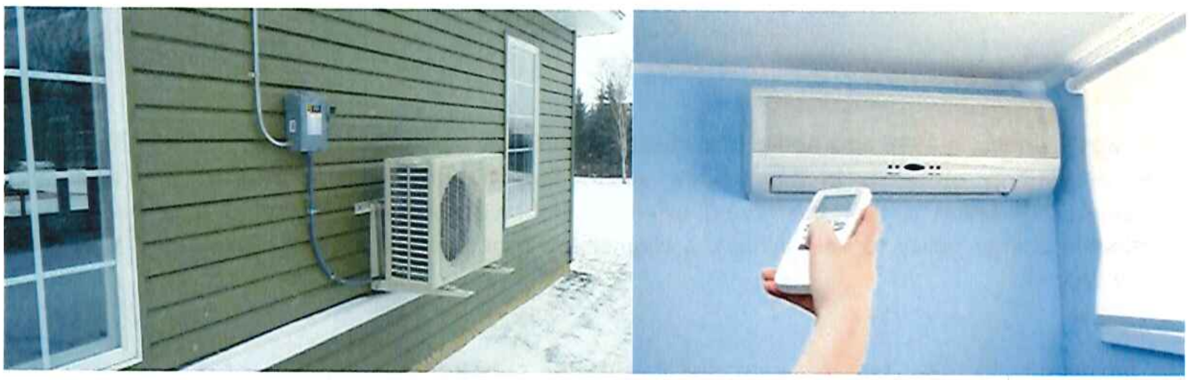
Northeast Energy Efficiency Partnerships



Ductless Heat Pump Meta Study

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About NEEP & the Regional EM&V Forum

REGIONAL EVALUATION,
MEASUREMENT & VERIFICATION FORUM

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.

The Regional Evaluation, Measurement and Verification Forum (EM&V Forum or Forum) is a project facilitated by Northeast Energy Efficiency Partnerships, Inc. (NEEP). The Forum's purpose is to provide a framework for the development and use of common and/or consistent protocols to measure, verify, track, and report energy efficiency and other demand resource savings, costs, and emission impacts to support the role and credibility of these resources in current and emerging energy and environmental policies and markets in the Northeast, New York, and the Mid-Atlantic region.

About Energy Futures Group

EFG is a consulting firm that provides clients with specialized expertise on energy efficiency markets, programs and policies, with an emphasis on cutting-edge approaches. EFG has worked with a wide range of clients – consumer advocates, government agencies, environmental groups, other consultants and utilities – in more than 35 states and provinces.

About Energy & Resource Solutions

For nearly twenty years, ERS has been leading efforts to promote a healthy economy and environment by guiding business, industry, government, and utilities in the efficient use of resources and the advancement of sustainable practices. ERS provides innovative and thoughtful solutions to help your organization improve its efficiency, minimize environmental impacts, and maximize economic competitiveness.

Ductless Heat Pump Meta Study

Table of Contents

Introduction

Ductless heat pumps (DHP) are all the rage within the utility, energy efficiency program administrator, evaluation, HVAC and solar industries, and environmental advocacy worlds. With all of this hype and activity, Northeast Energy Efficiency Partnerships' (NEEP) Regional EM&V Forum contracted with Energy Futures Group (EFG) and Energy and Resource Solutions (ERS) (the "researchers") to compile and synthesize the recently available evaluation studies on DHPs in order to understand how they are really performing and what energy efficiency programs should know as they design programs to encourage their installation. From the 40 studies and a series of industry interviews, the researchers were able to identify a number of key findings in terms of DHP performance, market barriers and opportunities, market acceptance and satisfaction, future product features and growth, program recommendations and knowledge gaps.

Given that the NEEP territory includes the colder regions of the Northeast, the general focus of this research has been on studies that address DHPs in colder climates, including the Pacific Northwest, mid-Atlantic and New England. This research examined performance in these climates, for both new cold-climate technology (systems that can provide heat consistently down to 5 degrees and colder) and for conventional heat pump technology. Also, most of the reports focus on single head units, but multi head units designed to perform at low temperatures introduce even more diversity into this category of technologies and will arrive on the market shortly. The studies examined for this meta-study are listed in Table 1.

