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REPORT #E15-290

Residential Inverter-Driven Heat Pump Technical and Market Assessment

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Navigant would also like to thank their research partners, Research Into Action (RIA), who were invaluable teammates during the completion of this work.

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Executive Summary

In an effort to explore market transformation opportunities in the residential space heating market of the Northwest, NEEA has focused on inverter-driven ductless heat pumps (DHPs) as a promising technology for displacing electric resistance heat. The market for this technology is evolving rapidly. Consequently, NEEA needs to assess the opportunity for targeting emerging DHP technologies or market segments for further intervention. The key objectives of this study are to:

- Identify relevant market segments in the Northwest, and quantify the maximum technical potential for displacing electric resistance heating in each segment;
- Identify current market barriers and likely market adoption issues for standard DHPs as well as other related specialized equipment in the Northwest; and
- Forecast the likely total displacement of electric resistance heating by standard and specialized DHPs over the next 20 years under different market adoption scenarios.

ES.1 Key Findings

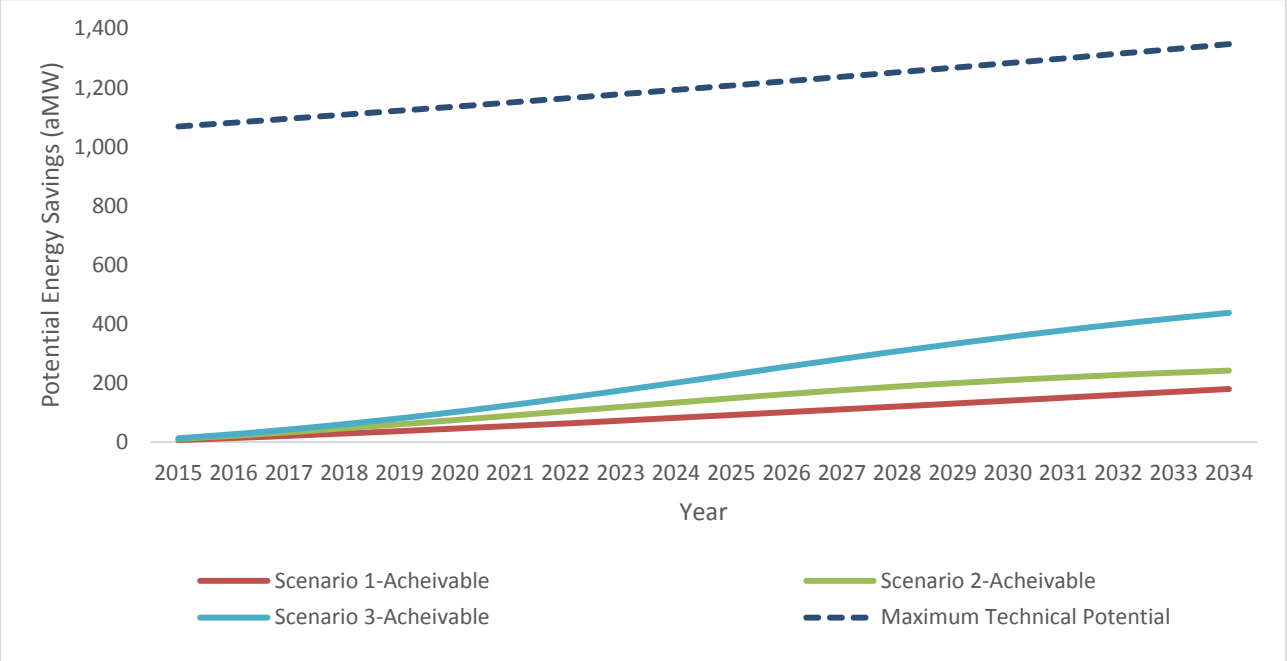
This section presents an abbreviated version of the key findings of this study. The main report contains a full version of the findings.

Modeled Results of Three Scenarios

Technical potential is the total displaced electric load that is possible, given technology limitations such as unit efficiency. It is a measure of the savings resulting from all eligible participants installing the measure that displaces the maximum possible electric load, regardless of cost or other barriers. Alternatively, achievable potential is the total displaced electric load that the model has forecasted while taking into account customer behavior. It accounts for cost effectiveness, customer awareness, marketing and other barriers. The achievable potential is always less than the technical potential for a given customer segment or technology.

As shown in
Figure 1, the potential model forecasts that the cumulative achievable potential savings for the high, medium, and low penetration scenarios are approximately 180 aMW, 240 aMW, and 440 aMW, respectively, over the twenty-year period ending in 2034. The dotted line represents the maximum technical potential, which reaches nearly 1,350 aMW in 2034. The achievable and technical potential values represented in
Figure 1 are the aggregate of all relevant technologies within all sectors in the Northwest.

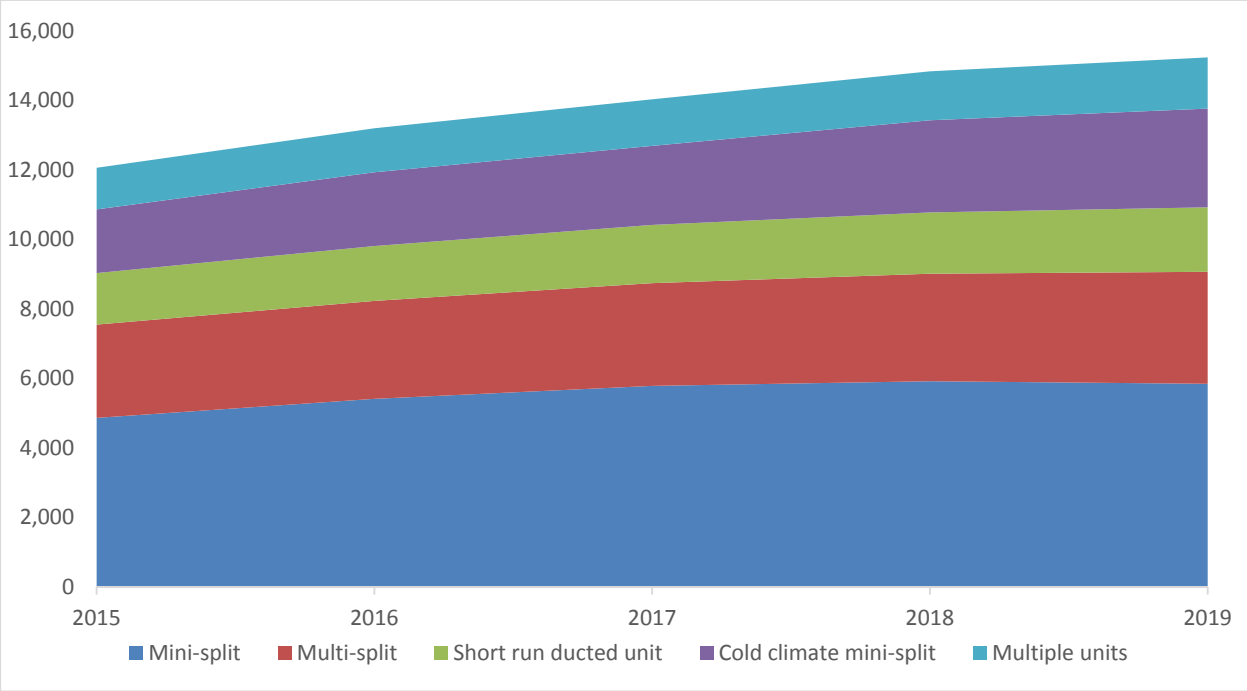
Figure 1. Low, Medium, and High Penetration Scenarios and Maximum Technical Potential Over Time



Source: Navigant Analysis

Figure 2 shows the achievable unit sales cumulative by technology over the next five years under the Low Penetration Scenario by technology.

Figure 2. Achievable Installations by Technology over Next Five Years



Source: Navigant Analysis

Equipment Costs

The Navigant team's research on equipment costs found that market actors from the NW believe that equipment costs will increase at least at the same rate as inflation because of material costs, despite their advanced development. Many international markets, which are much more mature than that of the NW, have lower installation costs due to installation volumes, familiarity of contractors, and different retail channels. Contradictory data on cost trends result in inconsistent findings on future equipment costs. Table 1 shows the equipment costs that the research team gathered during market actor interviews. These values also represented the costs that Navigant used in the potential model. Navigant used static costs over the twenty year modeled period[1].

Table 1. Equipment Cost Findings

Installed Cost by Technology	Average Cost	Range
Mini-split	$4,322	$3,500-$5,325
Multi-split	$6,079	$4,500-$7,000
Cold climate mini-split	$4,635	$3,200-$5,850
Short run ducted unit	$6,922	$4,000-$8,500
Multiple units (Estimate)	$8,000	N/A

Source: Navigant and Research Into Action Analysis

ES.2 Recommendations

The following list contains Navigant's key recommendations, which address the aforementioned findings. Additional context surrounding each recommendation can be found in the main body of the report.

- ***Sponsor the New Manufactured Housing Market***: In the latest Market Progress Evaluation Report (MPER) for NEEA's ductless heat pump initiative, Evergreen Economics found that the manufactured homes market has high, untapped potential, and the initial experience of market actors working with the Initiative has been very positive (Evergreen Economics 2014). Navigant recommends re-engaging with the manufactured home suppliers to address the gap in the market. Additionally, Navigant suggests offering an upstream incentive to housing manufacturers as part of the existing initiative.

- ***Incentivize More Technologies for the Single Family Existing Homes Market***: Navigant recommends expanding the current initiative to other technologies such as multi-split units, cold climate units, short-run ducted systems, and central inverter-driven systems to achieve a greater portion of the single-family existing homes market. As shown in Figure 2, the highest potential comes from cold climate heat pumps, then mini-split DHPs, then multi-split DHPs, then multiple units, then short-run ducted systems.

[1] The assumption of static costs over the twenty-year period is intended to serve as a proxy for the various price fluctuations such as price decreases, inflation, and changing incentive values. A static cost assumption essentially means that the real cost of equipment declines at the rate of inflation (2%/year).

- ***Consider Targeted Marketing toward the Multifamily Rental Market***: Navigant believes that targeting this sector should continue to be a low priority for NEEA given the lower potential savings available in this sector versus other sectors. However, if NEEA wishes to pursue the multifamily rental market with other initiatives and would like to include heat pumps in that initiative, Navigant recommends marketing the cooling and comfort amenity of DHPS to rental property owners. The marketing should focus on the increase to the overall value of their rental property, which in turn allows them to charge higher rent for their property. Additionally, NEEA could consider changing the financing for rental property owners to allow for on-bill financing or a leasing program[2].

- ***Focus Marketing Efforts on Awareness and Benefits of Short-run Ducted Systems***: Navigant recommends that NEEA increase marketing efforts on awareness and benefits of short-run ducted systems in the near term to alleviate homeowners' aesthetic concerns about the traditional DHP technology. This targeted marketing of ductless heat pumps should emphasize that there is a ductless heat pump solution for all applications.

- ***Promote Cold Climate Heat Pump Technology as Best Solution for All Participants***: To displace the most electric resistance heat possible, NEEA should consider promoting cold climate heat pump technology for all potential DHP installations, regardless of climate zone.

- ***Add Central Inverter-driven Heat Pumps to Current Initiative***: NEEA should consider adding central inverter-driven heat pumps to the current DHP initiative to achieve higher penetration in the part of the market where central heating and cooling is most applicable, such as homes already equipped with ducts. NEEA should also consider using their existing influence within the building codes context to restrict installation of electric forced air furnaces in new homes.

1 Introduction

This section presents an overview of the Northwest Ductless Heat Pump Initiative as well as an introduction to this study.

1.1 Northwest Ductless Heat Pump Initiative Background

NEEA works in collaboration with more than 140 Northwest utilities on behalf of more than 13 million energy consumers to sponsor initiatives that use the market power of the region to accelerate the innovation and adoption of energy-efficient products, services and practices.

In October 2008, the region launched the Northwest Ductless Heat Pump Project, a pilot aimed at demonstrating the use of inverter-driven ductless heat pumps (DHPs). NEEA designed the

[2] Green Mountain Power in Vermont currently runs a cold climate DHP leasing program where residential occupants can rent a unit for forty dollars per month. More details for this program are available at http://www.greenmountainpower.com/products-services/overview/heat-pump-services/.

pilot to displace electric resistance heat in existing Northwest homes. There are approximately one million detached, owner-occupied single-family electrically heated homes in the Northwest region. Based on findings from the regional pilot that ended in December 2009, NEEA initiated a full-scale Initiative in 2010. Additional information is available at www.goingductless.com.

Over ninety Northwest utilities currently offer DHP rebates for their customers, while NEEA's work focuses on upstream avenues to promote product availability, support local utility initiatives, and build consumer and market awareness, with the ultimate goal of market transformation.

1.2 Technical and Market Assessment Objectives

In an effort to explore market transformation opportunities in the residential space heating market of the Northwest, NEEA has focused on inverter-driven ductless heat pumps (DHPs) as a promising technology for displacing electric resistance heat. The market for this technology is evolving rapidly. Consequently, NEEA needs to assess the opportunity for market interventions in particular market segments or utilizing particular emerging DHP technologies. The key objectives of this study are to:

- Identify relevant market segments in the Northwest, and quantify the maximum technical potential for displacing electric resistance heating in each segment;
- Identify current market barriers and likely market adoption issues for standard DHPs as well as other related specialized equipment in the Northwest; and
- Forecast the likely total displacement of electric resistance heating by standard and specialized DHPs over the next 20 years under different market adoption scenarios.

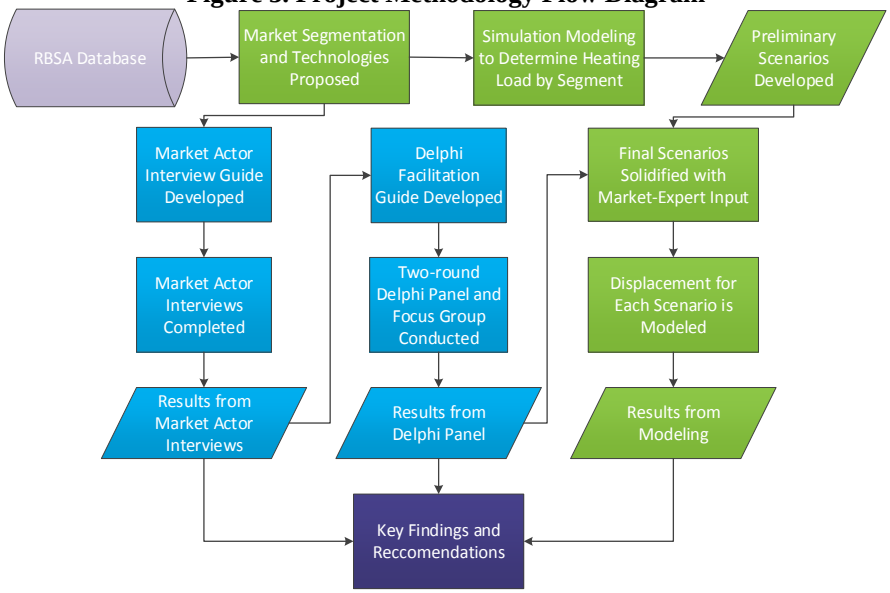
2 Study Methodology

The DHP-driven displacement of electric resistance heat is a fundamentally different application than most HVAC equipment retrofit applications, in that the DHP is typically not a full replacement of existing equipment because additional capacity is necessary to meet loads at low ambient temperatures. Additionally, DHPs are typically used to condition part of a home rather than a whole home. Navigant's previous work has shown that customers purchase ductless heat pumps for two main reasons: they want to save money on heating; they want a new central cooling amenity in a home without ducts; or they want to do both (Navigant 2014). The customer's desired results, existing equipment, and home characteristics mean that a wide variety of products may be installed. The Navigant team's discussions with manufacturers and distributors indicate that the DHP market is changing rapidly, with new varieties of products entering the market to meet specific niche applications. With this in mind, the Navigant team undertook the study based on the methodology shown in Figure 3.

Navigant split the project task into two main parts: market characterization of DHPs in the Northwest (shown in Figure 3 with light blue boxes) and potential load displacement of DHPs in

the Northwest (shown in Figure 3 with green boxes). Each of these tasks is discussed further in the following sections.

Figure 3. Project Methodology Flow Diagram



2.1 Market Characterization

The following three subsections outline the methods used to understand the Northwest market drivers and market-related inputs to the potential model.

