R1617 Connecticut Residential Ductless Heat Pumps Market Characterization Study – Final Report

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1 ABSTRACT

The R1617 Ductless Heat Pump (DHP) study examines the installation circumstances, impacts, and estimated adoption rate of program DHPs installed in Connecticut. The study (1) systematically determined the savings baseline from rebated DHP units in 2015 and 2016, (2) determined the electric and fossil fuel impacts of those units under each baseline condition, (3) explored the DHP marketplace from the contractor perspective, (4) developed a tool to estimate market adoption rates under various rebate and fuel cost levels, and (5) provided guidance for documenting DHP impacts in the CT Program Savings Document (PSD).

Using a survey of 90 participating customers, 23 contractors, and secondary meter data, and the support of a working group[1], this study found that DHPs present a unique opportunity to pursue a wide variety of energy outcomes in Connecticut depending on the circumstances in which they are installed. The baselines from DHPs observed in this study produced a very diverse set of energy impacts among multiple fuels, including the possibility of electric load building. The mix of baselines observed in this study, however, produce an average reduction in MMbtu per home.

A significant finding in the adoption model is that single family customers with fossil fuel who use the DHP units for heating and cooling were the most likely customer segment to participate when program rebate levels or the price of alternative fuel increased. These customers have an average impact that includes load building accompanied by significant therm savings and carbon reductions.

The current Program Savings Document (PSD) only credits electric savings to DHP installations. This savings approach is due to standing EEB policy that ratepayer funds not support fuel switching (and by extension not receive therm impact credit for such events). The baseline assumptions in the current PSD approach overstates true electric impacts as it does not include instances of load building. DHPs can be a valuable part of an efficiency portfolio, a vehicle to carbon reduction, and/or a means to induce strategic electrification. A threshold issue lies in the program determining its desired outcomes.

This study has five core recommendations:

- The study recommends three paths to calculate claimed impacts from DHPs. Path selection depends on what is known about a given installation and whether fuel switching is allowed. These paths are: (1) a blended approach that weights the baseline conditions observed in this study, (2) a series of impacts based on defined baselines (e.g., natural gas furnace, electric resistance, etc.) that are dependent on a handful of easily identifiable characteristics of the project, or (3) a custom baseline determined on a case-by-case basis (akin to this study).
- The study recommends program implementers consider rebating units only where the baseline can be understood as part of an audit, an online questionnaire, contractor assessment, or as the observation of load patterns indicate to help ensure DHP installations produce fuel impacts aligned with CT program goals.
- The study recommends the DHP Planning Tool be used to understand how incentive levels and alternative fuel prices affect outcomes credited to the program and help guide the design and implementation of the future DHP program.[2]

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[1] These key stages of working group input included the baseline approach, adoption modelling work and impact estimates.

[2] The current version of the DHP Planning Tool only measures participation and savings attributable to changes in program incentive levels and/or prices for alternative fuels. The impact on participation and savings from other program design features are not captured in the DHP Planning

- The study recommends that DHPs be monitored as part of the planned study (R1982) to update the PSD's equivalent full load hour (EFLH) factor.
- The study recommends the continued use of contactors to perform outreach and targeting of installation baselines to produce the program's desired impacts.

Tool. For midstream programs where the discounted equipment prices are passed to the contractors and then on to customers, the DHP Planning Tool can be used to quantify changes in participation and savings.

2 EXECUTIVE SUMMARY

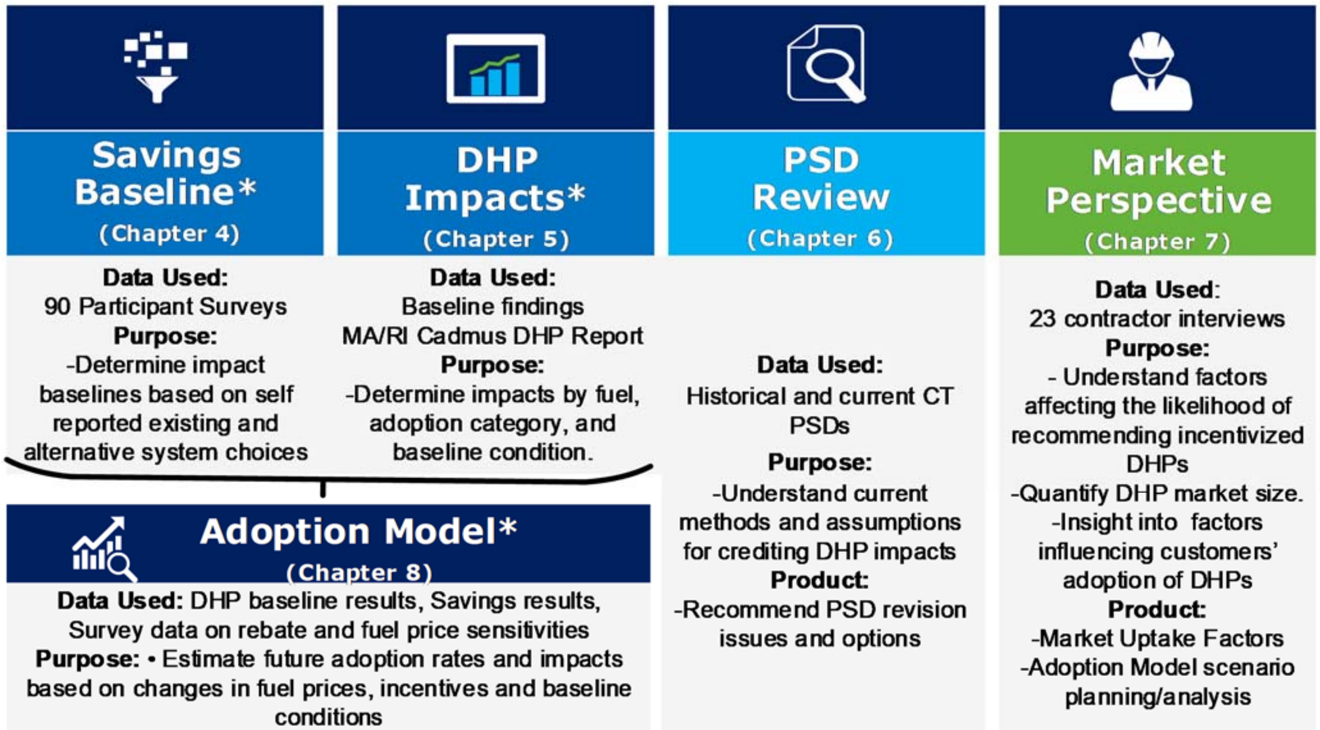
This study was commissioned by Eversource and United Illuminating Company (UI) and the Connecticut Energy Efficiency Board (EEB) as a baseline savings and market study of the Connecticut Residential Ductless Heat Pump (DHP) Program (R1617). A working group that included members of the EEB consultant team were integrated into the study to provide guidance and advice at critical stages. These key stages of group input included the baseline approach, adoption modelling work and impact estimates. Energize CT has several paths to receive incentives for DHP units, including audit-based programs and market rebates that have are evolving from a downstream to midstream design. The study brings together information from several primary and secondary data sources in a way that provides results on current DHP rebate impacts and future adoption rates. This report shows the actual baseline and impacts of DHPs as installed, provides guidance on paths to better document those impacts in the PSD and offers information that decision makers can use to understand how DHPs can be deployed and incentivized to achieve various policy goals.

DHPs are an efficient HVAC system that can be installed in lieu of less efficient electric and fossil fuel heating and cooling systems. Their compact nature and ease of installation – and their flexibility to provide both heating and cooling needs - have led to units being installed in households with multiple purposes in mind, introducing a great deal of complexity around appropriate baselines. The determination of the baseline requires understanding the usage of the DHP (cooling and/or heating), the type of space served by the unit (previously space conditioned or not) and the likely heating or cooling system that would have been installed in place of the DHP. This study examined the actual baselines from rebated DHP units in 2015 and 2016 and the impacts from those baselines though 90 participant surveys and analysis of secondary meter data. The baseline approach was systematically designed to gather information on specific installation circumstances for each location in the home served. The impact work was based on metered data from Massachusetts and Rhode Island[3] that was refined for Connecticut use and exercised the specific baseline and DHP efficiencies installed in the sample population. This study also used participant survey data to build a tool to predict future adoption rates and impacts based on varying levels of rebates and fuel prices.

Figure 2-1 shows the key components of the study and their relationship between each other. It also identifies the data inputs and purpose for each component.

3 Ductless Mini - Split Heat Pump Impact Evaluation December 30, 2016, Cadmus, prepared for the electric and Gas Program Administrators of Massachusetts and Rhode Island

Figure 2-1: Overview of Study



*The methods in these tasks were developed with assistance from a working group that included members of the EEB Consulting team.

The following describes the major findings and recommendations of the study.

2.1 Findings

2.1.1 Baseline Findings

The savings baseline for DHPs is very diverse in technologies and fuels used. The baseline determination is based on information gathered from participants on pre-existing equipment that served the space currently conditioned by the DHP or what they would have installed in the absence of the DHP. Baselines were determined at the head[4] level and free riders have been removed so their tendency to install a program eligible heat pump absent the program does not influence the baseline[5]. The heating savings baseline includes nearly 75% of systems that used fossil fuel. An additional 18% of heating baselines were electric resistance (see Table 2-1: Heating Savings Baseline). A quarter of the cooling baseline is no cooling, meaning that the customer would not have installed any cooling system, so the installed DHP unit represents a load build (see Table 2-2). The diverse baselines observed are the by-product of rebated installations not targeted to specific installation conditions, but rather available to the general customer base.

[4] A head refers to the indoor unit that provides the heating and cooling into the served space.

[5] The removal of free riders isolates the savings baseline from attribution/net factors. In this approach, the baseline is the equipment most likely to have been installed in place of the rebated DHP absent the influence of the program moving a customer from the baseline to the rebated DHP.

Table 2-1: Heating Savings Baseline

System Type and Fuel	Heads=101
Furnace - Oil	32.2%
Electric Resistance	17.6%
Boiler - Oil	32.2%
Furnace - Gas	9.9%
Other (wood stove, gas boiler)	3.1%
No Heating	3.0%
Solar	2.0%

Table 2-2: Cooling Savings Baseline

System Type	Heads=112
Window AC	41.9%
Central Air	30.3%
No Cooling	26.0%
Wall Mount AC	1.8%

2.1.2 Energy Impacts by Baseline Category

Using the baselines presented above, this study developed impacts for the installed DHP units, including total MMBtu. Table 2-3 shows the normalized per ton heating impacts by technology and fuel type for both retrofit and market baseline scenarios. Savings based on a market baseline are lower than those with a retrofit baseline due to higher baseline efficiencies assumed in the former. A negative value in the kWh Impact per Ton column indicates a load build. For example, where the heating baseline has a fossil fuel there is savings in that fuel but an increase in electricity due to the DHPs heating use. This table also includes a column with the overall weighted therm impact per ton based on the number of heads deemed to have a retrofit versus market baseline from the survey data. The weighted values use the number of heads with retrofit versus market baselines as gathered in the participant surveys and reflected in Table 3-3.

Table 2-3: Heating Impacts by Baseline Technology, Fuel, and Event (per Ton)

Baseline	Retrofit Baseline Therm Impact per Ton	Market Baseline Therm Impact per Ton	Weighted Therm Impact per Ton	kWh Impact per Ton	MMBTU Impact per Ton
Furnace - Oil	80.0	75.1	79.4	-513.8	6.2
Furnace - Gas	79.0	73.4	77.1	-513.8	6.0
Boiler - Oil	67.8	64.6	66.7	-513.8	4.9
Boiler Gas	67.0	63.8	65.4	-513.8	4.8
Electric Resistance	N/A	N/A	N/A	1,057.9	3.6
No Heating	N/A	N/A	N/A	-513.8	-1.8

Table 2-4 presents the normalized per ton cooling impacts by technology for both retrofit and market baseline scenarios. The central air conditioning impact per ton is higher than room air conditioners, particularly when customers reported the DHP unit displaced a pre-existing system. A no cooling baseline produces a load build of 132 kWh per year. As above, the final column shows the overall weighted impact per ton based on the number of heads deemed to have a retrofit versus market baseline from the survey data.

Table 2-4: Cooling Impacts by Baseline Technology and Event (per Ton)

Baseline	Retrofit kWh Impact per Ton	Market Baseline kWh Impact per Ton	Weighted Therm Impact per Ton
Room Air Conditioner	142.4	73.9	122.0
Central Air Conditioning	206.2	85.0	95.4
No Cooling	-132.1	-132.1	-132.1

2.1.3 PSD Review

The 2019 PSD credits electric savings but not fossil fuel savings for program rebated DHP units. Specifically, the 2019 PSD provides two savings calculations for electric kWh savings.

- The first is a lost opportunity calculation that is used to determine the savings for homes with a pre-existing fossil fuel heating system. This calculation method assumes the new DHP is displacing a standard efficiency DHP.
- The second is a retrofit calculation that is used to determine the savings for homes with a pre-existing electric resistance heating system. This calculation method uses the electric resistance as the heating baseline and a SEER of 10.1 for cooling.

The review of the formulas find that they are technically correct for determining electric impacts when the baselines are as assumed in the formula (i.e., when the baseline is in fact a standard DHP). However, the assumed measure baseline in this formula unrealistically oversimplifies the vast majority of baseline conditions observed in this study and is unlikely to produce an accurate estimate of savings. For example, it does not include load building that likely occurs when the baseline condition is no heating and/or cooling. In addition, the absence of the calculation of fossil fuel savings from DHPs in the 2019 PY PSD means a substantial customer benefit and source of carbon reduction is not being claimed or credited to this measure. The findings from the review are provided in Section 6 of this report.

2.1.4 Contractor Interviews

In-depth interviews were conducted with 23 contractors out of 281 who participated in the 2015-2016 Energize CT DHP Rebate Program. These contractors represented 25% of program (rebated) DHPs, reported to be involved in various installation event types (i.e., retrofit, lost opportunity) and deemed representative for purposes of this study. The interviews focused on home and customer characteristics that determined the recommendations and adoptions of DHPs. The key findings include:

- Contractors reported recommending DHPs (standard or high-efficiency) for 12% of their total cooling installations and for 8% of their total heating installations.
- The majority of DHP recommendations were for program-eligible high-efficiency DHPs (80%-99%, depending on type of cooling/heating usage).
- Most of the cooling recommendations were for cooling-only use (55%).
- Despite customers' concerns over cost of DHPs, contractors reported that across all market segments and types of usage, 83%-88% of customers still chose to install DHPs when recommended by contractors. Furthermore, 74%-80% of the customers installed high-efficiency DHPs.
- Contractors reported that of all their customers (both program participants and non-participants) who adopted a high-efficiency DHP about three-fifths applied and received a rebate through the program.

2.1.5 Adoption Market Modeling

Data from the participant telephone survey was used to model how program participation could be expected to change under different program scenarios and market conditions. To allow program planners to obtain projected participation under different scenarios, an Excel-based modelling tool was developed to quantify the effects of changes in the rebate level and in the price of alternative sources of fuel (fuel oil; natural gas; propane; wood, pellets, or coal; and electricity). We note that there are limitations in the penetration model as it relies on participant survey data and uses two variables as economic predictors; incentive level and fuel costs and relies on. Depending on how the user adjusts these two parameters in the planning tool will determine the electric and non-electric impacts. However, there are some overarching trends in the inputs that went into the tool as well as the outputs from this tool that are summarized below.

- Both the level of rebate and the cost of alternative fuels are positively correlated with the level of participation in the program. The change in the level of the rebate has a bigger impact than the change in price of alternative fuels.
- Based on this current mix of participants, an increase in the level of program participation translates to an increase in electricity consumption but a decrease in non-electric fuel consumption. The combination of the change in consumption results in a decrease in the amount of carbon dioxide that is produced from heating and cooling in the program-participant population. For an individual home, if the existing heating fuel is electric, installing a program-eligible DHP also leads to reduced electricity consumption.
- The largest participant population segment is those that have single-family homes with non-electric heating fuel who intended, at the time of purchase, to use their DHPs for heating with or without cooling.

2.2 Recommendations and Conclusions

Ductless heat pumps present a unique opportunity to pursue a wide variety of energy outcomes in Connecticut and are becoming increasingly viable in Connecticut's cold climate. DHPs are becoming more efficient, able to produce heat at lower outdoor temperatures, are relatively easy to install, and present an appealing way for customers to heat or cool a space with local controls in areas that might not be a candidate for extending existing HVAC systems or that need an entirely new system. The opportunities and flexibility DHP's provide, however, can result in a very diverse set of energy impacts, potentially among several fuels, including the possibility of electric load building. It is clear from this study that DHPs can be a valuable part of an efficiency portfolio, a vehicle to carbon reduction, a means to induce strategic electrification, customer total energy or cost savings, or several of these objectives at once. In 2019, there are several planned efforts to test and assess the ability to better control the circumstances in which a unit is installed and the types of energy savings that accumulate for DEEP, the utilities and their customers. The conclusions and recommendations below are intended to provide information to understand the energy implications of different baselines, guidance during this period of transition, and next steps depending on how DHPs are ultimately decided to be used.

Conclusion. The 2019-2021 C&LM plan indicates that a pilot will be run wherein DHPs will be targeted toward electric heat customers in the first half of 2019; then expanded to include customers who heat with fossil fuel beginning in July. The results of this pilot will help inform whether and how the programs continue to support fossil fuel displacement. No decisions on offering fuel switching as an ongoing program measure has been made yet. There also continues to be a broad rebate offer to customers who purchase an efficient DHP unit regardless of their current heating or cooling system type or fuel. This program channel produces a variety of baseline conditions, including some that likely induce load building. Standing EEB policy at this time is that ratepayer funds should not support fuel switching, which has an impact on how DHP impacts are accounted for in the PSD. The current PSD oversimplifies baseline conditions and produces only electric savings against like fuel baseline assumptions. This approach overstates true electric impacts and does not include impacts from other fuels that might be of interest to DEEP in the near future.

Recommendation. The decision on whether to allow fuel switching is a key driver of how the DHP entry is revised to better reflect true impacts in the PSD. There are several forms that entry might take. These include the three offered below or a system that allows any of the three paths, depending on what is known about a given installation. Note that these approaches range with respect to cost, level of difficulty to coordinate and perform, and feasibility, depending program design. For example, an upstream program with an instant rebate might only be able to reasonably use the blended baseline approach while installations recommended as part of an audit might benefit from the second approach.

- A blended baseline that weights the baseline conditions observed in this study and provides an average overall electric and fossil fuel impact per unit. This approach would produce impacts based on the population of projects at the time this study and could be updated as the nature of the installations change over time.
- A series of impacts based on defined baselines (e.g., natural gas furnace, electric resistance, etc.) that are dependent on a handful of easily identifiable characteristics of the project. This approach is more suitable for opportunities observed through audit offerings where pre-installation characteristics are known but is likely to be more challenging for mass market rebate offerings.

- A custom baseline that is determined on a case by case basis using techniques that are similar to those performed in this study. This approach would require a blend of understanding what, if anything, was serving the space prior to the DHP as well as what the customer would have done in the absence of the incentivized equipment. This approach would also require a system to produce the baseline condition based on the reported information.

Recommendation. There are several baseline conditions that likely induce load building. One of them is when the DHP unit is installed in a location that did not previously have heating or cooling. A second is when the DHP unit displaces a system that previously used fossil fuel or would have had the incentivized equipment not been installed. Since instances of these baseline conditions were observed from surveyed customers that received rebates in the marketplace, one can expect the continuation of DHP rebates will likely result in future installations of this nature. To avoid this, implementers might consider only rebating units where the baseline can be understood as part of an audit, an online questionnaire, contractor assessment, or as the observation of load patterns indicate. This would help ensure the DHP installation produces fuel impacts that are aligned with DEEP and program goals.

Conclusion. Single family customers with fossil fuel who use the DHP units for heating and cooling were the most likely customer segment to participate when program rebate levels or the price of alternative fuel increased. While the average impact for these customers includes load building, there are significant therm savings and carbon reductions.

Recommendation. The study recommends the DHP Planning Tool be used to understand how incentive levels and alternative fuel prices affect outcomes credited to the program and help guide the design and implementation of the future DHP program.[6] If program planners are interested in exploring how changes to the incentive levels or future price of alternative fuels could impact program participation the DHP Planning Tool can be used to understand the different scenarios.

Conclusion. The current PSD uses equivalent full load hours from a 2016 study of DHPs installed in 2013 and 2014 in Massachusetts and Rhode Island[7]. This study is also the basis of the savings in this report, albeit adjusted to accommodate the observed rates of pre-existing versus market baseline efficiencies by system type and fuel used. Since the installation of the units studied in Massachusetts and Rhode Island, DHPs have become increasingly more efficient and capable of operating at much colder temperatures. These improvements can have a large effect on the full load equivalent hours experienced in new systems.

Recommendation. A sample of DHPs should be monitored as part of the planned study (R1982) to update the PSD’s equivalent full load hour (EFLH) factor.

Conclusion. HVAC contractors appeared to have a strong influence over customers’ decisions to adopt DHPs and the efficiency of the installed equipment. Customers installed high-efficiency DHPs 74%-80% of the time contractors recommended high-efficiency equipment.

Recommendation. The study recommends that UI and Eversource leverage the customer-contractor relationship to further program participation by engaging contractors through outreach and education. In particular, as DHPs are targeted toward electric heat and fossil fuel customers as part of the 2019-2021 C&LM plan, close collaboration with contractors should achieve adoption among these customer segments.

[6] Footnote 2.
[7] ibid

3 INTRODUCTION AND METHODOLOGY

This study was commissioned by Eversource and United Illuminating Company (UI) and the Connecticut Energy Efficiency Board (EEB) as a baseline savings and market study of the Connecticut Residential Ductless Heat Pump Program (R1617). The study used the results of a survey conducted with 90 customer end-users who participated in the program between 2015 and 2016.The study sought to characterize what would have been installed in the absence of the incentivized equipment and to develop a market adoption model.[8] Secondary meter data and calculated heating and cooling EFLH from Massachusetts was used to derive electricity, natural gas and carbon impacts.

3.1 Program Background

3.1.1 Program Description

The 2015-2016 Energize CT program provided financial incentives to residential electric customers of UI and Eversource who install ENERGY STAR® ductless heat pumps (DHP). To participate in the DHP program, residential customers contact licensed contractors to select install the qualifying equipment. The contractors work with participating distributors to prepare price quotes for the DHP equipment and provide the necessary documentation to the customer to apply for the incentive. It should be noted that the current DHP program includes an instant rebate from the distributor in the price quote for the equipment negating the need for the customer to apply for the incentive.

Table 3-1 presents the minimum efficiency requirements and incentive levels for the 2015-2016 Energize CT DHP Program.

Table 3-1: Energize CT DHP Minimum Efficiency Levels and Incentives[9]

Eligible Equipment	Efficiency Requirements	Incentive
ENERGY STAR® AHRI[10] Rated Ductless Heating and Cooling System of Matched Assembly – Single Unit	20 SEER[11]/12.5 EER[12]/10 HSPF[13]	$300/Home
ENERGY STAR® AHRI Rated Ductless Heating and Cooling System of Matched Assembly – Multiple Unit	18 SEER/12.5 EER/9 HSPF	$1,000/Home

3.2 Evaluation Goals

This study was designed to characterize the market for DHPs in Connecticut and its impact on Eversource and UI savings portfolios in the future. To achieve these goals required a series of interrelated research and analytical tasks. The first step was to determine the type of heating that would be installed in the absence of the incentivized DHP and for cooling equipment as well. This information was obtained from a telephone

[8] The study included creating a model to determine how program participation could be expected to change under different program scenarios and market conditions.

[9] https://www.energizect.com/your-home/solutions-list/ductless-split-heat-pump-rebates

[10] AHRI – Air Conditioning, Heating and Refrigeration Institute. All equipment must be rated in the AHRI Heat Pumps and Heat Pump Coils directory found online at www.AHRIdirectory.org.

[11] SEER – Seasonal Energy Efficiency Ratio

[12] EER – Energy Efficiency Ratio

[13] HSPF – Heating and Seasonal Performance Factor

survey with 90 2015-2016 program participants. This information was used to derive the mix of heating and cooling equipment that would have existed without the program incentive.

The second step calculated the kWh, therms and carbon savings associated with replacing the heating/cooling equipment that would have been installed with a program DHP. The participant survey provided key information about the savings baseline, how the DHP was operated after installation and the space served by the DHP. Metered data and accompanying EFLH estimates from the 2016 study of DHPs in Massachusetts and Rhode Island[14] was used as part of the impact work.

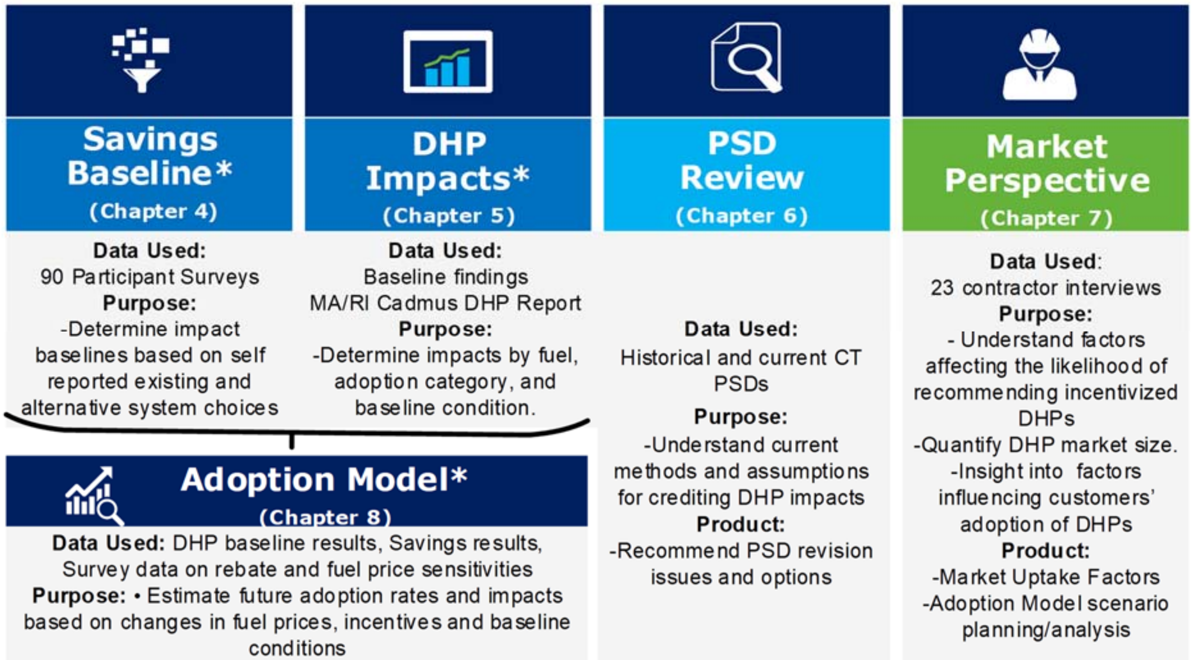
The third step was to review the current savings algorithms and modeling assumptions in the Connecticut Program Savings Document (PSD) to determine if the current PSD modeling assumptions accurately reflect the current baseline conditions. The assessment was based upon the findings from the first two steps.

