Group is a not-for-profit standards organization which develops standards in 57 areas. CSA convened a Development Committee (DC) made up of energy efficiency program administrators, government officials and ASHP experts in the fall of 2015 which was tasked with creating a variable capacity heat pump (VCHP) standard that would characterize this variable capacity ASHP systems over a wide range of temperatures and at many output points (maximum capacity, minimum capacity & several points in between). The DC members were organized around the common belief that the current North American heat pump performance standards (CSA C656 harmonized with AHRI 210 & 240) are not appropriate to characterize VCHPs through their wide range of operation or at low temperatures.

Their goal has been to develop an “express document” which will describe a voluntary test procedure for residential-sized ASHPs (ducted/ductless, single/multi, no heat recovery). The procedure will include air-to-water as well as air-to-air ASHP and AC.

The test procedure will use “dynamic,” real-world testing rather than traditional fixed-speed testing, meaning systems will be forced to rely on native controls to govern compressor, fan and defrost. The procedure is expected to produce seasonal COP ratings for heating and cooling across 8 North American climate zones. The procedure currently includes testing temperatures at -5°F, -22°F (or outdoor limit if higher) and 113°F and include informative application rating for fixed auxiliary, partial offset, differing climate profiles.

Some labs have done “proof of concept” tests using current draft version, with the focus on checking for issues and needed refinements. The process includes plans engage public comment and finalization in 2017.

## ASHP Market Characterization

This section will look at recent information regarding ASHP sales and costs as well as trends from the customer perspective; motivation, satisfaction, and operation.

### *Size of Regional ASHP Market by Annual Sales*

Recent sales data for 2015 suggests residential ASHPs (65,000 Btu and less) sales in the region were approximately 309,000.[2] The Northeast region made up roughly 70,000 of those units while the Mid-Atlantic region made up roughly 239,000. Breakdown of centrally-ducted versus ductless systems is quite different between regions with the ductless far outpacing ducted in the Northeast 79.7% percent to 20.3 percent. In the Mid-Atlantic, those relative numbers get flipped with 59.9 percent of the systems sold being centrally-ducted and 40.1 percent being ductless.

**Table 1: 2015 ASHP Sales in Northeast/Mid-Atlantic Region**

| | Total 2015 ASHP Sales | 2015 Ductless ASHP Sales | Percent of Total 2015 ASHP Sales (Ductless) | 2015 Ducted ASHP Sales | Percent of Total 2015 ASHP Sales (Ducted) |
|---|---|---|---|---|---|
| **Northeast Region[3]** | 70,144 | 55,905 | 79.7% | 14,239 | 20.3% |
| **Mid-Atlantic Region[4]** | 238,698 | 95,718 | 40.1% | 142,980 | 59.9% |
| **Combined Region** | **308,842** | **151,623** | **49.1%** | **157,219** | **50.9%** |

NYSERDA's 2015 Residential Statewide Baseline Study Volume 3: HVAC Market Assessment[5] suggests that the large majority of centrally-ducted ASHPs just met or barely exceeded minimum efficiency requirements (HSPF 8.2, SEER 13), while nearly the entire ductless market far exceed minimum efficiencies (97.5 percent of systems had SEER values of 15 or higher). While this is not necessarily representative of the region, we assume that this provides a general perspective of efficiency in the current ASHP market.

### *Installed Cost*

A NEEP-sponsored study (Navigant 2013) documented average installed costs of $3,078 for a ¾-ton, 18-SEER single-zone ductless ASHP and $3,874 for a two-ton, 18-SEER single zone ductless ASHP. This study may include costs for cooling-only systems. Average labor costs were reported to be $1,736 per single-

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[2] Data was obtained from 2015 Air Source Heat Pumps Ducted/Ductless Share Report, December 14, 2016, prepared by D&R International, Ltd. under data license by HARDI members participating in the Unitary HVAC Market Report. Reuse is prohibited without permission. All rights reserved.

[3] Northeast region includes; Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut and, New York

[4] Mid-Atlantic region includes; New Jersey, Pennsylvania, Delaware, Maryland, and Washington DC

[5] https://www.nyserda.ny.gov/-/media/Files/...stock.../Vol-3-HVAC-Res-Baseline.pdf

zone ductless unit according to the study's survey of contractors, although labor costs vary widely regionally and by application.

Some new research has been conducted since the 2013 report to better reflect current ASHP installed costs. Table 2 below summarizes those results. Looking at the costs in Table 2, a few trends emerge. It is clear that heat pumps in larger-scale programs or studies cost less than in small-scale programs. When comparing studies published during or before 2013 to the most current studies, one sees the prices have dropped and steadied. This may be attributed to more developed technology and contractors have gained experience. A Navigant study of the Pacific Northwest market projects the current cost trend to continue. It indicates a steady increase in equipment costs (in line with inflation) will be offset by cost reduction from more competition, experienced contractors, and greater availability in the market.

**Table 2: Installed Cost in Published Studies and State Programs**

| Source | Location or Utility | Estimated cost per home | System Description (if known):<br>a) # Zones<br>b) Average capacity<br>c) # of homes |
|---|---|---|---|
| Emerging Technologies Incremental Cost Study (Table 3-2,Energy & Resources Solutions and NEEP 2016) | Various | Cost per ton:<br>Multi-split: $3,728<br>VRF: $6,350<br>VRF with Heat Recovery: $9,198 | a) -<br>b) -<br>c) -<br>Data from 4 manufacturers |
| Residential Inverter-Driven Heat Pump Technical and Market Assessment (Navigant 2015)[6] | Pacific Northwest | Ductless mini-split: $4,322<br>Multi-split: $6,079<br>Cold climate mini-split (to 5°F): $4,635<br>Short run ducted unit: $6,922<br>Multiple units: $8,000 (estimate) | a) -<br>b) -<br>c) -<br>From market actor interviews |
| The Humpty Dumpty of Heating (Vitoff et al 2015) | Massachusetts | Minimum $3,000 (high efficiency units minimum: $3,600) | a) -<br>b) -<br>c) - |

[6] https://neea.org/docs/default-source/reports/residential-inverter-driven-heat-pump-technical-and-market-assessment.pdf?sfvrsn=4

<table>
<tr><td>Air Source Heat Pump Potential in Alaska (Stevens 2015)</td><td>Alaska</td><td>Mini-split minimum wholesale $3,200<br>Mini-split through distributor $5,000</td><td>a) 1 zone<br>b) -<br>c) 19 homes</td></tr>
<tr><td rowspan="2">Incremental Cost Study Phase Two Final Report (Navigant, 2013)</td><td rowspan="2">Massachusetts</td><td colspan="2">Ductless mini splits per NSTAR rebates
<table>
<tr><td colspan="4">SEER</td><td rowspan="2">System size (tons)</td></tr>
<tr><td>13</td><td>18</td><td>21 (typical)</td><td>26</td></tr>
<tr><td>$2,733</td><td>$3,078</td><td>$3,236</td><td>$3,460</td><td>¾</td></tr>
<tr><td>$2,803</td><td>$3,183</td><td>$3,407</td><td>$3,363</td><td>1</td></tr>
<tr><td>$3,016</td><td>$3,374</td><td>$3,640</td><td>-</td><td>1 ½</td></tr>
<tr><td>$3,273</td><td>$3,874</td><td>-</td><td>-</td><td>2</td></tr>
</table></td></tr>
<tr><td></td><td>a) Single port systems focused.<br>b) See table above. 70% ¾ to 1 ton units.<br>c) 605 units rebated.</td></tr>
<tr><td>Vermont’s CEED-Efficiency Vermont Cold Climate Heat Pump program (Marin 2013)</td><td>Vermont</td><td>$4,867 per home ($4,096 per unit)</td><td>a) 1 or 2 port systems<br>b) 19 BTU/h<br>c) 21 installed units at 18 sites</td></tr>
<tr><td>Public Service of New Hampshire, data since 2013 (Belair 2013)</td><td>New Hampshire</td><td>$4,032</td><td>a) Mostly single port systems<br>b) 16,033 BTU/h<br>c) 244 homes</td></tr>
<tr><td>Air Source Heat Pumps in Southeast Alaska (Stevens 2013)</td><td>Southeast Alaska</td><td>Single zone $3,000-$3,500<br>Multiple zones $6,000-$10,000</td><td>a) -<br>b) -<br>c) At least 70 to 90 heat pumps Interviews with installers</td></tr>
<tr><td>Heat Pumps: An alternative to oil heat for the Northeast… (Matley 2013)</td><td>Northeast</td><td>Retrofit: $4,000<br>Whole house install: $10,000</td><td>a) -<br>b) -<br>c)</td></tr>
<tr><td>Efficiency Maine's Low Income Weatherization program, 8/2012 to 8/2013 (Meyer 2013b)</td><td>Maine</td><td>$2,069</td><td>a) Mostly single port systems<br>b) Mostly 9,000 Btu/h<br>c) 1350 homes</td></tr>
<tr><td>Efficiency Maine's Open Market Pilot program, 12/2012 to 8/2013 (Meyer 2013b)</td><td>Maine</td><td>$3,228</td><td>a) Mostly single port systems<br>b) -<br>c) 660 homes</td></tr>
<tr><td>NYSERDA, data since 2012 (Borowiak 2013)</td><td>New York</td><td>$8,406</td><td>a) -<br>b) 29,873 BTU/h<br>c) 15 homes</td></tr>
</table>

| | | | |
|---|---|---|---|
| Northwest Ductless Heat Pump Initiative: Market Progress Evaluation Report #2 (Evergreen Economics 2012) | Northwest | $3,593 | a) 58% single port systems<br>b) 15,000 to 18,000 BTU/h capacity (most common)<br>c) 15,800 homes between 2010 - 10/2012 |
| Ductless Mini Pilot Study (Kema 2009) | Connecticut & Massachusetts | $4,926 | a) -<br>b) -<br>c) 26 homes |
| | | $12,267 | a) -<br>b) -<br>c) 14 homes |
| | Connecticut Light & Power (Connecticut) | $4,200 | a) 1 or 2 zones<br>b) 2 ton per home average<br>c) 85 homes<br>* Cost driven down because 1 vendor selected, less options offered |
| | United Illuminating (Connecticut) | $6,061 | a) 1 or 2 zones<br>b) 1.9 ton per home average<br>c) 10 homes |
| | National Grid (Massachusetts) | $8,637 | a) -<br>b) 2.7 tons per home average<br>c) 25 homes |
| | NSTAR (Massachusetts) | $9,440 | a) -<br>b) 2.3 ton per home average<br>c) 24 homes |
| | Connecticut & Massachusetts | $5,973 | a) -<br>b) 2.2 ton per home average<br>c) 144 homes |

## *Consumer Installation Scenarios*

There are several common ASHP installation scenarios in homes in the Northeast. Each has unique barriers and opportunities and the potential size of each market is difficult to quantify. Unique strategies may be appropriate to transform the market. Primary installation scenarios include:

- Targeted cooling solution – adding a heat pump to a zone with or without existing cooling systems. Consumer use of heating capabilities of heat pump vary.
- Displacement – adding a heat pump to a zone without removing existing heating system; motivations may be the addition of cooling or to reduce fossil fuel heating costs.
- Replacement – replacing an existing heating system (e.g. end of useful life)
- New construction or additions
    - Homes without natural gas availability
    - Low load homes
        - Zero energy all-electric homes with solar electric systems
        - Avoiding gas infrastructure costs and ongoing meter fees

While targeted cooling and heating/cooling displacement represent the majority of install scenarios, full HVAC replacement and use in new construction are becoming more common. Ductless systems make up all displacement scenario configurations. To replace central forced-air heating systems, many manufacturers now make variable-speed, air-to-air heat pumps designed to handle pressures in conventional residential duct systems.

In many new construction applications today, heat pumps (both ducted and ductless) are being installed as the primary heating system usually with some other form of heating to serve as a backup. Most often the backup systems are not designed to provide whole house heating but are more designed to provide auxiliary heat in the rare circumstances that the heat pumps are not meeting full heating load. Some strategies to provide auxiliary heating to a heat pump system designed as primary system in new construction include limited amount of electric resistance strip heaters, propane fireplace inserts or woodstoves.

In addition to ductless systems, compact ducted systems (sometimes called "ducted mini-splits") offer potential for providing modest levels of heating and cooling to secondary rooms. A slim fan coil installed above a hallway ceiling, for example, can provide air to two or three nearby bedrooms.

## *Market Research Insights*

A series of ASHP market research studies have been conducted since the original 2013 Market Strategies report. This section offers brief summaries, including important conclusions.

**CONNECTICUT ENERGY EFFICIENCY BOARD (EEB), R113 Ductless Heat Pump Evaluation**, June 27, 2016

This study was undertaken to identify the causes of the lower than expected realization rate for ductless heat pumps (DHPs) reported in the R16 Impact Evaluation of the 2011 program year, "Impact Evaluation: Home Energy Services— Income Eligible and Home Energy Services Programs (R16)." A secondary objective of the study was to provide forward-looking information to assist the utilities and EEB in getting the most impacts from DHPs.

Important conclusions:

Customers believe they are getting good value from their investment and have very positive feelings about the DHP program.

- Three primary drivers of the low realization rate in the R16 Impact Evaluation are:
    - Participants in the R16 study had a moderate number of installations that added to heating loads, which was not accounted for in the Program Savings Document (PSD) calculation used at the time.
    - The PSD cooling saving factor is based on program operations and installation conditions that differ from conditions among the 2011 participants (the reference year of the R16 impact study).
    - There is evidence that many customers are adopting control strategies that reduce the overall efficiency of their DHPs.
- Low oil prices are also likely to slow program growth among participants who might normally enter the program specifically to mitigate the high price of fossil fuels. It may not be possible for

program marketing efforts to overcome the cost/benefit of operating a DHP during periods of depressed fossil fuel prices.
- Study recommends that the PSD be updated to better reflect the conditions in which DHPs are being installed and operated.
- This study suggests that customer education and knowledge of how to integrate the DHP with their pre-existing system diminishes over time. Some ideas to help maintain high levels of desirable DHP operation includes providing additional information on the EnergizeCT web site on control, maintenance and operations strategies to supplement the functional information already provided on the site (e.g. "How a Heat Pump Works" and Heat pump FAQs). A new section might be called "How to maximize your DHP Savings." Additional delivery channels could be explored.

**Heat Pumps Potential for Energy Savings in New York, NYSERDA, March 2015**[7]

This report provides an assessment of the potential for energy savings from heat pumps in New York State. The report is comprised of the following sections:

- Results of the potential assessment;
- Methodology used for the assessment;
- Overview of selected heat pump technologies, their market status and ideal site characteristics for installation, and barriers to market adoption.

Important conclusions:

- Residential cooling energy would be reduced by year 20 by about 1.4 terawatt hours (TWh), or 27 percent of the cooling energy forecast.
- Increased electric space heating of about 25.6 TWh, which would increase the total residential electric forecast by about 42 percent.
- Gas and petroleum fuel space heating could be reduced by 84 percent and 81 percent, respectively.
- Non-fuel switching installation of heat pumps for space heating and cooling has much smaller potential than for fuel switching. Residential opportunities would reduce the electric space heating forecast by about 1.2 TWh, or 27 percent over 20 years, while the cooling forecast would be reduced by about 90 gigawatt hours (GWh), or two percent.

**NYSERDA Residential Statewide Baseline Study, Volume 3: HVAC Market Assessment July 2015**[8]

This volume presents the findings from the heating, ventilating, and air conditioning (HVAC) Market Assessment. The HVAC Market Assessment is a key component of the statewide residential baseline study. The purpose of the HVAC Market Assessment is to identify the baseline conditions for residential non-electric heating and water heating equipment, central air conditioning, and heat pumps in New York State. The study focused on units installed in single-family homes with one to four dwelling units, multifamily buildings, or in townhouse-style configurations where individual units have their own

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[7] https://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-Prices/Current-Outlook/Presentations/Heat-Pumps-Potential.pdf
[8] https://www.nyserda.ny.gov/-/media/Files/Publications/building-stock-potential-studies/residential-baseline-study/Vol-3-HVAC-Res-Baseline.pdf

heating systems. The market characterization describes where the market is now (based on equipment sold/installed in 2012 and after) and what percent of the equipment currently being sold is high efficiency.

Important conclusion associated with ASHPs:

- Efficiency for centrally ducted systems- Roughly 65 percent of the units sold in 2013 were considered "not high efficiency", with the other 35 percent reaching "Tier 1" efficiencies, zero percent reaching "Tier 2"
- Efficiency for ductless systems —over 97 percent of units sold in 2013 reached "Tier 2" efficiency levels.

**U.S. DOE Field Performance of Inverter-Driven Heat Pumps in Cold Climates, August 2015**[9]

To better understand and characterize heating performance, the US DOE Building America team, Consortium for Advanced Residential Buildings (CARB), monitored seven inverter-driven ASHPs across the northeast United States during the winter of 2013–2014. Researchers monitored heat output and electricity consumption. They then calculated coefficients of performance (COPs) over the course of the winter. The research included long- and short-term tests measuring power consumption; supply, return, and outdoor air temperatures; and airflow through the indoor fan coil. Airflow tests proved challenging and surprising because measured flow rates were only 50–80 percent of listed flow rates.[10]

Important conclusions:

- Overall monthly COPs of systems monitored were in the range of 1.1 to 3.1.
- Systems seemed able to deliver rated capacities at low temperatures (when loads were present).
- All heat pumps provided useful heating at subzero (Fahrenheit) temperatures, but efficiency varied significantly from site to site (even between sites with the same model heat pump).
- Measured airflow rates were much lower than listed values.[11]
- Manually setting the fan speed to "low" seemed to dramatically reduce capacity and efficiency.
- Higher return air temperatures near ceilings led to lower capacities and efficiencies.
- Setback strategies reduced electricity consumption, but frequent recovery did result in lower overall COPs.
- Most of the heat pumps in this project still provide heat at a lower cost than oil, propane, or electric resistance systems.

[9] http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/inverter-driven-heat-pumps-cold.pdf
[10] http://energy.gov/sites/prod/files/2015/09/f26/ba-case-study-inverter-driven-heat-pumps-cold.pdf
[11] Some manufacturers expressed concern regarding the method of capturing airflow as part of the research

### Ductless Mini-Split Heat Pump Customer Survey Results Study, September 2014[12]

The Massachusetts COOL SMART program offers rebates to customers for installing qualified, high-efficiency ductless mini-split heat pump (DMSHP) equipment in their homes. A web survey was conducted of participants in this program to better understand motivations for participating and how the DMSHP equipment is being used. The final survey included responses from 430 participants.

Important conclusions:

- DMSHPs are being installed as retrofit projects. Participant responses indicate that DMSHPs are being installed primarily in retrofit projects, rather than in new construction or major renovation projects. In fact, only one percent of participants indicated that the DMSHP was installed during the course of a new construction or major renovation project.
- The majority of participants are installing DMSHPs to obtain an improved level of comfort instead of a focus on saving energy. Roughly, one-third of participants indicate that saving money is a primary motivator for installing a DMSHP. The other two-thirds of participants report that improved comfort is the primary motivator for installing the DMSHP (i.e. providing a higher level of comfort; space not cooled/heated or cooled/heated adequately; or wanting zoned or central heating or cooling).
- DMSHPs are more often installed for cooling than heating. Almost 75 percent of participants use their DMSHP for both heating and cooling. However for those participants that use their DMSHP for only one function, the majority use their DMSHP for cooling. Ninety-nine percent of participants using only one function use their DMSHP for cooling, and only one percent of participants report that they use their DMSHP only for heating. Additionally, 82 percent of participants indicate that they provide all of the cooling for their space from the DMSHP, while only 19 percent indicate that they provide all of the heating for their space from the DMSHP.
- DMSHPs are being used to supplement, rather than replace existing heating systems. DMSHPs are on their own not meeting the needs of participants for heating the space they are installed in, at extremely cold temperatures. At temperatures below 15°F only 43 percent of participants indicate that their DMSHP provides sufficient heating to meet the needs of their entire space. While this could be an example of DMSHPs being sized for cooling requirements rather than heating requirements, it does point to the fact that DMSHPs are not typically installed to replace existing heating systems. For those participants who installed their DMSHP in a previously heated space (89 percent), only five percent removed the existing system. The rest of participants kept the existing system which now functions with the DMSHP to provide heating for the space.