Table 1. NEEP Meta Study - Studies Examined

NEEP Meta Study –Studies Examined	
☐ BHE-EMT Heat Pump Interim Report 2013	☐ KEMA Ductless Mini Pilot Study & Update 2009-2011
☐ BPA- ACEEE Performance of DHP in the Pacific NW 2010	☐ Mitsubishi Heat Pump Market Data 2011
☐ BPA DHP Engineering Analysis (Res) 2012	☐ Mitsubishi Indoor Unit Brochure 2011
☐ BPA DHP Retrofits Commercial Buildings 2012	☐ Mitsubishi M-series Features & Benefits 2011
☐ BPA Variable Capacity Heat Pump Testing 2013	☐ NEEA DHP Billing Analysis Report 2013
☐ Cadmus DMSHP Survey Results 2014	☐ NEEA DHP Evaluation Field Metering Report 2012
☐ CCHRC ASHP Report 2013	☐ NEEA DHP Final Summary Report 2014
☐ CSG DHP Performance in the NE 2014	☐ NEEA DHP Impact Process Evaluation Lab Testing Report 2011
☐ CSG Mini-split HP Efficiency Analysis 2012	☐ NEEA DHP Market Progress Evaluation 2 2012
☐ DOE DHP Expert Meeting Report 2013	☐ NEEA DHP Market Progress Evaluation 3 2014
☐ DOE DHP Fujitsu and Mitsubishi Test Report 2011	☐ NEEP DHP Report Final 2014
☐ DOER Renewable Heating & Cooling Impact Study 2012	☐ NEEP Incremental Cost study
☐ DOER Renewable Thermal Strategy Report 2014	☐ NEEP Strategy Report 2013
☐ Ductless Mini-Split Heat Pump Customer Survey Results	☐ NREL Improved Residential AC & Heat Pumps 2013
☐ Eliakim's Way 3 Year Energy Use Report 2013	☐ Rocky Mountain Institute DHP Paper 2013
☐ Efficiency Maine Case Study (Andy Meyer) 2014	☐ SCEC DHP Work Paper 2012
☐ Efficiency Maine EE Heating Options Study 2013	☐ Synapse Paper 2013 Heat-Pump-Performance
☐ Efficiency Maine LIWx Program Checkup 2014	☐ VEIC Mini Split Heat Pump Trends 2014
☐ Emera Maine Ductless Heat Pump Pilot Program 2014	☐ VELCO Load Forecast with Heat Pumps 2014

The researchers gathered, organized and synopsized the studies into a series of spreadsheets in order to more easily compare and contrast the findings of each. Information was cataloged in terms of "performance analysis" and "market analysis". In addition to these studies, the researchers also identified and interviewed 16 manufacturer representatives, DHP contractors and energy efficiency program administrators. All of this detailed information will be posted on the NEEP website (www.neep.org) along with a PowerPoint slide deck that summarizes all of the findings, conclusions and recommendations.

Performance Analysis

From the 40 studies examined, the researchers were able to extract some key information on the performance of DHPs. This was not always easy, as there was little consistency in terms of methodology or approach between studies. Many revealed challenges related to measuring key aspects of performance, some findings are not transferrable to the NEEP region and some studies simply conflicted with others. However, there were many critical findings which are reported below.

Cold Weather Performance

Field and laboratory testing demonstrate that heating at outdoor temperature ranges is consistent with manufacturer specifications, at least for the Mitsubishi and Fujitsu models tested. These DHP units are able to deliver heat as low as -20°F for some models. However, performance degrades in terms of total thermal output and COP as temperature drops, as would be expected. But, tested models are capable of delivering heat at approximately 60% of rated output at their lowest operating temperature ranges.

Despite the ability to perform at low temperatures, in some of the units the defrost cycle results in a parasitic energy penalty (typically less than 10%) during low temperature operation. This is difficult to quantify as both temperature and humidity are factors, and studies have not isolated this usage. As well, drain pan heaters, optional on some cold weather models but standard on others, also produce a small parasitic loss. Energy usage for defrost and drain pan heaters is not isolated in the reviewed studies, but should be in future research to better understand its impact on performance and to consider possible control strategies.

Coefficient of Performance (COP)

The Coefficient of Performance, or COP, is defined as the useful energy delivered, divided by the electrical energy input. The COP can be examined at any one point in time, at any given temperature, or averaged over a period of time or season. Baseboard electric heat has a theoretical COP of 1.0, but the studies found that DHPs could deliver COPs up to three and a half times that. Independent laboratory testing found that COPs were typically somewhat lower than, but in general agreement with the manufacturers' stated claims. As would be expected, studies reported that COPs varied significantly with temperature, as reported in the following Table 2. COP at Various Outdoor Temperatures.

Table 2. COP at Various Outdoor Temperatures

Outdoor Temperature	COP
≥40°F	≥ 3.5
10°F to 20°F	≈ 2.5 to 3.5
-10°F to -20°F	≈ 1.4
Average Seasonal	2.4 – 3.0

Field Testing of COP

All studies that attempted to field test for COP reported difficulty in obtaining accurate results. The standard COP testing protocol is for steady state testing and is usually conducted in a controlled laboratory setting and not in someone's house. Additionally, DHPs are designed to operate in continuous modulation which causes challenges in accurately determining the amount of heat delivered by the units since the compressor and fan speeds are constantly changing. There was also reported difficulty in accurately recording supply temperature without obtrusive measuring protocols, which would leave a blemished DHP indoor unit for the homeowner. Some studies also reported challenges trying to monitor interval power since it produces limited data points for continuously modulating systems.

Despite all of these measurement challenges, when field measured COP was reported, there was general agreement with lab test data, though with a wider range of results. However, many caveats usually accompanied the findings. All of these issues have led the researchers to conclude that in-field testing of COP may have limited value in the future.

HSPF & SEER

Heating Seasonal Performance Factor (HSPF) is the standard measure of heat pump heating efficiency, and Seasonal Energy Efficiency Ratio (SEER) is the cooling equivalent. The HSPF and SEER are determined through a standardized industry test and are not typically determined from field studies. Both HSPF and SEER are seasonal performance ratings derived from COP at multiple operating conditions. As in-situ COP was reported to be somewhat lower than manufacturer performance reports, HSPF and SEER are also assumed to be somewhat lower, but this was not reported conclusively in any of the studies.

