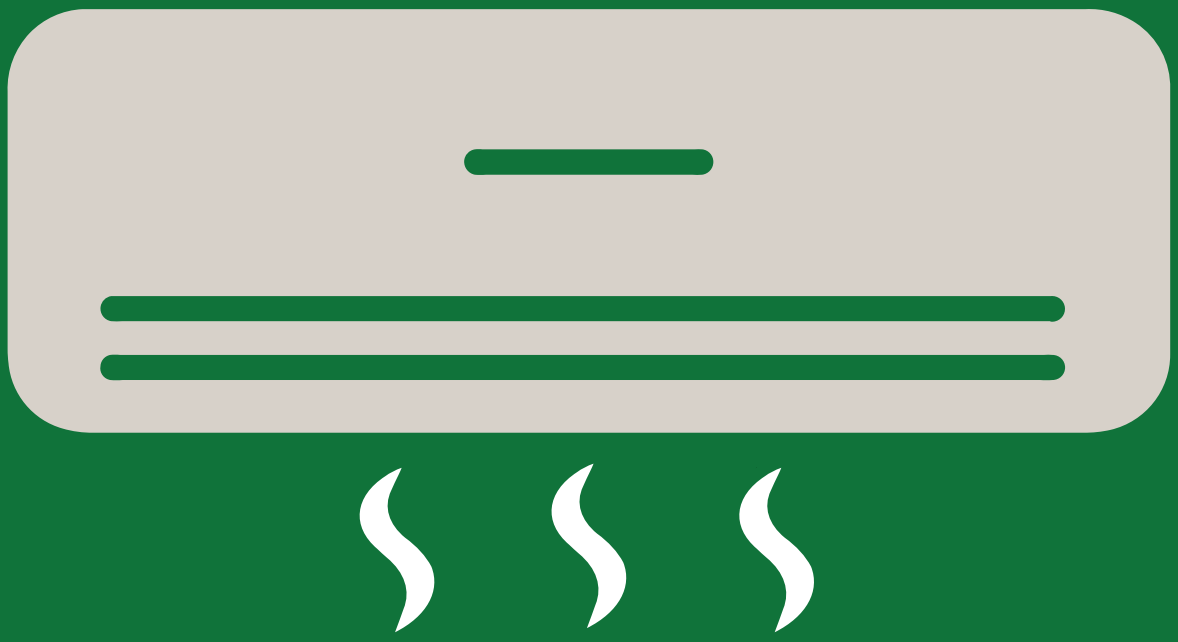
BONNEVILLE POWER ADMINISTRATION



2018-19 Residential HVAC Impact Evaluation Final Report

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1 EXECUTIVE SUMMARY

This report presents results from impact evaluation activities conducted on 2018-2019 residential HVAC measures for the Bonneville Power Administration (BPA), addressing the following measure groups:

1. Ductless heat pumps (DHPs) replacing electric zonal in heating zones 2 and 3
2. DHPs replacing electric forced air furnaces in heating zone 3
3. Air-source heat pump (ASHP) conversions in all heating zones
4. Variable speed heat pump (VSHP) conversions in all heating zones
5. Prescriptive duct sealing in all heating zones

Evergreen conducted billing analysis from residential customers of a sample of utilities in the region served by BPA to estimate electricity savings associated with each of the program measures listed above.

Evergreen also conducted a mail customer survey in February 2020 with a sample of households that received utility rebates and installed DHPs to replace electric zonal heating in heating zones 2 and 3 (measure group 1 in the list above) to better understand the variation in savings for this measure.

1.1 BILLING REGRESSION ANALYSIS RESULTS

Evergreen estimated the impact that each of the HVAC measures had on average daily and annual electricity consumption. For all measures, we found that participants used less electricity on average after installation; however, the degree of reduction differed considerably among the measures (Table 1).

Table 1: Estimated annual change in electricity use (in kWh) after installing HVAC measure

Row	*Measure*	*Heating Zone 1*	*Heating Zone 2*	*Heating Zone 3*
1	DHP Replacing Zonal Heating	NA	-912	-827
2	DHP Replacing Electric Forced Air Furnace	NA	NA	-1,813
3	ASHP with Duct Sealing	-2,422	-2,620	NA
4	ASHP *without* Duct Sealing	-4,162	-3,748	-3,748
5	VSHP with Duct Sealing	-5,473	-5,473	NA
6	VSHP *without* Duct Sealing	-1,198	-776	-776
7	Duct Sealing (without another measure)	-3,062	-2,198	-1,844

Source: Analysis by Evergreen Economics of data received from BPA utilities.

Customers that installed a VSHP with duct sealing experienced the greatest average reduction in electricity use (5,473 kWh per year), while customers that installed VSHP *without* duct sealing experienced annual savings of only about 1,200 kWh in heating zone 1 and 776 kWh per year in heating zones 2 and 3 (row 3 shows ASHP with duct sealing; row 4 shows without duct sealing). The data do not provide any insight into why savings were greater (on average) for customers that installed an ASHP without duct sealing, but it may be due to differences in home age, vintage of the respective ducting systems, or other factors not captured in the tracking databases provided by the participating utilities.

Customers that installed a DHP to replace zonal heating experienced a reduction in electricity use of 912 kWh for heating zone 2 and 827 kWh for heating zone 3. Evergreen surveyed a sample of customers that installed a DHP to try to understand what factors influenced electricity savings. Highlights from the survey are presented in the following report subsection.

Evergreen also analyzed data on customers that participated only in a duct sealing program (row 7)—that is, they did not also install a heat pump. Across all three heating zones, average annual electricity use dropped after duct sealing was conducted. Customers in heating zone 1 experienced the greatest average savings (3,062 kWh per year), while customers in heating zones 2 and 3 experienced average annual reductions in electricity use of 2,198 kWh and 1,844 kWh, respectively.

1.2 DHP SURVEY RESULTS

Evergreen conducted a mail survey in February 2020 with a sample of residential customers drawn from BPA program data on customers in heating zones 2 and 3 who installed a DHP to replace their old zonal heating system. A total of 131 surveys were completed, with a 73 percent response rate.

Based on the survey results, the main DHP purchase drivers were:

- Saving energy/reducing energy costs;
- Replacing an old heating system (mostly due to the old system's high energy costs);
- Adding air conditioning to the home (only one-third already had air conditioning); and
- Increasing comfort in the home.

Most households reported that they use the DHP to heat and cool most or all of their home, and around one-quarter increased the square footage of their home that is heated and/or cooled.

There were high rates of reported non-energy benefits from DHPs: nearly all reportedly noticed an increase in overall comfort; the majority noticed increased safety (over their older heating system) and increased air quality.

These survey results suggest that there is a complex set of changes in usage as a result of DHP installations that would lead to both energy savings and increased electricity usage.

Energy savings would be expected to result from

- Increased heating efficiency over older heating system (47% replaced their old heating system); and
- Increased cooling efficiency over older system (17% replaced their old cooling system).

Increased usage (or negative energy savings) could be expected to result from

- Wider and greater use of heating and/or cooling in the home (e.g., more rooms conditioned, increased comfort); and

- Added air conditioning where none was present before (66% did not have air conditioning prior to installing the DHP).

However, if compared to what customers reported they would have done in absence of buying the DHP, over one-third who did not have air conditioning prior said they would have bought a different cooling system (most commonly a window AC) that may have been less efficient at cooling than the DHP.

Evergreen compared survey responses to changes in electricity bills (pre- and post-DHP installation) and identified a handful of statistically significant results that help explain the variation in pre/post bills:

- Customers that reported heating their home with wood or wood pellets increased their electricity usage after installing a DHP (a difference of 15.6 kWh per day during winter compared to participants that did not report using wood or wood pellets).
- Customers that reported having natural gas service decreased their electricity use after installing a DHP on average by 15.4 kWh per day during the winter. In contrast, customers who reported having propane/bottled gas service increased their electricity use by nearly 10 kWh per day. However, this statistical result is just for gas service, and does not indicate whether the propane/bottle gas service was used for heating, or only for other purposes such as cooking or water heating.

Evergreen also identified some results that were not statistically significant in explaining changes in pre/post bills:

- Mail survey respondents who did not have cooling before adding a DHP did not increase their summertime electricity use after installing a DHP.
- There is no statistically significant correlation between the number of indoor DHP heads and the change in electricity usage after installing the DHP in the mail survey sample.
- There was no difference in electricity savings between customers that reported in the survey that they continued to use their old heating system(s) (of any type(s)) after installing a DHP and customers that stopped using their old heating system(s) once they installed the DHP.

The survey results on customers adding AC combined with the savings analysis on homes with wood heat suggest that savings estimates based on comparing pre and post bills may understate the comprehensive savings and benefits attributable to DHPs. This research could support updates to baseline assumptions for households that use wood heat and/or were planning to add central AC, and to cost/benefit analyses that address participant cost savings and non-energy benefits associated with reducing the use of wood heating.

2 INTRODUCTION

This report presents results from impact evaluation activities conducted on 2018-2019 residential HVAC measures for the Bonneville Power Administration (BPA).

2.1 BACKGROUND

BPA, along with its public power utility partners, acquires savings from a portfolio of energy efficiency programs and measures, including Unit Energy Savings (UES) measures utilizing a constant savings value for each measure application.

In early 2018, BPA identified select heat pump measures as focus areas for the 2018-2019 evaluation efforts. The results of the 2018 evaluation work identified additional residential HVAC measures whose results were inconclusive due to a small sample of projects.[1] BPA identified a subset of these residential UES measures as priorities to be evaluated again in an attempt to get conclusive results.

2.2 STUDY OBJECTIVES

This evaluation was designed to carry out research activities for select measures, building on the guidance provided in the 2018-2019 Evaluation Plan.[2] The evaluation and research activities were intended to address the following measure groups:

1. Ductless heat pumps (DHPs) replacing electric zonal in heating zones 2 and 3
2. DHPs replacing electric forced air furnaces in heating zone 3
3. Air-source heat pump (ASHP) conversions in all heating zones
4. Variable speed heat pump (VSHP) conversions in all heating zones
5. Prescriptive duct sealing in all heating zones

The study objectives were to develop the following results for each measure group:

1. Claimed savings: claimed units and claimed per unit savings
2. Evaluated savings (billing analysis results)
3. Realization rates
    a. Billing analysis results vs. claimed savings
    b. Billing analysis results vs. best-available UES
4. Savings as a percent of heating/cooling and total energy consumption

[1] https://www.bpa.gov/EE/Utility/Evaluation/Evaluation/Impact_Evaluation_of_Res_DHP_and_Prescriptive_Duct_Sealing_Measures_draft_report.pdf

[2] https://www.bpa.gov/EE/Utility/Evaluation/Documents/BPA_2020-21_Impact_Evaluation_Plan.pdf

3 METHODS

3.1 BILLING ANALYSIS

Evergreen conducted billing analysis on a sample of residential customers that installed the HVAC measures listed in Section 2.2 through Northwest utilities served by BPA.

3.1.1 COMPARISON GROUP ANALYSIS

Evergreen developed a comparison group for each energy efficiency measure evaluated through billing analysis. The comparison group does not meet the standards for a control group under a randomized controlled trial (RCT) experimental design, but does provide a baseline from which to measure the impact of installing each respective energy efficiency measure.[3]

Customers in a comparison group play an important role in the estimation of electricity saving impacts from an energy efficiency program. Without a comparison group, any change in energy consumption between the pre- and post-periods that is not associated with differences in electricity use in the pre-period or temperature (as represented by heating degree-day [HDD] and cooling degree-day [CDD]) is assumed to be due to the installation of the energy efficiency measure. However, changes in energy consumption between the pre- and post-periods may be due to one or more systematic factors outside of the model, such as changes in the economy, supply shocks within the regional electricity market, or society-wide changes in residential energy use.

By including comparison sites in the billing regression model that are similar to participant sites with respect to geographic location, electricity usage, and participation in the same energy efficiency program (at either an earlier or later date), we were able to control for the existence of any systematic external factors that might affect electricity usage, as well as eliminate initial group differences as an explanation for post-installation changes in electricity usage by program participants.

Assignment of a residential customer to the comparison group is not random, but rather determined based on one or more criteria (e.g., monthly energy consumption). Because of this, we refer to the analysis as a quasi-experimental design, thereby acknowledging that the comparison group does not meet the standard of a control group within an RCT experimental design.

While all of the customers that installed one of the five energy efficiency measures offered through any of the 26 utilities that provided data for this project are program participants, for the purpose of the billing analysis, we segment customers into one of two groups based on the number of months of billing data before and after installation of the energy efficiency measure:

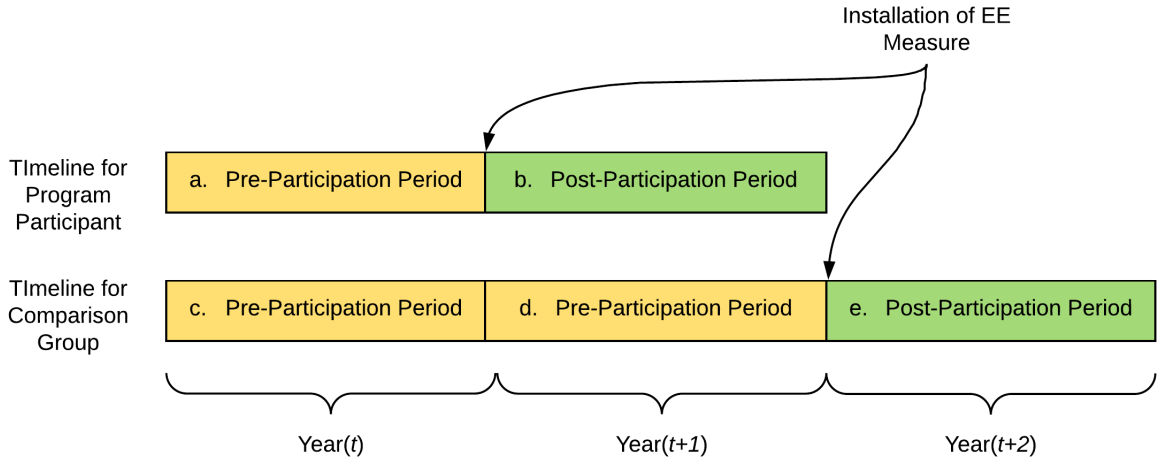
1. The “participant” group includes customers with at least 12 months of billing data prior to installation of the energy efficiency measure and at least 12 months of billing data after installation.
2. The “comparison” group includes customers with at least 24 months of billing data prior to installation of the energy efficiency measure or at least 24 months of billing data after installation of the energy efficiency measure.

[3] It is important to recognize that because the evaluation is not based on an RCT (or similar) experimental design, the treatment and comparison groups are only approximately equivalent even though they may have very similar monthly electricity usage.

Customers that did not meet either of these selection criteria were dropped from the billing analysis because we did not have enough months of data of electricity usage to estimate the change in electricity use associated with a respective energy efficiency measure (and therefore do not meet the criteria of a "participant"), nor do they have enough billing data to act as a comparison home to a participant.

Figure 1 is a representation of how residential customers that participated in an energy efficiency program in one year can be used as a comparison for customers that participated in an earlier year. The first row in the figure represents the program participant to be evaluated, while the second row represents the comparison group.

Figure 1: Integrating comparison households into the experimental design



For the sake of simplicity, the figure shows a three-year period in which Year (*t*) represents the 12-month period immediately before a customer in the participant group installed the HVAC equipment. It also represents the first 12 months of the 24-month period before a customer in the comparison group installed the HVAC equipment.

Year (*t+1*) represents the 12-month period after the energy efficiency measure was installed in the home of the program participant (the post-participant period) and represents the 12-month period immediately before a customer in the comparison group installed the HVAC equipment.

Finally, Year (t+2) represents the 12-month period after the energy efficiency measure was installed in the homes of customers in the comparison group.[4] In this example, only data for billing periods in Year (t) and Year (t+1) are used for statistical modeling. Year (3) is included in the figure only to show that the comparison group is composed of customers that installed the same or similar energy efficiency measure at a later date.