### Commonwealth of Massachusetts Accelerated Renewable Thermal Strategy, January 2014

"DOER initiated the Commonwealth Accelerated Renewable Thermal Strategy (CARTS) program and retained a team consisting of Navigant Consulting Inc. (Navigant) and Meister Consultants Group (MCG) to identify the best strategies to rapidly spur renewable thermal (RT) market growth in Massachusetts. This team was tasked with analyzing the impacts of accelerated market growth on the Commonwealth,

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[12] http://ma-eeac.org/wordpress/wp-content/uploads/Ductless-Min-Split-Heat-Pump-Customer-Survey-Results1.pdf

researching best practices from other jurisdictions, and developing a strategy to guide DOER's market development efforts. The CARTS program covered the following high-efficiency technologies: cold climate air-source heat pumps, biomass pellet\chip boilers and furnaces (chips were only considered for use in larger building applications), ground-source heat pumps, solar thermal systems, biofuels, and biogas. Through prior analysis, DOER identified the main opportunities as being in heat pumps, biomass, and solar thermal, with a secondary role for biofuels and biogas."

Top priority Strategies identified in the CARTS Report;

- Develop statewide renewable thermal goals for each technology (governance);
- Leverage, coordinate, and expand efforts across state agencies to meet short-term goals (governance);
- Launch comprehensive RT technology information campaign with MassSave (marketing);
- Support implementation of long-term, stable performance-based RT incentives (governance);
- Integrate RT in state and public buildings via "leading by example" and/or other state energy programs (governance);
- Integrate RT into the Stretch Energy Code and other building energy codes (governance);
- Develop low-cost financing for renewable thermal through the MassSave HEAT loan program (finance).

## Savings associated with ASHP installations; Energy, Cost, Peak load and Emissions

A growing collection of reports, manuals, evaluations and studies from the Northeast, Mid-Atlantic, and Northwest, contribute to the characterization of energy, related cost, peak demand and greenhouse gas savings associated with the installation of ASHPs in homes. While savings for a few of the many retrofit scenarios have been well documented, there remain several scenarios with poorly understood energy/cost/peak demand/GHG savings. Many of these scenarios involve some form of fuel switching or fuel displacement, which makes direct comparison of pre and post energy use difficult to assess. The scenarios that involve some form of fuel switching are the scenarios most likely to be common in the Northeast and Mid-Atlantic region.

One of the key drivers of the growing interest in new heat pump technologies in the 2013 report was the potential for lower operating costs for heating and cooling. Cold-climate ASHPs can usually deliver heating at much lower costs than can electric resistance, however the difference in operating costs compared to fuel oil and propane has shrunk considerably. Fuel and electricity costs certainly play an important role in these cost comparisons, and these costs vary in time and throughout the region.

This section examines the expected energy savings for a number of different retrofit and new construction applications. This section also includes analysis exploring electric demand impacts and potential climate benefits (namely GHG reductions) from the use of this technology.

### *Energy and cost savings when Displacing/Replacing Electric Resistance-based heating*

Below are highlights of three studies where ductless, inverter-driven ASHPs were installed in homes with electric resistance heat. Investigators made heating savings calculations by looking at electric utility bills during heating seasons before and after the heat pumps were installed.

- In Connecticut, a two-ton ductless heat pump was installed in each of 124 homes. Billing analysis showed 2,700 kWh/y average savings. The highest savings were over 11,500 kWh/y, but 26 homes experienced no savings or net increases in consumption; one home used over 4,000 kWh/y more. (Swift 2013).
- In several regions in the Northwest, ductless heat pumps were installed in 93 homes. Average savings were 3,049 kWh/y, but the standard deviation in savings was nearly as large: 2,424 kWh/y (Davis 2013).
- A separate study in the Northwest focused on cold-climate installations: 20 homes in areas with at least 8,000 $HDD_{65}$ Average savings were similar: 3,200 kWh/y. As with the other studies, there was a very wide range in savings (Davis 2013).

These three studies show remarkable consistency in two areas:

- Average annual savings from installing a ductless heat pump were approximately 3,000 kWh when offsetting resistance;
- There is a tremendous range in savings in all samples.

These annual heating savings values are in line with the 1,200-4,500 kWh/ton identified in the NEEP meta-study. The wide range in savings is likely a result of these factors:

1. Home thermal loads vary widely (size, plan, envelope performance, etc.)
2. Occupant understanding and operation of the heat pump
3. Control configuration (e.g. where thermostats are located, what set points used)
4. Layout of home and zoning.
5. Comfort (e.g. occupants may use more heat when they know it's more efficient)

Predicting savings when offsetting resistance is difficult, but the most important factor is probably number one; savings will be much higher in homes with larger heating loads. At $0.166/kWh (EIA 2013i) saving 3,000 kWh equates to $498.

### *Energy and cost savings when Displacing/Replacing Oil-based Heating*

Another key savings opportunity for homes in the Northeast is reducing fuel oil consumption. According to the U.S. Energy Information Agency (EIA 2009), the average amount of fuel oil used for space heating (in homes that use oil) is 70.5 MMBtu or approximately 507 gallons per year. At $2.07 per gallon, the average price for the 2015-16 heating season (EIA 2013i), which translates into an annual heating cost of $1,050[13]. If this same heating load were met entirely with an ASHP, the heat pump would consume approximately 6,200 kWh/year[14] – costing $1,029 at $0.166/kWh. This simple example ignores other costs such as maintenance and electricity needed to operate the oil system, but there is very little difference in operating costs.

In many homes, *displacing* oil heat may be more practical than *replacing* oil heating (i.e., the oil heating systems will remain in place but operate less frequently). From an equipment standpoint, replacing an oil heating system with one or more efficient ASHPs may not be straightforward. If replacing an oil furnace, a central, ducted ASHP may be viable. If replacing a hydronic system, several fan coils and/or new duct systems may be necessary.

It is very hard to predict how much of the oil load will be displaced; the only certainty is that – as in the electric resistance studies – there will be a very wide variations in the displaced load. In the electric heat studies, the remarkably consistent, average savings near 3,000 kWh/y corresponds to an average thermal load displacement of 5,000 kWh or 17.1 MMBtu (again assuming seasonal COP of the heat pump is 2.5). With current energy prices, the Table 3 below shows the net annual heating savings may be very small.

**Table 3: Estimate of heating savings when ASHP displaces oil; based on electric resistance displacement savings of 3000 kWh/y**

| | | |
|---|---|---|
| Oil Savings | 164 gallons | $339 |
| Added Electricity | 2,000 kWh | $332 |
| | Net Annual Savings: | $7 |

[13] With annual oil system efficiency of 75%.
[14] With annual heat pump COP of 2.5.

While not as widespread as fuel oil, liquid propane (LP) is used in many homes in the region. At costs of $2.71 per gallon, propane is much more costly than fuel oil per unit of energy (EIA 2013i). Displacing propane with efficient, inverter-driven ASHPs may result in net heating savings of $175 in this example.

These examples are oversimplified by necessity; they make broad assumptions about system efficiency, they do not include other O&M costs, and they neglect electricity associated with fossil fuel systems. At current energy prices, however, the heating savings of ASHPs compared to oil-fired systems are quite modest.

### *Estimated Operating costs of ASHPs in New Construction*

When considering HVAC systems for new homes, there are several situations where using ASHPs may make practical, economic sense:

- Where natural gas is not available;
- Thermal loads are modest so that, even if gas is available, the initial costs and ongoing utility fees associated with gas service are not justified;
- All-electric “zero net energy” homes where renewable electricity sources provide all energy needed in the home.

There is overlap possible within these categories. Eliakim’s Way, a recent development on Martha’s Vineyard built by South Mountain, demonstrates this quite well. Natural gas is not available on the island, and developers built very efficient homes that could achieve zero net energy performance. Of eight homes evaluated, average ASHP consumption was 1,269 kWh/y. In addition, homes used an average of 539 kWh/y for resistance heat. At electricity rates of $0.153/kWh (EIA 2013i), this translates into an annual heating bill of $277. Most of the electricity used in these homes, however, came from PV systems; two of the homes were net generators of electricity. In this development, ASHPs were an obvious, simple choice to provide both heating and cooling with low up-front costs and operating costs (Rosenbaum 2011).

**Figure 5: These Eliakim’s Way homes (built by South Mountain Company) are heated primarily by ductless heat pumps. Several homes achieve zero net energy (credit: South Mountain)**

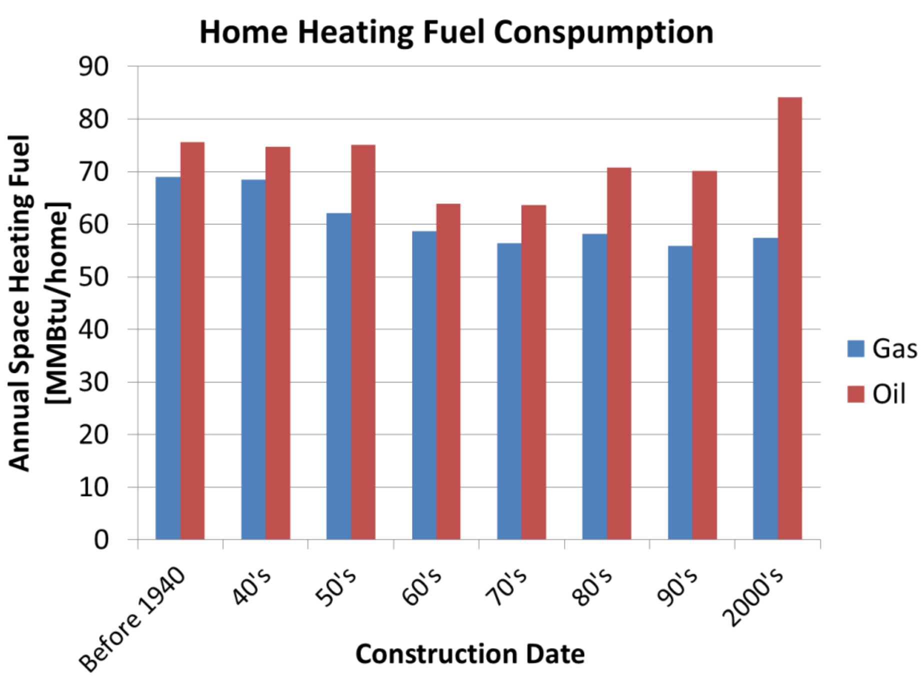
Elsewhere in Massachusetts, the builder and developer Transformations, Inc. has specialized in zero energy homes. The homes are very well insulated, very well air sealed, and typically use ductless ASHPs as the only heating and cooling system. Researchers were able to monitor ASHP performance in eight homes over several years and found typical heating energy ranged from 1,500 kWh/year to approximately 3,000 kWh/year (Ueno and Loomis 2014). At electric rates of $0.166/kWh, this translates into heating costs of $250-$500/year, but in these homes the solar electric systems provided most (and in many cases all) of the electric energy used on site. Transformations has found that ASHPs are the only practical heating and cooling systems for their low-load homes.

**Figure 6: A Transformation home in Easthampton, MA. ASHPs provide all heating and cooling. Photo credit: Building Science Corp**

### *Comparing Operating Cost across heating fuels*

According to RECS, the average heating load for homes in the Northeast is just over 50 MMBtu/y (EIA 2013g). Over the past half-century, the space heating consumption in homes has not declined substantially (see **Error! Not a valid bookmark self-reference.**). While efficient construction practices have made headway in the past decade or so, home size has also increased. In very recent years, with the adoption of recent versions of the

**Figure 7: Home space heating fuel from RECS (EIA 2013g)**



International Energy Conservation Code (IECC), it's hoped that home space heating loads will start to decline. In the two low-load examples above, the annual space heating loads are likely 10-25 MMBtu.

As discussed further in the following section, natural gas can often provide heating at lower costs than ASHPs. With historically low oil prices, costs for heating with oil may be quite comparable to ASHP heating costs. In very low-load homes, however, operating cost difference become quite small, and installation and infrastructure costs can be much more significant. An ASHP can provide both heating and cooling at costs that are often much lower than fossil-fired heating systems with separate cooling systems.

Table 4 shows example heating costs for several systems with several thermal loads. This table is oversimplified in many ways; it only shows one system efficiency, one set of fuel rates, and it makes assumptions about electricity needed for pumps, fans, controls, etc. for the non-heat pump systems. The simple efficiency calculations are shown to demonstrate three key points:

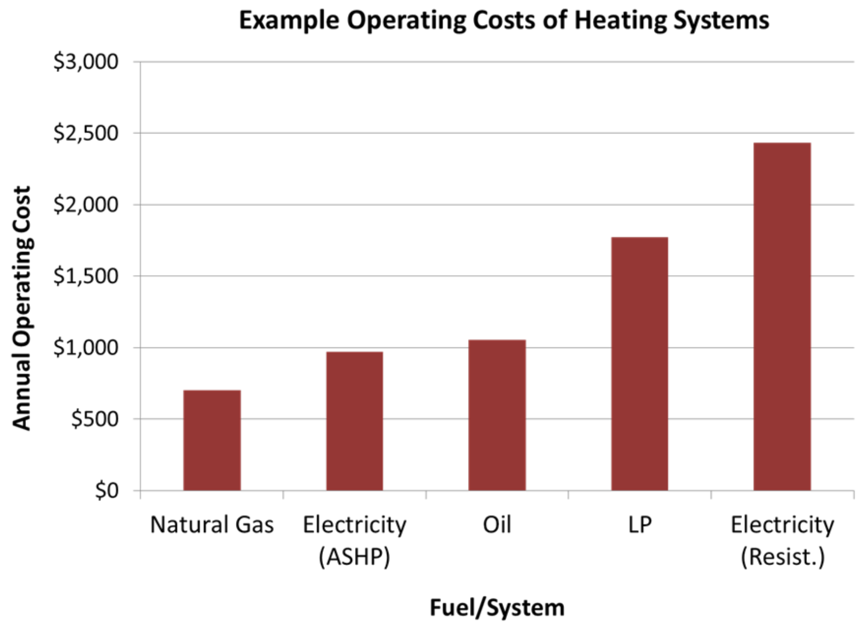
- Efficient natural gas systems have the lowest operating costs followed closely by ASHPs. Some studies suggest that the seasonal COP of heat pumps is closer to 3.0; in this case, gas and ASHP operating costs would basically be the same.
- Operating costs for electric resistance is approximately twice as high as gas and ASHP systems.
- As the heating loads become smaller, the differences in operating cost become much smaller. At 10 MMBtu/year – the load of an efficient apartment or a very efficient, zero-energy-type home – first-cost may be a much larger factor in system selection. At this point, the system with the lowest first-cost is often the most practical. This is often an ASHP (which provides both heating and cooling in one system) or even some electric resistance in extremely low load homes. There can be difficulty in even finding natural gas/oil/propane fueled systems designed to supply such small loads.

**Table 4: Estimated heating costs with various loads and fuels. Fuel prices from EIA (EIA 2016i)**

| | Fuel | Oil | LP | Natural Gas | Electricity (ASHP) | Electricity (Resist.) |
|---|---|---|---|---|---|---|
| | Seasonal Eff/COP | 80% | 90% | 90% | 2.5 | 100% |
| | Fuel Cost | $2.07 per gallon | $2.71 per gallon | $1.04 per therm | $0.166 per kWh | $0.166 per kWh |
| Example Home Type | Annual Heating Load | Approximate Annual Operating Cost* | | | | |
| Large, inefficient | 100 MMBtu | $2,111 | $3,547 | $1,406 | $1,946 | $4,865 |
| Average NE Home | 50 MMBtu | $1,055 | $1,774 | $703 | $973 | $2,433 |
| New, code-compliant | 30 MMBtu | $633 | $1,064 | $422 | $584 | $1,460 |
| Very efficient | 10 MMBtu | $211 | $355 | $141 | $195 | $487 |

*Fossil fuel operating costs include 150 kWh/y for fans, pumps, etc. per 10MMBtu of load. Costs do not account for different distribution efficiencies of various systems.

Figure 8: Estimated heating costs for an average Northeast home with an annual space heating load of 50 MMBtu




## *Greenhouse Gas Emission Savings*

Since 2013, our estimates for greenhouse gas (GHG) savings associated with ASHPs have changed fairly dramatically based on decreases in electricity generation-related emission profiles due to a changing fuel mix.

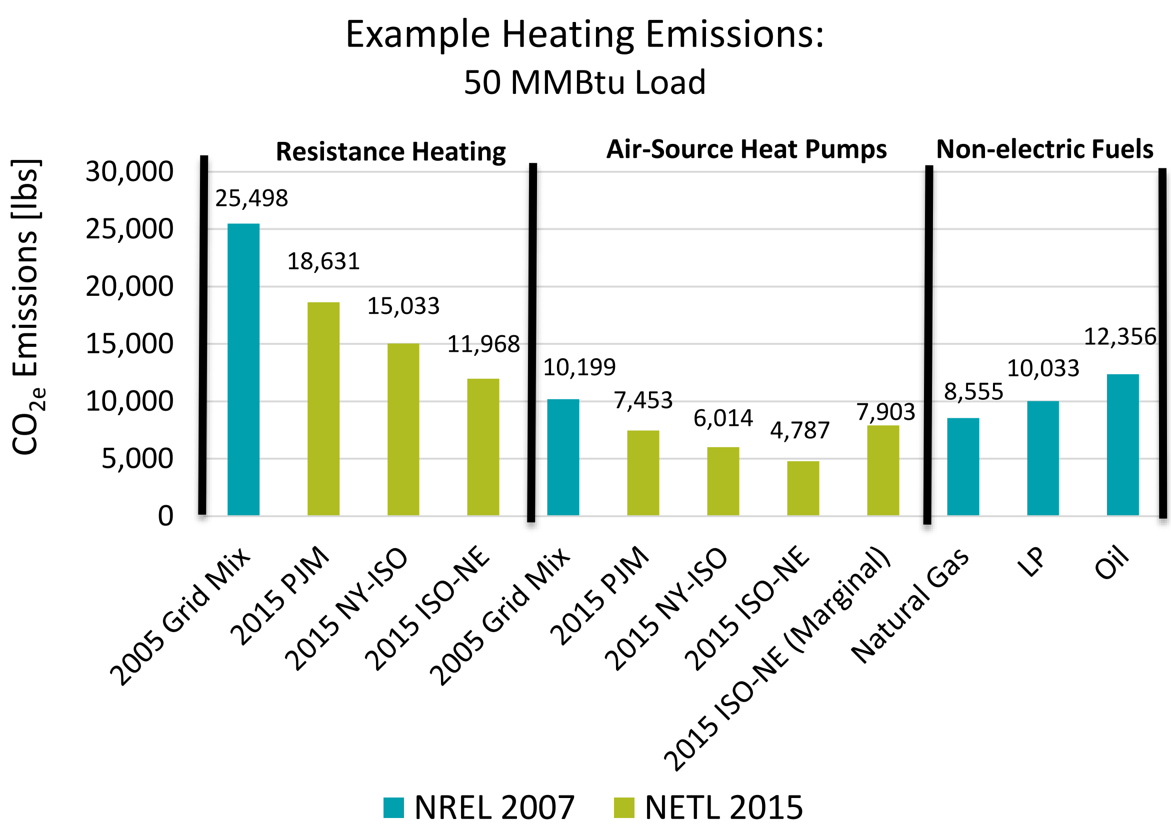
Table 5: Estimated greenhouse gas emissions (in equivalent pounds of CO2) for several fuels and systems.

| Fuel | Oil | LP | Natural Gas | ISO-NE Electricity (ASHP) | ISO-NE Electricity (Resist.) |
|---|---|---|---|---|---|
| Seasonal Eff/COP | 80% | 90% | 90% | 2.5 | 100% |
| $CO_{2e}$ [lbm] | 26.9 per gallon | 16.1 per gallon | 14.9 per therm | 1.35 per kWh | 1.35 per kWh |
| | Fuel and Emissions to meet 50MMBtu thermal load* | | | | |
| Fuel used | 450 gallons | 608 gallons | 556 therms | 5,862 kWh | 14,654 kWh |
| $CO_{2e}$ [lbm] | 12,356 | 10,033 | 8,555 | 7,903 | 19,755 |

*Fossil fuel system emissions include 750 kWh for fans, pumps, controls, etc. Values do not account for different distribution efficiencies of systems. ASHP and resistance heating values derived from ISO-NE marginal fuel mix and includes line losses. All $CO_{2e}$ figures include pre-combustion emissions.