HSPF test results are reported for one heating zone only (running through the middle of the U.S., and so therefore quite a bit warmer than the Northeast). Actual heating performance will be somewhat lower north of that zone. In addition, HSPF does not include testing at temperatures below 17°F, bringing into question the relevance of the HSPF procedure for some of the newer variable speed "cold climate" heat pumps.

SEER was reported to be more accurate for multiple climate zones, but not fully accurate for DHPs due to the standardized testing requirements.

Cost Factors

Installed costs are most easily compared on a per-ton (12,000 Btu) basis for single-head units. Given this means of comparison, the studies reported a range of installed costs of $2,500 - $5,000 for all cold climate models, with an average of about $3,500-$4,000 for one ton models. For three-quarter ton (9,000 Btu) units, installed costs are approximately 10-20% less, and for one and a half ton (18,000 Btu) units, they are generally about 10-20% more. The lowest costs were found in Maine where large program participation and contractor competition had driven down pricing. The highest costs were identified in California (at the ACEEE 2014 Summer Study) where an immature DHP market has not been able to penetrate the predominance of central air conditioning systems and central heat pumps.

The studies also indicated that incremental costs between a baseline, standard 8.2 HSPF unit and a high efficiency 11.0 HSPF model are generally between $400 and $600. Cold climate features add approximately $300 to this incremental cost. The total incremental costs of a cold climate 12.0+ HSPF model above the baseline 8.2 HSPF model are in the range of $700 to $900 as shown in Table 3. DHP Incremental Costs, below.

Table 3. DHP Incremental Costs

HSPF Base	HSPF Improvement	Incremental Cost
8.2 HSPF standard	11.0 HSPF high efficiency	$400 - $600
11.0 HSPF high efficiency	12.0+ HSPF Cold Climate	≈ $300
8.2 HSPF standard	12.0+ HSPF Cold Climate	$700-$900

System Sizing

The majority of studies focused on heating climates, and the typical DHPs installed were sized .75, 1.0 and 1.5 tons. Most systems were oversized for heating loads of the space/rooms served, even though they were typically undersized for the entire house. Until recently, there have been no multi-zone cold climate models, so all cold climate models were single-zoned, usually set up to heat multiple rooms with one unit. With this variable-speed equipment, there is little efficiency penalty for oversizing in most cases. However, in some very efficient new construction applications, oversizing was reported to introduce cycling and efficiency penalties.

Cooling tends to be oversized in heating-dominant climates since the systems are sized for heating loads. However, cooling performance is generally good at part load, and no problems or efficiency penalties were reported.

Energy Usage

Energy usage was reported to be highly variable in the studies, driven primarily by climate, weather and how the occupants chose to operate the DHPs. Most systems are not set up with a traditional thermostat but rather are controlled with a hand-held remote. Contractors did not always provide consistent instructions for using the DHPs, and for these reasons usage varies widely.

Total annual heating and cooling kWh consumption from the field monitoring studies ranged widely as reported below in Table 4. DHP Energy Usage in Heating-Dominated Climate.

Table 4. DHP Energy Usage in Heating-Dominated Climate*

Season – in Heating Dominated Climate	kWh Usage per Ton		
	Low	High	Average
Cooling	≈90	≈500	≈350
Heating	≈1,800	≈4,000	≈2,200
Total Annual Heating & Cooling	≈1,900	≈4,500	≈2,500

* The kWh usage numbers do not always total exactly as some studies collected heating or cooling data only.

We are awaiting data from two studies not yet released from New York and Massachusetts for more annual energy consumption for states in the NEEP region.

Energy Savings

Energy savings reported in the studies were also highly variable and driven primarily by local climate and whether the system was a replacement for electric heat or a partial displacement for a central fuel-fired heating system. Zoning factors and occupant operation also figured in determining energy savings. Multiple studies reported that there was little customer understanding as to proper methodologies for controlling DHPs when displacing heat from other systems. There was also some incidence of occupant "take back" in which--for cost, convenience, and comfort reasons--occupants seemed to use the DHPs more than would have been expected for just replacement of the previous system. This was especially noted in some studies in which there was prior biomass usage such as a woodstove that occupants discontinued using once the DHP was installed.

From the field monitoring studies, total annual heating savings were in the range of ≈1,200 to 4,500 equivalent kWh per ton when compared with a modeled baseline of electric resistance heating. As more cold climate multi-head systems arrive on the market, savings are expected to shift towards the upper end of this range. Cooling energy savings were modest in northern heating states, but more significant in states with increased cooling loads. We are awaiting cooling season savings from two pending studies that will supplement these findings.

Fuel Switching Potential

There is significant opportunity and consumer interest in reducing oil, propane and kerosene costs with DHPs. Additionally, there is much interest in fuel-switching as a methodology for reducing overall GHG emissions. While more field studies that quantify the cost savings are just now underway, the few completed studies that have looked at fuel savings have found significant operating cost savings when replacing an oil or propane system with DHPs, both in existing buildings and in new construction. That said, fuel cost variability will obviously have an impact on the customer economics of fuel switching, and the significant electric rate increases that are projected for areas of New England in the winter of 2014, coupled with declining oil prices, may reduce customer savings and, as a result, their near-term interest in replacement options. Policy decisions regarding GHG emissions and fuel switching will also be primary drivers regarding the potential of switching from one fuel to another.