[4] When working with monthly billing data, as we are for this project, the ideal is to have 12 months of billing data prior to installation of the energy efficiency measure and 12 months of billing data after the measure has been installed (and data for the comparison group for these same two 12-month periods).

Evergreen matched each customer in the participant group to a customer in the comparison group based on how closely the monthly electricity usage of the two customers aligned during the 12 months prior to the participant installing the energy efficiency measure.[5]

3.1.2 POST-ONLY WITH COMPARISON GROUP REGRESSION MODEL

Evergreen used a post-only with comparison group (POCG) regression model to evaluate the impact of installing any of the HVAC measures listed in Section 2.2 Study Objectives in the homes of residential customers that participated in one or more energy efficiency programs sponsored by a Northwest utility served by BPA. The POCG model is appropriate for study designs, such as impact evaluations of energy efficiency programs, where individuals self-select into the program and analysis of the energy impacts is conducted after ("post") installation of the measure. In addition, the customers comprising the comparison group are similar to participants in that they are from the same geographic area, are similar with respect to (monthly) electricity use, and they participated in the same or similar energy efficiency program—either at an earlier or later date.[6]

We considered numerous POCG model specifications of varying complexity, and settled on the following specification:

$$kWh_{i,t} = \beta_1 CDD_{i,t} + \beta_2 HDD_{i,t} + \sum_{j=1}^{12} \beta_j Mt_t \times kWh_{i,t-12} + \sum_{k=1}^{12} \beta_k Mt_t \times kWh_{i,t-12} \times Pt_i + \varepsilon_{i,t}$$

Where:

$kWh_{i,t} = Average\ daily\ kWh\ of\ customer\ i\ in\ month\ t\ of\ the\ post\ period$

$CDD_{i,t} = Average\ cooling\ degree\ days\ for\ participant\ i\ in\ month\ t$

$HDD_{i,t} = Average\ heating\ degree\ days\ for\ participant\ i\ in\ month\ t$

$Mt_t = Indicator\ variable\ that\ equals\ 1\ for\ month\ t, else\ 0$

$Pt_i = Indicator\ variable\ that\ equals\ 1\ if\ customer\ i\ is\ a\ participant, else\ 0$

$kWh_{i,t-12} = Average\ daily\ kWh\ of\ customer\ i\ in\ month\ t\ of\ previous\ year$

$\beta_1, \beta_2, \ldots = Parameters\ to\ be\ estimated\ in\ the\ model$

$\varepsilon_{i,t} = Random\ error\ term$

By specifying the model with an array of monthly indicator variables (Mt_t) interacted with electricity usage in the pre-period ($kWh_{i,t-12}$) and an indicator variable for participant (Pt_i), we were able to estimate energy impacts for the program for each calendar month.

3.1.3 VARIABLE BASE DEGREE DAY (VBDD) REGRESSION MODEL

The VBDD modeling approach differs from the POCG regression model in that it fits individual regression models for each customer's pre-installation billing data and the customer's post-installation billing data. This means that we estimated two regression models for each customer in the participant group.

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[5] We will choose the customer from the comparison group that minimizes the sum of squared errors in monthly electricity consumption.

[6] This is in contrast to a designed experiment, such as RCT, where information is known on the individuals before they begin participating in the study and the subjects of the study are randomly assigned to either a participant or control group.

The VBDD model is specified as follows:

$$kWh_m = \alpha + \beta_1 CDD_{T,m} + \beta_2 HDD_{T,m} + \varepsilon_m$$

Where:

$kWh_m = Average\ daily\ kWh\ in\ month\ m$

$CDD_{T,m} = Average\ cooling\ degree\ days\ at\ reference\ temperature\ T\ in\ month\ m$

$HDD_{T,m} = Average\ heating\ degree\ days\ at\ reference\ temperature\ T\ in\ month\ m$

$\alpha = Estimatad\ parameter\ representing\ daily\ baseload\ electricity\ usage$

$\beta_1, \beta_2 = Parameters\ to\ be\ estimated\ in\ the\ model$

$\varepsilon_m = Random\ error\ term$

Using the estimated coefficients from each customer's pre- and post-period models, we computed the weather normalized average consumption for the pre- and post-periods. We then computed the difference between the pre- and post-period weather normalized average consumption for each participant customer.[7]

The primary purpose of estimating VBDD models for program participants was to examine the distribution of changes in daily electricity use among participants. Whereas the post-only model provides estimates of the program level impact of installing a specific piece of equipment (as well as the impact for the average participant), the VBDD model simply measures the change in average daily electricity use for each participant while controlling for differences in temperature between the pre and post periods. Any change in electricity usage for an individual participant may be due entirely or in part to energy savings associated with installing the measure. However, because the VBDD model precludes the use of a comparison group, it is not possible to attribute a change in electricity use to the installation of the energy efficiency measure.

3.2 DHP CUSTOMER SURVEY

Evergreen conducted a mail customer survey in February 2020 with a sample of households that received utility rebates and installed DHPs to replace electric zonal heating in heating zones 2 and 3. The survey was intended to meet the following objectives:

- **Objective 1** – Understanding household usage of DHPs (how, when, where in the home, etc.)
- **Objective 2** – Characterizing change in heating and cooling usage since DHP installation (previous heating and cooling equipment and usage, how those systems are used with DHPs)
- **Objective 3** – Characterizing the factors that influenced the customer's decision to purchase a DHP
- **Objective 4** – Assessing customer satisfaction, comfort levels, and potential non-energy benefits (NEBs) associated with DHP installation
- **Objective 5** – Verifying project delivery

[7] Since each VBDD model is estimated using data for a single home (i.e., a "sample of one"), we did not differentiate the estimated change in daily electricity usage for each comparison home from the estimated change in daily electricity use for each participant home.

- **Objective 6** – Identifying household characteristics that may affect energy use (e.g., number in household)
- **Objective 7** – Categorizing building characteristics that will be needed to conduct a calibrated simulation (home size, vintage, supplemental heating and cooling equipment, etc.)
- **Objective 8** – Documenting changes to household and/or building since installation that may have a significant effect on energy use (e.g., remodels, change in household size).

3.2.1 SURVEY APPROACH

Evergreen used a written, paper mail platform to administer the DHP customer survey. The steps below outline the recruitment and data collection strategy.

1. **Coordinate with participating utilities** (January 2020): Evergreen developed protocols for contacting utility customers with BPA and participating utilities.
2. **Mail initial survey package** (early February 2020): Evergreen mailed sampled residential DHP program participants a package containing a letter describing the study background and incentive ($25) for returning a completed survey and providing Evergreen and BPA contact information for questions, written survey instruments, one $5 bill as a pre-incentive, and a return envelope (with postage).
3. **Mail follow-up package** (mid-February 2020): Evergreen mailed a follow up package to any DHP households that had not submitted completed surveys or called into the study line. The mailing included another copy of the written survey, a return envelope, and a postcard for respondents to provide their information for the incentive check.
4. **Enter and analyze survey responses** (late-February through March 2020): Evergreen conducted data entry and quality control on all returned surveys and analyzed survey responses.

3.2.2 SAMPLING AND WEIGHTING APPROACH

Evergreen developed a sample frame based on residential DHP participants who replaced electric zonal heating in zones 2 and 3. We identified the top five utilities with the highest number of participants to comprise the sample frame. After initial utility outreach (a joint effort between BPA and Evergreen), one of the five utilities dropped out, leaving four utilities and 223 customers. The goal was to get up to 100 returned surveys.

After accounting for 43 surveys that were returned to the sender, the response rate was 73 percent with 131 completed surveys (see Table 2). Evergreen applied sample household weights to the 131 completed surveys to represent the target population of 223 participating households.

Table 2: Survey sample and response by utility

Utility	*Participant Population (Initial Mailing)*	*Adjusted Sample (Subtracting returned to sender surveys)*	*Completed Surveys*	*Response Rate*
Flathead	129	101	69	68%
Idaho Falls	18	14	8	57%
Lincoln	28	24	19	79%
Mission Valley	48	41	35	85%
Total	223	180	131	73%

4 BILLING REGRESSION ANALYSIS RESULTS

Evergreen estimated the change in electricity usage for residential customers that installed one or more of the HVAC measures shown in Table 3 through an energy efficiency program operated by their electric utility during the 2016, 2017, or 2018 program years. For the two ductless heat pump (DHP) measures, the focus of our analysis was heating zones 2 and 3. For DHPs replacing zonal, there were sufficient data to estimate separate models for heating zones 2 and 3, whereas for DHPs replacing electric forced air furnaces (EFAFs), the sample of participants was not sufficient to model heating zones 2 and 3 separately. For variable-speed heat pumps (VSHPs) and air-source heat pumps (ASHPs), we estimated models that included all participants, as well as separate models for participants in heating zone 1 and participants in heating zones 2 and 3 (combined). Many of the customers that installed VSHPs and ASHPs also participated in the duct sealing program. For these customers, we developed separate estimates of savings for those that did and did not include duct sealing. Finally, we also estimated billing models for duct sealing for all participants, as well as for participants in each heating zone.

Table 3: Billing regression models estimated by measure

Measure	*Heating Zone (HZ)*				
	All HZs	*HZ2 & HZ3*	*HZ1*	*HZ-2*	*HZ-3*
DHPs Replacing Zonal		X		X	X
DHPs Replacing EFAFs		X			
VSHPs	X	X	X		
ASHPs	X	X	X		
Duct Sealing (w/o Heat Pump)	X		X	X	X

We used a post-only (with comparison group) regression model described in Section 3.1.2 to estimate electricity savings from the installation of each of these measures. Detailed tables of the output from each regression are included in Section **Error! Reference source not found.**.

4.1 DHP'S REPLACING ZONAL – SUMMARY OF RESULTS

Of the 853 residential customers in our sample that installed a DHP through a BPA-affiliated utility to replace electric zonal heating, 450 met the requirements to be considered a participant for modeling purposes (at least 12 months of pre-installation and post-installation billing data). The remaining customers were included in the pool of comparison sites if the customer had at least 24 months of pre-installation or post-installation billing data. All participant and comparison customers are located in heating zones 2 and 3.

Table 4 shows our estimates of the average daily change in electricity use for customers that replaced electric zonal heating with a DHP. We estimate that on average, customers in heating zones 2 and 3 reduced their electricity usage by 2.48 kWh per day or 903 kWh per year after

installing a DHP.[8] The impacts of installing a DHP differ by month, with the greatest savings occurring in the winter shoulder months of March, April, October, and November, which are typically heating months, but are generally milder than December, January, or February. It is not clear why savings were greater in the winter shoulder periods than in the winter, but it may be due to the way customers use their DHP in conjunction with other types of heating equipment. It may also be related to customer attitudes about the efficacy of DHPs during the coldest times of the year.

On average, installing a DHP did not increase electricity loads for customers during the summer months and, in fact, customers reduced their electricity use during the early part of summer (June and July).[9]

Table 4: Estimated average daily change in electricity usage for customers that installed a DHP replacing zonal heating

Month	*HZ2 & HZ3 (n=450)*		*HZ2 (n=256)*		*HZ3 (n=194)*	
	*Change in kWh**	*Statistical Significance***	*Change in kWh**	*Statistical Significance***	*Change in kWh**	*Statistical Significance***
January	-1.77	10%	-2.21	10%	-0.95	*NS*
February	-1.64	10%	-2.95	5%	0.41	*NS*
March	-4.08	1%	-5.25	1%	-2.32	*NS*
April	-3.07	1%	-4.53	1%	-0.97	*NS*
May	-2.04	5%	-1.70	*NS*	-2.45	10%
June	-2.17	5%	-2.37	5%	-1.89	*NS*
July	-2.21	5%	-2.19	10%	-2.36	10%
August	-0.66	*NS*	-0.20	*NS*	-1.39	*NS*
September	-0.77	*NS*	0.19	*NS*	-1.78	*NS*
October	-3.65	1%	-3.54	1%	-3.52	1%
November	-4.77	1%	-3.56	1%	-6.01	1%
December	-2.86	1%	-1.65	*NS*	-3.97	1%
Average Daily	**-2.48**	**1%**	**-2.50**	**1%**	**-2.27**	**1%**
Average Annual	**-903**	**1%**	**-912**	**1%**	**-827**	**1%**

Source: Analysis by Evergreen Economics of data received from BPA utilities.
* Negative values indicate reduction in electricity usage; positive values indicate increased use of electricity.
** The lower the value (i.e., 1%), the greater the statistical significance. "NS" indicates not statistically significantly different from zero.

[8] Estimates of the change in electricity use hold other factors, such as temperature and economy wide factors constant and, therefore, represent savings attributable to the installation of a DHP.
[9] The coefficients for August and September are negative – suggesting energy savings – but the estimates are not statistically significantly different from zero.

4.2 DHP'S REPLACING ELECTRIC FORCED AIR FURNACES – SUMMARY OF RESULTS

Of the 71 customers that installed a DHP to replace an EFAF, 39 met the criteria to be considered a participant for the purposes of modeling. Each of the 39 participant customers are located in heating zone 3. On average, customers reduced their electricity usage by nearly 5 kWh per day (1,813 kWh per year) as shown in Table 5. Estimated electricity savings varied considerably by month with the highest point estimates of electricity savings occurring during the winter months (December through March). These were also the only months in which the estimates of electricity savings are statistically significantly greater than zero. For the other months, the estimated change in electricity usage suggests customers saved energy; however, the estimates are not statistically significantly different from zero and so we cannot conclude savings occurred in those months.

Table 5: Estimated average daily electricity savings – DHP replacing EFAF

Month	*Heating Zone 3 (n=39)*	
	*Change in kWh**	*Statistical Significance***
January	-9.84	1%
February	-6.44	10%
March	-9.30	5%
April	-4.40	NS
May	-3.38	NS
June	-0.87	NS
July	-3.17	NS
August	-2.40	NS
September	-3.78	NS
October	-5.24	NS
November	-4.33	NS
December	-6.45	5%
Average Daily	**-4.97**	**1%**
Average Annual	**-1,813**	**1%**

Source: Analysis by Evergreen Economics of data received from BPA utilities.
* Negative values indicate reduction in electricity usage; positive values indicate increased use of electricity.
** The lower the value (i.e., 1%), the greater the statistical significance. "NS" indicates not statistically significantly different from zero.

4.3 AIR SOURCE HEAT PUMPS – SUMMARY OF RESULTS

There were 647 residential customers in our sample that installed an ASHP through a BPA-affiliated utility. Of these customers, 211 had sufficient pre-installation and post-installation electricity billing records (at least 12 months of each) to be categorized as participants for the purposes of modeling. Table 6 shows the number of participants that installed an ASHP by heating zone and by whether

the customer also participated in duct sealing. Of the 211 participants, only 35 also received duct sealing services in addition to installing an ASHP. Nearly all of them are located in heating zone 2. Of the 176 participants that did not also receive duct sealing, most (147) are located in heating zone 1.

Table 6: Participant homes that installed an ASHP by heating zone

Heating Zone	*With Duct Sealing*	*Without Duct Sealing*	*Total Participants*
Heating Zone 1	3	147	150
Heating Zone 2	32	14	46
Heating Zone 3	0	15	15
All Heating Zones	**35**	**176**	**211**

To develop estimates of the impact of installing ASHPs on electricity use, we estimated separate billing models for participants that included duct sealing when they installed an ASHP and those that did not include duct sealing. Table 7 shows the estimated change in electricity use for customers that installed an ASHP with duct sealing. We estimate that all participants reduced their electricity use on average by 6.64 kWh per day (2,422 per year). Considering only the 32 (of 35) customers located in heating zone 2, we estimate savings of 7.18 kWh per day (2,620 kWh per year).