Table 5 and Figure 9**Error! Reference source not found.** show global warming potential of several fuels/heating systems in units of equivalent pounds of carbon dioxide emissions ($CO_{2e}$). The values include emissions related to production, distribution and delivery of the fuel or electricity to a building – not just the emissions from the generation plants or the direct combustion of the fuels themselves (Deru and Torcellini 2007). We have used more updated emission values for electricity across the various regional ISOs to recalculate emission related to ASHP operation in comparison to other common heating fuels/systems. The calculations assume a 50 MMBtu thermal load in a home.

**Figure 9: Space heating-related Emissions across heating technologies and fuels, 2005 Assumptions Compared to 2015**[15]




In addition to regional variations, carbon dioxide equivalent emissions associated with electricity generation have been decreasing over time (see Figure 10). Natural gas and renewable energy have provided larger shares of the overall grid electricity supply, and this trend is likely to continue.

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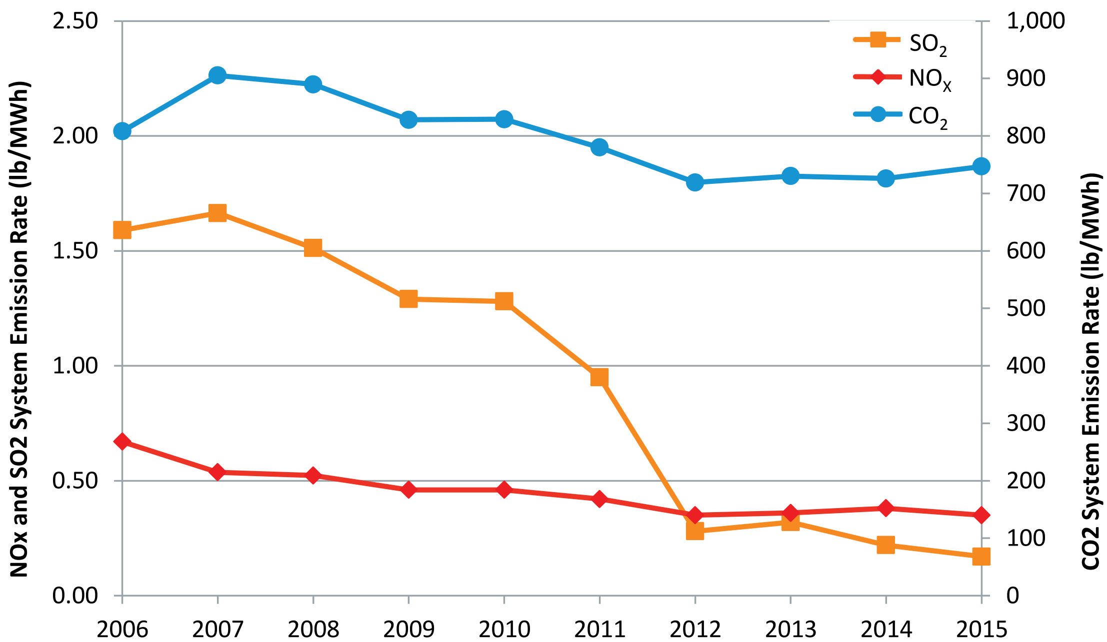
[15] Emission values assume an estimated 50 MMBtu thermal load. NREL 2007 figures are derived from source energy CO2e estimates published by NREL in 2007 and represent average fuel mix across entire Eastern Interconnection. All emission are based on yearly average fuel mixture, except “2016 ISO-NE (Marginal)” which is based on the fuel mixture of the marginal emission rate. NREL 2007 figures are derived from source energy CO2e estimates published by NREL in 2007. NETL 2017 figures are derived from the National Energy Technology Laboratory (NETL)’s Grid Mid Explorer, which provides source energy CO2e emissions estimates for various fuel mixes. Average fuel mixtures from PJM, NY-ISO, and ISO-NE, and marginal emissions from ISO-NE were imported into the Grid Mid explorer for lbs CO2e/kWh estimates, which were then revised to incorporate line loses of approximately 9.6 percent. The ASHP CO2e/kWh figures were then multiplied by 5,862 kWh to find the annual emissions associated with a 50MMBtu thermal load. The resistance heating CO2e/kWh figures were multiplied by 14,654 kWh to find the annual emissions associated with a 50 MMBtu thermal load.

Figure 10: Trend of lower CO2, NOx, and SO2 emissions from electricity generation; example showing New England region (ISO-NE Draft 2015 Emissions Report )




As more grid generation comes from renewable sources, emissions associated with grid-powered heat pumps will also decrease. In Vermont, for example, where emissions from grid generation are approaching zero, operating a heat pump on grid electricity may be a nearly emissions-free HVAC option.

## *Electric Demand Effects*

In the study done by KEMA on ductless heat pumps in Massachusetts and Connecticut (KEMA 2009), both summer and winter peak reductions (when displacing electric resistance) were estimated using TMY2 data for several sites in the Northeast. In Boston, for example, there is an estimated 24 Watt on-peak reduction for every 1,000 Btu/h in heat pump capacity. When displacing electric resistance heating, a 2-ton heat pump (24,000 Btu/h) results in an average demand reduction of 576 Watts. Installing approximately 1,700 2-ton heat pumps would result in a 1 MW winter peak reduction when displacing electric resistance.

A more difficult question arises when heat pumps are used to replace or displace oil or other fuels in homes. If these heat pumps displace older, inefficient cooling systems (such as window units), there will still be a decrease in summer demand (KEMA 2009). In the winter, however, shifting from fossil fuels to ASHPs will increase winter demand. Using the same Boston example above[16], installing a two-ton heat pump to displace fossil fuel heat will increase average winter on-peak demand by 16 W per 1,000 Btu/h capacity. Each two-ton heat pump would increase winter peak demand by 380 Watts on average; 2,600 two-ton heat pumps would increase winter demand by approximately one MW.

[16] Using a heat pump COP of 2.5, peak impacts from (KEMA 2009).

In a more recent study by Emera Maine (EMI 2014), monitoring 35 buildings found that there was an increase in peak demand both in the summer (140 Watts on average) and winter (350 Watts) after heat pumps were installed. The cooling increase is partly explained in that many of the buildings did not have cooling systems before heat pumps were installed.

These demand impacts will vary widely with weather, region, and even on a home-by-home basis. If heat pumps start to take a larger share of the residential market, however, utilities and regulators will need to examine the potential impacts on generation, transmission and distribution.

NEEP's Residential Energy Efficiency Database (REED, NEEP 2016) provides links to the latest technical reference manuals (TRMs) used by state and utility efficiency programs to calculate energy and demand savings. A review of these TRMs shows some trends in how programs in the Northeast account for demand impacts of efficient heat pumps. Many programs account for peak cooling impacts only. Programs that do account for winter peak effects do so by again comparing efficient heat pumps to "baseline" heat pumps, and demand savings (kW) is based on differences in HSPF. As discussed earlier, some TRMs address fossil fuel savings when an ASHP displaces gas, oil, or propane heat. None of the TRMs, however, appear to address increases in winter electric demand when fossil fuels are displaced.

| ASHP Demand Savings Characteristics in TRM | CT | DE | DC | ME | MA | MD | NJ | NY | PA | RI | VT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Both heating and cooling demand savings considered | X | | | X | X | | | | | X | X |
| Differentiation for ductless or mini-split ASHPs | X | X | X | X | X | X | | | X | X | X |

## *Regional Savings Potential*

Based on per unit energy savings estimates for ASHPs and the potential market for the technology discussed above, Table 6 estimates the regional savings potential under three scenarios: displacing oil heating with ASHPs, displacing propane heating with ASHPs and displacing electric resistance heating with ASHPs in existing homes. This is presented as an example only; the table necessarily includes many assumptions, but all assumptions are based on studies discussed previously. These values show savings related to heating only. There is also potential for cooling energy savings (when ASHPs displace older, inefficient air conditioners).

**Table 6: Regional Savings Estimates for ASHP adoption in existing homes (NEEP territory) when displacing oil, propane and electric resistance. Potential numbers of homes are estimates based on RECS information discussed above. Offset load (50 MMBtu) per home**

| | # of housing units shifting from Oil | Per unit annual cost savings ($) | Per unit annual carbon savings (CO2e) | % of load Displaced | Total annual cost savings ($) | Total Annual GHG savings (CO2e) |
|---|---|---|---|---|---|---|
| Savings from oil boiler/furnace to ASHP conversion | 6,100,000 | 82 | 4453 | 80% | 400,160,000 | 21,730,640,000 |

| | # of housing units shifting from Propane | Per unit annual cost savings ($) | Per unit annual carbon savings (CO2e) | % of load Displaced | Total annual cost savings ($) | Total Annual GHG savings (CO2e) |
|---|---|---|---|---|---|---|
| Savings from propane boiler/furmace to ASHP conversion | 700,000 | 801 | 2130 | 80% | 448,560,000 | 1,192,800,000 |

| | # of housing units shifting from Electric resistance | Per unit annual cost savings ($) | Per unit annual carbon savings (CO2e) | % of load Displaced | Total annual cost savings ($) | Total Annual GHG savings (CO2e) |
|---|---|---|---|---|---|---|
| Savings from electric resistance to ASHP conversion | 2,900,000 | 1460 | 11852 | 80% | 3,387,200,000 | 27,496,640,000 |
| | | | | | | |
| **Total Regional Savings** | | | | | **$4,235,920,000** | **50,420,080,000** |

The savings in new homes may be much more compelling but harder to quantify. In efficient new homes, inverter-driven ASHPs offer the potential to go without fossil fuels – to use a single electric system for all heating and cooling needs. Efficient ASHPs can provide heating savings compared to propane and heating costs similar to oil. Instead of a cost premium to install heat pumps in existing homes, in new homes, efficient ASHPs can often be installed at lower costs than fossil fuel alternatives;

a single system can provide both heating and cooling, and it avoids costs related to gas piping, oil and propane tanks, etc.

### *Existing Promotional Activity for ASHPs*

Over the past few years, the region has witnessed a surge in activity aimed at promoting the growth of ASHP technology between regional/national efforts, state/utility-based energy efficiency and renewable thermal programs as well as community level efforts. An outgrowth of the Leadership Advisory Committee that assisted in developing the 2013 Strategy Report, was the Northeast/Mid-Atlantic ASHP working group that NEEP has facilitated since 2013. The working group is a vehicle to coordinate market strategy implementation. NEEP's regional ASHP working group has met quarterly via webinar. The working group is made up of energy efficiency program administrators, renewable thermal program administrators, state policymakers, manufacturers, ASHP program implementers, etc.

**Energy Efficiency/Renewable Thermal Programs**

While a growing number of rate-payer funded energy efficiency programs offer promotional activities including incentives to encourage the adoption ASHP systems, the region has also witnessed the growth of several renewable heating and cooling initiatives aimed at promoting the growth of renewable thermal technologies (which typically include ASHPs, GSHPs, solar thermal, biomass systems, district heating and cooling, among others). See Table 7 for a combined summary of both energy efficiency program administrators and renewable thermal program administrators and their incentive offerings. While many offer monetary incentives to consumers for purchasing high performing ASHPs, many provide complementary market support such as consumer education, installer training, etc.

**Table 7: Incentive and Requirement Summary for Ductless Heat Pumps**

| Statewide/Territory specific program | Rebate Incentive | ENERGY STAR certification | HSPF | SEER | EER | Other Requirements |
|---|---|---|---|---|---|---|
| Connecticut[17] | $300/home (Single-Zone) | X | 10 | 20 | | |
| | $300/home (Multi-Zone) | X | 9 | 18 | | |
| Massachusetts | $250 | X | ≥ 9 | ≥ 18 | | |
| | $500 | X | ≥ 11 | ≥ 20 | | |
| Massachusetts Clean Energy Center[18] | $625 (Single-Zone) | X | ≥ 10 | ≥ 20 | ≥ 12.5 | NEEP ccASHP Spec, 100% of rated heating capacity delivered at 5°F |
| | $625/ton (Multi-Zone) | X | ≥ 9 | ≥ 17 | ≥ 12.5 | |

[17] A $1,000 rebate is available for homes with existing electric resistance heating WITH a Home Energy Assessment prior to installation

[18] Income eligible adders of $175/system or ton and $675/system or ton. Maximums apply for number of outdoor units eligible for rebates and total rebate dollar amount by project site.

| | | | | | | |
|---|---|---|---|---|---|---|
| Rhode Island | $250 | X | ≥ 9 | ≥ 18 | | |
| | $500 | X | ≥ 11 | ≥ 20 | | |
| Vermont | $600 (Single-Zone) | | ≥ 10.3 | ≥ 20 | ≥ 12 | COP @5°F ≥ 1.75; operation at -5° |
| | $600/800 (Multi-Zone) | | ≥ 10 | ≥ 17 | ≥ 12 | |
| New Hampshire[19] | $250/ton of cooling | X | ≥ 8.5 | ≥ 15 | ≥ 12.5 | |
| | $500/ton of cooling | X | ≥ 10 | ≥ 18 | ≥ 12.5 | |
| Maine | $500 (Single-Zone) | | ≥12 | | | |
| | $750 (Multi-Zone) | | ≥10 | | | |
| New Jersey | $500 | X | ≥10 | ≥ 20 | ≥12.5 | |
| Pennsylvania (PP&L) | $100/ton | | ≥ 8.6 | ≥ 16 | 12.5 | |
| | $150/ton | X | ≥ 9.5 | ≥ 17 | 12.5 | |
| | $200/ton | | 10.5 | 19 | 12.5 | |
| Energy Save PA | $100 | | ≥ 10.5 | ≥ 15 | | |
| Washington D.C.[20] | $300 | | ≥ 9 | ≥ 18 | ≥ 12.5 | |
| | $500 | | ≥ 10 | ≥ 20 | ≥ 13 | |

**Table 8: Incentive and Requirement Summary for Ducted Heat Pumps**

| Statewide/territory specific program | Rebate Incentive | ENERGY STAR certification [3] | HSPF | SEER | EER | Other Requirements |
|---|---|---|---|---|---|---|
| Connecticut | $500 | X | ≥ 10 | ≥ 18 | ≥ 13 | |
| Massachusetts | $250 | X | ≥ 8.5 | ≥ 16 | | |
| | $500 | X | ≥ 9.6 | ≥ 18 | | |
| Massachusetts Clean Energy Center[21] | $625/ton | X | ≥ 10 | ≥ 17 | ≥ 12.5 | NEEP ccASHP Spec, 100% of rated heating Capacity Delivered at 5°F |
| Rhode Island | $250 | X | ≥ 8.5 | ≥ 16 | | |
| | $500 | X | ≥ 9.6 | ≥ 18 | | |
| New Hampshire | $70/ton | X | | ≥ 15 | ≥12.5 | |
| Maine | $500 | X | ≥10 | | | |
| New Jersey | $300 | | ≥10 | ≥ 16 | ≥13 | |
| | $500 | | ≥10 | ≥ 18 | ≥13 | |
| PSEG- Long Island | $200 | | ≥8.5 | ≥16 | ≥13 | |
| | $350 | | ≥8.5 | ≥17 | ≥13.5 | |

[19] $250/ton Incentive available from New Hampshire Electric Coop for Heat Pump Systems offsetting 80% of total heating load. Must submit two (2) years heating fuel usage, type and efficiency of existing equipment

[20] Updated rebate amounts "coming soon"

[21] Income eligible adders of $175/system or ton and $675/system or ton. Maximums apply for number of outdoor units eligible for rebates and total rebate dollar amount by project site.

| | | | | | | |
|---|---|---|---|---|---|---|
| Pennsylvania (PP&L) | $200 | | ≥8.5 | ≥ 16 | ≥12.5 | |
| Energy Save PA | $250 | | ≥8.5 | ≥ 14.5 | | |
| | $325 | | ≥8.5 | ≥ 15 | | |
| | $400 | | ≥8.5 | ≥ 16 | | |
| Washington D.C.[22] | $500 | | ≥ 9 | ≥ 16 | ≥ 13 | |
| | $1000 | | ≥ 9.5 | ≥ 18 | ≥ 13 | |

In addition to the programs highlighted in Table 7 and Table 8, there are other programs and initiatives in the process of planning and/or launching in the region.

**Massachusetts Clean Energy Center (MassCEC)**

The Massachusetts Clean Energy Center (MassCEC) is a publicly-funded agency dedicated to accelerating the success of clean energy technologies, companies and projects in the Commonwealth—while creating high-quality jobs and long-term economic growth for the people of Massachusetts. MassCEC's Clean Heating and Cooling programs offer rebates to support the installation of renewable heating, hot water, and cooling technologies at homes across the Commonwealth. These technologies offer a high level of comfort, are generally more cost-effective to operate than traditional systems, and reduce your carbon footprint. MassCEC has announced a $30 million commitment to these technologies through 2020. Rebates of up to $6,000 are available. The program was recently expanded to include commercial mini-split installations, and are in the process of creating a VRF program.

**Massachusetts Alternative Portfolio Standard**

The Massachusetts Department of Energy Resources (DOER) has filed draft regulations to include renewable thermal in the Massachusetts Alternative Portfolio Standard (APS) pursuant to Chapter 251 of the Acts of 2014. The Alternative Energy Portfolio Standard (APS) was established as of January 1, 2009, under the Green Communities Act of 2008. APS offers a new opportunity for Massachusetts businesses, institutions, and governments to receive an incentive for installing eligible alternative energy systems, which are not renewable. Similar to the RPS, it requires a certain percentage of the state's electric load to be met by eligible technologies. Retail Electric Suppliers are required to document compliance with the APS in annual filings submitted to DOER. Suppliers can meet their compliance obligations by purchasing Renewable Energy Certificates (RECs) from qualified generators and/or making Annual Compliance Payments (ACPs) to MassCEC. The revenue generated from ACPs is used to fund new renewable generation projects throughout the Commonwealth.

**Connecticut Renewable Thermal Activity** - Feasibility of Renewable Thermal Technologies in Connecticut

[22] Updated rebate amounts "coming soon"

Yale Center for Business and the Environment is partnering with the Connecticut Green Bank, Eversource, United Illuminating and the Department of Energy and Environmental Protection (DEEP) to develop optimal policies and strategies that will advance renewable thermal technologies (RTT) in Connecticut. The purpose of the project is to quantify a realistic contribution from RTT to achieve Connecticut's overall target of reducing greenhouse gases, and to establish the necessary knowledge for qualified policy choices and strategies to advance RTT in Connecticut. The project will include a broad specter of RTTs, which will be evaluated with regards suitability for achieving Connecticut's long term goals and visions. Examples of technologies that will be included are air source heat pumps, ground source heat pumps, solar thermal hot water, biomass heating and district heating and cooling.

**New York State Energy Research and Development Authority (NYSERDA)**

The New York State Energy Plan, published in July 2015, set state carbon reduction targets of 40 percent by 2030 and 80 percent by 2050. Renewable thermal is expected to play a role in meeting those targets.

To support those goals, NYSERDA is developing a policy framework for renewable thermal technologies that will allow the sector to contribute to carbon reduction goals and support the creation of a viable long-term market for a range of renewable thermal technologies. The framework is expected to build on existing NYSERDA biomass and solar thermal programs, develop new programs where gaps exist, and provide greater context of renewable thermal activities across the state.