Finally, to help program administrators project participation and the corresponding electric and non-electric impacts, including carbon savings under different market conditions an Excel-based planning model was developed. The model was informed by interviews with 23 contractors to determine program impacts from changes in rebate levels, price of alternative sources of fuel (fuel oil; natural gas; propane; wood pellets; coal and electricity) and changes in the mix of customers (multi-family versus single family; electric and non-electric).

[14] Ductless Mini - Split Heat Pump Impact Evaluation December 30, 2016, Cadmus, prepared for the electric and Gas Program Administrators of Massachusetts and Rhode Island

Figure 3-1 shows the relationship between each of the program components and the data inputs and outcomes for each component. A working group that included members of the EEB consultant team were integrated into the study to provide guidance and advice at critical stages. These key stages of group input included the baseline approach, adoption modelling work and impact estimates.

Figure 3-1: Overview of Study



*The methods in these tasks were developed with assistance from a working group that included members of the EEB Consulting team.

3.3 Evaluation Methodology

3.3.1 Participant Survey

This section describes the survey of 2015-2016 program participants.[15] The participant survey results informed the baseline analysis, program savings analysis and the program adoption modelling.

Ninety program participants from the DHP savings program were randomly selected for a telephone survey. The total population of participants in that program period was 1,831 (153 UI and 1,678 Eversource). The sample of 90 was deemed enough to acquire detailed information on baselines and likelihood of installation under various pricing and fuel cost scenarios. The bullets below show the key research topics addressed in the survey. The final survey instrument is provided in APPENDIX A.

- Demographic – type of home, size, age, description of space served by DHP, etc.
- Relationship of space served by DHP with exposure to ambient temperatures and heating and cooling provided by other systems
- Presence of and type of previous heating/cooling equipment in DHP space: type, operation, presence of duct system, opportunity to expand duct system, space served by equipment
- DHP operation assumptions – pre-installation
- DHP operating behavior post-installation: use of back-up equipment, space served by DHP, set-points, etc.
- Reasons for installing DHP among participants and reasons for selecting non-DHP technologies among non-participants
- Effect of fuel prices and rebate levels on equipment choice

3.3.2 Baseline Analysis Methods

This section discusses the methods used to determine the appropriate savings baseline for high-efficiency ductless heat pumps (DHPs) promoted through Energize CT's rebate offering. Using the results of the participant survey data, this savings baseline analysis seeks to characterize what participants would have done had they not installed the program DHP. There are many factors that complicate the determination of a savings baseline for this technology. These include:

- Determining at the individual head (indoor wall-mounted units) level whether and how the served space was previously heated or cooled (vs a new space),
- Understanding how the customer is using the new unit to heat or cool the served space (which may differ from how they may have intended to use it), and
- The likely alternative heating or cooling system they would have installed (driven in part by level of awareness of standard DHP alternatives).

Determination of the DHP savings baseline encompasses a four-step process. A discussion of this process is presented here, and a diagram that shows the questions, responses and final baseline dispositions for both heating and cooling are found in Appendix B. Table 3-2 provides a summary of how baselines were assigned

[15] Participants were electric UI or Eversource customers.

based on participant survey responses. These steps are further detailed after the table. Note that baselines are developed for those heads that are providing heating and/or cooling. For example, if a head is only being used to provide heating and not cooling, it was factored into the heating baseline, but not the cooling baseline.

Table 3-2: Savings Baseline Source

When…	The Savings Baseline is …
1) A DHP head location is currently providing heating or cooling to a space that did not have a pre-existing system (additions, etc.)	The reported technology that would have been installed.
2) The respondent reported that had they not purchased the DHP they would have continued to use the pre-existing system to heat the space	The pre-existing system.
3) The respondent indicated that they were no longer going to use their pre-existing system at the time of deciding to install the DHP	The reported technology that would have been installed.
4) A respondent has been determined to be a free-rider[16]	Were not included in the baseline results.

The first step of determining the baseline was obtaining the types of systems previously serving the spaces now served by the program DHP. In this step, participants were asked to provide a list of pre-existing systems in their home prior to the DHP installation or to indicate if a space was not cooled or heated prior to the DHP. Then for each space served by an installed head, participants were asked what, if any, of the pre-existing systems served that room and what percent of the total heating or cooling load was provided by the pre-existing system. The pre-existing technology/ies for each DHP head was collected for spaces that were previously cooled or heated. For example, the survey gathered information about a pre-existing central air system could have served three or four spaces in a home and window units could supplement some of the cooling needs in some of those spaces. To capture this scenario, the percent of cooling from window units versus central air in each space served. This set of questions produced the percent of each head previously served by any pre-existing technologies and the ability for a head to have multiple baselines.

The next steps recognize that customers might install DHPs because they need or would like a new system, either as a replacement to a pre-existing system or to serve an addition or otherwise unconditioned space. In this scenario, information for all options considered to heat or cool the space by respondents, of which continuing the use of their pre-existing system may be one, was collected. In this battery of questions, participants were asked to provide a list of possible alternatives they considered to meet their heating and/or cooling needs, including the option of expanding their pre-existing system if one was available. Once all alternatives were gathered, each respondent chose the system they would most likely have installed or kept had they not installed the program DHP. This set of questions produced the technology that they would have used in the absence of the DHP to heat or cool the space. Like above, the survey gathered 100% of the planned heating or cooling technologies for each head. This includes whether they would have continued using their pre-existing system (if available), what they would have done to serve conditioned spaces not previously heated or cooled and what they would have done if they said they were planning to replace their previous system at the time of installing the DHP.

A critical step in determining the program baseline was to examine the free ridership tendencies among respondents and isolate the savings baseline for non-free riders. This refinement reflects the idea that

[16] A free-rider is a respondent who indicated they were very likely to install a program eligible DHP without a program incentive.

customers who were very likely to have installed the DHP absent the program (free riders) should not influence the baseline from which the program impacts are determined. The results section provides the baseline with all respondents followed by the final savings baseline after removing free riders.

3.3.3 DHP Program Impact Methodologies

3.3.3.1 Energy Impact Analysis Methods

The estimate of the consumption impacts for the key heating and cooling baselines used the analysis of metered data from a 2016 study of DHPs in Massachusetts and Rhode Island[17]. The savings estimates derived in this report were primarily for purposes of informing the electric, gas, and carbon impacts used in the DHP market adoption.

The DHP metered heating and cooling usage values from the Massachusetts study were utilized, which are the same values used in the current version of the Connecticut Program Savings Document (CT PSD). The heating EFLH is 442 hours to meet heating load of 5.36 MMBTU per ton and the cooling EFLH of 218 hours to meet a cooling load of 2.62 MMBTU per ton. The Massachusetts DHP report identified 14 weather stations that were used to analyze the data, but there was no detail about how the weather data was allocated to the sample, so it was not possible to replicate the Massachusetts study's methodology precisely.

Although it provided some very recent performance data for use as the basis for the EFLH in this study, there are some items to note regarding the DHP installations metered in the MA/RI study. In that study, there was a wide range of observed EFLHs though they were generally lower than anticipated. The study provided several reasons for the lower EFLH. These included the observation that not all units metered were used routinely for all seasons, systems in the sample were consistently sized larger than the cooling needs of the space served, and many units were in off or standby mode much of the time. We also note that the DHPs installed were not accompanied by education on how to use them in conjunction with other systems available to heat or cool, nor were they installed with integrated controls.

Initially the study intended to use DHP metered data from the Vermont Cold Climate DHP study, however that program targeted heating applications and included only cold climate DHP units. The Connecticut DHP program includes both standard and cold climate DHP and is implemented in a manner consistent with the MA program, so the Vermont results were not utilized. It is interesting to note that the Vermont EFLH for heating was 1,348 hours, over three times higher than the MA study value. Adjusting the Vermont metered data for Connecticut weather would have resulted in heating EFLH of 1,097 hours and a cooling EFLH of 429 hours, which indicates what the potential usage and savings for the DHPs could be if the program was implemented and performed more like the one in Vermont and not the one in Massachusetts.

The baseline portion of this report provides the heating and cooling baselines (comprised of non-free riders) by portion of installed heads. To attach impacts to the various baselines it was also examined whether the head level baselines provided by those respondents were pre-existing versus something the respondent would have installed in the absence of the DHP at the same time the DHP was installed. This information allows the analysis to use two different savings baselines for each technology (the pre-existing condition and current market standard). Table 3-3 and Table 3-4 show the baseline by number of heads for heating and cooling, respectively. Like the previous baseline results, fractions of heads indicate where more than one heating or cooling system was serving the space now served by the DHP unit. As is seen in the table, most

[17] http://ma-eeac.org/wordpress/wp-content/uploads/Ductless-Mini-Split-Heat-Pump-Impact-Evaluation.pdf

heating baselines rest upon the pre-existing condition, as indicated in earlier results. Cooling baselines present a mix of pre-existing and market standard depending on the technology.

Table 3-3: Heating Savings Baseline Detail

System Type and Fuel	Baseline (n=101 heads)[18]		
	Total	Pre-Existing	Market Standard
Furnace - Oil	32.5	28.5	4
Electric Resistance	17.8	13.8	4
Boiler - Oil	32.5	21.5	11
No Heating	3	N/A	N/A
Furnace - Gas	10	5	5
Solar	2	0	2
Stove - Gas	1.3	1.3	0
Boiler - Gas	1	1	0
Stove - Pellet	0.4	0.4	0
Stove - Wood	0.4	0.4	0

Note: fractions actions of heads indicate where more than one heating or cooling system was serving the space now served by the DHP unit

Table 3-4: Cooling Savings Baseline Detail

System Type and Fuel	Baseline (n=112 heads)		
	Total	Pre-Existing	Market Standard
Window Air Conditioning	47	33	14
Central Air Conditioning	35	3	32
Wall Mount AC	2	1	1
No Cooling	28	N/A	N/A

The baselines used in the savings analysis are presented in Table 3-5. These are from the 2018 PSD for each technology indicated. This was necessary because the DHP PSD entry carries heating and cooling baseline assumptions for standard DHP units only. For several technologies, there are unique baselines assumed for UI versus Eversource. When necessary, the analysis used weights of 29.3% and 70.7% (approximate customer split in Connecticut) to develop a single overall baseline efficiency for each technology and installation event. The efficiency used for electric resistance heating reflects a one-to-one relationship for energy in and out.

[18] Does not tie to total due to rounding.

Table 3-5: Heating Savings Baseline Efficiencies by Technology

System Type and Fuel	Assumed Efficiency (AFUE)		
	Utility	Pre-Existing*	Market Baseline
Furnace - Oil	UI	80%	83%
	Eversource	76%	82%
	Overall	77%	82%
Furnace - Gas	UI	78%	80%
	Eversource	78%	85%
	Overall	78%	84%
Electric Resistance	Both	100%	100%
Boiler - Oil	UI	80%	84%
	Eversource	78%	82%
	Overall	79%	83%
Boiler - Gas	UI	80%	82%
	Eversource	80%	85%
	Overall	80%	84%

* If known

Table 3-6 presents the baseline information for window and central air conditioning. These values were also gathered from the 2018 CT PSD. Unlike the heating baselines above, UI and Eversource use the same baseline assumptions for these technologies.

Table 3-6: Cooling Savings Baseline Efficiencies by Technology

System Type and Fuel	Assumed Efficiency (EER)	
	Pre-Existing*	Market Baseline
Window AC[1]	8.86	11.0
Central Air	8.0	11.0

* If unknown
[1] Window, 8,000 Btu/h

The next step of the savings work was creating per ton therm and electric impacts of heating and cooling provided by the installed DHP. These formulas used the assumptions presented above on loads, EFLH, and baseline efficiencies as key inputs. The formulas also used information on the installed heat pump efficiencies gathered from the tracking system for the baseline sample and other factors, as bulleted below.

- Average installed heating HSPF ($HSPF_i$): 10.44
- Average installed cooling SEER ($SEER_i$): 19.8
- Existing electric resistance Btu/watt-hour ($HSPF_e$): 3.413
- Duct leakage factor (DL): 1.15

The formulas used to calculate these normalized per ton impacts are presented Table 3-7. These per ton estimates were then applied to the rated capacities of the heads installed in each baseline condition.

Table 3-7: Formulas to Calculate Normalized per Ton Impacts

Baseline Condition	Formula
Heating	
Per ton kWh impact for fossil fuel or "no heating" baseline (load build)	$BTU/ton \div HSPF_i \times EFLH_h \div 1{,}000$
Per ton kWh impact for electric resistance baseline	$BTU/ton \times \left(\frac{1}{\mathrm{HSPF}_e} - \frac{1}{\mathrm{HSPF}_i}\right) \times EFLH_h \div 1{,}000$
Per ton therm impact for fossil fuel baseline*	Retrofit: $LPT_h \times \left(\frac{1}{AFUE_e}\right)$ Market: $LPT_h \times \left(\frac{1}{AFUE_b}\right)$
Cooling	
Per ton kWh impact for room air conditioner baseline	Retrofit: $BTU/ton \times \left(\frac{1}{\mathrm{SEER}_e} - \frac{1}{SEER_i}\right) \times EFLH_c \div 1{,}000$ Market: $BTU/ton \times \left(\frac{1}{\mathrm{SEER}_b} - \frac{1}{SEER_i}\right) \times EFLH_c \div 1{,}000$
Per ton kWh impact for central air conditioner baseline	Retrofit: $BTU/ton \times \left(\frac{1}{\mathrm{SEER}_e} - \frac{1}{SEER_i}\right) \times EFLH_c \div 1{,}000$ Market: $BTU/ton \times \left(\frac{1}{\mathrm{SEER}_b} - \frac{1}{SEER_i}\right) \times EFLH_c \div 1{,}000$
Per ton kWh impact for "no cooling" baseline	$BTU/ton \times \left(\frac{1}{SEER_i}\right) \times EFLH_c \div 1{,}000$

*Consistent with a study on DHP performed in Massachusetts[19], when the baseline system is delivered via ductwork, we assume additional 15% savings due to duct leakage.

3.3.3.2 Emissions Calculation Methods

The study estimated emissions reductions due to changes in electric and fossil fuel use due to the installed DHP units. The analysis used the available emission factors to calculate the amount of emissions saved using the formula shown in Equation 3-1: Emission Savings Calculation.

Equation 3-1: Emission Savings Calculation

$$\text{Savings Data (kWh) x Emission Factor (MT } CO_2e \text{ / unit) = Emissions Saved (MT } CO_2e\text{)}$$

Using this equation, known emission factors are used to convert energy usage or other activity data into associated quantities of emissions. Emissions factors are usually expressed in terms of emissions per unit of activity data (e.g. metric tons of CO_2 per kWh of electricity). The U.S. EPA's eGrid[20] was used as the source of emissions data for the New England Region. Applying the regional emissions factor is useful due to the imprecise available supply balance of electricity generated and consumed. For these calculations, we used the 2016 summary data. Note that the data reported for eGRID is source-based emissions data, i.e. the emissions take into account the fuel mix of the generation assets that supply the power grid. Applying the eGRID to programs savings data therefore results in saving estimates that are source-based rather than site-based.

The emissions factors from eGRID include emissions from carbon dioxide (CO_2), methane (CH_4) emissions as well as nitrous oxide (N_2O) emissions, the sum of which is known as the total equivalent (CO2e) emissions

[19] Ductless Mini-split, Heat Pump Study, Final Report, Cadmus, December 30, 2016 (p.51)
[20] https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

factor. Table 3-8 provides the electricity emissions factor used, however, customer choice and increasing rates of renewable energy on the grid can yield much lower electric emission factors 9including zero)

Table 3-8: New England Region 2016 Electricity System Emissions Rate

Regional Transmission Organization	CO_2 Emission Factor (lbs CO2 / MWh)	CO_2 Emission Factor (MT CO2e / kWh)
NPCC New England	563.7	0.0003

The second aspect taken into consideration is emissions from natural gas use and home heating oil. Similar to the electricity emissions calculations, real consumption or savings data was associated with a universal emission factor to calculate natural gas emissions. For natural gas, the analysis used an emissions factor reported by The Climate Registry (TCR)[21]. TCR data is a globally accepted source for producing greenhouse gas emissions inventories. TCR does not include CH_4 or N_2O emissions factors because these emissions are considered to be *de minimis* in natural gas fuels. The factors for home heating oil are reported by the US EPA[22]. For these savings estimates we calculated a CO_2e factor based on the CO_2, CH_4, and N_2O emissions associated with Distillate Fuel Oil No. 2. The emission factors are shown in Table 3-9.

Table 3-9: Natural Gas and Fuel Oil Emissions Factors

Fuel Type	Emissions Factor	Unit
Distillate Fuel No. 2	0.007396	MT CO_2e / Therm
Natural Gas	0.00531	MT CO_2 / Therm

3.3.4 DHP Contractor Interviews

This section describes the interviews conducted with 23 HVAC contractors who participated in the program from January 2016 through June 2017. It was assumed that participating contractors accounted for the majority of HE DHP installations in Connecticut. The data collected in the survey were used to derive estimates of the DHP market in Connecticut. The market size for supplemental and replacement installations, assumed the ratio for installations were the same for nonparticipating contractors as for participating contractors.

Figure 3-2 presents the research topics addressed in the DHP contractor survey. The complete interview guide is provided in APPENDIX C.

[21] https://www.theclimateregistry.org/wp-content/uploads/2016/03/2015-TCR-Default-EFs.pdf

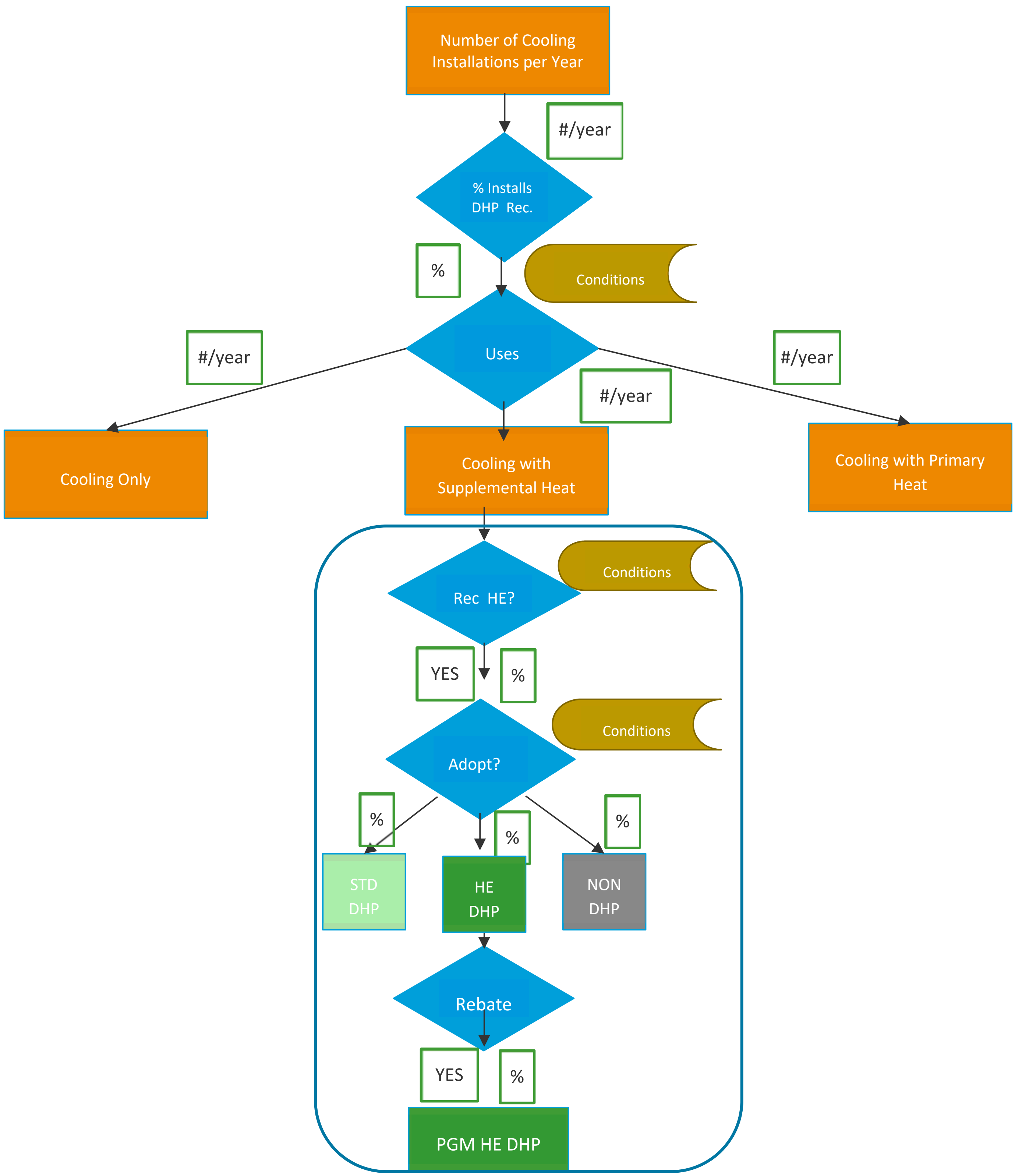
[22] https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

Figure 3-2: Contractor Survey Research Topics

Markets Served	Market Size	Home Characteristics and Adoption	Sales Strategy
• Type of HVAC equipment installed • Market segments served by contractor: new construction, replacement or expansion of existing homes, and/or installation of equipment to supplement existing equipment	• Annual number of cooling /heating installations • Frequency of replacement • % installations DHP recommended: intended space condition usage, % of cold weather DHPs recommended • Intended space condition usage for program eligible DHP • Adoption rate for program eligible DHP	• Characteristics considered or required when recommending DHP: ducts, presence of gas, floor plan, intended use, existing back-up system • Factors determining adoption of program eligible DHP • % customers receiving EnergizeCT DHP rebate	• Recommend DHP and upsell to program eligible DHP • Recommend program eligible DHP and then offer standard DHP • Approach varies by customer needs • Only sell program eligible DHPs

The analysis isolates the segment of the heating and/or cooling market where standard and HE DHPs are recommended and adopted. Furthermore, the analysis identifies the characteristics of the home and space conditioning requirements that influence contractors' recommendations of DHPs. Figure 3-3 indicates how the survey information was used in the decision tree analysis for cooling with supplemental heating installations. It first identifies the total number of annual cooling installations and the percentage of those installations where DHPs were recommended. The recommended DHP installations are then broken out by usage type. Within each usage type, the recommended DHP installations are further disaggregated into standard and HE DHPs. Finally, the number of program eligible DHPs is determined by applying the adoption rate for HE DHPs reported by contractors and the percentage of customers who apply for a rebate to the number of recommended HE DHPs. The structure and calculations are the same under each event type but shown only for the replacement/expansion event. The actual results from each line of inquiry are provided in Appendix D.

Figure 3-3: Contractor Survey Decision Tree



3.3.5 Adoption Model Methods

3.3.5.1 Overview

The study included modelling how program participation could be expected to change under different program scenarios and market conditions. To allow program planners to obtain projected participation under different scenarios, an Excel-based modelling tool was developed to quantify the effects of changes in the rebate level and in the price of alternative sources of fuel (fuel oil; natural gas; propane; wood, pellets, or coal; and electricity). Depending on how the user adjusts these parameters in the planning tool will determine the electric and non-electric impacts. If there is a larger switch from non-electric fuel to DHPs, then the overall electricity consumption may go up while the consumption of non-electric fuels will go down. However, assuming the user does not drastically change the allocation of the population groupings in the model, as the number of people participating in the program increases (within the range considered in this model), there is always a reduction the amount of carbon dioxide that is produced.

This section presents the source of the data used to estimate the model parameters, the structure of the model, and some of the trends in the results produced in the analysis. A detailed description of how to use the adoption modelling tool, and tool itself, is included in APPENDIX E.

3.3.5.2 Adoption Model Analysis Methods

This section reviews the data, model structure, and application of the tool. It is followed by a discussion of tool parameters and an example of results produced by the tool for a user-defined scenario.

3.3.5.3 Data

The main source of data for the analysis was the telephone survey of 90 DHP program participants. The survey asked participants about home characteristics, previous existing or alternative heating fuel(s), the characteristics of the DHP installation, and the likelihood of still buying the same (program-eligible) DHP if alternate fuel prices were less favorable or the rebate was smaller. Based on the results of the survey, the analysis grouped the population of participants into segments based on a combination of three, binary characteristics:

1. Type of home – single family vs. multi-family
2. Pre-existing heating fuel type – electric vs. non-electric
3. Intended use of the DHP – cooling only vs. heating with or without cooling

To determine participant price responses at varying program parameters (rebate levels) and market conditions (fuel prices) for the different population segments, participants were asked about their likelihood of buying the same DHP in the absence of the program. To measure the effect of changes in the rebate level, participants were asked how likely they would have been to install the program-eligible DHP if the rebate were: 20% lower, 33% lower, half as much, and not available. To measure the responsiveness to changes in the price of alternate fuel, participants, were asked how significant the price of alternate fuels, including fuel oil; natural gas; propane; and wood, pellets, or coal, was in their decision to install a program eligible DHP. If they responded that none of these fuel types were significant in their decision, responses were classified as still very likely to adopt an eligible DHP for all alternative fuel price levels. If they responded that at least one of these fuel types were significant, they were asked how likely they would have been to install the same DHP if the price of the alternative fuel had been: 20% lower at that time, 33% lower at that time, 50% lower at that time, and 75% lower at that time.

The questions asked for a response on scale of 1 to 5 where 1 is 'very unlikely,' 3 is 'neutral' and 5 is 'very likely. To translate these into probabilities of still purchasing, the model mapped the numbers or phrases into probabilities. Table 3-10 presents the mapped probabilities used in this analysis. A response of 5 equates to a high likelihood of still adopting the DHP, which is mapped to a 95% probability. By comparison, a response of 1 equates to a high unlikelihood of still adopting the same DHP, which is mapped to only a 15% probability. This is an asymmetrical mapping where "highly likely" is closer to 100% than "highly unlikely" is from 0, and similarly for "likely" and "unlikely."

Table 3-10: Mapped Probabilities of DHP Adoption Based on Participant Stated Likelihood of Still Adopting HE DHP

Response Number	Description on Participant Survey	Mapped Probability
1	Highly unlikely	15%
2	Unlikely	35%
3	Neutral	50%
4	Likely	85%
5	Highly likely	95%

3.3.5.4 Model Structure

To estimate differential price effects according to key customer characteristics, the tool incorporates a set of log-log regression models. These models were fit to the mapped probabilities across all customers of adopting the same DHP at varying price points. Equation 3-2 shows the functional form of the model. The models also account for differences between the population segments. The equation can be interpreted by saying a 1% change in X is associated with a B_1% change in Y, so B_1 is the elasticity of Y with respect to X. Appendix E lists all the coefficients and their standard errors for both the rebate and alternative fuel models.