Table 7: Estimated average daily change in electricity usage for customers that installed an ASHP with duct sealing

Month	*HZ1 & HZ2 (n=35)*		*HZ2 (n=32)*	
	*Change in kWh**	*Statistical Significance***	*Change in kWh**	*Statistical Significance***
January	-17.63	1%	-19.39	1%
February	-19.96	1%	-21.74	1%
March	-16.52	1%	-16.81	1%
April	-7.58	10%	-8.07	10%
May	0.72	NS	0.63	NS
June	1.87	NS	1.94	NS
July	0.45	NS	0.45	NS
August	0.75	NS	0.79	NS
September	0.71	NS	0.84	NS
October	-1.80	NS	-1.90	NS
November	-6.79	NS	-7.59	NS
December	-13.84	1%	-15.27	1%
Average Daily	**-6.64**	**1%**	**-7.18**	**1%**
Average Annual	**-2,422**	**1%**	**-2,620**	**1%**

Source: Analysis by Evergreen Economics of data received from BPA utilities.
* Negative values indicate reduction in electricity usage; positive values indicate increased use of electricity.
** The lower the value (i.e., 1%), the greater the statistical significance. "NS" indicates not statistically significantly different from zero.

Table 8 shows our estimates of electricity savings for customers that installed an ASHP, but did not include duct sealing. We estimate that these customers reduced their electricity use on average by 11.54 kWh per day (4,213 kWh per year). Customers reduced their electricity use in all months, but savings were particularly great in the winter and winter shoulder months. For the five-month period from October through March, we estimate that customers reduced their electricity usage by about 17 to 19 kWh per day.

We also estimated separate models for customers in heating zone 1 and in heating zones 2 and 3. Most customers we designated as participants are located in heating zone 1 (147 of 176), and our estimates of the change in energy use for customers in heating zone 1 closely align to our estimates for all customers. For customers in heating zones 2 and 3, we estimate reduced electricity usage in the months of January through April and October through December that ranged from 10 to nearly

28 kWh per day. However, for the months of May through September, we find no statistically significant evidence that electricity use changed.[10]

Table 8: Estimated average daily change in electricity usage for customers that installed an ASHP without duct sealing

Month	All Customers (n=176)		HZ1 (n=147)		HZ2 & HZ3 (n=29)	
	Change in kWh*	Statistical Significance**	Change in kWh*	Statistical Significance**	Change in kWh*	Statistical Significance**
January	-16.70	1%	-18.62	1%	-10.12	10%
February	-19.26	1%	-20.92	1%	-11.67	5%
March	-16.76	1%	-16.02	1%	-22.43	1%
April	-9.94	1%	-7.08	1%	-21.92	1%
May	-3.44	5%	-3.25	5%	-1.47	NS
June	-5.45	1%	-6.55	1%	3.43	NS
July	-7.69	1%	-9.29	1%	3.67	NS
August	-5.93	1%	-7.17	1%	4.28	NS
September	-3.49	5%	-3.50	5%	-1.96	NS
October	-10.98	1%	-9.88	1%	-13.13	1%
November	-19.46	1%	-17.11	1%	-24.24	1%
December	-19.41	1%	-17.45	1%	-27.67	1%
Average Daily	**-11.54**	**1%**	**-11.40**	**1%**	**-10.27**	**1%**
Average Annual	**-4,213**	**1%**	**-4,162**	**1%**	**-3,748**	**1%**

Source: Analysis by Evergreen Economics of data received from BPA utilities.
* Negative values indicate reduction in electricity usage; positive values indicate increased use of electricity.
** The lower the value (i.e., 1%), the greater the statistical significance. "NS" indicates not statistically significantly different from zero.

4.4 VARIABLE SPEED HEAT PUMPS – SUMMARY OF RESULTS

There were 193 residential customers in our sample that installed a VSHP through their BPA-affiliated utility; 70 had sufficient pre-installation and post-installation electricity billing records (at least 12 months of each) to be categorized as participants for the purposes of modeling.

[10] Note: our estimate of the average daily change in electricity use for all customers (-11.54) is slightly greater in absolute value than our estimates of the change in electricity use for the regions individually. While this does not seem improbable or even impossible, these estimates are from separate statistical models and are not statistically significantly different.

Table 9 shows the number of participants that installed a VSHP by heating zone and by whether they also participated in duct sealing. Of the 70 customers that installed a VSHP, 22 also received duct sealing services. Most customers were in heating zone 1, and only three customers were in heating zone 3.

Table 9: Participant homes that installed a VSHP by heating zone

Heating Zone	*With Duct Sealing*	*Without Duct Sealing*	*Total Participants*
Heating Zone 1	8	37	**45**
Heating Zone 2	14	8	**22**
Heating Zone 3	0	3	**3**
All Heating Zones	**22**	**48**	**70**

Table 10 shows the estimated change in electricity usage by month for customers that installed a VSHP with duct sealing. Given the small number of customers with sufficient billing data to be considered a participant, we only estimated a single billing regression model. Overall, we estimate customers saved about 15 kWh per day (5,473 kWh per year).

Table 10: Estimated average daily change in electricity usage for customers that installed a VSHP with duct sealing

Month	*All Customers (n=22)*	
	*Change in kWh**	*Statistical Significance***
January	-22.47	1%
February	-23.51	1%
March	-18.65	1%
April	-13.85	1%
May	-12.67	1%
June	-5.68	NS
July	-6.89	NS
August	-5.01	NS
September	-10.69	5%
October	-17.15	1%
November	-19.42	1%
December	-23.95	1%
Average Daily	**-14.99**	**1%**
Average Annual	**-5,473**	**1%**

Source: Analysis by Evergreen Economics of data received from BPA utilities.
* Negative values indicate reduction in electricity usage; positive values indicate increased use of electricity.
** The lower the value (i.e., 1%), the greater the statistical significance. "NS" indicates not statistically significantly different from zero.

Electricity savings differed greatly by month, with reductions in electricity use of greater than 22 kWh per day during the months of December, January, and February, and no statistically significant change in electricity use for the months of June, July, and August.[11]

Table 11 shows estimates of change in electricity use for customers that installed a VSHP, but did not participate in duct sealing. Across all customers, we do not find sufficient evidence that installing a VSHP without duct sealing led to a change in electricity use.[12] We do find evidence that for specific months (i.e., January, February, November, December), customers experienced a reduction in electricity use, but for other months, the estimated changes are not statistically significant.

[11] Note: While our point estimates of the change in electricity use for June, July, and August range from 5 kWh to 6.9 kWh per day, they are not statistically significantly different from zero.
[12] The average daily estimated change of -2.13 kWh is not statistically significantly different from zero.

Table 11: Estimated average daily change in electricity usage for customers that installed a VSHP without duct sealing

Month	*All Customers (n=48)*		*HZ1 (n=37)*	
	*Change in kWh**	*Statistical Significance***	*Change in kWh**	*Statistical Significance***
January	-7.18	5%	-10.01	1%
February	-5.37	10%	-9.85	1%
March	-2.77	NS	-8.79	1%
April	-0.56	NS	-0.96	NS
May	-4.20	NS	-4.13	NS
June	-2.41	NS	-0.77	NS
July	0.80	NS	2.54	NS
August	2.51	NS	3.03	NS
September	3.30	NS	3.55	NS
October	0.83	NS	0.10	NS
November	-5.50	5%	-6.57	5%
December	-4.97	10%	-7.54	1%
Average Daily	**-2.13**	**NS**	**-3.28**	**5%**
Average Annual	**-776**	**NS**	**-1,198**	**5%**

Source: Analysis by Evergreen Economics of data received from BPA utilities.
* Negative values indicate reduction in electricity usage; positive values indicate increased use of electricity.
** The lower the value (i.e., 1%), the greater the statistical significance. "NS" indicates not statistically significantly different from zero.

We do find evidence that customers in heating zone 1 did reduce their electricity use by just over 3 kWh per day (1,200 kWh per year) after installing a VSHP. Savings are concentrated in just the heating months of November through March. We did not estimate a separate billing regression model for customers in heating zones 2 and 3 due to the small number of participant homes in these zones (11 customers).

4.5 DUCT SEALING – SUMMARY OF RESULTS

Evergreen analyzed the impact of duct sealing for customers that did not also install either a VSHP or ASHP. There were 594 residential customers in our sample that received duct sealing (without installing a VSHP or ASHP) through their BPA-affiliated utility, and 238 had sufficient pre- and post-installation billing data (at least 12 months of each) to be categorized as participants for the

purposes of modeling. Table 12 shows the number of participants that received duct sealing by heating zone. Participation was greatest in heating zone 2.

Table 12: Customers that participated in duct sealing, but did not install a VSHP or ASHP by heating zone

Heating Zone	*Participants*
Heating Zone 1	66
Heating Zone 2	145
Heating Zone 3	27
All Heating Zones	**238**

Table 13 shows estimates of change in electricity use for all customers that only received duct sealing. On average, we estimate that customers that received duct sealing reduced their electricity use by nearly 7 kWh per day (2,531 kWh per year).

Table 13: Estimated average daily change in electricity usage for customers that received duct sealing, but not a VSHP or ASHP

Month	*All Customers (n=238)*	
	*Change in kWh**	*Statistical Significance***
January	-12.18	1%
February	-8.99	1%
March	-8.50	1%
April	-10.66	1%
May	-5.02	1%
June	-9.40	1%
July	-4.64	1%
August	-4.78	1%
September	-0.99	Not Sig
October	-1.44	Not Sig
November	-7.14	1%
December	-9.47	1%
Average Daily	**-6.94**	**1%**
Average Annual	**-2,531**	**1%**

Source: Analysis by Evergreen Economics of data received from BPA utilities.
* Negative values indicate reduction in electricity usage; positive values indicate increased use of electricity.
** The lower the value (i.e., 1%), the greater the statistical significance. "NS" indicates not statistically significantly different from zero.

Table 14 shows estimates of changes in electricity use by heating zone for customers that received only duct sealing. Across all three heating zones, we estimate that customers on average reduced their electricity usage, with the greatest reduction occurring in heating zone 1. Electricity savings for customers in heating zone 1 occurred in all months except September, when customers actually increased their electricity use, and October, when there was no statistically significant change in use. Savings tended to be greatest in the winter months, but customers in heating zone 1 experienced their greatest savings in June.

Table 14: Estimated average daily change in electricity usage for customers that received duct sealing, but not a VSHP or ASHP

Month	*HZ1 (n=66)*		*HZ2 (n=145)*		*HZ3 (n=27)*	
	*Change in kWh**	*Statistical Significance***	*Change in kWh**	*Statistical Significance***	*Change in kWh**	*Statistical Significance***
January	-11.06	1%	-14.35	1%	-2.82	Not Sig
February	-10.30	1%	-9.49	1%	-2.43	Not Sig
March	-13.08	1%	-8.06	1%	2.97	Not Sig
April	-14.18	1%	-9.25	1%	-4.76	Not Sig
May	-7.27	1%	-4.16	5%	-5.30	Not Sig
June	-17.15	1%	-3.44	10%	-2.47	Not Sig
July	-10.59	1%	-1.80	Not Sig	-2.97	Not Sig
August	-8.01	1%	-1.48	Not Sig	-11.93	1%
September	5.07	5%	-0.90	Not Sig	-12.21	1%
October	3.35	Not Sig	-2.38	Not Sig	-5.59	Not Sig
November	-7.38	1%	-6.44	1%	-9.48	5%
December	-10.06	1%	-10.52	1%	-3.62	Not Sig
Average Daily	**-8.39**	**1%**	**-6.02**	**1%**	**-5.05**	**1%**
Average Annual	**-3,062**	**1%**	**-2,198**	**1%**	**-1,844**	**1%**

Source: Analysis by Evergreen Economics of data received from BPA utilities.
* Negative values indicate reduction in electricity usage; positive values indicate increased use of electricity.
** The lower the value (i.e., 1%), the greater the statistical significance. "NS" indicates not statistically significantly different from zero.

Customers in heating zones 2 and 3 also experienced reductions in electricity use, but to a lesser extent than customers in heating zone 1. Across all three heating zones, there was little-to-no consistency in savings by month. For example, the greatest reduction in electricity use for customers in heating zone 3 occurred in August and September, while there is no statistical evidence that customers in heating zone 2 experienced any change in electricity use.

5 DHP CUSTOMER SURVEY RESULTS

This section presents results from the ductless heat pump (DHP) customer survey fielded in February 2020. The survey was intended to support the assessment of DHP savings and builds on the guidance provided in the 2018-2019 Evaluation Plan. The survey was distributed to customers who installed DHPs to replace electric zonal heating in heating zones 2 and 3.[13]

Sample sizes are reported for each result, up to a maximum of 131 total responses. Some questions were left blank or respondents were directed to skip certain questions that do not apply to them based on their prior responses.

5.1 SUMMARY OF RESULTS

PURCHASE MOTIVATION

When asked top of mind why they bought the DHP, saving energy/reducing energy costs was #1 (53%), followed by getting AC (35%). When prompted with a list of potential benefits, comfort was also a top reason for purchase (73% said it was extremely or very important).

About half (47%) said they bought the DHP to replace an old heating system. The most commonly cited reason (when prompted with a list of potential reasons) was that the old system's energy costs were too expensive (85% of those that bought the DHP to replace an old heating system).

Few (17%) bought the DHP to replace an old cooling system.

DHP USAGE

Most respondents (72%) were initially interested in buying a DHP for both heating and AC, and another 11 percent for just AC. Only 15 percent said they were only interested in it for heating while 35 percent of DHP purchasers were intending to add cooling to their home, which would result in an increase in cooling usage.

Most respondents use their DHP to heat and cool the whole house or most of the house. Those that use it only for one or two rooms mostly use it for the living room.

When prompted with a series of questions around how they have changed their cooling and heating since installing the DHP, most (77%) said they use AC more frequently and use it at a lower temperature than before (61%). A lower percentage have changed how they heat their home, with 48 percent heating more frequently and 37 percent heating at a higher temperature.

OLD SYSTEM USAGE

Before installing the DHP, the most common heat source was electric baseboard heating (56%), followed by wood-burning stove (31%).[14] Two-thirds (65%) continued to use their older heating system after installing the DHP. Wood-burning stove (33%) and electric baseboard heating (32%) are the most commonly used systems in conjunction with the DHP. About half of those respondents

[13] This effort is part of a broader analysis that Evergreen is conducting for BPA of residential HVAC measures including air-source heat pump conversions, variable speed heat pumps conversions, DHPs replacing electric forced air furnaces in heating zone 3, DHPs replacing electric zonal heating in heating zones 2 and 3, and prescriptive duct sealing in all heating zones. Evergreen previously submitted results from the billing analysis conducted on all program measures via memo in September 2019.

[14] Most who have a wood stove also had another heating source. Only 4 percent of survey respondents had just a wood stove prior to installing a DHP.

(that continued to use their older heating system) reportedly use it less than they use the DHP, 15 percent said they use it the same, and 16 percent use it more.

Before installing the DHP, one-third of respondents had AC. Of those, only 11 percent reported that they continue to use the older system since installing the DHP.

ACTIONS TAKEN HAD THEY NOT BOUGHT A DHP

Nearly all (82%) survey respondents would have continued using their old heating system, had they not bought a DHP.

Three-quarters said they would have purchased a cooling system had they not bought a DHP, which impacts DHP baseline assumptions. Even though many added cooling usage by purchasing a DHP, most reported that they were going to buy some other type of cooling system had they not bought the DHP.

CHANGES IN BILLS

Half of respondents (53%) said they had lower heating bills since installing the DHP, while 25 percent said they experienced no change and 22 percent said they had higher bills. Changes in cooling bills depended on whether the respondent had prior AC or not. Those that did not have prior AC had fairly similar responses regarding a change in cooling bills as the heating responses. Those that did not have prior AC were much more likely to say their cooling bills went up (44%).

NON-ENERGY BENEFITS

Nearly all DHP purchasers (92%) indicated that yes, they noticed "an increase in overall comfort," and 66 percent noticed "an increase in safety compared to other heating systems they have used in the past or are currently using now."[15] Half (50 percent) indicated they noticed an improvement in air quality. Satisfaction with the quality of the heating and cooling is high—93 percent are highly satisfied with the quality of cooling, and 82 percent are highly satisfied with the quality of heating.

