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

Northeast Energy Efficiency Partnerships
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Northeast Energy Efficiency Partnerships

NEEP was founded in 1996 as a non-profit whose mission is to serve the Northeast and Mid-Atlantic to accelerate energy efficiency in the building sector through public policy, program strategies and education. Our vision is that the region will fully embrace energy efficiency as a cornerstone of sustainable energy policy to help achieve a cleaner environment and a more reliable and affordable energy system.

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Steven Winter Associates, Inc.
Improving the Built Environment Since 1972

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This report reflects the opinion and judgments of the NEEP staff developed in consultation with the Advisory Committee and does not necessarily reflect those of NEEP Board members, NEEP Sponsors, or project participants (including Leadership Advisory Committee participants) and funders.

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EXECUTIVE SUMMARY

Cold Climate Air-Source Heat Pumps Have Arrived

Residential air-source heat pumps (ASHP) offer a major opportunity for homes across the Northeast/ Mid-Atlantic region to reduce home heating energy consumption, costs and greenhouse gas (GHG) emissions, and for States to meet energy policy goals to achieve all cost-effective energy efficiency. This report characterizes that opportunity, identifies market barriers to the broad adoption of ASHP systems, and recommends near-term and long-term program, industry and policy strategies to realize the important potential for energy and cost savings as well as for avoided GHG emissions offered by home ASHP systems.

Residential ASHP are HVAC products that use electricity to provide space heating and, in many instances, space cooling to homes by extracting latent heat in ambient air from one location and transferring it to another. Recent advances in heat pump technology have improved ASHP performance levels, specifically under cold weather conditions, to the point that now, for the first time, ASHPs offer a legitimate space heating system alternative for the Northeast/Mid-Atlantic region which is otherwise largely served by the traditional heating fuels of natural gas, oil and propane and electric resistance. Compared to the traditional heating systems, ASHP's offer superior efficiency performance and provide both home heating and cooling through a single system.

Historically, ASHPs have been inadequate for home heating in the colder climates typical of the Northeast / Mid-Atlantic region. The key issue is that older, conventional ASHP's do not have the capacity or efficiency to sufficiently perform during very cold weather, resulting in heavy reliance on inefficient backup resistance heating systems at freezing temperatures. However, today's high efficiency, high performing ASHP systems (ductless "mini-split" systems being today's most common configuration) can perform at a high level of efficiency even at very low ambient temperatures. As a result, new ASHP's offer an exciting pathway to reduce home heating energy use and costs while reducing associated greenhouse gas emissions.

In recent years, HVAC manufacturers have introduced an exciting range of new ASHPs products to United States' markets. Many of these ASHP products use variable-speed compressors which significantly improve overall system efficiency and performance. Some of these systems perform well at low outdoor temperatures (near or below 0°F). In this report, we refer to these latter systems as cold-climate air-source heat pumps (ccASHPs). They are appropriate in the colder portions of Northeast region (typically IECC climate zones 5, 6 and possibly 7).

Our assessment of the market potential for ASHP systems in the Northeast/Mid-Atlantic region suggests very large opportunities to reduce home heating energy consumption and costs. For example, existing housing data suggests potential ASHP retrofit opportunities for approximately 7.7 million existing low rise homes that currently use electricity, oil or propane to space heat. Adoption of ASHPs in homes that currently heat with electric resistance could provide annual energy cost savings of approximately $1.2 Billion and avoid over 7 million metric tons of annual carbon emissions (equivalent to the annual carbon emissions associated with the energy used by nearly 350,000 homes). Similarly, adoption of ASHP to displace home oil heating could save $1 Billion in annual energy cost and avoid 1.1 million metric tons of annual carbon emissions. New home construction is another attractive market for ASHPs, especially in highly efficient homes with low heating loads or building locations without access to natural gas.

A key barrier to the rapid market introduction of this new generation of high performing ASHP products is lack of well documented energy/cost/peak demand impacts of ASHP installations in scenarios that involve some form of fuel switching (e.g., from heating oil or propane to ASHP) or fuel displacement (e.g., to displace burning of heating oil, propane or natural gas). Such installations are likely to be common in the Northeast/Mid-Atlantic region. Other key barriers include; lack of standardized metrics that describe ASHP capabilities to operate effectively and efficiently at low temperatures typical of the region, lack of consumer and installer awareness of the latest technology, effective controls to manage multiple heating systems, high upfront costs and lack of policy level awareness/support.

To enhance the likelihood of long term market success in the region, NEEP convened a regional collaborative process to develop recommended market strategies to overcome the barriers to broad market adoption of residential ASHP systems. In the spring of 2013, NEEP assembled a Leadership Advisory Committee (LAC) of ASHP stakeholders. The LAC included manufacturers, regulators, utilities, program administrators, engineers, consultants and other contractors. Over the course of several months, the LAC identified barriers and developed strategies to realize increased benefits of residential ASHPs in NEEP's territory, which includes the Northeast and Mid-Atlantic regions.

The strategies represent a combination of existing strategies already being successfully implemented, in and outside of the region, and a collection of new strategies informed by the LAC. While the recommended strategies reflect the region's current understanding of the market and potential implications of broader ASHP penetration, the report identifies a number of data gaps that further research and analysis will be necessary to fill in order to make an even stronger program and policy case for their extensive deployment.

Table ES-1 below summarizes the market strategy areas that respond directly to the critical barriers identified by the Leadership Advisory Committee. More detailed activities are presented in the Regional Strategy Section of the report.

Table ES-1: Recommended Market Strategies to Accelerate Market Adoption of Residential Air-Source Heat Pumps

Near-Term 2014-2015 Regional Stakeholders work through coordinated efforts to:
1. Develop more accurate tools to predict energy and cost savings associated with ASHP installations, through collection of real world performance data
2. Develop standardized Metrics for Cold Climate ASHP Performance
3. Increase Consumer Awareness and Education
4. Expand HVAC Contractor Awareness and Education
5. Improve Integration of ASHPs with Other Heating Systems
6. Provide ASHPs at Affordable Costs to Consumers
7. Characterize policy implications of large scale deployment of ASHPs
Long-Term 2016-2018 Regional Stakeholders work through coordinated efforts to:
8. Clarify the policy case for broad-scale deployment of ASHPs
9. Support federal appliance efficiency standards that incorporate improved cold climate performance metrics
10. **Support International Code Council** recognition of ASHP in model energy codes

We urge states, efficiency program administrators and industry to work together to achieve thoughtful and coordinated implementation of the strategies presented herein to achieve the large potential for energy and costs savings offered by the broad adoption of ASHP systems across the Northeast/Mid-Atlantic region. NEEP stands ready to assist those 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 a residential HVAC technology that use electricity to provide a combination of space heating and, in some 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 compressor has come to market over the past several years. These systems have demonstrated radically improved heating performance under low temperature conditions (near or below 0°F), while continuing to offer highly efficient cooling and, in the process, has opened up vast new markets, including the Northeast and Mid-Atlantic regions.

Some efficient ASHPs can provide space heating at half the cost of many fuel oil or propane systems and at one third the cost of electric resistance heating. Heating costs with efficient ASHPs are often comparable to new natural gas heating systems.

The latest generation of ASHPs present the Northeast/Mid-Atlantic region with new and significant energy savings opportunities. These latest-generation heat pumps have the potential to provide an efficient electric heating alternative in the Northeast and Mid-Atlantic markets where the traditional heating fuels have been natural gas, oil, propane, and sometimes electricity.

NEEP views the expanded use of this particular technology in the region as a potential pathway to multiple outcomes:

- Reduction in energy use (site and/or source) associated with space heating
- Reduction of greenhouse gas emissions associated with residential space heating
- Reduction in costs to heat homes
- Development of an effective solution for comprehensively meeting heating/cooling loads in low load homes (i.e. zero-net energy homes)

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 fully taking 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 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 commercialization stage. 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.

CURRENT STATE OF AIR-SOURCE HEAT PUMP TECHNOLOGY

Residential air-source heat pumps provide space heating and cooling to homes. An air-source heat pump 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 U.S. 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 (near or below 0°F). In many parts of the world – especially in Asia – variable-speed "ductless" or "mini-split" systems are the standard for homes.

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

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. During cooling operation, this cycle is reversed.

Warm air is delivered to the home (during heating season) 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. During the cooling season, 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.

Figure 1. A ductless heat pump fan coil

Terminology and the Scope of this Study

Figure 2 presents basic residential 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. **Air-to-air** heat pumps are the most prevalent and the focus of this report. However, there are at least two manufacturers offering variable-speed **air-to-water** heat pumps in the United States. 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.

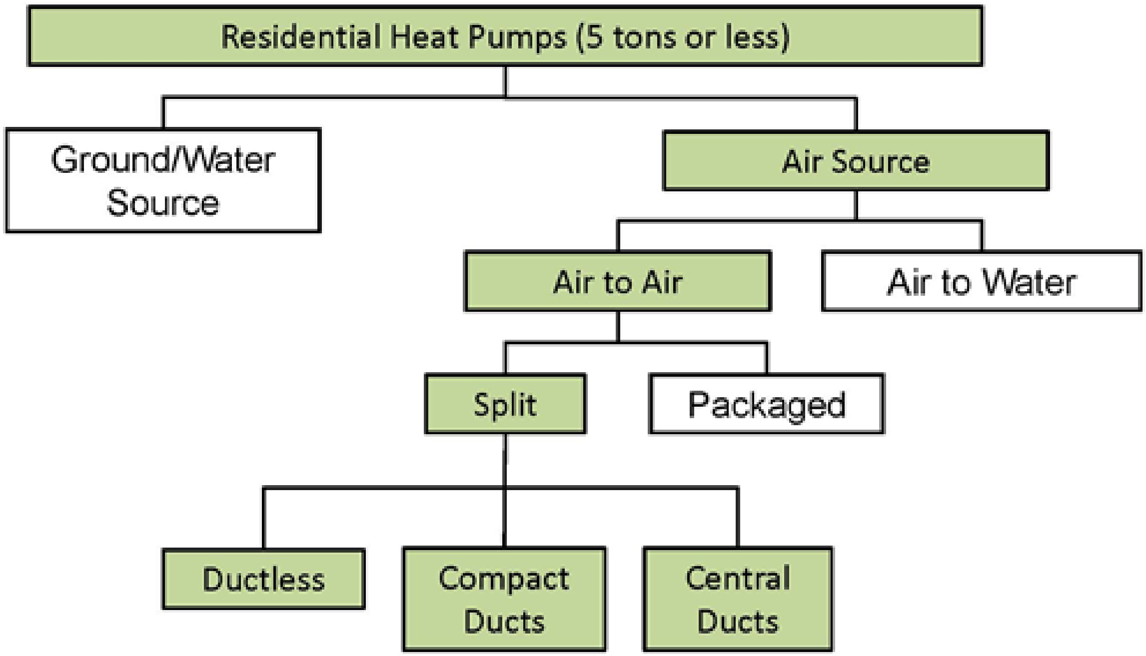


Figure 2. Categorizing Residential Heat Pumps
(Scope of report includes products highlighted in green)

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 often quite costly and are not within the scope of this study.

Packaged heat pumps have all components (compressor, condenser and evaporator coils, fans, etc.) in a single appliance. Packaged terminal heat pumps (PTHPs, see Figure 3) are often used in hotels and apartments. They are installed through a wall and deliver heating and cooling directly to the space. Packaged rooftop units are often seen in commercial buildings; these connect to duct systems which distribute heating and cooling. This report focuses on **split** systems where the outdoor unit and indoor fan coils are separated; refrigerant piping and wiring connect the two.

Figure 3. A packaged, terminal heat pump (PTHP) from inside and outside.

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**, however, does not generally apply to all variable-speed heat pumps. 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.

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** 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).
- A **ductless** heat pump (DHP) delivers conditioned air to a home without use of ducts. Ductless fan coils in homes are most often wall mounted.
- **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".

While conventional, central forced air systems are very common in U.S. homes, there are few inverter-driven, central ducted heat pumps available. Some manufacturers have recently begun making such products; while promising for many applications, installed costs and performance data are not widely available.

Most 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-port** systems where one outdoor unit serves a single fan coil (which can be either ducted or ductless). See bottom 2 illustrations in Figure 4 below.
- **Multi-port** systems where multiple fan coils (typically 2-4) are served from a single outdoor unit. See top illustration in Figure 4 below.

The "ports" referred to here are for refrigerant connections at the outdoor unit; refrigerant lines from most fan coils run all the way back to the outdoor unit in these systems. In addition to size, one difference between a multi-port and a VRF system is this home-run configuration. In VRF systems, refrigerant lines often have branches or manifolds within the building; this does not happen in most residential multi-port systems.