NYSEDA is also conducting a market characterization study for ductless mini-split heat pumps to assess current baseline conditions. The study should be completed in early 2017.

To better understand in-field performance of ASHP systems, NYSERDA has also launched Program Opportunity Notice (PON) 1327.[23] This PON seeks to address barriers to widespread adoption of heat pumps, including cold-climate split-system air-source heat pumps and ground-source heat pumps, and low-capacity (maximum input rating of less than 45,000 Btu/hour) natural gas furnaces, by demonstrating and validating the energy savings, cost-effectiveness and other performance indicators of these systems. This project will involve the field testing of roughly 80 unique systems.

**Community level Programs**

After two successful years of focus on rapidly increasing the deployment of solar PV in the residential sector, Solar Tompkins has turned to the promotion of non-fossil fuel alternatives and efficiency measures for home heating and domestic hot water, which, combined, account on average for three quarters of the total energy use in Tompkins County homes. The HeatSmart Tompkins program accelerates the transition of home-heating away from fossil fuels via deployment of highly efficient air- and ground-source heat pumps in combination with improvement of building efficiency through better insulation and air sealing. This program will be offered in Tompkins County for a second time beginning in early 2017.

[23] PON 3127 Emerging Technology Demonstration Projects - Residential HVAC

This is a limited-time program intended to jump-start the rate of homeowners adopting both building envelope and heat pump technologies. Heatsmart Tompkins offers tremendous opportunities and benefits for participating residents. By offering lower-than-market rate pricing and a simple process with vetted Installation Partners, the program makes home energy efficiency easily achievable. Insulation and air sealing, together with an air- or ground-source heat pump system can provide great comfort, immediate cost savings, and have a positive environmental impact against climate change by reducing greenhouse gases emitted as a product of heating with fossil fuels. Further, heat pumps can be powered by renewably-generated electricity which allows the next step toward shrinking household carbon footprints.

**Clean Energy States Alliance**

CESA's renewable thermal project works with member states to evaluate renewable heating and cooling technologies and develop policies and programs that support best practices to further develop the market for renewable thermal technologies.

The project currently covers the following technologies: advanced biomass heating systems, air source heat pumps, ground source heat pumps, and solar thermal. CESA members are interested in learning more about these relatively new technologies, including their overall efficiency, performance, and emissions attributes. In addition to system performance, states are interested in the sustainability of feedstocks (wood pellets), air quality impacts, and project costs. Lastly, several state members have adopted, or are in various stages of pursuing, thermal provisions for state Renewable Portfolio Standards. CESA involvement with RPS thermal provisions has mostly fallen under our State-Federal RPS Collaborative project.

To date, the primary focus of the renewable thermal project has been on biomass thermal system efficiency, emissions, testing, and standards. CESA is researching and drafting biomass thermal program best practices and hopes to develop a collaborative approach to biomass thermal policy. Policy recommendations for biomass thermal storage systems are under development.

Other issues of common interest for potential collaboration in renewable thermal include pellet sustainability, metering and monitoring heating and cooling systems, emissions and efficiency testing, standards, and program best practices. Like many of our other projects, CESA staff research and survey program best practices from around the country, facilitate discussion among state members, and seek consensus on best practices for accelerating market uptake.

**Renewable Thermal Alliance**

The Renewable Thermal Alliance (RTA) is a private – public partnership established to develop the infrastructure for large-scale deployment of renewable thermal technologies (RTTs). The five-year mission of the Alliance is to catalyze a regional market for renewable thermal technologies through sharing best practices and harmonizing standards, explore asset quality, provide analytic tools and develop scalable financing models. Based on the notion that the thermal market is regional rather than state bound, that viable business models can add value, that standardization and harmonization will drive volume and that financing models are central to leverage private capital, a partnership across states has been established. Yale Center for Business and the Environment, Connecticut Green Bank, the energy efficiency program administrators in Connecticut and NYSERDA had played leadership roles.

The potential role that RTTs can play in achieving states' climate ambition is gaining focus across the US. Thermal end uses accounted for respectively 70% and 44% of energy delivered to residential and commercial customers in 2013 (EIA AEO 2015). Renewable thermal can replace existing thermal end uses based on fossil fuels and electricity, and thus provide an essential contribution to achieving states climate ambitions.

**ASHP Leasing Programs**

The Vermont-based Cold Climate Heat Pump Program allows homeowners to rent equipment for up to a 15-year term. Monthly costs range from $41.99 for a ¾-ton unit to $54.99 for a 1.5-ton unit, and with this program up-front cost is effectively eliminated. The program also requires an authorized installer to provide equipment and labor. Installation and materials are built into the flat monthly fee. Green Mountain Power (GMP) is responsible for the service and maintenance of the ASHPs.

The Cold Climate Heat Pump Program only had 300 units for lease in 2013, and customer reaction was so fast that the program was tapped out in only days. The program continues to see high demand with over 1,000 units being leased. The complete program description is available online: http://products.greenmountainpower.com/product/ductless-heat-pump/

Maine's legislature and Governor recently approved new legislation, "An Act To Enable Low-income and Other Customers Greater Access To Efficient Electric Heat Pumps through Unique Financing and Third-party Installation and Maintenance" that establishes a new ASHP program which allows transmission and distribution utilities to implement programs to provide efficient electric heat pumps to customers who are unable to purchase and install heat pumps due to income or other reasons. The program's design and operation is subject to review and regulation by the Public Utilities Commission and may include rates for customers participating in the program to cover program costs, which costs may be paid only by customers participating in the program, and the program must offer customer choice of qualified third-party installers. The utility may own the heat pump provided to a customer participating in the program and may charge the customer for the costs associated with providing the heat pump and the customer must be provided an option to later buy the heat pump provided on reasonable terms approved by the commission.

## Identification and Prioritization of Market Barriers and Market Opportunities

In order to design effective market intervention strategies to accelerate market adoption of ASHPs in the region, we must understand both key barriers in the market today as well as opportunities in the marketplace to leverage.

NEEP surveyed the regional ASHP working group, made up of heat pump manufacturers, efficiency program administrators, engineers, contractors, and other interested parties to better understand the persistent barriers faced by the ASHP market. The survey asked respondents to rank the severity of market barriers that had originally been identified by the 2013 report, on a 1-4 scale, four representing a most critical market barrier. The survey also sought to identify market barriers that emerged since 2013. NEEP received 35 responses in the summer of 2016 which provided the input to the results below. The highest scoring barriers are shaded red and the high scoring market opportunities are shaded green. One interesting observation is that nearly every barrier/opportunity that had been identified in 2013 received scores over 2.5 in 2016 suggesting that there haven't been major shifts in market barriers.

### *Market Barrier/Opportunity Survey Results*

**Table 9: Market Barriers**

| Listed # | Category | Market Barrier | Weighted Average (1-4) |
|---|---|---|---|
| 1 | Consumer | Poor awareness of ASHP technologies | 3.24 |
| 2 | Consumer | Negative perceptions/psychology (comfort perceptions like heat pumps don't work in cold climates, noisy, long recovery from setback, "electric heating is bad", etc. | 2.57 |
| 3 | Consumer | Aesthetics of ductless fan coils | 2.41 |
| 4 | Consumer | High upfront cost | 2.87 |
| 5 | Installer | Inability to find an experienced installer | 2.03 |
| 6 | Installer | In general, HVAC community lacks familiarity/experience installing this technology (particularly ductless) | 2.49 |
| 7 | Installer | Poor sizing/installation practices lead to system under performance | 2.68 |
| 8 | Technology | Inability of some systems to deliver sufficient amounts of heat in cold conditions (i.e. one for one replacement of existing system) | 2.57 |
| 9 | Technology | Inability of some systems to distribute heat/cool effectively | 2.27 |
| 10 | Technology | Effective control systems to manage multiple heating systems | 2.84 |
| 11 | Metrics | Current industry test method does not adequately characterize cold weather performance of HPs | 3.27 |
| 12 | Program | Program regulators don't allow promotion of technology (i.e. provide incentives) in fuel switching situations | 2.67 |
| 13 | Cross-cutting | Challenge of accurately evaluating/predicting savings, including defining baseline energy use for various scenarios (various fuels, displacement vs. replacement) | 3.27 |

| | | | |
|---|---|---|---|
| 14 | Policy | Unfamiliarity of ASHP technology within policymaker community and its relation to existing policy goals (i.e. energy/ghg reduction, zero energy buildings) | 2.65 |
| 15 | Policy | Momentum in policy community for natural gas expansion (neighborhood-level and generation-level) | 2.65 |
| 16 | Policy | Unclear tradeoff between reducing primary energy/GHG emissions, building electric load | 2.63 |

**Table 10: Opportunities to leverage**

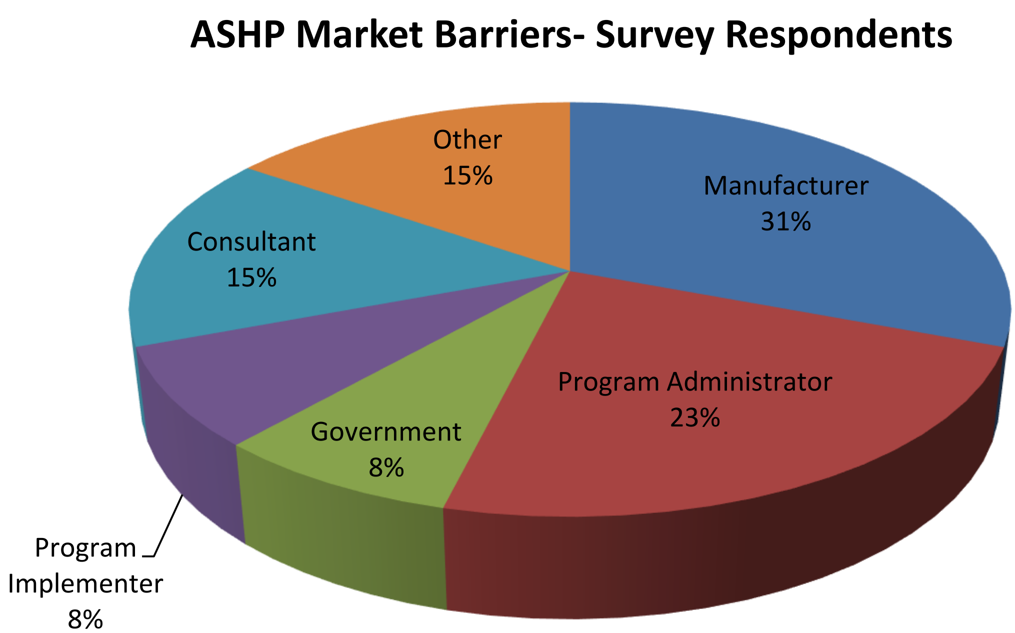
| Listed # | Category | Market Opportunity | Weighted Average (1-4) |
|---|---|---|---|
| 17 | Consumer | Fuel cost savings advantage over electric resistance, oil, and LP | 2.97 |
| 18 | Consumer | "Green technology"- GHG emission advantages compared to oil/propane | 2.73 |
| 19 | Consumer | Consumers increasingly looking for cooling solutions throughout region | 2.94 |
| 20 | Consumer / Installer | "Install-ability" of ductless systems (simple and fast for knowledgeable installer) | 3.11 |
| 21 | Consumer | Inefficient heating/cooling systems prevalent in small multifamily (under four units) | 2.83 |
| 22 | Policy | On local scale; Interest in avoiding infrastructure costs of natural gas expansion (into new housing developments) | 2.44 |
| 23 | Policy | On state/regional scale; Interest in avoiding expensive expansion of gas infrastructure, easing gas bottlenecks | 2.69 |
| 24 | Policy | Increased interest/promotion of Renewable thermal technologies | 2.62 |
| 25 | Metrics | ccASHP Specification provides tool to better identify/select systems for cold-climates | 3.03 |

**Table 11: Respondents provided additional write-in comments regarding barriers/opportunities:**

| | |
|---|---|
| **Consumer Barriers** | "lack of awareness that heat pumps even exist, or if there is awareness, especially a sense that "they don't work in cold climates", or "they don't work below freezing".. |
| | "Costs vary significantly in the market, with a large range in pricing for the installed cost of essentially the same system" |
| | With the drop in oil prices, comfort cooling is the main reason to buy in 2016. All of these issues are getting less and less significant. |
| **Installer Barriers** | Installers are available, but may not themselves yet trust or be willing to recommend this technology for primary heat. |
| | Many northern installers have limited experience with ducted heat pumps and don't offer them as an option. |
| | There is poor informational feedback on how efficiently the unit is operating once installed, therefore there is a lack of readily available accurate information on system economics relative to oil and gas-fired systems. |

| | |
|---|---|
| **Program Barriers** | Inability to develop savings calculations without believable seasonal COP values. |
| | Better models for savings are not needed for different types of equipment or in differing installation use cases. |
| **Policy Barriers** | Easiest way to get greater heat pump adoption is for regulators to allow electric utilities to promote fuel switching. This will create the larger carbon savings than energy efficiency programs, at no additional cost.<br>Furthermore, the incremental electric sales will reduce electric rates. Regulators very rarely understand that electricity, when used in efficient heat pumps, is by far the cleanest heating fuel in terms of carbon emissions. Heat pumps in New England reduce natural gas home heating $CO_2$ emission by 40 percent and oil emission by 60 percent. There is considerable policy misalignment between the jurisdiction with climate change response mandates and utility regulatory bodies' rules. |
| **Cold climate metrics Barriers** | With respect to ccASHP Spec and program promotion, metrics have to be proved. Show the math, using real numbers on upfront costs, fuel savings, etc. |
| **Technology** | CO2-based systems may be available in the near future and their 1/2000 of the global warming potential of present-day refrigerants. |

**Figure 11: Stakeholder breakdown of survey respondents**



## Regional Market Transformation Strategies

With a strong understanding of the current market, including key barriers and opportunities to leverage, regional stakeholders worked collectively through the regional ASHP initiative to develop strategies that will effectively overcome the barriers and leverage the market opportunities.

This section describes seven key regional market transformation strategies, including tactical details for each of them. While they are framed as recommendations to the broad community of regional stakeholders, the sub-strategies identify specific stakeholders for implementation. Earnest deployment of the recommended market strategies outlined here should produce the necessary market conditions in order for accelerated and sustained uptake of ASHPs throughout the Northeast and Mid-Atlantic regions.

### List of Regional Market transformation strategies

1. Increase consumer education and awareness
2. Increase installer/builder awareness of, and confidence in, ASHP through expanded training and education
3. Reduce upfront costs of installed systems through robust and aligned promotional programs and the support of alternative business models
4. Mobilize state and local policymakers to expand support for ASHPs
5. Promote advanced control technologies to allow automated coordination among multiple heating systems
6. Enable the promotion of climate-appropriate ASHPs through improved performance metrics
7. Develop more accurate tools to predict energy, cost and GHG savings associated with ASHP installation through collection and analysis of real world performance data

### *Strategy #1: Increase consumer education and awareness*

Many consumers in the Northeast simply do not know what an ASHP is; if they do, many believe that it is not appropriate for heating applications in colder Northeast climates. A decade ago, they may have been correct. For this market to truly flourish, consumer awareness of and confidence in ASHPs as a cold-climate heating technology must be solidified. There must be a greater understanding about the existence, availability, and potential benefits of ASHPs that operate, and operate efficiently, at cold temperatures. Efficient, inverter-driven ASHPs are a relatively new technology in the U.S. marketplace with significant performance improvements over traditional ASHPs. These messages must come from a variety of stakeholders including independent trusted sources such as state/federal agencies, and utility/energy efficiency program administrators, or a coordinated regional platform funded by such organizations.

Fortunately, many entities throughout the region, including energy efficiency programs and increasingly renewable thermal programs are promoting ASHPs (See Efficiency Maine, Efficiency Vermont, and the Massachusetts Clean Energy Center). Of course manufacturers, distributors and installers are also promoting these systems. All of these actors market to and educate consumers.

Understanding when and where consumers look for information is important for determining methods for disseminating information on efficient ASHP options. If a homeowner is looking to replace an old or failed heating system, they may go to the internet to search for replacement options such as a utility website to find information on heating systems and available incentives. Information on the efficient ASHP technology should be included with more traditional heating systems on the website. One region of the country where significant outreach and education efforts has been undertaken in promotion of ASHPs is the Pacific Northwest. The Northwest Energy Efficiency Alliance (NEEA) developed the "Going Ductless" marketing program to increase awareness (http://goingductless.com).

In order to improve the effectiveness of the broader industry message, regional stakeholders should implement a number of strategies.

**Strategy 1a) Regional market actors should continue to deliver consumer-oriented educational messages promoting ASHP technology.** Messaging should s**olidify** the **reputation of ASHPs as a heating technology, not solely a cooling solution. Messages should be disseminated by utilities, state agencies, NGO's, manufacturers/retailers and installers through a variety of channels (i.e. efficiency program websites, POP materials, TV, radio, etc.). Regional stakeholders should consider funding a regional ASHP informational campaign/website that communicates basic educational ASHP messages with a single "voice."**

**Strategy 1b) Non-manufacturer market actors should develop and disseminate case studies and testimonials for different heat pump applications, including centrally ducted systems. These are often considered more credible by consumers when they are provided by parties other than the product manufacturer.**

ASHPs present unique value propositions to several categories of consumers. Based on enhanced value proposition, there are target markets and applications that marketing should be focused on.

**Target Markets and Applications for Efficient ASHPs**

The 2013 Leadership Advisory Committee identified the following applications that are particularly attractive for efficient ASHPs:

- Existing homes without duct work looking for an expanded cooling solution - ductless ASHPs provide heating AND cooling. Customers are initially attracted by the cooling function but can learn to effectively utilize the heating function to achieve exciting savings.
- Existing homes heating w oil/propane/electric resistance – adding a heat pump to a high traffic zone without removing existing heating system; comfort from zoned heating or addition of cooling is often the chief motivation. The energy use of the existing heating system is displaced by the new heat pump, but the existing system may be left in place for backup or to supplement during the coldest days. With low oil/propane prices, the return is more about added comfort than it is about cost savings. Cost savings in electric resistance scenarios is always going to be compelling.
- New construction, low-load homes – fossil-fuel heating systems are certainly still the standard in the region, but ASHPs offer a technology better suited for low-loads as they can operate at part-load over longer periods of time offering superior efficiency to most fossil fuel systems that will have to short cycle, resulting in low efficiencies.
- New construction, without existing gas service – extending a gas line to a home and installing gas plumbing in a building has cost, and residential gas service typically costs $100-$200 per year (not for gas itself - just the meter fees). Some builders are finding that it's less expensive to forego gas and use efficient heat pumps in the home. These homes may be custom homes striving to be net-zero or townhomes and apartment buildings with modest loads.

While direct education and marketing to the end user is paramount, there are additional market actors that impact consumer education and choice. Additional stakeholders, including installers, builders and developers, architects and mechanical system designers must also carry these messages forward.

**Strategy 1c) Regional stakeholders should develop educational presentations or workshops for residential architects and mechanical designers as well as multifamily housing market actors (approved for CEUs when appropriate).**

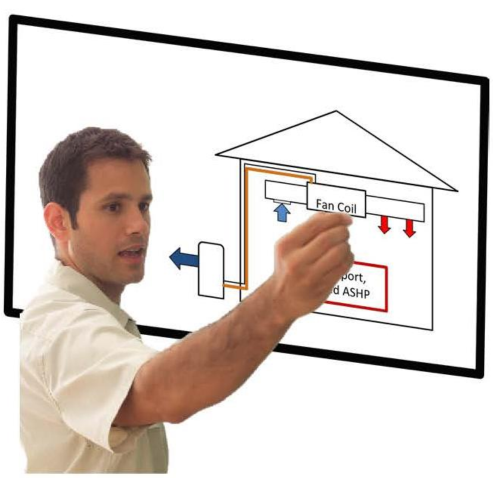
## *Strategy #2: Increase installer/builder awareness of, and confidence in, ASHPs through expanded training and education*

Contractors and installers represent the frontline when it comes to consumer education for heating and cooling technologies in existing homes. Builders represent that same frontline when it comes to new construction. Contractors and builders with knowledge and experience installing ASHPs are likely to effectively communicate the value proposition presented by ASHPS. In order to further develop an infrastructure of enthusiastic ASHP contractors and builders, education and training are needed.