5.2 BACKGROUND

All or nearly all responding households:

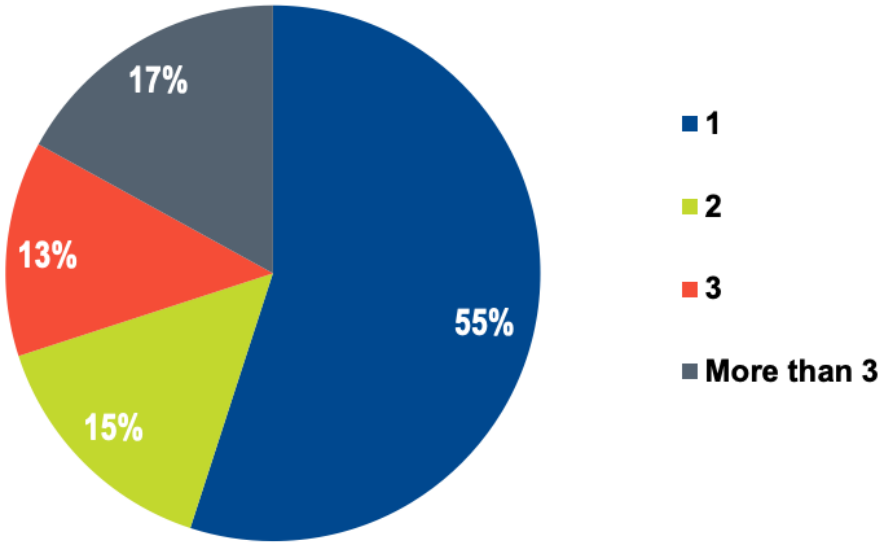
- Have the DHP still installed (100% n=128, Q2)
- Installed the DHP in a primary residence (96% n=128, Q3)
- Owned the home in which the DHP was installed (100% n=128, Q4)
- Use the DHP for heating (99% n=128, Q5)
- Use the DHP for air conditioning (98% n=128, Q6)

Though only 42 respondents answered the question, just over half of respondents reported having an indoor single head DHP (see

[15] Survey respondents were not directly asked to explain why they felt an increase in safety, but one respondent wrote in a free-response section that the DHP was "less likely to burn the house down."

Figure *2*) (an example was shown on the survey). Presumably, the survey participants that did not respond (n=89) were not sure.

Figure 2: Number of indoor units (heads) (n=42, Q7)



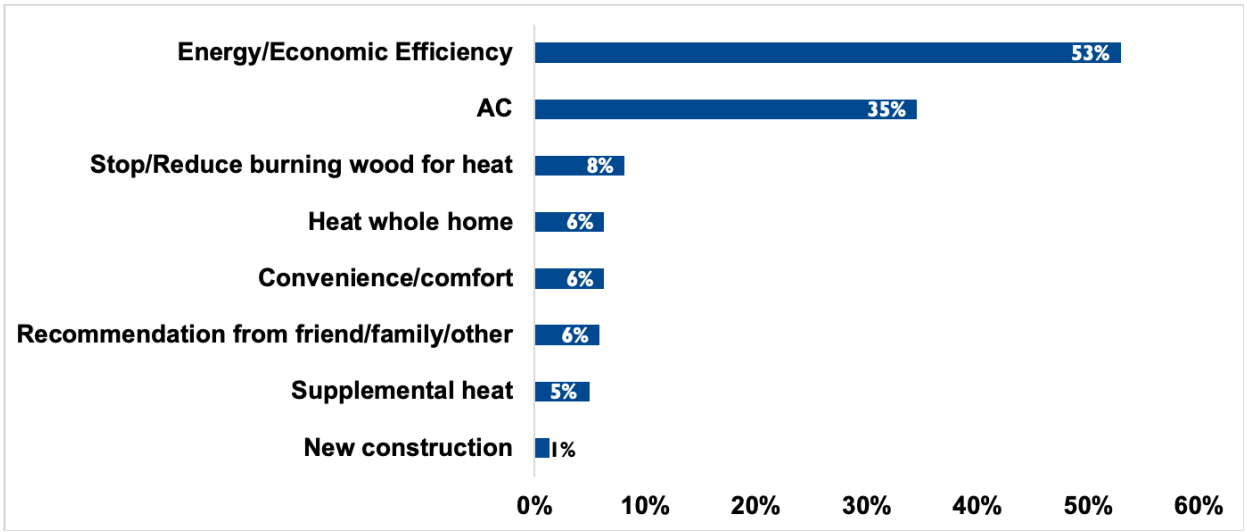
5.3 DECISION MAKING

Respondents were split almost 50/50 regarding decision-making (n=126, Q8), with 49 percent saying they decided with other family members to buy a DHP, and 50 percent saying they were the primary decision maker (1% said they were not involved in the decision.)

Figure 3 displays the results of an open-ended question: "In your own words, what was your main reason for seeking out a new system?"

We report up to two reasons per respondent, categorizing the verbatim responses. More than half (53%) bought the DHP for energy efficiency or economic reasons, while over one-third (35%) bought it to get air conditioning (about 13% said both of those reasons).

Figure 3: Main reason(s) for seeking out a new system (n=131, Q9, multiple responses allowed, open-ended)



Below are select verbatim responses that are illustrative of the responses for the most commonly cited reasons:

Save energy/money, more efficient unit:

- "Ductless heat pumps are more energy efficient than electric baseboards."
- "Help with my electric bill."
- "High efficiency for a low cost."

For the air conditioning:

- "The main factor for installing the mini split system was the AC. We liked the heat too."
- "We wanted air conditioning for summer. Our condo did not have one. This seemed to be a great option."
- "Wife wanted some kind of AC for the summer."

Both to save energy/efficiency and for the air conditioning:

- "We purchased this unit primarily for AC; the cost savings for heat was a bonus."
- "Needed better heating for home than the old electric baseboard I had. AC was [an] added benefit."
- "To save on heating cost in the winter and provide AC in the summer."

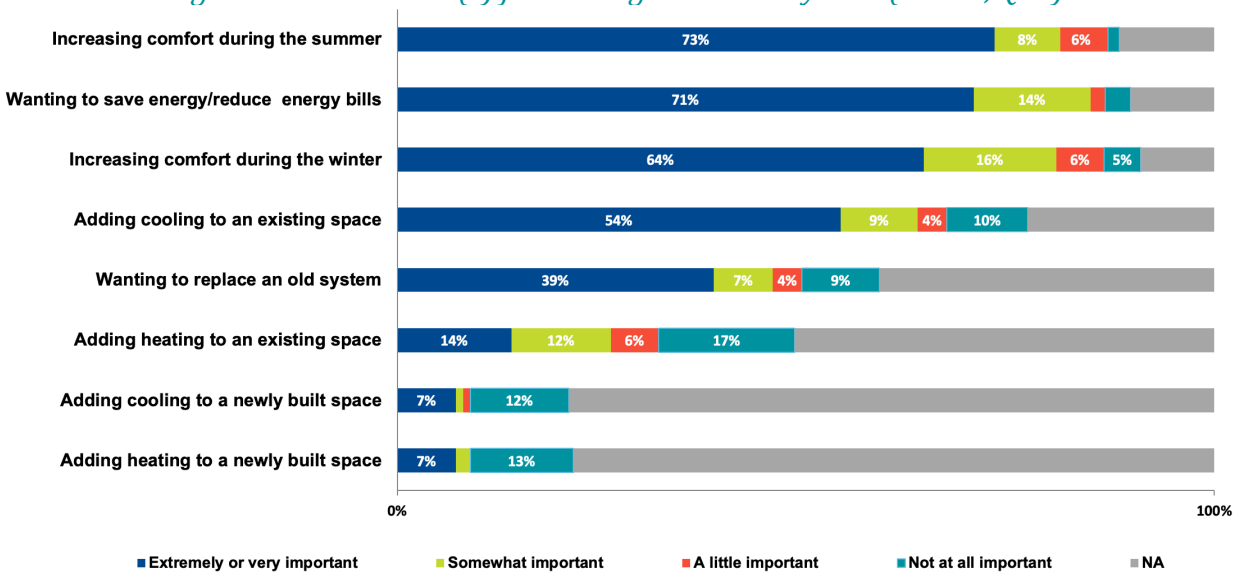
To stop/reduce burning wood for heat:

- "More energy efficient, tired of chopping wood."
- "Tired of dealing with a wood stove as main heat. Chimney creosote issue. Smoke back up issues."
- "Advanced age cannot continue to heat with wood"

Respondents were also asked to rank the importance of eight factors in choosing a new system. This question contrasts with the prior question, which was unprompted, where respondents provided a verbatim response regarding the main factor. This prompted question presented a list of potential factors and a scale of importance: extremely, very, somewhat, a little, or not at all important.

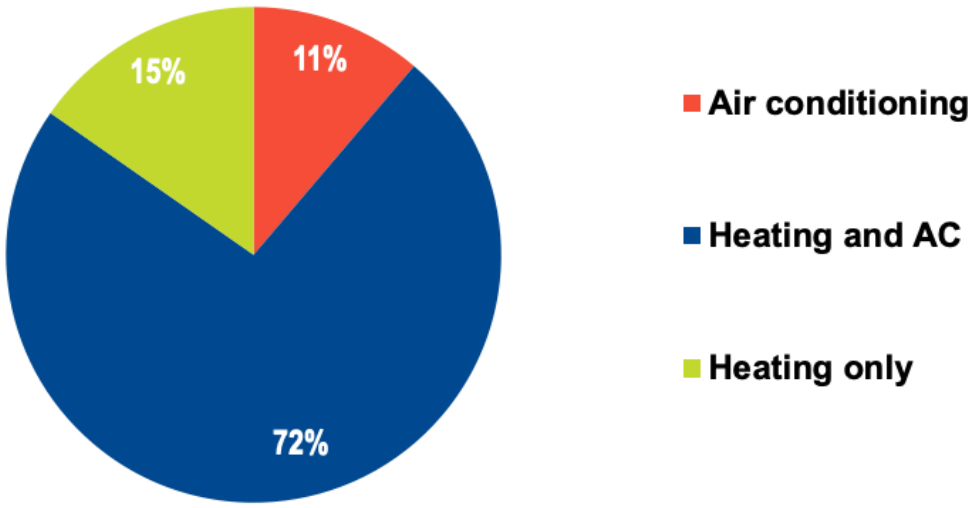
The prompted results (Figure 4) are consistent with the unprompted results presented previously where energy/cost savings and adding air conditioning were top motivations for the DHP purchase. Differences in responses between the two questions are mainly around comfort—where respondents were prompted, they were very likely to say that comfort was extremely or very important to their purchase decision. While comfort was not the main top of mind purchase motivation (saving energy was the #1 unprompted reason), it is clearly an important benefit associated with adding air conditioning and being able to heat more of the home.

Figure 4: Main reason(s) for seeking out a new system (n=131, Q15)



Over two-thirds of respondents (72%) initially looked at buying a new DHP for both heating and cooling (see Figure 5).

Figure 5: Initial interest in buying DHP – for cooling, heating, or both (n=123, Q10)



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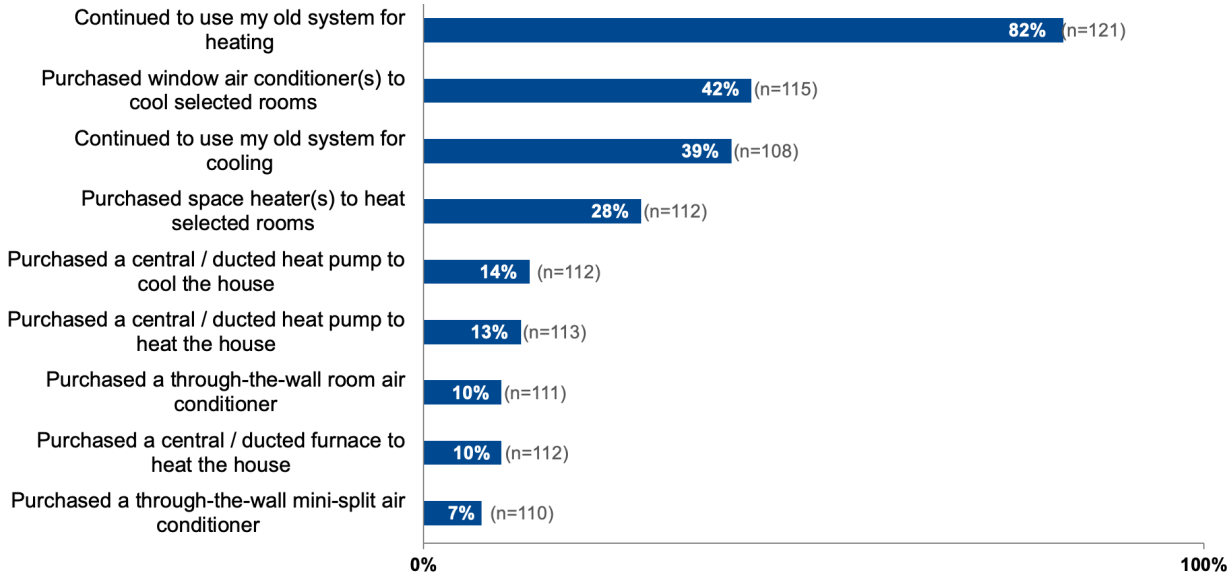
About half of respondents (47% n=122, Q11) said they bought a DHP to replace an old heating system. Fewer (17% n=122, Q13) said they bought a DHP to replace an old cooling system.

Respondents were asked to indicate yes or no to a set of actions that they would have taken if they had not purchased a DHP (

Figure 6). Most respondents (82%) said they would have continued to use their old heating system. Many (42%) said they would buy a window air conditioner, while 39 percent would keep using their existing cooling system.

Figure 6: What action(s) would have been taken had they not bought a DHP (n varies, Q16)



Looking across the cooling system responses, 70 percent said they would either continue to use their current cooling system or buy a new cooling system.

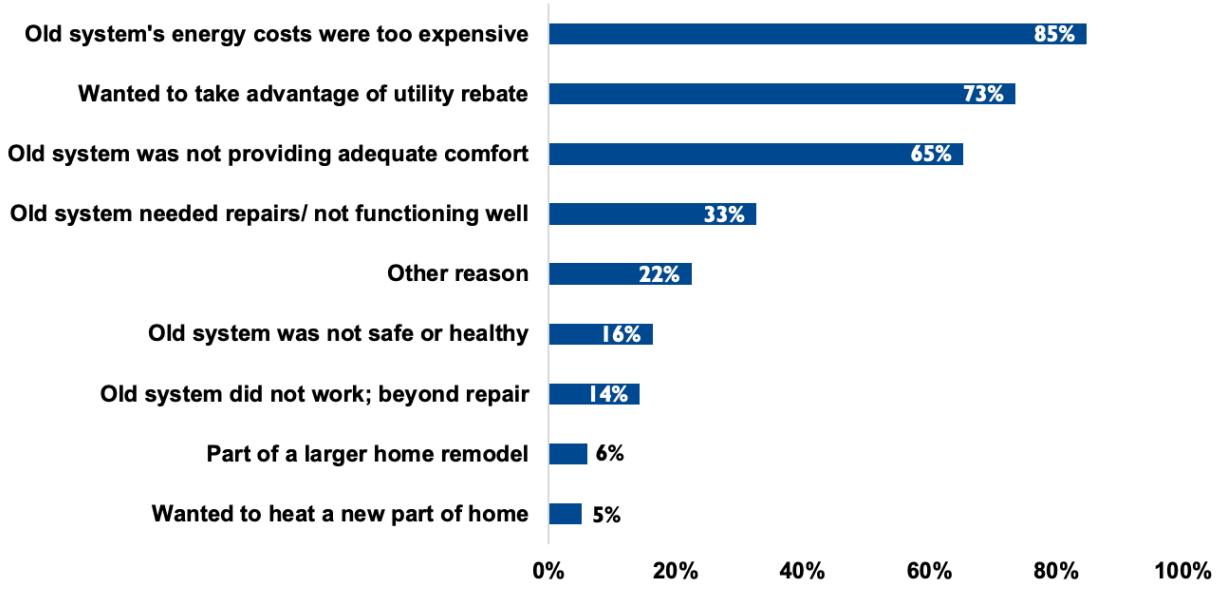
REPLACING OLD HEATING SYSTEM (N=57)

This section is focused on the 47 percent of respondents that said they purchased a DHP to replace an old heating system (Q11).