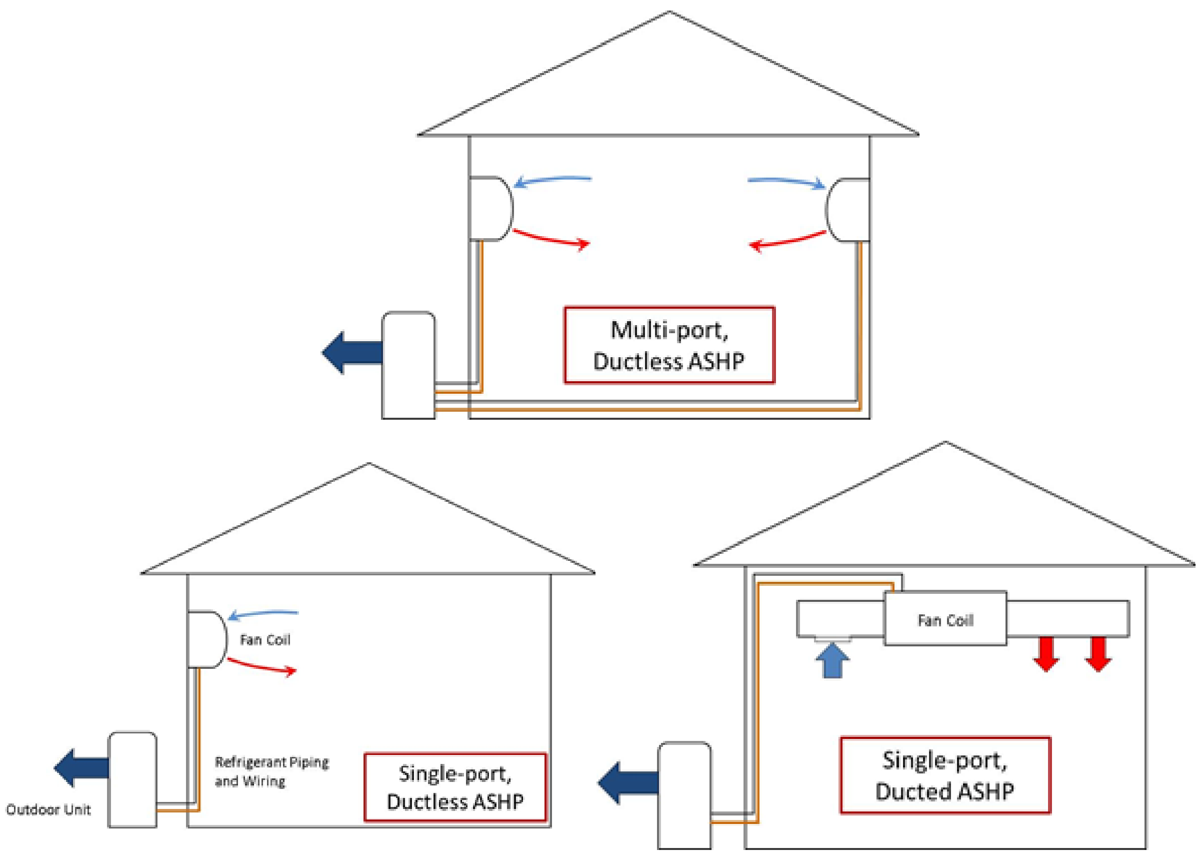


Figure 4. Example schematics of several air-source heat pump configurations.

Single-port systems are sometimes referred to as **mini-split** systems, though this term is not used consistently. Some use mini-split to refer to only ductless systems, some use it to designate small systems (i.e. small heat pump capacity). To avoid confusion, the term mini-split is not used in this document.

Similarly, the term **multi-split** is sometimes used to refer to multi-port systems (a single outdoor unit serving 2-4 indoor fan coils). But as with mini-split, this term is not used consistently; some use multi-split when referring to larger VRF systems.

While there are several electric-powered heating and cooling systems that may be appropriate in homes, the focus of this report is on efficient, split, air-to-air heat pumps that are appropriate for homes in NEEP's territory. The term cold-climate air-source heat pump (ccASHP) is used when referring to air-to-air heat pumps that are appropriate in the colder portions of NEEP's territory (typically IECC climate zones 5, 6 and possibly 7). This term, ccASHP, is currently a qualitative designation. There are not widely accepted criteria for determining which ASHPs are appropriate cold-climate heat pumps. Such criteria could be very useful for stakeholders in NEEP's territory, and some regional programs have begun developing criteria (discussed later in this document). Generally speaking, with current technology, ccASHPs use inverter-driven, variable-speed compressors and have good efficiencies and capacities at temperatures near or below 0°F.

Homes in the milder climates within NEEP's territory, such as IECC zone 4, can still take advantage of efficient, inverter-driven ASHPs. In these milder climates, however, the ccASHP class of equipment, with good performance at temperatures well below freezing, may not be needed.

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). This standard is the basis for compliance with DOE's minimum efficiency standards (specified in the Federal Register at 10 CFR 430.23(m)) for residential central air conditioners and heat pumps, which became effective April, 2008. This standard defines two efficiency metrics for ASHPs:

- **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.
- **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.

SEER and HSPF both have 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). Many efficiency standards also require air conditioners and heat pumps to have minimum EER values. EER is defined as 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.

One other metric used to describe efficiency of heat pumps is **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.

To determine heating capacity and HSPF of variable-speed heat pumps, 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 (Figure 5). 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.

Figure 5. AHRI Climate Regions

Federal Regulations: Minimum Efficiencies

ASHPs are covered under DOE's Appliance and Equipment Standards Program. Current DOE conservation standards for residential air-source heat pumps (effective 2006, DOE 2012) include these minimum efficiencies:

- SEER: 13 Btu/Wh
- HSPF: 7.7 Btu/Wh

New regulations that are to be effective on January 1, 2015 will require that equipment have the following minimum efficiencies:

- SEER: 14 Btu/Wh
- HSPF: 8.2 Btu/Wh

In addition, 2015 federal standards will require that systems installed in several states in the southwest have minimum EER values (11.7-12.2 depending on capacity, DOE 2012).

ENERGY STAR Requirements

While DOE sets minimum system efficiencies, EPA manages the ENERGY STAR™ program for appliances. 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 (EPA 2013a):

- SEER: 14.5
- EER: 12
- HSPF: 8.2

The ENERGY STAR website also lists criteria for the "Most Efficient" heat pumps available in 2013 (EPA 2013c). To attain the "Most Efficient" designation, ASHPs must meet these criteria:

- SEER: 18
- EER: 12.5
- HSPF: 9.6

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

The current ENERGY STAR criteria are similar to the upcoming 2015 minimum efficiency criteria. Accordingly, ENERGY STAR is currently determining how to raise the bar on ASHP certification (EPA 2013b). One very noteworthy item in the 2015 DOE minimum efficiency standards is the additional requirements for cooling systems in the Southwest. While these requirements do not affect the Northeast, these regulations have an important implication: the federal government is shifting away from its one-size-fits all approach to HVAC equipment regulation. Intuitively, this regional approach seems sensible. In regions with greater cooling/heating loads, it is more cost effective for consumers to purchase and operate high efficiency equipment..

The regional approach, however, makes labeling complicated; air conditioners and heat pumps would need region-specific labels. While other ENERGY STAR products have adopted this approach (e.g. windows, EPA 2009), regional rating of conventional air conditioners and heat pumps is further complicated in that air conditioner and heat pump performance ratings (SEER, EER, HSPF) depend on several pieces of equipment: the outdoor unit, the indoor coil, and the air handler. ENERGY STAR is currently evaluating how to address these challenges with regional standards (EPA 2013b).

Heating Performance Metrics in Cold Climates

At a minimum, ASHP manufacturers generally provide the following information to characterize heating performance:

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

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 ccASHPs 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 ccASHPs 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 ccASHPs 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.

Figure 6. 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)

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 and peak demand 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 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/Mid-Atlantic region.

A recent NEEP effort (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 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.

The algorithms used by programs are quite similar (see Table 1). Electricity reductions (DkWh) are based on differences in HSPF (HSPFbase vs. HSPFee) and estimated run times (EFLH). As discussed above, HSPF does not provide an accurate representation of efficient, inverter-driven ASHP performance. Using HSPF likely results in under-prediction of savings from efficient, inverter-driven ASHPs when compared to conventional ASHPs.

Table 1. Overview of algorithms used by various programs to predict savings from efficient heat pumps (ERS 2013).

TRM	Annual Energy Savings Algorithm
NY, 2011	DkWh = units xx ([-] x EFLHc + [-] x EFLHh)
UI/ CL&P, 2012	DkWh = EFLHh x CAP x ([-] x
MA, 2010	DkWh = tons xx ([-] x EFLHc + [-] x EFLHh) + DkWhseal
PA, 2011	DkWh = kBtu/hr x ([-] x EFLHc x LF + [-] x EFLHh x LF)
VT, 2011	DkWh = kBtu/hr x ([-] x EFLHc + [-] x EFLHh)

One of the key drivers of the growing interest in new heat pump technologies is 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, fuel oil, and propane systems. Some studies show that operating costs are on par with natural gas systems. Fuel and electricity costs certainly play an important role in these cost comparisons, and these costs vary throughout the region.

This section will carefully examine the current state of savings for a number of different retrofit and new construction applications. This section also includes analysis exploring source energy ramifications, electric demand impacts, and potential climate benefits (carbon emission reductions) from the use of this technology. While most of the section focuses on savings at the household level, regional savings are extrapolated for a couple of different scenarios.

Replacing Electric Resistance Heat

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 HP 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 HDD65. 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.

The wide range in savings is probably largely explained by these reasons:

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 1; savings will be much higher in homes with larger heating loads. At $0.153/kWh (EIA 2013i) saving 3,000 kWh equates to $459.

Replacing Oil

Another key savings opportunity for homes in the Northeast is reducing fuel oil consumption. According to EIA (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 $3.87 per gallon (EIA 2013i), this translates into an annual heating cost of $1,962[1]. If this same heating load were met entirely with an ASHP, the heat pump would consume approximately 6,200 kWh/year[2] – costing $948 at $0.153/kWh. There is a 50% reduction in operating cost in this example.

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.

Displacing Oil

In many homes, a lower-cost option is displacing rather than replacing oil heating (i.e., the oil heating systems will remain in place but operate less frequently). 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). The table below shows the net annual savings in this example is over $300.

Table 2. Estimate of heating savings when ASHP displaces oil; based on electric resistance displacement savings of 3000 kWh/y.

Oil Savings	164 gallons	$633
Added Electricity	2,000 kWh	$306
	Net Annual Savings:	$327

While not as widespread as fuel oil, liquid propane (LP) is used in many homes in the region. At costs of $3.00 per gallon, propane is more costly than fuel oil: $33/MMBtu for propane, $28/MMBtu for oil at $3.87 per gallon (EIA 2013i). Displacing propane with efficient, inverter-driven ASHPs may result in slightly higher savings.

New Homes

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;

1 With annual oil system efficiency of 75%.
2 With annual heat pump COP of 2.5.

- 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 7. These Eiakim's Way homes (built by South Mountain Company) are heated primarily by ductless heat pumps. Several homes achieve zero net energy (credit: South Mountain).

In Western Massachusetts, Rural Development Inc.'s Wisdom Way Solar Village is a similar development where gas heating was used but where ccASHPs may have been more practical. In 12 of these very efficient homes, average annual gas bills were $377. Nearly one third of this value ($116) was utility fees. In addition, bringing natural gas to the site cost the developer $30,000, not including gas plumbing within the homes. While the homes are working quite well, this is a situation where an all-electric approach with efficient heat pumps could have saved money both for the developer and home occupants.

Figure 8. Total gas bills for these western Massachusetts homes were only $377 per year, but both the developer and home occupants could have saved by using heat pumps.

Most new homes, of course, do not strive for zero-energy performance. 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 Figure 9). 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 2009 IECC (and in some cases 2012 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 10-15 MMBtu.

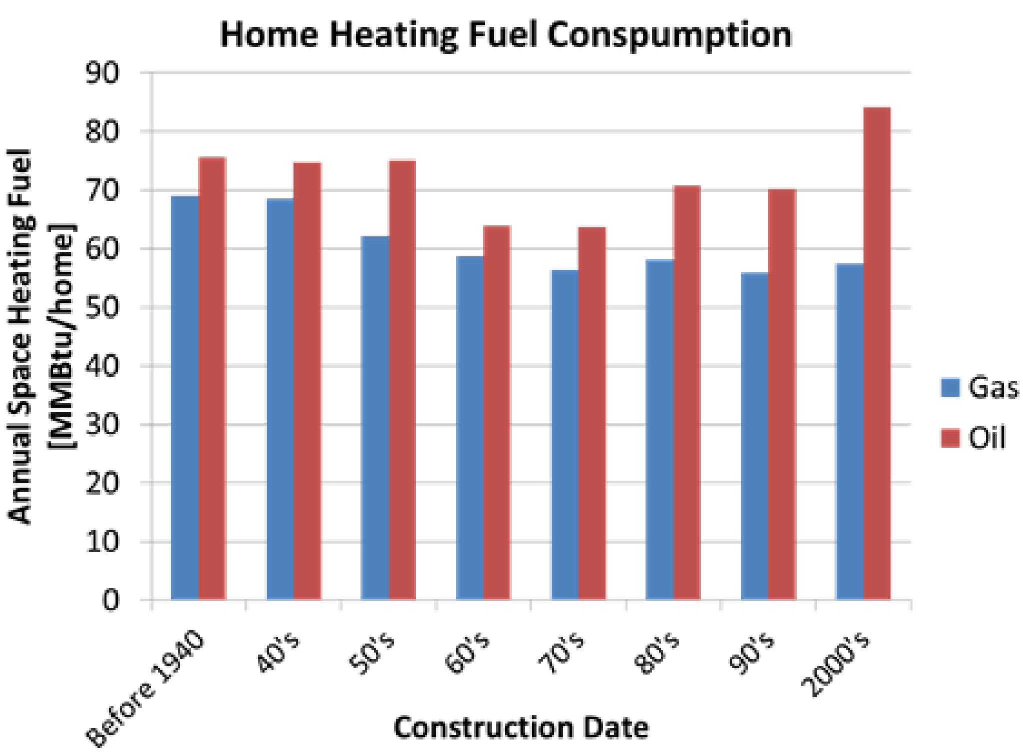


Figure 9. Home space heating fuel from RECS (EIA 2013g).