Equation 3-2. Functional form of the log-log model

$$\ln Y = \beta_0 + \beta_1 \ln X + \varepsilon$$

Where:

Y = probability an individual will participate

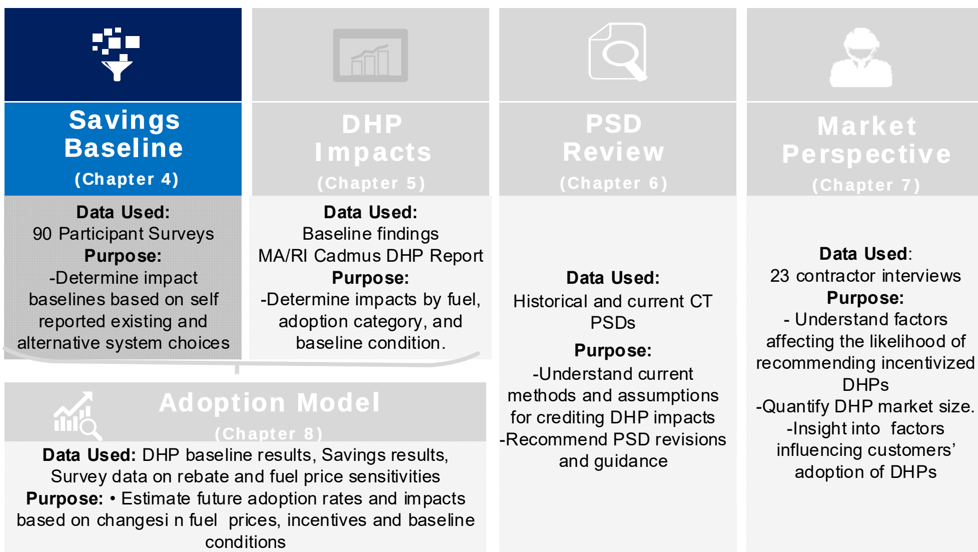
X = ratio of price point compared to 2015 level

The fitted models provide the overall elasticity of adoption with respect to each price variable. This elasticity represents the average responsiveness across the participant population segments. While the actual distribution of participant use cases and characteristics is unknown, the survey respondents provide the best available estimate of these characteristics. Thus, an elasticity that is effectively the average responsiveness across the survey respondents is a meaningful estimate of the average across the current participants.

4 DHP BASELINE ANALYSIS FINDINGS

This section of the report presents the results of the baseline analysis (Figure 4-1). There are many factors that complicate the determination of a savings baseline for this technology. These include determining at the individual head (indoor wall-mounted units) level whether and how the served space was previously heated or cooled (vs a new space), understanding how the customer is actually using the new unit to heat or cool the served space (which may differ from how they may have intended to use it), and the likely alternative heating or cooling system they would have installed (driven in part by level of awareness of standard DHP alternatives).

Figure 4-1: DHP Baseline Analysis



A systematically designed survey performed with participants was used to drive this analysis. This section begins with a summary of the analysis approach and presents key findings. After that we review the detailed results and findings, including information on the homes and locations where the units were installed, pre-existing systems used to heat or cool the space and the systems that would have been installed in the absence of the DHP purchase.

4.1 Key Findings about DHP Baselines

The cooling and heating system savings baseline at the head level were developed based on one of three scenarios, as bulleted below. In the final analysis, all respondents determined to be free riders were removed from the analysis. The questions used to gather the baseline information inquired about all spaces and square footage served by each indoor head and allowed multiple baselines per head.

- When a DHP head location is currently providing heating or cooling to a space that did not have a pre-existing system (additions, etc.) the analysis uses the reported technology that would have been installed in the absence of a DHP as the baseline. The baseline is unconditioned when a respondent indicates the space would have remained uncooled or unheated.

- When a respondent reported that they would have continued to use the pre-existing system to heat or cool the space, the analysis uses the pre-existing system as the baseline.

- When a respondent indicated that they were no longer going to use their pre-existing system at the time of deciding to install the DHP, the reported technology that would have been installed is used as the baseline.
- Respondents determined to be free riders are not included in the baseline results.

Table 4-1 presents the final heating and cooling baselines based upon respondents determined not to be free riders (i.e., after removing the 29 respondents who reported they were very likely to install their DHP absent the rebate). This baseline accommodates the fact that customers who were very likely to have installed the DHP absent the program (free riders) should not influence the program baseline. This final refinement only marginally changed the cooling baseline based on all respondents presented earlier but did reduce the electric heating categorization substantially in the heating baseline (from 23.6% to 17.6%).

Table 4-1: Heating and Cooling Baselines

Heating Savings Baseline (Non-free riders only)

System Type and Fuel	Heads=101
Furnace - Oil	32.2%
Electric Resistance	17.6%
Boiler - Oil	32.2%
No Heating	3.0%
Furnace - Gas	9.9%
Solar	2.0%
Other	0.0%
Stove - Gas	1.3%
Boiler - Gas	1.0%
Stove - Pellet	0.4%
Stove - Wood	0.4%

Cooling Savings Baseline (Non-free riders only)

System Type	Heads=112
Window AC	41.9%
Central Air	30.3%
No Cooling	26.0%
Wall Mount AC	1.8%

As part of this analysis, we observed participant responses that suggest that many customers might be installing DHPs in lieu of central AC systems for economic or ease of installation reasons and that there is substantial heating use that is accompanying that decision. The most frequent rooms cited as served by the DHP installations were family rooms, bedrooms, and kitchens.

4.2 DHP Baseline Analysis and Results

The 90 participants surveyed installed 123 DHP outdoor compressor units with a total of 210 indoor heads. Program participants were permitted to install more than one program DHP in their home in any combination of exterior and interior units. Thirty-one participants had only a single head installed, 21 installed two heads, 11 installed three heads, and 26 installed more than three heads. In the interest of keeping survey length (and time) manageable, for the participants that installed more than three heads, the survey asked questions about the four heads the participant considered the most important for their heating and cooling needs.

4.2.1 Housing Characteristics

Table 4-2 presents the house style where the program DHPs were installed, as reported by respondents. Most respondents (67) installed them in single family homes. The balance was installed in duplex or two-family style homes (three respondents) or apartment style units with two or more apartments in the building (four respondents).

Table 4-2: Participant House Types

House Type	Number
Colonial	31
Ranch	21
Cape Cod	15
Farm-style	7
Contemporary	7
Bungalow	1
Converted Barn	1
No Answer	7
Total	**90**

Table 4-3 presents the year of construction of the homes that DHP was installed in. No homes were new construction. Nearly all homes where a DHP was installed were built before 2000, with nearly two thirds built before 1980. In the rightmost column, we provide the percent of Connecticut homes constructed in those years according to the census bureau[23]. Overall, homes with the program DHP installed are slightly older than those in the general Connecticut population, although the difference is marginal.

Table 4-3: Year of Home Construction

Year of Construction	Respondents		CT 2016 Census
	Number	Percent	Percent
Before 1940	17	19%	21%
1940 - 1959	19	21%	22%
1960 - 1979	23	25%	28%
1980 - 1999	25	28%	20%
After 2000	5	6%	9%
Don't Know	1	1%	0%
Total	**90**	**100%**	**100%**

4.2.2 DHP Location and Use

Respondents were asked about the portion of their home served by the DHP units. Eleven respondents reported their DHP was installed to serve a new addition to their home, 41 reported the new unit serves part

[23] https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

of their existing home, and 38 indicated the entire home is served by the new unit. Table 4-4 provides further information on the nature of the DHP installation.

Table 4-4: Portion of Home Served by DHP

Portion of House	Number	% of Sample
Entire Home	38	42%
Part of Existing Home	41	45%
Addition	11	12%
Total	**90**	**100%**

This rate of installations serving an entire home is substantial. One possibility is that the installation of ductless heat pumps is cheaper than installing a ducted system in homes that want to get cooling throughout their home. To examine this issue further, we tabulated these results against other survey results. In Table 4-5 we present responses regarding the portion of the home served by the installed DHP for heating and/or cooling needs. Among the 38 homes who reported the DHP serves their entire home, 34 (~90%) reported they use their DHPs for heating and cooling with half of the remainder reporting they use it for heating only and half for cooling only. This rate of both heating and cooling use is moderately higher than those units reported to serve part of existing homes. These results do suggest that many customers might be installing DHPs in lieu of central AC systems for economic or ease of installation reasons and that there is substantial heating use that is accompanying that decision.

Table 4-5: Portion of Home Served by Program Ductless Heat Pumps

Current Use	Installed to Serve			
	Addition	Entire Home	Part of Existing Home	Totals
Heating	1	2	2	5
Cooling	0	2	7	9
Both	10	34	32	76
Totals	**11**	**38**	**41**	**90**

Table 4-6 presents responses regarding the portion of the home served by the installed DHP to the presence of a pre-existing heating or cooling system. The three additions with a heating pre-existing system might be instances where the addition was off an area where its pre-existing system was being used for an interim period before DHP installation.

Table 4-6: Portion of Home Served by Pre-existing System Presence

Heat/Cool	Pre-Existing System	Installed to Serve			
		Addition	Entire Home	Part of Existing Home	Totals
Heating	Yes	3	29	36	74
	No	8	9	5	16
	Totals	11	38	41	90
Cooling	Yes	1	27	30	66
	No	10	11	11	24
	Totals	11	38	41	90

Figure 4-2 presents the fraction of rooms served by the 196 installed DHP heads regardless if the head serves multiple rooms due to building construction or occupant behavior. For example, 34% served bedrooms in whole or part, 29% served family/living rooms, etc. The question allowed respondents to answer more than one room if a head served more than one type. Nearly two-thirds of the installed DHP heads serve bedrooms and family/living room spaces with the two next most common room types as kitchen and dining rooms. The 'other' room type includes sunporches, great rooms, small offices, garages, dance studios, etc. When we examined patterns of installation when multiple heads were installed, we found that 56% of those installations served a common space and a bedroom.

Figure 4-2: Rooms served by Program DHP

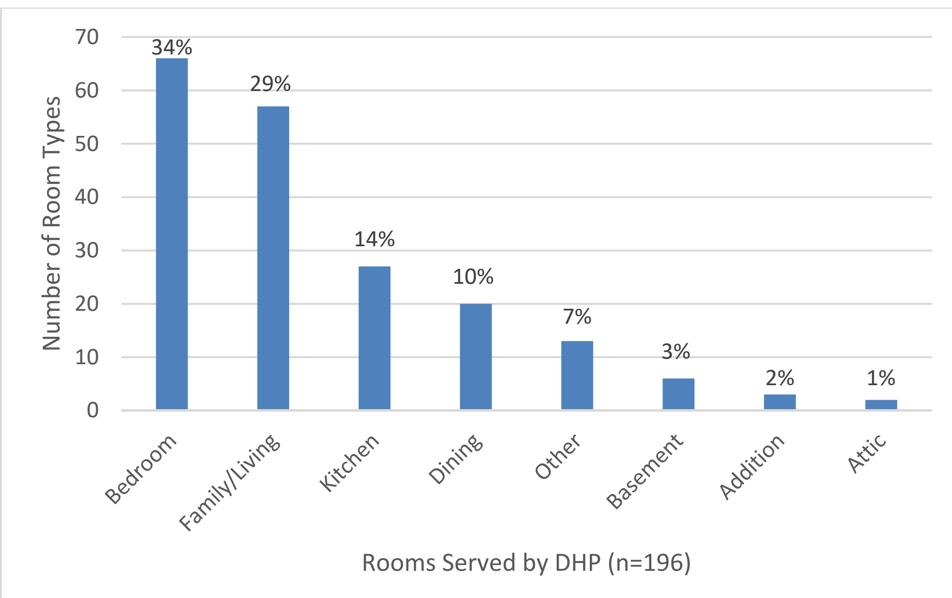


Table 4-7 presents how many of each type of room is served among the 90 homes with a program installed DHP. For example, among the 90 participants contacted 70% installed a DHP head in a family or living room and 58% installed one in a bedroom.

Table 4-7: Rooms served by Program DHP

Room Type	N	%
Family room/living room	63	70%
Bedroom	52	58%
Kitchen	29	32%
finished basement	10	11%
Other	8	9%
Addition/Attic	7	8%
Sunroom	4	4%
Bonus room	3	3%

Connecticut program participants were queried on how they originally planned to use their DHP versus how they ended up actually using the DHP: cooling, heating, or both. More than three-quarters of respondents (70 of 90) are using the DHP as originally intended, as shown in Table 4-8. The only significant deviation from the original purpose of the DHP were 17% of respondents (15 of 90) who reported they planned to use the DHP only for cooling but eventually decided to heat the spaces served with the DHP. Ten of these 15 respondents had pre-existing cooling systems.

We examined the circumstances around the fifteen respondents who reported they are now using the DHP for heating though they did not originally intend to do so. All but one of them reported they were primarily displacing gas- or oil-fuel furnace or boiler pre-existing systems with the DHP heating use. One of them reported their electric resistance system was displaced. The reported intended use of these systems is very similar to that observed in the Massachusetts DHP study in 2016[24]. In the Massachusetts study, 66% of 116 participants stated they intended to use the DHP for both heating and cooling, which is the same as the findings here (67%). Reported intentions for cooling-only and heating-only use were also very similar with roughly 30% and 5% reporting those planned uses, respectively.

Table 4-8: Intended versus Actual use of Program Ductless Heat Pumps

Intended Use	Current Use			
	Heating Only	Cooling Only	Both	Totals
Heating Only	3	0	2	5
Cooling Only	1	9	15	25
Both	1	1	58	60
Totals	**5**	**10**	**75**	**90**

4.3 Existing and alternative systems

In the survey, participants were asked about both the pre-existing system and the likely alternative that would have been installed in place of the DHP unit separately for both cooling and heating systems. In the first part of this section we review responses regarding their pre-existing system, then provide results for

24 The Cadmus Group, Inc. and COOL SMART Impact Evaluation Team (2015), *Ductless Mini-Split Heat Pump (DMSHP) Baseline Determination*, Prepared for Massachusetts Program Administrators, www.cadmusgroup.com

alternative systems considered and what respondents were most likely to do in the absence of the DHP. Eight heating system types[25] and eight cooling systems[26] were provided to the participants to categorize the variety of pre-existing systems. The results listed in this section are provided at the head level where the program DHP is currently used to provide some or all of the heating or cooling load of the space. If the participant is not using the program DHP for heating or cooling, they are not considered part of the baseline determination (for that particular use).

4.3.1 Pre-existing Systems

4.3.1.1 Heating Systems

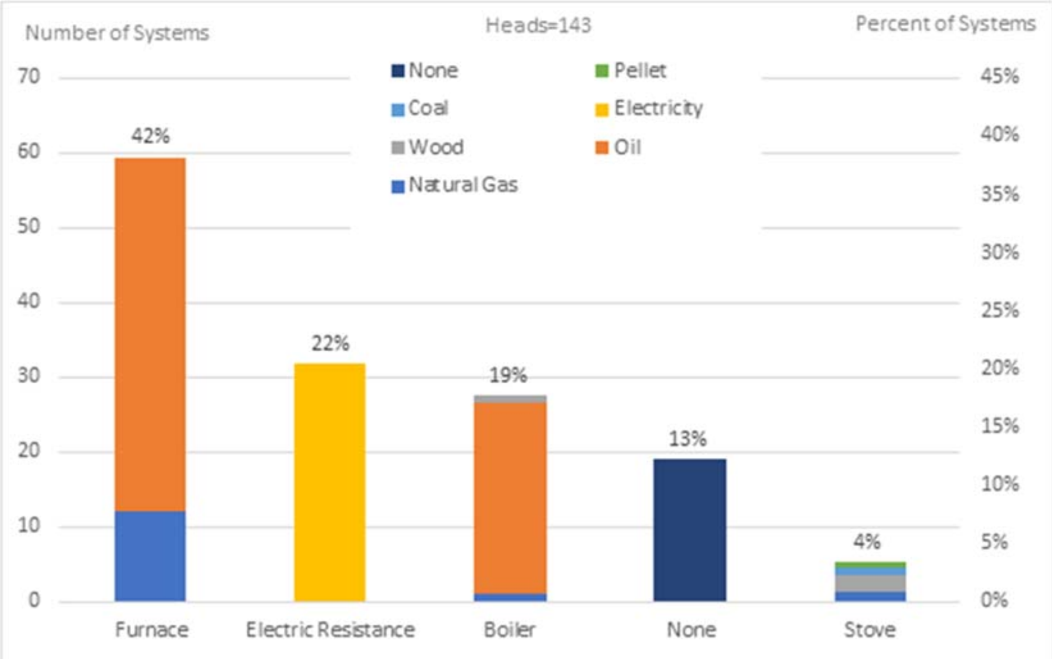
A total of 167 head level responses were recorded for pre-existing systems and the corresponding alternative systems the program participant most likely would have installed in the absence of the program DHP. Unfortunately, some head level responses did not have sufficient information for categorization into a pre-existing heating system and several heads are not used for heating, resulting in 143 head level responses.

Figure 4-3 shows the number and percent of pre-existing heating system types reported to previously serve the spaces now heated by the program DHP. Four pre-existing technologies were reported to provide the heating loads prior to the program DHPs. Most systems (65%) were fossil or carbon-based fuel systems including furnaces, boilers, and stoves. Among the pre-existing systems, 80% of furnaces and 93% of boilers were fueled by oil. Twenty-two percent of replaced systems were low efficiency electric resistance units that include plug-in heaters, wall units, and electric radiant systems. Thirteen percent of spaces did not have pre-existing heating systems. None of the spaces were served by a pre-existing DHP. These are reflected in the ‘none’ category and are considered unconditioned in the pre-existing state. These unconditioned spaces are mostly garages, attics, the third floor of houses, and new additions.

[25] Heating systems were furnaces, boilers, electric resistance units, stoves, standard DHPs, heat pumps, wall units, or plug-in heaters

[26] Cooling systems were central air, window air conditioner (AC) unit, wall mounted AC unit, ductless mini-split AC units, standard DHPs, high-efficiency DHPs, or heat pumps

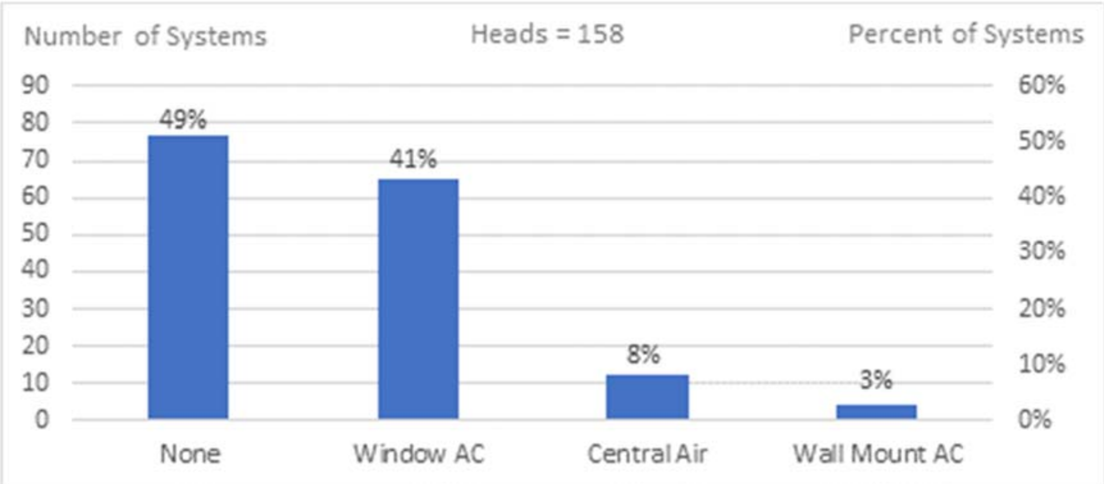
Figure 4-3: Pre-existing Heating System Type and Fuel Source by Head



4.3.1.2 Cooling Systems

The number of program DHP heads in use for cooling totaled 158 heads. Roughly half of participant spaces now served by a program DHP were unconditioned and did not contain a pre-existing system, as shown in Figure 4-4. Three technology types were reported as pre-existing systems installed in the spaces now served by the program DHPs. Window air-conditioner (AC) units were the most popular with 41% of spaces using these units to meet the cooling need followed by a distant second minority of 7.6% using central air and 2.5% using a wall mount AC unit. No respondents reported they had a pre-existing DHP serving the cooling needs of a location where the new DHP now serves.

Figure 4-4: Pre-existing Cooling System Type by Head



4.3.2 Likely Alternative Technologies in Absence of DHP

While the above discussion focuses on the pre-existing heating and cooling systems, this section discusses what the participant would have installed in the absence of the DHP system. This section begins with a discussion of what respondents reported they would have installed in spaces that were not previously conditioned. This includes opportunities to expand their previous system to previously unconditioned areas now served by the DHP. We then review overall findings related to what respondents would have done to serve the heating and cooling needs of the space had the DHP not been installed.

4.3.2.1 Alternatives Considered in Previously Unconditioned Spaces

As part of our survey, we asked participants with previously unconditioned spaces what they considered installing in the absence of the DHP unit. There were 19 program DHP heads providing heating in spaces that previously did not have a heating system and 77 installed in spaces that previously did not have a cooling system. This is not surprising as cooling systems are more of an amenity and heating systems a necessity in the Northeast.

In the absence of the DHP, 40% of respondents reported they would have installed electric resistance heating and 20% would have installed an oil boiler. Few would have left the space unheated. Conversely, 40% reported they would have left their space uncooled. Among the remaining respondents who did not have previous cooling in the space, half reported they would have installed window conditioners and half would have installed central air conditioning systems. The 26% that would have done central air suggest that they would have done a whole house solution had the DHP not been installed (as shown in Table 4-9).

Table 4-9: Alternative Systems Likely Installed in Unconditioned Spaces

New Technology	Number of Heads	% of Unconditioned Spaces
Heating		
Electric Resistance	8	42.1%
Boiler - Oil	4	21.1%
Previously Unconditioned	3	15.8%
Furnace – Oil	2	10.5%
Furnace – Undetermined Fuel	2	10.5%
Total	**19**	**100%**
Cooling		
Previously Unconditioned	31	40.3%
Window AC	22	28.6%
Central Air	20	26.0%
Wall Mount AC	2	2.6%
Ductless Minisplit	1	1.3%
Portable AC	1	1.3%
Total	**77**	**100%**

Table 4-10 presents results for the subset of respondents from Table 4-9 that reported they did not have pre-existing cooling or heating systems serving the space now served by the DHP but did have an existing central system in their home available for expansion into that space. There were relatively few respondents who had this opportunity (eight heating and three cooling) and even fewer that reported they considered expanding their central systems. Three respondents reported they considered expanding their heating or cooling system, but either could not find a contractor to perform the expansion, wanted local control over their settings or opted for the efficiency in the program DHP. Overall, there were few people who were able to consider expansion of their previous system, with fewer still ultimately regarding it as a viable alternative.

Table 4-10: Opportunities Considered for System Expansion

System	Heads Available for expansion	Considered	Reason why not expanded
Heating			
Furnace	6	1	"Considered existing system, oil furnace, but couldn't find anybody to extend system to (unheated) finished basement. Didn't consider any other options other than existing system and HE DHP."
Boiler	1	1	"We wanted separate control of the comfort in that space and contractor recommended against."
Heating Stove	1	1	"Looking for energy efficiency."
Cooling			
Central Air	3	1	"We wanted separate control of the comfort in that space."

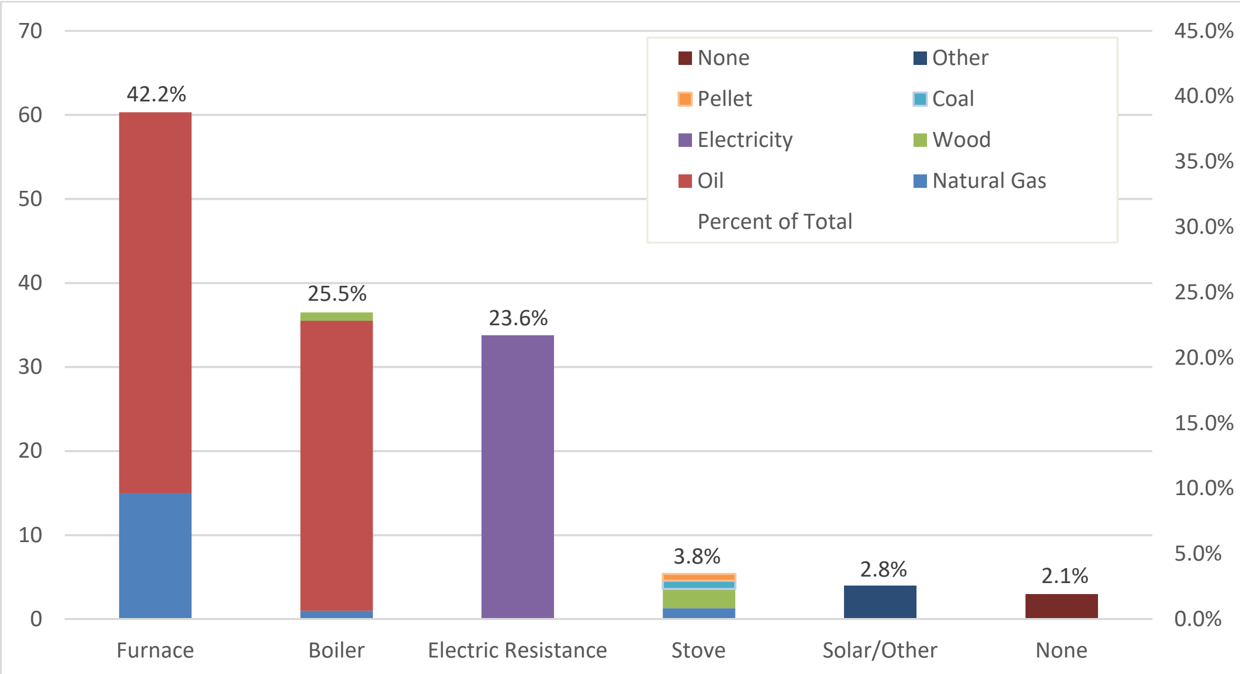
4.3.2.2 Heating Systems

Figure 4-5 presents the final responses regarding the system that respondents would have used to serve their heating needs in the absence of the DHP (after asking about all alternative systems including expansion considerations, how they would have handled previously unconditioned spaces, etc.). The information in this figure is for those heads that are currently being used for heating.

It is clear that participants wanted to provide heating to their unconditioned spaces in light of the reduction in unconditioned spaces from 12.9% (see Figure 4-3) to 2.1%. Other differences between the earlier reported pre-existing systems and these results include an increase in the number of boilers, electric resistance units, and stoves that the participants would have chosen to install. The number of furnaces remains unchanged. The 'other' category contains two heads from a participant that considered a passive solar system and 2 unclassified central air/heat systems of a participant due to an inability to classify the specific fuel type which would have slightly increased the number of furnaces considered.