The studies identified "displacement" of an existing central system as a key strategy, wherein the DHP is set up to serve part of the living space or is used as the primary heating source except during extremely cold temperatures when the central system can supplement heat. Given the prices of oil and propane in recent years, and depending on the efficiency of the existing central heating system, customers can see significant heating savings with these arrangements. The NEEP New Hampshire study (NEEP EM&V Forum 2014) found net fuel savings of 22 MMBtu per ton and $465 per ton of fuel savings, after accounting for the operation of the DHPs. This study also reported that homeowners tended to displace more of the fuel oil system heating as they became more familiar with the performance of the DHPs. The recent Maine study (Emera 2014) found average fuel oil savings of $585, an increase in electric costs to operate the heat pump in the winter of $226, and net average savings of $359 per participant. This study did note that customers could have increased savings by better controlling the DHP and pre-existing heating system.

When the existing central heating system is natural gas-fired, there are generally only small or negligible operating cost savings for replacing or displacing the system with DHPs.

On the cooling side, DHPs can also be useful to displace less efficient central air conditioning systems, although contractors tend not to focus on this application. Rather, they are more commonly used to replace very inefficient and noisy window air conditioners.

In some instances, DHPs are installed to provide supplemental heat or cooling to parts of homes or additions where the central system is insufficient.

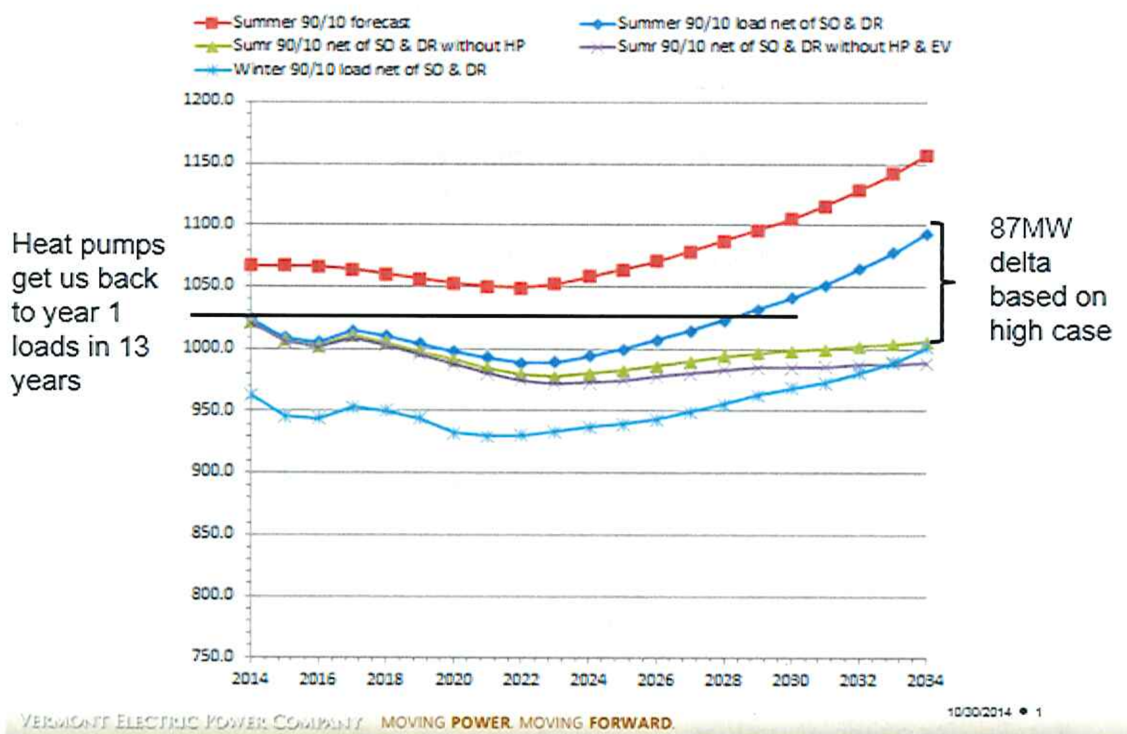
Demand and Load Shape

DHP systems rarely operate at full rated input power since the energy demand for the units continuously modulates. Studies found that typical heating demand is in the range of 20-80% of rated input power. In cold climates, cooling demand range is typically 5-25% of rated input power, but this is sporadic and variable. One Northeast study (NEEP EM&V 2014) found that summer load shapes were coincident with NE-ISO peak periods, but that on average systems operated well below rated output, suggesting that predicting load impacts from DHP based on their capacity might significantly overstate the potential peak impact of their increasing use.

A recent evaluation from Maine (Emera 2014) showed an average increase in both summer and winter peak demand of 0.14 kW and 0.35 kW respectively per heat pump installed. The averages include both residences that previously had no cooling systems and those in which the DHP replaced an existing cooling system.