2.1.1 Primary Data Collection

The Navigant team collected primary data from market actors, including market and technology experts, representatives from leading manufacturers and distributors in the Northwest, and installation contractors who have been active in installing DHPs. The first phase of data collection consisted of in-depth interviews with a sample of representatives from each market actor group. The second phase involved a modified Delphi panel whose participants included many of the most knowledgeable subset of the interview respondents.

2.1.2 Market Actor Interviews

The team conducted the first phase phone interviews with a sample of market actors in the DHP supply chain, as well as market and technology experts to obtain a broader understanding of:

- The current awareness, adoption, and installation practices of DHP technologies;
- Their perspective on future market growth;
- Suitable DHP applications;
- Market barriers and opportunities; and
- Current installation costs.

The primary purpose of these surveys was to generate initial estimates of input assumptions for the DHP achievable potential forecast model, and to identify important factors and market barriers that could influence the future success of NEEA's Initiative in promoting DHPs[3].

The team identified and sought targeted interviewees, rather than attempting to achieve a representative sample of all market actors because they were seeking the best information possible rather than a representative share of the market. The team gathered information from the most active players in the growing Northwest DHP market.

NEEA provided an initial contact list of market experts, manufacturers, and wholesale distributors. During the interviews, the interviewer sought additional contacts with whom interviewees have working relationships, in order to supplement the original contact list.

To develop an initial list of installers, the team used the contact list that they had previously used for the development of the 2010 NEEA DHP Initiative's Market Progress Evaluation Report (MPER) to identify active installers at that time, with the intention of contacting the most experienced and knowledgeable installers in the region. Each of the contacted installers had completed at least twenty-two DHP installations by 2010 (up to a maximum of 618). The team also selected installers from each of the NEEA-served states in which these installations occurred. Of the 523 contacts in the original list, the team selected and contacted ninety-eight installers. The final response rate was 17% with a cooperation rate of 56%.[4]

Between November 5th and December 12th, 2014, the team completed surveys with a total of twenty-nine market actors. Table 2 summarizes the sampling of the four market actor groups, and basic characteristics of survey respondents.

Table 2. Summary of Sampling for the Market Actors Survey

Group	Completed	Sample Frame	Contact Descriptions
Market and Technology Experts	3	7	Experts on DHP technology as well as market conditions in the PNW.
Manufacturers	4	7	Regional sales managers of major DHP manufacturing companies.
Wholesale Distributors	7	16	Owners and sales/marketing managers of most active residential DHP wholesale and distribution companies in the PNW.
Installation Contractors	15	98	Owners and sales managers of active residential DHP installation companies in the PNW.
Total	**29**	**-**	**-**

[3] 5Appendix A includes the interview guide used to collect data from market and technology experts, manufacturers, and wholesale distributors and 5Appendix B includes the interview guide used to collect data from installation contractors.

[4] The calculation method of the response and cooperation rates are: Response rate equals the number of completed interviews divided by the number of eligible participants. Cooperation rate equals the number of completed interviews divided by the number of eligible participants with whom the team made an actual contact and spoke.

2.1.3 Delphi Panel and Focus Group

The second phase of the primary data collection was two rounds of Delphi panel sessions with the most knowledgeable subset of the respondents to the above surveys.[5] The primary purpose of this data collection phase was to obtain feedback on the initial DHP achievable installation forecast model developed by the Navigant team. The team based the initial forecast model on the data gathered from the market actor interviews, in combination with other secondary data to further improve the model. The Delphi panel was also used to develop a deeper understanding of unresolved issues relating to the future success of NEEA's DHP Initiative.

The team designed the first Delphi panel session to be self-directed, where panelists were asked to review the calibrated forecast model and key assumptions used as inputs, and then respond to an online survey that asked a series of questions to obtain panelists' reaction to the forecast as well as the key assumptions. The second Delphi panel session involved a webinar where a facilitator presented an adjusted model based on the feedback provided during the first Delphi panel session, and posed questions to seek group discussions about several uncertain key assumptions and unsolved issues that could impact NEEA's DHP Initiative[6].

The team recruited panelists from the pool of respondents to the market actors surveys with priority given to the individuals who provided the most insightful responses and excluded the individuals who did not demonstrate high a level of experience or knowledge of the Northwest DHP market. Table 3 summarizes the Delphi panelist selection.

Table 3. Summary of Delphi Panelist Selection

Group	Selected	Recruiting Frame
Market and Technology Experts	3	3
Manufacturers[7]	2	4
Wholesale Distributors	3	7
Installation Contractors[8]	0	4
Total	**8**	**18**

[5] A Delphi panel is a structured data collection method originally developed for technological forecasting with an intention of extracting opinions from a group of experts. Conventional Delphi panels seek iterative feedback to questionnaires from panel members though controlled and anonymous environments where panelists are encouraged to revise their previous answers in light of answers from other panel members, expecting range of answers to converge towards a correct or more concordant. The team's approach for this study employed this conventional approach in combination with an additional component of a webinar discussion, similar to a focus group.
[6] The facilitation guide and the feedback survey can be found in 5Appendix C and 5Appendix D, respectively.
[7] One manufacturer only participated in the first round of the Delphi panel sessions.
[8] The research team was unable to gain cooperation from any installation contractors for participation in the Delphi panel sessions.

2.2 Potential Modeling

The following subsections illustrate the steps taken and methods used to forecast the likely total displacement of electric resistance heating by DHPs and other specialized technologies over the next 20 years, specifically in the period between 2015 and 2034.

2.2.1 Characterization of the RBSA Database

To determine the potential displaceable electric resistance load, Navigant first identified the relevant market segments for inclusion in the potential modeling and then quantified the total electric load in the Northwest by market segment. Navigant used the Residential Building Stock Assessment (RBSA)[9] data to quantify the percentage of homes using each type of primary heat source. Table 4 shows the breakdown of heating system type and fuel for each housing segment.

Table 4. Breakdown of Heating System Type and Fuel by Sector

Primary Heating System Type	Primary Heating Fuel	Single Family	Manufactured	Multifamily
Air Source Heat Pump	Electric	12%	14%	1%
Baseboard Heater	Electric	12%	2%	81%
Boiler	Electric	1%	0%	0%
	Gas	4%	0%	1%
Dual Fuel Heat Pump	Electric	1%	0%	0%
Ductless Heat Pump	Electric	1%	1%	0%
Fireplace	Wood	0%	1%	0%
Forced Air Furnace	Electric	5%	52%	3%
	Gas	44%	12%	9%
	Oil	4%	1%	0%
Ground Source Heat Pump	Electric	1%	0%	0%
Heating Stove	Gas	3%	0%	1%
	Pellets	2%	2%	0%
	Propane	1%	0%	0%
	Wood	8%	13%	0%
Packaged Terminal Air Conditioner or Heat Pump	Electric	0%	0%	3%
Plug-In Heater	Electric	1%	2%	0%
Other[10]	Other	0%	0%	1%
Total Electrically-Heated		**34%**	**70%**	**88%**

[9] NEEA is conducting a comprehensive research study of energy efficiency in Northwest residential buildings called the Residential Building Stock Assessment (RBSA). This study will inform future energy planning efforts, as well as energy efficiency utility programs and rebates offered by the region's utilities, the Energy Trust of Oregon and the Bonneville Power Administration. The data can be found at http://neea.org/resource-center/regional-data-resources/residential-building-stock-assessment.

[10] Other heating system types include: oil boiler, propane boiler, propane fireplace, oil heating stove, steam central HVAC system, oil central HVAC system

Primary Heating System Type	Primary Heating Fuel	Single Family	Manufactured	Multifamily
Total All Fuels		**100%**	**100%**	**100%**

Source: Navigant Analysis of RBSA data

Table 5 shows the total electric resistance load by sector for each heating system type.

Table 5. Electric Heating Use by System Type and Sector

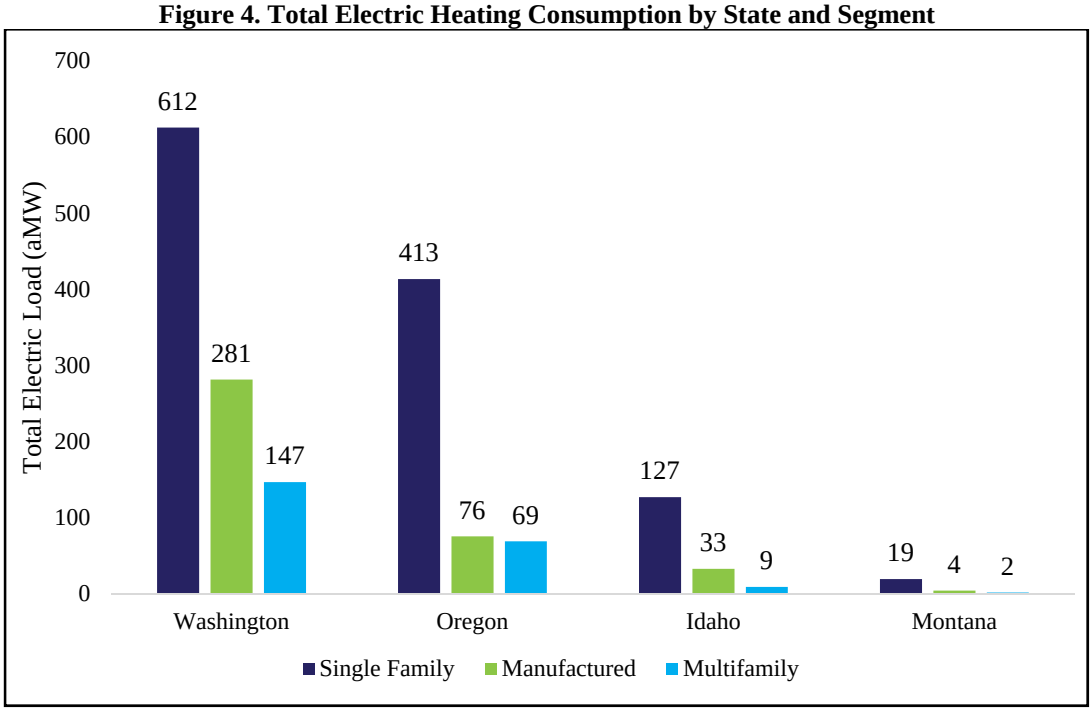
Primary Heating System Type	Total Load (aMW)	Single Family	Manufactured	Multifamily
Air Source Heat Pump	478	83%	17%	1%
Baseboard Heater	638	66%	1%	33%
Boiler	19	100%	0%	0%
Dual Fuel Heat Pump	41	100%	0%	0%
Ductless Heat Pump	55	92%	8%	0%
Forced Air Furnace	484	38%	60%	2%
Ground Source Heat Pump	25	100%	0%	0%
Packaged Terminal Air Conditioner or Heat Pump	8	0%	0%	100%
Plug-In Heater	44	78%	22%	0%

Source: Navigant Analysis of RBSA data

The team then created a subset of data from the RBSA databases including only those homes that use electric heating. Homes in the residential and manufactured sector have heating loads calculated and specified in the RBSA data. Multifamily homes did not have this data available and the team used square footage and energy intensity to determine the heating load in these homes[11]. Figure 4. Total Electric Heating Consumption by State and Segment shows the total electric heating consumption for each segment.

[11] Navigant used the RBSA square footage data for multifamily homes and the energy intensity (W/sqft) from residential homes in the RBSA data to estimate the energy consumption of multifamily homes for each region in the RBSA database.

Figure 4. Total Electric Heating Consumption by State and Segment



Source: Navigant Analysis

2.2.2 Scenario Development

In order to provide results that are easy to understand and actionable, Navigant developed three distinct market adoption scenarios. The team developed the scenarios by characterizing the RBSA database to determine areas of high potential, modeling to gauge the effects of each input on the result, and aggregating industry expert's insights to understand the market dynamics in the Northwest. From these data sources, Navigant determined the final three scenarios:

1. **The Low Penetration Scenario** (also called "Scenario 1") represents the DHP initiative continuing on a business as usual basis. This scenario assumes that activity and incentives continue as they have in the past several years for the full 20-year forecast.

2. **The Medium Penetration Scenario** (also called "Scenario 2") includes all incentives and activity from the low penetration scenario, plus an additional marketing campaign intended to improve customer awareness of all inverter-driven heat pump technologies from 2016 to 2018.

3. **The High Penetration Scenario** (also called "Scenario 3") includes all incentives and activity from the medium penetration scenario, plus the addition of:

    a. A specific campaign intended to increase awareness of ducted heat pumps, including central inverter-driven heat pumps;

b. An increase in the available market size of renters (from 5% to 20%), which simulates an uptake from rental property owners due to advertising the additional cooling amenity and resulting the increase in rental income available; and

c. A specific promotion of DHPs in new manufactured housing using an upstream incentive.

2.2.3 Modeling

The Navigant team used the proprietary DSMSim model to estimate the technical and achievable potential for each of the three scenarios. DSMSim is a bottom-up technology-diffusion and stock-tracking model implemented using a System Dynamics framework. DSMSim is equipped with an interface that facilitates detailed inspection (graphical or tabular) and quality control of all model output and intermediate variables, at the measure level, across customer segments, territories, and simulation scenarios.

Technical Potential

Technical potential is a measure of the savings resulting from all eligible participants immediately installing the technology that displaces the maximum possible electric load, regardless of cost or other barriers. In the context of this study, it represents the amount of electric load displaced by replacing all electric heating with DHPs. The technical potential can increase as a function of time if there is a net gain of housing from the new construction market. The combined technical potential for both retrofit and new construction, $Total\ Technical\ Potential$, is given by the equation:

$$Total\ Technical\ Potential = Existing\ Building\ Stock_{YEAR} * Measure\ Density * Savings_{YEAR} * Technical\ Suitability + New\ Buildings_{YEAR} * Measure\ Density * Savings_{YEAR} * Technical\ Suitability$$

where $Existing\ Building\ Stock_{YEAR}$ is the number of residential households in the Northwest with electric heat, $Measure\ Density$ is defined as one DHP system per household, $Savings_{YEAR}$ is the energy saved per year for a DHP system over the baseline of electric heating and $Technical\ Suitability$ is the fraction of homes that could accept a DHP technology.

Achievable Potential

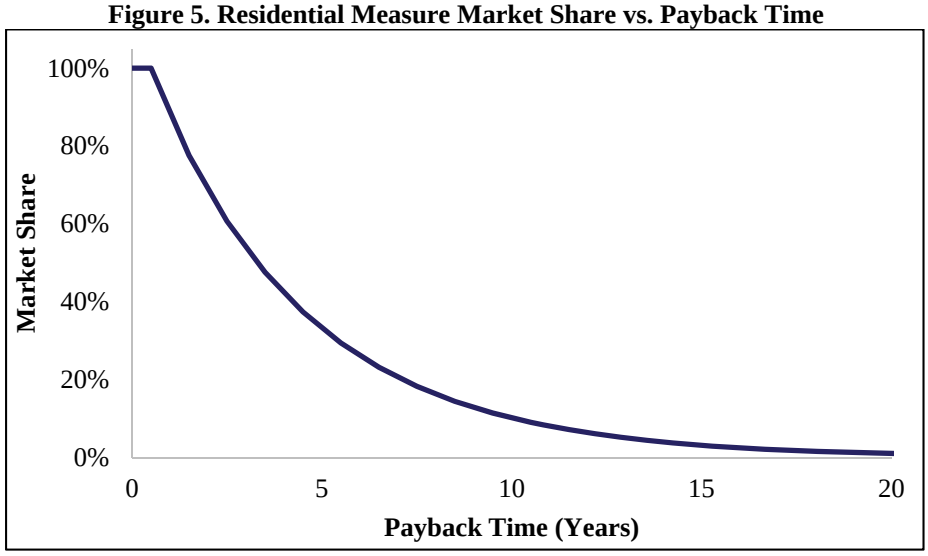
The achievable potential is the total forecasted displaced electric load while considering customer market adoption. It accounts for the cost effectiveness, customer awareness, marketing and other barriers. Calculation of achievable potential is fundamentally more complex than the calculation of technical potential. The adoption of energy-efficient technologies can be broken down into calculation of the "equilibrium" market share and calculation of the dynamic approach to equilibrium market share.