This subset was asked a series of yes/no questions about potential reasons that respondents cited for wanting to replace their old heating system with a new DHP (

Figure 7). The most common cited reason that respondents said they wanted to replace their old heating system with a new DHP was because the old system's energy costs were too expensive (85%). The next most commonly cited reason was to take advantage of the utility rebate (73%), followed by the old system not providing adequate comfort (65%). (See the open-ended responses below Figure 7 regarding motivations for buying the DHP for additional reasons for replacing the older heating system, including issues with wood burning stoves.)

Figure 7: Reason(s) for replacing old heating system (yes/no questions - % yes reported, n=57, Q12)



The verbatim responses for respondents who chose "other" included:

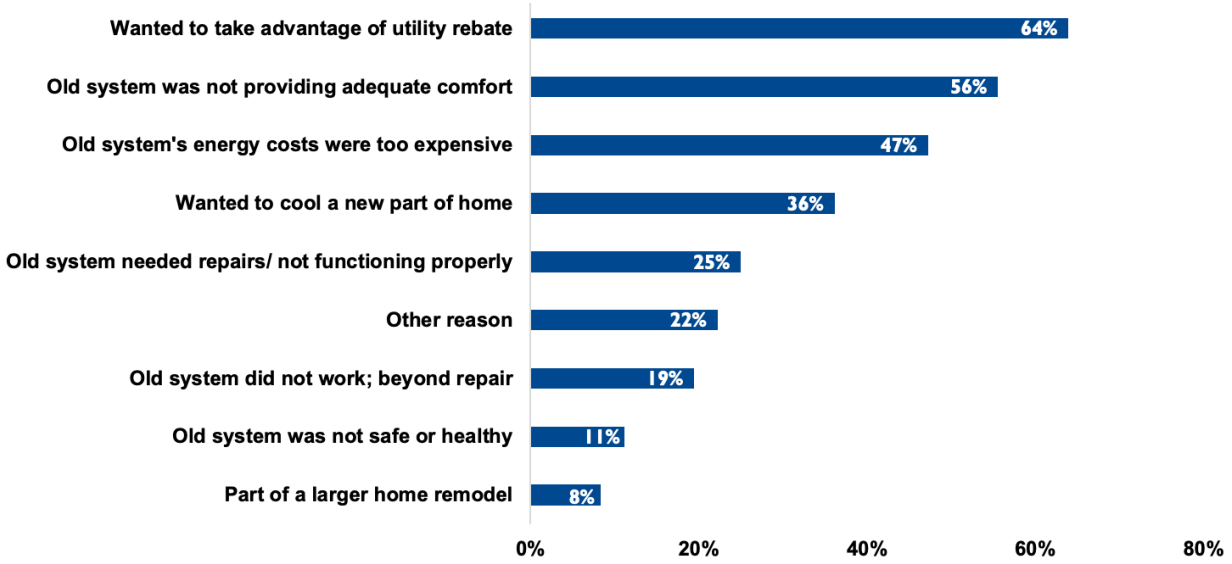
- "Add value to home"
- "Better system (compared) to electric baseboard"
- "Convenience"
- "Did not have air conditioning"
- "Existing system wouldn't allow air (flow)"
- "Help to filter and cool during smoky days"
- "Old system was old"
- "Too large of area for wall heaters (to heat)"
- "(Won't need to) wash filters"
- "Wood heat - time consuming and messy"
- "Wood stove"

REPLACING OLD COOLING SYSTEM (N=22)

This section is focused on the 17 percent of respondents who said they purchased a DHP to replace an old cooling system (Q13). Similar to the old heating system survey questions, this subset was asked a series of yes/no questions about potential reasons that respondents said they wanted to replace their old cooling system with a new DHP (

Figure 8). The most common reason that respondents cited for wanting to replace their old cooling system with a new DHP was to take advantage of the utility rebate (64%), followed by the old system not providing adequate comfort (56%). Nearly half indicated that the old system's energy costs were too expensive (47%).

Figure 8: Reason(s) for replacing old cooling system (n=22, Q14, multiple responses allowed)



The verbatim responses for respondents who chose "other" were as follows:

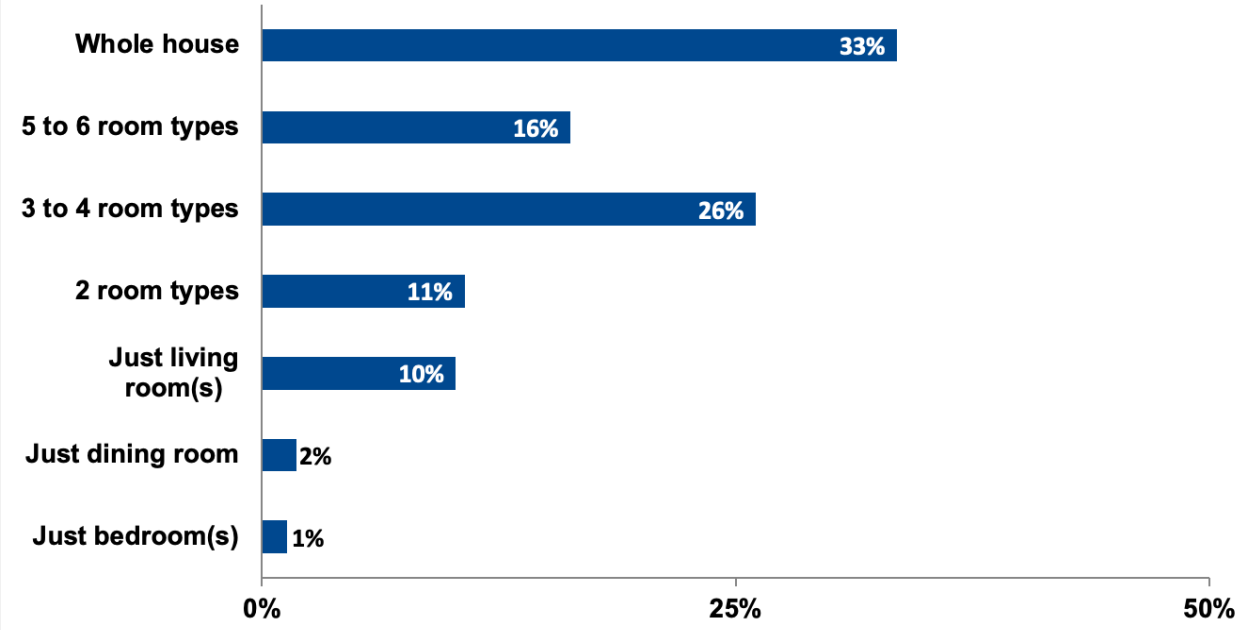
- "Added value to home"
- "Evaporators did not fit well"
- "Replace window units"
- "Would have only had window AC"

5.4 SYSTEM USAGE

AREA SERVED BY DHP

Respondents indicated which rooms are served by the DHP (Figure 9). The most common response was the whole house (33%), followed by 3 to 4 room types (26%)—most often including the kitchen, dining, and living room(s). One-quarter (24%) of respondents reportedly use the DHP in only one or two rooms, the vast majority including the living room.

Figure 9: Room(s) served by DHP (n=127, Q17)



A small portion (27%) of respondents said that the area that is cooled in their home has increased, with a median increase of 1,050 square feet, and fewer (8%) said the area that is heated has increased, with a median increase of 400 square feet (see Table 15). Many respondents that reported an increase in space cooled had previously not cooled their home using another system, whereas respondents that reported an increase in space heated had already been heating their homes using another system. This could explain the larger increases in square footage for cooled space.

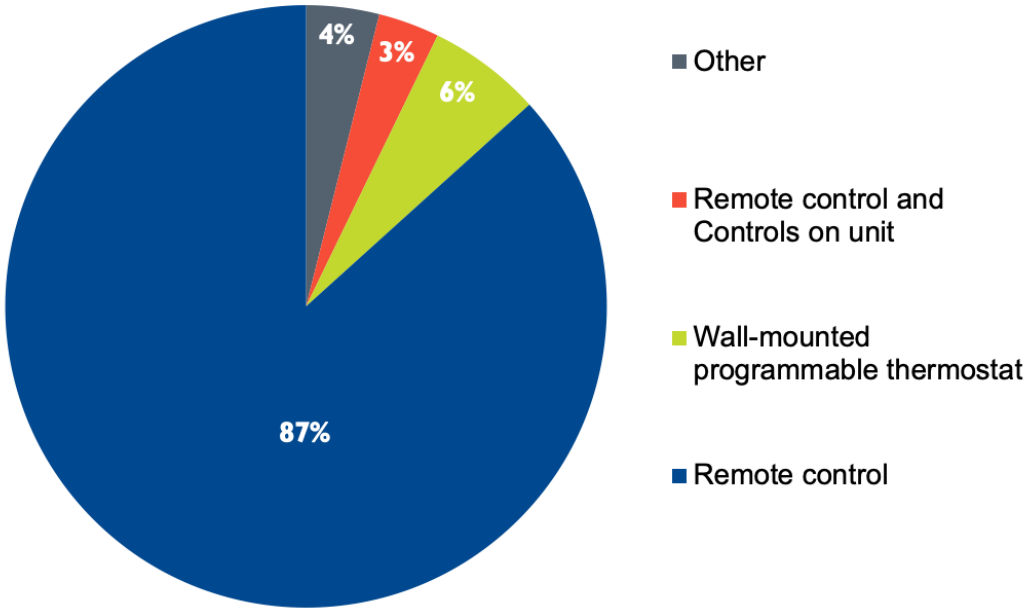
Table 15: Increase in space cooled (n=113, Q18) and heated (n=110, Q19) since installing DHP

Utility	*% that Increased the space that is cooled/heated*	*Average Square Footage Increase*	*Median Square Footage Increase*
Cooling	27% (n=113)	1,200 (n=30)	1,050 (n=30)
Heating	8% (n=110)	675 (n=9)	400 (n=9)

CONTROLS

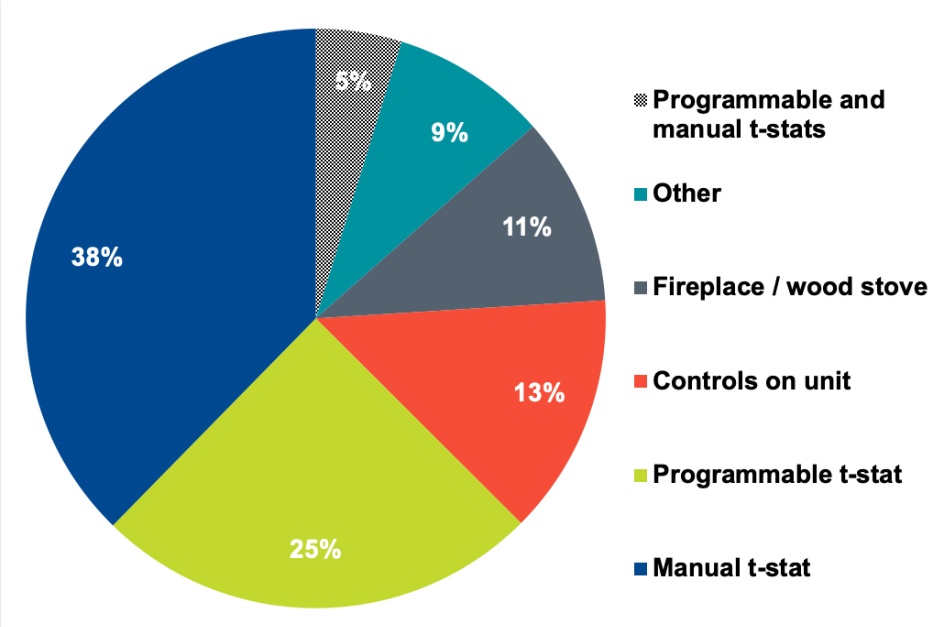
Nearly all (87%) respondents said they use only a remote control for their DHP (Figure 10). A small fraction (6%) use a programmable thermostat, while fewer (3%) said they use both a remote control and controls on the unit. The remainder ("other" in Figure 10) use just the controls on the unit, a remote control with a programmable thermostat, or a manual wall-mounted thermostat.

Figure 10: DHP controls in use (multiple responses allowed, n=127, Q20)



Of those respondents that continue to use their old heating system(s), the most commonly used controls are a manual thermostat, followed by a programmable thermostat (Figure 11). Thirteen percent use the controls on the unit.

Figure 11: Old heating system (still in use) controls (multiple responses allowed, n=86, Q21)

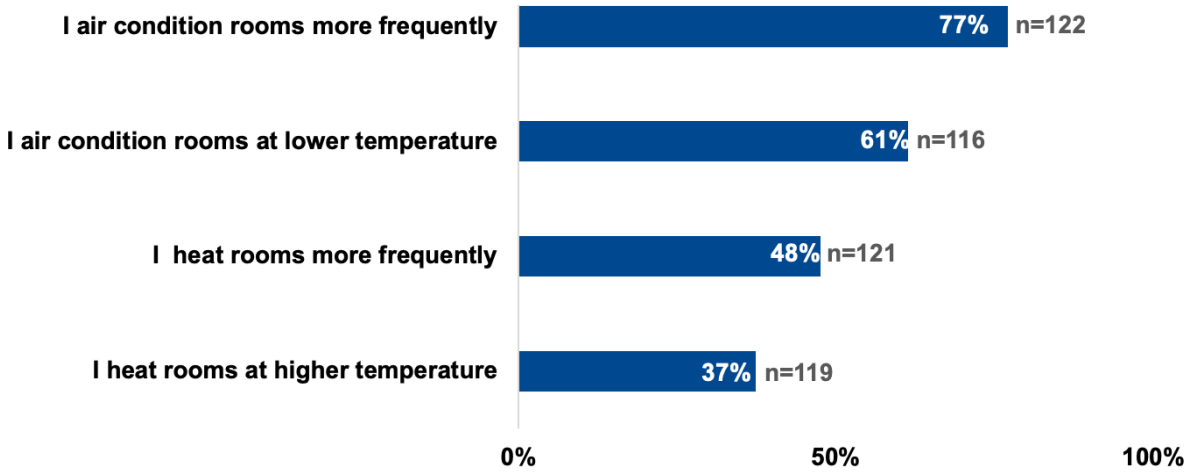


5.5 SELF-REPORTED CHANGES IN USAGE AND ENERGY BILLS

Respondents were asked a series of yes/no questions regarding how they have changed the way they heat and cool their homes since installing the DHP. As shown in Figure 12, the most commonly

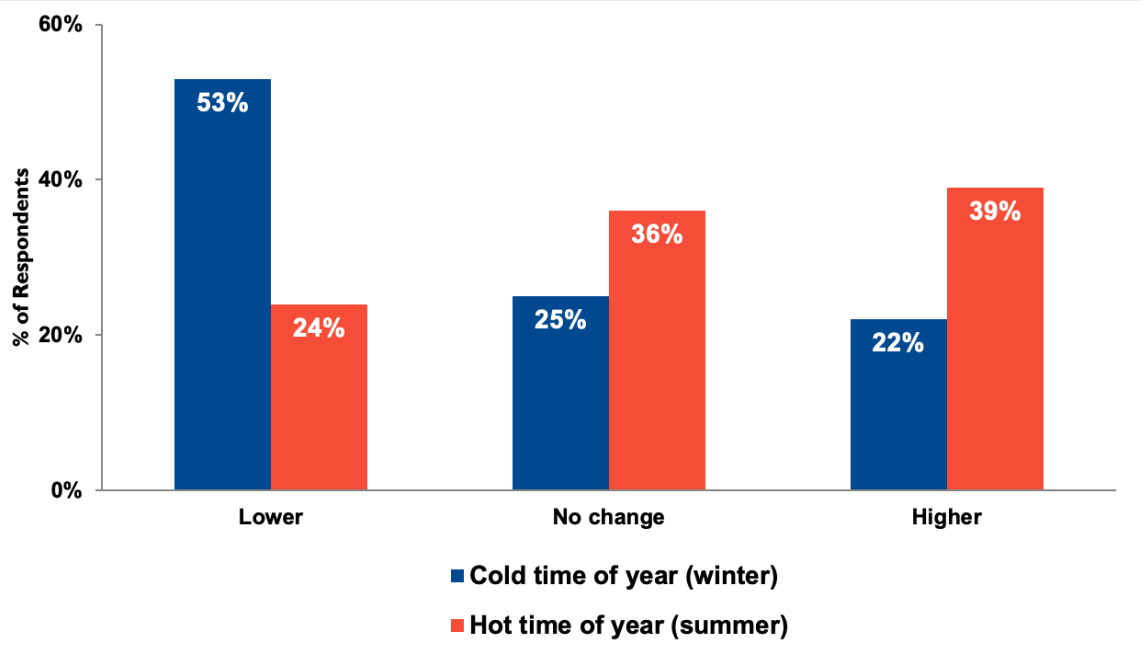
cited change was to air condition rooms more frequently (77%), followed by air conditioning rooms at a lower temperature (61%). Changes in heating were reported less frequently; 48 percent heat rooms more frequently and 37 percent said they heat rooms at a higher temperature.