Table 3 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 two 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 a wash. Operating costs for fuel oil, propane, and electric resistance systems are usually more than 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.

Cost Comparisons Across Heating Fuels

Table 3. Estimated heating costs with various loads and fuels. Fuel prices from EIA (EIA 2013i[3]).

	Fuel	Oil	LP	Natural Gas	Electricity (ASHP)	Electricity (Resist.)
	Seasonal Eff/COP	80%	90%	90%	2.5	100%
	Fuel Cost	$3.87 per gallon	$3.00 per gallon	$1.15 per therm	$0.15 per kWh	$0.15 per kWh
Example Home Type	Annual Heating Load	Approximate Annual Operating Cost*				
Large, inefficient	100 MMBtu	$3,710	$3,880	$1,506	$1,794	$4,484
Average NE Home	50 MMBtu	$1,855	$1,940	$753	$897	$2,242
New, code-compliant	25 MMBtu	$927	$970	$376	$448	$1,121
Very efficient	10 MMBtu	$371	$388	$151	$179	$448

*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.

Ducted vs. Ductless

One component that the energy values here do not necessarily incorporate is distribution system losses – especially duct losses. Practitioners in the home energy field have become quite familiar with the potential liabilities of duct systems. When ducts are installed in

3 http://www.eia.gov/forecasts/steo/tables/pdf/wf-table.pdf

crawlspaces, attics, in outside walls, etc., they can lose tremendous amounts of energy. Studies have shown average duct systems in older homes are only 60-70% efficient (LBNL 2003); this means 30-40% of the thermal energy that goes into them is lost and does not reach the spaces it's meant to condition.

Hydronic systems, because they rarely leak, are often much more efficient than duct systems. Pipes running in basements, in outside walls, etc. can still reduce a system's distribution efficiency. When offsetting such inefficient systems, ductless ASHPs (DHPs) can provide substantially more savings than shown in the tables above. This is not meant to recommend DHPs as an alternative to duct sealing or improving distribution efficiency, but DHP savings when offsetting inefficient distribution systems can be considerably higher.

Lack of distribution can also be a comfort liability for ductless heat pumps. In some homes, secondary spaces (i.e. spaces not heated by the DHP) may be uncomfortable. Occupants may use less efficient systems, such as electric resistance heaters, to improve comfort. Like savings impacts, these comfort liabilities will vary tremendously in different homes with different systems.

Source Energy and Emissions

While using heat pumps to displace fuel oil and propane can result in significant operating cost savings, reductions in source energy and greenhouse gas emissions may be more modest. Table 4 shows global warming potential of several fuels in units of equivalent pounds of carbon dioxide emissions (CO2e). The values include energy needed to distribute or deliver fuel or electricity to a building – not just the emissions from the plants or the fuels themselves (Deru and Torcellini 2007). The emission value for electricity is an average for the eastern U.S. The table also shows the emissions associated with meeting a 50 MMBtu thermal load in a home. In this simple example, using a heat pump – running on standard electricity from the grid – results in 24% less CO2e than using fuel oil but 6% more CO2e than using natural gas. Using the same example, Table 5 shows that source energy variations are similar (source energy ratios from Deru and Torcellini 2007).

Table 4. Estimated greenhouse gas emissions (in equivalent pounds of CO2) for several fuels and systems.

Fuel	Oil	LP	Natural Gas	Electricity (ASHP)	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	1.74 per kWh	1.74 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	10,199	25,498

*Fossil fuel system emissions include 750 kWh for fans, pumps, controls, etc.
Values do not account for different distribution efficiencies of systems.

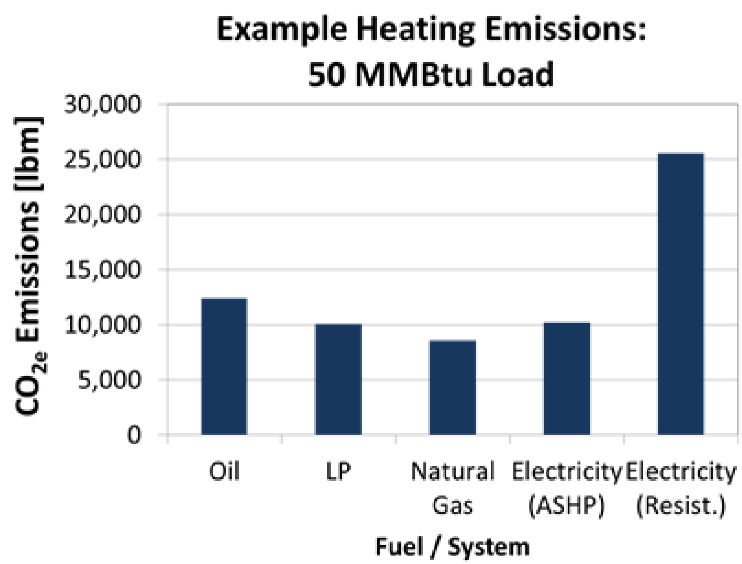


Figure 10. Estimated emissions from systems described in Table 4.

Table 5. With the same fuels systems and efficiencies as Table 4, source energy needed to meet a 10 MMBtu thermal load.

	Oil	LP	Natural Gas	Electricity (ASHP)	Electricity (Resist.)
Source/Site Energy Ratio	1.158	1.151	1.092	3.443	3.443
Source Energy to Meet 50 MMBtu thermal load [MMBtu]	74.1	65.7	62.4	68.9	172.2

*Fossil fuel systems include 750 kWh for fans, pumps, controls, etc.
Values do not account for distribution efficiencies of systems.

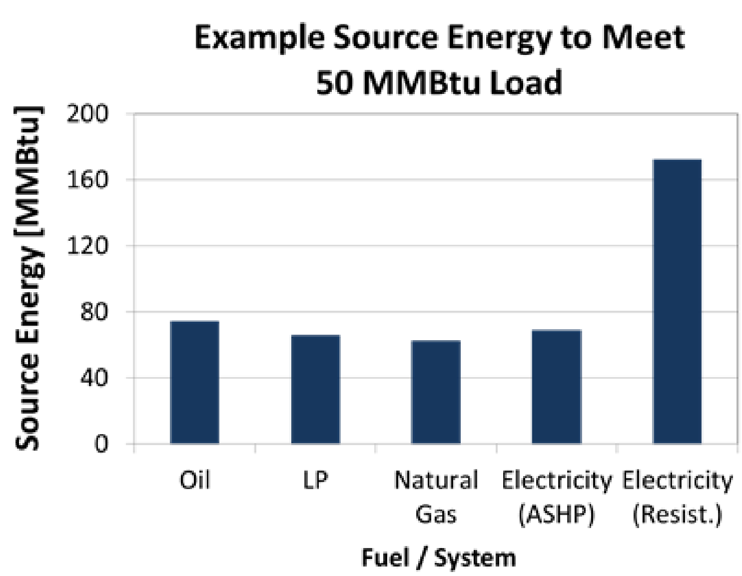


Figure 11. Example source energy needed to meet heating loads described in

While the emissions and source energy values presented here do not always present overwhelming arguments for ASHPs over fossil fuel systems (especially natural gas), stakeholders rightly point out that these overall numbers do not tell the whole story. Source energy and emissions from electricity can vary tremendously from region to region. EPA's eGRID service breaks down emission values by region and by state (EPA 2012). Figure 12 shows the large disparity in emission rates of states within NEEP's territory. In addition to regional variations, carbon dioxide emissions associated with electricity generation have been decreasing over time (see Figure 13). Natural gas and renewable energy have provided larger shares of the overall grid electricity supply, and this trend is likely to continue.

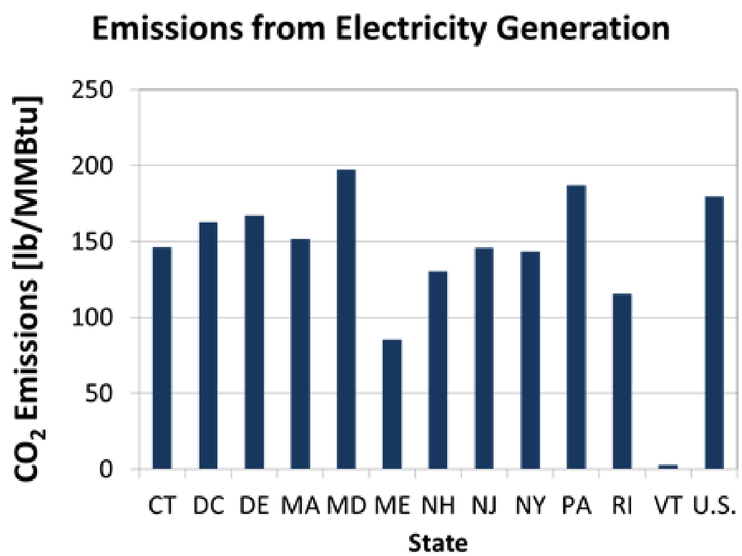
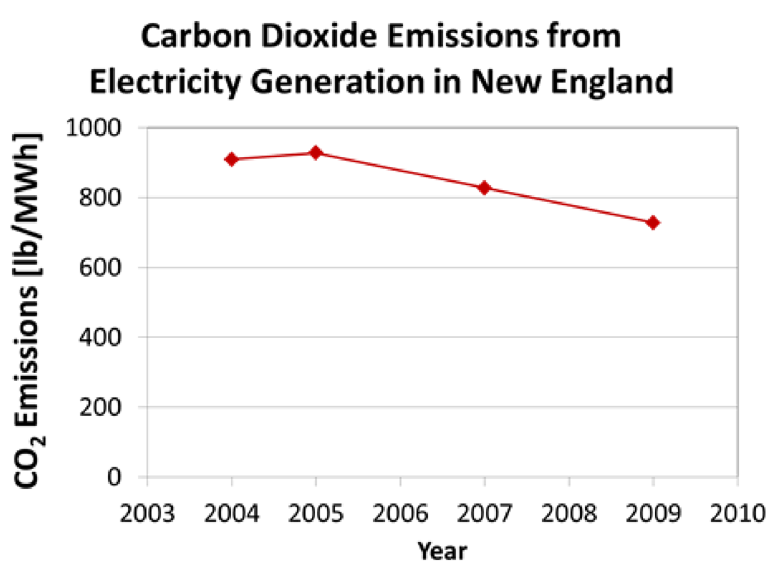


Figure 12. Carbon dioxide emissions associated with electricity generation in NEEP territory (EPA 2012[4]).



4 http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2012V1_0_year09_SummaryTables.pdf

Figure 13. Trend of lower carbon dioxide emissions from electricity generation; example showing New England region (EPA 2012[5]).

As more grid energy 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 (see Figure 12), operating a heat pump on grid electricity may be a nearly emissions-free HVAC option. At a much more local level, renewable energy installed on or near a building can provide energy needed to operate a heat pump. Several zero-net energy buildings in the region have followed this model. The Amherst, MA home in Figure 14 generates more electricity than it consumes – including energy to operate the inverter-driven ASHP (located at the southeast corner of the home).

Figure 14. This Massachusetts home won the NESEA "Zero Energy Buildings" award in 2012. All heating and cooling is provided by a ccASHP.

Electric Demand Effects

NEEP's Emerging Technologies report (ERS 2013) also reviews 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.

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

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5 http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

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[6], installing a 2-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 2-ton heat pump would increase winter peak demand by 380 Watts on average; 2,600 2-ton heat pumps would increase winter demand by approximately 1 MW.

These numbers are obviously only estimates, and 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.

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

ASHP MARKET AND MARKET POTENTIAL

Sales Trends

Shipments of unitary equipment over the past several years for the entire U.S. are shown in Figure 15. Unitary air conditioners and heat pumps are factory-made assemblies that normally include an evaporator and a compressor/condenser combination. Shipments of unitary equipment began to decline in 2005 with the downturn in the housing market. Meanwhile, the shipments of ductless systems (both heating and cooling) show a fairly consistent increase of 17% per year to nearly 350,000 units in 2011. While these sales data do not clearly document the specific applications that the ductless systems are being utilized for (primarily cooling applications, primarily heating applications or applications utilizing a mix), anecdotal information suggest that cooling applications make up the majority.