In general, contractors are a lot more aware of new technologies than consumers, but outreach and education is still important to broaden awareness and assure the quality of installations. As was the case for consumers, there are also different types of contractors to target:

- Traditional HVAC contractors – should see the ductless ASHP technology as an attractive option for installations where installing ductwork is challenging. Anecdotal reports from several contractors in the Northeast indicate that most heat pumps installed in existing homes are primarily installed to add enhanced cooling where no cooling (or ductwork) existed.
- Home performance contractors – who may or may not be equipment installers, are often the initial contact with a homeowner considering an energy retrofit of an older home. These home energy retrofits represent a key target market for efficient ASHPs. The energy audit is an opportune time for the homeowner to become aware of the technology and seek out more information. The home performance contractor is providing better service by being up-to-date on the latest technologies and providing customers with options.
- Oil and propane delivery companies/contractors – are looking for ways to meet consumers' needs for cleaner and more affordable heating. Efficient ASHPs offer customers an opportunity to reduce heating costs associated with oil-fired systems without abandoning the oil system (and the need for some oil deliveries and service). ASHPs operate year-round which may reduce the cyclical labor demands of the oil heating business.

**Figure 12: Training programs increase contractor awareness**




For new construction or complete system replacement, there is concern that builders are loath to install ductless (or compact ducted) heat pumps instead of conventional central systems for two reasons:

- Builders are not familiar or experienced with heat pump systems;
- Builders are nervous about relying on heat pumps as a sole source of heating in cold climates.

Many HVAC contractors and builders express concern that ASHPs do not or cannot provide adequate heat under extreme conditions or at low temperatures. While this is a very important concern, and auxiliary or backup heat is appropriate in some situations, there are a growing number of very efficient homes in the Northeast that use ASHPs as the primary or only source of heat. It's important for contractors to be aware of the capabilities and limitations of specific equipment and have guidance that suggests how to design ASHP systems that may or may not include back up heating strategies, taking into account customer needs, costs, etc.

**Figure 13: Cold-climate ASHPs operate at low temperatures, so it is important to keep outdoor units elevated and unobstructed from snow and ice. (Photo credit: Joe Swift)**

While most of the major ASHP manufacturers provide training directly to their installer networks, several programs have developed and implemented contractor outreach and education materials, including Vermont in the Northeast:

- Efficiency Maine
- Green Mountain Power
- GoingDuctless

NEEP is also in the process of developing Installer guidance materials on the subjects of sizing, selecting and installing ASHPs in cold climates.

**Strategy 2a) Regional stakeholders, including manufacturers and program administrators, should develop educational contractor training materials on efficient, inverter-driven ASHP technology to increase contractor confidence. Trainings, via presentations, workshops, and/or webinar, should include information on:**

- **How the technology works;**
- **Important differences from traditional ASHPs;**
- **Leverage installer best practice resources in development (NEEP's focus on appropriate ASHP sizing, selection and installation practices in cold climates);**
- **Highlight ease of installation;**
- **Compelling messages that resonate with the target stakeholder groups:**
    - **Traditional HVAC contractors – ASHPs offer cooling solution, especially well-suited for homes that heat with hydronic systems, as well as a highly efficient heating solution to customers**
    - **Home performance contractors – ASHPs enable them to offer customers more options and demonstrates their knowledge and expertise, i.e. value.**
    - **Fossil-fuel heating system installers – Inverter-driven ASHPs provide an attractive additional product offering that is relatively easy to install, offers cost savings opportunities to their customers and can keep work force busy year-round.**

**Strategy 2b) Manufacturers should develop consumer-oriented educational material to be disseminated by contractors directly or via the internet.**

**Strategy 2c) Programs offering financial incentives for the installation of high performance ASHPs should require the installer to either have participated in some form of ASHP-specific training or complete some form of quality installation protocol.**

**Strategy 2d) Regional stakeholders should work together to develop case studies for contractors and builders to highlight the benefits of installing efficient ASHPs versus other HVAC technologies. This should include analysis of the comprehensive trade-offs between new construction with ducted technology vs. new construction with ductless technology. Other areas to compare could include comfort, convenience, first costs, operating costs, energy use, carbon footprint, maintenance requirements, aesthetics, space requirements, ease of home ventilation for IAQ, etc.**

As experience grows within the new construction/builder community, there may be opportunities to incorporate ASHPs into sustainable/high performance building programs, beginning with voluntary programs (i.e. ENERGY STAR Homes, LEED, etc.), with considerations for mandatory building programs in the future (i.e. building energy codes)

## *Strategy #3: Reduce upfront costs of installed systems through robust and aligned promotional programs and the support of alternative business models*

According to the recent available cost data for ASHPs, it appears that installed costs have been fairly steady over the past few years. The "Installed Cost " section above reviews system costs from several programs and studies. The data collected (Table 2) are not always consistent with respect to number of heat pumps installed, type of equipment, capacity, etc., but the average range of installed costs for a single, roughly one ton ductless heat pump falls into the $3,500 – $4,000 range. From looking at the data sets where capacity is available, average installed cost range is $2,500-$3,000 per ton for multi-zone systems. Installed costs of compact-duct ASHP systems and fully-ducted central systems are not well documented, as these systems have not yet achieved similar penetration in homes.  Stakeholders agree that driving these costs down through economies of scale will be a key driver to reduced long term costs.

One conclusion we reached in 2013 — that high volume contractors consistently installed systems at the lowest costs — has been challenged. Analysis of the MassCEC program experience did not support this assertion and in some cases showed higher installed costs from high volume installers. Beyond the current data, there are concerns that simply driving installed costs down may put pressure on quality, sizing, selection and installation practices, which are crucial aspects of high performing systems.

**Promotional Programs**

As the program incentive summary (*Appendix A: 2016 Energy Efficiency Program Activity Summary – Air Source Heat Pumps*) suggests, there is robust activity from energy efficiency and renewable thermal programs to promote ASHPs across the region. Direct consumer rebates are one of the most common tools used to encourage the installation of high performance systems. Stakeholders, particularly manufacturers, indicate that based on relatively low market adoption of this technology in the region, customer facing rebates/incentives are still very effective in driving uptake. There are, however, certainly opportunities for the region's programs to create more alignment around specific performance requirements. NEEP's ccASHP specification presents a tool to better identify systems likely to perform well in cold temperatures typical of the region.

**Strategy 3a) Energy efficiency and Renewable thermal programs should continue to offer downstream (customer level) incentives and further explore upstream incentive opportunities (contractor/distributor level). Regional program should better align around high-performance and quality installation (i.e. NEEP's Cold Climate ASHP Specification, NEEP's forthcoming Best Practice Installation Guidance).**

**ASHP Leasing Program**

Up-front cost to purchase and install an ASHP has been cited as a critical barrier to broader uptake. Green Mountain Power has implemented a unique leasing program to reduce – or eliminate – upfront costs for homeowners.

**Strategy 3b) Encourage energy service companies to offer alternative business models that provide ASHPs to the market with no up-front installation cost (i.e. leasing models, no-money-down financing, etc.). Efficiency and/or renewable thermal programs could either incentive these models or offer them directly to consumers.**

**Community-level Promotional Programs**

The 2013 report suggested that community, bulk-purchase programs (aka "solarize" strategy) could be adopted for efficient ASHP systems. Solarize programs have been implemented in many parts of the region to encourage the installation of solar electric systems at a community scale. The goal of a these programs is to overcome barriers like cost, complexity, and long-time spans from inquiry to installation, in order to install a substantial number of solar electric systems (NREL 2011). For a number of reasons, the bulk-purchase model is very difficult to transfer to ASHPs.

**Figure 14: Marketing logo for Heat Smart Tompkins**

The public knows much less about ASHPs, the risks are generally higher, the technology and sizing are more complicated, there is no single system that suits all installations, and the economics are generally not as good.

HeatSmart Tompkins in upstate New York provides a sneak peek into the potential for an alternative to the "solarize" bulk purchase-style program. Its program has sought to simplify the purchasing process of ASHPs in a number of important ways including streamlined pricing from pre-approved vendors, providing education and technical assistance, etc.

Community program for efficient ASHPs could dramatically increase adoption in regions identified as prime candidates for ASHPs (e.g. limited access to natural gas, older homes, no central cooling). Installation costs decrease noticeably with larger program participation.

**Strategy 3c) To increase concentrated installations and reduce installation cost, communities and/or state agencies should develop and implement community-based programs for ASHPs.**

One very clear trend is the ability to drive down costs for per unit installs when multiple units are being installed at a single building or location.

The Efficiency Maine low-income program deserves notice in achieving low installed cost for ccASHPs. Occupants of electrically-heated homes (resistance) who meet low-income thresholds are eligible for this program. The systems were all single-zone, mostly with 9,000 Btu/h capacities; average installed cost is $2,069. Noted reasons for program success:

- Program helps installers increase quality and decrease costs by sharing best practices;
- Program works with wholesalers to convince them to reduce their prices;
- Program works directly with manufacturers who recognize the opportunity and now offer special pricing to wholesalers who discount to Efficiency Maine. (Meyer 2013b)

A. By educating contractors and increasing sales volume across the state, the success in Efficiency Maine's low-income program may have allowed for lower prices in the market-rate program. Average installed costs in the market-rate incentive program (usually for larger systems) was $3,228. Many other agencies and utilities sponsor incentive programs for heat pumps; a summary of these efforts is in Appendix A.

**Strategy 3d) Drive equipment and installation costs down through economies of scale. Contractors and efficiency programs should target low-rise multi-family buildings and townhomes (both new and existing). These can be attractive targets for installing larger quantities of efficient ASHPs and thereby reduce costs.**

## *Strategy #4: Mobilize state and local policymakers to expand support for ASHPs*

When compared to existing heating fuels (oil, propane, gas and electricity) and technologies (forced hot-air furnaces and forced hot-water boilers, electric resistance units), electrically-driven ASHPs (at current emission rates) present significant carbon reduction opportunities. The region's policymaking community has formally and informally committed to 80 percent economy-wide carbon reductions by 2050, the target that the scientific community agrees will prevent the most harmful impacts of climate change. In order to achieve these ambitious goals it is becoming increasingly clear that besides deep levels of efficiency and increased utility scale and distributed renewable energy generation, important energy using sectors such as transportation and space heating must transition to cleaner fuels and technologies. While natural gas has been seen as valuable bridge fuel to a cleaner future, an attractive candidate for its long term replacement appears to be "clean" electricity and high performance ASHPs and GSHPs. These systems are currently the most efficient heating systems that run on electricity.

**Strategy 4a) Leverage existing policy interests in carbon reduction strategies (i.e. expansion of renewable energy generation, electric vehicles, zero energy homes) to build general policy support for proactive ASHP deployment activities.**

If the premise of strategic electrification becomes a more broadly accepted strategy, there remain outstanding questions about impacts. A broad deployment of electrically powered ASHPs will have significant impacts on the electric grid (including capacity/peak load), use of delivered fuels, natural gas infrastructure, and GHG emissions. There may be a variety of scenarios that needs consideration including likely growth of renewable electric generation, and the convergence of battery storage, enabling peak demand management. Until a clearer picture of those impacts is developed, policy makers may withhold strong support for electrification generally and for ASHPs more specifically, which in a number of ways could temper the near and long term growth of this technology.

**Strategy 4b) Conduct further analysis to better describe regional impacts of broad ASHP deployment on energy usage (across fuels), peak electricity demand, costs to consumers and utilities and associated emission impacts.**

- **Conduct additional research of consumer's current usage patterns of ASHPs, (i.e. heating use versus cooling use) to help inform regional impact analysis.**

While ratepayer-funded efficiency programs offer valuable resources to support the adoption of efficient ASHPs, the programs have constraints when approaching a technology like ASHPs.

Many utilities and program administrators across the region have run retrofit programs where efficient ASHPs represent some amount of electric savings compared to minimally compliant ASHPs. They provide incentives to motivate consumers to make the choice to purchase and install the more efficient unit. Proactive promotion of ASHPs to explicitly save other fuels (i.e. oil) does not align with the framework and directives they have historically been given by regulators. Electricity rate payers are paying for cost-effective electricity reductions. State energy regulators have historically been very clear to energy efficiency program administrators on both the electric and gas sides that the role of these programs is not to promote fuel switching through their promotional activities. This materializes in electric programs driving electricity savings and gas programs driving gas savings. Regulators have handled oil and propane savings that are indirectly achieved through electric and gas programs differently across the region.

With carbon reductions growing in importance across the region, there are opportunities to more closely align promotional activities with these outcomes. As highlighted in the market assessment, an increasing number of states have begun to implement programs aimed at achieving carbon reductions through the replacement of existing fossil fuel based technologies with low emission electricity-based technologies.

This has materialized in MassCEC's Clean Heating and Cooling program, and Efficiency Vermont's Cold-climate ASHP program. NYSERDA is developing a renewable heating and cooling program, and Connecticut and Rhode Island are exploring such programs. Efficiency Maine's ASHP program can be used to displace delivered fuels. Labeling heat pumps as "renewable" may be a good strategy to raise interest and awareness of the technology. There are some concerns about this term, however, as most heat pumps use grid electricity, and most grid electricity is still not from renewable sources. Some have argued that ASHPs are using electricity to mechanically harvest solar energy from the atmosphere. So even while the region works to make electricity itself more renewable, ASHPs — using electricity that is mostly still not renewable — constitute a renewable energy technology.

**Strategy 4c) States should develop/expand "renewable thermal" programs aimed at reducing carbon emissions through the increased adoption of qualifying technologies, including ASHPs. This construct helps to avoid sensitive fuel switching issues faced by many ratepayer-funded energy efficiency programs in proactively promoting fuel switching.**

Several states, including Massachusetts, are developing portfolio standards for renewable energy, in an effort to promote increased usage of renewable energy sources and ultimately reduce GHG emissions. These standards require energy distribution companies to document compliance with the standards in annual filings. Distribution companies can meet their compliance obligations by purchasing certificates (i.e. TRECs) from qualified generators. In Massachusetts' case, ASHPs will be an eligible technology for which certificates can be created. This offers additional value streams for ASHPs and other renewable and renewable thermal technologies.

**Strategy 4d) State lawmakers should adopt state renewable/alternative portfolio standards and include ASHP as an eligible technology.**

## *Strategy #5: Promote advanced control technologies to allow automated coordination among multiple heating systems*

While a growing variety of ASHP system configurations have made incorporation of ASHPs a possibility for nearly any new or existing home in the region, the overwhelming market opportunity rests in the existing housing stock in which ASHPs are either being installed to meet full heating load of the home or just being asked to provide enhanced heating and cooling. Much of the recent growth of ASHPs in existing homes in the Northeast have been ductless, and are most often installed to *displace* existing heating systems rather than to *replace* them. In these scenarios where heat pumps displace some existing form of heating – whether electric resistance, oil/propane boiler, etc. – the existing system remains installed and operational. This reality of operating two heating systems, at times simultaneously, can cause a number of issues including underuse of the heat pump, inefficient operation of the two systems and in a worst case scenario two systems that are competing (existing heating system heating the space while heat pump attempts to cool the space). Each of these have the potential to lead to dissatisfaction with consumers and unrealized benefits.

In order for consumers and energy stakeholders to achieve the maximum amount of heating that ASHPs are able to displace, and do so efficiently, homeowners must either have a keen understanding of how to operate two heating systems to optimize heat pump operation and minimize the existing system operation or install a high-cost system of multi-stage thermostat in combination with an add-on heat pump interface module. While installer/consumer education represents a near-term solution to this conundrum, low-cost integrated control systems that manage the dual heating system operation automatically is the preferred solution.

There are a number of sophisticated multi-stage thermostats that are able to work with ductless ASHPs and traditional heating systems, but require an interface module (wired or wireless) to the heat pump. This type of set up is expected to evolve as it is anticipated that several market leaders will have wireless interfaces built into the units as a standard feature to communicate with wireless thermostats, both proprietary thermostats and non-proprietary.

In practice, these multi-stage thermostats are able to prioritize ASHP operation over a secondary heating system until they are no longer able to maintain temperature setting. These thermostats sense this drop and activate secondary system operation. Once the temperature is satisfied, the thermostat once again turns off secondary system operation.

Proper installation and integration of these controls requires a fair amount of training and experience; adding them to a home can be involved and costly.

Because of the complicated nature of advanced thermostat installation and programming, it's not recommended that they be promoted by programs today. From an incentive program perspective, as cost and complexity of integrated control systems decreases, add-on incentives for integrated controls may be appropriate in the near future however. In addition to improved customer comfort and savings, some advanced control systems may offer demand response potential.

**Strategy 5a) Regional stakeholders should encourage the manufacture and installation of low-cost integrated control systems that effectively manage the operation of multiple heating systems (ASHPs and displaced heating systems), with prioritization of ASHP operation.**

- **This will require major manufacturers to build wireless interfaces into the units as a standard feature to "talk" to wireless multi-stage thermostats.**
- **Programs should engage manufacturers to share the features of an integrated control system that would be of most interest to them.**
- **As integrated control systems become lower cost and more consumer friendly, programs should consider offering incentives to enable greater ASHP operation.**
- **As more control products are developed, explore potential for demand response capabilities.**

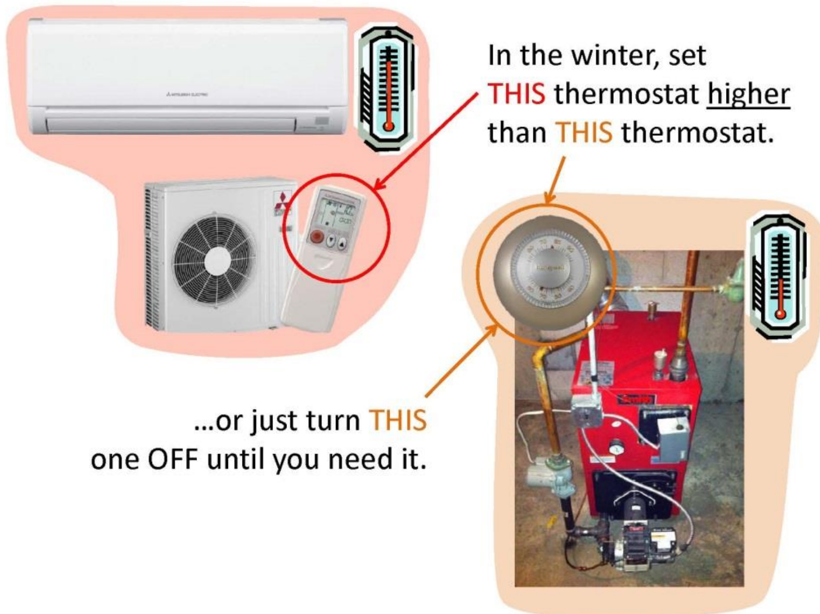
In the very near term, consumer education around two-system operation is recommended. In most displacement scenarios, a ductless ASHP has its own control system (including thermostat) that is totally independent from the controls of the existing system. In order for occupants to achieve significant savings from the heat pump, the heat pump thermostat must be set appropriately so that it is being called on to deliver maximum heat throughout as much of the heating season as possible. This manifests itself by setting the heat pump thermostat higher than the existing system thermostat. For example, if the ductless ASHP thermostat is set to 70°F and the thermostat for the oil boiler is set to 68°F (and if the thermostats are in the same area), the oil system will only fire if the heat pump cannot keep up with the load. When feasible the thermostats should be mounted near each other, which may mean mounting the sensor for the indoor head remotely to be close to, and at the same height as, the existing thermostat.