A 20 year load forecast from the Vermont Electric Power Company (VELCO 2014) that examined a hypothetical saturation of heat pumps in 25% of Vermont homes showed a decreasing statewide electric load due to multiple large solar photovoltaic systems coming on line over the next few decades. The added heat pump load would not increase Vermont's grid load beyond 2014 levels for approximately 13 years. Loads would only begin to grow above current levels as the heat pump load off-sets the new renewable generation after 2027. "Figure 1. VELCO 20 Year Load Forecast with 25% Heat Pump Saturation" shows this impact.

Figure 1. VELCO 20 Year Load Forecast with 25% Heat Pump Saturation



Cooling Season Load Building

In the Pacific Northwest and the Northeast, studies indicate that the majority of homes already have some level of air conditioning. Much of this is in the form of window air conditioners. Many DHP customers initially sought central air conditioning systems but contractors steered them in the direction of DHPs instead. Therefore, many DHPs get installed and end up replacing much less efficient air conditioners with a highly efficient DHP. The result is that there is little evidence of summer load building, and the net effect is even some cooling load savings. In moderate climates, DHPs nearly always replace less efficient air conditioning systems.

One of the questions unresolved in most of the studies is the final disposition of the replaced air conditioning systems; do they just get sold and installed elsewhere, or are they taken out of service? The opportunity to decommission systems that are removed seems like an important issue for DHP programs to address to ensure that the available savings are fully realized.

DHP Scenarios - Existing Buildings

The reviewed studies concluded that the current market for DHPs is dominated by installations in existing buildings. Energy efficiency program administrators may find it helpful to consider the multiple existing building and new construction scenarios in which DHPs may be used. Existing building scenarios are presented below along with a suggested baseline to use in determining savings for each scenario.

1. **Replacement/displacement of electric resistance heat**

   Window air-conditioner replaced or central AC displaced

   Baseline for screening: Electric resistance (COP 1) & standard AC

2. **Replacement of central heat pump**

   Heat pump for primary heat and cooling, with electric resistance coil heating below 17°F

   Baseline for screening: Heat pump @ existing or standard HSPF (includes resistance factor)

3. **Displacement of oil, gas, propane central heat**

   Variable heating usage – climate and user discretion

   Window AC replaced or central AC displaced

   Baseline for screening options:

   a. Standard efficiency DHP
   b. Window AC @ existing or standard EER & partial heating fuel displacement

DHP Scenarios- New Construction

The most likely new construction scenarios and suggested baselines follow.

1. **New Construction - standard home**

   Multiple zone heating and cooling

   Baseline for screening options:

   a. Standard DHP
   b. Standard central heat pump

2. **New Construction - extremely efficient home**

Single or multiple zone heating and cooling – may serve as the only installed heating/cooling system

Baseline for screening: Standard DHP

It is important to note there are a multitude of other scenarios that could be considered, including DHP systems that are, for instance, interfaced with central fuel-fired heating systems, that provide heating with a biomass supplement, that are geared toward small commercial applications, and that are interfaced with photovoltaics.

Market Analysis

Some of the 40 studies examined provided insights and analysis on DHP market characteristics. This section summarizes those findings.

Market Characteristics

To better understand the potential for DHP applications in the Northeast, Table 5 summarizes the regional heating and cooling characteristics of homes in NEEP's territory in 2013.

Table 5. NEEP Residential Characteristics 2013

Region	Electric Heat	Oil Heat	Central A/C
Northeast	12.5%	31%	30%
Mid-Atlantic	26%	6%	65%

In Maine, in 2013 before operating their DHP program, 4% of the market already had a DHP installed, and there was only a 20% awareness of heat pumps, which is in line with customer awareness levels that manufacturers report.

In terms of who DHP customers are, there are very limited available data. What there are come from those areas with the longest-running programs: Maine, Massachusetts, and the Pacific Northwest. In the Pacific Northwest and Maine, customers chose DHP primarily to reduce heating costs. In the Northwest, it is electric heat and in Maine, oil. The Massachusetts Cool Smart program focused more on cooling, but the majority of the participants utilized the DHPs for heating and cooling, with the existing heating systems fueled with oil or natural gas. In Maryland, where lower-cost natural gas is widely available and cooling loads are larger, contractors reported that customers generally call looking for cooling, but then take advantage of the heating savings once the DHPs are installed.

Market Barriers

Studies revealed both market barriers and program barriers with DHPs. Market barriers tend to vary with maturity of market, and can change quickly as programs increase awareness. The usual market barriers in less developed markets include the following: price, lack of awareness, lack of understanding of benefits, hard to find qualified contractors, etc. In addition, there were numerous reports of aesthetic objections to indoor units (leading to increased use of short-run/concealed duct units in the Northwest. A lack of multi-head units for cold climates was also noted frequently as a customer barrier, although that should be resolved by 2015, when these products are expected to enter the market.

Market Opportunities

Market assessment studies noted that successful weatherization programs that in the past had not been able to address electric heat replacement because of the high cost of distribution for central systems have been able to overcome that barrier with DHPs. The key approach identified has been heating *DIS*placement, not *Re*placement. With increased contractor experience and customer awareness in markets with programs and promotions, DHPs are experiencing 10% to 30% growth annually. In Alaska, installers reported a surge of interest in DHPs and no need for advertising after initial program launch and promotion.