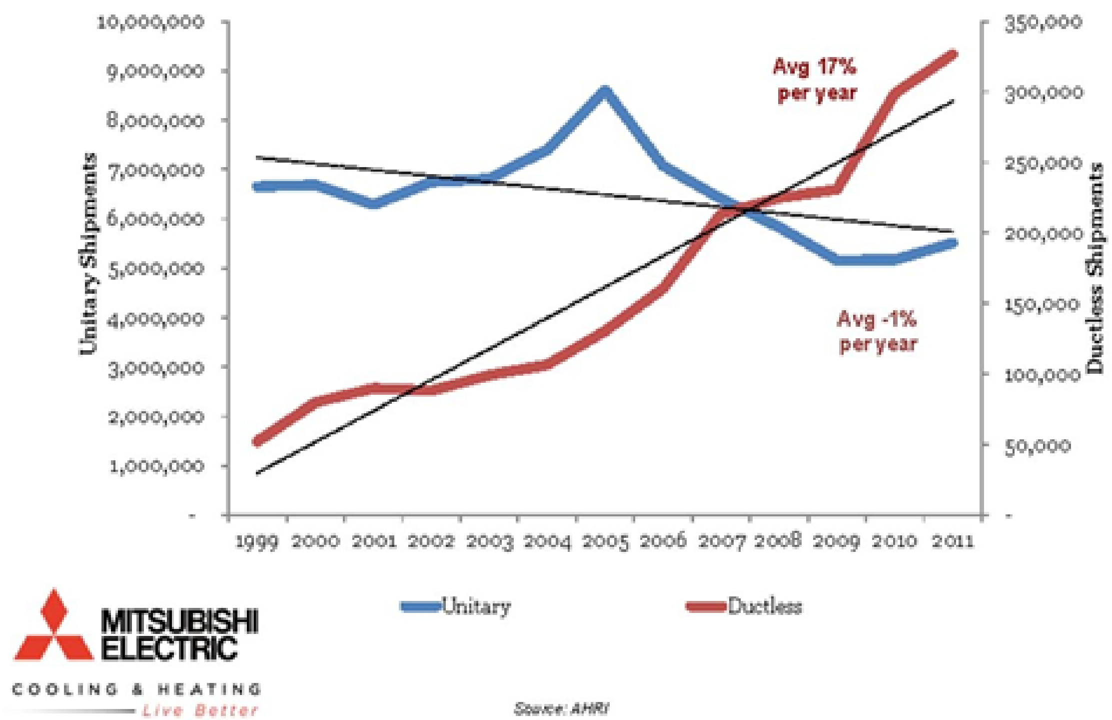

Figure 15. Shipments of unitary AC and heat pumps in the U.S. from all manufacturers (AHRI data, courtesy of Mitsubishi Electric)

There are many manufacturers of residential, ductless ASHPs, but Mitsubishi and Fujitsu together represent approximately half the market. The top five manufacturers, including LG, Daikin, and Panasonic, have 75-80% of the ductless market nationwide (both heat pumps and cooling only). Of all the residential ductless systems that Mitsubishi sold in the US, Mitsubishi reported that 71% were single-port systems (i.e. a single fan coil connected to an outdoor unit).

After talking with manufacturers and distributors, the authors estimate current annual sales of residential, inverter-driven heat pumps are 150,000-200,000 systems in the Northeast alone. Both Fujitsu and Mitsubishi have reported significant, steady growth in sales in the Northeast: 25-35% per year over the past several years.

The path to market for ductless heat pumps primarily follows the traditional path utilizing distributors and certified dealers/installers. However, it is possible to purchase lesser known systems online through vendors such as Amazon. Larger manufacturers frown on this direct, online sales practice, as there are much lower chances that the system will be installed properly by a qualified contractor.

Large manufacturers have, however, participated in marketing programs where representatives displayed systems in big box stores such as Home Depot and Costco. These systems are not available for consumers to purchase and bring home; consumers are still required to hire a qualified installer.

Current 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:

- Replacement – replacing an existing heating system (e.g. end of useful life)
- 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
- New construction or additions
    - Homes without natural gas availability
    - Low load homes
        - Net zero all-electric homes with solar electric systems
        - Avoiding gas infrastructure costs and on going meter fees

A recent Massachusetts evaluation report (Cadmus 2013) states that more than 95% of ductless mini-split systems are either first-time cooling installations or are replacing window air conditioners. What is not reported is how many of these installations are heat pump systems rather than just air conditioning. The systems were promoted within a cooling program, but the installed cost difference between AC-only and heat pump is minimal.

Efficiency Program Activity

Several states currently incentivize heat pump installation, and several program administrators in the Northeast were surveyed to obtain information on such activity. Low income programs, such as Connecticut's Home Energy Solutions (HES) Income-Eligible program and

Efficiency Maine's Low Income Weatherization program, seem to be the most active. In Connecticut's HES program the 3,500+ installs were at 51 different sites, indicating multifamily housing (CEEF 2012).

Table 6. Heat Pumps Installations

State & Program	Program Term	Air to Air Ducted Heat Pumps Installed	Ductless Split Heat Pumps Installed
Connecticut (UI) (Parsons 2013)	1/2013 to 8/2013	9	16
	2012	29	168
Connecticut's Ductless Heat Pump Rebate program (CEEF 2012)	2011	n/a	490
Connecticut's Home Energy Solutions Income Eligible program (CEEF 2012)	2011	n/a	3,576
Efficiency Maine's Low Income Weatherization program (Meyer 2013a)	8/2012 to 8/2013	n/a	1,350
Efficiency Maine's Open Market Pilot program (Meyer 2013a)	12/2012 to 8/2013	n/a	660
Efficiency Vermont's Cold Climate Heat Pump program (Faesy 2013)	4/2013 to 8/2013	0	11
Massachusetts (Cape Light Compact) (Dudley 2013)	1/2013 to 8/2013	1	217
	2012	1	524
Public Service of New Hampshire (Belair 2013)	1/2013 to 8/2013	190	244
NYSERDA (Borowiak 2013)	1/2013 to 8/2013	14	7
	2012	14	8

Installed Cost Data

Several published studies were reviewed to obtain installed cost information. While the age of the studies and level of system detail varied, a rough "typical" installed cost for a single-port ductless heat pump is $3,500-$4,000. From the studies where capacity is noted, installed costs average near $2,500-$3,000 per ton. The studies involved one- and two-port systems primarily.

Table 7. Installed Cost in Published Studies and State Programs

Source	Location or Utility	Estimated cost per home	System Description (if known): a) # Zones b) Average capacity c) # of homes
Ductless Mini Pilot Study (Kema 2009)	Connecticut & Massachusetts	$4,926	a) - b) - c) 26 homes
		$12,267	a) - b) - c) 14 homes
	Connecticut Light & Power (Connecticut)	$4,200	a) 1 or 2 zones b) 2 ton per home average c) 85 homes * Cost driven down because 1 vendor selected, less options offered
	United Illuminating (Connecticut)	$6,061	a) 1 or 2 zones b) 1.9 ton per home average c) 10 homes
	National Grid (Massachusetts)	$8,637	a) - b) 2.7 tons per home average c) 25 homes
	NSTAR (Massachusetts)	$9,440	a) - b) 2.3 ton per home average c) 24 homes
	Connecticut & Massachusetts	$5,973	a) - b) 2.2 ton per home average c) 144 homes
Efficiency Maine's Low Income Weatherization program, 8/2012 to 8/2013 (Meyer 2013b)	Maine	$2,069	a) Mostly single port systems b) Mostly 9,000 Btu/h c) 1350 homes
Efficiency Maine's Open Market Pilot program, 12/2012 to 8/2013 (Meyer 2013b)	Maine	$3,228	a) Mostly single port systems b) - c) 660 homes
Northwest Ductless Heat Pump Initiative: Market Progress Evaluation Report #2 (Evergreen Economics 2012)	Northwest	$3,593	a) 58% single port systems b) 15,000 to 18,000 BTU/h capacity (most common) c) 15,800 homes between 2010 - 10/2012

Source	Location or Utility	Estimated cost per home	System Description (if known): a) # Zones b) Average capacity c) # of homes
NYSERDA, data since 2012 (Borowiak 2013)	New York	$8,406	a) - b) 29,873 BTU/h c) 15 homes
Public Service of New Hampshire, data since 2013 (Belair 2013)	New Hamp-shire	$4,032	a) Mostly single port systems b) 16,033 BTU/h c) 244 homes
Vermont's CEED-Efficiency Vermont Cold Climate Heat Pump program (Marin 2013)	Vermont	$4,867 per home ($4,096 per unit)	a) 1 or 2 port systems b) 19 BTU/h c) 21 installed units at 18 sites

Other assessments and reports are consistent with the average costs in this table. A recent report on heat pumps in the Northeast estimates ASHP installation at $4,000 per unit for a retrofit (Matley 2013). Similarly, estimated installation costs for a single ductless ASHP in small homes (1,000 ft2) in Southeast Alaska homes were $3,000 to $3,500; estimated costs for homes twice this size were $6,000. The same study ballparks a larger home with a multiport ductless ASHP to cost $8,000 to $10,000 (Stevens 2013).

A NEEP-sponsored study (Navigant 2013) documents average, installed costs of $3,078 for a ¾-ton, 18-SEER unit and $3,874 for a 2-ton, 18-SEER unit. This study may include costs for cooling-only systems. Average labor costs were reported to be $1,736 per unit according to the study's survey of contractors, although labor costs vary widely regionally and by application.

Looking at the costs in the table above, it is clear that prices are starting to drop as this technology has gotten more robust and contractors have gained experience. It is also clear that heat pumps in larger-scale programs or studies cost less than in small-scale programs.

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 16. NEEP's Northeast and Mid-Atlantic Region

For reference, the International Energy Conservation Code (IECC) defines seven climate zones as shown below in Figure 17. 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.

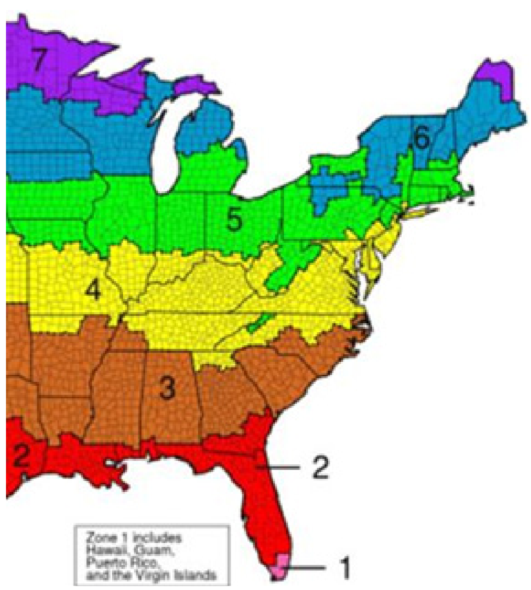

Figure 17. IECC Climate Zones

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 (see Figure 5).

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

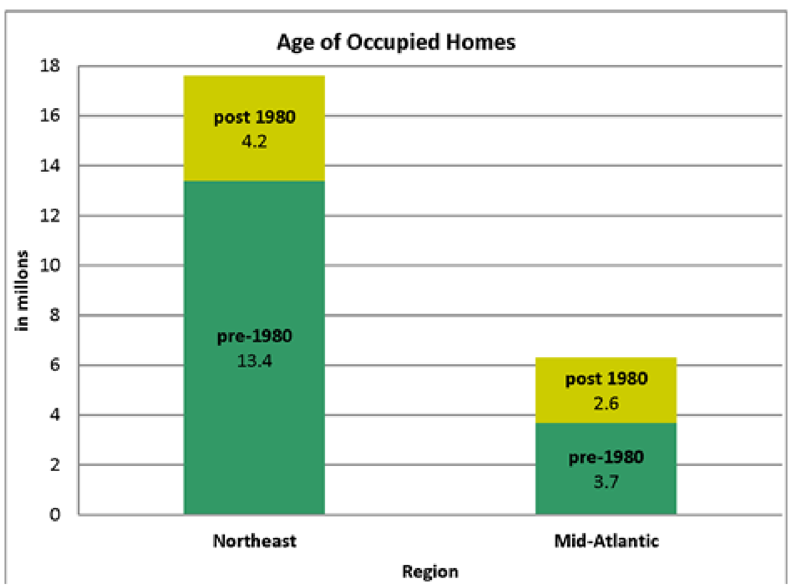

Figure 18. Age of Occupied Homes (EIA 2013e & 2013f)

Housing Type

Of the 17.6 million homes in the Northeast region, 75% 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% 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.

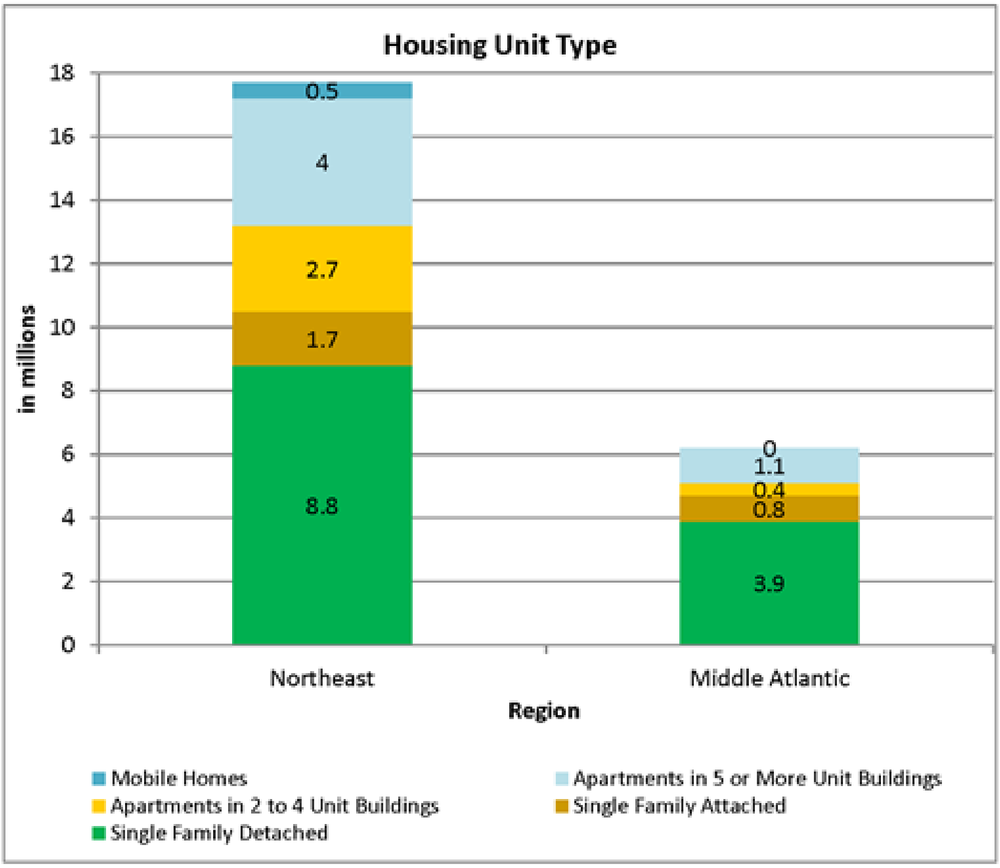

Figure 19. Housing Unit Type (EIA 2013e & 2013f)

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% of homes use oil. In contrast, in the Mid-Atlantic region, 58% use gas and only 6% use oil.