Figure 12: Since installing DHP, percent that changed heating and cooling usage (yes/no questions - % yes reported, n varies, Q24)



About half of respondents reported that their heating bills were lower since installing the DHP, compared to only 24 percent that said their cooling bills were lower (Figure 13).

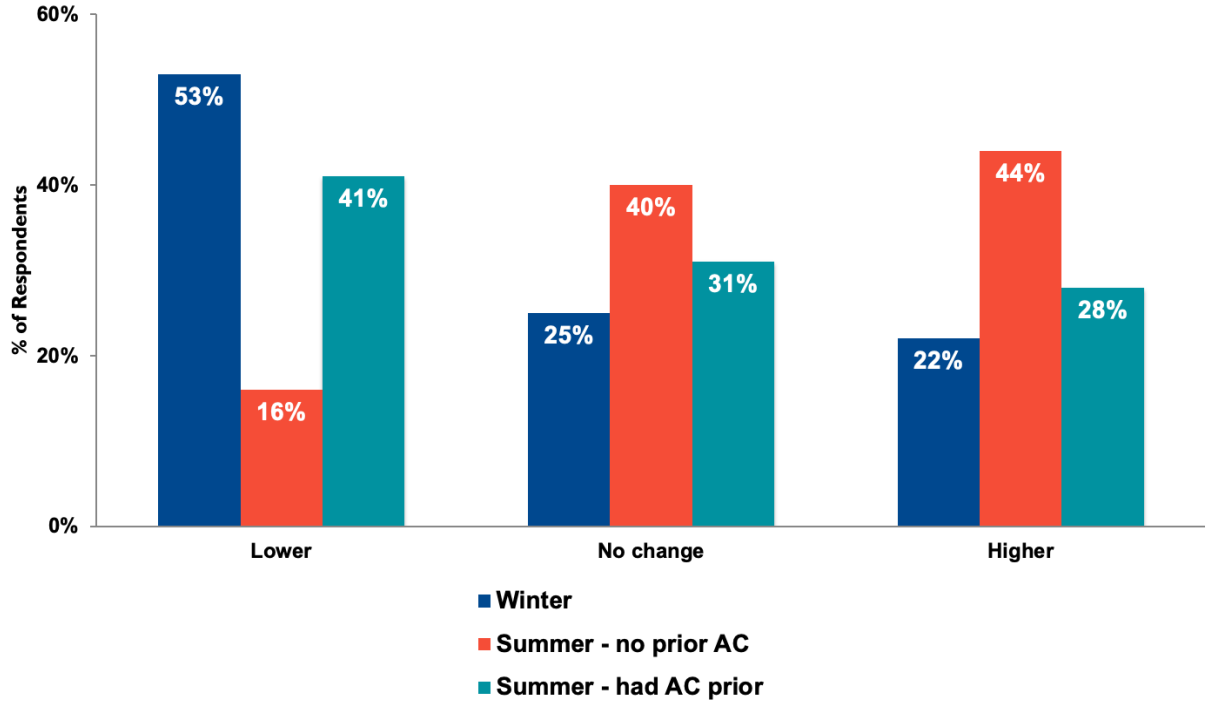
Figure 13: Self-reported change in energy bills during cooler (n=126, Q42) and hotter (n=126, Q43) times of the year



Perceived changes in summer cooling bills based on respondent self-report (not verified based on actual bills) depended on whether households had air conditioning prior to installing the DHP (Figure 14). Households that already had AC were most likely to say their summer bills went down

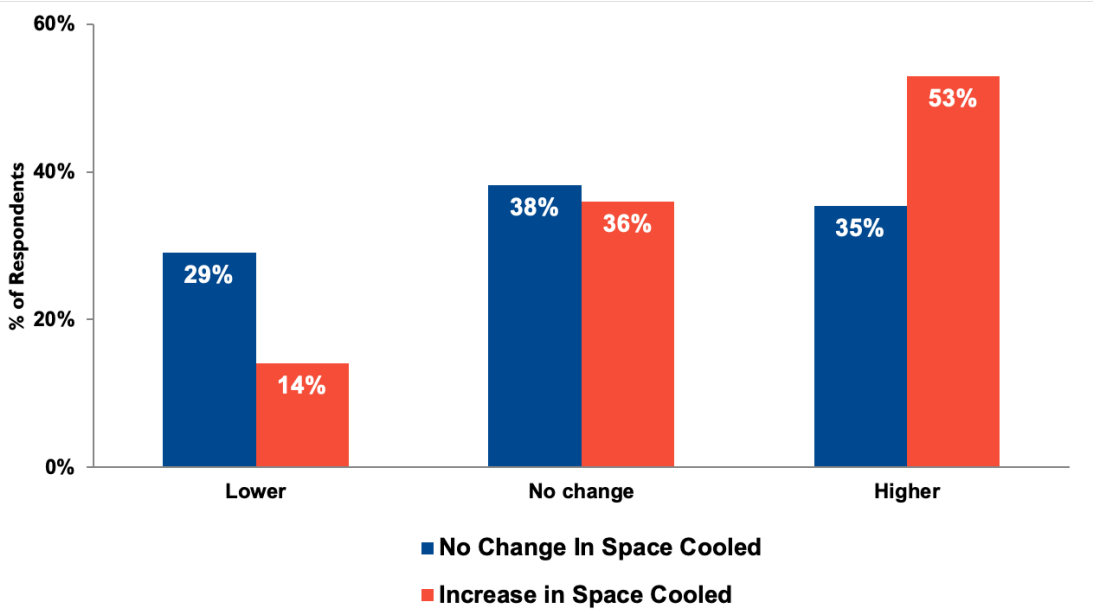
(41%), while those that did not previously have AC were most likely to say their bills went up (44%).

Figure 14: Perceived change in energy bills (self-reported) during cooler times/winter (n=126, Q42/Q43) and hotter times/summer (no prior AC n=81, prior AC n=44, Q34)



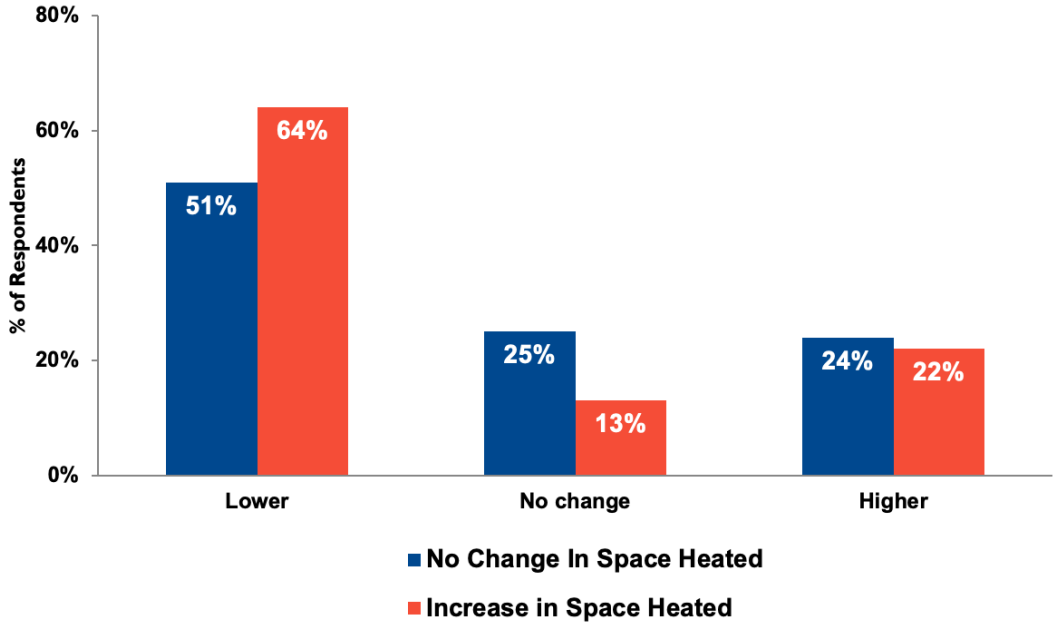
Intuitively, households that increased the space cooled in the hotter times of the year were more likely (53%) to report higher energy bills when compared to those that cooled the same amount of space as before DHP installation (see Figure 15).

Figure 15: Perceived change in energy bills (self-reported) for households with no change in space cooled (n=81, Q18) vs. households that increased space cooled (n=29, Q18) during hotter times of the year (n=110, Q43)



In contrast to the cooling results, for households that increased their space heated, there was a significant (64%) report of lower energy bills (see Figure 16). Of those respondents with increased space and decreased energy bills (n=5), four responded that they either removed their old heating system, or they use it significantly less than the DHP (Q31).

Figure 16: Self-reported change in energy bills for households with no change in space heated (n=98, Q19) vs. households that increased space heated (n=9, Q19) during cooler times of the year (n=107, Q42)



USAGE OF PRIOR HEATING SYSTEM

Respondents were asked a series of questions about how they used their heating system before and after installing the DHP. For this next section, the survey prompted respondents to consider all prior heating sources as their "old heating system."

First, respondents indicated what type of heating system(s) they used to heat their home prior to getting the DHP (Table 16). Most (56%) homes used electric baseboard heating, and 31 percent used wood-burning stoves. Respondents that selected "Other" wrote in "radiant heating," "pellet stoves," and "diesel stoves" as prior heating sources, for example.

Table 16: Heating system used prior to DHP (n=128, multiple responses allowed, Q25)

Old Heating System	*% of Respondents*
Electric Baseboard Heating	56%
Wood-Burning Stove	31%
Electric Wall Fan	29%
Electric Space Heater	26%
Gas Fireplace	20%
Wood-Burning Fireplace	12%
Gas Furnace or Boiler	6%
Electric Furnace	3%
No Old System	1%
Other	12%

If respondents used more than one heating option, they indicated their primary source (Table 17). The primary heating source was a wood-burning stove (32%), followed by electric baseboard heating (24%).

Table 17: Primary heat source prior to DHP, if multiple (n=80, Q27)

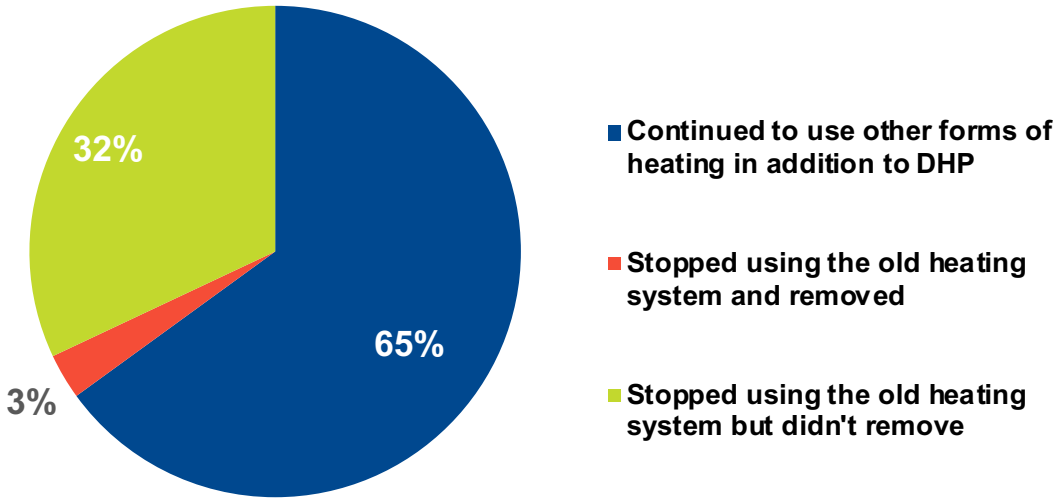
Primary Heat Source	*% of Respondents*
Wood Burning Stove	32%
Electric Baseboard	24%
Gas Fireplace	17%
Electric Wall Fan	13%
Other	13%
Total	**100%**

Then, respondents were asked how often they used non-electric heat prior to getting the DHP. Forty percent said either "never," "almost never," or "rarely," while 46 percent answered "almost all the time," or "most of the time." Fourteen percent of respondents answered that they used non-electric heat "about half of the time" (n=126, Q26).

Once the DHP was installed, 77 percent of respondents answered that the DHP is used to heat the exact same rooms of their house as they did with their old heating system (n=124, Q28).

Next, respondents were asked about their old heating system usage after installing the DHP. Most (65%) responded that they continued to use other forms of heating in addition to the DHP (Figure 17).

Figure 17: Old heating system usage after DHP installation (n=126, Q30)



If they continued to use their old heating system, respondents were asked which heating systems they continued to use (Table 18). Wood-burning stoves and electric baseboard heating were used most frequently, at 33 percent and 32 percent, respectively.

Table 18: Other heating systems used since DHP installation

Heating System	*% of Respondents*
Wood-Burning Stove	33%
Electric Baseboard Heating	32%
Gas Fireplace	23%
Electric Wall Fan	21%
Electric Space Heater	19%
Wood-Burning Fireplace	8%
Electric Furnace	3%
Gas Furnace or Boiler	2%
Electric Heat Pump	1%
Other	10%

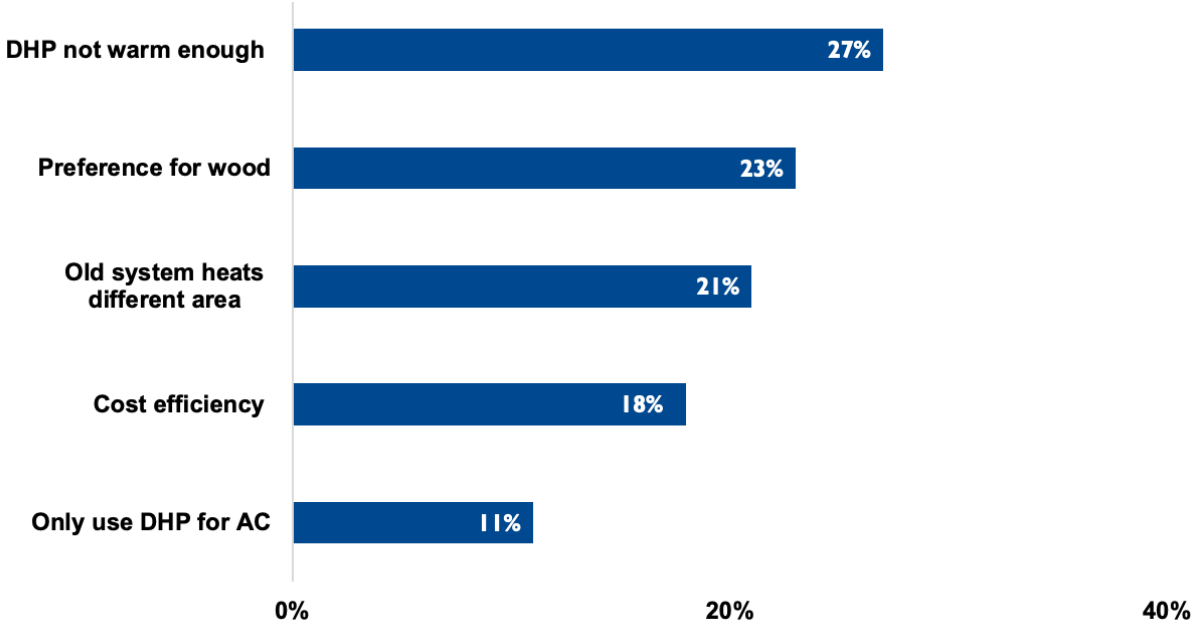
For respondents that continued to use other forms of heating, they were asked how often they used their old heating system in comparison to the DHP (Table 19). Most homes use the old systems less than the DHP (42% significantly less, and 11% slightly less), and 15 percent use both systems about the same.