Customer Satisfaction

Across the board, customers are reportedly happy. In the Pacific Northwest, 92% reported high levels of satisfaction. In Maine, the question "would you recommend the program?" received a 9.7 on a scale of 1 to 10. In Connecticut and Massachusetts, 38 out of 40 participants rated their satisfaction at a 4 or 5 on a 5 point scale.

In general, customers are widely satisfied with cooling, sometimes less so with heating, especially at lower temperatures. However, these results regarding heating performance are often from older studies that did not include the more recent cold climate systems. More recent surveys reported that customers used DHPs for heating down to rated temperature ranges, and there has been general satisfaction regarding heating performance at these low temperatures. Some customers reported still needing to utilize other heating systems. However, there is reported increased reliance on DHPs for heating during cold conditions as users gain experience with the systems. A recently completed Massachusetts survey of 430 DHP program participants revealed that satisfaction with heating performance was significantly higher when DHPs designed for cold climate heating were installed.

Comfort

As with customer satisfaction, there is general agreement from multiple studies that customers are satisfied or very satisfied with comfort of DHPs. In fact, some customers identified increased comfort as a key benefit (less so with large rooms or complicated room shapes) and most participants reported increased comfort, especially due to heat being provided to areas that were not well heated before.

Interviews

The following section summarizes 16 interviews the researchers conducted with DHP manufacturers, program administrators (PAs) and contractors, listed in Table 6 below.

Table 6. Interviews Conducted

Manufacturers	Program Administrators	Contractors
Daikin Fujitsu Mitsubishi	Connecticut Massachusetts/Rhode Island Maine New York Vermont	Delaware Connecticut Massachusetts Maine New Hampshire Pennsylvania Vermont

Manufacturers

The major DHP manufacturers interviewed have been making DHPs for 30-50 years, and selling them in the U.S. for between 10-30 years. Due to increases in awareness, energy efficiency, program promotions and better performance from newer technologies, all expect 10-50% growth over the foreseeable future. Their contractors are trained and ready for growth in the Northeast, they report.

DHP sales used to all be pushed by the contractors, but utilities are starting to stir interest and legitimize DHPs for consumers. High oil prices are driving consumers to ask contractors for solutions and DHPs are increasingly offered and sold, though expected jumps in retail electric rates in the winter of 2014-15, coupled with falling oil prices, may cause consumer interest to moderate in the near term.

Future Developments

Manufacturers are reporting a long list of future DHP developments, including the following:

- Multi-head cold climate units are coming soon (by 2015);
- Integrated heat pump water heaters by the end of 2015;
- Controls and integration into existing central systems;
- Utility controls of building level systems for demand-response;
- New technologies and more cold climate performance with higher efficiencies;
- Lower prices with more competition and new products at different price points;
- Increased mix and match flexibility of indoor and outdoor units, while simplifying installation for contractors; and
- Slim lines, different heads, hidden cassettes, etc. for more applications and acceptable aesthetics.

Program Suggestions

Manufacturers provided a number of suggestions aimed at existing and upcoming DHP programs. Some of these included considering leasing and rental programs for DHPs (like solar Power Purchase Agreements), changing program eligibility criteria to include commercial buildings, better integration of smart communications for demand-response programs, and a focus on better control options, including remote controls and total system integration. Some of the manufacturers also suggested that the program administrators need to figure out the right cold climate standards and work with AHRI to institute them, including looking at warrantee length (e.g., 10-12 years) as a way to promote quality products. Since most manufacturers do not sponsor in-field evaluation of their products, they suggested continuing to evaluate field performance of DHPs and sharing the data.

Program Elements

Manufacturers also suggested specific program elements that they thought would promote customer participation and the uptake of cold climate quality DHPs. These included consumer education and awareness campaigns and offering and promoting incentives. However, some would rather have lower incentives with more promotion and education than higher incentives. As well, some prefer tiered incentives, others a single threshold tier. Other program elements suggested by manufacturers included having programs provide more contractor and manufacturer education on installation requirements and other program elements, simplifying program offerings and the paperwork processes, and coordinating and integrating promotion, education and training efforts with the manufacturers.

Program Administrators (PAs)

DHPs are generally relatively new to PAs. PAs tend to be learning about the DHP market as they go and are just beginning to start conducting market assessments to better understand the potential DHP markets and how their existing programs are performing. PAs are also learning about how customers use DHPs, but this is evolving and changing. DHPs are increasingly installed as supplemental systems to displace expensive oil, propane and electric heat, along with some new home installations.

PAs are expecting growth with DHPs. Those PAs without DHP programs are planning to launch them and those with DHP programs are preparing for a growing and changing marketplace. While customer awareness of DHPs is limited currently, it is increasing with program efforts and contractor training and familiarity and comfort selling the DHP systems.

While growth is on the horizon, PAs still see barriers. These include equipment cost, savings calculations and attribution. In terms of contractors, barriers include awareness, familiarity, and comfort with a new technology and faith that the DHPs will perform. A significant barrier includes lack of consumer awareness, information, and demand.