The equilibrium market share is the percentage of households that choose to purchase a technology provided they are aware of the technology and its merits. For an energy efficient

measure, the key differentiator between the efficient measure and baseline technology is energy and thus cost savings over the lifetime of the measure[12]. Some measures, like DHPs, add an amenity such as cooling or noise reduction. The lifetime measure cost savings coupled with increased amenity come at the cost of upfront expenses to the consumer. Because of these upfront costs, only a fraction of aware consumers will adopt any given measure. The equilibrium market share is calculated as a function of the payback time of the efficient measure as compared to a baseline technology. The equilibrium market share also changes over time as factors that influence payback change. Rising electricity prices, inflation or changes in price of technologies all influence the equilibrium market share as a function of time.

Navigant used equilibrium payback acceptance curves to determine the market share for competing technologies. This method is a simplification used to estimate a customer's probability of selecting an energy efficient technology over a baseline technology when measure or location specific data is not available. The best source available at this time for residential equilibrium payback acceptance curves in the United States comes from primary research conducted by Navigant in the Midwest United States in 2012 (Navigant 2013). Navigant considers that the nature of the decision-making process is such that the data developed using Midwest customers is representative for the U.S. as a whole. To develop these curves, Navigant conducted surveys of 400 residential customers. These surveys presented decision makers with numerous choices between technologies with low up-front costs, but high annual energy costs, and measures with higher up-front costs but lower annual energy costs. Navigant conducted statistical analysis to develop the set of curves shown below in Figure 5, which were leveraged in this study.

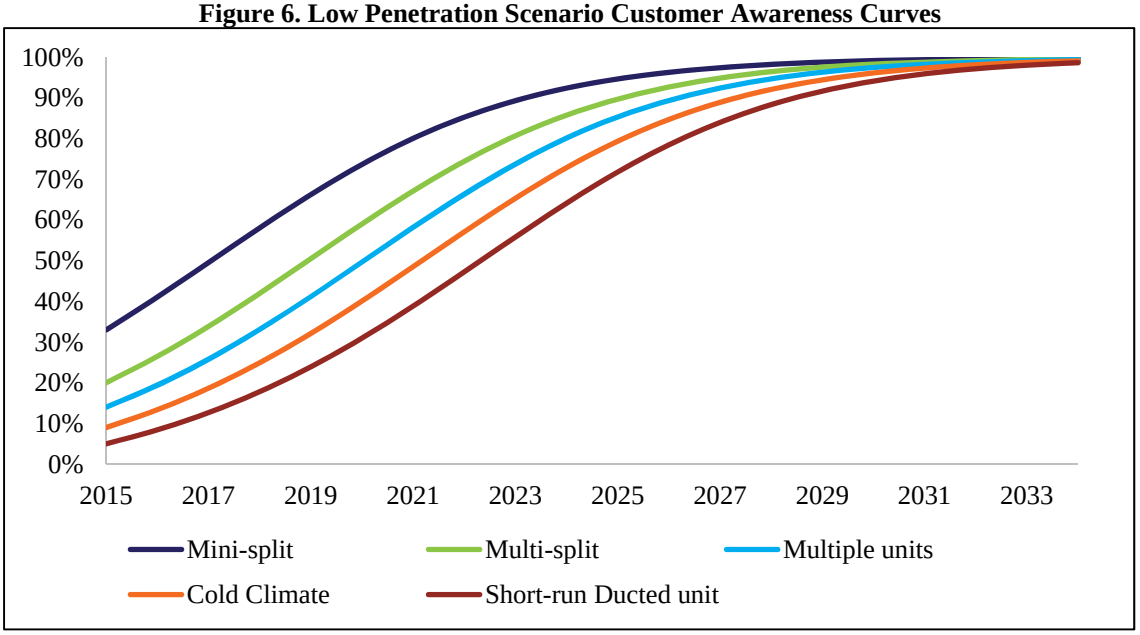
Figure 5. Residential Measure Market Share vs. Payback Time



[12] Navigant assumes that the lifetime of a ductless heat pump is 15 years for this study (NWPCC 2009).

The dynamic approach to equilibrium market share is calculated as a function of the equilibrium market share at any given time step and the adoption from word of mouth or marketing. The Navigant team calculates awareness of potential adopters using an enhanced version of the classic Bass diffusion model to simulate the S-shaped approach to equilibrium. This S-shaped approach to equilibrium of market share is observed for a wide range of technologies. Figure 6 shows the Bass diffusion curves, which represent customer awareness for each technology in for the Low Penetration scenario[13]. Likewise, Figure 7 shows the Bass diffusion curves representing customer awareness for each technology for the Medium and High Penetration scenarios. Table 6 shows the initial and revised assumptions for the initial value of the customer awareness curve for each technology based on the Navigant team's primary data collection.

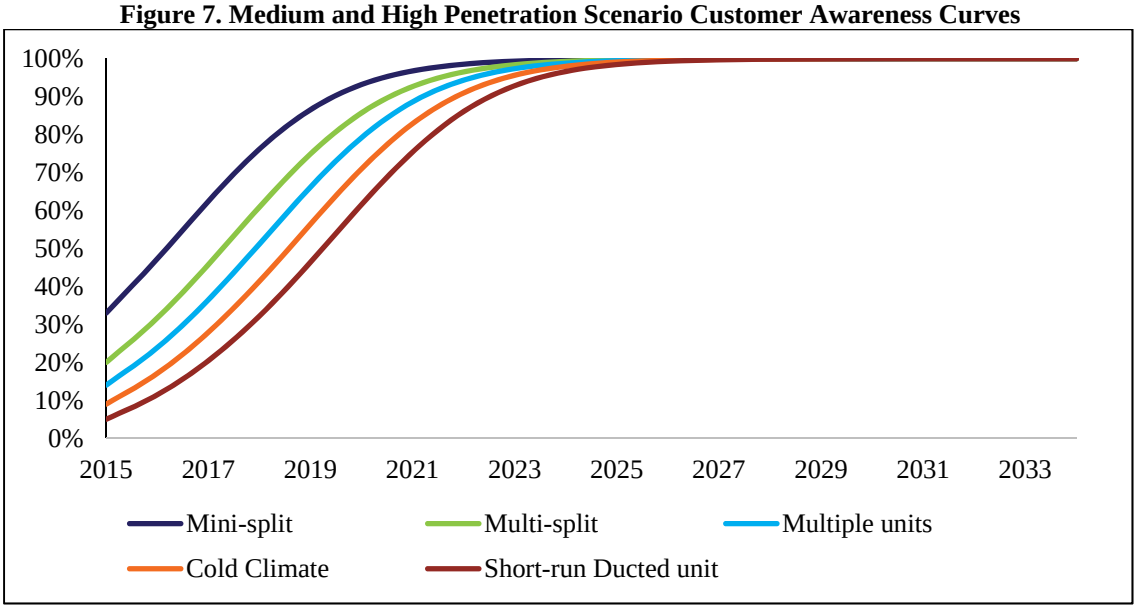
Figure 6. Low Penetration Scenario Customer Awareness Curves



Source: Navigant Analysis

[13] The terminology for the various technologies used in this report is as such:
Mini-split: a single outdoor unit connected to a single indoor unit
Multi-split: a single outdoor unit connected to multiple indoor units
Multiple units: any configuration of mini-splits and multi-splits that results in multiple outdoor units connected to multiple indoor units; a single data point of multiple units indicates a single site or single installation with more than one unit present
Cold climate unit: a mini-split unit which utilizes a higher compression ratio and can therefore maintain capacity at low temperatures, sometimes down to twenty degrees below freezing
Short-run ducted unit: utilizes the same inverter-driven technology as a DHP, but the indoor air handling unit is hidden in the ceiling with short ducts to distribute the air within the room and/or to multiple adjacent rooms

Figure 7. Medium and High Penetration Scenario Customer Awareness Curves



Source: Navigant Analysis

Table 6. Initial and Revised 2015 Customer Awareness Assumptions

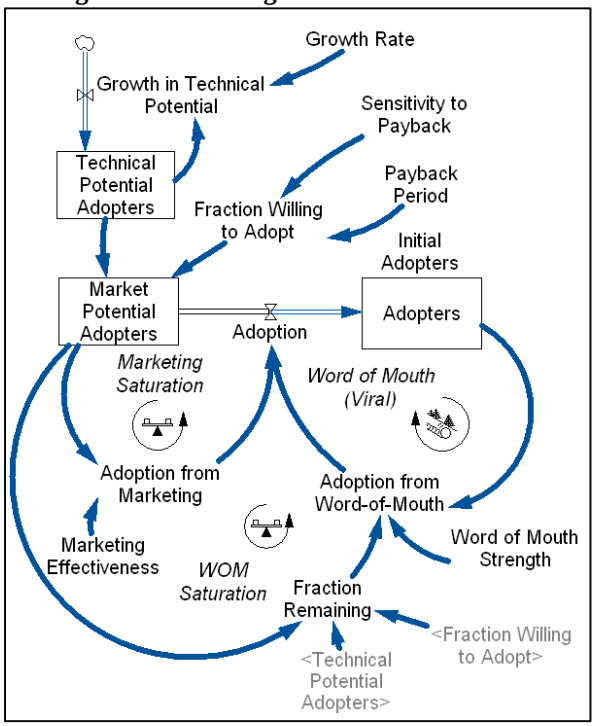
Current Customer Awareness	Initial Estimate	Revised Estimate[14]	Range
Mini-split	30%	33%	10%-60%
Multi-split	25%	20%	10%-25%
Cold climate mini-split	10%	9%	5%-10%
Short run ducted unit	5%	5%	3%-5%
Multiple units	10%	14%	10%-30%

Source: Navigant and RIA Analysis

In Navigant's model, potential adopters become to adopters by two primary mechanisms: adoption from external influences, such as marketing and advertising, and adoption from internal influences, or word of mouth. Figure 8 is a diagram that illustrates the causal influences underlying the Bass model.

[14] According to NEEA's most recent MPER, the overall customer awareness of DHP systems is 48% (with 43% aware without any informational aids), which was based on phone survey results of homeowners without DHPs. The sample size for this research was n=200. The research in this study was conducted through expert determination, and therefore, produced different results than the phone survey study based on homeowners recollection of the measure. The evaluation team is confident that the two results are within the same margin for error.

Figure 8. Flow Diagram of Diffusion Model



Source: Navigant Analysis

Model Calibration

As with any forecasting model, the model outputs are only as good as the model inputs, model structure and underlying assumptions. While it is impossible to validate a future scenario against real data, Navigant checked the model starting assumptions and forecasting for reasonability. By conducting a two-phase Delphi panel/focus group, the team was able to present their modeling assumptions to experts and revise them as necessary based on industry expert knowledge. Some of the key parameters that Navigant was able to verify include customer awareness of technologies, potential displacement of heating load, landlord adoption of technology, influence of ducting on customer adoption and the influence of appearance on customer decision making. Table 7. Modeling Assumptions shows the modeling assumptions that were revised as a result of the Delphi panel.

Table 7. Modeling Assumptions Revised as Result of Delphi Panel

Assumption Type	Technology	Initial Estimate	Revised Estimate	Range
Current Customer Awareness	Mini-split	30%	33%	10%-60%
Current Customer Awareness	Multi-split	25%	20%	10%-25%
Current Customer Awareness	Multiple units	10%	14%	10%-30%
Current Customer Awareness	Cold climate mini-split	10%	9%	5%-10%
Current Customer Awareness	Short run ducted unit	5%	5%	3%-5%
Heating Load Displaced by DHP system	Mini-split	50%	49%	25%-65%
Heating Load Displaced by DHP system	Multi-split	68%	78%	68%-100%
Heating Load Displaced by DHP system	Multiple units	91%	88%	70%-100%

Assumption Type	Technology	Initial Estimate	Revised Estimate	Range
Heating Load Displaced by DHP system	Cold climate mini-split	55%	62%	55%-100%
Percentage of Landlords who would consider using DHPs	All	5%	6%	5%-10%
Percentage of Landlords who would consider using DHPs with utility finance	All	10%	15%	5%-35%
Percentage of Landlords who would consider using DHPs with increased incentives	All	20%	21%	10%-35%
Percentage of Landlords who would consider using DHPs with direct install	All	40%	73%	65%-95%

Source: Navigant and RIA Analysis

3 Findings

This section details the findings from the potential modeling of the three scenarios and varying DHP technologies.

3.1 Market Segment and Technology Pairings

This section details the relevant market segments that Navigant identified in the Northwest and the relative size of the electric resistance load in each market segment.

3.1.1 Barriers and Segments

The Navigant team developed a list of barriers that prevent ductless heat pumps from meeting more of the overall heating load in the Northwest. The barriers are split into three areas: technical limitations, physical limitations, and market limitations. These limitation areas are discussed in the following sections. The team identified these barriers through the team's professional judgment and interviews with market experts, manufacturers, distributors, and installers, and further explored in the Delphi panel.

Technical Limitations

Technical limitations are the barriers directly related to the capability of the current technology to meet the heating load of the house. These limitations have technical solutions. These limitations are:

- Temperature/climate-related limits to unit capacity
- Spatial restrictions to heat flowing to the full home such as the size of house, floor plan, and number of stories
- Whether the wall construction dictates that it is cost-prohibitive to run refrigerant lines

Physical Limitations

The physical limitations are barriers related to the occupant's willingness to purchase a ductless unit regardless of their knowledge and understanding of the technology. These limitations primarily have market solutions. These limitations are:

- The presence and condition of existing ducts in the house
- The house's current access to natural gas

Market Limitations

The market limitations are barriers related to the occupant and his or her chosen contractor. These limitations have market solutions. The limitations in this category are:

- Occupant limitations such as financial barriers, lack of awareness, or a distaste for the aesthetics of DHPs; and
- Contractor barriers include lack of knowledge, experience, or distrust in the technology's capabilities.

The detailed limitations are listed in the second column of Table 8. Each unique permutation of the primary limitations will result in a unique market segment. The Navigant team has identified the market segments where a one-to-one installation is likely to be applicable and contribute to a substantial portion of the house's load, as shown in the fourth column of Table 8. In the fifth and sixth columns of Table 8, the team has indicated the size of the limitation for a single head system and a multi-head system, respectively. The relative size of the electric load in each market segment in shown in the ninth column of Table 8.

3.1.2 Technologies

The seventh and eighth columns of Table 8 show Navigant's suggested technology solutions and marketing solutions, respectively. The gray shaded cells indicate areas that are not relevant to populate.