Table 19: Old system usage in comparison to DHP (n=103, Q31)

	% of Respondents
Significantly less than DHP	42%
Slightly less than DHP	11%
About the same as DHP	15%
Slightly more than DHP	4%
Significantly more than DHP	12%
No old system usage	16%
Total	**100%**

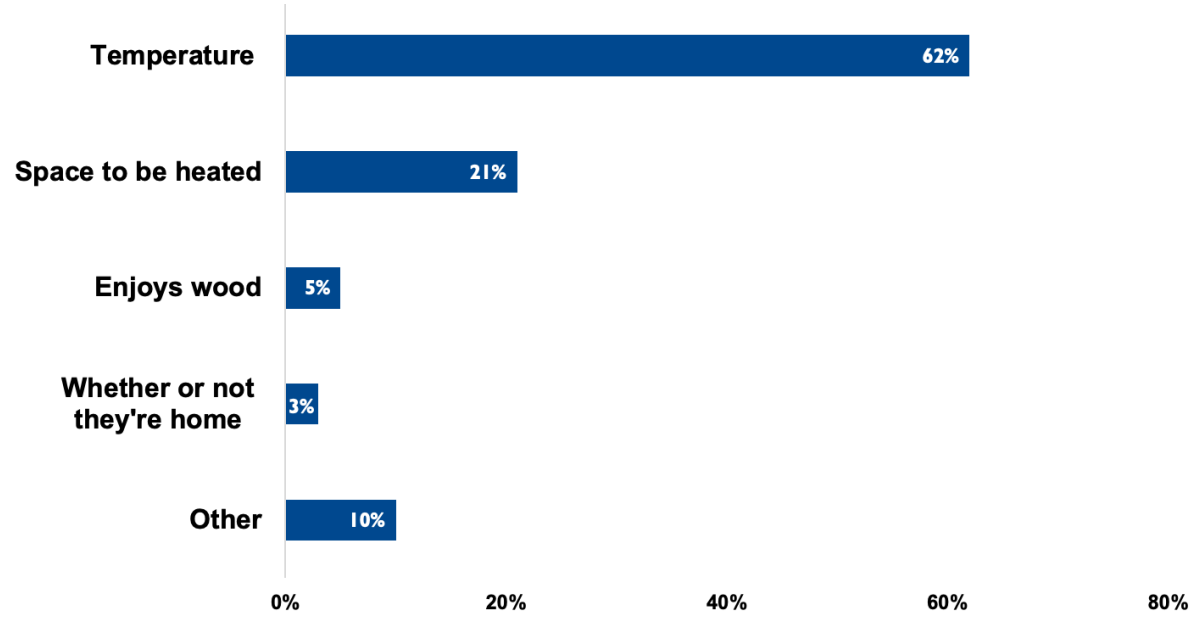
Respondents who use their old heating system more than the DHP were then asked why (open-ended). The 29 responses are categorized below (Figure 18).

Figure 18: Reasons for old heating system use more than DHP (n=29, Q32)



When asked about how homes decide on which heating system to use (open-ended), respondents gave a range of answers categorized below (Figure 19).

Figure 19: How homes decide which system to use (n=62, Q33)



Below are select verbatim responses that are illustrative of the most commonly cited reasons for deciding which system to use.

Temperature:

- "If it is very cold I use both systems."
- "On the coldest days the DHP does not quite keep the house totally comfortable so we supplement it with wood heat."

Space to be heated:

- "Mostly use DHP to heat specific rooms. Use gas fireplace to help with living room."
- "The DHP does not reach all of our bedrooms."

Enjoys wood:

- "I like the wood heat."

Whether or not they are home:

- " We maintain a level with DHP then warm up with wood stove when occupied."
- "Burn wood when I'm home. Ductless runs upstairs during the day + night."

Other:

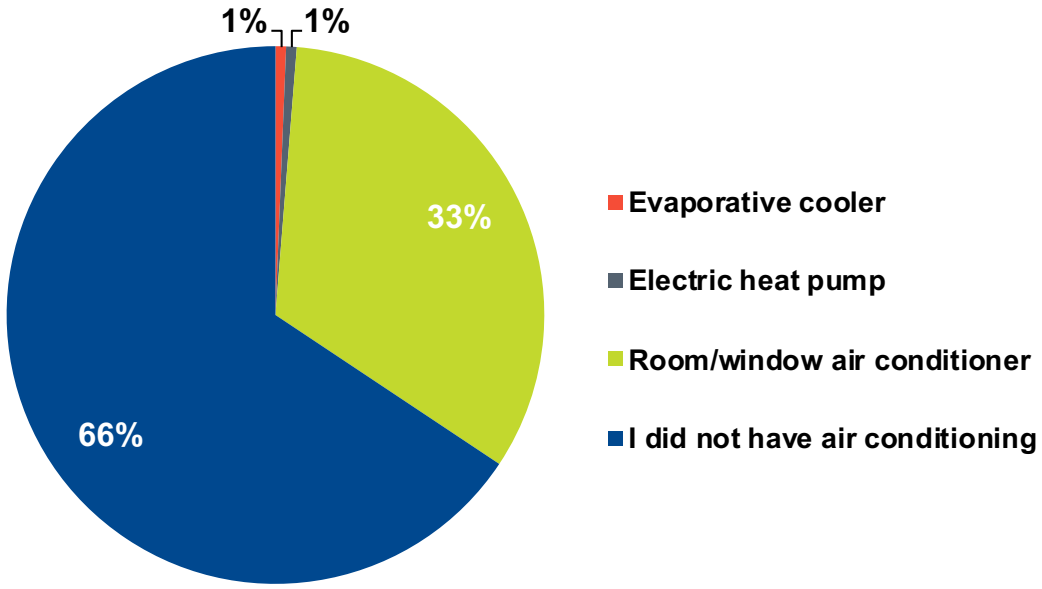
- "Electric wall cadette for a short time to heat bedroom quickly with door shut."
- "Try to consider energy costs."

USAGE OF PRIOR COOLING SYSTEM

Respondents were also asked a series of questions about how they used their cooling system before and after installing the DHP.

First, respondents indicated what type of cooling system(s) they used to heat their home prior to getting the DHP (Figure 20). Most respondents (66%) had no cooling system in place prior to DHP installation, and 33 percent used room/window AC units.

Figure 20: Cooling system used prior to DHP installation (n=127, Q34, multiple responses allowed)

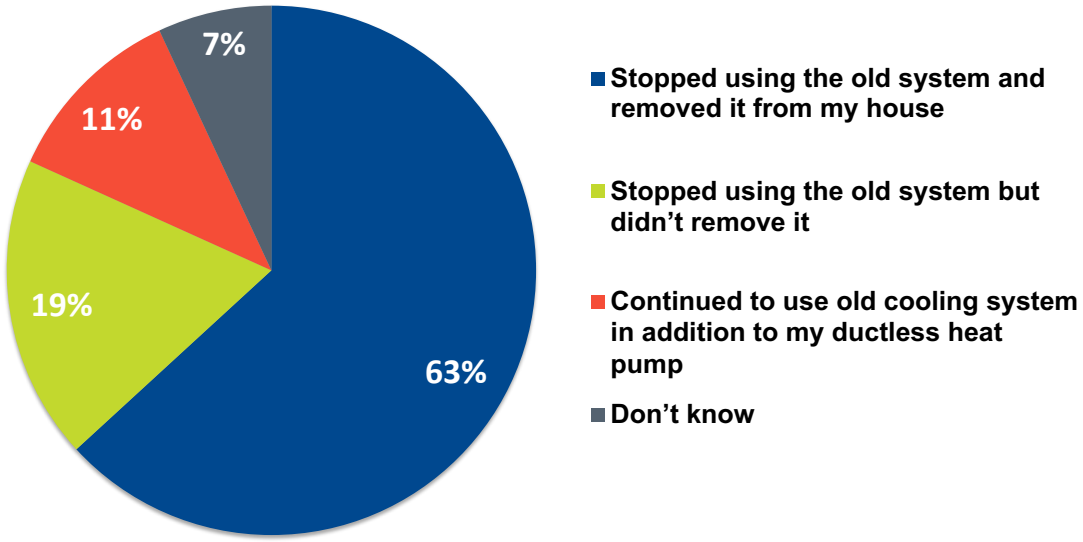


Next, respondents that had a cooling system in place prior to DHP installation were asked a number of questions to understand usage of the DHP system in cooling.

When respondents were asked if the DHP is used to cool the exact same rooms of their house as they did with their old cooling system, 64 percent said yes (n=55, Q35). Of those who answered no, write in answers noted that the DHP cools more spaces than their prior system.

Respondents were also asked about their old cooling usage after installing the DHP. Most (63%) responded that they stopped usage of their old system and removed it from their home, while only 11 percent continued to use both systems (Figure 21).

Figure 21: Old cooling system usage after DHP installation (n=51, Q36)



Of the homes that use both their old cooling system and the DHP, 75 percent of respondents answered that they use their old system significantly less or slightly less (65% and 10%, respectively) than the DHP for cooling. 10 percent stated that they use their old system more than the DHP, and 15 percent answered that they use both systems about the same (n=11, Q37).

Respondents were asked (open-ended) how they decide which air conditioning system to use in their home, and the eight answers were categorized into two reasons: temperature and location. Half (52%) of respondents answered that the temperature outside influenced their decision, and the other half (48%) stated that the space to be cooled was an important factor. Examples of verbatim responses are below:

Temperature:

- "When it hits 90+ outside."
- "What is the outside temp(erature)."

Space to be cooled:

- "Use old system AC in another area of home."
- "I only cool upstairs rooms."

5.6 COMFORT, QUALITY, AND SATISFACTION WITH DHP

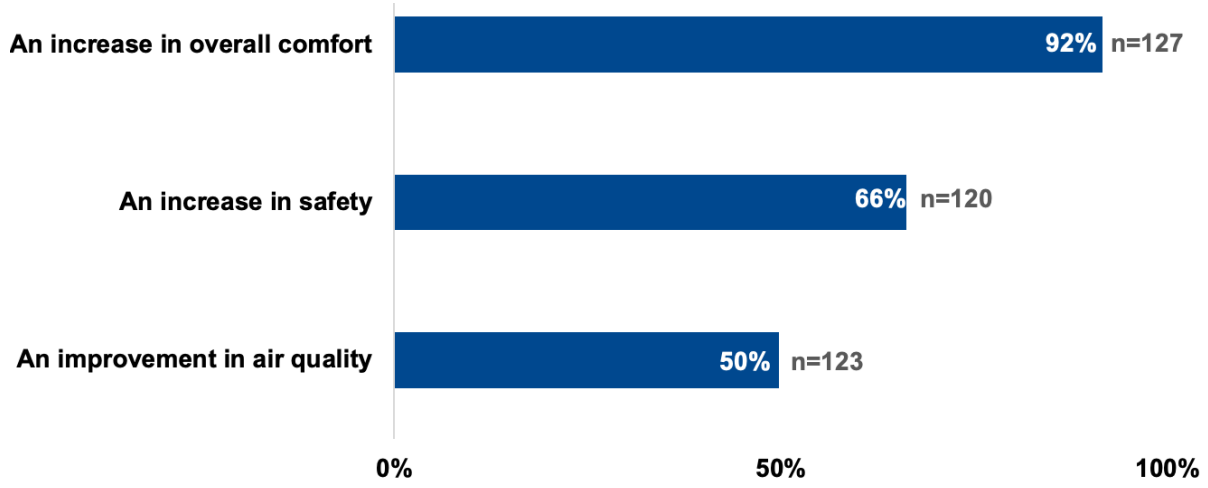
Respondents were asked a series of questions about other potential benefits associated with installing a DHP. Figure 22 below shows the responses to a series of yes/no questions asking about potential improvements in comfort, safety, and air quality since installing the DHP. Nearly all (92%) said they noticed an increase in comfort. Around two-thirds (66%) reported noticing an increase in safety compared to other heating systems they have used in the past or are using now.

Some verbatim responses that categorize feelings around safety are listed below:

- "Less concern about the safety aspects of baseboard heaters"
- "Less likely to burn the house down"

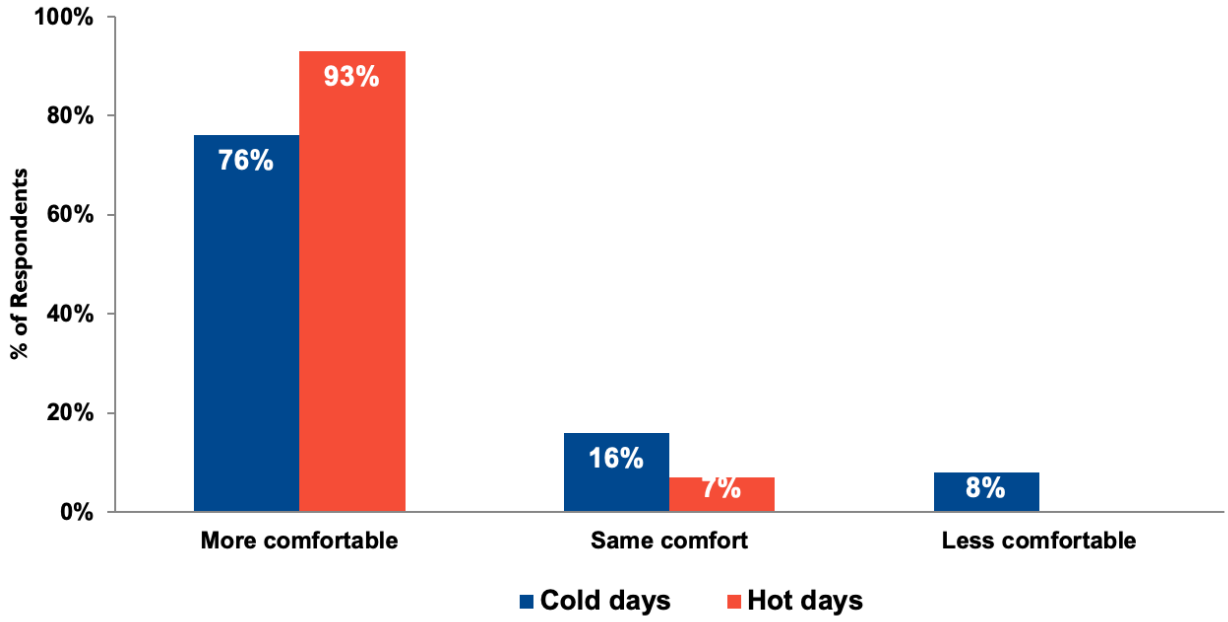
Half (50%) noticed an improvement in air quality in their home.