Responses in the 'none' category includes those head locations where the respondent indicated they would not have heated the space in the absence of the DHP. These spaces included one non-purposed basement, one finished basement, and one attic.

Figure 4-5: Likely Heating System Installed in Absence of DHP



Comparing Figure 4-5 to Figure 4-3, it is clear that the majority of respondents reported that the pre-existing technologies were the most likely system to be used in the absence of the DHP. In fact, this was the case for 85% of the heads used for heating. However, there was still a moderate number of respondents who reported that they would have chosen a different system (had they not installed the DHP) reflected in Figure 4-5. Table 4-11 shows the movement from the pre-existing systems to the system that would have occurred in the absence of the DHP. For example, seven oil fueled furnaces would have switched to a boiler or electric resistance, while one gas furnace would have switched to electric resistance. Nine electric resistance units would have switched to furnaces and boilers. Finally, 16 spaces that did not have a pre-existing system had other systems in mind to meet their heating needs had they not purchased the program DHP.

Table 4-11: Savings Baseline Changes from Pre-existing Systems

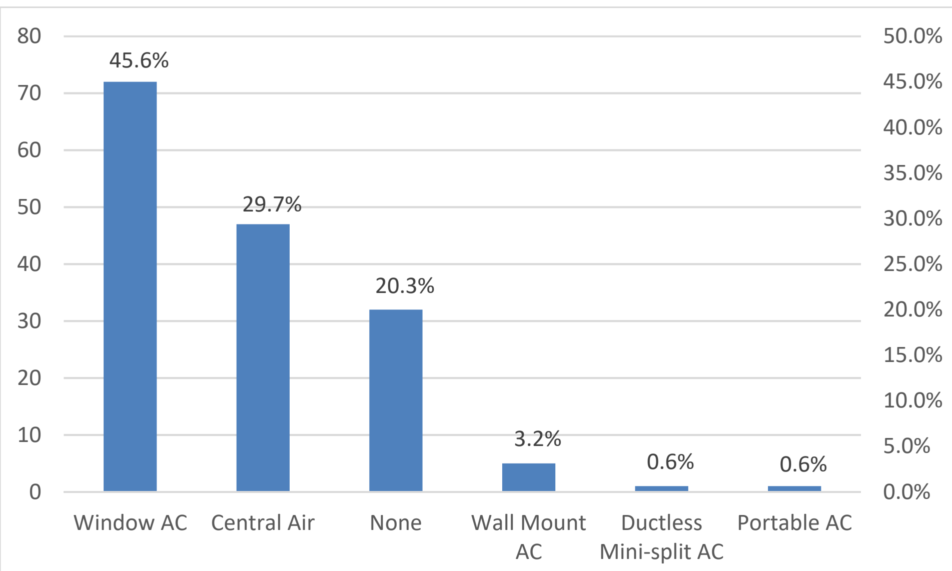
		(In the Absence of the DHP) I would have switched to…						
				Furnace				
Pre-Existing		Boiler (Oil)	Electric Resistance	Gas	Oil	Propane	Other	Total
Boiler (oil)							2	2
Electric Resistance		3			3	3		9
Furnace	Gas		1					1
	Oil	4	2	1				7
None		4	8		2		2	16
Totals		**11**	**11**	**1**	**5**	**3**	**4**	**20**

4.3.2.3 Cooling Systems

The number of total head level responses in the cooling analysis is 158 heads. Recall that earlier we presented results that showed the pre-existing condition for nearly half of the locations had no air conditioning, 41% had window AC and 8% had central air conditioning. Figure 4-6 shows that in the absence of the DHP, window AC units would have remained the largest type of technology used to cover the cooling loads of these spaces with a small increase in adoption, though central air adoption would have increased substantially. The current PSD assumes a ductless mini-split AC unit as the baseline however, in this study only one respondent indicated that they would have installed that equipment type.

An increase specifically related to technologies that would have been adopted in the absence of the DHP to cover the cooling need of previously unconditioned spaces accounts for most of the increases in AC technologies. Twenty-two window AC units, 20 central air systems, 2 wall mount AC units, a ductless mini-split system, and a portable AC unit would have likely conditioned the previously unconditioned spaces had the program DHP not been installed. Other changes between the pre-existing condition and the cooling technologies that would have been installed includes 16 participants with pre-existing window AC units who would have replaced those systems with central air had the DHP program not been available. So even though window AC units remain the most likely to have met cooling needs in the spaces now served by the program DHP, a significant portion of previous window AC owners would have abandoned those systems for central air.

Figure 4-6: Likely Cooling System Installed in Absence of DHP



4.3.3 Heating and Cooling Baseline Results

Table 4-12 and Table 4-13 show the breakout of technologies and fuels that represent the heating and cooling baselines based upon the compiled fractions at the head level of the values presented in Figure 4-5 and Figure 4-6. These results include one of the following:

1) The reported technology that would have been installed when a DHP head is currently providing cooling or heating to a space that did not have a pre-existing system,

2) the pre-existing system when the respondent reported that had they not purchased the ductless heat pump they would have continued to use the pre-existing system, or

3) what the respondent indicated they would have installed if they were no longer going use their pre-existing system at the time of deciding to install the DHP.

Information gathered on the free ridership tendencies of respondents and the final savings baseline absent those deemed to be free riders are described below.

Table 4-12: Heating Savings Baseline (All Respondents)

System - Fuel	Heads=143
Furnace - Oil	31.7%
Electric Resistance	23.6%
Boiler - Oil	24.1%
No Heating	2.1%
Furnace - Gas	10.5%
Solar	1.4%
Other	1.4%
Stove - Gas	0.9%
Boiler - Gas	0.7%
Stove - Coal	0.7%
Stove - Pellet	0.6%
Stove - Wood	1.6%
Boiler - Wood	0.7%

Table 4-13: Cooling Savings Baseline (All Respondents)

System	Heads = 158
Window AC	45.6%
Central Air	29.7%
No Cooling	20.3%
Wall Mount AC	3.2%
Ductless Mini-split AC	0.6%
Portable AC	0.6%

Table 4-14 presents the likelihood of DHP installation under various rebate scenarios. This question was asked of all respondents and including inquiries on likelihood of install if the rebate were 10% lower, 20% lower, half that received, and if it had not been available. Eighteen respondents (20%) reported that absent the rebate they were very unlikely to install the program DHP. Twenty-nine (32%) reported they were very likely to install it absent the rebate. These 29 individuals are regarded as free riders.

Table 4-14: Likelihood of DHP Installation Under Different Rebate Scenarios

Likelihood of DHP Installation if rebate were ...	10% lower	20% Lower	Half	Not available
1 Very Unlikely	3	9	14	18
2	2	9	11	15
3 Neutral	16	17	15	15
4	18	13	14	8
5 Very Likely	47	37	31	29
DK	4	5	5	5
Total	**90**	**90**	**90**	**90**

Table 4-15 and Table 4-16 present the final heating and cooling baselines based upon respondents determined not to be free riders (i.e., not including the 29 respondents who reported they were very likely to install their DHP absent the rebate). This baseline accommodates the fact that customers who were very likely to have installed the DHP absent the program (free riders) should not influence the program baseline. This refinement only marginally changed the cooling baseline based on all respondents presented earlier but did reduce the electric heating categorization substantially in the heating baseline (from 23.6% to 17.6%).

Table 4-15: Heating Savings Baseline (Non-free riders only)

System Type and Fuel	Heads=101
Furnace - Oil	32.2%
Electric Resistance	17.6%
Boiler - Oil	32.2%
No Heating	3.0%
Furnace - Gas	9.9%
Solar	2.0%
Other	0.0%
Stove - Gas	1.3%
Boiler - Gas	1.0%
Stove - Pellet	0.4%
Stove - Wood	0.4%

Table 4-16: Cooling Savings Baseline (Non-free riders only)

System Type	Heads=112
Window AC	41.9%
Central Air	30.3%
No Cooling	26.0%
Wall Mount AC	1.8%

4.3.4 Additional Considerations

As part of a series of call back surveys we completed with 60 of the 90 participants to clarify pre-existing system information and alternate technologies considered, we asked several questions about familiarity with DHP technology, awareness of DHP efficiency options, and their experience with contractor provided options that might have been less efficient than that rebated through the program (see Table 4-17). These call-backs were attempted with all survey respondents with those completed intended to provide context around the results from all 90 surveyed participants. Most respondents were familiar with ductless heat pumps before talking with their contractor (82%), with nearly the same portion indicating they knew the DHP unit received through the program was high efficiency. Nearly two thirds of respondents (63%) were not aware of the availability of lower efficiency DHP units, which manifests itself in nearly no alternative baselines reported for standard efficiency units reported above.

We also examined the efficiency of heat pumps recommended and adopted as part of a series of 20 contractor interviews. Those results largely corroborated the information observed among respondents here. In those results, it was noted that when contractors recommend DHP, they recommend high-efficiency units between 77-100% of the time depending on the circumstances of the installation (new construction vs retrofit) and planned use (heating vs cooling). The majority of decision makers were reported to similarly opt for the high-efficiency unit with few selecting standard models (3-11%), depending on circumstance and planned use.

Table 4-17: DHP Familiarity and Contractor Experience (n=60)

Call back Inquiry	No	Yes	Don't Know	N/A
Were you familiar with DHPs before talking to the contractor?	11	49	0	0
Did you know the unit you received through the program was a HE DHP?	9	51	0	0
Did you know there are lower efficiency units on the market?	38	22	0	0
Did the contractor talk to you about an option to install a lower efficiency DHP that wouldn't have qualified for the rebate?	49	7	3	1

We cross tabulated awareness of lower efficiency units in the marketplace with several other questions in the survey to assess if there are particular characteristics associated with those aware of standard DHP units versus those that are not. We examined the presence of pre-existing heating and cooling equipment, purchase intention for heating and/or cooling use, and planned use of pre-existing systems to provide conditioning needs with the DHP for those aware versus not aware. No meaningful differences in responses between these two groups were found when examined in this way.

In the participant survey, we asked about how the use of the DHP has affected the use of other cooling and heating equipment in the home. These questions were geared toward understanding if respondents are switching their post room occupancy patterns to use their new DHP system in lieu of less efficient systems. new systems. Table 4-18 shows that when asked about the effect of the DHP on their use of cooling systems, 57% report that it has had no change while 30% indicate they are using the DHP to provide cooling to other rooms. Table 4-19 presents the frequency of DHP use to cool other rooms among the 30% that reported doing so in Table 4-18. The number that are using the DHP to cool other rooms 'all' or 'half the time' of the total sample of 90 is 23%.

Table 4-18: Effect of DHP on Use of Other Cooling Equipment

How has DHP affected the use of other cooling equipment in home?	n	%
I use DHP to add cooling to other rooms of home (leave doors open, lower thermostat in other rooms)	27	30%
I use this room more often and use other rooms less (shut door and isolate room, increase thermostat in other rooms)	6	7%

I use other rooms to cool this room (leave doors open, rely more on cool from other rooms)	1	1%
Other	5	6%
No Changes	51	57%
Total	**90**	**100%**

Table 4-19: Frequency of DHP use to Cool Other Rooms

Of those who reported adding cooling to other rooms of the home from the question above...would you say this extra space is being cooled by the DHP?	n	%
All the Time	17	63%
About Half Time	4	15%
Infrequently	4	15%
Don't know/don't remember	2	7%
Total	**27**	**100%**

Table 4-20 and Table 4-21 show the effect of the DHP on the use of heating in other rooms in the same manner the cooling results are presented above. Table 4-20 shows that when asked about the effect of the DHP on their use of heating systems, 52% report that it has had no change while 24% indicate they are using the DHP to provide heating to other rooms. Table 4-21 presents the frequency of DHP use to heat other rooms among the 24% that reported doing so in Table 4-18. The number that are using the DHP to cool other rooms 'all' or 'half the time' of the total sample of 90 is low at 12%.

Table 4-20: Effect of DHP on Use of Other Heating Equipment

How has DHP affected the use of other heating equipment in home?	n	%
I use DHP to add heating to other rooms of home (leave doors open, lower thermostat in other rooms)	19	24%
I use this room more often and use other rooms less (shut door and isolate room, turn down heat in other rooms)	10	13%
I use other rooms to heat this room (leave doors open, rely more on heat from other rooms)	4	5%
Other	3	4%
No Changes	42	52%
Don't Know	2	2%
Total	**80**	**100%**

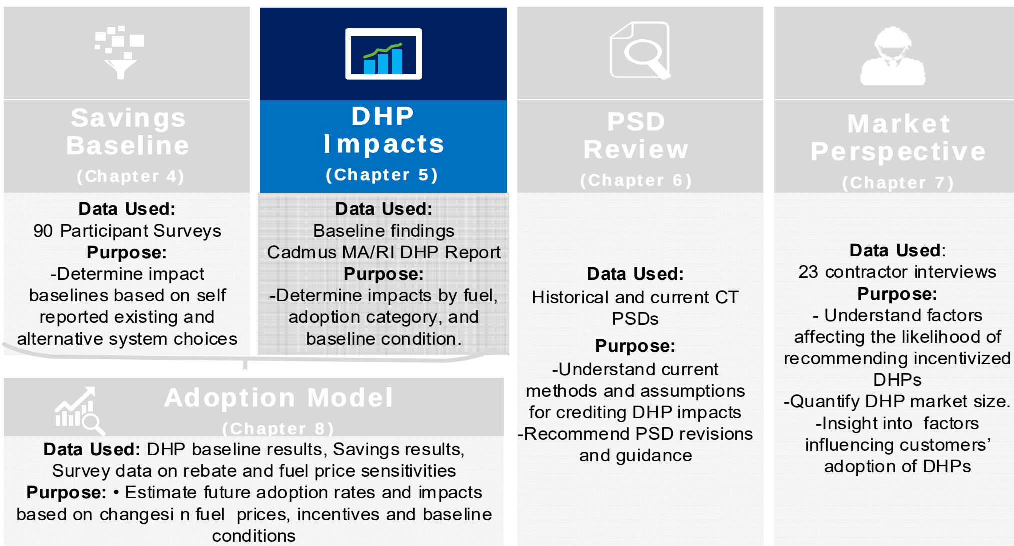
Table 4-21: Frequency of DHP use to Heat Other Rooms

Of those who reported adding heating to other rooms of the home from the question above ...would you say this extra space is being heated by the DHP?	n	%
All the Time	11	52%
About Half Time	2	9%
Infrequently	7	33%
Don't know/don't remember	1	5%
Total	**21**	**100%**

5 DHP PROGRAM IMPACTS

This section of the report presents the impacts of the DHP units. These results are calculated using the baseline results presented in Section 4.3.3 and include electric and fossil fuel impacts. The estimate of the consumption impacts for the key heating and cooling baselines used the analysis of metered data from a 2016 study of DHPs in Massachusetts[27]. This information was combined with PSD-based efficiencies for each baseline and event (lost opportunity vs retrofit) and the efficiencies of the installed DHP units.

Figure 5-1: Overview of DHP Program Impacts



After estimating these impacts, greenhouse gas emission savings were also calculated. The direct fuel savings impacts and the greenhouse gas impacts are a key part of the DHP market adoption model/tool. Specifically, all impacts were rolled up to the market adoption category of building type and heating/cooling fuel.

5.1 Key Findings about DHP Impacts

While this section includes normalized impacts relative to several heating and cooling technologies and fuels, the key impacts that are used in the adoption modelling tool are provided in the table below. These impacts use the appropriate baseline for each indoor head installed within each group used in the adoption model as discussed in Section 3.3.5.3. This calculation was made by using the indoor capacities installed and the normalized heating and cooling impacts per ton of rated capacity to that of each head and baseline. Note that in the final model, multifamily was collapsed into a single entry since the two sub categories only had one sample point in each. Table 5-1 summarizes the DHP impacts by adoption category. This table also includes an overall MMbtu impact for each adoption category that uses standard factors[28] to convert the site savings values. The overall weighted average savings is 10.7 MMBtu per home.

[27] http://ma-eeac.org/wordpress/wp-content/uploads/Ductless-Mini-Split-Heat-Pump-Impact-Evaluation.pdf

[28] 1 therm = 99,976 BTU,

Table 5-1: Fuel and Carbon Impacts by Adoption Category (avg per home)

Adoption Tool Category	n	kWh Impact (avg per home)	Therm Impact (avg per home)			Overall MMBtu Impact (avg per home)	Carbon Reductions (metric tons of CO2)
			Overall	Oil	Gas		
Multi Family Electric Heat	1	3,185.7	-	-		10.9	0.8
Multi Family Non-Electric Heat	1	-1,351.8	273 .4	273.4		22.7	1.7
Single Family Electric Heat	8	588.4	112.9	71.5	41.3	13.3	0.9
Single Family Cooling Only, Non-Electric Heat	12	-601.9	101.9	72.9	29.0	8.1	0.5
Single Family Not Only Cool, Non-Electric Heat	38	-713.4	130.5	123.9	6.6	10.6	0.8

5.2 DHP Program Impact Results

Table 5-2 shows the normalized per ton heating impacts by technology and fuel type for both retrofit and market baseline scenarios, including total MMBTU. The methods to develop these estimates are presented in Section 3.3.3. Savings based on a market baseline are lower than those with a retrofit baseline due to higher baseline efficiencies assumed in the former. Recall, market baselines were used when a participant reported they would have installed an alternative technology to serve the heating needs of the space served by the new DHP. Retrofit baselines were used when a participant reported they would have continued using their pre-existing system to serve the heating needs of the space served by the new DHP. A negative value in the kWh change column indicates a load build. For example, where the heating baseline has a fossil fuel there is savings in that fuel but an increase in electricity due to the DHPs heating use. This table also includes a column with the overall weighted therm impact per ton based on the number of heads deemed to have a retrofit versus market baseline from the survey data (Table 3-3).

Note also that these values include a 15% savings increase where appropriate to account for duct leakage savings that occur when a central system is replaced with a ductless system.

Table 5-2: Heating Impacts by Baseline Technology, Fuel, and Event (per Ton)

Baseline	Retrofit Baseline Therm Impact per Ton	Market Baseline Therm Impact per Ton	Weighted Therm Impact per Ton	kWh Impact per Ton	MMBTU Impact per Ton
Furnace - Oil	80.0	75.1	79.4	-513.8	6.2
Furnace - Gas	79.0	73.4	77.1	-513.8	6.0
Boiler - Oil	67.8	64.6	66.7	-513.8	4.9
Boiler Gas	67.0	63.8	65.4	-513.8	4.8
Electric Resistance	N/A	N/A	N/A	1,057.9	3.6
No Heating	N/A	N/A	N/A	-513.8	-1.8

Table 5-3 presents the normalized per ton cooling impacts by technology for both retrofit and market baseline scenarios. The retrofit and market baselines were applied in the same way as the heating impacts above. The central air conditioning impact per ton is higher than room air conditioners, particularly when customers reported the DHP unit displaced a pre-existing system. A no cooling baseline produces a load build of 132 kWh per year. As above, the final column shows the overall weighted impact per ton based on the number of heads deemed to have a retrofit versus market baseline from the survey data (Table 3-4).

Table 5-3: Cooling Impacts by Baseline Technology and Event (per Ton)

Baseline	Retrofit kWh Impact per Ton	Market Baseline kWh Impact per Ton	Weighted kWh Impact per Ton
Room Air Conditioner	142.4	73.9	122.0
Central Air Conditioning	206.2	85.0	95.4
No Cooling	-132.1	-132.1	-132.1

The DHP adoption tool required fuel impacts at the household level for five categories. These categories were determined by testing the significance of different independent variables on adoption, including home characteristics, the primary source of heat, the age of the home, where the DHP was located, the number of heads, and the intended use of the DHP (prior to purchase). More detail on the analytical process undertaken and selection of the key categories is provided in that portion of this report. In the final analysis, three binary variables were used to define the adoption categories: single family vs. multi family, electric vs. non-electric heat, and intended for cooling only vs. intended for cooling and/or heating.

To calculate the impacts at the household level for each adoption category, we assigned the appropriate baseline to each indoor head from the participant survey. Recall, the baseline analysis was ultimately founded upon only non-free riders, which are also the participants used in this analysis. We then gathered the indoor capacities installed by those participants from the tracking data. Next, we calculated the impact per head by multiplying the normalized heating and cooling impacts per ton of rated capacity to that of each head and baseline. In many cases, there is fuel switching occurring between the baseline and the installed DHP. In these cases, we use the estimated consumption of the DHP or baseline unit as the reported impact. The final step was summing the impacts by fuel (both positive and negative) across all heads in each adoption category and calculating the average per participant per category. These results are provided in Table 5-4 and are included in the DHP adoption tool impact estimates. This table also includes an overall MMbtu impact for each adoption category. The overall weighted average savings is 10.7 MMBtu per home.

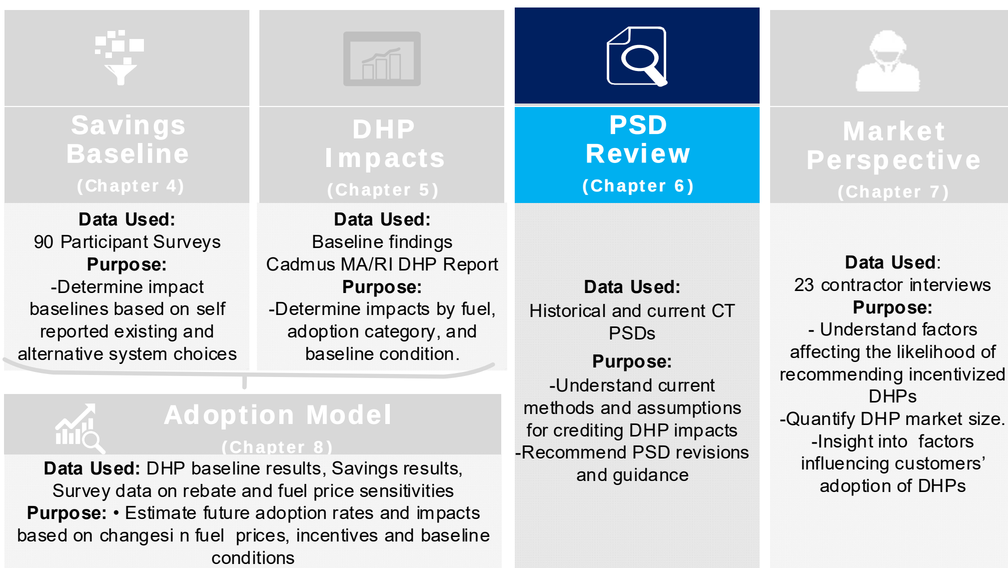
Table 5-4: Fuel and Carbon Impacts by Adoption Category

Adoption Tool Category	n	kWh Impact (avg per home)	Therm Impact (avg per home)			Overall MMBtu Impact (avg per home)	Carbon Reductions (metric tons of CO2)
			Overall	Oil	Gas		
Multi Family Electric Heat	1	3,185.7	-	-		10.9	0.8
Multi Family Non-Electric Heat	1	-1,351.8	273 .4	273.4		22.7	1.7
Single Family Electric Heat	8	588.4	112.9	71.5	41.3	13.3	0.9
Single Family Cooling Only, Non-Electric Heat	12	-601.9	101.9	72.9	29.0	8.1	0.5
Single Family Not Only Cool, Non-Electric Heat	38	-713.4	130.5	123.9	6.6	10.6	0.8

6 PSD REVIEW

This section of the report summarizes the 2019 PSD calculation, including the assumptions used to build up the savings estimates for lost opportunity and retrofit installation events (Figure 6-1). This examination reviews how the PSD is currently handling the impacts from DHPs and provides the foundation for recommending how the PSD can be revised to more accurately estimate those impacts moving forward.

Figure 6-1: Overview of PSD Review



6.1 Key Findings about the PSD Review

The 2019 PSD credits electric savings but not fossil fuel savings for program rebated ductless heat pump units, indicating a substantial lost opportunity for the program to claim savings and carbon reductions.

The 2019 PSD provides two savings calculations for electric kWh savings. Setting aside the assumed baselines that produce only electric savings, the formulas themselves are correct.

- The first is a lost opportunity calculation that is used to determine the savings for homes with a pre-existing fossil fuel heating system. This calculation method assumes the new DHP is displacing a standard efficiency ductless heat pump. This method is reported to be used for upstream rebated units.

- The second is a retrofit calculation that is used to determine the savings for homes with a pre-existing electric resistance heating system. This calculation method uses the electric resistance as the heating baseline and a SEER of 10.1 for cooling. This method is reported to be used for direct install heat pumps where the existence of electric resistance baseline is verified.

Though fossil fuel savings are not included in the 2019 PY PSD for DHP installations, their monetary benefits were included in the 2017 version of the PSD. It is unclear why this element of the PSD is not in in the 2018 and 2019 versions. In the absence of the calculation of fossil fuel savings from DHPs in the 2019 PY PSD, a substantial customer benefit and source of carbon reduction is not being claimed or credited to this measure.

6.2 PSD Review Results

The PSD for the 2019 program year (PY) offers two methods for estimating DHP energy savings. The first option is to use a default methodology with calculations and assumptions from the PSD. The second is to perform a custom analysis such as DOE-2 or billing analysis with a savings cap of 50% of heating consumption. This review is of the PSD calculation methodology, which is the method used to estimate the tracked (*ex ante*) savings impacts for the majority, if not all, of the program DHPs installed.

Below are the retrofit and lost opportunity (new construction) electric energy savings calculations. As indicated in the PSD, "A DHP installed in an existing home with electric resistance heating system is considered to have Retrofit savings. A DHP installed in a home with fossil fuel heating system is considered to have Lost Opportunity savings (or new construction). This calculation method produces electric savings from heating by either displacing resistance heat (retrofit) or a less efficient heat pump (lost opportunity/new construction). Electric savings from cooling assumes a baseline of 10.1 or 14.0 for retrofit and lost opportunity events, respectively.