Table 8. Limitation Determination for Each Unique Limitation Condition

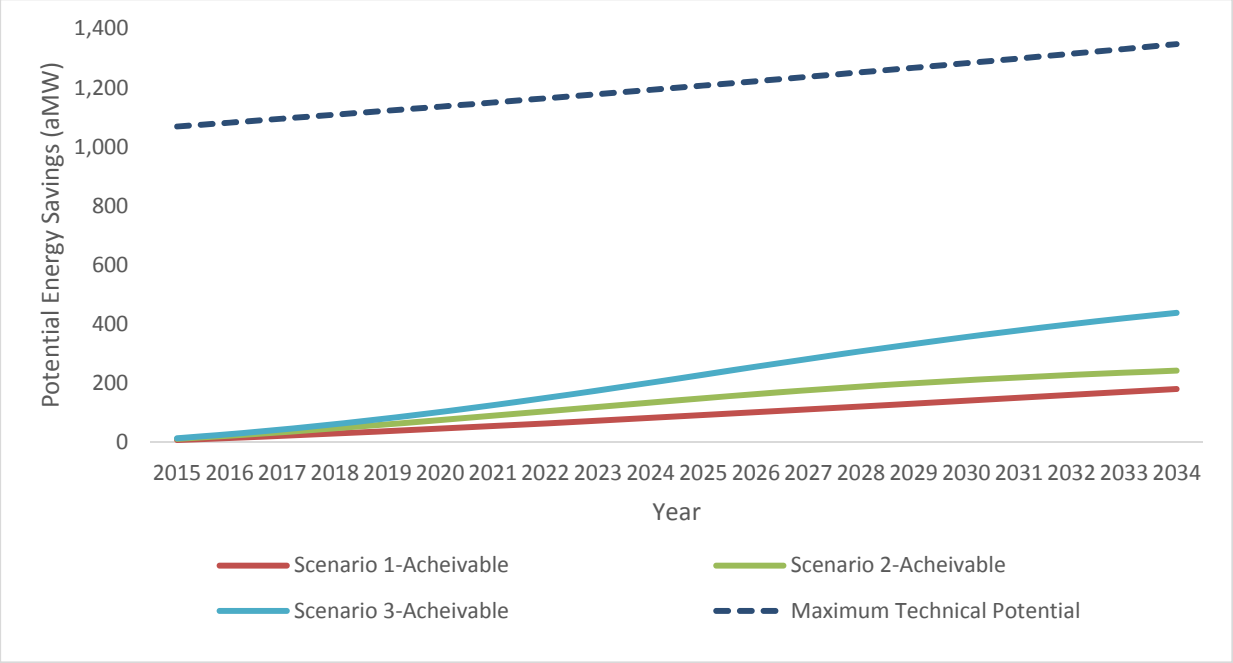
Limitation Categories		Condition Details	Is one-to-one installation applicable?	Size of Single Head Limitation (Qualitative)	Size of Limitation if multiple heads installed?	Additional Technology Solution(s)	Market Solution(s)	Relative Size of Electric Resistance Load*
Technical Limitations	Temperature	RTF Heating Zone 3	Yes	High	High	Cold climate compressor		6%
		RTF Heating Zone 1 or 2	Yes	Medium	Medium	Cold climate compressor		94%
	Spatial	House greater than 2000 sq ft	Yes	High	Medium	Multiple outdoor units		37%
		House between 1200 and 2000 sq ft	Yes	Medium	None	Multiple indoor units		40%
		House less than 1200 sq ft	Yes	Low	None	Multiple indoor units		22%
		House has open floor plan	Yes	Low	None	Multiple indoor units		51%
		House has closed-off rooms	Yes	Medium	None	Multiple indoor units, Short run duct		48%
		Multi-story houses	Yes	Medium	None	Multiple indoor units		23%
		Single-story houses	Yes	Low	None	Multiple indoor units		75%
	Wall Construction	Prohibitive to run refrigerant lines	No	Infinite	Infinite	Short run ducted unit, Floor mounted indoor unit		2%
		Not prohibitive to run refrigerant lines	Yes	None	-	-		98%
Physical Limitations	Presence of Ducts	Ducts present	Yes	Medium	Medium	Inverter-driven ducted heat pump, AHU replacement	Marketing of additional technology solution(s)	29%
		No ducts present	Yes	None	-	Multiple outdoor units, multiple indoor units,	Marketing of additional technology solution(s)	64%
		Ducts non-functional	Yes	Low	Low	Multiple outdoor units, multiple indoor units,	Marketing of additional technology solution(s)	6%
	Access to Gas	House has access to gas	Yes	High	High	-	Marketing of additional technology solution(s)	DK
		House does not have access to gas	Yes	None	-	Multiple outdoor units, multiple indoor units,	Marketing of additional technology solution(s)	DK
Market Limitations	Occupant Limitations	Renter occupied	Yes	High	High		Restructure initiative to target landlords	13%
		Owner occupied	Yes	Low	Low		-	86%
		Owner has capital	Yes	None	-		-	DK
		Owner does not have capital	No	Infinite	Infinite		Restructure initiative to target low income populations	DK
		Owner approves of appearance of DHP	Yes	None	-		-	88%
		Owner does not approve of appearance of DHP	No	Infinite	Infinite		Marketing of additional technology solution(s)	12%
		Occupant understands correct operation of DHP	Yes	Low	Low		-	DK
		Occupant does not understand correct operation of DHP	Yes	Medium	Medium		Homeowner education	DK
		Owner is aware of DHP technology	Yes	None	-			33%
		Owner is unaware of DHP technology	Yes	High	High		Marketing of DHP technology	67%
	Contractor Limitations	Contractor is aware of DHP technology	Yes	None	-		-	DK
		Contractor is unaware of DHP technology	Yes	High	High		Contractor education	DK
		Contractor trusts DHP technology	Yes	None	-		-	DK
		Contractor does not trust DHP technology	Yes	High	High		Contractor education	DK
		Contractor has no experience with DHP technology	Yes	High	High		Contractor education	DK
		Contractor has experience with DHP technology	Yes	None	-		-	DK
		Contractor knows how to install DHP	Yes	None	-		-	DK
		Contractor does not know how to install DHP	Yes	High	High		Contractor education	DK

*Size of electric resistance load is based solely on houses with electric resistance. Houses without electric resistance are not included in these calculations. Many Market Limitation factors were not available in the RBSA data, and therefore Navigant could not analyze the size of the load in some relevant market segments.

3.2 Modeled Results of Three Scenarios

As shown in Figure 9, the potential model forecasts that the achievable potential savings for the high, medium, and low penetration scenarios are approximately 180 aMW, 240 aMW, and 440 aMW, respectively, over the twenty-year period ending in 2034. The dotted line represents the maximum technical potential, which reaches nearly 1,350 aMW in 2034. The achievable and technical potential values represented in Figure 9 are the aggregate of all relevant technologies within all sectors in the Northwest.

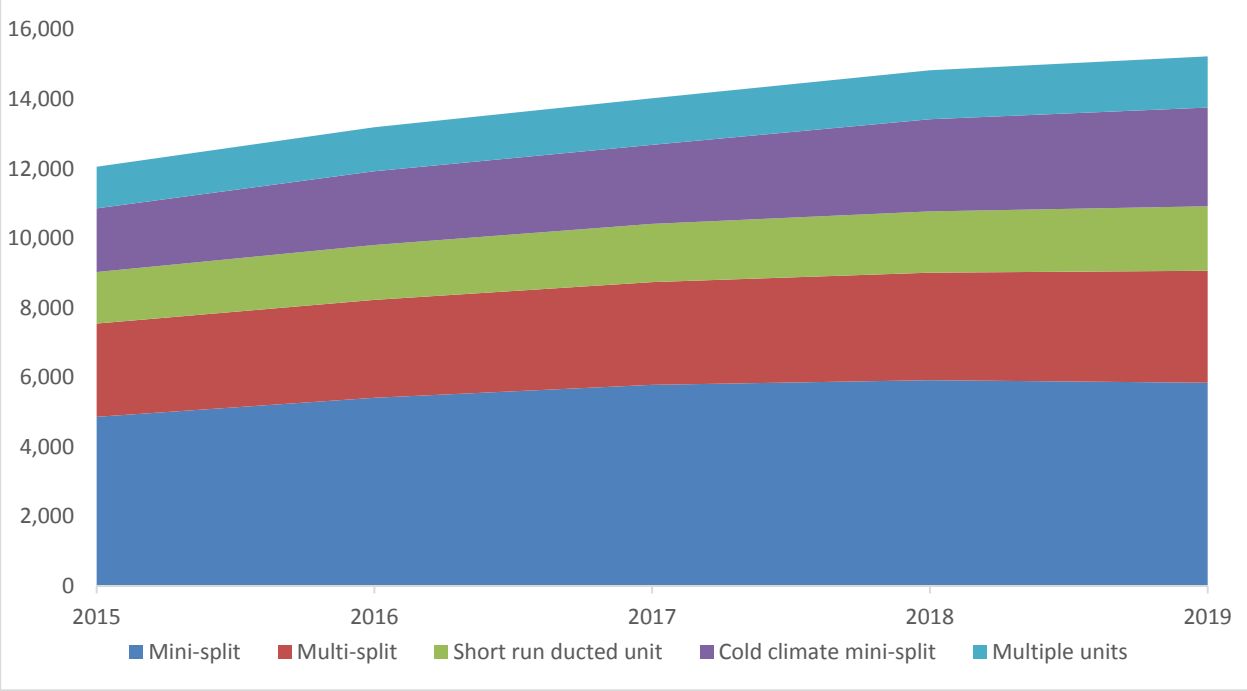
Figure 9. Low, Medium, and High Penetration Scenarios and Maximum Technical Potential Over Time



Source: Navigant Analysis

Figure 10 shows the cumulative achievable unit sales over the next five years under the Low Penetration Scenario by technology.

Figure 10. Achievable Installations by Technology over Next Five Years



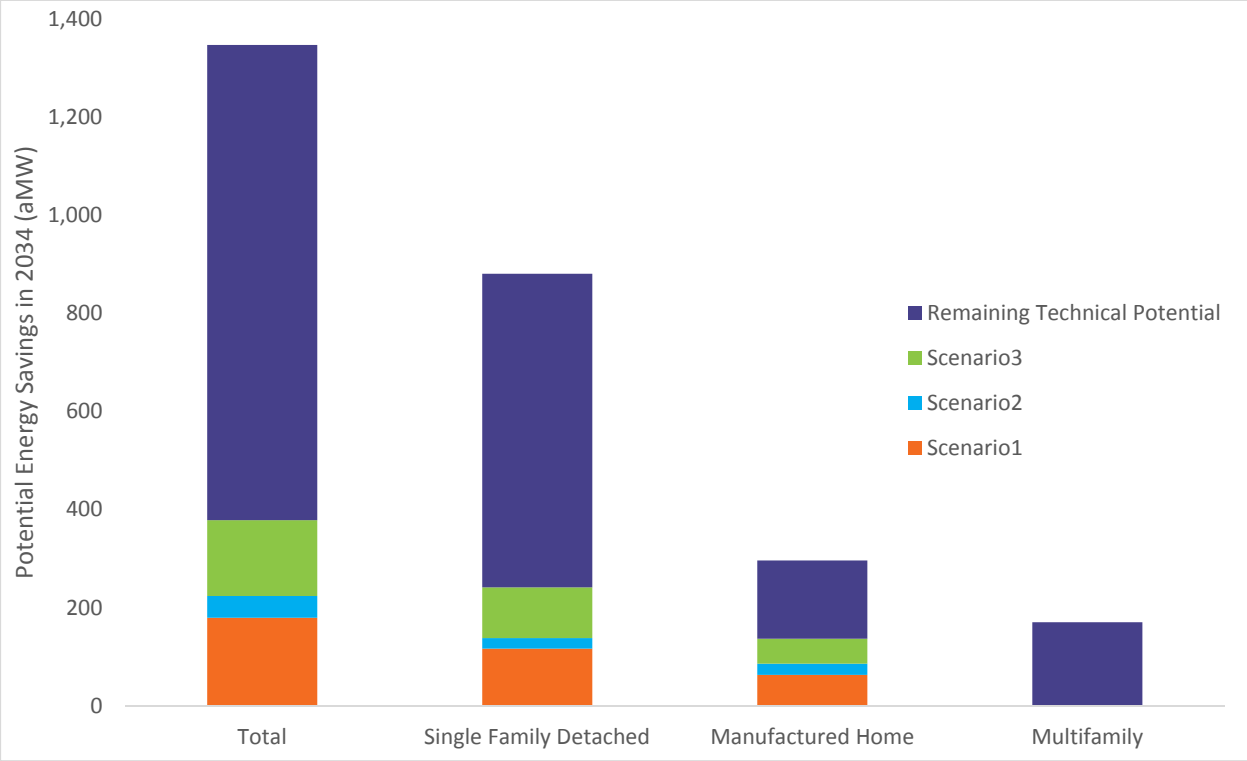
Source: Navigant Analysis

3.3 Savings Potential by Groups

In 2034, the Navigant model projects a total electric resistance load of 2,260 aMW and a total technical potential from DHPs and other inverter-driven heat pump technologies of 1,347 aMW. This represents a total technical potential of 60% of the total electric resistance load that can be met in 2034.

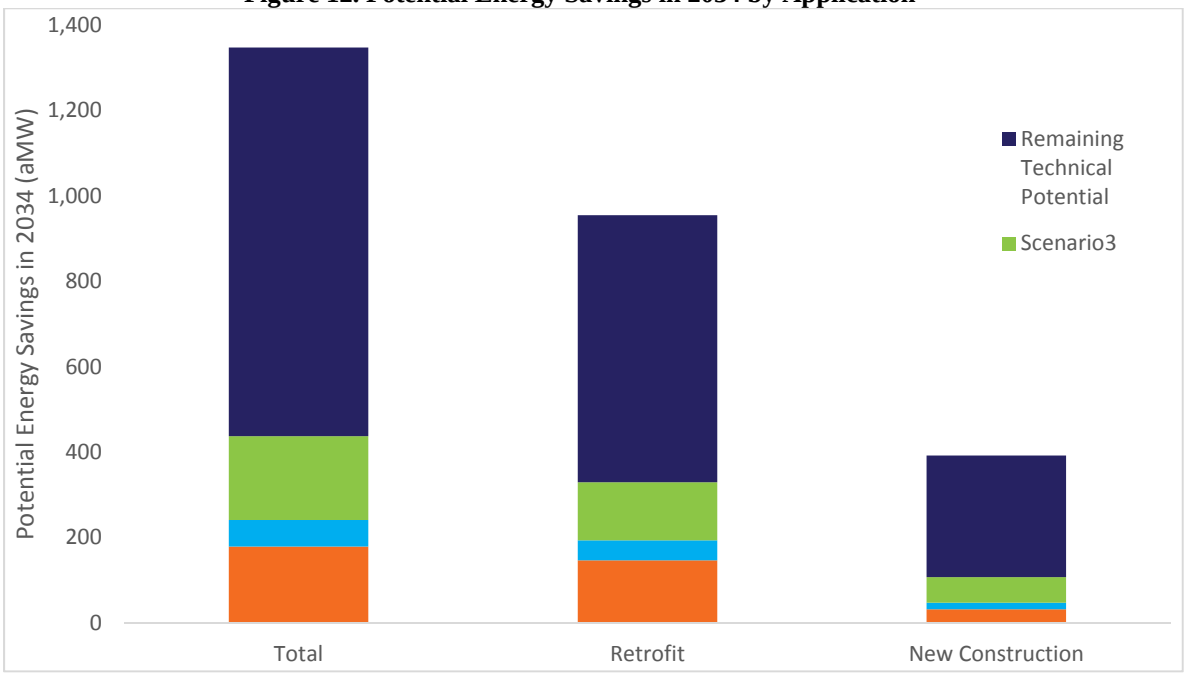
Figure 11, Figure 12, and Figure 13 show the achievable potential of each scenario and the remaining technical potential by sector, application, and technology, respectively. The savings values associated with each of these Figures are given in5Appendix E. Figure 13 does not show the remaining technical potential because it is confusing for the individual technologies. For the same reason, the scale of Figure 13 is much different from that of Figure 11 and Figure 12.

Figure 11. Potential Energy Savings in 2034 by Sector



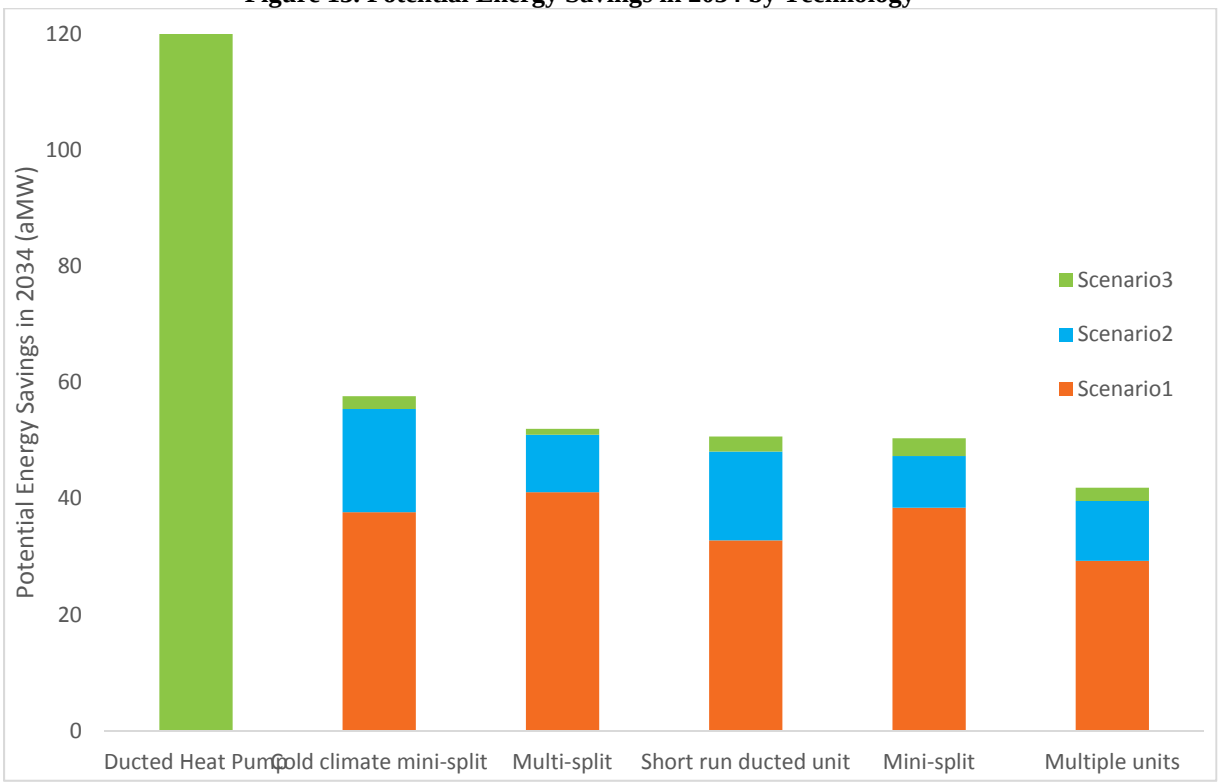
Source: Navigant Analysis

Figure 12. Potential Energy Savings in 2034 by Application



Source: Navigant Analysis

Figure 13. Potential Energy Savings in 2034 by Technology



Note: Ducted Heat Pump savings in Scenario 3 reflect the incremental increase in ducted heat pump sales due to a new initiative focused on promoting ducted heat pumps.