PAs realize that in order to be successful, programs need to have a customer focus. They are aware that customers want heating bill reductions, year-round comfort and affordability, and the ability to distinguish a quality DHP product that will work in cold climates vs. an inferior product. In order to deliver, they are providing incentives that range from $300-$1000, generally tiered by efficiency and without too many strings and program complications attached. Some are thinking about incentivizing improved controls in order to better generate predictable savings.

Driving Demand

Most PAs report that contractors are the key to the DHP market and can act as the program's sales force. In some instances, PAs are simply showing contractors that there is a market, providing outreach and training, providing direct-to-contractor incentives and setting them loose. These efforts are generally supported with customer education and advertising to drive demand. Cooperative marketing with distributors has been effective with some programs, along with a website presence. Others are working with manufacturers and their reps to train counter people, training distributors to make more sales, supporting social marketing and blogging, and offering conferences, workshops and a home show presence to address homeowner and contractor questions and build confidence in the technology. There are some great examples of tips, videos and other materials available, especially from Maine and the Pacific Northwest.

Eligibility and Savings

Eligibility is largely based on being an electric utility customer without gas service. For the most part, savings are calculated based on incremental electric efficiency over a baseline DHP unit, assuming the baseline unit would have been installed otherwise regardless of the existing heating fuel. In other words, most programs assume that they are not responsible for the customer deciding to install a heat pump in the first place, but rather focus their efforts on working to induce the customer to purchase a high efficiency heat pump instead of a baseline efficiency unit.

Next Steps for Success

PAs suggested a number of ways they could build and support successful programs. Some of these included establishing a "cold climate" DHP standard, working with manufacturers, distributors and contractors to bring in products that operate reliably in particular climate zones, distinguishing the "cheap stuff" from quality cold climate DHPs in product promotion, determining how to reliably estimate savings, and fully researching and understanding unique market characteristics before launching a program.

Contractors

Most of the eight contractors interviewed were identified to the researchers by the manufacturers, thus they represented some of the leading regional DHP contractors in the Northeast. They were primarily full-service HVAC contractors, but included some smaller niche contractors, including one home performance weatherization contractor who has just recently branched into DHPs. Experience ranged from 1 to 28 years, with an average of about 10 years selling, installing and servicing DHPs. Most all reported growing DHP sales at 20-30% per year, in line with the manufacturers' growth projections.

Contractors reported liking a number of aspects of DHPs. These included their high efficiency, versatility for multiple applications, space conditioning for cold or hot rooms and additions, and the fact that they are profitable to install. However, they also dislike some elements of the technology including the fact that they may not provide sufficient comfort in old leaky homes, have a slow recovery rate, and have no cold climate multi-head models yet.

On the positive side, contractors reported that DHPs are adaptable and flexible to install, very reliable and durable with tens of thousands of installations, excellent customer satisfaction, and good to excellent manufacturer support.

Applications

Contractors report that customers' primary reasons for installing DHP vary across the full spectrum of applications. In some homes customers are looking for improved cooling performance and use DHPs to replace window AC units. In the North, most (70-80%) are looking to offset oil or propane to reduce high heating costs. Typically these are retrofit applications where the DHPs do not replace existing central systems, but rather are used to significantly reduce homes' reliance on the central systems by providing heat in areas of the home that are used the most. To obtain the greatest savings, customers would keep thermostat settings low for less-used areas of the home that still depend on the central system for primary heat. During periods of extreme cold, the central system may be needed to maintain temperatures even in areas where the heat pump is used as the primary system most of the time.

In the southern mid-Atlantic regions that were looked at the focus of DHP use is on cooling, though customers also use mini-splits to provide both heating and cooling in new additions when it is impractical to extend existing central systems. In this application the economic savings may have less to do with operating costs than with the avoided construction costs associated with expanding distribution to the addition.

Controls

Controls are handled inconsistently among the contractors interviewed. Most, but not all provide some limited education on system operation to their customers. Some push integrated controls to better ensure maximizing savings, but most just provide the simple controls included with the units. The lack of controls that are clearly understood by customers, and especially that are integrated with the existing central heating system remains an issue that undermines full achievement of the savings potential for this technology. Contractors would welcome better controls.

Customer Experience

The contractors reported virtually no customer issues. Thousands of DHPs have been installed and only a few complaints were reported as well as very few performance issues. They are all convinced that this technology, especially the newer cold climate models, are designed well and work as advertised.

In terms of comfort and savings, most call the contractor looking for a heating or cooling or a zoned comfort solution (based on the season; in winter, it's heating, in summer, cooling). In the North, the concerns are around oil cost reductions, while it is cooling solutions in the South.

Program Interactions

Where there are programs, customers hear about DHPs and contact the contractors. Most contractors work with local programs, but not all do due to paperwork hassles and low incentives in some regions. All contractors report that incentives help drive interest and demand, and program endorsement helps legitimize DHPs. Some suggested that affordable financing would be helpful, as would figuring out better controls and providing incentives for them. Many also mentioned it would be helpful if programs supported and encouraged more small commercial projects.