Shown below, this PSD formula relies on direct inputs on the capacity and efficiency of the unit installed. The heating and cooling EFLH used in these calculations are from the Massachusetts Cadmus study on ductless heat pumps (2016).

$$\text{Retrofit: Annual heating kWH savings} = \text{CAP}_\text{H}\ \text{x}\left(\frac{1}{\text{HSPF}_\text{e}} - \frac{1}{\text{HSPF}_\text{I}}\right)\text{x EFLH}_\text{H}\text{x}\ \frac{1}{1{,}000}$$

$$\text{Retrofit: Annual cooling kWH savings} = \text{CAP}_\text{c}\ \text{x}\left(\frac{1}{\text{SEER}_\text{e}} - \frac{1}{\text{SEER}_\text{I}}\right)\text{x EFLH}_\text{c}\text{x}\ \frac{1}{1{,}000}$$

$$\text{Lost Opportunity (New Construction): Annual heating kWH savings} = \text{CAP}_\text{H}\ \text{x}\left(\frac{1}{\text{HSPF}_\text{b}} - \frac{1}{\text{HSPF}_\text{I}}\right)\text{x EFLH}_\text{H}\text{x}\ \frac{1}{1{,}000}$$

$$\text{Lost Opportunity (New Construction): Annual cooling kWH savings} = \text{CAP}_\text{c}\ \text{x}\left(\frac{1}{\text{SEER}_\text{b}} - \frac{1}{\text{SEER}_\text{I}}\right)\text{x EFLH}_\text{c}\text{x}\ \frac{1}{1{,}000}$$

where,

$\text{CAP}_\text{H} = \text{Nominal Heating Capacity in BTU/hr}$
$\text{CAP}_\text{C} = \text{Nominal Cooling Capacity in BTU/hr}$
$\text{HSPF}_\text{e} = \text{Heating Seasonal Performance Factor, Existing (3.413)}$
$\text{HSPF}_\text{I} = \text{Heating Seasonal Performance Factor, Installed}$
$\text{HSPF}_\text{b} = \text{Heating Seasonal Performance Factor, Baseline (8.2, code))}$
$\text{SEER}_\text{e} = \text{Seasonal Energy Efficiency Ratio, Existing (10.1)}$
$\text{SEER}_\text{I} = \text{Seasonal Energy Efficiency Ratio, Installed}$
$\text{SEER}_\text{b} = \text{Seasonal Energy Efficiency Ratio, Baseline (14.0, code)}$
$\text{EFLH}_\text{H} = 442$[29]
$\text{EFLH}_\text{C} = 218$[1]

Fossil fuel savings are not included in the 2019 PY PSD for DHP installations. However, the monetary benefit of fossil fuel savings was a part of the DHP entry in the 2017 PY PSD. That PSD version also explicitly indicates that savings from fuel switching are not claimed for DHP, although installations were likely producing such impacts but not claiming them. Neither element is present in the 2018 or 2019 PY PSD. This appears to be the result of standing board (EEB) policy that does not support fuel switching with ratepayer

[29] Ductless Mini-split, Heat Pump Study, Final Report, Cadmus, December 30, 2016 (Table ES-4, p. 6)

funds. In the absence of the calculation of fossil fuel savings from DHPs in the 2019 PY PSD, a substantial customer benefit and source of carbon reduction is not being claimed or credited to this measure, though it is accruing and could be. In the 2016-2018 C&LM Plan update filed in the spring of 2018, DEEP notes a plan to modify its benefit-cost methodology to reflect the full value experienced by customers, including greenhouse gas emissions. Fossil fuel savings can offer a substantial cost savings to customers and greenhouse gas savings to the state.

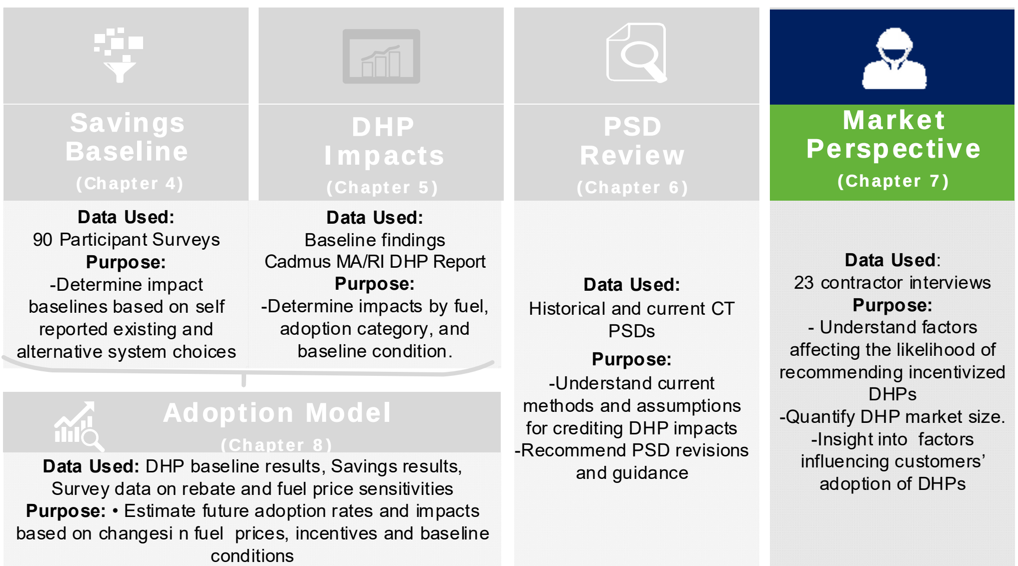
It is clear from the baseline result that the assumed measure baseline in this formula unrealistically oversimplifies the vast majority of baseline conditions observed in this study and is unlikely to produce an accurate estimate of savings. A key threshold issue in how to evolve the PSD to better reflect the true impacts of this measure lies in whether the EEB will allow ratepayer funds to support fuel switching moving forward for utility claimed purposes or as part of a larger effort to displace fossil fuels This study provides fossil fuel and electric impacts (including load building) in Chapter 5 that can be integrated into the PSD depending on the direction that the EEB and DEEP takes. This study also provides three ways the entry might be organized as part of its recommendations. These include those offered below or a system that allows any of the three paths, depending what is known about a given installation. Note that these approaches range with respect to cost, level of difficulty to coordinate and perform, and feasibility, depending program design.   For example, an upstream program with an instant rebate might only be able to reasonably use the blended baseline approach while installations recommended as part of an audit might benefit from the second approach.

- A blended baseline that weights the baseline conditions observed in this study and provides an average overall electric and fossil fuel impact per unit. This approach would produce impacts based on the population of projects at the time this study and could be updated as the nature of the installations change over time.
- A series of impacts based on defined baselines (e.g., natural gas furnace, electric resistance, etc.) that are dependent on a handful of easily identifiable characteristics of the project. This approach is more suitable for opportunities observed through audit offerings where pre-installation characteristics are known but is likely to be more challenging for mass market rebate offerings.
- A custom baseline that is determined on a case by case basis using techniques that are similar to those performed in this study. This approach would require a blend of understanding what, if anything, was serving the space prior to the DHP as well as what the customer would have done in the absence of the incentivized equipment. This approach would also require a system to produce the baseline condition based on the reported information.

7 DHP CONTRACTOR INTERVIEWS

This section of the report presents the results of the DHP contractor interviews (Figure 7-1). The contractor interviews provided the basis for quantifying the size of the DHP market in Connecticut and insight into the drivers that determine whether contractors recommend DHPs and the factors influencing customers' adoption of DHPs.

Figure 7-1: Overview of DHP Contractor Interviews



7.1 Key Findings

In-depth interviews were conducted with 23 contractors who participated in the 2015-2016 Energize CT DHP Rebate Program. The interviews focused on home and customer characteristics that determined the recommendations and adoptions of DHPs. The key findings include:

- Contractors reported recommending DHPs (standard or high-efficiency) for 12% of their total cooling installations and for 8% of their total heating installations.
- The majority of DHP recommendations were for high-efficiency DHPs (80%-99%, depending on type of cooling/heating usage).
- About half of the cooling recommendations were for cooling-only use (55%).
- Despite customers concerns over cost of DHPs, contractors reported that across all market segments and types of usage, customers still chose to install DHPs when recommended by contractors (83%-88%). Furthermore, most customers installed high-efficiency DHPs (74%-80%).
- Contractors reported that of all their customers (both program participants and non-participants) who adopted a high-efficiency DHP only 63% applied and received a rebate through the program.

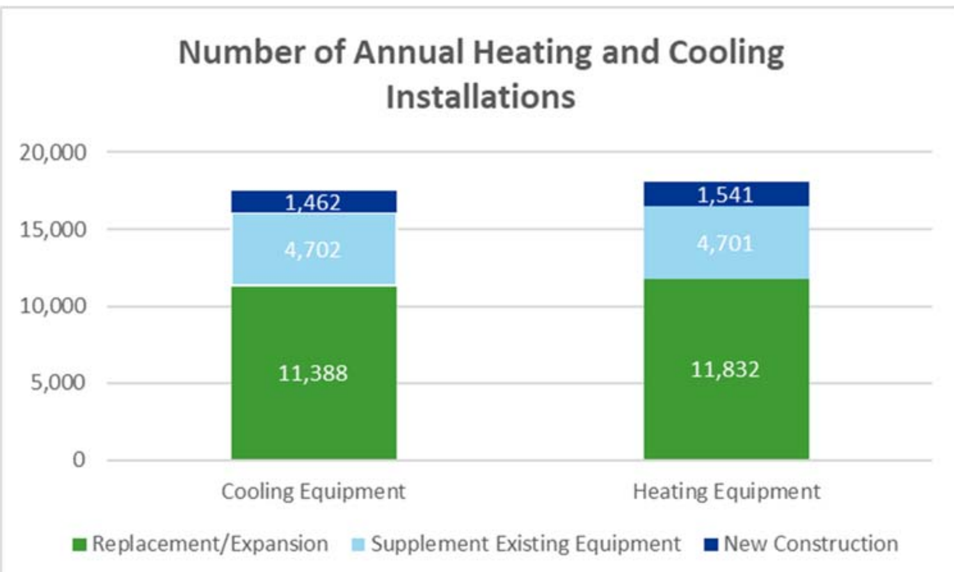
7.2 DHP Contractor Analysis and Results

According to program tracking data, 236 participating DHP contractors installed 1,157 high-efficiency DHPs through the Energize CT DHP Rebate Program between January 2016 and June 2017. In-depth interviews were conducted with 23 contractors who represented roughly 25% of the program DHPs. The contractors interviewed for the study installed both heating and cooling equipment however, six of the contractors only focused on existing home market segment. The following section describes the findings from the interviews

7.2.1 Market Characterization and Market Share for DHPs

Contractors were first asked about the total number of heating and cooling installations they complete annually. This estimate included all equipment types, central air conditioning systems standard DHPs, high-efficiency DHPs, furnaces, boilers, etc. and excluding room air conditioners. The contractors' responses were weighted to population to derive an estimate for the entire market of heating and cooling installations in Connecticut.[30] As shown in Figure 7-2: Residential Heating and Cooling Installations by Market Segment there were nearly as many heating installations as cooling installations (18,075 versus 17,551 installations, respectively). For both heating and cooling end uses, most (92%) installations occurred in existing homes as replacements and expansions to existing systems (65%) or to provide supplemental space conditioning needs (27%).[31] Census data on residential new construction in CT in 2017[32] shows a total of 2,582 single family and two-unit buildings built. This suggests the number of contractor estimated heating and cooling installations might be low. This would result in the market potential estimates provided in Appendix D may represent the lower bound of that estimate.

Figure 7-2: Residential Heating and Cooling Installations by Market Segment



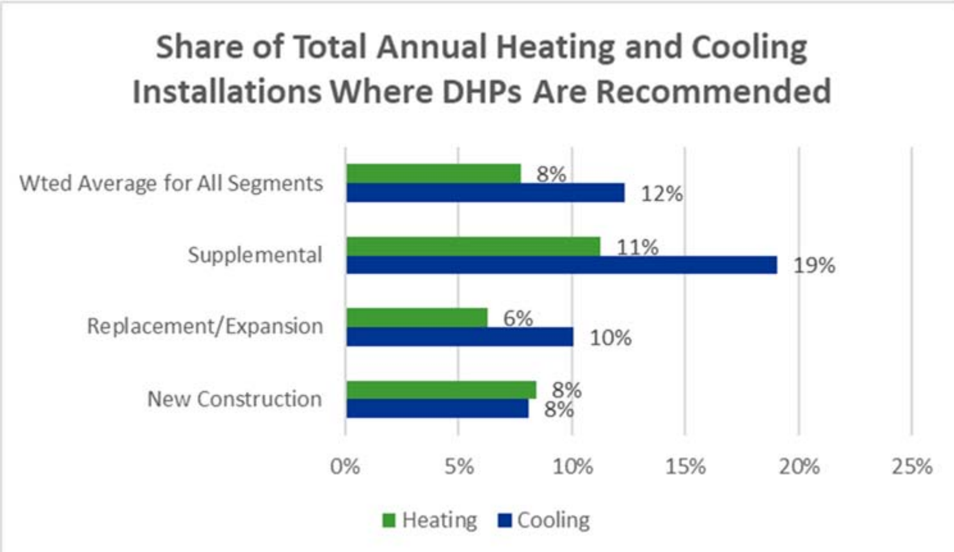
The contractor survey then asked a series of questions to identify the market share that standard and high-efficiency DHPs represented of the total heating and cooling installation market. Contractors reported recommending DHPs (standard or high-efficiency) for 12% of cooling installations and for 8% of heating installations. As shown in Figure 7-3 DHPs were most commonly recommended for supplemental heating/cooling installations.

30 Weight = N (total number residential heating/cooling contractors in Connecticut = 276) / n (# of interview respondents)

31 Installations are defined as home or housing unit.

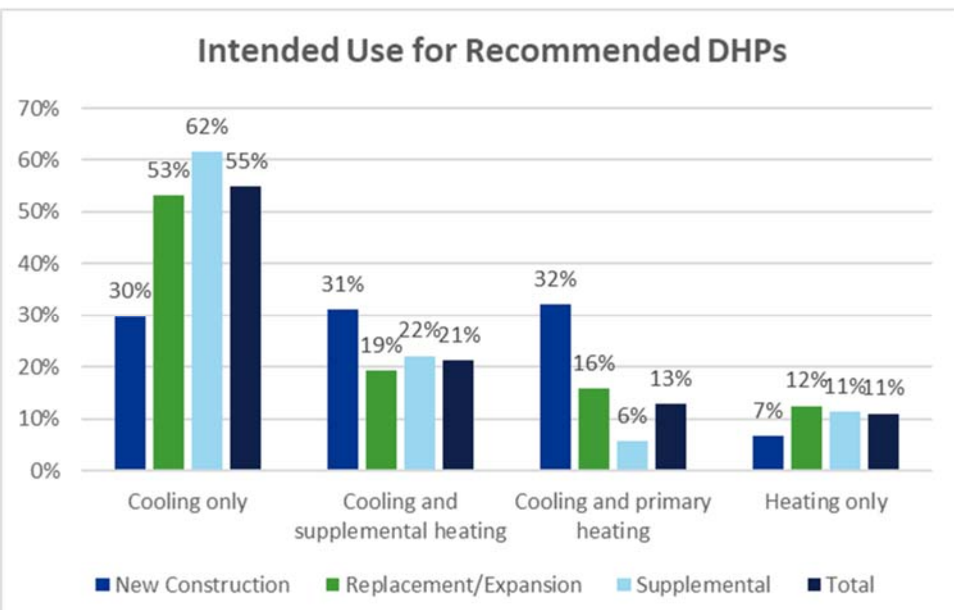
32 https://www.census.gov/construction/bps/

Figure 7-3: Cooling and Heating Applications where DHPs are Recommended[33]



For the installations where DHPs were recommended, contractors were asked about the intended use of the DHPs. As shown in Figure 7-4, 55% of the recommended DHPs were for cooling-only applications while only 11% were for heating-only applications.

Figure 7-4: Intended Use for DHPs[34]

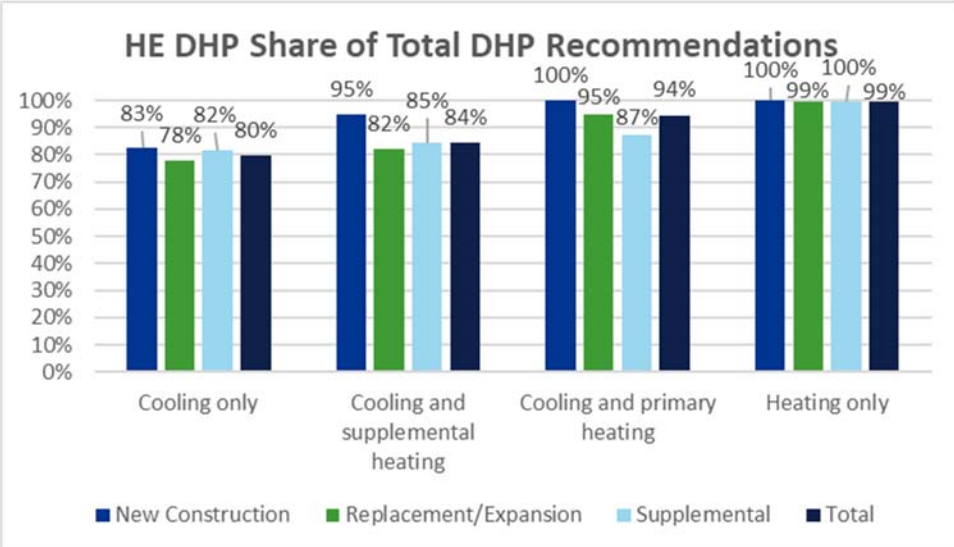


The majority of the recommended DHPs were program-eligible high efficiency units. As shown in Figure 7-5 this finding was consistent across market segments and usage types.

[33] Weight = N (total number residential heating/cooling contractors in Connecticut = 276) / n (# of interview respondents)

[34] Total weighted value calculated using the following: Weight = N (total number residential heating/cooling contractors in Connecticut = 276) / n (# of interview respondents)

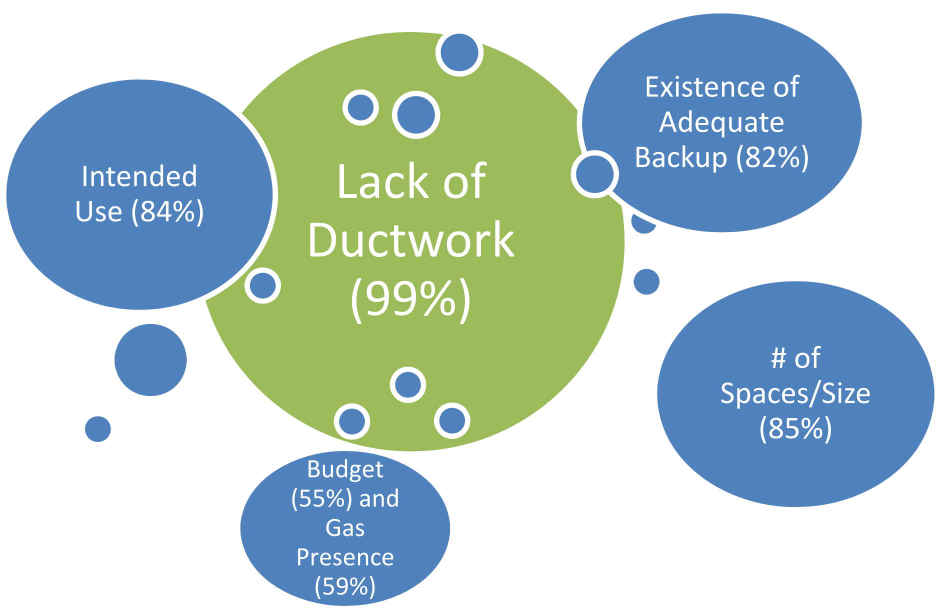
Figure 7-5: Recommended High-Efficiency DHP by Market Segment



Home Characteristics Affecting DHP Recommendations and Adoption

Contractors were asked a series of questions regarding home characteristics that influence their decision to recommend either a standard or high-efficiency DHP. The majority (99%) of respondents stated the lack of ductwork was the most significant influence affecting the recommendation of DHPs. Figure 7-6 shows the most commonly reported factors.

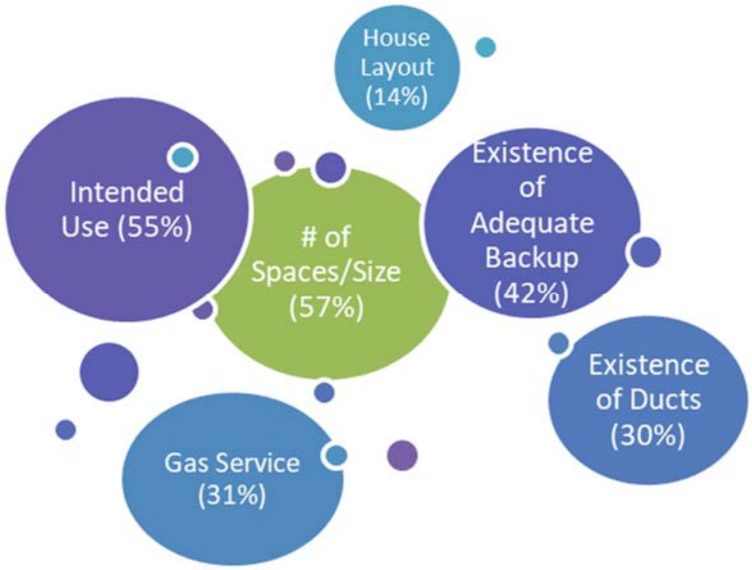
Figure 7-6: Factors Influencing Recommendation of DHP



Other reasons noted by respondents included customers desire for quieter equipment, provide supplemental heating to cooler spaces in their homes and desire for non-coal/gas/oil equipment.

When asked about which characteristics of the home influenced the recommendation of high-efficiency DHPs, the top three factors cited included the number of rooms to be served by the equipment, the intended use of the equipment and the existence of an adequate backup system (Figure 7-7).

Figure 7-7: Home Characteristics Present or Lacking When Recommending High-efficiency DHPs



Contractors cited financial concerns as the key driver in determining if a customer adopts a DHP, especially for high-efficiency DHPs. Figure 7-8 shows the other commonly cited adoption factors. As shown in Figure 7-9, despite customers concerns over cost and other factors, contractors reported that across all market segments and type of usage, customers still chose to install DHPs when recommended by contractors (83%-88%). Furthermore, most customers installed high-efficiency DHPs (74%-80%) and paid an average of $6,340 for equipment and installation excluding the program rebate or $4,254 per ton.[35] APPENDIX D provides the detailed breakout of the decision tree variables used to calculate the market share for high-efficiency DHPs.

It is interesting to note, that contractors reported that of all their customers (both program participants and non-participants) who adopted a high-efficiency DHP only 63% applied and received a rebate through the program. This finding could be the result of one or a combination of factors such as customer awareness of the rebate program or perceived barriers to applying for a rebate (e.g., complexity of paperwork, length of time it took to receive the rebate, the amount of the rebate, etc.).

[35] Based on UI and Eversource program tracking records.

Figure 7-8: Factors Influencing Customers Decisions to Adopt a DHP

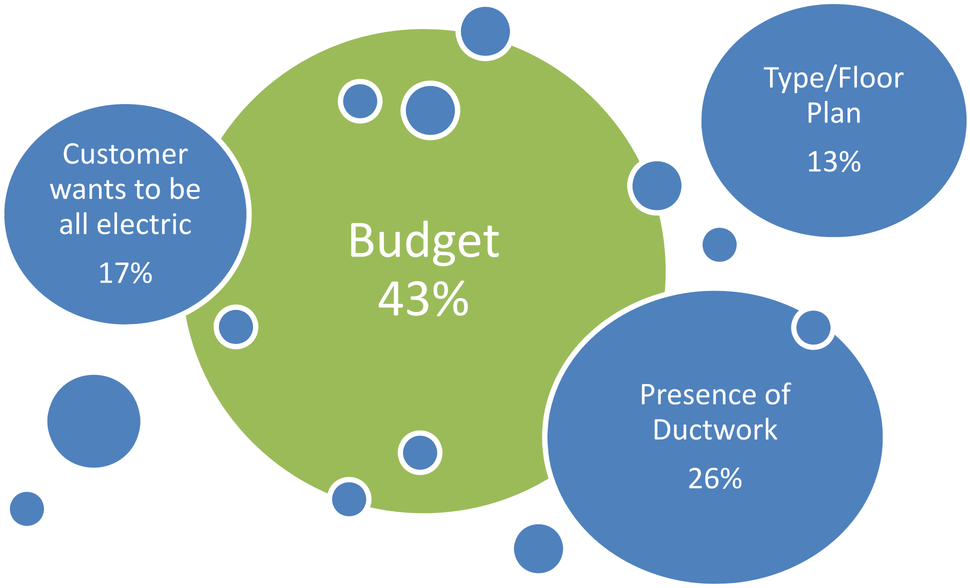
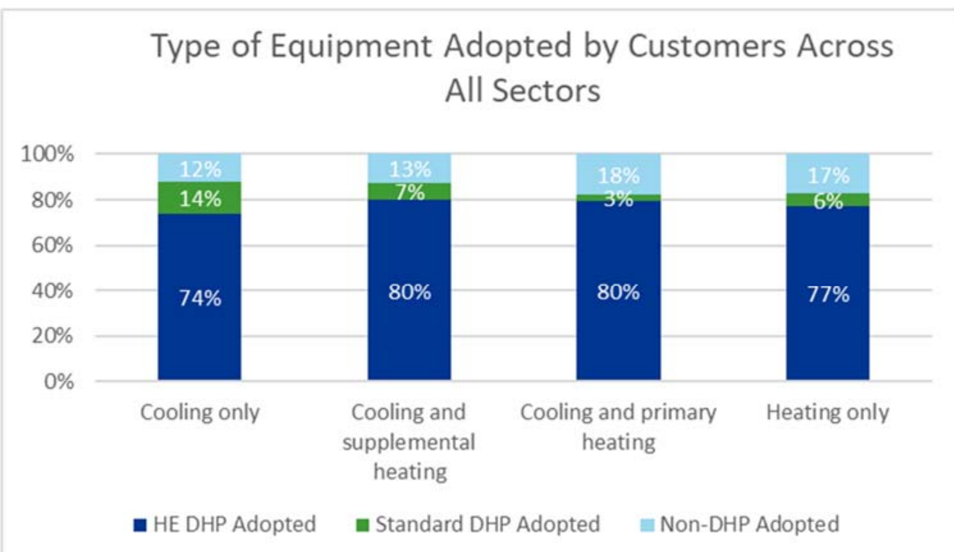


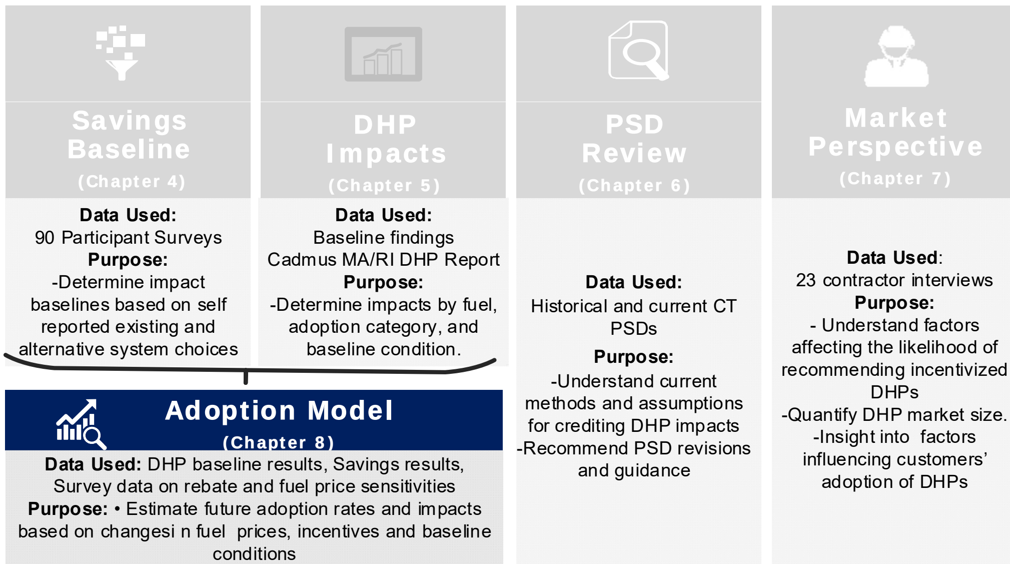
Figure 7-9: Adoption of High-Efficiency DHPs



8 DHP MARKET ADOPTION ANALYSIS AND PLANNING TOOL

This section of the report presents the results of the DHP Market Adoption Analysis and the development of the DHP Planning Tool (Figure 8-1).