Source: Navigant Analysis

3.4 Equipment Costs

The Navigant team's research on equipment costs found that market actors from the NW believe that equipment costs will increase at least at the same rate as inflation because of material costs, despite their advanced development. Many international markets, which are much more mature than that of the NW, have lower installation costs due to installation volumes, familiarity of contractors, and different retail channels. Contradictory data on cost trends result in inconsistent findings on future equipment costs. Table 9 shows the equipment costs that the research team gathered during market actor interviews. These values also represented the costs that Navigant used in the potential model. Navigant used static costs over the twenty-year modeled period.[15]

Table 9. Equipment Cost Findings

Installed Cost by Technology	Average Cost	Range
Mini-split	$4,322	$3,500-$5,325
Multi-split	$6,079	$4,500-$7,000
Cold climate mini-split	$4,635	$3,200-$5,850
Short run ducted unit	$6,922	$4,000-$8,500
Multiple units (Estimate)	$8,000	N/A

Source: Navigant and RIA Analysis

Based on market actor interviews and secondary research, a key factor that could contribute to a lower cost for future equipment is increased competition in the marketplace. Particularly, when inverter-driven heat pumps have broader retail channels and higher installation volumes that enable more efficient installations and increase contractor familiarity, equipment costs may fall. This particular market dynamic has led to reduced costs in other markets as they expand, which Navigant has documented in their related research of the international DHP market. It is not clear whether the same price reduction will occur in the U.S. market.

4 Recommendations

The following subsections contain Navigant's key recommendations, which address the aforementioned findings.

4.1 Sponsor the New Manufactured Housing Market

In the latest Market Progress Evaluation Report (MPER) for NEEA's ductless heat pump initiative, Evergreen Economics found that the manufactured homes market has high, untapped potential, and the initial experience of market actors working with the Initiative has been very positive (Evergreen Economics 2014). Navigant recommends re-engaging with the manufactured home suppliers to address the gap in the market. Additionally, Navigant suggests offering an upstream incentive to housing manufacturers as part of the existing initiative.

[15] A static cost assumption is equivalent to a decline in real costs at the rate of inflation (2%/year).

4.1.1 Potential Savings

New homebuilders rarely use ductless heat pumps in the new construction market segment, particularly the new manufactured homes market. Manufactured homes comprise 22% of the Northwest's new construction market electric load and 14% of the existing homes in the Northwest.[16] Almost all new manufactured homes are shipped with electric forced air furnaces. Currently, manufactured housing retailers offer air source heat pumps as upgrades. In theory, the price of these systems could be lowered and saturation increased by installing the indoor units upstream at the manufacturer. **The new construction market in the Northwest has not been penetrated by DHPs and is unlikely to be receptive to DHPs without further market intervention.**

Navigant's model projects the total electric load in the new manufactured home market segment to be 141 aMW in 2034. The total technical potential load that could be displaced by DHPs and other inverter-driven technologies is 86 aMW. In the most optimistic scenario (the High Penetration Scenario), Navigant's model projects that DHPs and other inverter-driven technologies could displace 28 aMW of electric resistance load. This represents a 14-aMW increase from the load displaced in the Low Penetration Scenario, which represents the business as usual case.

Additional savings could be available in the new single-family homes market at large with standard (non-inverter-driven) ducted air source heat pumps. NEEA should encourage standard air source heat pumps as another efficient way to displace electric resistance heat in the new construction market.

4.1.2 Barriers to Adoption

The barriers to adoption for the new single family and manufactured housing markets are:

- Single-family homebuilders and new construction trade allies believe that DHP costs are too high to justify their use.
- New manufactured home market actors are unfamiliar with the DHP technology and its benefits.

4.2 Incentivize More Technologies for the Single Family Existing Homes Market

Navigant recommends expanding the current initiative to other technologies such as multi-split units, cold climate units, short-run ducted systems, and central inverter-driven systems to achieve a greater portion of the single-family existing homes market. As shown in Figure 10, the highest potential comes from mini-split DHPs, then multi-split DHPs, then short-run ducted systems, then cold climate heat pumps, then multiple units.

[16] The Navigant team derived these values from the raw RBSA data files.

4.2.1 Potential Savings

The current DHP initiative focuses primarily on the retrofit of heating within single-family existing residences, making this the most penetrated market segment currently. The current initiative has been partially responsible for approximately 35,000 total installations between 2008 and 2014. Navigant has found that the current initiative has been successful in encouraging the installation of DHP systems in a 1:1 configuration within single-family residences. **The single-family market still has large potential in residences where technologies beyond the 1:1 installation configuration are more appropriate. These technologies include multi-split, cold climate, short-run ducted, or ducted inverter-driven heat pumps.**

Navigant's model projects the total electric load in the single-family home market segment to be 1,478 aMW in 2034. The total technical potential load that could be displaced by DHPs and other inverter-driven technologies is 881 aMW. In the most rigorous scenario (the High Penetration Scenario), Navigant's model projects that DHPs and other inverter-driven technologies could displace 230 aMW of electric resistance load. This represents a 153-aMW increase from the load displaced in the Low Penetration Scenario, which represents the business as usual case.

4.2.2 Barriers to Adoption

The barriers to adoption of new technologies in the existing single-family housing market are primarily related to a lack of homeowner and contractor awareness, and the high cost of DHPs.

4.3 Consider Targeted Marketing toward the Multifamily Rental Market

Navigant believes that targeting this sector should continue to be a low priority for NEEA given the lower potential savings available in this sector versus other sectors. However, if NEEA wishes to pursue the multifamily rental market with other initiatives and would like to include heat pumps in that initiative, Navigant recommends marketing the cooling and comfort amenity of DHPS to rental property owners. The marketing should focus on the increase to the overall value of their rental property, which in turn allows them to charge higher rent for their property. Additionally, NEEA could consider changing the financing for rental property owners to allow for on-bill financing or a leasing program[17].

4.3.1 Potential Savings

Because of the high upfront costs and older building stock, rental property owners are not installing DHPs for their rental properties, even when other limitations are not present. Additionally, since investment property owners typically do not pay the electric bill for their tenants, the potential monthly cost savings do not persuade them to install DHPs. **Therefore,**

[17] Green Mountain Power in Vermont currently runs a cold climate DHP leasing program where residential occupants can rent a unit for forty dollars per month. More details for this program are available at http://www.greenmountainpower.com/products-services/overview/heat-pump-services/.

investment property owners in the Northwest multifamily market segment have not adopted DHPs and are unlikely to do so without further market intervention. However, this market segment does not contribute significantly to total electric resistance heating load.

Navigant's model projects the total electric load in the multifamily rental market segment to be 227 aMW in 2034. The total technical potential load that could be displaced by DHPs and other inverter-driven technologies is 135 aMW. In the most rigorous scenario (the High Penetration Scenario), Navigant's model projects that DHPs and other inverter-driven technologies could displace 0.1 aMW of electric resistance load. This represents a 0.1-aMW increase from the load displaced in the Low Penetration Scenario, which represents the business as usual case.

4.3.2 Barriers to Market

The primary market barrier in this market segment is that the property owner specifies the equipment, but the tenant pays the monthly energy bill, which dictates that the person paying the premium for high efficiency equipment will likely not see the monthly energy savings. This problem is particularly exacerbated by equipment with high upfront cost, such as DHPs and other inverter-driven heat pump technologies.

4.4 Focus Marketing Efforts on Awareness and Benefits of Short-run Ducted Systems

Navigant recommends that NEEA increase marketing efforts on awareness and benefits of short-run ducted systems in the near term to alleviate homeowners' aesthetic concerns about the traditional DHP technology and to emphasize to homeowners that this technology allows for more configurations accommodating multiple rooms. This targeted marketing of ductless heat pumps should emphasize that there is a ductless heat pump solution for all applications.

4.4.1 Potential Savings

Short-run ducted systems combine the efficiency of DHPs with the convenience of a hidden system that conditions most or all rooms. Market actors said ductless system appearance was an issue for 12% of customers. **Short-run ducted systems can address demand for whole house comfort conditioning, which is not possible with typical mini-split (1:1) DHP configurations, or even most multi-split configurations.**

The total technical potential load that could be displaced by short-run ducted heat pump technology is 1,233 aMW. This assumes that all situations where a short-run ducted heat pump is possible to be installed has received it. In the most rigorous scenario (the High Penetration Scenario), Navigant's model projects that DHPs and other inverter-driven technologies could displace 51 aMW of electric resistance load. This represents a 23-aMW increase from the load displaced in the Low Penetration Scenario, which represents the business as usual case.

4.4.2 Barriers to Market

The short-run ducted heat pump technology, while promising for certain market segments, is less mature than others are which drives a disruptive installation and consequentially a high product cost and consumer resistance, creating a market barrier. Additionally, this product is particularly dependent on a contractors' awareness of the benefits because there is a distinct lack of homeowner awareness for this product.

4.5 Promote Cold Climate Heat Pump Technology as Best Solution for All Participants

To displace the most electric resistance heat possible, NEEA should consider promoting cold climate heat pump technology for all participants.

4.5.1 Potential Savings

Cold climate heat pumps are aesthetically identical to their standard counterparts but allow for more efficient operation and higher capacity at low temperatures. However, contractors are currently not differentiating cold climate heat pumps in their sales because the population centers within the NW are not in the coldest areas, so they perceive little added value to installing cold climate heat pumps. The only incremental barriers to cold climate heat pumps are a moderately higher price relative to their standard counterparts. **Cold climate heat pumps are not currently achieving market traction in the NW, but are worth pursuing for their long-term benefits of potential demand reduction. Cold climate units can meet a greater load on very cold days, alleviating the need for more supplemental heat**.

The total technical potential load that could be displaced by cold climate ductless heat pump technology is 1,118 aMW. This assumes that all situations where a cold climate ductless heat pump is possible to be installed has received it. In the most optimistic scenario (the High Penetration Scenario), Navigant's model projects that DHPs and other inverter-driven technologies could displace 54 aMW of electric resistance load. This represents a 29-aMW increase from the load displaced in the Low Penetration Scenario, which represents the business as usual case.

4.5.2 Barriers to Market

Installers do not value – or they do not believe that most customers will value – the benefit of cold climate heat pumps relative to standard heat pumps. Additionally, some contractors do not trust the performance metrics of a cold climate heat pump, leading to skepticism of their benefits.

4.5.3 Broader Market Implications

Winter peaks will likely become a greater concern for more utilities in the region as winter capacity constraints increase over the next 20 years (PNUCC 2014). NEEA should consider promoting cold climate heat pumps to address this need, as well as for their overall energy savings.

4.6 Add Central Inverter-driven Heat Pumps to Current Initiative

NEEA should consider adding central inverter-driven heat pumps to the current DHP initiative to achieve higher penetration in the part of the market where central heating and cooling is most applicable, such as homes already equipped with ducts. NEEA should also consider using their existing influence within the building codes context to restrict installation of electric forced air furnaces in new homes.

4.6.1 Potential Savings

Market actors agree that a homeowner with a ducted HVAC system is unlikely to replace it with a ductless system, even in the absence of other market barriers. Therefore, ducted homes with electric resistance heat are a key target market segment for inverter-driven ducted heat pumps. **DHPs are not a likely solution to replace electric forced air furnaces in ducted homes because contractors and homeowners will seek ducted options first due to their ease of installation, low cost, familiarity, and convenience of central comfort conditioning.**

The total technical potential load that could be displaced by central inverter-driven heat pump technology is 399 aMW. This assumes that all situations where a central inverter-driven heat pump is possible to be installed has received it. In the most optimistic scenario (the High Penetration Scenario), Navigant's model projects that central inverter-driven heat pumps could displace 110 aMW of electric resistance load. This represents a 110-aMW increase from the load displaced in the Low Penetration Scenario, which represents the business as usual case.

4.6.2 Barriers to Market

The primary barrier to installation of a central, ducted inverter-driven heat pump is that the standard (non-inverter-driven) version will be much less expensive for the near future and homeowners will perceive little added benefit of the inverter-driven version.

4.6.3 Broader Market Implications

Standard (non-inverter-driven) ducted air source heat pumps also have a large market opportunity in the segment of homes with existing ducts. Any new air source heat pump will still be far more efficient than electric resistance heat.

5 References

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NWPCC. 2009. *Draft Conservation Supply Curve Files: New and Existing Single Family & Manufactured Home HVAC Conversions and Upgrades to High Efficiency Heat Pumps.*

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Appendix A Market Actor Interview Guide for Distributors, Manufacturers, and Experts

Introduction

Hello, my name is _____ and I'm calling on behalf of the Northwest Energy Efficiency Alliance (NEEA). They provided me with your name. [IF NEEDED: NEEA is a non-profit organization that facilitates acceleration of energy-efficient products in the Pacific Northwest in partnership with utilities, Bonneville Power Administration, and Energy Trust of Oregon.]
NEEA is reviewing its promotion of ductless heat pumps (or DHPs) in the region, and your expert knowledge will help to inform the DHPs energy saving potential and the roles of NEEA and utilities in achieving this. We would like your help to better understand the electric resistance heating replacement market for DHPs and related technologies in the Northwest, including Washington, Oregon, Idaho and most of Montana.
[IF MANUFACTURER OR DISTRIBUTOR]
Are you the best person at your firm to discuss sales of heat pumps, as well as your market activities in this region?
→ IF NO: Can you transfer me to that person or give me a name and number I can call?
COLLECT CONTACT INFO: _____, email as well if possible
[IF ASKED] I'm calling from an independent research firm in Portland Oregon called Research into Action contracted to conduct this study for NEEA.
[READ] NEEA will publish what we learn from market experts like you in a form that will not identify individual contributors.
[ONCE CONNECTED TO BEST CONTACT:]
To get even a general understanding of the heat pump market, we are likely to need about 45 minutes of your time.

Screening [ASK ALL]

S1. Do you have time to answer some questions now? [*If needed*: This is not a sales call and your answers will be completely confidential.]

1. Yes [SKIP to Q1]
2. No

[IF S1 = NO]
S2. No problem, is there a better time to contact you?

1. Yes (Record contact date/time:) _____Try to get an email so you can schedule on calendars - Thank and terminate
2. No

INTRODUCTION [ALL]

Q1. First tell me a little about yourself and your firm? What is your title and role?

Q2. How long have you been working with DHP technologies?

1. Less than one year
2. 1 – 2 years
3. 3 – 5 years
4. 6 – 9 years
5. 10+ years

[IF MANUFACTURER OR DISTRIBUTOR]

Q3. What areas of the US do you serve?

1. Entire US [SKIP TO NEXT QUESTION]
2. Northwest [Yes/No] [IF YES] Washington, Oregon, Idaho, and Montana?
3. Northeast [Yes/No]
4. Southwest [Yes/No]
5. Southeast [Yes/No]

Throughout the remainder of this interview, if you don't have experience with or opinions on something I asked about, feel free to decline to answer.

Awareness, Current and Future Penetration [DISTRIBUTORS]

By talking with you and other distributors, we'd like to estimate general market awareness. Let's start with some background on the supply chain.