Electricity is used for heating in 12.5% and 25.8% 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% of Northeast homes and 11.1% of Mid-Atlantic homes.

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

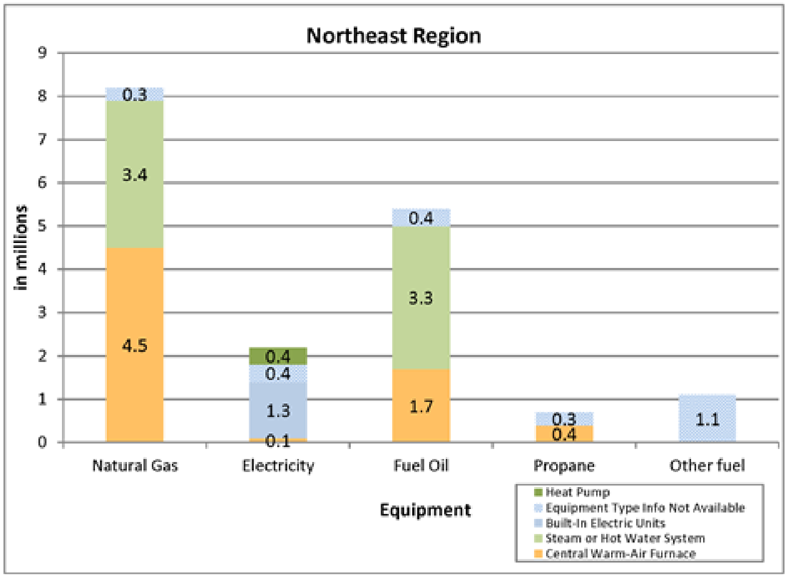

Figure 20. Heating Equipment in Northeast Region (EIA 2013c)

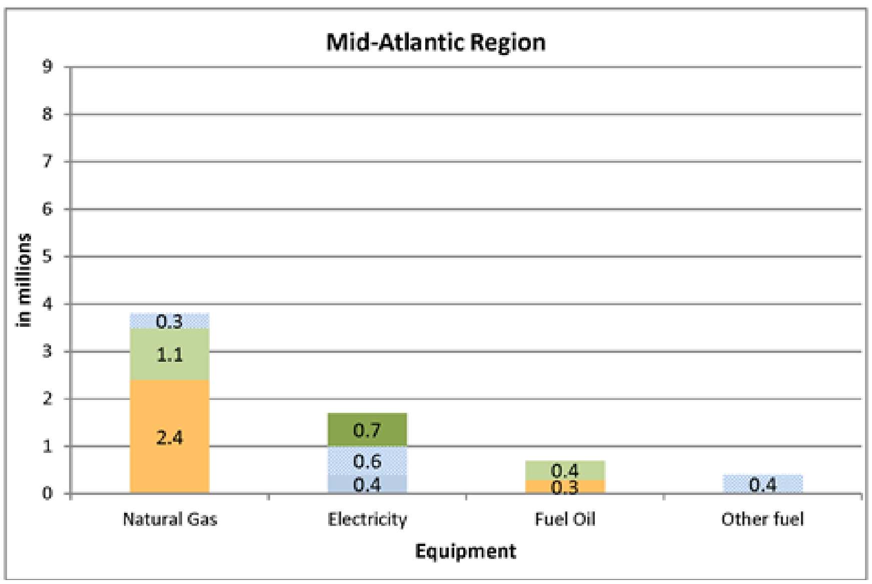

Figure 21. Heating Equipment in Mid-Atlantic Region (EIA 2013d)

Cooling Equipment

In the Northeast, only 30% 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% of homes in the Mid-Atlantic have central air conditioning systems, but half of them are more than 10 years old – candidates for replacement.

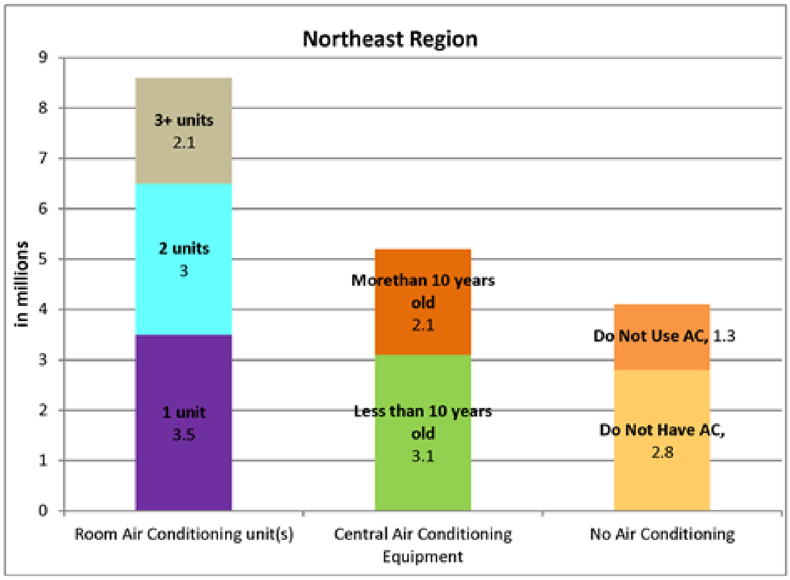

Figure 22. Cooling Equipment in Northeast Region (EIA 2013a)

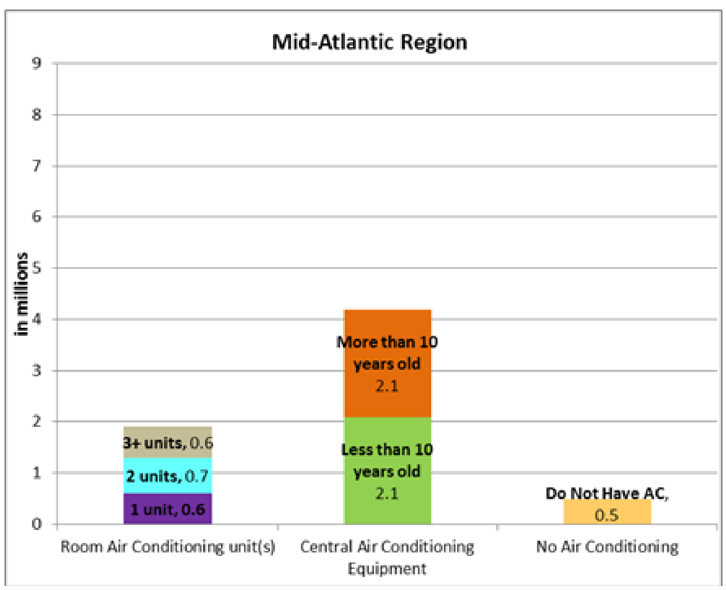

Figure 23. Cooling Equipment in Mid-Atlantic Region (EIA 2013b)

Existing Housing Target Markets

The existing housing characteristic data suggests several significant market opportunities in the Northeast region. If we assume that 25% of the homes are apartments in buildings of 5 or more units and exclude them, there are 10 million homes constructed prior to 1980, 9.5 million homes without central air conditioning, and 4 million homes that use oil for heating. As demonstrated in Figure 24 below, these population numbers are not additive and the overlap is not known, but it is believed to be substantial. An excellent heat pump candidate home would be an older home that is getting an energy retrofit including a smaller and more energy efficient heating system. If the home used electric resistance or oil for heating previously, the electric heat pump offers energy cost savings. If the home did not have central air conditioning, the heat pump would also provide a significant summer time comfort improvement. These same target markets in the Mid-Atlantic region are substantially smaller.

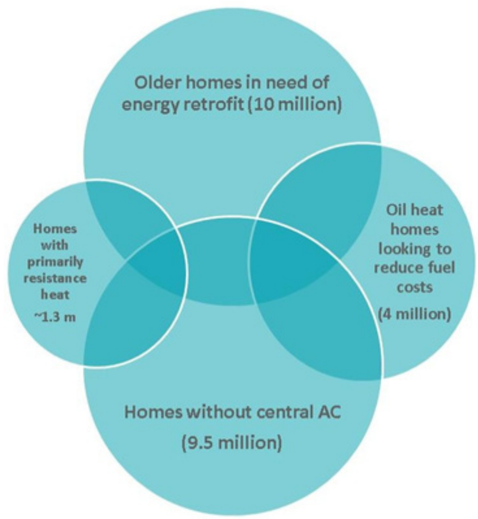

Figure 24. Northeast Region Existing Housing Target Markets

Overall Savings Potential

Based on per unit energy savings estimates for ASHPs and the potential market for the technology discussed above, Table 8 estimates the regional savings potential under two example scenarios: displacing oil 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 past 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 8. Examples of potential heating-related savings for efficient ASHPs in NEEP territory when displacing oil and electric resistance. Potential numbers of homes are estimates based on RECS information discussed above.

		Annual Average per Home			
	Installed Cost	Operating Cost Savings	Reduced Emissions [lbm CO_{2e}]	Reduced Source Energy [MMBtu]	IRR*
Older Homes, Displacing Oil	$5,000	$327	738	1.8	3.1%
Displacing Electric Resistance	$5,000	$459	5,232	35.3	8.6%

		Annual Potential, Overall Market		
	Potential No. Homes	Operating Savings [million]	Reduced Emissions [tons CO_{2e}]	Reduced Source Energy [Bil. Btu]
Older Homes, Displacing Oil	3.1 Million	$1,019	1,149,143	5,541
Displacing Electric Resistance	2.7 Million	$1,239	7,063,548	95,387

*Assuming 3% energy inflation and 15-year lifetime.

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 electricity for all loads. Efficient ASHPs can provide heating savings compared to oil and propane; heating costs are often close to those of efficient natural gas systems. Instead of a cost premium in existing homes, in new homes, efficient ASHPs can often be installed at much lower costs than other alternatives; a single system can provide both heating and cooling, and it avoids costs related to gas piping, oil and propane tanks, etc.

IDENTIFICATION AND PRIORITIZATION OF MARKET BARRIERS

During the summer of 2013, NEEP convened a Leadership Advisory Committee (LAC) consisting of stakeholders across the Northeast and Mid-Atlantic. The LAC consisted of heat pump manufacturers, utilities, regulators, engineers, contractors, and other interested parties. The LAC met several times via conference call and webinar – along with much e-mail correspondence – throughout the summer. In August, the LAC identified the top barriers to efficient ASHPs becoming more widespread in the region, and LAC members voted on the most critical barriers to address. The full list of barriers is captured in Appendix B. While the issues evaluated were many and complex, authors have summarized them in two overall categories.

Consumer and Contractor Barriers

- There is poor awareness of available technologies by consumers and contractors alike. Some of this awareness gap is related to cold-weather performance. Older ASHPs did not have good cold-climate performance, and there are still systems on the market that do not have good cold-climate efficiencies and capacities. Because of these inefficient systems, "electric heating" may carry a stigma in the minds of some consumers.
- Complicating matters, with current performance rating metrics, it's not easy to tell (for both contractors and consumers) which systems are appropriate for colder climates.
- Studies have shown that there is certainly potential for reducing home heating costs, but the same studies show the range in savings is very large and hard to predict.
- Installation costs can be high and can be hard to justify with variable, uncertain savings.
- Ductless ASHPs are not appropriate replacements for existing ducted systems in homes (oil or gas-fired furnaces). In existing homes, displacing older systems is often more practical, but this presents challenges relating to integration and controls.

Regulatory, Utility, and Program Barriers

- For regulators and program administrators, the challenge of predicting energy consumption and/or savings is again a key barrier.
- Complicating this further, many of the prime targets for operating cost savings involve offsetting fuel oil or propane while increasing electricity use. Promoting fuel switching through the ratepayer-funded energy efficiency programs is often problematic, especially when source energy and/or emissions reductions achieved by moving to ASHPs are unclear.

The following section explores these barriers in more detail along with suggested strategies stakeholders may use to overcome them.

REGIONAL STRATEGIES

Strategy #1. Develop more accurate tools to predict energy and cost savings associated with ASHP installation.

Probably the most common, recurring barrier that arose in the LAC's communications was the uncertainty in predicting energy consumption and/or savings, given the diversity of scenarios under which ASHPs can be installed:

- For consumers, it is difficult to assess investing in ASHPs without knowing the likely savings.
- It is awkward for contractors if they cannot provide valid operating cost comparisons of several systems.
- 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 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. Results of larger-scale evaluations can help stakeholders predict savings more accurately in a variety of applications.

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

1. Pre/post utility bill analyses where electricity and/or fuel bills are compared before and after heat pumps are installed.
2. Field metering studies that involve installing equipment to monitor detailed performance of ASHPs.

There is a need for both 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. Several studies even show several homes with increased electricity consumption when a heat pump is installed. 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. Evaluations of efficient ASHP savings when displacing these fuels would certainly be valuable.

Strategy 1a) Implement larger-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 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.

Startegy 1b) 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), and researchers at the National Renewable Energy Laboratory have developed a field monitoring protocol for ductless heat pumps (Christensen et al. 2011).

Strategy 1c) Drive coordination and consistency on methods and protocols used in ASHP evaluations.