Figure 8-1: Overview of Market Adoption Analysis



8.1 Overview

The study included modelling and resulting savings from program participation could be expected to change under different program scenarios and market conditions. The planning tool developed in the study provides program planners with the ability to project program participation and the corresponding electric and non-electric impacts, including carbon savings under different market conditions including changes in:

- Current level of program participation
- Program rebate level
- Price of alternative sources of fuel: fuel oil; natural gas; propane; wood pellets; coal and electricity
- Changes in the mix of customers: multi-family versus single family; electric and non-electric

With the planning tool, the program planners and administrators can quantify how changes in the design of the program or shifts in market conditions affect the program savings. Furthermore, it can be used to determine how program incentive levels can achieve participation goals and savings impacts.

This section presents the source of the data used to estimate the model parameters, the structure of the model, and some of the trends in the results produced in the analysis. A detailed description of how to use the adoption modelling tool, and tool itself, is included in APPENDIX E.

8.2 Adoption Model Analysis Methods

This sub-section reviews the data, model structure, and application of the tool. It is followed by a discussion of tool parameters and an example of results produced by the tool for a user-defined scenario.

8.2.1 Data

The main source of data was the telephone survey of 90 DHP program participants. The survey asked participants about home characteristics, previous existing or alternative heating fuel(s), the characteristics of the DHP installation, and the likelihood of still buying the same (program-eligible) DHP if alternate fuel prices were less favorable or the rebate was smaller. Based on the results of the survey, the analysis grouped the population of participants into segments based on a combination of three, binary characteristics:

1. Type of home – single family vs. multi-family
2. Pre-existing heating fuel type – electric vs. non-electric
3. Intended use of the DHP – cooling only vs. heating with or without cooling

To determine participant price responses at varying program parameters (rebate levels) and market conditions (fuel prices) for the different population segments, participants were asked about their likelihood of buying the same DHP. To measure the effect of changes in the rebate level, participants were asked how likely they would have been to install the program-eligible DHP if the rebate were: 20% lower, 33% lower, half as much, and not available. To measure the responsiveness to changes in the price of alternate fuel, participants were asked how significant the price of alternate fuels, including fuel oil; natural gas; propane; and wood, pellets, or coal, was in their decision to install a program-eligible DHP. If they responded that none of these fuel types were significant in their decision, responses were classified as still very likely to adopt an eligible DHP for all alternative fuel price levels. If they responded that at least one of these fuel types were significant, they were asked how likely they would have been to install the same DHP if the price of the alternative fuel had been: 20% lower at that time, 33% lower at that time, 50% lower at that time, and 75% lower at that time.

The questions asked for a response on scale of 1 to 5 where 1 is 'very unlikely,' 3 is 'neutral' and 5 is 'very likely.' To translate these into probabilities of still purchasing, the model mapped the numbers or phrases into probabilities. Table 8-1 presents the mapped probabilities used in this analysis. A response of 5 equates to a high likelihood of still adopting the DHP, which is mapped to a 95% probability. By comparison, a response of 1 equates to a high unlikelihood of still adopting the same DHP, which is mapped to only a 15% probability.[36] This is an asymmetrical mapping where 'highly likely' is closer to 100% than 'highly unlikely' is from 0, and similarly for 'likely' and 'unlikely.' The model uses this asymmetrical mapping because the survey asks respondents about their likelihood of still purchasing what they actually did purchase, if prices were different. Literature has proven that consumers tend to over-predict their likelihood of purchasing various items, so the model also assumes that consumers tend to over-predict their likelihood of not purchasing a program-eligible DHP when they actually did purchase it.

[36] The mapped probabilities were determined after a brief literature review and testing the sensitivity of the responses. The literature review included 2 studies that collected data on what people mean by qualitative terms such as 'likely' or 'unlikely.' The first is from a 1994 study by Sherman Kent reproduced in a CIA overview, which asked 23 NATO military officers what probability they assign to various qualitative terms. The second was a 2017 study published on Github using data gathered from 46 respondents on Reddit with the /r/sample size community, using the same questions as the NATO study. Both mapping studies also exhibit asymmetry, but this study assumed that the underlying asymmetries were more severe because the surveys gave respondents both a numeric value (1 through 5) and a word label for the two end points ('highly (un)likely') and the middle ('neutral').

Table 8-1: Mapped Probabilities of DHP Adoption Based on Participant Stated Likelihood of Still Adopting Program-Eligible DHP

Response Rating	Description on Participant Survey	Mapped Probability
1	Highly unlikely	15%
2	Unlikely	35%
3	Neutral	50%
4	Likely	85%
5	Highly likely	95%

8.2.2 Model Structure

To estimate differential price effects according to key customer characteristics, the tool incorporates a set of log-log regression models. These models were fit to the mapped probabilities across all customers of adopting the same DHP at varying price points. Equation 8-1 shows the functional form of the model. The models also account for differences between the population segments. We can interpret the equation by saying a 1% change in X is associated with a B_1% change in Y, so B_1 is the elasticity of Y with respect to X. 0 lists all the coefficients and their standard errors for both the rebate and alternative fuel models.

Equation 8-1. Functional Form of the Log-Log Model

$$\ln Y = \beta_0 + \beta_1 \ln X + \varepsilon$$

Where:

- Y = probability an individual will participate
- X = ratio of price point compared to 2015 level

From the fitted models, we have the overall elasticity of adoption with respect to each price variable. This elasticity represents the average responsiveness across the participant population segments. While the actual distribution of how participants are utilizing their program-eligible DHP and their household characteristics is unknown, the survey respondents provide the best available estimate of these characteristics. Thus, an elasticity that is effectively the average responsiveness across the survey respondents is a meaningful estimate of the average across the current participants.

Figure 8-2 and Figure 8-3 show the weighted curves overlaid with the average responses to the relative survey question. The blue dots show the value of the estimated adoption curve. These are plotted at each of the price points asked on the survey, as well as for the symmetric point at price ratios above 1. The 'X' marks the average response of the question to show how well the model fits the average data. These curves represent the overall population participation; however, each population segment has its own participation curve. To compare the specific curves for each population segment, see Figure E-2 and E-3 in APPENDIX E.

Figure 8-2: Rate of Program Participation at Different Rebate Levels

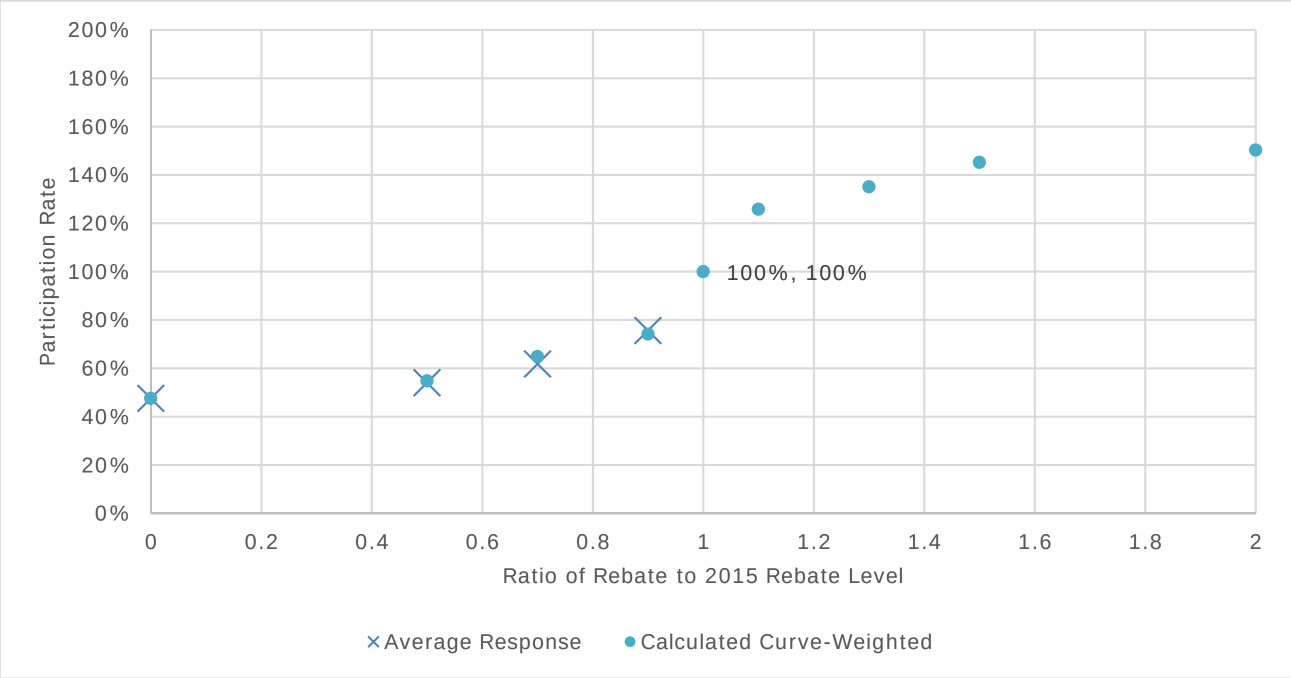
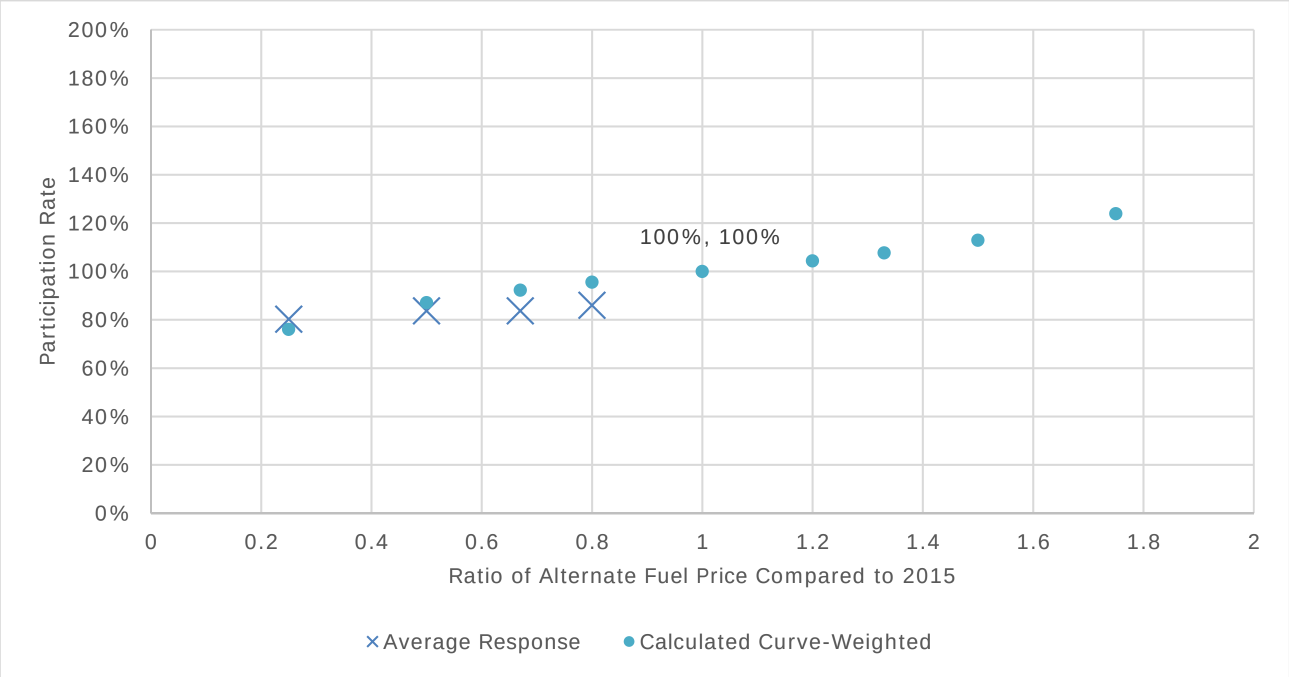


Figure 8-3: Rate of Program Participation at Alternate Fuel Price Levels



8.2.3 Applying the Model

To estimate the combined effect of change in a fuel price and change in incentive level, the tool assumes that the percentage effects are additive. That is, the overall percent change in participation due to specific changes in rebates and fuel prices would be the sum of the separately modelled percent changes due to each. This assumption essentially means that we're making a first-order approximation to the effects of multiple factors on adoption, where interactive effects are not estimated.

Because the model only includes responses from participants, it can only incorporate direct information on how adoption rates would decline if prices and incentives were less favorable to DHP, not how adoption would increase if they were more favorable. Because of this, the model extends the estimates from the 'less favorable' side of the rebate/price curves to the 'more favorable' side. There remain uncertainties with this extension, since nonparticipant responses could not be investigated directly. In terms of program activity, the tool uses the assumption that for the 'more favorable' side, the estimated effects are symmetrical[37]. That is, if a given price change in one direction would reduce adoption among current participants by X%, the same magnitude change in the opposite direction would increase adoption by X% above current participation levels.

There are some weaknesses associated with this methodology. The curves are based on a small sample size and information only from participants, so projecting effects of price changes to increased adoption at more favorable conditions is extrapolating the models beyond the range of the observed data. However, the symmetry assumption does not mean that the same incremental percentage of nonparticipants would be moved to buy program-eligible DHPs with a price change as is indicated by the participant analysis. Rather, the symmetry assumption means that, out of the whole population, the proportion or people who will adopt program-eligible DHPs moves incrementally up or down by the same amount in either direction for the same magnitude price shift in one direction or the other.

8.3 Key Results and Discussion

Changing the parameters in the tool yields different results for both the current assumed starting point and a user-defined scenario. The different population segments respond differently to changes in rebate level and alternative fuel costs. So, changing the population allocation or the starting number of program participants in the current assumed baseline will produce different results. However, there are some identifiable trends in the results. Results presented in this section are based on the 2015/2016 level of participation and the population segment allocation from the participant survey. The bullets below summarize the key findings.

- Both the level of rebate and the cost of alternative fuels are positively correlated with the level of participation in the program. The change in the level of the rebate has a bigger impact than the change in price of alternative fuels.
- Based on this current mix of participants, an increase in the level of program participation translates to an increase in electricity consumption but a decrease in non-electric fuel consumption. The combination of the change in consumption results in a decrease in the amount of carbon dioxide that is produced from heating and cooling in the program-participant population. For an individual home, if the existing heating fuel is electric, installing a program-eligible DHP also leads to reduced electricity consumption.

[37] For small changes from the current price, this is essentially what's meant by an elasticity, and the symmetry is a reasonable assumption. For larger changes in price, the assumption is less certain. Absent specific information on the other half of the curve that would suggest its pattern should curve up or down more compared to the symmetry assumption, this assumption is retained as a plausible representation of the unknown pattern. Without the symmetry constraint, extrapolating from the "data" to the "no-data" side could result in some extreme and unlikely projections.

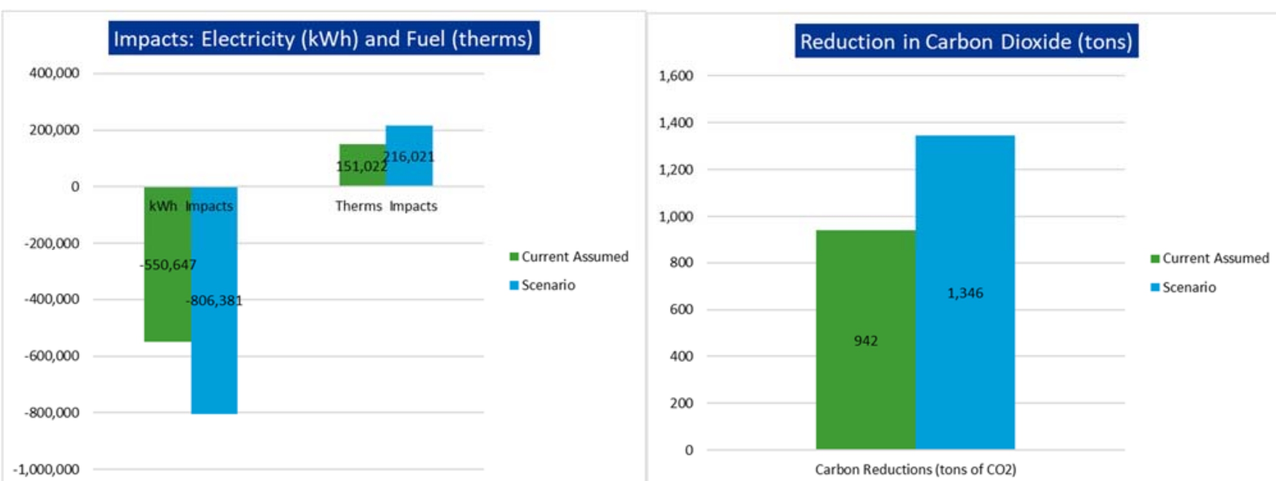
- The largest participant population segment is those that have single-family homes with non-electric heating fuel who intended, at the time of purchase, to use their DHPs for heating with or without cooling.

In both models, participation is positively correlated with the level of rebate and the cost of alternative fuels. So, a higher level of rebate and a higher cost of alternate fuel are correlated with a higher level of participation. However, the change in the rebate has a larger effect than a change in the price of alternative fuel costs. Based on these curves, a 30% increase in the rebate level translates to a 35% increase in the participation rate. Because of the symmetry assumption, this also means that a 30% decrease in the rebate level translates to a 35% decrease in participation. By comparison, a 33% increase in the price of alternate fuels only leads to about an 8% increase in participation.

Because of our assumption that the effects of rebates and alternative fuel prices are additive, a 30% increase in the level of the rebate and a 33% increase in the price of alternative fuels results in a 43% increase in overall participation. The group of participants that experiences the highest rate of change in this scenario (53%) is the single family, non-electric baseline heating fuel where the user intends to use the DHP for heating with or without cooling segment at. Comparatively, the group with the lowest rate of change are the multi-family participants at 17%.

In this same scenario, the impacts of that increase in participation lead to about a 251 MWh increase in the annual consumption of electricity (from 548 to 799 MWh) but a decrease in non-electric fuel consumption of about 64,000 therms (150,865 to 214,858 therms saved) across the participant population. This change results in an additional reduction of about 41,0000 tons of carbon dioxide (942 to 1,346 tons of CO_2 saved). These impacts are summarized in Figure 8-4.

Figure 8-4: Impacts of Changes in Participation, Rebate = 130% and Alternate Fuels = 133%



Results show that when the existing heating fuel is electric, a higher level of DHP participation translates to a reduction in the total amount of kWh consumed and a reduction in the electricity consumed. In comparison, when the prior existing fuel is not electric heat, there is an electric load increase, but there is still a reduction in the number of therms consumed. Using the 2015/2016 allocation of participants into the different segments, carbon dioxide emissions decline anytime there is an increase in adoption of DHPs.

Currently the largest participant population segment – representing more than 50% of all participants – is those that have single-family homes with non-electric heating fuel who intended, at the time of purchase, to use their DHPs for heating with or without cooling. Based on this current mix of participants, an increase in the number of participants will result in increased electrical load and a decrease in the consumption non-electric fuel. The combination of this still results in an overall net decline in the production of carbon dioxide emissions. If the allocation of program participant characteristics changes, this trend could also change. The planning tool, as explained in APPENDIX EAPPENDIX E, allows the user the change the key parameters and visualize the resulting impacts and compare different scenarios.

APPENDIX A: DHP Program Participant Survey

Notes:

1. Notes to interviewer are in square brackets [] and *italicized*.
2. in programmed survey are in curly brackets {} and *italicized*.

I. Recruiting

[READ} Hi, this is ***, calling on behalf of <COMPANY>. We understand that you participated in <COMPANY>'s ductless heat pump rebate program within the past few years. We are following up with customers like you to learn more about your experiences with the program and learn of any ways to improve the services and programs provided to customers like you. If you complete this survey, we will provide you with a $10 gift card as compensation for your time and opinions.

[If needed: My firm is called GreatBlue Research and we have been hired by Eversource and United Illuminating.]

A. According to the records provided by Energize CT, you received a rebate for the installation of one or more high-efficiency ductless heat pumps (DHP) at your home at [ADDRESS]. Is this correct?
   1. Yes – *[Skip to I.B]*
   2. No – *[Thank and Terminate]*
   3. Refuse – *[Thank and Terminate]*
   4. Don't know – *[Skip to I.C]*

B. Are you willing to participate in this effort?
   1. Yes *[Skip to I.G]*
   2. No – *[Thank and Terminate]*
   3. Don't know *[Read I.E and/or I.F as appropriate]*

C. Is there someone else who would know about the installation of the program DHP in your home?
   1. Yes
   2. No – *[Thank and Terminate]*
   3. Don't know

D. When would be a good time for us to call back to talk to someone who might know about this project?
   1. [Record answer, thank, and terminate]
   2. Refused – *[Thank and Terminate]*

E. [*If necessary]* We have some general questions about your home, about the reasons you installed a ductless heat pump, and about your use of it since that time. Everything we talk about will be kept confidential and only reported as part of a larger group of results. Your responses will in no way affect the rebate you received or equipment you installed.

F. [*If necessary]* We anticipate this will take approximately 30 minutes of your time.

G. Is this a good time to talk?
1. Yes – *[Skip to II.A]*
2. No

H. When would be convenient for you?
1. *[Record answer]*

II. Basic Home Characteristics

[READ] Now I would like to get some basic information about your home.

A. Is your home
  1. Single family
  2. Duplex or two-family *[Skip to 0C]*
  3. Apartment/condo in a 2-4-unit building *[Skip to 0C]*
  4. Apartment/condo in a 5+ unit building *[Skip to 0C]*
  5. Townhouse or row house (one or more shared walls with another house) *[Skip to 0C]*
  6. Mobile home, house trailer *[Skip to 0C]*
  7. Other, please specify: ________________________ *[Skip to 0C]*

B. What type of single family best describes your home?
  1. Ranch
  2. Colonial
  3. Cape Cod
  4. Split level
  5. Farm-style
  6. Contemporary
  7. Other, please specify: __________________________

C. Approximately when was your home first built?
  1. *[Record answer]*
  2. Don't Know
  3. Refused

D. Are your exterior walls made of: *[More than one response allowed]?*
  1. Brick
  2. Wood
  3. Stucco
  4. Aluminum/vinyl siding
  5. Other, please specify: ________________________

[READ] Now I would like to ask you some information about the space served by the program DHP(s) in your home.

E. Was the program DHP installed to serve:
  1. Your entire home?
  2. Part of your existing home?
  3. An addition
  4. Don't know – *[Skip to I.C]*
  5. Refused – [Thank and terminate]

F. How many program DHPs were installed in your home?
  1. 1
  2. 2
  3. 3
  4. More than 3
  5. Don't know

G. How many heads does(do) the program DHP(s) have?
1. 1 [SKIP TO II.I]
2. 2
3. 3
4. More than 3
5. Don't know

H. Please tell me the spaces served by each DHP head installed in your home

[NOTE: For each head determine the type and number of rooms served by that head. For example, one head may serve the kitchen, family, and dining room.]

Head #	Kitchen	Family/Living	Dining	Bedroom	Sunporch	Other (specify)
1						
2						
3						
4						
5						
6						
7						

[SKIP TO II.J.]

I. *[SKIP TO II.J IF II.E = 1]* What type of space(s) was the program DHP installed to serve:
1. Kitchen
2. Family room/living room
3. Dining room
4. Bedroom
5. Sunporch
6. Other, please specify: _________________

J. What is the size of the area served by the program DHP in square feet?
1. *[Record answer. SKIP to II.O]*
2. Don't know *[IF II.E =1 SKIP TO II.N, IF II.E. = 2 or 3, SKIP TO II.K.]*

K. That's ok, let's try get figure out about how big the space is. Is the space just one room, or more than one room?
1. One room *[SKIP to II.M.]*
2. More than one room
3. Refused

L. How many rooms are in the space served by the program DHP(s)?
1. 2
2. 3
3. 4
4. 5
5. More
6. Don't know

M. Which would you say best describes the size of this/each room?

Description	Rm1	Rm2	Rm3	Rm4	Rm5
1. The same as a small "student" bedroom, sized for one twin bed, desk, chair and dresser.					
2. The same as a medium bedroom, sized for two twin beds or one double or queen bed with 3 or so pieces of furniture, e.g. two dressers and maybe a desk					
3. The same as a large bedroom, sized for a queen bed, and at least two dressers					
4. The same as an extra-large bedroom, sized for a king bed, and 3 – 5 other pieces of furniture					
5. Great room / family room					
6. Other					
7. Don't know					

N. How many bedrooms and bathrooms are served by the program DHP?
1. Number of bedrooms [Record answer]
2. Number of bathrooms [Record answer]

O. How many outside walls are there in the space served by the program DHP?
1. 1
2. 2
3. 3
4. 4
5. Other (e.g. octagonal shape room) *[Record answer]*
6. None

P. What is located above the space served by the program DHP(s):
1. Roof
2. Attic
3. Another room

Q. *[IF II.E =3, SKIP TO III.A.]* Was there heating equipment installed in the space served by the program DHP before the DHP was installed?
1. Yes
2. No *[Skip to II.T]*
3. Don't know *[Skip to II.T]*
4. Refused *[Skip to II.T]*

R. Was the pre-existing heating equipment installed in the spaced served by the program DHP used to heat the space?
1. Yes
2. No
3. Don't know
4. Refused

S. Can the pre-existing equipment still be used to heat the space?
1. Yes
2. No
3. Don’t know
4. Refused

T. Was there cooling equipment installed in the space served by the program DHP before the DHP was installed?
1. Yes
2. No *[Skip to III.A]*
3. Don’t know *[Skip to III.A]*
4. Refused *[Skip to III.A]*

U. Was the pre-existing cooling equipment installed in the spaced served by the program DHP used to cool the space?
1. Yes
2. No
3. Don’t know
4. Refused

V. Can the pre-existing equipment still be used to cool the space?
1. Yes
2. No
3. Don’t know
4. Refused

III. HVAC Characteristics – Existing and Baseline Heating and Cooling Equipment

[READ] The next series of questions is about the heating and cooling equipment in your home, before the installation of the DHP.