Q4. Do all of your customers (dealers/installers) deal with residential HVAC equipment? About how many is that in NW? [GET A NUMBER, IF POSSIBLE]

Q5. About what percentage of these HVAC dealers are aware of DHPs?

Q6. And what percentage are installing DHPs now? [INTERVIEWER: This should be of all customers]

Q7. In the Northwest, have adoption rates tended to vary depending on …

1. …the dealer's location in the Northwest? [IF YES, DESCRIBE]
2. …the availability of natural gas in their area? [IF YES, DESCRIBE]
3. Does adoption vary for larger versus smaller dealers? [IF YES, DESCRIBE]

Q8. Who's not installing DHPs?

1. Why is that?
2. What reservations do installers still have with DHP technology?
3. What percentage of your dealers would you estimate lack trust in DHP technology? %%
4. What other issues do dealers/installer have with DHP systems?
5. Are there any other challenges you have promoting DHP? Dealer concerns about customer aesthetics or preferences?

Q9. What percentage of your HVAC dealers do you expect will be installing DHPs within 5 years?

Q10. What key features of DHPs do you emphasize?

Q11. About what percentage of your dealers lack the proper training to install, commission, and size DHP systems? %%

1. Please describe the training that installers need to install, commission, and size DHPs?

DHP: Appropriate Market Shares [ASK ALL]

I'd like your views on the suitability of five DHP technologies for the current residential electric resistance heat replacement market in the Northwest.

[ASK ALL]

Q12. The five I'm interested in are [READ LIST, BUT SKIP LAST ITEM]. [A.] Starting with [READ FIRST ONE], in what percentage of residences with electric resistance heating in Northwest is this technology <u>likely to be suitable</u>?

1. [B.] And among those, what percentage do you think this technology <u>might actually appeal to</u>?
2. [C.] What positive features of this DHP option are likely to drive its adoption?

	Residential Market in NW		
	A. % of residences suitable for this option	B. Where suitable, what % might appeal to	C. Positive features driving the adoption of this technology?
Cold climate DHP systems capable of maintaining high heating capacity down to 5 degrees F and colder. [Any combination of outdoor compressors and indoor units]			
Moderate climate DHP systems			
Short-run <u>ducted</u> DHPs			
Packaged terminal heat pump (PTHP)			
Replacement of central electric furnace with central heat pump			
And finally, what proportion of			

Northwest residences with resistance heating aren't suited to any of these technologies			

Q13. In general, over the next 5 years, how do you expect the residential market for DHP technologies to change, if at all?

1. [IF PERCENTAGE NOT STATED] And in percentage terms, how much do you expect this market to grow over the next 5 years.

Q14. [IF MANUFACTURER OR DISTRIBUTOR] Out of your total HVAC sales, about what proportion comes from DHP?

Q15. [ALL] Please estimate how much you expect the overall DHP market in the Northwest to grow over the next 10 years?

Q16. Now I'd like to drill down a bit for DHP systems for three indoor/outdoor configurations, namely ductless 1-to-1 mini-split systems, ductless multi-split with1 outdoor and 2-4 indoor units, and multiple outdoor systems. Starting with the mini-split :

1. About what proportion of the NW's residential electric resistance heating replacement market is this technology suitable for?

2. And what percent of this market do you think this technology would appeal to? [ITERATE for EACH OPTION BELOW]

	Residential Market: % suitable for this application	% that this technology might appeal
ductless mini-split (or 1-1 systems)		
ductless multi-split (1 outdoor and 2-4 indoor units)		
Multiple ductless outdoor systems		

Q17. Over the next 5-10 years, do you expect the appeal of these three DHP systems to shift substantially?

1. Yes
2. No
3. Don't Know

Q18. [IF YES/PROBABLY]: In which of these configurations do you expect customer appeal to increase? [SELECT UP TO TWO OPTIONS]

1. 1-to-1 mini-splits
2. 1-to-many splits
3. Multiple outdoor systems

[ASK IF MANUFACTURER OR DISTRIBUTOR, ELSE SKIP TO Q22]

Q19. Please tell me if you are currently marketing any of the following DHP technologies in the Northwest starting with…. [ASK "B" AND "C" WHERE APPLICABLE]

	A. Yes/No	**B. [IFA=YES] Does this include various combinations of outdoor and indoor units? [Yes/No]**	**C. [IF A=NO] When do you expect to market this in the NW? [YEAR]**
Cold climate DHP systems			
Moderate climate DHP systems			
Short-run ducted DHPs		N/A	
Packaged terminal heat pump (PTHP)		N/A	
Replacement of central electric furnace with central heat pump		N/A	

Q20. How, if at all, has the option of ceiling cassettes broadened the adoption of DHP systems?

Current Costs and Projected Costs

[ASK IF MANUFACTURERS OR DISTRIBUTORS, ELSE SKIP TO Q22]

Now I'd like to ask you to estimate the cost of different DHP systems.

Q21. What is the most common efficiency level -- SEER and HSPF - of DHPs being sold in the Northwest? ##

1. How will this typical efficiency level differ in colder areas, such as in Idaho and western Montana? [SEER Average:] ##

2. What is the typical HSPF for a SEER 16 1.5 ton mini-split DHP?

Q22. Now, what is the average selling price of a...

	Average cost
A SEER 16, 1.5 ton mini-split DHP (1 outdoor - 1 indoor unit) in NW – a typical high efficiency unit?	
A SEER 16 1.5 ton multi-split DHP with <u>two indoor</u> heads	
A cold climate mini-split DHP systems with the same sized SEER 16 1.5 ton unit?	
And how much would it cost to install a short-run ducted DHP system with the same sized SEER 16 1.5 ton mini-split unit?	
And how much would it cost to install the same sized packaged terminal heat pump (PTHP) unit?	
Last, how much would it cost to replace a central electric furnace with central heat pump?	

Q23. How might these costs change over the next five years? [% increase or decrease: _____]

Consumer Acceptance [ASK ALL]

Q24. What types of people have been open to installing ductless heat pumps so far – what do the early adopters in the Northwest look like?

Q25. If you were planning a marketing campaign to increase the sale of mini-split and multi-split DHPs in the Northwest how would you think about spending your marketing budget? Would you be "not at all likely," "somewhat" or "very likely" to develop target messages for …

1. Homes with electric central heating? [Not at all likely, Somewhat, Very likely]
2. Homes with electric baseboard heating? [Not at all likely, Somewhat, Very likely]
3. Homes heated by oil or propane? [Not at all likely, Somewhat, Very likely]
4. Homes heated primarily by wood? [Not at all likely, Somewhat, Very likely]
5. And how likely would you be to target Single Family home owners? [Not at all likely, Somewhat, Very likely] → **[IF SOMEWHAT OR VERY LIKELY, ASK OPEN ENDED:]** (A.)What specific home styles would you target: [Single or Multi-story or Both?] (B.) What size or range of sizes would you market DHP to? (C.) What about number of rooms – what is the target market here? (D.) And would applicability across construction types, say wood vs masonry, be mentioned in your campaign? [Y/N]
6. And now, how likely would it be that you'd include the multifamily market in this campaign? [Not at all likely, Somewhat, Very likely]

7. What about the manufactured home sector? [Not at all likely, Somewhat, Very likely]
8. Would you develop messages for residences in specific climate zones - moderate and cold? [Not at all likely, Somewhat, Very likely]
9. Any comments you would like to add on what you view are good target markets?

Barriers [ASK ALL]

Q26. According to a recent study, one million residences in the Northwest use some electric resistance zonal or forced air heating, yet few have adopted DHP systems to date. Using a scale of 0 to 10 where '0' means "not at all" and '10' means a " extremely limiting," please rate the extent to which you think the following factors are limiting the adoption of mini-split and multi-split DHP in the NW's residential electric resistance heating replacement market:

1. Applicability because of home design
2. Product availability → [IF Rating >=4:] Q24a. Is this an issue in all or just certain areas in the NW? [IF SOME] Which areas?
3. Retailer adoption → [IF Rating >=4:] Q24b. Is this a factor in all or just certain areas in the NW? [IF SOME] Which areas?
4. Installer training
5. Public awareness
6. Aesthetics of the wall mounted indoor unit – "head"
7. Aesthetics of ceiling cassettes?
8. Profitability for supply chain actors (distributors, retailers, installers)
9. Cost of DHP to homeowners

Q27. What, if anything else, had limited the adoption of DHP in the Northwest?

Q28. How, if at all, do the critical factors you mentioned differ for single-family, manufactured or multifamily sectors?

Technology Market Readiness [MARKET EXPERTS & MANUFACTURERS ONLY]

Q29. Thinking of market readiness of *current* DHP technologies, are the available technologies able to address all of the weather and home-style needs we find in the Northwest? [TECHNOLOGY APPLICABILITY ISSUES]

1. Are the DHP technologies we've talked about today working equally well to meet the needs of certain markets, such as single-family, manufactured home, and multifamily residences? YES/NO. →[IF NO] Where are they not working well?
2. Where in the supply chain (from other manufacturers, distributors, and installers) are the bottlenecks that are limiting broader adoption of DHP technology?
3. Are customers across single-family, manufactured homes, and multi-family sectors equally aware of DHP technology? Where is the biggest potential for marketing to encourage adoption?

4. Are optional configurations, including ceiling cassettes or short-run ducted systems adequately addressing consumer issues – aesthetics and other preferences? Why or why not? [CONSUMER PREFERENCE ISSUES]

Q30. Do you have any opinions about what manufacturers, utilities and NEEA, and other stakeholders should do to enhance market adoption of DHPs?

Q31. What <u>new</u> DHP technologies can we expect to see entering the resistance heat replacement market place within the next year or two?

1. What types of homes in this market are these technologies being designed for?
2. What if any of the new technologies are being designed to serve a specific market segment – such as single-family, manufactured or multi-family residences?
3. Are these innovations likely to "compete with" the standard 1-to-1 DHP application? [Yes/No]
4. [IF YES] Over the next 5 years, by what percentage might we expect the number of 1-to-1 projects to decline as these new DHP technologies enter the market?

Additional Contacts [MARKET EXPERT,MANUFACTURERS AND/OR DISTRIBUTORS – SEE SKIPS:]

[ASK IF MARKET EXPERT]

Q32. We'd like to talk with other several manufacturers that market DHPs in the Northwest. Who would you suggest we call? [PROGRAMMER: PIPE IN OUR MANUFACTURER LIST SO INTERVIEWER CAN CONCENTRATE ON *NEW* CONTACT INFO]

BUSINESS:
CONTACT NAME:
PHONE:
EMAIL:

[ASK IF MARKET EXPERT]

Q33. And lastly, NEEA has engaged us to develop a Potential Study for DHP diffusion over the next 20 years in the Northwest. Would you be willing to be considered, along with other experts, as part of Delphi panel discussions we plan to hold over teleconference in early December. [Yes / No / Maybe]

[IF MARKET EXPERT, SKIP TO Q34]

[ASK IF MANUFACTURER]

Q34. We'd like to talk with several distributors marketing DHPs in the Northwest. Who would you suggest we call? [PROGRAMMER: PIPE IN OUR MANUFACTURER LIST SO INTERVIEWER CAN CONCENTRATE ON *NEW* CONTACT INFO]

BUSINESS:
CONTACT NAME:
PHONE:
EMAIL

[IF MANUFACTURER, SKIP TO Q34]

[ASK IF DISTRIBUTOR]

Q35. We'd like to talk with installers in the NW that are active in DHP installations. Who would you suggest we call?

BUSINESS:
CONTACT NAME:
PHONE:
EMAIL

Q36. That is all the questions I have. Is there anything else you'd like to add before we close?

_____

THANKS AGAIN – WE APPRECAITE YOUR HELP. [TERMINATE]

End of Survey

Appendix B Market Actor Interview Guide for Installation Contractors

Introduction

Hello, my name is _____ and I'm calling on behalf of the Northwest Energy Efficiency Alliance (NEEA). [IF NEEDED: NEEA is a non-profit organization that facilitates acceleration of energy-efficient products in the Pacific Northwest in partnership with utilities, Bonneville Power Administration, and Energy Trust of Oregon.]
Could I speak with the owner or the sales manager at your company to discuss sales of heat pumps, as well as your market activities?
COLLECT CONTACT INFO: _____, email as well if possible
[ONCE BEST PERSON REACHED] repeat introduction.
NEEA promotes ductless heat pumps (or DHPs) in the region, and your expert knowledge will help to us to estimate the DHPs energy saving potential. We would like your help to better understand customer adoption of DHPs in the electric resistance heating replacement market in the Northwest, including Washington, Oregon, Idaho and most of Montana.
We anticipate the interview will take about 30 minutes. To thank you for your time we will send you XXXXXX once we complete the interview.
[IF ASKED ABOUT WHO WE ARE] I'm calling from an independent research firm in Portland Oregon called Research into Action contracted to conduct this study for NEEA.
[READ] NEEA will publish what we learn from market experts like you in a form that will not identify individual contributors.

Screening

S3. Do you have time to answer some questions now? [*If needed*: This is not a sales call and your answers will be completely confidential.]

2. Yes [SKIP to Q1]
3. No

[IF S1 = NO]
S4. No problem, is there a better time to contact you?

4. Yes (Record contact date/time:) _____Try to get an email so you can schedule on calendars - Thank and terminate
5. No

Introduction

Q37. First please tell me your title and role at your company?

Q38. How long has your company been working with DHP technologies? [DO NOT READ, SELECT ONE]

1. Less than one year

2. 1 – 2 years
3. 3 – 5 years
4. 6 – 9 years
5. 10+ years

Q39. Which of the following States in the Northwest does your company serve? [READ, MULTIPLE RESPONSE]

1. Washington
2. Oregon
3. Idaho
4. Montana
5. None of the above - THANK and TERMINATE

Q40. During the past 12 months, what percentage of your residential DHP installations have been in… [READ, MULTIPLE RESPONSE]

1. Single-family residences [%]
2. Manufactured homes [%]
3. Multi-family buildings [%]

Throughout the remainder of this interview, if you don't have experience with or opinions on something I asked about, feel free to decline to answer. In addition, my questions all address your residential customers only.

Awareness, Current and Future Penetration

By talking with you and other DHP installers, we'd like to estimate the residential customer base for DHPs in the Northwest. Let's start with the current market for DHPs.

Q41. For about what percentage of your residential customers would DHPs provide a more energy efficient heating option than the current system?

1. Of those customers, what percentage are using electric resistance heating for their primary source of heating?
2. What types of heating systems do you recommend DHPs replace or supplement? [READ ALL, CHECK ALL THAT APPLY]:
   1. Electric baseboard
   2. Electric forced air
   3. Wood/pellet stoves
   4. Propane or other delivered fuels systems
   5. Low efficiency natural gas furnace
   6. Other: _____

Q42. What key features of DHPs do you emphasize to your customers? [CHECK ALL THAT APPLY] *[Revised from Market Actor guide to include closed ended options]*

1. Easy installation / no need for ducting
2. Lower total project cost than a ducted system
3. Energy efficiency
4. Savings on energy bill
5. Clean / green / environment friendly
6. Non-energy benefits (Increased comfort, reduced noise, dehumidification)
7. Cooling wanted; heating and AC in one system
8. Incentives offered
9. Other: _____

Q43. In the past two years, have utility incentives played a "major" "minor," or "no" role in helping you to close the sale of DHP systems?

1. Major
2. Minor
3. No role at all
4. Don't know

Q44. Would you say your customers are primarily looking to DHPs for … [READ ALL, SELECT ONE]

1. Heating
2. Air conditioning
3. or both equally
4. [PROGRAMMER: ADD OPEN ENDED OPTION FOR CLARIFICATION]

Q45. In what percentage of your DHP projects might DHPs add cooling load in the summer?

Q46. Before you explain DHP to potential customers, about what percentage are ALREADY aware of this technology for…

[INTERVIEWER: Should be percent of all potential DHP customers.]

1. heating? [METRIC]
2. cooling? [METRIC]

Now let's turn to your DHP projects…

Q47. Let's talk about the last two years, what trend are you seeing – are DHP installations increasing, decreasing, or staying about the same year over year?

Q48. Thinking of your customers that didn't have natural gas, about what percentage installed a DHP system during the past two years?