In these scenarios, it's critical that occupants understand how the controls work and operate the controls accordingly. It's also critical that contractors are mindful of existing system controls and thermostat locations when installing a heat pump. Contractors should also provide occupants with basic operational instructions. If the wrong thermostat is adjusted, the back-up system may run more than desired. If occupants go away on vacation, they must remember to turn both thermostats down.

Occupant education is the short-term solution to integration challenges, and several programs have developed consumer education materials:

- http://www.efficiencymaine.com/docs/Heat-Pump-User-Tips.pdf
- https://goingductless.com/assets/documents/uploads/DHP_Homeowners-Guide_FNL_REF.pdf

**Figure 15: Develop instructions that make operation as clear as possible**




The issue of set-backs is another key to consumer education. Because of the variable-speed capabilities of many inverter-driven ASHPs, the most efficient way to operate them is somewhat different than for most other heating systems. Variable-speed heat pumps operate very efficiently at part-load. They are at their least efficient when operating at full speed – such as when recovering from set-back. Some anecdotal evidence has shown that heat pumps use less energy overall when thermostat set points are not changed, i.e. heat pumps run continuously all day at lower, much more efficient speeds. More research is needed to evaluate how consumption varies with control settings and behavior patterns.

**Strategy 5b) Installers must educate consumers on how to operate their ASHP in conjunction with other heating system(s).**

- **Programs should provide general operational literature (e.g. set ASHP thermostat higher than oil thermostat, only use other system when needed for comfort, follow manufacturer instructions for filter cleaning, etc.)**
- **Manufacturers should provide educational and operational literature that is very clear.**
- **Contractors should be encouraged/required to walk home owners through the basics of operation and maintenance before they call a job complete.**

## *Strategy #6: Enable the promotion of climate-appropriate ASHPs through improved performance metrics*

As was the case in 2013, industry-standard performance testing for ASHPs does not adequately characterize system performance, especially likely performance in conditions across the Northeast region. This reality creates challenges for the marketplace in the Northeast region to adequately identify systems capable of high performance in cold conditions.

In response to this reality, NEEP, with the assistance of a regional advisory committee, developed the Cold-climate Air-Source Heat Pump Specification. The "spec" has brought increased transparency to the market with respect to heat pump operation across their variable speed range as well as low temperature performance. While an increasing number of energy efficiency and renewable thermal program administrators are leveraging the specification for a host of different purposes (MassCEC, NYSERDA, Efficiency Vermont), more should consider its use to send clear and consistent messages to manufacturers regarding the importance of designing systems capable of high heating performance in conditions typical of our region.

**Strategy 6a) Energy Efficiency/Renewable Thermal programs throughout the region should leverage the publically-available ccASHP Specification for a variety of potential purposes. Specific uses could include:**

- **Using the specification list to differentiate ASHPs that will operate most efficiently at low temperatures from those that either cannot operate, or do so inefficiently.**
- **Using the specification list to "qualify" products for promotional offerings including, but not limited to, rebates.**
- **Using the performance information in the specification list to aid in heat pump selection, particularly low temperature capacities.**

While the spec has been very useful, it is not a final solution. Much of the performance data provided by manufacturers – including all of the cold temperature data – does not result from standardized test procedures. It's not always clear how manufacturers determine some of these values, and it's likely that different manufacturers obtain these values in different ways. This gap is hopefully closing. In Canada, the CSA is currently developing a set of test procedures for ASHPs that should help address standardized cold-weather performance, gaps related to part-load performance, and other discrepancies between laboratory tests and real-world conditions. Concerns have been raised by industry representatives that additional testing requirements have a price tag that impact the costs of doing business. CSA and heat pump stakeholders should seek to balance the benefits of more accurate test procedures with the potential cost burden of new testing procedures.

**Strategy 6b) NEEP and the ccASHP Specification advisory committee should monitor and support development of the CSA heat pump testing procedures. When the procedures are finalized (expected in 2017), NEEP and committee should consider their incorporation into the ccASHP specification.**

Figure 16: An inverter-driven ASHP in a snowy climate.

If stakeholders across the region and in other cold climates begin to implement strategies such as these, it could demonstrate to national agencies and organizations – such as USDOE, EPA/ENERGY STAR and/or CEE –that creating performance requirements based on more appropriate testing and rating procedures for cold-climate ASHPs is feasible. Successful development and implementation of CSA standards can only advance this cause.

**Strategy 6c) Leverage increased program adoption of climate appropriate requirements (i.e. ccASHP specification) to influence regional and national groups –such as NEEA, MEEA, AHRI, DOE, ENERGY STAR, Natural Resources Canada, CEE– to include more realistic test procedures as part of qualification to their ASHP programs.**

## *Strategy #7: Develop more accurate tools to predict energy, cost and GHG savings associated with ASHP installation through collection and analysis of real world performance data.*

A recurring barrier that arose during development of the 2013 strategy report was the uncertainty in predicting energy consumption and/or savings, given the diversity of scenarios under which ASHPs can be installed:

- For consumers, it remains difficult to assess investing in ASHPs without knowing the likely savings;
- For contractors, it is challenging to provide accurate projections for savings in comparisons to the systems currently operated;
- For regulators and program administrators, it is very difficult to establish proper policies, programs, and incentive levels if the savings and other benefits are in question. There is inadequate data to support one-size-fits-all deemed savings estimates.

**Studies and Evaluations**

To improve understanding and expectations for ASHP performance, many stakeholders agree that there is need for more evaluations of installed systems, particularly centrally ducted ASHP systems. While it is fortunate that there are a series of new in-field research studies to be completed in late 2016 and 2017, both inside the region and in other cold climate regions, the technology is constantly evolving and there may be further studies to keep up with technological advances. Results of larger-scale evaluations can help stakeholders predict savings more accurately in a variety of applications.

Generally speaking, there are three main types of evaluations of inverter-driven ASHPs:

A. Pre/post utility bill analyses where electricity and/or fuel bills are compared before and after heat pumps are installed;
B. Field metering studies that involve installing equipment to monitor detailed performance of ASHPs;
C. Conducting controlled monitoring of ASHP systems within "laboratory homes" (i.e., test houses) that have adequate instrumentation built into the home. These homes have greater capabilities of measuring actual heat delivery, a measurement with high difficulty "in the field."

There is a need for all types of studies in NEEP's territory.

Utility bill analyses can generally be done on much larger scale. Past studies have shown significant savings (on average) when inverter-driven ASHPs displace electric resistance, but the studies also show dramatic ranges in savings. Future studies should include other evaluation parameters such as home size, age, occupancy, demographics, etc. to possibly explain the broad range in savings.

No large-scale utility bill studies have been done to document savings when inverter-driven ASHPs are used to displace or replace oil or propane heating. (An ongoing study in Vermont is expected to provide greater detail of interactive effects between ASHPs and existing systems). Evaluations of efficient ASHP savings when displacing these fuels would be valuable with such a high percentage of regional homes currently relying on them.

**Strategy 7a) Regional energy efficiency program administrators should implement large-scale utility bill analysis study to evaluate changes in heating energy consumption after efficient ASHPs are installed. Include documenting reduced consumption of various fuels (oil, propane, natural gas). Analysis should document how heating energy consumption patterns vary with:**

- **Energy or fuels displaced (especially elec. resistance, oil, and propane)**
- **System types displaced (hydronic, central furnace, etc.)**
- **Home characteristics (size, year of construction, single-family/multi-family, etc.)**
- **Demographics (no. of occupants, age, schedules, etc.)**

**The analysis should also include a similar examination during the cooling season to inform cooling savings assumptions under a variety of scenarios (previously utilized room air conditioner(s), no previous cooling, etc.).**

While very useful, pre/post evaluations record differences in overall energy use. These differences are subject to weather variations, occupant behavior, and system interactions that are impossible to predict. Field monitoring studies typically require instruments to monitor temperature, humidity, air flow rates, and electrical energy consumption of ASHPs and record data at short intervals. These studies can help stakeholders understand performance of specific pieces of equipment in varying conditions and applications much better. They often support and validate computer models. These studies are more expensive and usually cannot be implemented on a very large scale.

**Strategy 7b) Regional energy efficiency and/or renewable thermal program administrators should continue to conduct focused monitoring studies on inverter-driven ASHPs in different applications. Monitor thermal energy and electric consumption in detail to assess performance during varying weather conditions, under different loads, in conjunction with different legacy heating systems, with various control strategies, etc. Year round monitoring would provide valuable information about energy usage during the cooling season of units with cooling capabilities.**

While stakeholders will have slightly different goals when evaluating ASHP performance, there is likely merit in communicating about – if not standardizing – several evaluation methods and protocols. Some methods are presented in reports of past evaluations (KEMA 2009, Baylon et al. 2012, EE 2012, Williamson 2015), and researchers at the National Renewable Energy Laboratory have developed a field monitoring protocol for ductless heat pumps (Christensen et al. 2011). The variable-speed nature of inverter-driven ASHPs makes accurate monitoring more challenging; monitoring the variable airflow of ductless heat pumps can be especially challenging. It is easy to underestimate the complexity, and this can lead to large assumptions which can compromise the evaluation results. With respect to detailed performance evaluations of systems, monitoring *fewer* systems in *greater* detail will lead to more reliable results.

**Strategy 7c) Regional stakeholders conducting in-field monitoring activities should be seeking coordination and consistency on methods and protocols used in ASHP evaluations with other researchers.**

Long-term, integrated onboard metering would provide invaluable data to technology evaluators and consumers alike.

**Strategy 7d) Manufacturers and/or third party metering designers work to develop metering technology to incorporate into ASHPs for real-time performance evaluation and reporting. Such onboard systems would provide real-time feedback to system operators with information such as power draw (W), heat being delivered (Btu/hour), average hourly/daily/monthly "COP", hourly/daily/monthly kWh usage.**

**Modeling Improvements**

Many designers, developers, and program administrators rely on energy modeling tools to assess savings from various efficiency measures in both existing and new construction applications. Many modeling tools, however, are not able to accurately model inverter-driven ASHPs. In REM/Rate (v14.3) for example, one of the most common tools to model energy performance of single-family homes, there are three fields a modeler must enter when modeling an air-source heat pump (whether variable speed, single speed, or two speed):

- HSPF
- Heating capacity at 47°F
- Heating capacity at 17°F

For issues related to inadequate performance metrics (See strategy 2), there are no parameters in the software to accurately characterize the part-load, variable-speed benefits which allow ccASHPs to operate efficiently over most of the heating season. Nor is there a way to characterize performance at colder temperatures; default capacity and performance assumptions are used by the software for all types of heat pumps.

The evaluations suggested above, especially detailed monitoring, can be very useful for energy modelers. Results from studies can help calibrate energy models and make them much more accurate.

**Strategy 7e) Regional stakeholders work with software providers (such as AEC, makers of REM/Rate) to develop guidelines and/or to incorporate features that allow more accurate modeling of inverter-driven heat pumps.**

## Regional Market Transformation Theory of Change and Goal

Based on our assessment of the regional ASHP market, it is clear that while ASHPs have established a viable and growing market, there remains a significant opportunity to further accelerate adoption of the technology and, in the process, achieve exciting energy, cost, and carbon savings to the Northeast/Mid-Atlantic region. In the previous section, seven key market strategies were presented that we project will collectively accelerate the adoption of ASHPs in the region.

NEEP projects that earnest implementation of the recommended market strategies outlined in the Regional Market Transformation Strategies section will produce the necessary market conditions in order for accelerated and sustained uptake of ASHPs throughout the Northeast and Mid-Atlantic regions.

This section presents a projected market trajectory in relation to the market strategies, a “theory of change” and an associated long-term goal.

**Figure 17: Market Transformation for ASHPs in the Northeast/Mid-Atlantic Region**

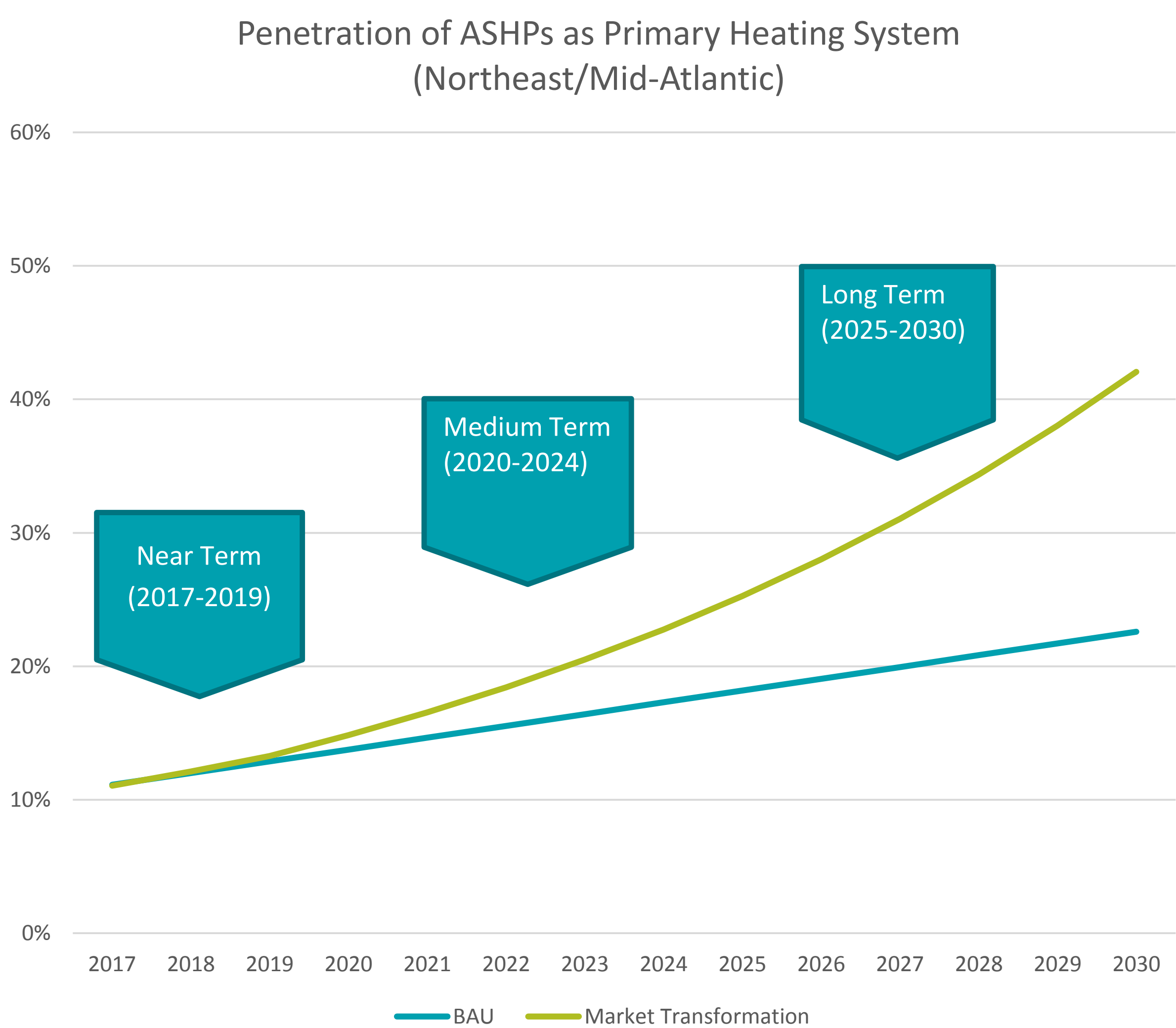


Figure 17 includes two market projections for penetration of ASHPs in the region serving as the primary heating system; one projecting business as usual (BAU) and the other projecting an accelerated adoption of ASHPs as primary heating system. Instead of focusing on a specific efficiency/performance-level goal that we want to see systems achieve in the long term (e.g. all ASHPs sold in region are HSPF 12 or higher), or driving adoption of ASHPs without regard to homeowner usage (e.g. 50 percent of homes have installed ASHPs but only a portion use them as primary heating system), we chose to focus on driving adoption of ASHPs that serve as the households primary heating system. As referenced earlier, many ductless ASHPs are being installed with a cooling solution as a primary driver. Shifting usage becomes part of the challenge for these homes. Of course, the installation of high efficiency/performance ASHPs is critical, but this will not be the only tracking metric.

NEEP utilized the U.S. EIA data and current sales data as the primary inputs to current market. NEEP then applied assumptions about market growth in the two scenarios. The model assumes 10 percent annual growth in sales to meet the goal versus flat market growth in the business as usual (BAU) case. We also include a growing "realization rate" of 70-90 percent for the market transformation scenario and a static 70 percent rate for the BAU scenarios, which means that a certain percent of systems installed are actually operated as the primary heating system.

The US EIA performs periodic updates to its Residential Energy Consumption Survey (RECS). This will serve as the primary tracking device along with annual sales figures when they can be collected. The most recent RECS survey suggested that of the roughly 24 million households in the Northeast and Mid-Atlantic regions, only 400,000 households utilized ASHPs as their primary heating system in 2009. By reaching our goal of 40 percent penetration of ASHPs as the primary heating source, that number must jump to over 10 million households.

**"Theory of change"**

The timeline below presents a potential market transformation story, or "theory of change" highlighting several key inflection points that are essential to drive market success. This theory of change can be thought of as the story we would tell in 2030 of how ASHPs overcame a number of market barriers to become a common space heating technology throughout the region.

**Near Term (2017-2019)**

Successful implementation of the seven-part integrated strategy presented in this report is projected to achieve several outcomes in the next three years:

1. Stakeholders increase affordability of ASHPs through robust and aligned promotional programs and stimulate the growth of alternative business models to deliver ASHPs with reduced upfront cost barrier.
2. Regional stakeholders drive increased consumer awareness of and confidence in ASHPs through strategic marketing and communications, including a more substantial web presence.
3. Manufacturers, distributors and program administrators drive increased installer awareness of and confidence in ASHP through expanded training and education.

4. Stakeholders invest in comprehensive impact analyses that bolsters policymaker comfort with concept of strategic electrification of key sectors including space heating. Programs are designed to stimulate this transition.
5. Stakeholders support the growth of climate-appropriate ASHPs through improved performance metrics, beginning with voluntary programs (e.g. Cold Climate ASHP Specification, ENERGY STAR, CEE).
6. Stakeholders work cooperatively to promote advanced control technologies to allow automated coordination between multiple heating systems (ductless ASHPs and existing systems).
7. Stakeholders develop more accurate tools to predict energy, cost and GHG savings associated with ASHP installation through collection of real world performance data.
8. Regional stakeholders conduct outreach to new construction community to position ASHPs as a trusted HVAC solution for new home construction and gut rehab.

**Medium term (2020-2024)**

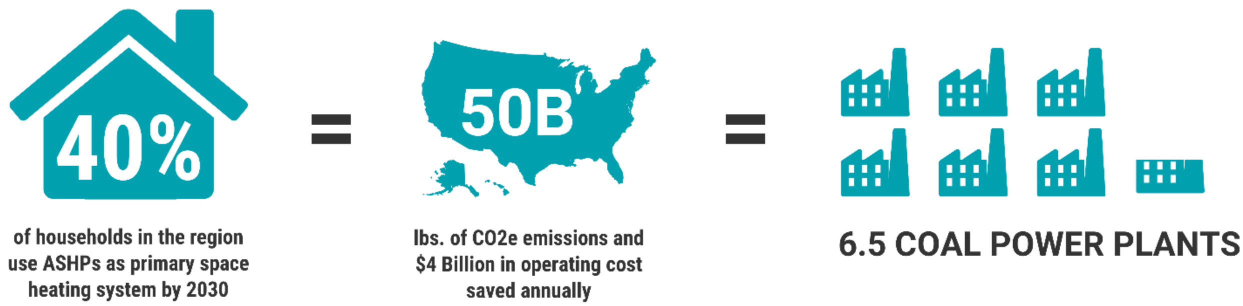
1. Robust third-party service provider market provides ASHPs to consumers "as a service," requiring no money down and attractive terms.
2. Contractor education efforts have successfully improved installation practices for ASHPs.
3. Climate change action policies around the region remain aggressive, programs to promote clean energy technologies and strategic electrification gain momentum.
4. Improved test procedures/metrics (i.e. CSA) are adopted by regulatory programs including DOE's appliance standards efficiency regulations.
5. Technology advances offer consumers simplified integrated controls paired with improved on-board metering technology to provide real-time performance data.
6. Manufacturers continue to improve ASHP performance with greater seasonal COPs, low temperature COPs and enhanced capacity maintenance.
7. Combination ASHP systems that provide space conditioning in addition to domestic hot water heating gain traction in the regional market.
8. Carbon reductions become more valuable through market based schemes. Technologies that demonstrate carbon reductions are incentivized, increasing the value of ASHPs.