A. What type(s) of primary and secondary heating equipment did you have in your home prior to the installation of the program DHP? *[Do not read. Check all that apply. Prompt with "Any other source of heat" until "no".]*

Answer #	Type	Fuel	Portion of home served, or specific area	*[SKIP IF II.E=3]* Did it serve the space with the program DHP? (Y/N) *[If II.G >1 indicate head number as defined by II.H]*	*[SKIP IF II.E=3]* "Prior to the installation of program DHP head #X, what percent of heat provided to the area this head serves was provided by <EQUIPMENT TYPE III.A.#>"	Age
	a.	b.	c.	d. *[pipe answer to column a. into this question for clarity]*	e. *[pipe answer to column a. into this question for clarity. ASK ONLY IF III.A.#.d. = Yes]*	f.
III.A.1	Furnace w duct	Natural gas				
III.A.2	Furnace w duct	Oil				
III.A.3	Furnace w duct	Propane				
III.A.4	Furnace w duct	Coal				
III.A.5	Furnace w duct	Wood				
III.A.6	Boiler	Natural Gas				
III.A.7	Boiler	Oil				
III.A.8	Boiler	Propane				
III.A.9	Boiler	Coal				

III.A.10	Boiler	Wood				
III.A.12	Electric resistance	NA				
III.A.13	Stove	Natural gas				
III.A.14	Stove	Propane				
III.A.15	Stove	Coal				
III.A.16	Stove	Wood				
III.A.17	Stove	Pellet				
III.A.18	Standard DHP	NA				
III.A.19	Heat pump	Ground source				
III.A.20	Heat pump	Air source				
III.A.21	Heat pump	Water source				
III.A.22	Heat pump	Dual fuel				
III.A.23	Heat pump	Ductless – non-HE				
III.A.24	Wall heater	Natural gas				
III.A.25	Wall heater	Propane				
III.A.26	Plug in heater	Electric				
III.A.27	Other					
III.A.28	None*					

[IF RESPONDENT DOES NOT SELECT ANY OF THE HEATING OPTIONS ABOVE TO SERVE THE SPACE SERVED BY THE PROGRAM DHP, PLEASE CONFIRM THAT THERE WAS NO HEATING EQUIPMENT INSTALLED THAT SERVED THE DHP SPACE]*

B. During a typical heating season, what temperature do you set your heating system during:
1. Weekday daytime hours? *[Record temperature setting]*________
2. Weekday night time hours? *[Record temperature setting]*________
3. Weekend daytime hours? *[Record temperature setting]*________
4. Weekend night time hours? *[Record temperature setting]*________

C. What cooling equipment did you have in your home prior to the installation of the program DHP? *[Check all that apply]*

Answer #	Type	Quantity	Portion of home served, and/or specific area(s)	[SKIP if II.E=3] Did it serve the space with the program DHP? (Y/N)	Age
	a.	b.	c. pipe answer to column a. into this question for clarity	d. pipe answer to column a. into this question for clarity	e.
III.C.1	Central air				
III.C.2	Window air conditioner				
III.C.3	Wall mount air conditioner				
III.C.4	Ductless mini split AC				
III.C.5	Standard DHP				
III.C.6	High-efficiency DHP				
III.C.7	HP – air source				
III.C.8	HP – ground source				
III.C.9	HP – water source				
III.C.10	HP – non-HE				
III.C.11	None*				

[IF RESPONDENT DOES NOT SELECT ANY OF THE COOLING OPTIONS ABOVE TO SERVE THE SPACE SERVED BY THE PROGRAM DHP, CONFIRM THAT THERE WAS NO COOLING EQUIPMENT INSTALLED THAT SERVED THE DHP SPACE]*

D. During a typical cooling season, what temperature do you set your cooling system during:

1. Weekday daytime hours? *[Record temperature setting]*________
2. Weekday night time hours? *[Record temperature setting]*________
3. Weekend daytime hours? *[Record temperature setting]*________
4. Weekend night time hours? *[Record temperature setting]*________

E. At the time of deciding to install the program DHP, did you consider heating, or increasing the heat to, the room(s) now served by the new program DHP using your existing equipment?
1. Yes
2. No *[SKIP to III.G]*
3. Don't know *[SKIP TO III.G]*

F. Why didn't you expand the existing heating system? *[Check all that apply]*
1. It was not physically possible

[PROMPTS:

- *IF ducted system – "Could you have run a duct to this space?"*
  - *IF piped system – "Could you have run piping or added a zone to your existing system?"*
  - *IF no distribution – No prompt, accept answer to above.]*

2. It was too expensive
3. It wouldn't have provided the comfort we wanted
4. We wanted separate control of the comfort in that space
5. Contractor recommendation
6. Other – *[Record answer]*

G. *[SKIP TO III.I IF III.C. = NONE]* At the time of deciding to install the program DHP, did you consider cooling, or expanding the cooling, to the rooms now cooled by the program DHP space using your existing equipment?
1. Yes
2. No *[SKIP to III.I]*
3. Don't know *[SKIP to III.I]*

H. Why didn't you expand the existing cooling system? *[Check all that apply]*
1. It was not physically possible

[PROMPTS:

- *IF ducted system – "Could you have run a duct to this space?"*
- *IF no distribution – No prompt, install a window AC.]*

2. It was too expensive
3. It wouldn't have provided the comfort we wanted
4. We wanted separate control of the comfort in that space
5. Contractor recommendation
6. Other – *[Record answer]*

[READ] The next questions are about the heating and cooling equipment you may have considered installing instead of the program DHP.

I. Now please tell me what options you considered for meeting the heating needs of the space served by the program DHP. Which were you most likely to install instead of the program DHP to meet the heating needs of the space now served by the program DHP?

Answer #	Type	Fuel	Considered	Most likely if not DHP
	a.	b.	c.	d.
III.I.1	Furnace w duct	Natural gas		
III.I.2	Furnace w duct	Oil		
III.I.3	Furnace w duct	Propane		
III.I.4	Furnace w duct	Coal		
III.I.5	Furnace w duct	Wood		
III.I.6	Boiler	Natural Gas		
III.I.7	Boiler	Oil		
III.I.8	Boiler	Propane		
III.I.9	Boiler	Coal		
III.I.10	Boiler	Wood		
III.I.11	Electric resistance	NA		
III.I.12	Stove	Natural gas		
III.I.13	Stove	Propane		
III.I.14	Stove	Coal		
III.I.15	Stove	Wood		
III.I.16	Stove	Pellet		
III.I.17	Standard DHP	NA		
III.I.18	Heat pump	Ground source		
III.I.19	Heat pump	Air source		
III.I.20	Heat pump	Water source		
III.I.21	Heat pump	Dual fuel		
III.I.22	Heat pump	Ductless – non-HE		
III.I.23	Wall heater	Natural gas		
III.I.24	Wall heater	Propane		
III.I.25	Plug in heater	Electric		
III.I.26	Used existing system			
III.I.28	High-efficiency DHP	Electric		
III.I.29	Other			
III.I.30	None			

J. Now please tell me what options you considered for meeting the cooling needs of the space served by the program DHP. Which were you most likely to install instead of the program DHP to meet the cooling needs of the space now served by the program DHP?

Answer #	Type	Quantity *[number of units, e.g. 1 heat pump]*	Considered	Most likely
	a.	b.	c.	d.
III.J.1	Central air			
III.J.2	Window air conditioner			
III.J.3	Wall mount air conditioner			
III.J.4	Ductless mini split AC			
III.J.5	Standard DHP			
III.J.6	High-efficiency DHP			
III.J.7	HP – air source			
III.J.8	HP – ground source			
III.J.9	HP – water source			
III.J.10	HP – non-HE			
III.J.11	Used existing system			
III.J.13	None			

IV. Pre-installation Operational Assumptions

[Read] Next, I have a series of questions about you were initially planning to use the DHP.

A. Thinking back to the time when you were considering installing the program DHP, were you planning to use it for heating, cooling, or both?
   1. Heating
   2. Cooling *[SKIP to IV.E]*
   3. Both
   4. Don't know / don't remember

B. During the heating season did you plan to heat the space now served by the program DHP all the time, about half time, or only infrequently (e.g. special occasions or very cold days)?
   1. All the time
   2. About half time
   3. Infrequently
   4. Don't know / don't remember

C. During the heating season did you plan to keep the program DHP space at the higher, lower, or at same temperature as the rest of the house?
   1. Higher
   2. Lower
   3. The same
   4. Don't know

D. *[ONLY IF III.A.d = Yes]* During the heating season how did you plan to use the existing system to heat the room(s) now heated by the program DHP after installation?
1. As the primary heat source
2. Regularly but not full time
3. Occasionally (e.g. when very cold)
4. As back-up only
5. Not at all
6. Other

E. During the cooling season did you plan to cool the space now served by the program DHP all the time, about half time, or only infrequently (e.g. special occasions or very hot days)?
1. All the time
2. About half time
3. Infrequently
4. Don't know / don't remember

F. During the cooling season did you plan to keep the room(s) now cooled by the program DHP space at a higher, lower, or at same temperature as the rest of the house?
1. Higher
2. Lower
3. The same
4. Don't know

G. *[SKIP TO V.A. IF III.C. = NONE or IF III.C.d = no]* During the cooling season how did you plan to use the existing system to cool the room(s) now cooled by the program DHP space after installation?

1. As the primary cooling source
2. Regularly but not full time
3. Occasionally (e.g. when very hot)
4. As back-up only
5. Not at all
6. Other

V. Post-installation Operation

[Read] This next series of questions is about your experience since installing the program DHP

A. Since installing the program DHP have you used it for heating, cooling, or both?
   1. Heating
   2. Cooling *[SKIP TO V.J]*
   3. Both

B. During the heating seasoning did the program DHP heat the space it served all the time, about half time, or only infrequently (e.g. special occasions or very cold days)?
   1. All the time
   2. About half time
   3. Infrequently
   4. Don't know / don't remember

C. During the heating season did you keep the program DHP space at a higher, lower, or at same temperature as the rest of the house?
   1. Higher
   2. Lower
   3. The same
   4. Don't know

D. *[SKIP TO V.E. IF II.E=3]* During the heating season did you use the pre-existing system to heat the program DHP space: *[Select one]*
   1. As the primary heat source
   2. Regularly but not full time
   3. Occasionally (e.g. when very cold)
   4. As back-up only
   5. Not at all
   6. Other

E. Thinking only about the space the program DHP was installed to serve, what percentage of that space's heating needs is provided by the program DHP?
   1. *[Record answer]*
   2. Don't know

F. *[IF V.E.1. < 100%]* Under what conditions did you use the pre-existing system or another method (e.g. plug in heaters) to heat the program DHP space?
   1. *[Record answer, prompt for outside temperature if appropriate]*
   2. Don't know

G. How has use of the DHP affected use of other heating equipment in home?
   1. Use DHP to add heating to other rooms of home (leave doors open, lower thermostat in other rooms).
   2. Use this room more often and use other rooms less (shut door and isolate room, turn down heat in other rooms)
   3. Use other rooms to heat this room (leave doors open, rely more on heat from other rooms)
   4. Other *[Record response]*
   5. No changes *[SKIP TO V.J.]*

6. Don't know

H. [*IF V.G ≠ 5]* Compared to the space the DHP was installed for, is this additional space:
   1. Significantly larger
   2. Somewhat larger
   3. The same size
   4. Somewhat smaller
   5. Significantly smaller

I. *[IF V.G = 1]* Would you say this extra space is being heated by the program DHP all the time, about half time, or only infrequently (e.g. special occasions or very cold days)?
   1. All the time
   2. About half time
   3. Infrequently
   4. Don't know / don't remember

J. During the cooling season did the program DHP cool the space it served all the time, about half time, or only infrequently (e.g. special occasions or very hot days)?
   1. All the time
   2. About half time
   3. Infrequently
   4. Don't know / don't remember

K. During the cooling season did you keep the program DHP space at a higher, lower, or at same temperature as the rest of the house?
   1. Higher
   2. Lower
   3. The same
   4. Don't know

L. *[SKIP TO V.M IF III.C. = NONE OR II.E=3]* During the cooling season did you use the pre-existing system to cool the program DHP space: *[Select one]*
   1. As the primary cooling source
   2. Regularly but not full time
   3. Occasionally (e.g. when very hot)
   4. As back-up only
   5. Not at all
   6. Other
   7. Don't know

M. Thinking only about the space the program DHP was installed to serve, what percentage of that space's cooling needs is provided by the program DHP?
   1. *[Record answer]*
   2. Don't know

N. *[IF V.M < 100%]* Under what conditions did you use the pre-existing system or another method (e.g.room AC) to cool the program DHP space?
   1. *[Record answer, prompt for outside temperature if appropriate]*
   2. Don't know

O. How has use of the DHP affected use of other cooling equipment in home?
1. Use DHP to add cooling to other rooms of home (leave doors open, adjust thermostat in other rooms).
2. Use this room more often and use other rooms less (shut door and isolate room, increase thermostat setting in other rooms)
3. Use other rooms to cool this room (leave doors open, rely more on cool from other rooms)
4. Other
5. No changes *[SKIP TO VI.]*

P. Compared to the space the DHP was installed for, is this additional space:
1. Significantly larger
2. Somewhat larger
3. The same size
4. Somewhat smaller
5. Significantly smaller

Q. *[IF V.P. = 1]* Would you say this extra space is being cooled by the program DHP all the time, about half time, or only infrequently (e.g. special occasions or very hot days)?
1. All the time
2. About half time
3. Infrequently
4. Don't know / don't remember

VI. Decision Factors

[Read] The next questions ask about the decision-making process you used and the factors you considered prior to installing a program eligible DHP.

A. On a scale of 1 to 5, where 1 is "very insignificant", 3 is "neutral" and 5 is "very significant," how significant were each of the following features of program eligible ductless heat pumps to you when you were making your decision? Please let me know if you were unaware of these features at the time of your decision. *[Check all that apply]*

Feature	1	2	3	4	5	DK	Unaware
1. Programmable thermostat							
2. Ability to heat and cool with one unit							
3. Ability to heat or cool the space differently from the rest of the house							
4. Silent operation							
5. Speed to reach desired temperature							
6. Lower operating cost							
7. Ease of installation compared to alternatives							
8. High efficiency							
9. Utility endorsement							
10. Utility rebate							
11. Other (please specify)							

B. On a scale of 1 to 5, where 1 is "very insignificant", 3 is "neutral" and 5 is "very significant," how significant were each of the following factors in your decision to install a program DHP? Please let me know if you were unaware of these factors at the time of your decision.

Reason	1	2	3	4	5	DK	Unaware
1. Structural constraints							
2. Contractor recommendations							
3. Purchase cost of alternative							
4. Price of alternative fuel(s)							
5. Ease of DHP installation							
6. Efficiency of DHP operation							
7. Ability to heat/cool space separately							
8. Low-noise of DHP							
9. Maintenance benefit of DHP							
10. Program incentive							

11. Other DHP features (please specify)							

C. Thinking back to the time when you were making your decision to install the program eligible heat pump, on a scale of 1 to 5, where 1 is "very insignificant", 3 is "neutral" and 5 is "very significant," how significant in your decision-making process was the price of: *[Ask for all fuels, check NA if not considered]*

Fuel	1	2	3	4	5	DK	NA
1. Fuel oil							
2. Natural gas							
3. Propane							
4. Wood, pellets, or coal							
5. Electricity							

[The responses for the following questions will be randomized and not be in ascending order]

D. *[ONLY IF VI.C.1 =>4]* Since you said the price of fuel oil was a significant factor in your decision making, on a scale of on a scale of 1 to 5 were 1 is "very unlikely" and 5 is "very likely" how likely would have been to stall the same DHP if the price of fuel oil had been:

Fuel Oil Price Sensitivity	1	2	3	4	5	DK
1. 20% lower at that time?						
2. 33% lower at that time?						
3. 50% lower at that time?						
4. 75% lower at that time?						

E. *[ONLY IF VI.C.2. =>4]* Since you said the price of natural gas was a significant factor in your decision making, on a scale of on a scale of 1 to 5 were 1 is "very unlikely" and 5 is "very likely" how likely would have been to stall the same DHP if the price of natural gas had been:

Natural Gas Price Sensitivity	1	2	3	4	5	DK
1. 20% lower at that time?						
2. 33% lower at that time?						
3. 50% lower at that time?						
4. 75% lower at that time?						

F. *[ONLY IF VI.C.3VI.C.3. =>4]* Since you said the price of propane was a significant factor in your decision making, on a scale of on a scale of 1 to 5 were 1 is "very unlikely" and 5 is "very likely" how likely would have been to stall the same DHP if the price of propane had been:

Propane Price Sensitivity	1	2	3	4	5	DK
1. 20% lower at that time?						
2. 33% lower at that time?						

3. 50% lower at that time?						
4. 75% lower at that time?						

G. *[ONLY IF VI.C.4 =>4]* Since you said the price of wood, pellets or coal was a significant factor in your decision making, on a scale of on a scale of 1 to 5 were 1 is "very unlikely" and 5 is "very likely" how likely would have been to stall the same DHP if the price of these fuels had been:

Wood, Pellet, Coal Price Sensitivity	1	2	3	4	5	DK
1. 20% lower at that time?						
2. 33% lower at that time?						
3. 50% lower at that time?						
4. 75% lower at that time?						

H. Since your DHP runs on electricity, on scale of on a scale of 1 to 5 were 1 is "very unlikely" and 5 is "very likely" how likely would have been to install the same DHP if:

Electric Bill Price Sensitivity	1	2	3	4	5	DK
1. It would have increased your average monthly bill by 5%						
2. It would have increased your average monthly bill by 10%						
3. It would have increased your average monthly bill by 15%						
4. It would have increased your average monthly bill by 20%						

I. On scale of on a scale of 1 to 5 were 1 is "very unlikely," 3 is "neutral" and 5 is "very likely" how likely would you have been to install the program-eligible DHP if the rebate were:

Rebate Sensitivity	1	2	3	4	5	DK
1. 10% lower?						
2. 30% lower?						
3. Half as much?						
4. Not available?						

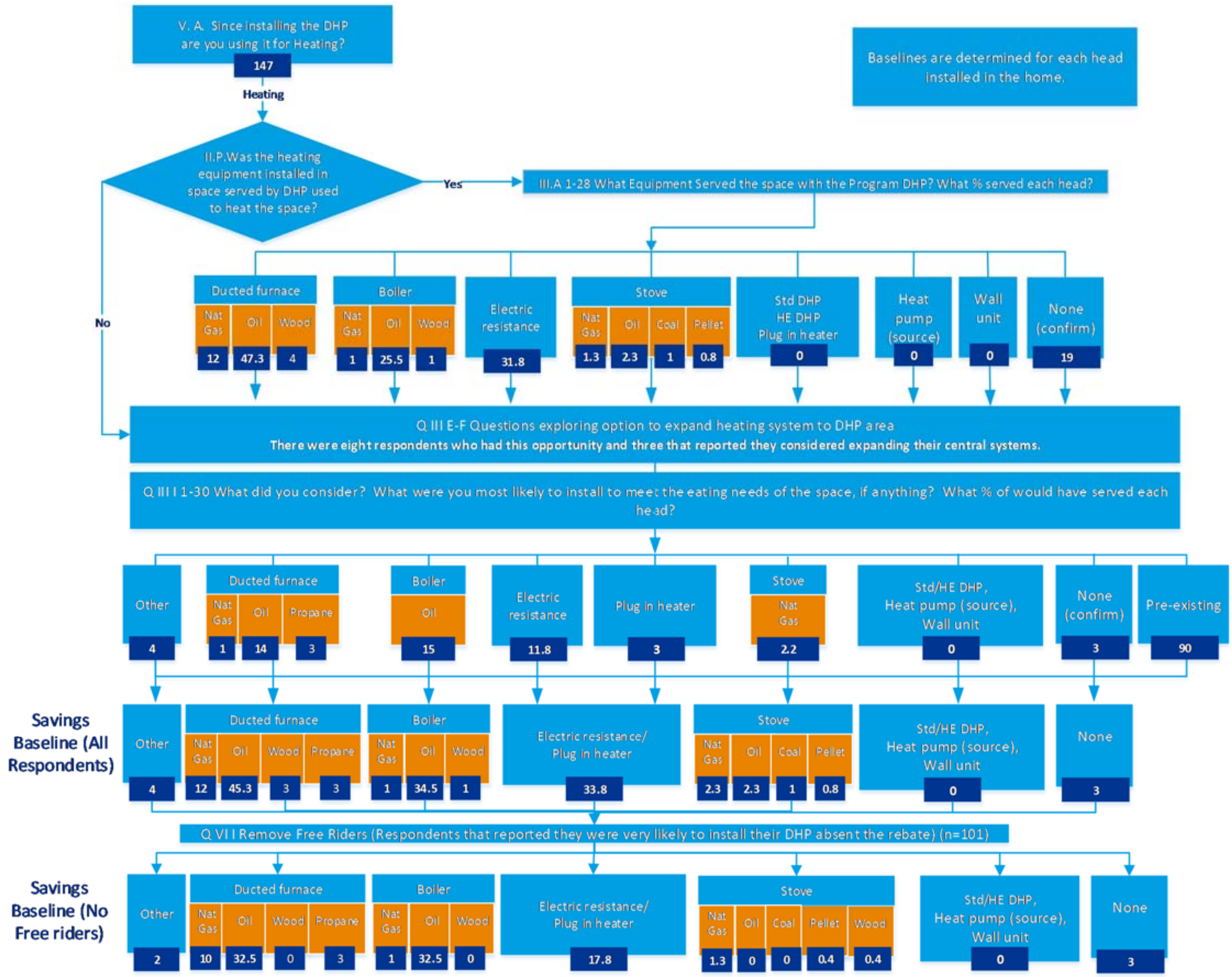
J. *[IF ANY OF VI.I.1. through VI.I.4. =<3 or DK]* If the rebate levels had been lower or non-existent, what do you think was the likelihood you would have installed a standard efficiency DHP in the space instead of a program eligible DHP, on the same 1 to 5 scale?

Rebate Sensitivity 2	1	2	3	4	5	DK
1. Standard Efficiency Installed Absent Rebate						

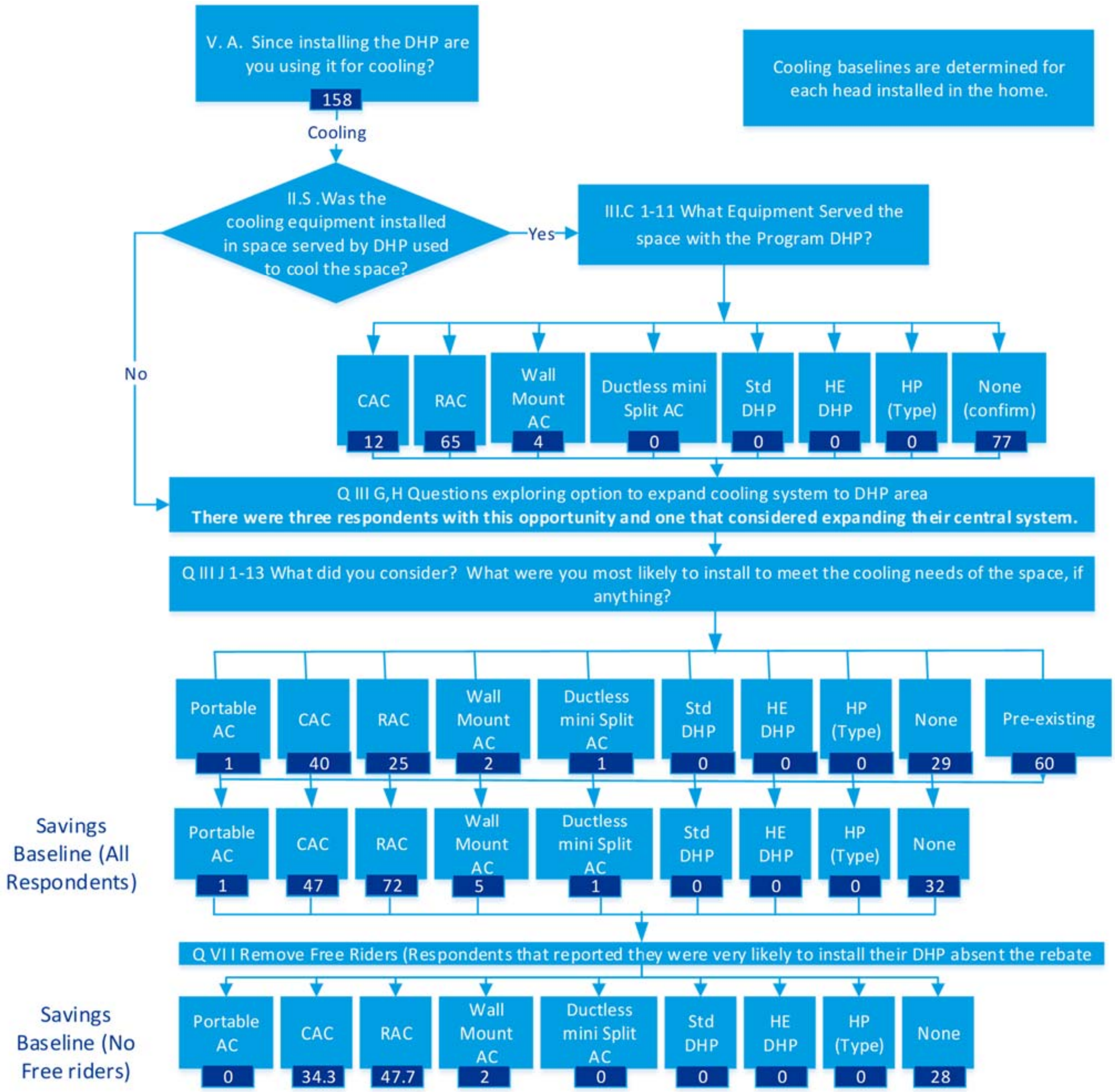
[TERMINATE] – That's all the questions I have for you today. I appreciate your willingness to talk with me. On behalf of Energize CT and our utility sponsors, I thank you for your time today.