Q49. Thinking of projects where your company <u>has recommended</u> a DHP, about what percentage of those projects has the DHP option fallen through <u>primarily because of cost</u>? [METRIC]

Q50. What reservations do you have about the DHP technology, if any? [CHECK ALL THAT APPLY]

1. Concern with reliability
2. Savings claims
3. Applicability to home configuration
4. Maintenance – tuning issues
5. Customer call backs
6. Other [SPECIFY]:
7. No reservations

Q51. Did you or other installers at your company take training on selling, installing, commissioning, and sizing DHP systems?

1. What training would help you sell, install, commission, and size DHPs?

DHP: Appropriate Market Shares

Now I'd like to ask you about the suitability of five DHP technologies for the current residential electric resistance heat replacement market.

[ASK ALL]

Q52. The five I'm interested in are [READ LIST, BUT SKIP LAST ITEM].

1. [A.] Starting with [READ FIRST ONE], in what percentage of your residential customers with electric resistance heating is this technology likely to be suitable?
2. [B.] And among those, what percentage do you think this technology might actually appeal to?
3. [C.] And what features of this DHP option are likely to drive its adoption?

	Residential Market		
	D. % of residences suitable for this option.	E. Where suitable, what % might appeal to?	F. Positive features driving adoption of this technology?
Cold climate DHP systems capable of maintaining high heating capacity down to 5 degrees F and colder. [Any combination of outdoor			

compressors and indoor units]			
Moderate climate DHP systems			
Short-run ducted DHPs			
Packaged terminal heat pump (PTHP)			
Replacement of central electric furnace with central heat pump			
And finally, what proportion of residential customers with resistance heating aren't suited to any of these technologies			

Q53. Thinking about the past 12 months, how many residential HVAC projects has your company completed?

1. And of those projects, what percentage were DHPs?

2. During the past 12 months, out of your total residential HVAC sales, about what percentage comes from DHPs?

Q54. In five years' time, what percentage of your total HVAC sales do you expect to come from DHPs?

1. And how about in 10 years? [PERCENTAGE INCREASE: _____]

Q55. Now I'd like to drill down a bit for DHP systems for three indoor/outdoor configurations, namely ductless 1-to-1 mini-split systems, a ductless multi-split with 1 outdoor and 2-4 indoor units, and multiple outdoor systems. Starting with the mini-split:

1. About what percentage of your electric resistance heating residential customers is this technology suitable for?

2. And to about what percent of these customers do you think this technology would appeal to? [ITERATE for EACH OPTION BELOW]

-

	% of customers suitable for this application	% that this technology might appeal
ductless mini-split (or 1-1		

systems)		
ductless multi-split (1 outdoor and 2-4 indoor units)		
Multiple ductless outdoor systems		

And in terms of energy use….

Q56. When you install a mini-split DHP in a residence to replace an electric resistance heating system, what proportion of the heating load are you typically designing to meet?

1. And when you install multi-split DHP to replace an electric resistance heating system, what proportion of the heating load are you typically designing to meet?

Q57. Over the next 5-10 years, do you expect the appeal of these three DHP systems to shift substantially?

1. Yes
2. No
3. Don't Know

Q58. [F PREVIOUS Q = YES/PROBABLY]: In which of these configurations do you expect customer appeal to increase? [1-to-1, 1-to-many, multiple outdoor systems]

Q59. Please tell me if you are currently marketing any of the following DHP technologies in the residential market starting with…. [ASK "B" AND "C" WHERE APPLICABLE]

	D. Yes/No	**E. [IFA=YES] Does this include various combinations of outdoor and indoor units? [Yes/No]**	**F. [IF A=NO] When do you expect to market this? [YEAR]**
Cold climate DHP systems			
Moderate climate DHP systems			
Short-run ducted DHPs		N/A	
Packaged		N/A	

terminal heat pump (PTHP)			
Replacement of central electric furnace with central heat pump		N/A	

Q60. What is the most common efficiency level – SEER and HSPF – of DHPs system you are selling?

1. Thinking of the coldest areas you serve, how does this typical SEER level differ? [SEER Average:]

2. What is the typical HSPF for a SEER 16 1.5 ton mini-split DHP?

Consumer Acceptance

Q61. What types of people have been open to installing ductless heat pumps so far?

Q62. If you were planning a marketing campaign to increase the sale of mini-split and multi-split DHPs in your service area how would you think about spending your marketing budget? Would you be "not at all likely," "somewhat" or "very likely" to develop target messages for …

1. Homes with electric central heating? [Not at all likely, Somewhat, Very likely]
2. Homes with electric baseboard heating? [Not at all likely, Somewhat, Very likely]
3. Homes heated by oil or propane? [Not at all likely, Somewhat, Very likely]
4. Homes heated primarily by wood? [Not at all likely, Somewhat, Very likely]
5. And how likely would you be to target Single Family home owners? [Not at all likely, Somewhat, Very likely] → **[IF SOMEWHAT OR VERY LIKELY, ASK OPEN ENDED:]** (A.)What specific home styles would you target: [Single or Multi-story or Both?] (B.) What size or range of sizes would you market DHP to? (C.) What about number of rooms – what is the target market here?
6. [SKIP IF NO TO MULTIFAMILY] And now, how likely would it be that you'd include multifamily market in this campaign? [Not at all likely, Somewhat, Very likely]
7. [SKIP IF NO TO MANUFACTURED HOMES] What about the manufactured home sector? [Not at all likely, Somewhat, Very likely]
8. Would you develop messages for residences in specific climate zones - moderate and cold? [Not at all likely, Somewhat, Very likely]
9. Any comments you would like to add on what you view are good target markets?

Barriers

We are getting close to the end now…

Q63. According to a recent study, one million residences in the Northwest use some electric resistance zonal or forced air heating, yet few have adopted DHP systems to date. Using a scale of 0 to 10 where '0' means "not at all" and '10' means a " extremely limiting," please rate the extent to which you think the following factors are limiting the adoption of mini-split and multi-split DHP in the residential electric resistance heating replacement market:

1. Applicability because of home design
2. Product availability
3. Retailer adoption
4. Installer training
5. Public awareness
6. Aesthetics of the wall mounted indoor unit – "head"
7. Aesthetics of ceiling cassettes?
8. Profitability for supply chain actors (distributors, retailers, installers)
9. Cost of DHP to homeowners

Q64. What, if anything else, is holding back customer acceptance of DHP?

1. Nothing to add
2. Open-ended response: ____

Q65. [SKIP IF NO TO BOTH MULTIFAMILY AND MANUFACTURED] How do the critical factors you mentioned differ for single-family, manufactured or multifamily sectors?

Current Costs

Now I'd like to ask you to estimate installed costs of different DHP systems.

Q66. What is the average project cost for customers installing a…

	Average cost to customer
A SEER 16, 1.5 ton mini-split DHP (1 outdoor - 1 indoor unit) – a typical high efficiency unit?	
A cold climate mini-split DHP systems with the same sized SEER 16 1.5 ton unit?	
And how much would it cost to install a short-run ducted DHP system with the same sized SEER 16 1.5 ton mini-split unit?	
And how much would it cost to install the same sized inverter-driven packaged terminal heat pump (PTHP) unit?	
Last, how much would it cost to replace a central electric furnace with central heat pump?	

Q67. What is the average installed cost of a SEER 16 1.5 ton multi-split DHP with two indoor heads? [PROGARAMMER ADD TEXT BOX FOR A "IT DEPENDS ON…" RESPONSE

Q68. Do you have any opinions about what manufacturers, utilities and NEEA, and other stakeholders should do to enhance customer adoption of DHPs?

Q69. Who is your primary DHP distributors?

Company and contact name and phone number:

Q70. Finally, what is the address you would like us to send XXXXXXX for participating in this research?

Name:
Street address:
City:
State:
Zip code:

THANKS AGAIN – WE APPRECIATE YOUR HELP. [TERMINATE]

End of Survey

Appendix C Delphi Panel Discussion Guide

Welcome and Introductions (5 minutes)

- Hi everyone! I want to thank you for participating today. First, please note that all panelists' lines are muted now but it will be soon unmuted. We'd like to assure anonymity of your participation, and we'd like to ask you to refrain from mentioning your name or your organization to the extent possible during this session. If any questions we ask that may touch proprietary issues, please just say you can't speak about it.
- My name is XXXXXXXX and I work for Research Into Action in Portland Oregon. I'm facilitating today's session. I also have XXXXXXXX in the room to assist, she is a research director at Research Into Action.
- We have 7 panelists who are online today including some DHP market and technology experts, and representatives from manufacturers as well as whole sale distributors.
- We have a couple of housekeeping issues. First, we are recording this session. We will analyze the session for research purposes only, and you will never be personally identified in any reports or other formats. Second, our discussion will take about 90 minutes. After this session, we will mail you the honorarium by this Friday.

Now, let me briefly talk about today's format. First, this is a group conversation where I will ask you some questions and you will be the talkers. My job is to:

- Help guide the flow of the conversation to address specific issues and questions.
- Make sure everyone's comments are heard
- Make sure we cover the questions Navigant and NEEA wants answered. Sometimes this means I may have to break off the conversation and ask us to move on.
- I also want you to know that I am not an expert on DHP market nor technologies. So, while I want to hear any questions you may have, I may not be able to answer them.

Your job as a panelist is to:

- Participate and speak loudly enough for all to hear
- Take turns and don't talk over one another
- Share the floor so everyone gets a chance to talk, but we encourage you to talk with each other as part of the main conversation.
- Lastly, you all have been asked to contribute today because you each have individual experiences and opinions. Please remember there are no right or wrong answers.

Now, I'm going to unmute the line.

- Any questions before we begin?

Explanation of DHP Market Penetration Forecast Model (5 minutes)

[Slide#2] Now, I'd like to start with the DHP market penetration forecast. I'd like to thank you for the feedback you gave last week. Navigant calibrated the forecast based on your feedback.

[Slide#3] This is a revised total achievable installation of all DHP types all the way through 2019. The annual achievable potential is defined as the amount of installations that Navigant predicts will happen each year under a specific set of assumptions.
[Slide#4] This is the current estimated market share by DHP technology type. We estimate about 40% is a moderate climate mini-split, a quarter is multi-split, and 14% is multiple outdoor and multiple indoor configuration type. Cold climate mini split is about 14% also. The short-run ducted systems is estimated about 8%.
[Slide#5] This is the overall achievable installations by these 5 DHP technologies through 2019. We estimated the overall installations will continue to grow but the growth will slow down after 2017 especially in mini split systems.

Discussion of Key Assumptions (40 minutes)

- **[SLIDE#7]** Now, I'd like to start by reviewing key assumptions for the DHP market penetration forecast model. What's shown now is a summary of the input assumptions that didn't change much based on your feedback or have less impact on our forecast. I'll give you about 45 seconds to review these now, and we'll talk about it. [Wait for 45 seconds] We don't want to spend too much time on these, but if anyone still think these assumptions are incorrect, we'd like to allow a brief discussion.
    a) Does anyone have strong opinions about any of these?
    b) Anyone wants to offer a different opinion?
    c) Have I heard from everyone?
    -

- **[Slide#8]** There are three assumption points that are critical to this forecast model but we still don't have confidence because of the wide range of values this group provided. Those are: This slide shows the range of values and the average value of each.
    i. The impact of duct work on customer adoption of DHPs
    ii. The current DHP installation rate and potential for new construction homes
    iii. About short-run ducted systems – one is 1) heating load displacement, and two is 2) satisfaction with its appearance
        a) **[Slide#9-11]** Starting with the first assumption: % of homes with electric heating and with functional ducts that a DHP could be a suitable technology as a replacement of current system, our revised estimate is 44%, but your responses still ranged widely.
        b) I'd like any one of you to start critiquing the average value of 44% and why you think this is the reasonable estimate, under-estimated, or over-estimated.
        c) Anyone wants to offer a different opinion?
        d) Have I heard from everyone?
        e) [REPEAT FOR OTHER 2 ASSUMPTIONS]

Discussion of Remaining Issues (25 Minutes)

[Slide#12] We have 5 remaining issues that are important to understand the context of future DHP market environment. We'd like to cover as many of these 5 topics as possible.

1. **[Slide#13] Possible change in installation cost:** Some people believe that as the market competition increases and installers gain more experiences with DHP installations, cost of installation especially labor cost will decrease. We'd like your insights on this issues, and if installation cost will decrease (or increase), to what extent it may in the next 5 years.

a) Can any one of you start discussing your thoughts?
b) Anyone wants to offer a different opinion?
c) Have I heard from everyone?

2. **[Slide#14] Other emerging technologies:** Should NEEA be concerned about non-DHP emerging technologies that may potentially compete with DHPs in the electric resistance heating replacement market?

a) Can any one of you start discussing your thoughts?
b) Anyone wants to offer a different opinion?
c) Have I heard from everyone?

3. **[Slide#15] Promotion of DHP's Cooling Feature:** In manufacturer- and distributor-led contractor trainings, is DHP's cooling feature stressed? What percent of installers are currently advertising cooling features as a selling point?

a) Can any one of you start discussing your thoughts?
b) Anyone wants to offer a different opinion?
c) Have I heard from everyone?

4. **[Slide#16] Renter Market:** Renter market, including single-family, multifamily, and manufactured homes, is a challenging segment for NEEA to penetrate due to split incentive, but potential market size is large. We'd like your insights and ideas on how NEEA can cost effectively penetrate this market. Some examples are: 100% incentive and direct install program, on-bill financing option, increase in utility incentive, joint incentive for property owners and renters, providing turn-key marketing materials for property owners to promote DHP-equipped units to renters.

[**Split incentive**: Split incentive in rental housing is where landlord does not necessarily have reasons to install something that will save their tenants money unless they can raise the rent and capture some of those savings, or their building has comfort problems that they can solve with this technology.]

a) Can any one of you start discussing your thoughts?
b) Anyone wants to offer a different opinion?
c) Have I heard from everyone?

5. **[Slide#17] DHP market among homes heated by non-electric non-gas fuels:** While our study focuses on residential customer adoption of DHP in the electric resistance heating replacement market, recent study of Residential Building Stock Assessment found 14% of the NW single-family homes are primarily heated by oil, wood, pellet, and other delivered fuels, and

40% of NW single-family homes use these non-electric non-gas fuels for their secondary heating systems. We'd like your insights on suitability and appeal of DHP technologies for these homes heated by non-electric non-gas fuels.

d) Can any one of you start discussing your thoughts?
e) Anyone wants to offer a different opinion?
f) Have I heard from everyone?

Concluding Remarks (10 minutes)

[Slide#18-19] As we finish up, I wanted to ask you a more general question. Among the many things NEEA could do to enhance the market adoption of DHPs among electric resistance heating replacement market, what is the most important factor NEEA can influence? I'd like to go around one person at a time to make sure that we hear from each of you.

Appendix D Delphi Panel Online Feedback Survey

Introduction

Thank you for your help with this important research! This survey will guide you through a series of questions relating to the inputs that helped shape Navigant's DSM model. Throughout this survey we will be referring to five specific DHP technologies. These technologies include:
Mini-split: A single outdoor unit with a single indoor head in moderate climate applications.
Multi-split: A single outdoor unit with multiple indoor heads in moderate climate applications.
Multiple units: Multiple outdoor units with multiple indoor heads in moderate climate applications.
Cold climate mini-split: A single outdoor unit specially designed for colder climates with a single indoor head.
Short run ducted unit: A single outdoor unit connecting to indoor unit(s) that service with short run ducts.
Please note for many of the following questions we provide the average percentage for various parameters used in the DSM model. These percentages were derived from in-depth interviews with DHP market actors, including market experts, manufacturers, distributors, and installers. When providing your own estimates, don't worry too much about the current predictions. Use your knowledge of the industry and market to make a best guess for the parameters.

Contact

To start, please provide your name and your company's name below.
Your name (1)
Your company's name (2)

Questions

Q71. Current Customer Awareness Corresponds to slide #15

The following question asks your opinion about the percentage of electric resistance heated homes in the Northwest (all sectors including single-family, manufactured homes, and multifamily) that are aware of various DHP technologies. Electric resistance heating includes electric baseboard, electric forced-air, Cadet heater, etc. This does not include homes heated by oil, propane, wood, or other delivered fuel.
For each technology in the table below, please:

1. Review the average percentage of residences who are aware of the technology.
2. Indicate if the percentage is under estimated, a reasonable estimate, or over estimated.
3. Provide your best estimate of the percentage of residences who are aware of the technology.
4. Provide any additional comments you have about the estimate you provided.