**Long term (2025-2030)**

1. Consumers and installers consider ASHPs to be the preferred HVAC technology for most residential space conditioning application.
2. Combination ASHP systems that provide space conditioning in addition to domestic hot water heating become common in the market.
3. ASHPs become predominant technology used for space conditioning in residential new construction and gut rehab projects. The International Code Council's (ICC) International Energy Conservation Code (IECC) model building energy code's performance pathway is most easily satisfied with ASHPs.

**Regional Goal and impact:**

## NORTHEAST AND MID-ATLANTIC REGIONAL GOAL




Can this ambitious goal be reached in the next 13 years? The region can look to Scandinavia for inspiration. In Norway, a country of five million people, ASHP sales hit nearly one million over the past 10 years.[24] This kind of market development ramp up in the Northeast/Mid-Atlantic region, with a market over 10 times as large as Norway suggests the goal is in fact achievable. Of course market conditions that contributed to this growth in Norway are different than the Northeast U.S. and, in many cases, our region may face market barriers not present in Norway, but the experience nonetheless suggests that this growth is not unprecedented.

NEEP projects that a sustained regional initiative can successfully transform the residential space heating market to a market where ASHPs are the most broadly utilized technology to heat homes. NEEP stands ready to lead this regional effort through the power of collaboration. We urge regional stakeholders to actively engage and support this region work in order to achieve the important benefits associated with such a transformation.

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# Appendix A: 2016 Energy Efficiency Program Activity Summary – Air Source Heat Pumps

**Incentive and Requirement Summary for Ductless Heat Pumps**

| State | Rebate Incentive | ENERGY STAR certification | HSPF | SEER | EER | Other Requirements |
|---|---|---|---|---|---|---|
| Connecticut[25] | $300/home (Single-Zone) | X | 10 | 20 | | |
| | $300/home (Multi-Zone) | X | 9 | 18 | | |
| Massachusetts | $250 | X | ≥ 9 | ≥ 18 | | |
| | $500 | X | ≥ 11 | ≥ 20 | | |
| Massachusetts Clean Energy Center[26] | $625 (Single-Zone) | X | ≥ 10 | ≥ 20 | ≥ 12.5 | NEEP ccASHP Spec, 100% of rated heating capacity delivered at 5°F |
| | $625/ton (Multi-Zone) | X | ≥ 9 | ≥ 17 | ≥ 12.5 | |
| Rhode Island | $250 | X | ≥ 9 | ≥ 18 | | |
| | $500 | X | ≥ 11 | ≥ 20 | | |
| Vermont | $600 (Single-Zone) | | ≥ 10.3 | ≥ 20 | ≥ 12 | COP @5°F ≥ 1.75; operation at -5° |
| | $600/800 (Multi-Zone) | | ≥ 10 | ≥ 17 | ≥ 12 | |
| New Hampshire[27] | $250/ton of cooling | X | ≥ 8.5 | ≥ 15 | ≥ 12.5 | |
| | $500/ton of cooling | X | ≥ 10 | ≥ 18 | ≥ 12.5 | |
| Maine | $500 (Single-Zone) | | ≥12 | | | |
| | $750 (Multi-Zone) | | ≥10 | | | |
| New Jersey | $500 | X | ≥10 | ≥ 20 | ≥12.5 | |
| Pennsylvania (PP&L) | $100/ton | | ≥ 8.6 | ≥ 16 | 12.5 | |
| | $150/ton | X | ≥ 9.5 | ≥ 17 | 12.5 | |
| | $200/ton | | 10.5 | 19 | 12.5 | |
| Energy Save PA | $100 | | ≥ 10.5 | ≥ 15 | | |
| Washington D.C.[28] | $300 | | ≥ 9 | ≥ 18 | ≥ 12.5 | |
| | $500 | | ≥ 10 | ≥ 20 | ≥ 13 | |

25 A $1,000 rebate is available for homes with existing electric resistance heating WITH a Home Energy Assessment prior to installation

26 Income eligible adders of $175/system or ton and $675/system or ton. Maximums apply for number of outdoor units eligible for rebates and total rebate dollar amount by project site.

27 $250/ton Incentive available from New Hampshire Electric Coop for Heat Pump Systems offsetting 80% of total heating load. Must submit two (2) years heating fuel usage, type and efficiency of existing equipment

28 Updated rebate amounts "coming soon"

**Incentive and Requirement Summary for Ducted Heat Pumps**

| State | Rebate Incentive | ENERGY STAR certification [3] | HSPF | SEER | EER | Other Requirements |
|---|---|---|---|---|---|---|
| Connecticut | $500 | X | ≥ 10 | ≥ 18 | ≥ 13 | |
| Massachusetts | $250 | X | ≥ 8.5 | ≥ 16 | | |
| | $500 | X | ≥ 9.6 | ≥ 18 | | |
| Massachusetts Clean Energy Center[29] | $625/ton | X | ≥ 10 | ≥ 17 | ≥ 12.5 | NEEP ccASHP Spec, 100% of rated heating Capacity Delivered at 5°F |
| Rhode Island | $250 | X | ≥ 8.5 | ≥ 16 | | |
| | $500 | X | ≥ 9.6 | ≥ 18 | | |
| New Hampshire | $70/ton | X | | ≥ 15 | ≥12.5 | |
| Maine | $500 | X | ≥10 | | | |
| New Jersey | $300 | | ≥10 | ≥ 16 | ≥13 | |
| | $500 | | ≥10 | ≥ 18 | ≥13 | |
| PSEG- Long Island | $200 | | ≥8.5 | ≥16 | ≥13 | |
| | $350 | | ≥8.5 | ≥17 | ≥13.5 | |
| Pennsylvania (PP&L) | $200 | | ≥8.5 | ≥ 16 | ≥12.5 | |
| Energy Save PA | $250 | | ≥8.5 | ≥ 14.5 | | |
| | $325 | | ≥8.5 | ≥ 15 | | |
| | $400 | | ≥8.5 | ≥ 16 | | |
| Washington D.C.[30] | $500 | | ≥ 9 | ≥ 16 | ≥ 13 | |
| | $1000 | | ≥ 9.5 | ≥ 18 | ≥ 13 | |

[29] Income eligible adders of $175/system or ton and $675/system or ton. Maximums apply for number of outdoor units eligible for rebates and total rebate dollar amount by project site.
[30] Updated rebate amounts “coming soon”

## Appendix B: Complete List of Market Barriers from 2013 Report

The 2013 report recommended regional strategies to overcome a number of key market barriers. In order to concentrate strategies on the highest priority barriers, the LAC was surveyed to assist in the identification of key barriers. The barriers that were ultimately selected came from the more comprehensive list below:

**Category 1- Consumers**

1. Poor awareness of ASHP technologies;
2. Negative perceptions/psychology (noise, recovery from setback, "electric heating is bad", comfort perceptions, etc.);
3. Technology operates differently than incumbent space conditioning technologies (i.e. need for customer/occupant education on controls, interaction with primary/secondary heating system);
4. Attractiveness of partial load solution;
5. Aesthetics of ductless fan coils;
6. High upfront cost;
7. Inability to accurately forecast energy/cost savings;
8. Potentially long payback;
9. Inability to find an experienced installer.

**Category 2- Installer/Contractor Community**

1. General lack of familiarity/experience among HVAC community in installing this technology (particularly ductless);
2. Weary of incorporating new technology into their business (i.e. inertia);
3. Uncertain how to identify ideal candidates (particularly ductless);
4. Uncertain how to size (particularly ductless);
5. Lack confidence in forecasting operational cost/savings;
6. Not "selling" this technology to customers;
7. Question of whether installer base/service industry keep up with current/growing demand.

**Category 3- Technology Performance/Quality**

1. Inability of some systems to deliver sufficient amounts of heat in cold conditions;
2. Inability of some systems to distribute heat/cool effectively;
3. Ability of industry to maintain product quality in time of rapid growth.

**Category 4- Performance Metrics (test procedures and efficiency metrics)**

1. Current industry test method does not adequately determine cold weather performance of HPs;
2. HSPF may not be good for comparing inverter to non-inverter HPs.

**Category 5- Energy Efficiency Programs**

1. Unfamiliarity within Energy Efficiency Program Administrator community;
2. Program regulators don't allow promotion of technology (i.e. provide incentives) in fuel switching situations;

3. Challenge of accurately evaluating/predicting savings, including defining baseline energy use for various scenarios (various fuels, displacement vs. replacement);
4. Unclear which applications are most likely to deliver maximum energy savings.

**Category 6- State/Regional Policy**

1. Unfamiliarity of ASHP technology within policymaker community and its relation to existing policy goals (i.e. zero energy buildings, expansion of distributed PV);
2. Momentum in policy community for natural gas expansion (neighborhood-level and generation-level);
3. Hesitance of policymakers to build electric load growth (kWh and kW for both summer and winter peak impacts);
4. Complexity of modeling/predicting source energy /operational cost savings;
5. Unclear potential for reducing primary energy/GHG emissions.

**Category 7- Miscellaneous Opportunities to leverage**

1. Combine with residential solar PV installation, reducing new load to grid and creating little to no heating and cooling bills;
2. Fuel cost savings advantage over electric resistance, oil, and propane;
3. Install-ability of ductless systems (simple and fast for knowledgeable installer);
4. Demand response potential;
5. Multifamily and townhomes (under four households) may represent attractive application;
6. On local scale (in new construction, avoid infrastructure costs of natural gas expansion);
7. On state/regional scale (avoid expensive expansion of gas infrastructure, ease gas bottlenecks).

# Appendix C: Regional Climate/Building stock Analysis

**NEEP Region Climate Analysis**

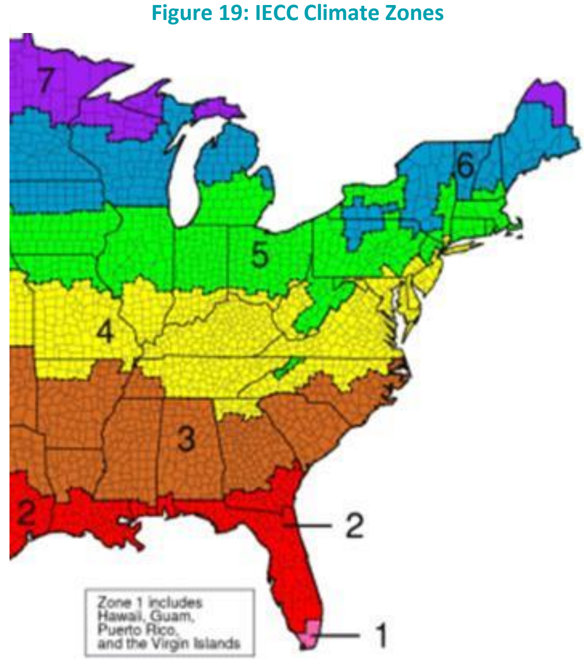
NEEP's geographic region of interest includes a rather broad spectrum of climate conditions. An ASHP installed in the Washington D.C. area with monthly average temperatures ranging from 29°F to 89°F (TWC Monthly Averages for Washington D.C.) will perform differently than an ASHP installed in Portland, Maine where average temperatures range from 13°F to 79°F (TWC Monthly Averages for Portland, ME). For this study, the authors sought to sector the region by climate and then examine the key housing characteristics in each climate region.

Figure 18: NEEP's Northeast and Mid-Atlantic Region

For reference, the International Energy Conservation Code (IECC) defines seven climate zones as shown below in **Error! Reference source not found.**. The NEEP region includes IECC Zones 4, 5, 6 and 7. In the following section, we examine housing characteristics for a Northeast region that is predominantly IECC zones 5 and 6 and a Mid-Atlantic region that is predominantly zone 4.

To confuse matters, the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) utilizes six climate regions for approximating seasonal performance and these regions are NOT the same as the IECC/DOE zones. The NEEP region includes AHRI regions IV and V. Region V in the Northeast is very similar to the IECC Zone 6.

Figure 19: IECC Climate Zones



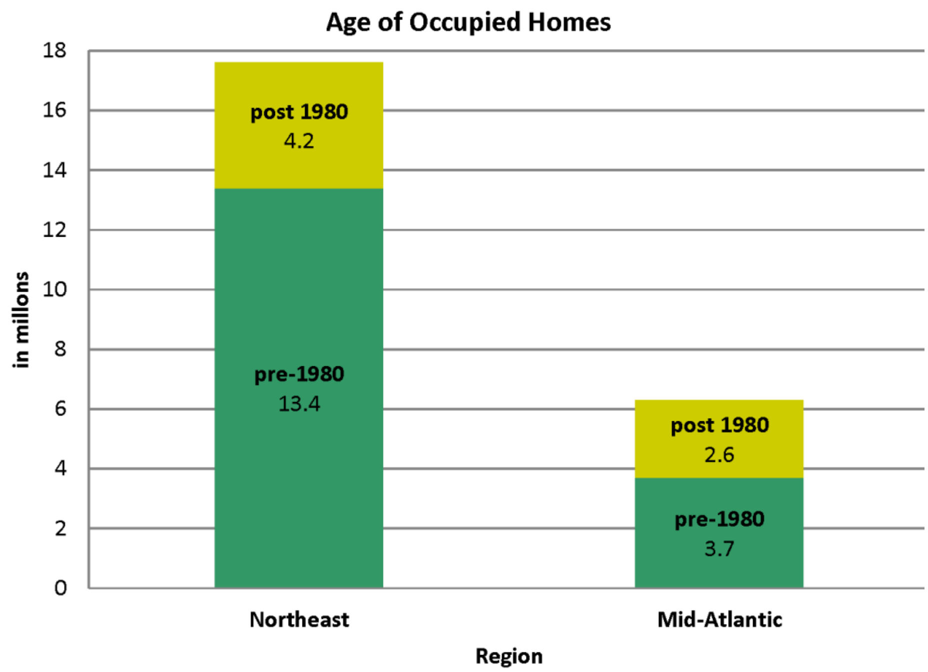

**Regional Market Data**

The Energy Information Administration's Residential Energy Consumption Survey (RECS) provides a wealth of relevant characteristic information for the existing housing market. The authors aggregated the RECS data into a Northeast region that is predominantly IECC zones 5 and 6 and a Mid-Atlantic region that is predominantly zone 4. The Northeast includes the six New England states, New York, and Pennsylvania. The Mid-Atlantic region includes New Jersey, Delaware, Washington D.C., Maryland, and West Virginia. West Virginia could not be readily excluded from the compiled data. Not only are the climates for these two regions different, but the housing characteristics are as well. The RECS data includes occupied single-family and multifamily homes.

### Housing Age

In the Northeast, 13.4 million (76 percent) occupied homes are more than 30 years old – likely candidates for significant energy retrofit work. In the Mid-Atlantic, homes are somewhat newer with only 59 percent (3.7 million) constructed before 1980.

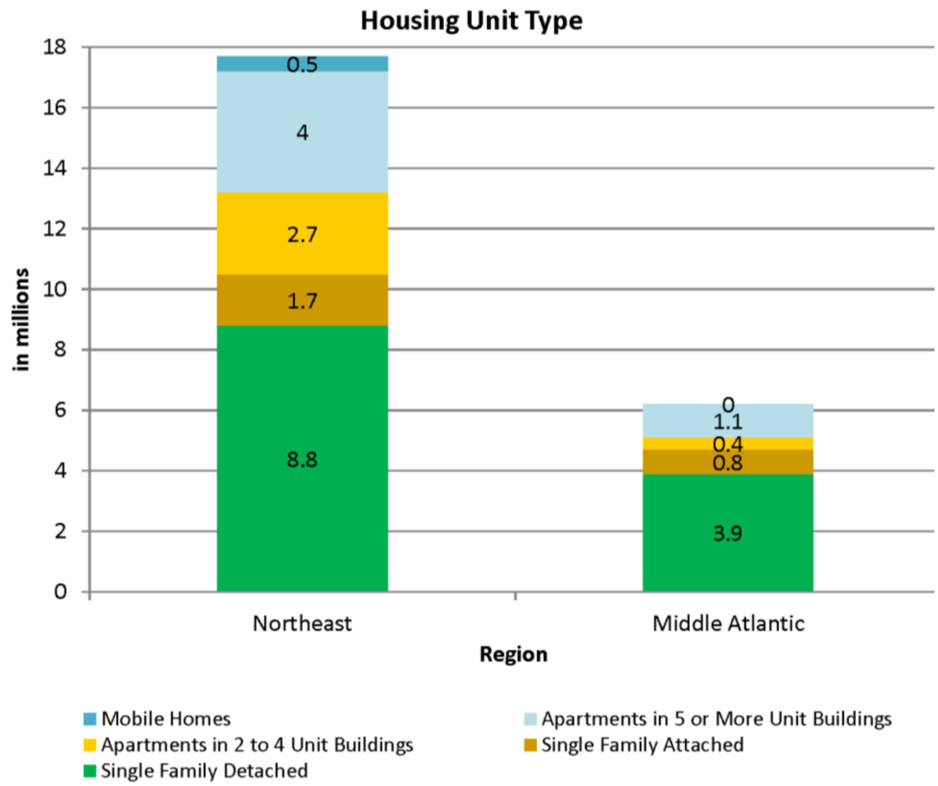
**Figure 20: Age of Occupied Homes (EIA 2013e & 2013f)**




### Housing Type

Of the 17.6 million homes in the Northeast region, 75 percent of them are in attached and detached single-family buildings and small apartment buildings. This is the residential market of most interest for this study. Apartment buildings of five or more units are more likely to have larger, commercial-scale HVAC systems. In the Mid-Atlantic, 82 percent of the homes are either attached or detached single-family buildings or small apartment buildings. The region has fewer urban centers and their high-rise apartment buildings.

Figure 21: Housing Unit Type (EIA 2013e & 2013f)




## Housing Heating Fuel and System

The Northeast region's limited natural gas distribution infrastructure is apparent in the heating fuel data. In the Northeast, gas is used for space heating in less than half of the homes and 31 percent of homes use oil. In contrast, in the Mid-Atlantic region, 58 percent use gas and only six percent use oil.

Electricity is used for heating in 12.5 percent and 25.8 percent of homes in the Northeast and Mid-Atlantic regions, respectively. The majority of these are electric resistance systems – prime targets for replacement with a much more efficient cold-climate heat pump. Heat pumps are currently used in only 2.3 percent of Northeast homes and 11.1 percent of Mid-Atlantic homes.

Hydronic heating systems are used in 38 percent of Northeast homes and 23 percent of Mid-Atlantic homes. These homes most likely do not have ducted air conditioning systems.