Modeling Improvements

> *"Programs must be able to accurately predict energy savings through computer modeling in order to justify installation in existing homes… and to meet energy efficiency goals for new homes." -Lori Borowiak, NYSERDA*

Many designers, developers, and program administrators rely on energy modeling tools to assess savings from various efficiency measures. 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

There are no parameters in the software to characterize the part-load, variable-speed benefits which allow ccASHPs to operate so 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.

In many ways, developers of REM/Rate (and other modeling tools) have their hands tied; the data needed to predict performance at various outdoor conditions and at various loads are not consistently available from manufacturers. This challenge is very closely related to a barrier discussed in the next section: standardized tests (especially those in AHRI Standard 210/240) do not allow for accurate assessment of a heat pump's performance in cold weather.

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.

Stragey 1d) 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.

Strategy #2. Develop Standardized Metrics for Cold Weather Performance

In order to allow stakeholders to identify products that perform effectively and efficiently under conditions common to several states in the region, improved cold climate performance ratings are necessary.

Current AHRI standards (210/240, see "Performance Metrics, Ratings, and Standards" above) require that heat pumps be tested at outdoor temperatures of 17°F at full capacity. There is no requirement for testing at colder temperatures, nor are tests done at part-load conditions at 17°F (which will normally be the case if a heat pump is designed to provide heat down to 0°F).

In much of the Northeast, outdoor temperatures regularly drop below 17°F, and many manufacturers do indeed publish capacities and power consumption at outdoor temperatures near or below 0°F. There are several challenges when using these data:

- Not all manufacturers provide such data.
- Manufacturers provide data at different outdoor conditions (making comparisons challenging)
- Manufacturers publish data at different capacities (full load, different part loads, etc.)
- Different (even conflicting) data are sometimes presented in engineering literature, specifications, and marketing material for the same product.

Figure 25. An inverter-driven ASHP in a snowy climate.

Strategy 2a) Encourage AHRI to amend standardized test procedures for heat pumps in order to accurately measure:

- ***Performance at colder outdoor conditions - near or below 0°F, including capacity and power consumption.***
- ***Part-load performance (capacity, power consumption) over a wider range of outdoor conditions.***

One solution would be to amend AHRI standard 210/240 so consistent data at lower temperatures are available for all products – or perhaps products that earn a new "cold-climate" designation. At the time of report publishing, AHRI is convening a technical committee to evaluate and revise standard 210/240.

In addition to helping stakeholders select appropriate cold-climate equipment, more rigorous and standardized testing of cold-climate heat pumps at lower temperatures and various load fractions could help professionals model heat pump performance; this is discussed more in the following section.

The most common metric used to evaluate heat pump efficiency is HSPF. As discussed above, the calculation procedures for HSPF assume that a heat pump cannot meet a space's heating needs at cold temperatures (below 25-30°F). Just as air conditioners have a separate rating (EER) to better assess performance in extremely hot climates, there's a need for a well-defined metric to assess heat pump performance in colder climates. Expanded, standardized testing at colder temperatures would be valuable, but in the short-term there may be a metric that can easily be calculated from existing test and rating data.

"We need realistic test procedures that reflect performance in our cold climates that can reliably be used to distinguish units that work in the Northeast from those that don't." -Richard Faesy, Energy Futures Group

Because HSPF calculations assume the heat pump cannot meet the entire heating load, all HSPF values include a significant amount of electric resistance operation. HSPF values assume 25-35% of electricity used goes to resistance. If the space heating load in HSPF calculations were smaller – for example, set to equal the heat pump heating capacity at 17°F – an alternative HSPF value could be calculated. This alternative value (called HSPF17 in this example) would reflect operation of the heat pump over a much larger range and much lower electric resistance operation.

The authors performed some preliminary calculations on two example heat pumps: one ccASHP (i.e. inverter driven, variable speed, designed for cold-climate operation) and one conventional single-speed heat pump of moderate efficiency.

- For the conventional ASHP:
  Standard HSPF = 8.1, HSPF17 = 9.1
- For the ccASHP:
  Standard HSPF = 10.6, HSPF17 = 16.6

When less electric resistance is assumed, HSPF17 rises for all heat pumps. For the ccASHP, however, HSPF17 is 56% higher than standard HSPF (HSPF17 is 13% higher for the conventional ASHP). While all HSPF calculations are oversimplified and do not reflect real-world performance, these HSPF17 values could be used to distinguish good ccASHPs where conventional HSPF falls short. This may be a temporary solution, but a modified, cold-climate HSPF could more accurately reflect the benefits of variable-speed heat pumps over a much wider operating range when compared to conventional, single-speed systems. Such a metric also uses only values already known from testing under current AHRI Standard 210/240.

Strategy 2b) In concert with AHRI and other national stakeholders, examine an temporary alternative HSPF-type metric which assumes a heat pump can provide more of a space's heating load at colder temperatures. This could highlight the advantages of variable-speed heat pumps over conventional, single-speed heat pumps.

In the meantime, Efficiency Vermont has implemented a program to provide incentives for heat pumps that are approved for cold climates (Efficiency Vermont 2013[7]). In brief, to be listed on Efficiency Vermont's approved list, heat pump manufacturers must document:

- COP is at least 1.75 at maximum capacity when outdoor temperature is 5°F
- Heat pump must maintain its full "nominal" capacity when outdoor temperature is 5°F

This program has drawn acclaim from many stakeholders in the Northeast as a simple method to provide incentives only to heat pumps appropriate for cold climate applications. Most efficiency programs currently rely primarily on HSPF which, as discussed previously, does not accurately predict performance of variable-speed heat pumps in colder climates. Program administrators in the southern portions of NEEP's range may want to develop similar climate-appropriate standards.

While not identical, the performance metrics required by Efficiency Vermont are similar to those described by the U.S. Department of Energy's Cold-Climate Heat Pump Program. The goal of the DOE project is to develop an ASHP providing 48,000 British thermal units per hour heating capacity with a coefficient of performance of 4.5 at the 47°F AHRI rating condition, and an efficiency degradation of 50%, and capacity loss of 25% at -13°F ambient conditions.

Strategy 2c) Energy Efficiency programs should adopt and implement climate-appropriate performance requirements such as Efficiency Vermont's program for cold-climate heat pumps. Performance details may vary with climate, especially IECC Climate zone 4.

If stakeholders across the region – and in other cold climates – begin to implement strategies such as these, it could demonstrate to national agencies – such as AHRI and ENERGY STAR – that creating more appropriate testing and rating standards for cold-climate ASHPs is feasible.

7 http://www.efficiencyvermont.com/for_my_home/ways-to-save-and-rebates/energy_improvements_for_your_home/Cold-climate-heat-pump/overview.aspx

Strategy 2d) Leverage increased program adoption of climate appropriate requirements to influence national groups –such as AHRI, ENERGY STAR, etc. – to provide more useful and rigorous test standards and more meaningful performance ratings for cold climate heat pumps. In the case of ENERGY STAR, separate cold-climate performance requirements for ASHPs is recommended.

Strategy #3. Increase Consumer Education and Awareness

> *"Lack of awareness trumps all other barriers."*
> *-Eric Dubin,*
> *Mitsubishi Electric*
>
> *"People are not aware this technology even exists or how it works."*
> *-Jake Marin, VEIC*

Many consumers simply do not know what a heat pump is; if they do, many believe that they are not appropriate for colder Northeast climates. A decade ago, they may have been correct. For more consumers to drive the market, there must be a greater understanding about the existence, availability and potential benefits of cc ASHPs. Efficient, inverter-driven ASHPs are a relatively new technology in the U.S. marketplace with significant performance improvements over traditional ASHPs. Consumers need to be made aware of the technology, its savings potential, and its performance capabilities with targeted education initiatives. To be most effective, different target audiences should be identified and education pieces should be customized for each audience.

Target Markets & Applications for Efficient ASHPs

The LAC has identified the following applications that are particularly attractive for efficient ASHPs:

- Existing homes – replacing an existing heating system that is near or at the end of its useful life. The operating cost advantages of efficient, inverter-driven ASHPs over oil-fired or electric resistance heating systems are significant.
- Existing homes – adding a heat pump to a zone without removing existing heating system; addition of cooling may be the primary motivation. The energy use of the existing heating system is displaced by the new heat pump, but the existing system is able to be left in place for backup or to supplement during the coldest days.
- Existing low load homes – this may be an existing apartment building undergoing a retrofit that includes the addition of cooling.
- New construction – where natural gas is not available.
- New construction, low-load homes – fossil-fuel heating systems are certainly still the standard in the region. 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. Homeowners might pay more for water heating, clothes drying, etc., but the reduction in

monthly gas service fees can outweigh these costs. These homes may be custom homes striving to be net-zero or townhomes and apartment buildings with modest loads.

The target audiences for these attractive applications are:

- Homeowners
- Builders and developers
- Architects and mechanical system designers
- Multifamily building owners, including cooperatives and housing authorities

Strategy 3a) Develop consistent, consumer-oriented educational messages to be disseminated by utilities, manufacturers/retailers and installers through a variety of channels (i.e. efficiency program websites, POP materials, TV, radio, etc.) Different pieces should be developed to address each of the target applications. Dissemination should be broad as well as targeted to capture the target audiences identified.

Strategy 3b) As regional performance data is collected, develop education and outreach materials based on savings achieved and feedback from consumers with respect to comfort and performance. Also develop and disseminate case studies and testimonials for different heat pump applications. These are often considered more credible by consumers when not provided by the product manufacturer.

"Homeowners who are replacing a heating system have a tendency to stick with what they know. Most consumers do not know or understand about the new inverter technology and the many benefits this technology offers."
-Lori Borowiak, NYSERDA

It's also important to consider the decision-making process and the different scenarios when homeowners take action. 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 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. Currently this is not usually the case with most efficiency programs in the region.

Strategy 3c) Within current heating system programs administered by efficiency programs, appropriate AHSPs should be listed as an efficient heating system that can provide year-round comfort and savings.

Strategy 3d) Within current cooling system programs administered by efficiency programs, efficient ASHPs should be identified as a cooling system alternative that can provide year-round comfort and savings.

Two regions of the country where significant outreach and education efforts have been undertaken are the Pacific Northwest and Vermont. The Northwest Energy Efficiency Alliance (NEEA) developed the "Go Ductless" marketing program to increase awareness (http://goingductless.com/). Vermont has also launched a Cold Climate Heat Pumps program promoting cold climate heat pumps to displace oil or propane use for heating. Efficiency Vermont has also utilized their blog to communicate to consumers.

Strategy 3e) Develop educational presentations or workshops for residential architects and mechanical designers as well as multifamily housing market actors (approved for CEUs when appropriate):

Strategy #4. Expand Contractor Awareness and Education

> *"…Connecticut requires that a contractor attend a Utility training AND a manufacturer training in order to offer the rebate to residential customers."*
> *Jenn Parsons,*
> *United Illuminating*

In general, contractors are 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:

- 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, a key target market for efficient ASHPs. This is the 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 and contractors who are looking for ways to meet consumers needs for more affordable heating. Efficient ASHPs offer customers an opportunity to reduce heating costs associated with oil-fired systems without completely eliminating them as a customer. ASHPs operate year-round which may reduce the cyclical labor demands of the oil heating business.
- Traditional HVAC cooling 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 central cooling where none existed, in which case there is no ductwork.

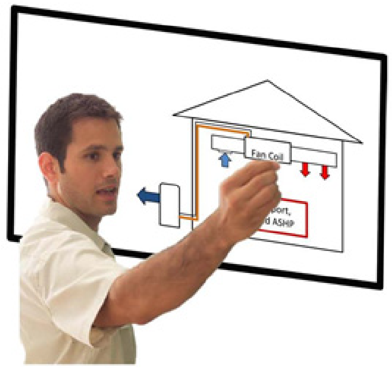

Figure 26. Training programs increase contractor awareness.

For new construction or complete system replacement, some members of the LAC expressed concern that HVAC contractors are loath to install ductless (or compact ducted) heat pumps instead of conventional central systems for two reasons:

- contractors are not familiar or experienced with heat pump systems
- the heat pump systems cost less, and contractors' revenue will be reduced

The premise of the reduced revenue is certainly true: ductless heat pump systems can cost less than conventional systems (central boilers or furnaces with ducts, piping, etc.). This is especially true if the conventional system includes air conditioning. So why will contractors move toward less expensive systems (and make less money)? Because the simplicity of ductless heat pumps is often very appealing to contractors. While the budget for DHP systems may be lower, they are simpler, easier, quicker to install, and perhaps even more profitable.

Several programs have developed and implemented contractor outreach and education materials, including Vermont in the Northeast:

- http://www.efficiencyvermont.com/for_our_partners/contractor_supplier_partners/heat-pump.aspx
- http://www.greenmountainpower.com/upload/photos/392Contractors_Guide_with_Logo_-_Web.pdf
- http://www.efficiencyvermont.com/docs/for_partners/contractors/Contractor-QA-Checklist.pdf
- The Go Ductless program in the Northwest.

Strategy 4a) 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.*
- *Highlight ease of installation, but also important considerations (controls, snow, condensate lines, unit throw into the space, etc.).*

Strategy 4b) In order to drive contractor interest in ASHPs, trainings should deliver compelling messages that resonate with the target stakeholder groups.

- *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.*
- *Traditional HVAC contractors focused on air-conditioning installations – ASHP provide a much less intrusive option in homes where the installation of ductwork is especially challenging.*

Strategy 4c) Develop consumer oriented educational material to be disseminated by contractors directly or via the internet.