	.				.	.
	Under-estimated (1)	Reasonable estimate (2)	Over-estimated (3)	Don't know (4)	Your best estimate (%) (1)	Additional comments (1)
DHPs in general Average percent = 30% (1)	❍	❍	❍	❍	•	•
Mini-split DHP Average percent = 30% (2)	❍	❍	❍	❍	•	•
Multi Split DHP Average percent = 25% (3)	❍	❍	❍	❍	•	•
Multiple units Average percent = 10% (4)	❍	❍	❍	❍	•	•
Cold Climate Mini Split Average percent = 10% (5)	❍	❍	❍	❍	•	•
Short run ducted unit Average percent = 5% (6)	❍	❍	❍	❍	•	•

Q72. Heating Load Corresponds to slide #16

The following question asks your opinion about the average percentage of heating load five DHP technologies are designed to meet, assuming a typical single-story, single-family, Northwestern home that is 1,600 sq. ft. with 2 bedrooms.

For each technology in the table below, please:

1. Review the average percentage of heating load displaced.
2. Indicate if the percentage is under estimated, a reasonable estimate, or over estimated.
3. Provide your best estimate of the percentage heating load displaced by the technology.
4. Provide any additional comments you have about the estimate you provided.

	.				.	.
	Under-estimated (1)	Reasonable estimate (2)	Over-estimated (3)	Don't know (4)	Your best estimate (%) (1)	Additional comments (1)
Mini-split DHP Average percent = 50% (1)	❍	❍	❍	❍	•	•
Multi Split DHP Average percent = 68% (2)	❍	❍	❍	❍	•	•
Multiple units Average percent = 91% (3)	❍	❍	❍	❍	•	•
Cold Climate Mini Split Average percent = 55% (4)	❍	❍	❍	❍	•	•
Short run ducted unit Average percent = 68% (5)	❍	❍	❍	❍	•	•

Q73.

In the Northwest region, the Northwest Energy Efficient Alliance (NEEA) has specified 3 climate zones with climate zone 1 being the most moderate and 3 being the coldest. Climate zone 1 includes both Portland and Seattle. Climate zone 2 includes colder cities such as Twin Falls, Idaho and climate zone 3 represents the coldest areas in the region such as Great Falls, Montana. In which of these climate zones would you recommend a cold climate DHP over a moderate climate DHP? Select all that apply.

- ❑ Climate zone 1 (including Portland and Seattle) (1)
- ❑ Climate zone 2 (including Twin Falls, Idaho) (2)
- ❑ Climate zone 3 (including Great Falls, Montana) (3)
- ❑ Don't know (4)

Q3a

Please provide any additional comments you have below.

Q4 Potential Barriers
Customer Satisfaction In a recently published study, NEEA found that 12% of all residential customers in the Pacific Northwest found appearance of DHPs to be a primary concern with DHP systems. What percentage of these concerned customers do you think would be satisfied with a short-run ducted system?

Q5
In the next five years, do you expect the public's perception of DHP appearance will...

- ❍ Remain the same (3)
- ❍ Improve slightly (2)
- ❍ Improve significantly (1)
- ❍ Don't know (4)

Q5a
Please provide any additional comments you have below.

Answer If In the next five years, do you expect the public's perception of DHP appearance will... Improve significantly Is Selected Or In the next five years, do you expect the public's perception of DHP appearance will... Improve slightly Is Selected Or In the next five years, do you expect the public's perception of DHP appearance will... Remain the same Is Selected

Q5b
Please describe reasons why you think the public perceptions of DHP appearance will ${q://QID16/ChoiceGroup/SelectedChoices}.

Q6 Potential Barriers
Landlord/Renter Adoption The following question asks your opinion about the percentage of electric resistance heated renter occupied units in the Northwest (all sectors including single-family, manufactured homes, and multifamily homes) where a DHP system might be considered by either the landlord or the tenant.
For each scenario in the table below, please:

1. Review the average percentage of renter occupied units that might consider a DHP.
2. Indicate if the percentage is under estimated, a reasonable estimate, or over estimated.
3. Provide your best estimate of the percentage of rental occupied units.
4. Provide any additional comments you have about your estimate.

	.				.	.
	Under-estimated (1)	Reasonable estimate (2)	Over-estimated (3)	Don't know (4)	Your best estimate (%) (1)	Additional comments (1)
Percent of rental units currently considering DHPs Average percent = 5% (1)	❍	❍	❍	❍	•	•
Percent of units that would consider DHPs with an increase of utility finance options Average percent = 10% (2)	❍	❍	❍	❍	•	•
Percent of units that would consider DHPs with an increase in utility incentives Average percent = 20% (3)	❍	❍	❍	❍	•	•
Percent of units that would consider DHPs with a 100%	❍	❍	❍	❍	•	•

incentive and direct install program Average percent = 40% (4)						

Q7

What Ideas do you have to reach the multifamily or renter market?

Q8 Physical Limitations

The following question asks your opinion about the percentage of ducted homes in the Northwest (all sectors including single-family, manufactured homes, and multifamily homes) with electric resistance heating that any DHP technology would be a better option than replacing with a central heating system.

For the following two ducted homes types, please:

1. Review the average percentage of ducted homes where a DHP would be a better option.
2. Indicate if the percentage is under estimated, a reasonable estimate, or over estimated.
3. Provide your best estimate of the percentage of ducted homes where a DHP would be a better option.

4. Provide any additional comments you have about your estimate.

	.				.	.
	Under-estimated (1)	Reasonable estimate (2)	Over-estimated (3)	Don't know (4)	Your best estimate (%) (1)	Additional comments (1)
Homes with functional ducts Average percentage = 50% (1)	❍	❍	❍	❍	•	•
Homes with duct systems in need of repair Average percentage = 100% (2)	❍	❍	❍	❍	•	•

Q9

How would you rate the market potential for DHP technologies among ducted homes with an electric furnace in the Northwest (all sectors including single-family, manufactured homes, and multifamily homes)? Is there...

- ❍ No potential (1)
- ❍ Low potential (2)
- ❍ Medium potential (3)
- ❍ High potential (4)
- ❍ Don't know (5)

Q10
Using a scale of 1 to 5, with 1 meaning "not at all difficult" and 5 meaning "extremely difficult", please rate the level of difficulty of DHP installations due to the physical limitations of the following existing building types.

	1 - Not at all difficult (1)	2 (2)	3 (3)	4 (4)	5 - Extremely difficult (5)	Don't know (6)
Single-family (1)	❍	❍	❍	❍	❍	❍
Manufactured homes (2)	❍	❍	❍	❍	❍	❍
Multifamily homes (3)	❍	❍	❍	❍	❍	❍

Q11 New Construction
The following question asks your opinion about the percentage of new construction homes in the Northwest that have DHPs. This includes any DHP technology and could be either a primary or secondary heating system.
For each home type in the table below, please:

1. Review the average percentage of new construction homes with any DHP technologies.
2. Indicate if the percentage is under estimated, a reasonable estimate, or over estimated.
3. Provide your best estimate of the percentage of new construction homes with any DHP technologies.
4. Provide any additional comments you have about your estimate.

	.				.	.
	Under-estimated (1)	Reasonable estimate (2)	Over-estimated (3)	Don't know (4)	Your best estimate (%) (1)	Additional comments (1)
All sectors Average percentage = 8% (1)	❍	❍	❍	❍	•	•
Single-family Average percentage = 8% (2)	❍	❍	❍	❍	•	•

Manufactured homes Average percentage = 8% (3)	❍	❍	❍	❍	•	•
Multifamily Average percentage = 8% (4)	❍	❍	❍	❍	•	•

Q12

That was the last question. Before submitting your responses, please leave any additional information or comments you may want to share with other Delphi panelists and the research team.

END

Thank you for your time! We will talk to you at 10:30am PST next Tuesday, January 13th. Please see the email or slide #5 of the PowerPoint presentation for webinar participation information. Please click "submit" to complete your survey.

Appendix E Achievable and Technical Potential by Group

Table 10. Achievable and Technical Potential by Scenario, Sector, and Year (aMW)

Customer Segment	Single Family Detached				Multifamily				Manufactured Home			
Scenario	1	2	3	Technical	1	2	3	Technical	1	2	3	Technical
2015	4.3	6.4	8.3	698.7	0.0	0.0	0.0	135.1	2.2	3.8	4.3	234.8
2016	8.8	13.2	17.3	707.2	0.0	0.0	0.0	136.7	4.4	7.9	9.0	237.7
2017	13.7	20.7	27.7	715.9	0.0	0.0	0.0	138.4	6.9	12.5	14.5	240.6
2018	18.8	28.6	39.3	724.7	0.0	0.0	0.0	140.1	9.6	17.5	20.9	243.6
2019	24.2	37.0	52.2	733.6	0.0	0.0	0.0	141.8	12.5	22.8	27.9	246.6
2020	29.6	45.6	66.2	742.6	0.0	0.0	0.0	143.6	15.5	28.2	35.2	249.6
2021	35.3	54.9	81.4	751.7	0.0	0.0	0.0	145.4	18.6	33.9	43.1	252.7
2022	41.1	64.3	97.5	760.9	0.0	0.0	0.0	147.1	21.8	39.5	51.3	255.8
2023	46.9	73.7	114.5	770.3	0.0	0.0	0.1	148.9	25.1	45.0	59.9	258.9
2024	52.9	83.2	132.1	779.7	0.0	0.0	0.1	150.8	28.6	50.4	68.6	262.1
2025	59.0	92.6	150.4	789.3	0.0	0.0	0.1	152.6	32.0	55.6	77.4	265.3
2026	65.1	101.8	168.8	799.0	0.0	0.0	0.1	154.5	35.5	60.5	86.0	268.6
2027	71.3	110.5	187.1	808.8	0.0	0.0	0.1	156.4	38.9	65.0	94.3	271.9
2028	77.6	118.5	205.0	818.7	0.0	0.0	0.1	158.3	42.4	69.2	102.2	275.2
2029	84.0	126.0	222.4	828.8	0.0	0.0	0.2	160.3	45.9	72.9	109.4	278.6
2030	90.5	132.9	239.3	839.0	0.0	0.0	0.2	162.2	49.4	76.2	116.1	282.0
2031	97.0	139.4	255.6	849.3	0.0	0.0	0.2	164.2	52.8	79.2	122.2	285.5
2032	103.5	145.1	271.1	859.7	0.0	0.0	0.2	166.2	56.3	81.8	127.7	289.0
2033	109.9	150.3	285.9	870.2	0.0	0.0	0.2	168.3	59.7	84.2	132.7	292.5
2034	116.4	155.2	300.0	880.9	0.0	0.0	0.3	170.3	63.0	86.3	137.3	296.1

Table 11. Technical and Achievable Potential by Scenario, Application, and Year (aMW)

Market	New Construction				Retrofit			
Scenario	1	2	3	Technical	1	2	3	Technical
2015	0.7	0.7	1.0	18.2	1.5	3.0	4.1	1050.4
2016	1.4	1.4	1.9	36.6	3.1	6.3	8.7	1045.1
2017	2.3	2.4	3.5	55.1	4.8	10.0	13.9	1039.9
2018	3.3	3.6	5.5	73.7	6.6	14.2	19.7	1034.7
2019	4.5	4.8	8.0	92.5	8.6	18.9	26.2	1029.5
2020	5.7	6.1	11.1	111.4	10.7	24.1	33.5	1024.4
2021	6.9	7.5	14.5	130.5	12.9	29.9	41.6	1019.2
2022	8.2	8.8	18.4	149.7	15.4	36.4	50.7	1014.1
2023	9.6	10.3	22.6	169.1	18.0	43.5	60.8	1009.1
2024	11.0	11.8	27.0	188.6	20.9	51.3	72.2	1004.0
2025	12.4	13.3	31.6	208.2	23.9	59.7	84.6	999.0
2026	13.8	14.9	36.3	228.1	27.2	68.8	98.0	994.0
2027	15.2	16.5	41.1	248.0	30.6	78.4	112.2	989.0
2028	16.7	18.2	46.0	268.2	34.3	88.5	127.2	984.1
2029	18.3	19.8	51.0	288.4	38.2	98.8	142.6	979.2
2030	19.9	21.5	56.1	308.9	42.4	109.2	157.6	974.3
2031	21.5	23.2	61.2	329.5	46.7	119.7	172.7	969.4
2032	23.3	25.0	66.4	350.3	51.3	130.0	187.5	964.6
2033	25.0	26.8	71.8	371.3	56.2	140.1	202.0	959.7
2034	26.8	28.6	77.2	392.4	61.3	149.7	215.8	954.9

Table 12. Technical and Achievable Potential by Scenario, Technology, and Year (aMW)

Technology	Cold Climate			Multiple Units			Multi-split			Short Run			Mini-split			Ducted Heat Pump		
Scenario	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
2015	0.8	1.9	1.4	1.0	1.9	1.3	1.6	1.5	1.0	1.1	2.2	1.6	2.0	2.7	2.5	N/A	N/A	4.8
2016	1.6	4.0	2.9	2.1	3.9	2.8	3.2	3.0	2.1	2.3	4.7	3.3	4.0	5.5	5.1	N/A	N/A	10.1
2017	2.6	6.3	4.7	3.3	6.1	4.5	4.9	4.8	3.3	3.6	7.4	5.3	6.2	8.6	8.2	N/A	N/A	16.3
2018	3.6	8.7	6.6	4.5	8.5	6.3	6.7	6.7	4.7	4.9	10.3	7.6	8.6	11.9	11.7	N/A	N/A	23.4
2019	4.8	11.3	8.7	5.8	11.0	8.4	8.6	8.9	6.4	6.4	13.3	10.0	11.1	15.2	15.1	N/A	N/A	31.6
2020	6.0	14.2	11.1	7.1	13.6	10.6	10.6	11.4	8.4	7.8	16.5	12.7	13.6	18.1	18.3	N/A	N/A	40.5
2021	7.4	16.6	13.2	8.5	16.3	13.0	12.6	15.4	12.0	9.4	19.8	15.6	16.0	20.6	20.5	N/A	N/A	50.0
2022	8.8	19.1	15.6	10.0	19.0	15.6	14.8	19.4	15.8	11.0	23.2	18.7	18.3	23.1	22.8	N/A	N/A	60.3
2023	10.5	21.7	18.2	11.5	21.7	18.3	17.0	23.2	19.6	12.7	26.5	22.0	20.4	25.7	25.2	N/A	N/A	71.1
2024	12.3	24.6	21.1	13.1	24.2	21.1	19.3	26.8	23.3	14.4	29.7	25.4	22.4	28.2	27.7	N/A	N/A	82.2
2025	14.3	27.4	24.0	14.7	26.7	23.8	21.6	30.7	27.5	16.3	32.7	28.8	24.0	30.7	30.2	N/A	N/A	93.5
2026	16.4	30.4	27.4	16.4	28.9	26.5	23.9	34.4	31.5	18.2	35.5	32.1	25.6	33.1	32.7	N/A	N/A	104.6
2027	18.5	33.4	30.7	18.1	30.9	29.1	26.2	37.8	35.4	20.2	38.0	35.3	27.2	35.4	35.2	N/A	N/A	115.7
2028	20.7	36.7	34.5	19.8	32.7	31.6	28.5	40.5	38.7	22.1	40.2	38.4	28.8	37.6	37.7	N/A	N/A	126.4
2029	23.1	39.9	38.2	21.5	34.3	33.8	30.7	42.9	41.8	24.1	42.2	41.1	30.4	39.6	40.1	N/A	N/A	136.9
2030	25.7	43.0	41.9	23.2	35.7	35.8	32.9	45.2	44.8	25.9	43.8	43.6	32.1	41.4	42.4	N/A	N/A	147.1
2031	28.4	45.9	45.5	24.8	36.9	37.7	35.1	47.4	47.5	27.8	45.2	45.8	33.7	43.1	44.6	N/A	N/A	156.9
2032	31.3	49.3	49.7	26.4	37.9	39.3	37.2	48.6	49.1	29.6	46.4	47.7	35.3	44.7	46.7	N/A	N/A	166.5
2033	34.4	52.4	53.8	27.9	38.8	40.7	39.2	49.9	50.6	31.2	47.3	49.3	36.9	46.1	48.6	N/A	N/A	175.9
2034	37.7	55.5	57.7	29.3	39.6	41.9	41.1	51.0	52.0	32.8	48.1	50.7	38.5	47.3	50.4	N/A	N/A	184.8