Figure 22: Heating Equipment in Northeast Region (EIA 2013c)

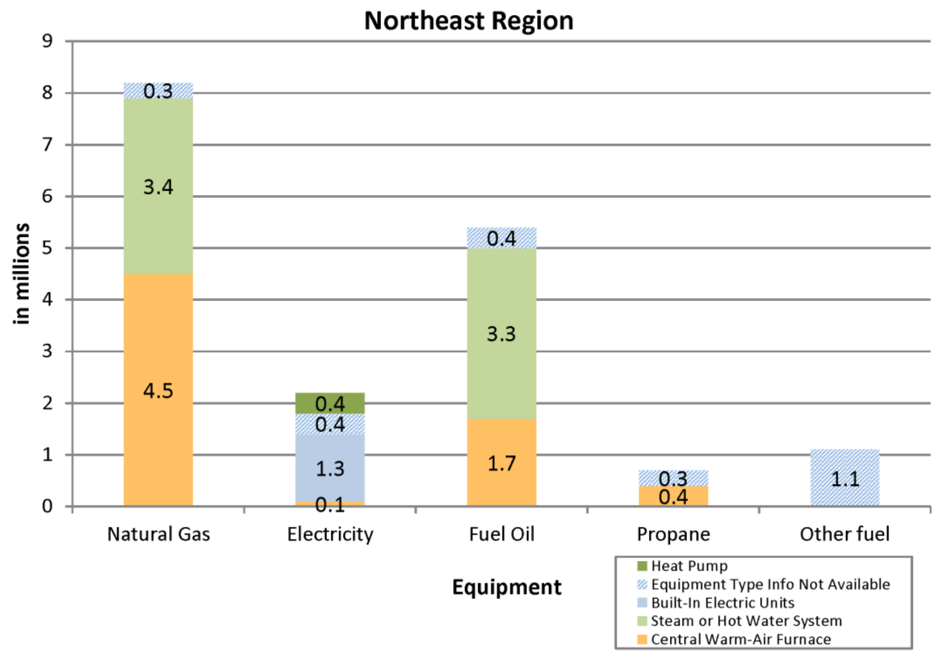
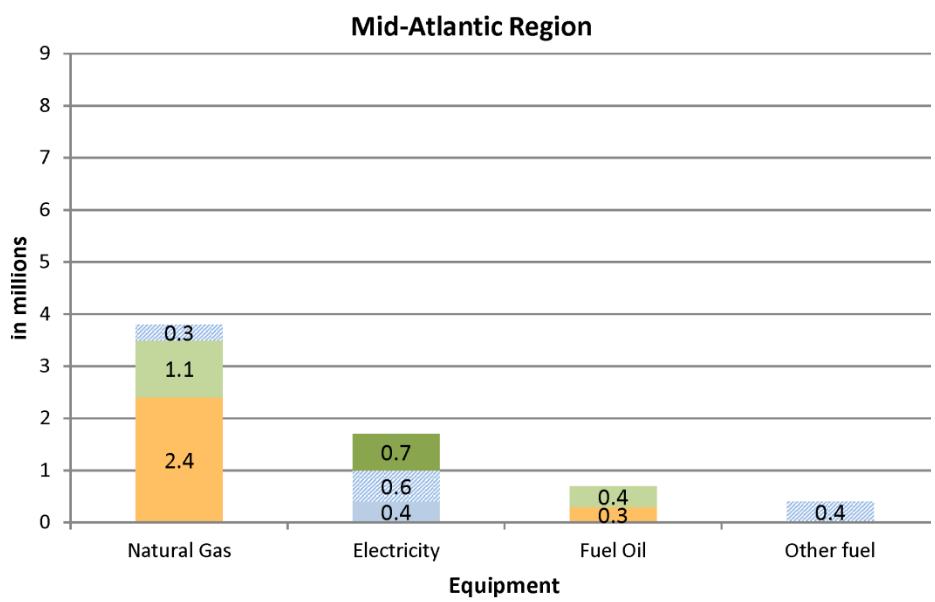



Figure 23: Heating Equipment in Mid-Atlantic Region (EIA 2013d)




## Cooling Equipment

In the Northeast, only 30 percent of homes have central air conditioning systems. Homes seeking to add air conditioning for improved comfort or upgrade from window units are prime targets for the installation of ductless heat pumps. In contrast, 65 percent of homes in the Mid-Atlantic have central air conditioning systems, but half of them are more than 10 years old – candidates for replacement.

**Figure 24: Cooling Equipment in Northeast Region (EIA 2013a)**

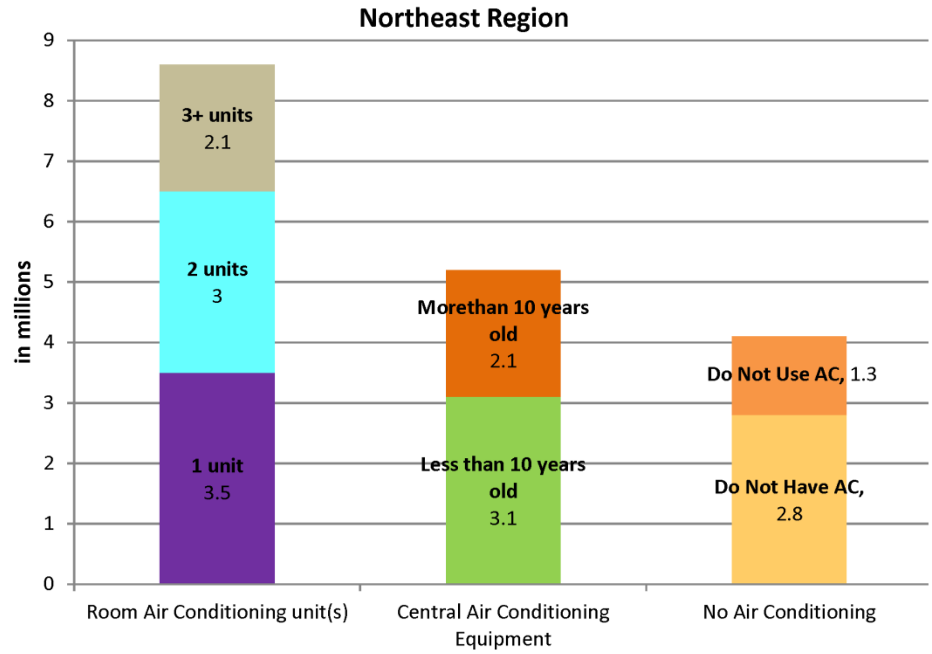



**Figure 25: Cooling Equipment in Mid-Atlantic Region (EIA 2013b)**

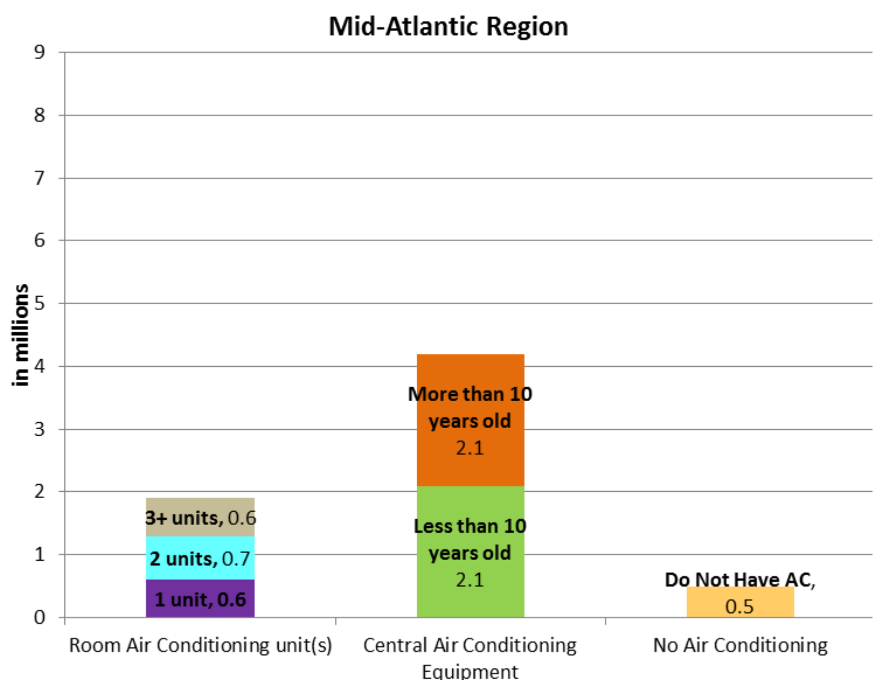
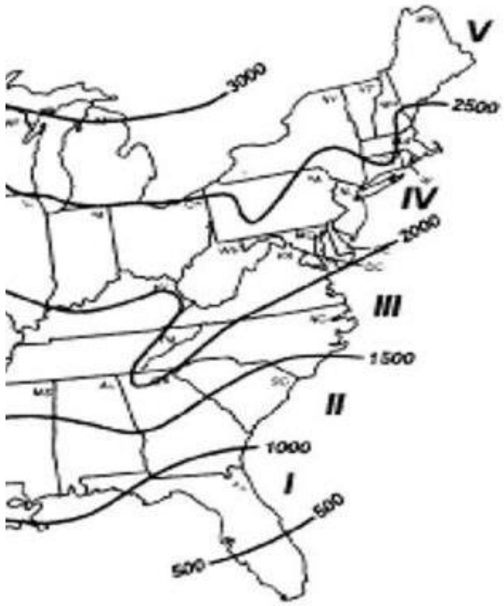


**Figure 26: AHRI Climate Regions**



# Appendix D. Overview of ASHP energy savings equations from State TRMs.

## *Energy Savings Calculations Methodologies*

A Regional EM&V Forum project (Emerging Technologies Research Report, ERS 2013) explored how energy efficiency programs from the region had been treating energy savings from ASHPs. The report compiled algorithms from several electric energy efficiency programs in the Northeast used to estimate savings from efficient heat pumps. Historically, efficiency programs have estimated savings based on the difference in efficiency levels between high and base efficiency heat pumps. As part of this current report, these efficiency calculations were revisited to see if and how ASHP savings calculations had changed.

The algorithms used by programs are often very similar, and most primarily rely on HSPF (for heating savings) and SEER (for cooling savings). These efficiency metrics are typically combined with heat pump capacities and hours of operation to obtain electric energy savings. Hours of operation are often specified for a specific region in the TRM.

Since the 2013 report, more state TRMs have begun to separate ductless and/or mini-split ASHPs from conventional ASHPs. Many TRMs still use the same equations to calculate energy savings for any type of ASHP, but the baseline efficiency values may be different for different types of heat pumps. Connecticut uses similar equations for all types of heat pumps, but the equations for ductless ASHP savings includes coefficients derived from a pilot evaluation study (KEMA ###) to more accurately predict savings.

One other difference between some equations for ductless and central ASHPs involves duct leakage. Rhode Island and Pennsylvania, for example, have provisions to include duct leakage savings when ductless heat pumps are installed.

The Vermont TRM is unique in that it *only* references variable speed mini-split heat pumps. This equation includes calculating heat pump savings at very low temperatures (below 5°F) where conventional heat pumps don't typically operate. The TRM also reduces HSPF values by 10 percent in the colder, Vermont climate.

Most states only address ASHPs replacing/displacing other electric heat, but two TRMs include procedures when ASHPs offset fossil fuel. The fossil fuel saving calculations in NEEP's Mid-Atlantic TRM (used by DE, DC, and MD) involves estimating annual heating load offset by the heat pump and dividing by natural gas efficiency. The Vermont TRM has more prescriptive approach for different fuel types and various heat pump capacities.

Table 12 contains an overview of which state TRMs mention ductless/mini-split heat pumps and include offsetting fossil fuels. See *Appendix D. Overview of ASHP energy savings equations from State TRMs*. for a summary of energy saving calculations for most states in the region. For reasons of brevity, only the core equations are presented. References are provided for more detail and explanations, and links to this and more information is available on NEEP's Regional Energy Efficiency Database (https://reed.neep.org/Default.aspx). Where equations appear to include only heating savings, cooling savings are calculated separately according to air conditioning measures.

**Table 12: Some features of State Technical Resource Manuals**

| ASHP Characteristics in TRM Energy Savings | CT | DE | DC | ME | MA | MD | NJ | NY | PA | RI | VT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Differentiation for ductless or mini-split ASHPs | X | X | X | X | X | X | | | X | X | X |
| Provisions for ASHPs offsetting fossil fuel | | X | X | | | X | | | | | X |

**Connecticut** - Heating savings for a conventional, split ASHP:

$$AKWH_H = EFLH_H \times CAP_H \times \left(\frac{1}{HSPF_e} - \frac{1}{HSPF_b}\right) \times \frac{1}{1000\ W/kW}$$

$$AKWH_H = EFLH_H \times CAP_H \times \left(\frac{1}{HSPF_e} - \frac{1}{HSPF_b}\right) \times \frac{1}{1000\ W/kW}$$

Heating savings for ductless or mini-split heat pumps:

$$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times \frac{1}{0.171} \times SF_H \times \frac{1}{1000}$$

$$AKWH_H = CAP_H \times \left(\frac{1}{HSPF_E} - \frac{1}{HSPF_I}\right) \times \frac{1}{0.171} \times SF_H \times \frac{1}{1000}$$

0.171 is a conversion factor based on a pilot study

$SF_H$ is a savings factor which varies by location in the state based on a pilot study

Reference: CL&P, UI 2012. http://www.energizect.com/sites/default/files/2013%20PSD_ProgramSavingsDocumentation-Final110112.pdf.

**Delaware**, the **District of Columbia**, and **Maryland** use NEEP's "Mid-Atlantic Technical Reference Manual." For central ASHPs, energy savings are calculated as follows.

At time of sale:

ΔkWH = (FLHcool * BTU/hour * (1/SEERbase - 1/SEERee))/1,000

+ (FLHheat * BTU/hour * (1/HSPFbase – 1/HSPFee))/1,000

Early replacement:

ΔkWH for remaining life of existing unit (1st 6 years) =

(FLHcool * BTU/hourCool * (1/SEERexist - 1/SEERee))/1,000

+ (FLHheat * BTU/hourHeat * (1/HSPFexist – 1/HSPFee))/1,000

ΔkWH for remaining measure life (next 12 years)=

(FLHcool * BTU/hourCool * (1/SEERbasereplace - 1/SEERee))/1,000

+ ( FLHheat * BTU/hourHeat* (1/HSPFbasereplace – 1/HSPFee))/1,000

For "Ductless Mini-Split Heat Pumps" replacing electric heat, savings are calculated as follows.

ΔkWH = (CoolingLoadDHP * (1/SEERbase - 1/SEERee)) +

(HeatLoadElectricDHP * (3.412/HSPFbase – 3.412/HSPFee))

For "Ductless Mini-Split Heat Pumps" replacing gas heat, electric savings are calculated as follows,

ΔkWH = (CoolingLoadDHP * (1/SEERbase - 1/SEERee)) –

(HeatLoadGasDHP * 293.1 * 0.85 * (3.412/HSPFee)))

Gas savings are calculated as follows:

ΔMMBtu = HeatLoadGasReplaced / AFUEexist

Reference: NEEP 2015, http://www.neep.org/sites/default/files/resources/Mid-Atlantic_TRM_V5_FINAL_5-26-2015.pdf.

The **Maine** TRM refers to central air source heat pump and ductless heat pumps separately. Ductless heat pump savings are fixed based on modeling of typical homes weighted for climate and population throughout the state. Annual electric energy savings for a ductless heat pump is as follows.

$\Delta kWh/yr = 1{,}902$

$\Delta kWh_H/yr = 1{,}815$

$\Delta kWh_C/yr = 88$

For central ASHPs savings are calculated as follows.

$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}$

$\Delta kWh_{COOL} = CAP_C \times (1 / SEER_{BASE} - 1 / SEER_{EE}) \times EFLH_{COOL}$

$\Delta kWh_{HEAT} = CAP_H \times (1 / HSPF_{BASE} - 1 / HSPF_{EE}) \times EFLH_{HEAT}$

Reference: Efficiency Maine 2016, http://www.efficiencymaine.com/docs/EMT-TRM_Retail_Residential_v2016_4.pdf.

The **Massachusetts** TRM has separate sections for "Air Source Heat Pumps" and "Ductless MiniSplit Heat Pumps." The savings equations are the same with different baseline values.

$$\Delta kWh = Tons \times \frac{12\ kBtu/hr}{Ton} \times \left[\left(\frac{1}{SEER_{BASE}} - \frac{1}{SEER_{EE}}\right) \times Hours_C + \left(\frac{1}{HSPF_{BASE}} - \frac{1}{HSPF_{EE}}\right) \times Hours_H\right]$$

Reference: MassSave 2012, http://ma-eeac.org/wordpress/wp-content/uploads/TRM_PLAN_2013-15.pdf.

**New Jersey** – Electric energy savings for high-efficiency air conditioners and ASHPs are calculated as follows.

Cooling Energy Savings (kWh) = $CAPY/1000 \times (1/SEER_b - 1/SEER_q) \times EFLH_c$

Heating Energy Savings (kWh) = $CAPY/1000 \times (1/HSPF_b - 1/HSPF_q) \times EFLH_h$

Reference: NJ Clean Energy 2014, http://www.njcleanenergy.com/files/file/Appeals/NJ%20Protocols%20Revisions%202013%20Update_04-16-2014_clean.pdf.

The **New York** TRM refers only to "Central Air Source Heat Pumps" with energy savings calculated as follows.

$$\Delta kWh = units\ x\ \frac{kBtuh_{out}}{unit} \times \left(\frac{1}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat}$$

Reference: TecMarket Works 2010, http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/766a83dce56eca35852576da006d79a7/$FILE/TechManualNYRevised10-15-10.pdf.

The **Pennsylvania** TRM has different sections for "High Efficiency Air Source Heat Pumps" and "Ductless Mini-Split Heat Pumps." The savings equations are the same with different baseline values.

$$\Delta kWh/yr_{heat} = \frac{CAPY_{heat}}{1000\, {}^{W}/_{kW}} \times \left(\frac{OF \times DLF}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat}$$

$$\Delta kWh/yr_{cool} = \frac{CAPY_{cool}}{1000\, {}^{W}/_{kW}} \times \left(\frac{OF \times DLF}{SEER_{base}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool}$$

$$\Delta kWh/yr_{heat} = \frac{CAPY_{heat}}{1000\, {}^{W}/_{kW}} \times \left(\frac{OF \times DLF}{HSPF_{base}} - \frac{1}{HSPF_{ee}}\right) \times EFLH_{heat}$$

$$\Delta kWh/yr_{cool} = \frac{CAPY_{cool}}{1000\, {}^{W}/_{kW}} \times \left(\frac{OF \times DLF}{SEER_{base}} - \frac{1}{SEER_{ee}}\right) \times EFLH_{cool}$$

Reference: Pennsylvania PUC 2016, http://www.puc.pa.gov/Electric/pdf/Act129/Act129_TRM-2016_Redlined-Final.pdf.

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| **Rhode Island** - Electric energy savings for air source heat pumps are calculated as follows.<br><br>Gross kWh = Tons × 12 × [(1/SEER_base - 1/SEER_ee) × Hours_C +<br><br>(1/HSPF_base - 1/HSPF_ee) × Hours_H]<br><br>Electric energy savings for "Ductless MiniSplits" are calculated as for ASHPs shown above plus savings associated with duct sealing.<br><br>Gross kWh = ΔkWh_ASHP + ΔkWh_DuctSealing<br><br>Reference: National Grid 2013. https://www9.nationalgridus.com/non_html/eer/ri/RI%20PY2014%20TRM.pdf. |
| The **Vermont** TRM only references "Variable Speed Mini-Split Heat Pumps." When displacing electric heat, savings are calculated as follows:<br><br>$\Delta kWh = \left[Q_{cooling} \times FLH_{cooling} \times \left(\frac{1}{SEER_{Baseline}} - \frac{1}{SEER_{Efficient}}\right) + \sum_{i=1}^{n} (Q_{Heating \geq 5°F,i}) \times \left(\frac{1}{HSPF_{Baseline} \times 90\%} - \frac{1}{HSPF_{Efficient} \times 90\%}\right) - \sum_{i=1}^{n} (Q_{Heating<5°F,i}) \times \left(\frac{1}{HSPF_{Efficient} \times 90\%}\right)\right] \times \frac{1\ kWh}{1{,}000\ Wh} + \sum_{i=1}^{n} (Q_{Heating<5°F,i}) \times \%ElecHeat \times \frac{1\ kWh}{3{,}412\ Btu}$<br><br>Reference: Efficiency Vermont 2015, http://psb.vermont.gov/sites/psb/files/docketsandprojects/electric/majorpendingproceedings/TRM%20User%20Manual%20No.%202015-87C.pdf. |


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