Strategy 4d) Efficiency programs should provide incentives or other support to contractors who display inverter-driven ASHPs in their showrooms. This enables both contractor and consumer awareness.

Strategy 4e) Develop case studies for contractors and consumers alike to highlight the potential operating cost and easy installation of efficient ASHPs.

Strategy #5. Improve Integration of ASHPs with Other Heating Systems

> *"Without integrated controls, we are going to see more confusion and disappointment with DHP installations. Savings will be all over the place."*
> *- Jake Marin, VEIC*

In existing homes, ASHPs are most often installed to displace existing heating systems rather than to replace them. In the studies where ductless heat pumps displaced electric resistance heat, the resistance heat – whether resistance furnaces or baseboard heaters – remained installed and operational. In most displacement scenarios, a DHP has its own control system (including thermostat) that is totally independent from the controls of the existing system. In order for occupants to achieve savings from the heat pump, the heat pump thermostat must be set higher than the existing system thermostat. For example, if the DHP thermostat is set to 70˚F and the thermostat for the oil furnace 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.

In these scenarios, it's critical that occupants understand how these 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 oil system may fire more than desired. If occupants go away on vacation, they must remember to turn both thermostats down or one system will continue to heat the home.

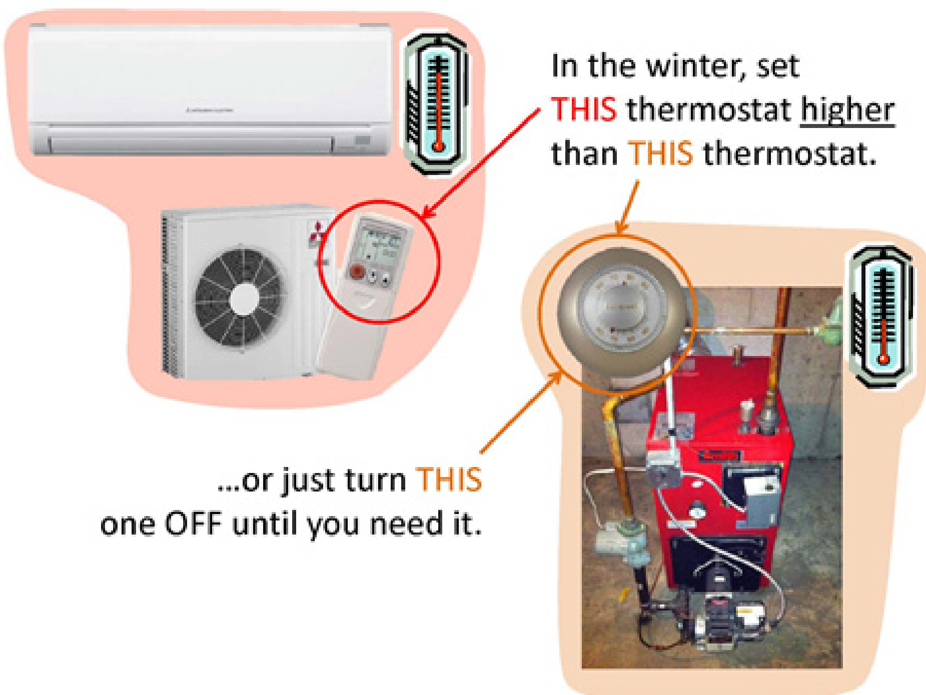

Figure 28. Develop instructions that make operation as clear as possible.

> *"The technology operates differently; there's need for controls to maximize savings."*
> *- Joe Swift,*
> *Northeast Utilities*

Many DHP controllers have an "Auto" setting where the DHP will automatically select its operating mode (heating or cooling) when air temperature is at least 4˚F below or 4˚F above the set point. In a worst-case scenario (which has been reported several times), one occupant might leave the home and turn down both thermostats to 65˚F to save energy. Another occupant may return home and set the oil thermostat up to 70˚F. In this scenario, the heat pump can turn on in cooling mode to "fight" the oil heating system.

Because of their variable-speed capabilities, the most efficient way to operate many inverter-driven ASHPs 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.

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

- http://goingductless.com/sites/default/files/resources/GoingDuctless_HomeownerGuide.pdf
- http://goingductless.com/consumer/helpful-resources/informational-videos
- http://www.greenmountainpower.com/upload/photos/391Homeowner_Guide_with_Logo_-_WEB.pdf

Strategy 5a) 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.***

Longer term, an integrated control system – that can control both heating systems – could be beneficial for many reasons. Most ductless heat pumps, however, are not easily compatible with standard thermostats. Some heat pumps can be integrated into more advanced control systems (from Honeywell, Johnson, etc.), but cost for this hardware alone is near $500. 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 cost and complexity of current integrated control systems, it's not recommended that they be mandated in any way. From an incentive program perspective, add-on incentives for integrated controls may be appropriate: these can encourage the development and deployment of better controls while acknowledging their current limitations. In addition to improved customer comfort and savings, some advanced control systems may offer demand response potential.

Strategy 5b) Encourage manufacture and installation of integrated control systems (for both heat pumps and displaced heating systems).

- ***As current systems are expensive, complex, and sometimes difficult to install, incentives to encourage better controls are appropriate.***
- ***As more control products are developed, explore potential for demand response capabilities.***

One other possible solution to clashing controls and heating systems is to replace the older system entirely. There are a few challenges associated with this approach:

- One or two ductless heat pumps installed in central spaces may not provide adequate comfort in remote spaces or bedrooms.
- In homes with high loads, heat pumps may not have adequate capacity to meet the load during extremely cold weather.
- Ductless heat pumps are not designed to be direct replacements for conventional heating systems in the Northeast.

Note that the first two bullets do not apply to all homes. In very efficient homes, as when rigorous energy improvements have been made, loads may be small enough that it is not necessary to deliver heating to each and every space. And with careful design, heat pumps can be sized to meet the design loads under very cold conditions. 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 2-3 nearby bedrooms.

The last bullet is certainly valid – ductless heat pumps are not intended to be drop-in replacements for central forced-air or hydronic systems common in Northeast homes. Ductless heat pumps, however, are not the only efficient, cold-climate ASHPs on the market. To replace central forced-air heating systems, Carrier, Bryant, and Daikin manufacture variable-speed, air-to-air heat pumps designed to handle pressures in conventional residential duct systems. These are relatively new to the U.S. market, and most carry a substantial price premium, but it’s hoped that prices come down as market volume and competition grow.

For hydronic systems and domestic water heating, Daikin’s Altherma air-to-water heat pump is a possible replacement. Air-to-water systems are generally not as efficient as air-to-air heat pumps, and air-to-water systems also carry a price premium. Again, competition and increased volume in this arena may lead to more affordable systems in the future.

Strategy 5c) Encourage manufacture and installation of more cost-effective heat pump systems that can integrate with conventional distribution systems (e.g. central duct systems, hydronic baseboard).

Strategy #6. Provide ASHPs at Affordable Costs to Consumers

> *"Need to get installed costs down – savings uncertainty becomes less important with lower upfront cost." – Jamie Howland, Environment Northeast*

The "Installed Cost Data" section above reviews system costs from several programs and studies. The data collected (Table 7) 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, ductless heat pump seems to be $3,500 – $4,000. From looking at the data sets where capacity is available, average installed cost range is $2,500-$3,000 per ton.

Costs of multi-port systems are not easy to infer from the studies, but it is clear that the average cost for a two-port system is lower than the cost of two single-port 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.

One very clear trend in the cost table (Table 7) is that the programs or studies with larger sample sets have lower installed costs. This is certainly logical, and other studies (EE 2013, Mately 2013) have documented that contractors who are more experienced and deal with larger volumes consistently install heat pumps at lower costs. Part of the solution to high cost barriers, therefore, will be to simply drive higher number of ASHP installations.

> *"There's need for strong incentives [for consumers] to invest in this technology." —Nathan Strong, NSTAR*

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 are all single-port, 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)

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 6a) Drive equipment and installation costs down through economies of scale. Contractors and efficiency programs may 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 6b) Efficiency programs should continue to offer incentives for heat pumps, but require more rigorous performance qualifications (such as Efficiency Vermont's cold-climate criteria).

ASHP Leasing Program

Green Mountain Power has implemented a unique program to reduce – or eliminate – upfront costs for homeowners. The Vermont-based Cold Climate Heat Pump Program allows homeowners to rent equipment for a 15 year term. Monthly costs range from $43.57 for a ¾-ton unit to $53.00 for a 1.5-ton unit. Initial installation cost has been cited as a critical barrier in wider adoption of ccASHPs, and with this program up-front cost is effectively eliminated. The program also requires an authorized installer to provide equipment and labor.

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 complete program description is available online: http://www.greenmountainpower.com/customers/heat-pump-rental/

Strategy 6c) Investigate implementing an ASHP Lease program to eliminate customers' up-front installation costs.

Community-level Bulk Purchasing

Several LAC members suggested that a "Solarize"-type strategy could be adopted for efficient ASHP systems. Solarize programs have been implemented in Connecticut[8] and Massachusetts[9] to encourage the installation of solar electric systems at a community scale. The goal of a Solarize program 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). These bulk installations drive equipment and labor costs down substantially, and the program provides valuable contractor support and customer education. In the Solarize model, the first step is for a town or city to commit to participate, and the community remains involved throughout the entire process. For the first seven to 11 months the community is challenged to plan, get volunteers, get contractors, and educate consumers. In the following 13 to 23 months customers are enrolled and solar panels are installed. The program's short 2-3 year duration is aimed at spurring customers to action.

8 http://solarizect.com/

9 http://www.masscec.com/solarizemass

Figure 29. Marketing material for Solarize CT (Credit: Solarize Connecticut 2013)

A "Solarize"-like program for efficient ASHPs could dramatically increase adoption in regions identified as prime candidates for ASHPs (e.g. no access to natural gas, older homes, no central cooling). As Table 7 shows, installation costs decrease noticeably with larger program or purchase volumes.

Strategy 6d) To increase concentrated installations and reduce installation cost, state agencies and/or utilities can investigate developing "Solarize"-like programs for ASHPs.

Strategy #7. Develop clearer policy case for broad-scale deployment of ASHPs

A broad deployment of ASHPs will have impacts on the electric grid, use of delivered fuels, natural gas infrastructure, ghg emissions, and peak load. Until a clearer picture of those impacts is developed, policy makers may withhold strong support for ASHPs, which in a number of ways could temper the potential growth of this technology.

Strategy 7a) 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.***

Many utilities and program administrators across the country have run retrofit programs where heat pumps replace – or displace – electric resistance heating. This is a no-brainer – customers can save substantially on heating costs, utility programs can claim substantial electric energy savings, and the effort for all parties is usually very cost effective. Electricity rate payers are paying for cost-effective electricity reductions.

However, regulators often make it hard for efficiency programs – funded largely by electric system benefit charges (SBCs) – to provide incentives to move consumers away from oil or propane towards electric heating systems. Electrical load is added to the grid system at the expense of a fossil fuel. This is generally not the intended use of SBC program funds.

Until state/regulatory policy is resolved to allow for "fuel displacement", PAs are not going to go out on a limb to cross oil dealers and appear to use ratepayer funds to switch customers to electricity. States need to establish clear policies in the name of moving buildings away from fossil fuels to a renewably-powered grid, and heat pumps are then the solution to our heating (and cooling) issues. Once the states set the policy, PA's will be able to offer programs that encourage heat pump installations and will be able to educate and drive the market. It all flows down from the highest level state policy. This initiative by NEEP should focus on this highest level issue as priority #1 in order to burst the dam and promote the technology."
– Richard Faesy, Energy Futures Group

Programs funded by SBCs are not the only way to incentivize moving from oil or propane to efficient ASHPs. State tax credits or programs run by other agencies can provide incentives. Some SBC-funded programs can, however, claim savings based on source energy savings or reduced greenhouse gas emissions (see "Source Energy and Emissions" above).

One potential way to overcome regulatory fuel-switching hurdles is to link ASHPs – efficient electric heating systems – with renewable electric generation. If a home installs both an efficient ASHP and a PV system, there may be no net increase – or in many cases a net decrease – in electricity purchased from the utility. Even if renewables are not installed on-site, energy from off-site renewables can be used to power heat pumps. The nature of the electrical grid is changing; many regions are mandating that larger and larger portions of grid electricity be provided by renewables. An efficient electric heating system has the potential to be powered by renewable energy – either on-site or off-site, either now or in the future. This versatility is not available in fossil-fuel heating systems. Managers of both efficiency programs and renewable energy programs have begun to explore potential synergies in this area.

Strategy 7b) Begin with discussions at the state level to understand specific perspectives on fuel switching hurdles. Commonalities across the state level discussions could then be used to initiate regional policy discussions.

Strategy 7c) Outline a policy that links ASHPs to renewable energy generation and the associated positive climate impacts.

Strategy 7d) Leverage existing policy interests (i.e. expansion of solar PV, zero-net energy homes) to build support for ASHP deployment.

With the low price of natural gas across the region (relative to fuel oil and propane), many states are looking to expand natural gas distribution to many more areas – allowing homes and businesses to save money by switching from oil to natural gas. Such homes already have electric service, and efficient heat pumps can provide heating at costs very comparable to natural gas. Why not switch to heat pumps and save the considerable expense of expanding the gas infrastructure? Certainly there are capacity concerns related to electricity distribution, but these can be addressed at much lower expense than expanding gas infrastructure. There is a need for studies to investigate such issues:

- Costs and benefits of natural gas expansion
- Electrical transmission and distribution effects of large-scale ASHP adoption
- Costs and benefits of improving electric T&D accordingly
- Environmental and emissions implications of all of the above

While regional approaches to investigating these questions are encouraged, the answers will vary with local conditions (climate, type of region/community, proximity to gas, state of existing infrastructure, etc.).