APPENDIX B: Baseline Decision Trees and Results

Heating



Cooling



V. A. Since installing the DHP are you using it for cooling?
158
Cooling
Cooling baselines are determined for each head installed in the home.
II.S .Was the cooling equipment installed in space served by DHP used to cool the space?
Yes
No
III.C 1-11 What Equipment Served the space with the Program DHP?
CAC 12
RAC 65
Wall Mount AC 4
Ductless mini Split AC 0
Std DHP 0
HE DHP 0
HP (Type) 0
None (confirm) 77
Q III G,H Questions exploring option to expand cooling system to DHP area
There were three respondents with this opportunity and one that considered expanding their central system.
Q III J 1-13 What did you consider? What were you most likely to install to meet the cooling needs of the space, if anything?
Portable AC 1
CAC 40
RAC 25
Wall Mount AC 2
Ductless mini Split AC 1
Std DHP 0
HE DHP 0
HP (Type) 0
None 29
Pre-existing 60
Savings Baseline (All Respondents)
Portable AC 1
CAC 47
RAC 72
Wall Mount AC 5
Ductless mini Split AC 1
Std DHP 0
HE DHP 0
HP (Type) 0
None 32
Q VI I Remove Free Riders (Respondents that reported they were very likely to install their DHP absent the rebate
Savings Baseline (No Free riders)
Portable AC 0
CAC 34.3
RAC 47.7
Wall Mount AC 2
Ductless mini Split AC 0
Std DHP 0
HE DHP 0
HP (Type) 0
None 28

APPENDIX C: DHP Contractor Interview Guide

Interviewer		Survey Length (min.)	
Completion Date			
DNV GL ID #			

Respondent Information

Company Name	
Street Address	
City, State, Zip	
Contact Name	
Contact Title	
Phone	
Alt info (email, cell)	

Call Tracking

Date/Time	Notes/result/actions: (Who spoke to, new contact info, when to call back, etc.)

This interview guide is intended to facilitate a discussion with R1617 DHP participating contractors.

Instructions to the interviewer, which are not intended to be read, are enclosed in [square brackets].

A. Introduction

Hello ____ my name is ___ and I'm calling on behalf of the <UTILITY>.

According to our records, in the past two years your company has installed ductless heat pumps as part of the CT Energize program. <UTILITY> would like to ask a representative from your company some questions that will help them to improve their residential Ductless Heat Pump program (DHP).

1. Are you able to confirm that your company installed one or more high-efficiency ductless heat pumps (DHP) under the CT Energize program within the past 2 years. Is this correct?
    a. Yes – [Skip to A.1]
    b. No – [Skip to A.5]
    c. Refuse – [Thank and Terminate]
    d. Don't know – [Skip to A.5I.C]

2. Are you willing to participate in this effort?
    a. Yes - [Skip to A.3.]
    b. No – [Thank and Terminate]
    c. Don't know [Read A.7I.E and/or A.8 as appropriate]

3. Is now a convenient time to talk?
    a. Yes - [Skip to B.1]
    b. No – [Skip to A.4]
    c. Don't know [Read A.7I.E and/or A.8 as appropriate]

4. When would be a good time for us to call back to discuss your company's participation CT Energize's DHP program?
    a. [Record answer, thank, and terminate]
    b. Refused – [Thank and Terminate]

5. Is there someone else who would know about the installation of the program DHP in your home?
    a. Yes – [Skip to A.6]
    b. No – [Thank and Terminate]
    c. Don't know

6. When would be a good time for us to call back to talk to someone who might know about this project?
    a. [Record answer, thank, and terminate]
    b. Refused – [Thank and Terminate]

7. [*If necessary]* We have some general questions about your residential heating and cooling projects you completed over the past 2 years. We anticipate this will take approximately 20 minutes of your time. Everything we talk about will be kept confidential and only reported as part of a larger group of results. Your responses will in no way affect the rebate you received or equipment you installed.

8. [IF THEY HAVE QUESTIONS ABOUT OUR LEGITIMACY, THEY CAN CONTACT xx of xxx at xxx.xxx.xxx]

B. General Market Questions

First, I would like to ask a few questions about the installation of DHPs your company has done over the past 2 years.

1. Approximately how many residential heating and cooling projects has your company installed in in the past 2 years? [If necessary, HOW MANY JOBS DID YOU HAVE IN THE PAST TWO YEARS]? A rough estimate or a range is fine.
   ____

   [Don't know]..-97
   [Refused]..-98

2. For all projects, what percentage of the of your projects were [should add to 100%]:
   a. An addition to a home _______________
   b. A new construction home _______________
   c. An existing home to replace failed cooling and/or heating equipment ____________
   d. An existing home as part of a major renovation _____________
   e. An existing home to supplement the existing cooling and/or heating equipment ____________

   [Don't know]..-97
   [Refused]..-98

[For each response in B,2, ask the following sequence of questions]

3. Approximately what percentage of your residential heating and cooling installations over the past 2 years where DHPs considered?
   _____%

   [Don't know]..-97
   [Refused]..-98

4. For those projects where a DHP was considered, approximately what percentage of projects installed a DHP?
   _____%

   [Don't know]..-97
   [Refused]..-98

C. Non-DHP Installations – Not Considered

For the next few questions I'd like to ask similar questions for projects where DHPs were not considered.

1. For the projects where DHPs were not considered, what percentage of the projects were installed in [should add to 100%]:
    a. An addition to a home _______________
    b. A new construction home _______________
    c. An existing home to replace failed cooling and/or heating equipment ____________
    d. An existing home as part of a major renovation _____________
    e. An existing home to supplement the existing cooling and/or heating equipment ____________

[Don't know]...-97
[Refused]...-98

2. For the projects where DHPs were not considered, what percentage of those project were installed to provide:
    a. Cooling only _______________
    b. Heating only _______________
    c. Both cooling and heating

[Don't know]...-97
[Refused]...-98

[For each response in C.1, ask the following sequence of questions]

3. Of the percentage of homes where a DHP was not installed in <Response to Question C.1>, what percentage of those homes had an existing duct system in the space served by the new cooling and/or heating equipment?

    ____

[Don't know]...-97
[Refused]...-98

4. Of the homes with existing duct systems, how important on a scale of 1 to 7, with 1 being not very important and 7 being very important, was it in influencing your decision to not consider DHP an option?

    ____

5. Of the percentage of homes where a DHP was not installed in <Response to Question C.1>, what percentage of those homes had access to natural gas?

    ____

[Don't know]...-97
[Refused]...-98

6. Of the homes with access to natural gas, how important on a scale of 1 to 7, with 1 being not very important and 7 being very important, was access to natural gas in influencing your decision to not consider DHP an option?

____

7. Of the percentage of homes that did not have access to natural gas, what percentage of those homes used the following fuel types to serve the space that was served by the new cooling and/or heating equipment?
   a. Oil _______________
   b. Propane _______________
   c. Wood ____________
   d. Electric _____________
   e. Other ________________

[Don't know]..-97
[Refused] ....-98

8. Are there other characteristics of homes where DHPs are not feasible and therefore, not considered as an option? [Open ended. Probe on home ages, sizes of space served by new heating/cooling equipment, number of DHPs that would be prohibitive, costs, etc. Probe on scale of 1 to 7 how important, with 1 being not very important and 7 very important.]

____

[Don't know]..-97
[Refused] ....-98

Type of Installation	Existing duct system?	Access to natural gas (Y/N)	Type of fuel (oil/propane/wood/electric/other)	Other home characteristics
An addition to a home				
A new construction home				
An existing home to replace failed cooling and/or heating equipment				
An existing home as part of a major renovation				
An existing home to supplement the existing cooling and/or heating equipment				

D. Non-DHP Installations – Considered Not Installed

For the next few questions I'd like to ask similar questions for projects where DHPs were considered but not installed.

1. For the projects where DHPs were considered but not installed, what percentage of the projects were [should add to 100%]:
   a. An addition to a home _______________
   b. A new construction home _______________
   c. An existing home to replace failed cooling and/or heating equipment ____________
   d. An existing home as part of a major renovation _____________
   e. An existing home to supplement the existing cooling and/or heating equipment ____________

[Don't know]..-97
[Refused]..-98

2. For the projects where DHPs were considered but not installed, what percentage of those projects were:
   1. Cooling only _______________
   2. Heating only _______________
   3. Both cooling and heating

[Don't know]..-97
[Refused]..-98

[For each response in D.1, ask the following sequence of questions]

3. Of the percentage of homes where a DHP was considered but not installed in <Response to Question D.1>, what percentage of those homes had an existing duct system in the space served by the new cooling and/or heating equipment?

   ____

[Don't know]..-97
[Refused]..-98

4. Of the homes that had existing duct systems, how important on a scale of 1 to 7, with 1 being not very important and 7 being very important, was access to natural gas in influencing your decision to consider DHP an option?

   ____

5. Of the percentage of homes where a DHP was considered but not installed in <Response to Question D.1>, what percentage of those homes had access to natural gas?
   a. ___________
   b. [Don't know] -97
   c. [Refused] -98

6. Of the homes with access to natural gas, how important on a scale of 1 to 7, with 1 being not very important and 7 being very important, was access to natural gas in influencing your decision to consider DHP an option?

   ____

7. Of the percentage of homes that did not have access to natural gas, what percentage of those homes used the following fuel types to serve the space that was served by the new cooling and/or heating equipment?
    a. Oil _______________
    b. Propane _______________
    c. Wood ____________
    d. Electric _____________
    e. Other ________________

[Don't know]..-97
[Refused] ....-98

8. Are there other characteristics of homes or reasons where DHPs are common across homes where DHPs were considered but not installed? [Open ended. Probe on home ages, sizes of space served by new heating/cooling equipment, number of DHPs that would be prohibitive, costs, etc. Probe on scale of 1 to 7 how important, with 1 being not very important and 7 very important.] ____________

[Don't know]..-97
[Refused] ....-98

Type of Installation	Existing duct system?	Access to natural gas (Y/N)	Type of fuel (oil/propane/wood/electric/other)	Home characteristics and reasons not installed
An addition to a home				
A new construction home				
An existing home to replace failed cooling and/or heating equipment				
An existing home as part of a major renovation				
An existing home to supplement the existing cooling and/or heating equipment				

E. DHP Installations – Considered and Installed

Finally, I would like to ask a few questions about the projects where DHPs were considered and installed by your company over the past 2 years.

1. For the projects that included DHPs, what percentage of the DHPs were installed in [should add to 100%]:
    a. An addition to a home _______________
    b. A new construction home _______________
    c. An existing home to replace failed cooling and/or heating equipment ____________
    d. An existing home as part of a major renovation _____________
    e. An existing home to supplement the existing cooling and/or heating equipment ____________

[Don't know]..-97
[Refused]..-98

2. For the projects that included DHPs, what percentage of the DHPs were installed to provide:
    a. Cooling only _______________
    b. Heating only _______________
    c. Both cooling and heating

[Don't know]..-97
[Refused]..-98

[For each response in E.5, ask the following sequence of questions]

3. Of the percentage of homes where a DHP was installed in <Response to Question D.5>, what percentage of those homes had an existing duct system in the space served by the DHP?

    ____

[Don't know]..-97
[Refused]..-98

4. Of the homes with existing duct systems, how important on a scale of 1 to 7, with 1 being not very important and 7 being very important, was it in influencing your decision to consider DHP an option?

    ____

5. Of the percentage of homes where a DHP was installed in <Response to Question D.5>, what percentage of those homes had access to natural gas?

    ____

[Don't know]..-97
[Refused]..-98

6. Of the homes with access to natural gas, how important on a scale of 1 to 7, with 1 being not very important and 7 being very important, was access to natural gas in influencing your decision to consider DHP an option?

    ____

7. Of the percentage of homes that did not have access to natural gas, what percentage of those homes used the following fuel types to serve the space that was served by the DHP?
    a. Oil _______________
    b. Propane _______________
    c. Wood ____________
    d. Electric _____________
    e. Other ________________

[Don't know]..-97
[Refused]..-98

8. Are there other characteristics of homes that were important in influencing your decision to consider DHPs? [Open ended. Probe on home ages, sizes of space served by new heating/cooling equipment, number of DHPs that would be prohibitive, costs, etc. Probe on scale of 1 to 7 how important, with 1 being not very important and 7 very important.]
    ____

[Don't know]..-97
[Refused]..-98

Type of Installation	Existing duct system?	Access to natural gas (Y/N)	Type of fuel (oil/propane/wood/electric/other)
An addition to a home			
A new construction home			
An existing home to replace failed cooling and/or heating equipment			
An existing home as part of a major renovation			
An existing home to supplement the existing cooling and/or heating equipment			

This concludes all the questions I have for you today. Do you have any questions for me or comments about the program before we finish? [IF NO, THANK AND TERMINATE]

APPENDIX D: Contractor Decision Tree Results

Question	Cooling			
Average time to replacement (years)	16.7			
	NC	Retrofit	Supplemental	Total/AVG
Total # of Annual Installs	1,462	11,388	4,702	17,551
% of installations where DHP (standard or HE) recommended	8.1%	10.1%	19.1%	12.3%
	Heating			
Average time to replacement (years)	22.1			
	NC	Retrofit	Supplemental	Total
Total # of Annual Installs	1,541	11,832	4,701	18,075
% of installations where DHP (standard or HE) recommended	8.4%	6.3%	11.2%	7.7%

Question	New Construction			
	Cooling only	Cooling and supplemental heating	Cooling and primary heating	Heating only
Types of DHP rec.:	30%	31%	32%	7%
% of those that are HE rec.	82.6%	94.6%	100.0%	100.0%
% of HE rec. where:				
a. HE adopted	84.0%	83.5%	80.7%	84.1%
b. standard DHP adopted	4.3%	3.3%	0.7%	3.4%
c. non-DHP adopted	11.7%	13.2%	18.6%	12.5%
% of HEDHP getting rebate	62.6%			
	Retrofit			
	Cooling only	Cooling and supplemental heating	Cooling and primary heating	Heating only
Types of DHP rec.:	53.1%	19.3%	15.8%	12.5%
% of those that are HE rec.	77.8%	82.2%	94.9%	99.4%
% of HE rec. where:				
a. HE adopted	75.8%	81.8%	79.1%	75.3%
b. standard DHP adopted	11.4%	6.4%	2.6%	6.3%
c. non-DHP adopted	12.7%	11.8%	18.9%	18.4%
% of HEDHP getting rebate	62.6%			

Question	Supplemental			
	Cooling only	Cooling and supplemental heating	Cooling and primary heating	Heating only
Types of DHP rec.:	61.6%	22.2%	5.6%	11.4%
% of those that are HE rec.	81.5%	84.6%	87.5%	99.6%
% of HE rec. where:				
a. HE adopted	70.2%	76.8%	80.3%	78.4%
b. standard DHP adopted	18.0%	9.4%	4.4%	5.0%
c. non-DHP adopted	11.9%	13.8%	15.3%	16.6%
% of HEDHP getting rebate	62.6%			
	Total			
	Cooling only	Cooling and supplemental heating	Cooling and primary heating	Heating only
Types of DHP rec.:	54.9%	21.3%	12.8%	11.0%
% of those that are HE rec.	79.7%	84.4%	94.5%	99.5%
% of HE rec. where:				
a. HE adopted	73.5%	79.9%	79.6%	76.9%
b. standard DHP adopted	14.2%	7.3%	2.5%	5.6%
c. non-DHP adopted	12.3%	12.8%	18.2%	17.5%
% of HEDHP getting rebate	62.6%			

APPENDIX E: Adoption Model Tool and Model Specifications

How the Tool Works

The adoption modeling tool produces results for a current assumed starting point and a scenario that the user develops. There are three main tabs in the tool: User Guide, Summary, and Detailed Results. The user can create a scenario for comparison in this tool by adjusting different input parameters on the 'Summary' tab. Adjustments made on the 'Summary' tab will automatically be made on the 'Detailed Results' tab as well. The figure below is a screen shot of the 'Summary' tab in the tool. The input parameters are highlighted in yellow and the results of the scenario are in green.

There are three types of parameters that the user can adjust to develop a scenario:

1. The starting number of program participants in the current assumed baseline. The tool provides the number of program participants in 2015, 1,197 participants. The '% change in starting number of program participants' cell (G4) allows the user to select a change factor to increase or decrease that starting level of participation. The results of the scenario are compared to this current assumed starting point.

2. The mix of types of homes that participate in the program. The 2015 mix of homes is provided in the tool. The home characteristics include single-family vs. multi-family, the type of heating fuel in the home prior to DHP adoption, and the intended use of the DHP prior to the purchase. To change the mix of homes, the user can manually adjust the 'Revised Mix' cells (G9:G14), The total allocation of homes should always be kept at 100%.

3. The scenario factors. This is the section that allows the user to adjust the level of the rebate and the price of alternate fuels. The user can choose an option in the 'Select a Rate' cells (G19:G20) to adjust the scenario. A 0% change means that the rebate or the price of alternate fuel does not change from the 2015 level. A 50% rate means that the rebate or price is 50% higher than its original value, while a -50% rate means that the rebate or price is 50% lower than its original value.

The 'Summary' tab also shows the high-level results of the chosen scenario. The user can also view a more detailed breakdown of the results by the home characteristics, see the 'Detailed Results' tab. Positive impacts indicate savings associated with the chosen scenario, while negative impacts indicate increased energy consumption.

Figure E-0-1: Screenshot of 'Summary' tab on the Planning Tool

HOOSE THE STARTING # OF PROGRAM PARTICIPANTS	
2015 starting number of program participants	1,197
% change in starting number of program participants	0%
Current assumed number of program participants	1,197

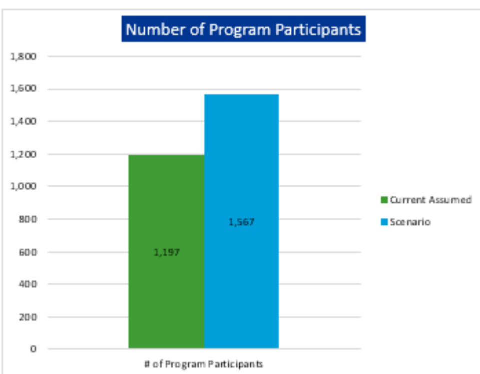
Scenario input
Scenario output

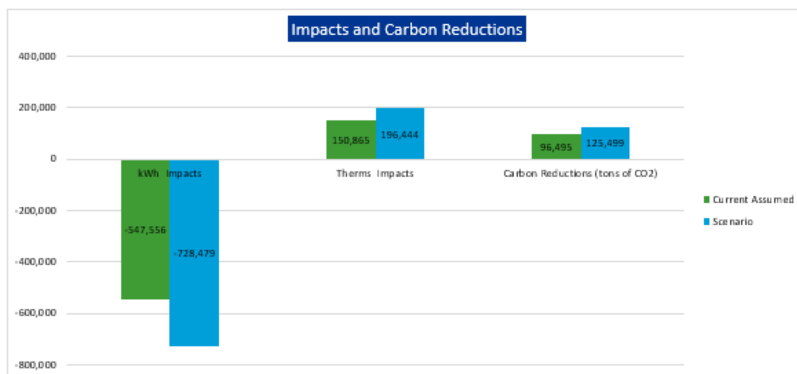
IOSE THE MIX OF HOME CHARACTERISTICS PARTICIPATING IN THE PROGRAM				
Type of Home	Heating Fuel Prior to DHP Adoption	Planned Use of DHP at Purchase	2015 Mix	Revised Mix
Multi Family	Non-Electric	Heating (with or without cooling	4.8%	4.8%
Multi Family	Electric	Heating (with or without cooling	2.4%	2.4%
Multi Family	Non-Electric	Cooling Only	1.2%	1.2%
Single Family	Non-Electric	Heating (with or without cooling	51.2%	51.2%
Single Family	Electric	Heating (with or without cooling	13.1%	13.1%
Single Family	Non-Electric	Cooling Only	27.4%	27.4%
Total			**100.0%**	**100.0%**

* total allocation must equal 100%

DEVELOP A SCENARIO	
Scenario Factor	Select a Rate
% change in the rebate, compared to 2015 rebate	10%
% change in the real price of alternate fuels, compared to 2015	20%

SUMMARY OF RESULTS	# of Program Participants	kWh Scenario Impacts	kWh Impact Participant	Therm Program	Therm Impact Participant
Current Assumed	1,197	(547,556)	(457)	150,865	126
Scenario	1,567	(728,479)	(465)	196,444	125
Difference	370	(180,923)	(7)	45,579	(1)
% Change	0	0	0	0	(0)





Model Specifications

Table E-1: Log-log regression coefficients (rebate)

	Single Family			Multifamily		
	Estimate	Standard Error	Probability	Estimate	Std Err	Probability
Intercept	-0.258	0.060	0.000	-0.065	0.049	0.195
LN(Rebate)	0.838	0.187	0.000	0.282	0.224	0.222
LN(Electric)*LN(Rebate)	-0.304	0.301	0.315	-0.308	0.189	0.119
LN((1-Electric)*Cooling Only))*LN(Rebate)	-0.653	0.185	0.001	-0.308	0.189	0.119

Code:

Electric: 1 = electric pre-existing heat; 0 = not electric pre-existing heat

Cooling Only: 1 = intended purpose of DHP is cooling only; 0 = intended purpose of DHP is not cooling only

Single Family: 1 = single family; 0 = not single family

Figure E-2 Rate of Program Participation at Different Rebate Levels, by Population Segment

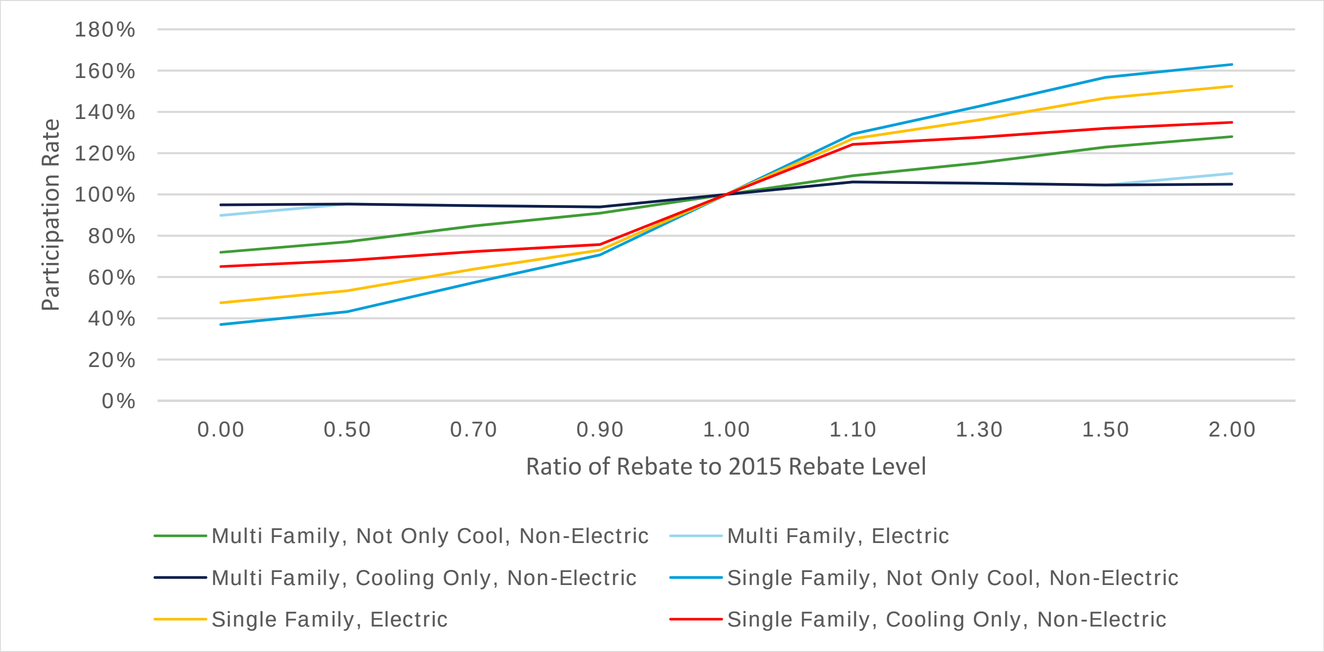


Table E-2: Log-log regression coefficients (alternate fuel)

	Estimate	Standard Error	Probability
Intercept	0.000	0.000	0.000
LN(Fuel Cost)	0.190	0.075	0.011
LN(Single Family)*LN(Fuel Cost)	0.074	0.081	0.362
LN(Electric)*LN(Fuel Cost)	-0.032	0.097	0.745
LN((1-Electric)*Cooling Only))*LN(Fuel Cost)	-0.181	0.048	0.000

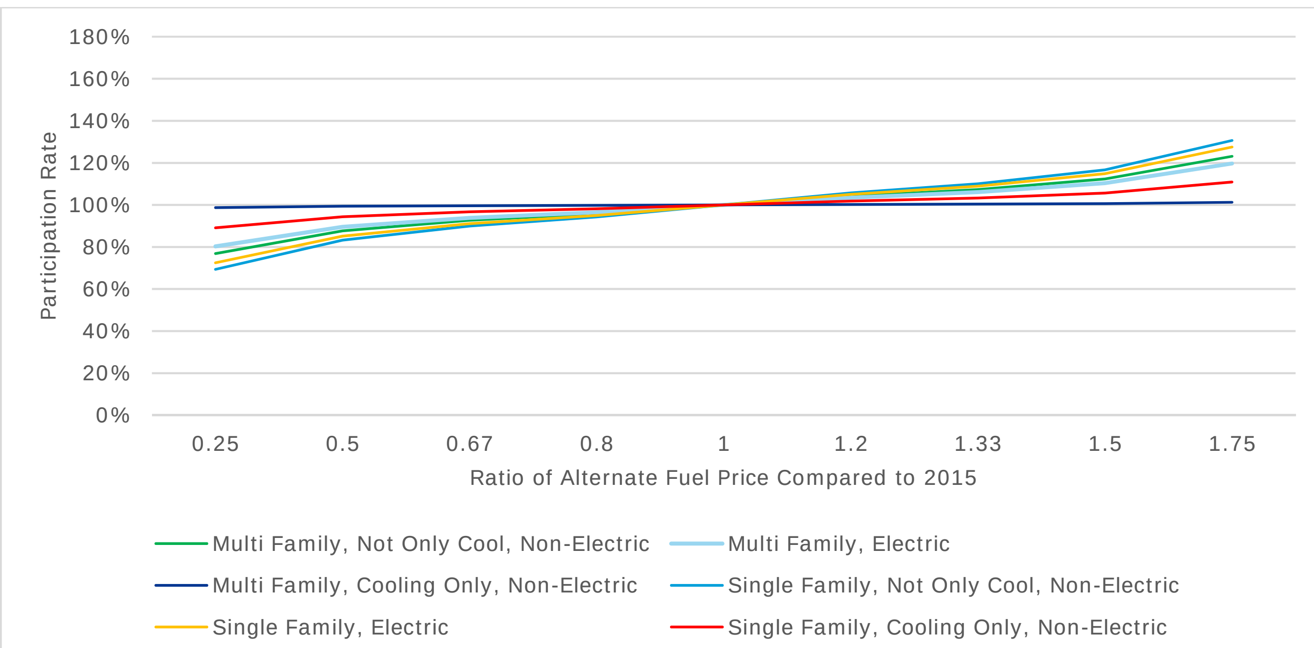
Code:

Electric: 1 = electric pre-existing heat; 0 = not electric pre-existing heat

Cooling Only: 1 = intended purpose of DHP is cooling only; 0 = intended purpose of DHP is not cooling only

Single Family: 1 = single family; 0 = not single family

Figure E-3: Rate of program participation at alternate fuel price levels, by population segment



About DNV GL

DNV GL is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas, power and renewables industries. We also provide certification, supply chain and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter and greener.