Knowledge Gaps

The researchers identified a number of open and unresolved questions as part of this research. In hopes of encouraging future studies and research to address some of these DHP questions, we have included the following list of knowledge gaps:

- Possible performance improvements through controls optimization and customer education;
- Measure life:
    - Variability from other HVAC equipment;
    - Warranty period as a proxy; and
    - How the availability of replaceable components affects estimates of system measure life in cost-effectiveness screening;
- Parasitic losses (drain heaters, frost cycles, etc.);
- Effects of different control strategies (wall thermostats, remotes, modes);
- Demand response suitability;
- Disposition (re-used elsewhere in the home; sold; given away; junked; etc.) of window AC units that are replaced by DHP;
- Cost-effectiveness of displacing gas heat at various outside temperatures;
- Net GHG effects of replacing various fuels;
- Reliability and accuracy of HSPF & SEER test data for DHPs by climate zone;
- Performance at low temperatures (<5 degrees);
- More load shape, energy use, and energy savings information
- More field performance (as opposed to laboratory) testing, especially with new multi-head cold-climate mini-split systems;

- Performance and savings in different climate zones; and
- Applicability of the "cold climate" specification that is currently under development.

Conclusions

From all of the studies and conversations, it is apparent that the market and programs should anticipate DHP growth. With high oil prices, reliable products, cold climate technology, satisfied customers and multi-head units arriving shortly, the Northeast is poised for cold climate DHP expansion. Manufacturers, distributors and contractors are ready to step in and help. Homeowners are looking for heating alternatives, but they often aren't aware of DHPs or the difference in performance between cold climate and standard DHPs. Rather they look to contractors for recommendations for their heating and cooling solutions. PAs can play a useful role in tying all of these pieces together and supporting this market, while generating savings. But PAs will also need policy guidance from regulators and legislators as they maneuver the tricky world of fuel switching and the challenges related to measuring savings. These questions are now under active discussion and hopefully some of the information presented here can help to better inform their resolution.

Recommendations

From analyzing these studies and talking to the industry, the researchers put forward a number of recommendations that follow.

To PAs (Implementers/Planners/Evaluators):

1. Support premium efficiency and durable DHPs as a replacement and displacement space conditioning option for new construction and existing buildings for residential, multifamily and small commercial customers through energy efficiency programs;
2. Support continued development of NEEP's "cold climate" DHP specification (see: http://www.neep.org/initiatives/high-efficiency-products/emerging-technologies/ashp);
3. Support development of a simple DHP savings calculator that will enable programs, contractors, suppliers and homeowners to input some information about their building that would then provide energy usage, cost and savings estimates;
4. Provide outreach and education to customers and contractors on the benefits of DHPs to increase awareness and create a DHP "buzz" in the market;
5. Keep the programs simple and focused on DHPs without burdening contractors with excessive requirements for building efficiency, paperwork, or data;
6. Offer financial incentives based on incremental costs in order to jump-start the DHP market and build customer and contractor interest;
7. Prepare the market from the outset for the inevitable future ramp-down of incentives anticipating future improved market acceptance and uptake— which has the potential to be rapid;

8. Coordinate efforts with manufacturers and distributors to take advantage of the mutual interests in promoting the highest quality and best performing DHPs, and leverage the tremendous technical, marketing, training, communications and contractor resources that the manufacturers can bring to the table;
9. Engage the best quality contractors and provide training to make sure that top-notch contractors are representing the program, and then promote these contractors to customers;
10. In addition to focusing on residential properties, expand program offerings to also include multifamily, commercial and rental properties since there are tremendous opportunities in these sectors as well for DHP installations;
11. Fund and conduct on-going research and field studies to better understand DHP usage and savings and to fill the knowledge gaps listed above and noted in the final section on Recommended Follow-On Research below;

To the HVAC Industry:

12. Support development of a revised HSPF calculation standard with AHRI that includes lower temperature ranges and is aligned with inverter based modulating operation;
13. Develop and provide for DHPs a climate-specific HSPF for all heating climate zones;
14. Coordinate efforts with PAs to take advantage of the mutual interests in promoting the highest quality and best performing DHPs, and leverage the marketing, financial, legitimacy, customer and other relationship resources that PAs can bring to the table;

To Policy Makers/Commissioners/Air Regulators:

15. Encourage all-fuels programs with GHG emissions reduction as a key metric.

Recommended Follow-On Research

The following research tasks have risen to the surface after completing this study. The researchers suggest that the energy efficiency community would benefit from additional research that focuses on at least the following issues and questions:

1. Fund further field studies focusing on metered/billing data and actual fossil fuel reductions to better understand DHP usage and savings across various cold climates;
2. Develop a DHP energy use, cost and savings calculator for programs, contractors, suppliers and homeowners, where inputting some information about a house would be sufficient to provide reasonable savings estimates;
3. Research and address all of the "knowledge gaps" identified on pages 23-24 above, and reproduced here for convenience:

- Possible performance improvements through controls optimization and customer education;
- Measure life:
  - Variability from other HVAC equipment;
  - Warranty period as a proxy; and
  - How the availability of replaceable components affects estimates of system measure life in cost-effectiveness screening;
- Parasitic losses (drain heaters, frost cycles, etc.);
- Effects of different control strategies (wall thermostats, remotes, modes);
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- More field performance (as opposed to laboratory) testing, especially with new multi-head cold-climate mini-split systems;
- Performance and savings in different climate zones; and
- Applicability of the new "cold climate" specification.

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