Timing may be right to effect change related to infrastructure issues. Many areas in the Northeast are struggling with high oil costs and (relatively) cheap gas. Connecticut's 2012 Comprehensive Energy Strategy, for example, has led to the creation of Integrated Resource Plan to be released for public comment in January 2014 (Dowling 2013); expansion of gas infrastructure is a key element. Also in Connecticut, Yankee Gas is planning to increase gas rates for customers on newly installed natural gas lines to offset the added infrastructure costs (Simoni 2013). Situations such as these could make efficient heat pumps more compelling.

Strategy 7e) For regions where gas infrastructure expansion is being examined or encouraged, evaluate costs, benefits, and other issues related to increased efficient ASHP penetration in lieu of expanded natural gas infrastructure.

MARKET TRANSFORMATION

In conclusion, NEEP projects that earnest implementation of the recommended market strategies outlined in Regional Strategies will produce the necessary market conditions in order for accelerated and sustained uptake of ASHPs throughout the Northeast and Mid-Atlantic regions. While ASHPs have experienced some regional growth in recent years, it is likely that the technology has been used for efficient space cooling. While opportunities continue to exist on the cooling side, the strategies are focused on the long term expanded deployment of ASHPs as a space heating technology.

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 ten years of how ASHPs overcame a number of market barriers to become a common space heating technology throughout the region.

Near Term (2014-15)

- Energy Efficiency programs, manufacturers and contractors expand marketing efforts of ASHPs, driving consumer awareness and interest.
- Regional Stakeholders work with Energy Efficiency Program Evaluators to secure avenues to conduct Field testing/research in order to better characterize savings opportunities, especially in cases of fuel replacement/displacement.
- Energy Efficiency Programs continue to offer consumer incentives for ASHPs to reduce upfront costs, while requiring rigorous cold climate performance standards.
- Regional stakeholders engage with policy makers (i.e. state regulators, energy efficiency advisory boards, state energy offices) to discuss the potential regional impacts associated with a broader deployment of ASHPs, as well as the issues surrounding fuel switching promotion.
- Regional stakeholders engage ENERGY STAR’s next criteria revision process for ASHPs to suggest inclusion of regionally specific requirements. The region should suggest low temperature performance requirements beyond the HSPF requirements currently prescribed.
- Regional stakeholders work with AHRI’s 210/240 test procedure committee to amend/supplement the test procedure to establish a standardized method to effectively characterize cold climate efficiency/performance.
- Stakeholders work with developers of energy modeling tools to improve accuracy of inverter-driven ASHPs models which recognize the true efficiencies of high performing ASHPs.

Long Term (2016-2018)

- Through further research and analysis, regional stakeholders develop a clearer policy case for the broad deployment of ASHPs, addressing questions about fuel switching, load building, peak demand impacts, climate impacts, and gas expansion alternatives.
- Regional Stakeholders engage the next revision of DOE’s federal standard for ASHP (Proposed rule due 2017) to incorporate a regionally specific standard and propose the incorporation of amended test procedure revisions (i.e. AHRI 210/240) which recognize cold climate performance.
- The International Code Council’s (ICC) 2018 International Energy Conservation Code (IECC) model building energy code recognizes efficiency opportunities associated with space heating through the use of ASHPs.

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APPENDIX A: ENERGY EFFICIENCY PROGRAM ACTIVITY SUMMARY – AIR SOURCE HEAT PUMPS

State	2013 Promotional Activities for Ductless Heat Pump	2013 Promotional Activities for Heat Pump
Connecticut	$250/system (up to $1000): ≥14.5 SEER, 12 EER, 8.2 HSPF Ductless heating and cooling system must be ENERGY STAR certified.[1]	$250/unit: ≥14 SEER, 11 EER, 8 HSPF Central AC or Heat Pump system must be ENERGY STAR certified.[2]
Maine[3]	$600 per home: ≥10 HSPF Mini-split heat pumps eligible for plus 7.75% financing if necessary.	None
Maryland[4]	$300/AC unit: ≥16 SEER, 13 EER $300/heat pump unit: ≥16 SEER, 13 EER, 9 HSPF Must replace existing systems. Ductless Mini-Split systems must be ENERGY STAR certified.	$200/unit: ≥14.5 SEER, 12 EER, 8.2 HSPF, $300/unit: ≥15 SEER, 12.5 EER, 8.5 HSPF, $500/unit: ≥16 SEER, 13 EER, 9 HSPF Must replace existing systems. ASHP systems must be ENERGY STAR certified.
Massachusetts[5]	$150/unit: ≥16 SEER, 12 EER, 8.2 HSPF, $300/unit: ≥19 SEER, 12.5 EER, 10 HSPF, $500/unit: ≥20 SEER, 13 EER, 10 HSPF Ductless mini-split heat pump system must be ENERGY STAR certified. Cooling-only units are not eligible.	$150/unit: ≥14.5 SEER, 12 EER, 8.2 HSPF, $300/unit: ≥15 SEER, 12.5 EER, 8.5 HSPF, $500/unit: ≥16 SEER, 13 EER, 8.5 HSPF Central AC or ASHP system must be ENERGY STAR certified.
New Hampshire[6]	$200 (cooling only): ≥14.5 SEER, 12 EER $900 for ductless mini-split heat pump systems : ≥19 SEER, 12.5 EER, 10 HSPF Systems must be ENERGY STAR certified	$450: ≥14.5 SEER, 12 EER, 8.2 HSPF Air Source Heat Pump systems must be ENERGY STAR certified.
New Jersey[7]	$500/unit: ≥17 SEER, 13 EER, 8.5 HSPF Additional $200 available for Sandy Relief.	$500/unit: ≥17 SEER, 13 EER, 8.5 HSPF Additional $200 available for Sandy Relief.
New York	None	None

State	2013 Promotional Activities for Ductless Heat Pump	2013 Promotional Activities for Heat Pump
New York (Long Island)[8]	$300/unit: ≥18 SEER, 12.5 EER Ductless mini-split systems incentives apply to early retirement installations. and the contractor receives $100 on first, & $50 on each additional Ductless Mini Split System	$1400/ Ducted ASHP unit: ≥16 SEER, 13 EER, 8.5 HSPF $1000/ Ducted Split AC unit: ≥15 SEER, 12.5 EER, 8.5 HSPF Incentives apply to early retirement installations. and the contractor receives $200 on first, & $50 on each additional Air Source Heat Pump.
Pennsylvania[9]	Duquesne territory Ductless mini-split heat pump: $95 Must be ENERGY STAR certified systems. FirstEnergy: Ductless mini-split AC: $50: ≥15 SEER, ≥12 EER Ductless mini-split heat pump: $100: ≥15 SEER, ≥12 EER, ≥8.5 HSPF	Duquesne - Heat Pump: $95/ton: ≥14 SEER, 8.6 HSPF PPL: $100/unit: ≥15 SEER $200/unit: ≥16 SEER FirstEnergy: $250: ≥14.5 SEER, 12 EER, 8.5 HSPF, $325: ≥15 SEER, 12 EER, 8.5 HSPF, $400: ≥16 SEER, 12 EER, 8.5 HSPF PECO: $300: ≥15 SEER, 12 EER, 8.2 HSPF, $400: ≥16 SEER, 12 EER, 8.2 HSPF ASHP systems must be ENERGY STAR certified unless otherwise noted.
Rhode Island[10]	$150/unit: ≥16 SEER, 12 EER, 8.2 HSPF, $300/unit: ≥19 SEER, 12.5 EER, 10 HSPF, $500/unit: ≥20 SEER, 13 EER, 10 HSPF Ductless mini-split heat pumps system must be ENERGY STAR certified. Cooling-only units are not eligible.	$150/unit: ≥14.5 SEER, 12 EER, 8.2 HSPF, $300/unit: ≥15 SEER, 12.5 EER, 8.5 HSPF, $500/unit: ≥16 SEER, 13 EER, 8.5 HSPF Central AC or ASHP system must be ENERGY STAR certified.
Vermont[11]	≥20 SEER, 9 HSPF $750 for 1st ductless mini-split system, $500 for second unit	≥13 SEER $500/ton for central split-system heat pumps.
Washington, D.C.	None	None

Endnotes

1. http://energizect.com/residents/programs/ductless-split-heat-pump-rebates
2. http://energizect.com/residents/programs/high-efficiency-heating-cooling
3. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME26F&re=0&ee=0 & http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=ME25F&re=0&ee=0
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6. http://www.nhsaves.com/HeatingRebate/heatingcooling.html
7. http://www.njcleanenergy.com/residential/programs/cooladvantage/heat-pumps#COOLAdvantage_rebate_table
8. http://www.lipower.org/pdfs/cei/rebate-coolhomes-app.pdf
9. https://www.pplelectric.com/save-energy-and-money/rebates-and-discounts/residential/rebates/air-source-heat-pump.aspx
10. http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=PA55F&re=0&ee=0,
11. http://energysavepa-home.com/media/uploads/FE_RebateFormResidentialFINAL2_HR-2.pdf, https://portal.ecosconsulting.net/peco/rebate/downloads/CentralHeatingCooling_061213.pdf
12. https://www1.nationalgridus.com/Files/AddedPDF/POA/Residential%20Cooling_RI_EE5139_FORM%20(6).pdf
13. http://www.efficiencyvermont.com/for_my_home/ways-to-save-and-rebates/energy_improvements_for_your_home/Cold-climate-heat-pump/overview.aspx

APPENDIX B: COMPLETE LIST OF MARKET BARRIERS

This report recommends 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

10. In general, HVAC community lacks familiarity/experience installing this technology (particularly ductless)
11. Weary of incorporating new technology into their business (i.e. inertia)
12. Uncertain how to identify ideal candidates (particularly ductless)
13. Uncertain how to size (particularly ductless)
14. Lack confidence in forecasting operational cost/savings
15. Not "selling" this technology to customers
16. Question of whether installer base/service industry keep up with current/growing demand?

Category 3- Technology Performance/Quality

17. Inability of some systems to deliver sufficient amounts of heat in cold conditions
18. Inability of some systems to distribute heat/cool effectively
19. Ducted ASHP systems not capable of acting as one-for-one replacement (i.e. for gas furnace)

20. Ducted systems designed for Asian market/climates; implementation issues in NA markets/climates
21. Can industry maintain product quality in time of rapid growth?

Category 4- Performance Metrics (Test procedures and efficiency metrics)

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

Category 5- Energy Efficiency Programs

24. Unfamiliarity within Energy Efficiency Program Administrator community
25. Program regulators don't allow promotion of technology (i.e. provide incentives) in fuel switching situations
26. Challenge of accurately evaluating/predicting savings, including defining baseline energy use for various scenarios (various fuels, displacement vs. replacement)
27. Unclear which applications are most likely to deliver maximum energy savings

Category 6- State/Regional Policy

28. Unfamiliarity of ASHP technology within Policymaker community and its relation to existing policy goals (i.e. ZNE buildings, expansion of distributed PV)
29. Momentum in policy community for natural gas expansion (neighborhood-level and generation-level)
30. Hesitance of policymakers to build electric load growth (kWh and kW (Summer and winter peak impacts)
31. Complexity of modeling/predicting source energy /operational cost savings
32. Unclear potential for reducing primary energy/ghg emissions

Category 7- Miscellaneous Opportunities to leverage

33. Fuel cost savings advantage over electric resistance, oil, and propane
34. Install-ability of ductless systems…simple and fast for knowledgeable installer
35. Demand response potential
36. Multifamily and townhomes (under 4 households) may represent attractive application
37. On local scale; In new construction, avoid infrastructure costs of nat. gas expansion
38. On state/regional scale; Avoid expensive expansion of gas infrastructure, ease gas bottlenecks

APPENDIX C: SUMMARY OF NEEA DUCTLESS HEAT PUMP STRATEGIES

People in the Northwest have undertaken a similar effort to develop regional market strategies. A bullet summary of strategies from their report is below; the full report is here: http://neea.org/docs/reports/northwest-ductless-heat-pump-initiative-market-progress-evaluation-report-2.pdf

Homeowners

- Homeowner education - tech and incentive awareness
- Collaborate Bank/credit union for financing options
- Contractors display DHPs in showrooms
- Funding assistance
- Multi-media marketing for public awareness
- Incentivize word of mouth marketing (Family and friends) is considered very effective
- Oversight group provided gap funding to fill gap where utility cannot supply (until gain momentum)
- Radio, TV public service announcements
- Quality assurance inspections performed (at random or trouble contractors)
- Social media campaign during heating season (including $10,000 prize to interact on web; smaller prizes for interaction and word of mouth referrals; on Facebook and initiative website)
- “Blitz” campaign for an area slow to adopt; partnered with contractors, distributors, and utility
- Phone surveys to monitor customer/public awareness, interest, usage/maintenance, and satisfaction

Utilities

- Interviews with utilities
- Some utilities offer low interest loans (“on-bill” or off bill payment)

Contractors

- Contractor training network
- Hands-on training includes install, circuit boards, trouble shooting, and servicing
- “Healthy competition” keep installation prices in check
- Interviews with contractors

Manufacturers/Distributors

- Distributors and manufacturers involved in marketing and contractor training
- Manufacturers display DHPs in retail stores (like Home Depot) to see/experience
- Collaborate with distributors to push cold climate DHP models
- Ensure products are available; better if multiple options
- Interviews with manufacturers/distributors