Figure 22: Noticed improvements in air quality, comfort, and safety since installing DHP (yes/no questions - % yes reported, n varies, Q44/45)



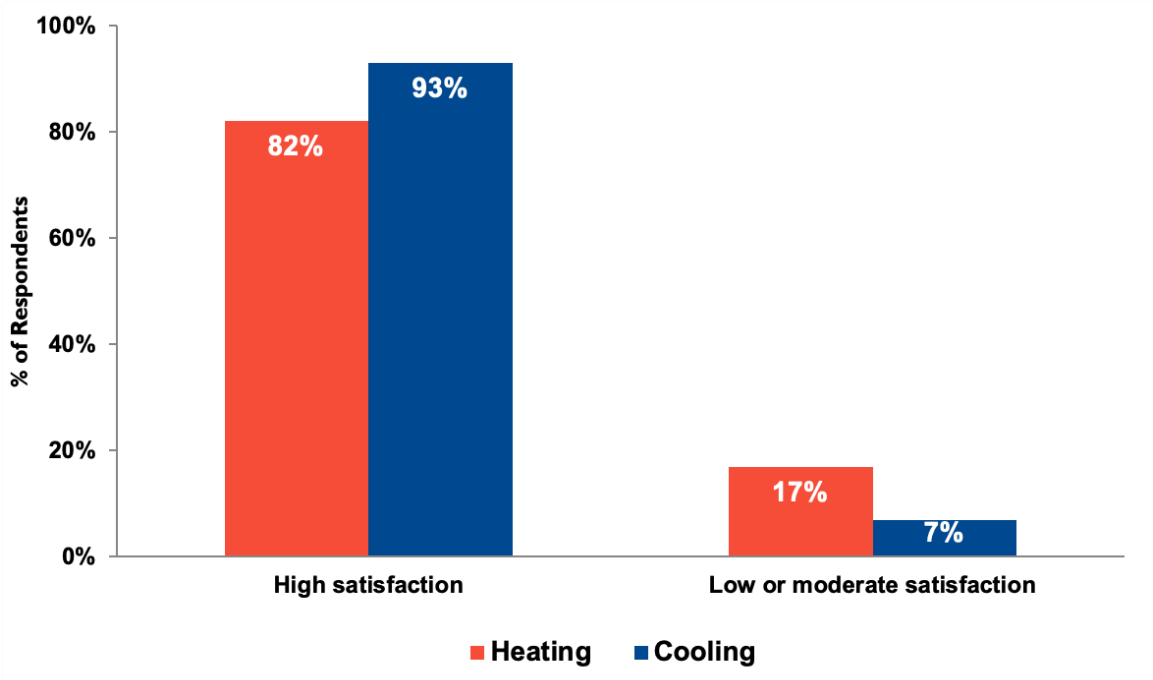
Respondents were asked to describe their comfort level on cold and hot days compared to their comfort prior to having a DHP. As shown (Figure 23), nearly all respondents (93%) said they are more comfortable on hot days, and three-quarters said they are more comfortable on cold days.

Figure 23: Comfort with DHP on cold (n=125, Q22) and hot (n=126, Q23) days



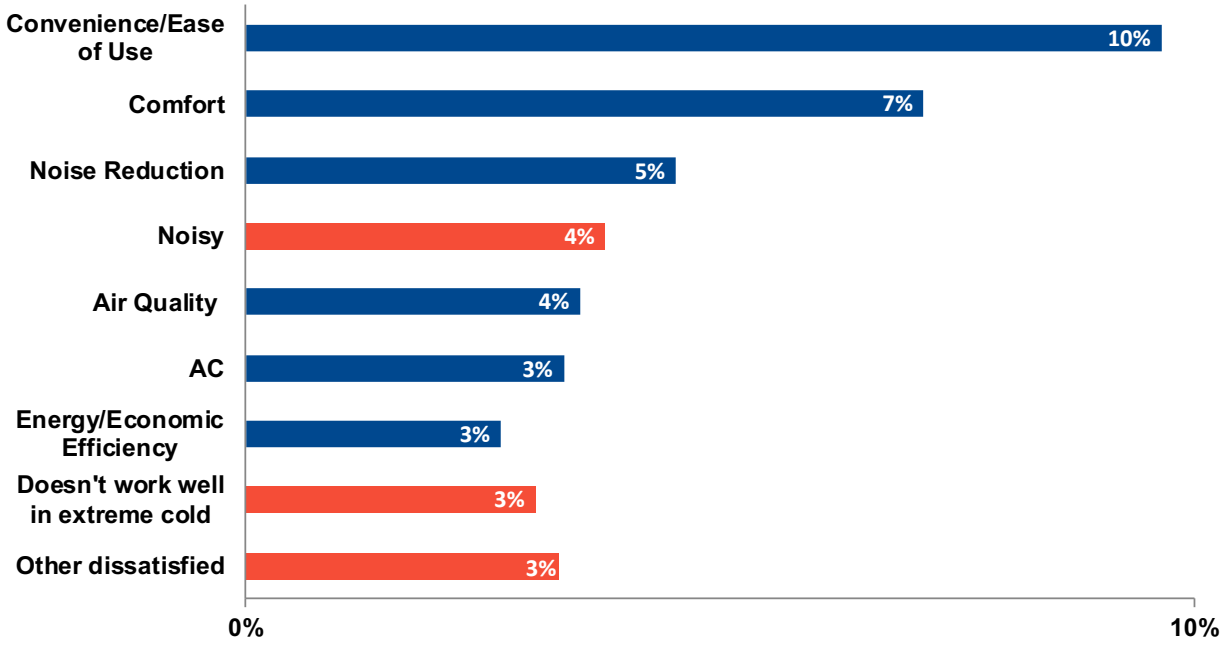
Respondents also indicated how satisfied they were with the quality of the DHP's heating and cooling (Figure 24). Satisfaction levels are quite high, with satisfaction of the cooling higher than the heating.

Figure 24: Satisfaction with quality of heating and cooling provided by DHP



After being prompted to identify additional benefits associated with the DHP, respondents were asked (open-ended) if they had noticed any other effects (positive or negative). Figure 25 categorizes the 44 responses provided, with blue shading indicating a positive attribute and orange a negative attribute. Ten percent of all respondents indicated that the DHP was convenient or easy to use, while 7 percent noted that comfort was increased (though this question was intended to identify additional benefits not already mentioned). Five percent of respondents said the DHP offered noise reduction, while 4 percent said the DHP was noisy.

Figure 25: Other effects noticed (positive – blue; negative – orange, n=131, Q46) (open-ended, responses categorized)



Below are select verbatim responses that are illustrative of the most commonly cited effects. Note that the improvements in air quality encompass both reduction in wood smoke inside the home and also the ability to use the AC to filter the home during fire season.

Convenience / ease of use:

- "Remote control aspect is great. Quick filter wash is a plus. "
- "We love the consistency whether home or not."

Comfort:

- "Greater comfort level in the open areas of the main floor."
- "More even heat distribution."

Noise reduction:

- "I love how quiet it is."
- "It does not make as much noise (as prior unit)."

Noisy:

- "It will sometimes make some terrible high pitch buzzing noise."

- “The defrost cycle is rather noisy.”

Air quality:

- "During fire season it keeps the air in my house much cleaner."
- "Stop using wood stove helped my sinus issues. My house does not get black film buildup on windows from woodstove."

AC:

- “Very nice for cooling in summer."
- "Great for AC."

Energy/economic efficiency:

- "Cut back our bills during the winter."
- "We are just more comfortable knowing we can have the heat on more of the time and that the bill will be lower."

Does not work well in extreme cold:

- "When the temperature drops below 20, the heat pumps are not very effective."
- “DHP doesn't keep up when the outside temps are very low. Almost need an alternative for these times.”

Other dissatisfied:

- “Ice builds up around outside unit during winter months.”
- “Bills are higher now in summer because we basically had no cooling before. Higher in the winter because the unit is used to heat the whole house. Before we used heat units only in rooms we were using.”

5.7 HOUSEHOLD CHARACTERISTICS

This section summarizes the characteristics of households and dwellings that respondents self-reported. (Home attributes were not validated.)

- Nearly all DHPs are installed in Single Family Detached Homes (Table 20).
- Most DHPs are installed in homes built between 1940 and 1979 (Table 21).
- 62 percent of respondents have double or triple-paned windows (Table 25).
- Nearly all homes reported attic and wall insulation, and more than three-quarters have weather-stripping (Table 26).

Table 20: Self-reported type of home (n=128, Q51)

Type of Home	*% of Respondents*
Single Family Detached	64%
Single Family Attached	29%
Small Multifamily (2 – 4 units)	2%
Multifamily (more than 4 units)	1%
Manufactured	1%
Other	2%
Total	**100%**

Table 21: Self-reported age of home (n=129, Q52)

Year Built	*% of Respondents*
Prior to 1920	3%
1920 - 1939	7%
1940 - 1959	29%
1960 - 1979	38%
1980 - 1999	18%
2001 - 2019	4%
Total	**100%**

Table 22: Self-reported size of home (n=129, Q54)

Square Footage	*% of Respondents*
0 – 999	7%
1000 – 1999	42%
2000 – 2999	35%
3000 – 3999	12%
4000+	2%
Total	**100%**

Table 23: Self-reported years occupied home (n=129, Q53)

Years Occupied	*% of Respondents*
Less than 3 years	11%
3 – 6 years	22%
7 – 10 years	6%
10 – 15 years	12%
More than 15 years	50%
Total	**100%**

Table 24: Self-reported gas service in home (n=128, Q55)

Gas Type	*% of Respondents*
Natural gas	17%
Propane or other bottled gas	19%
No gas	63%
Total	**100%**

Table 25: Self-reported double pane or triple pane windows in home (n=127, Q56)

% of All Windows in Home That Are Double or Triple Pane	*% of Respondents*
0% - 24%	5%
25% - 49%	3%
50% - 74%	8%
75% - 99%	17%
100%	62%
Don't know	6%
Total	**100%**

Table 26: Self-reported home features (n=126, Q57, multiple mentions allowed)

Feature	*% of Respondents with Feature*
Attic Insulation	94%
Floor Insulation	41%
Wall Insulation	94%
Door/Window Weather-Stripping	77%

Table 27: Number of people moved into home since installing DHP (n=129, Q47)

Number of People Moved In	*% of Respondents*
0	89%
1 – 2	7%
3 or more	4%
Total	**100%**

Table 28: Number of people moved out of home since installing DHP (n=129, Q48)

Number of People Moved Out	*% of Respondents*
0	91%
1 – 2	7%
3 or more	2%
Total	**100%**

Table 29: Self-reported home improvement measures taken (n varies, Q49/50/58)

Improvement	*% of Respondents*	*n*
Added square footage prior to installation	2%	128
Replaced old appliances after installation	16%	125
Installed solar panels before or after installation	0%	126

5.8 COMPARING SURVEY RESPONSES TO ENERGY USE

Evergreen compared participants' survey responses to their change in electricity use after installing the DHP.[16] The goal of this comparative analysis was to determine if there are characteristics of the participant or their home that help explain why some customers that install a DHP reduce their electricity consumption, while electricity use for others either does not change or actually increases. We used the pre-installation and post-installation VBDD models for each customer to compute three measures of change in electricity use in the year after the DHP was installed:

1. **Anytime** – Average daily change in kWh in year after installing DHP
2. **Winter** – Average daily change in kWh during the winter months (December, January, February) in year after installing DHP
3. **Summer** – Average daily change in kWh during the summer months (June, July, August) in year after installing DHP

The number of customers surveyed was relatively small, and any differences in electricity use between subgroups of customers would need to be pronounced to be greater than the sampling error. For most survey questions, we found no statistically significant relationship between customers' responses and their change in electricity use after installing a DHP. In some instances, as we describe below, the lack of statistical significance is an important finding. There were also a small number of survey questions that were statistically significant and that helped explain why some customers decreased electricity consumption while others increased their electricity consumption after installing a DHP.

The remainder of this section describes key findings related to the following characteristics:

5.8.1 STATISTICALLY SIGNIFICANT RESULTS

1. **Wood and wood pellets** – Customers that heated their home with wood or wood pellets (solely or in combination with other forms of heating) prior to installing a DHP increased their electricity usage after installing a DHP.
2. **Gas service** -
    a. **Propane or other bottled gas service** – Customers that have propane or other bottled gas service delivered to their home increased their electricity usage after installing a DHP.
    b. **Natural gas service** – Customers that have natural gas service to their home decreased their electricity usage after installing a DHP.

[16] Change in electricity usage was computed as the weather normalized difference in average daily usage, measured in kWh, between the 12 months prior to installing the DHP and the 12 months after installation.

3. **Perceived change in energy bills** - Customers were consistent in how they perceived their electricity bill changed during the winter and how their actual use of electricity actually changed. For the summer months, we did not find any relationship between electricity usage and perceptions of electricity usage.

5.8.2 RESULTS THAT WERE NOT STATISTICALLY SIGNIFICANT

4. **Results that were not statistically significant** - Customers that did not have cooling before adding a DHP did not increase their summertime electricity use after installing a DHP. We also found that there was not a clear distinction between the number of indoor DHP heads and the change in electricity usage after installing the DHP. We also found no difference in electricity savings between customers that continued to use their old heating system after installing a DHP and customers that stopped using their old heating system.

CUSTOMERS THAT HEATED WITH WOOD PRIOR TO INSTALLING DHP

Survey respondents were provided with a list of home heating equipment and asked to indicate which equipment they used prior to installing the DHP. Each type of equipment in the list included the operating fuel (electric, gas, wood). Respondents were asked to "check all that apply" and were provided with space to write in any other heating equipment not on the list. Most survey respondents indicated that they used two or more types of heating equipment.

Evergreen identified all respondents that indicated that they heated with wood or wood pellet (either as their sole source of heat or in combination with another source) and compared their change in electricity use to respondents that did *not* indicate they heated with wood or wood pellets prior to installing the DHP. Table 30 shows the average change in electricity use for survey respondents that reported heating with wood or wood pellets prior to installing a DHP and those that reported they did not.

Table 30: Average daily change in electricity usage by those who heated with wood or wood pellets vs. those who did not

Did you use wood or pellet to heat your home prior to installing DHP?	*Count*	*Time of Year*	*Mean Change in Daily kWh*	*Standard Error*
Yes – I Did Heat with Wood or Wood Pellets	55	Anytime	1.45	1.77
		Winter	5.70	3.54
No – I Did Not Heat with Wood or Wood Pellets	76	Anytime	-5.03	1.53
		Winter	-9.90	2.82

Not surprisingly, customers that reported heating with wood or wood pellets increased their electricity usage after installing the DHP. Despite the fact that all but one of these customers reported keeping their wood/pellet stove or fireplace, it is clear that the convenience of a DHP—relative to the operation and maintenance of a wood/pellet stove or fireplace—led these customers to rely less on wood to heat their home and more on electricity. In fact, 64 percent of customers that

heated with wood or wood pellets reported using their old system less or not at all after installing the DHP.

Table 31 shows the difference in mean daily electricity usage between customers that heated with wood and those that did not. We estimated that customers that did not heat with wood or wood pellets saved on average 6.6 kWh more per day in the year after installing the DHP and 15.6 kWh more per day during the winter. Table 31 also shows the lower and upper bounds of the 90 percent confidence interval for the actual difference in means, which ranges from 8.2 kWh per day to as much as 23.0 kWh per day during the winter months.

Table 31: Difference in means between customers that heated with wood prior to installing a DHP and homes that did not, 90% confidence interval

Time of Year	*Difference in Means**	*Standard Error of Difference*	*Lower Bound 90% CI*	*Upper Bound 90% CI*
Anytime	6.5	2.35	2.6	10.4
Winter (Dec, Jan, Feb)	15.6	4.48	8.2	23.0

* Calculated as absolute value of difference in *Mean Change in Daily kWh* shown in Table 30.

The difference in electricity use between customers that heated with wood and customers that did not narrowed after installing a DHP.

Prior to DHP installation, customers that heated with wood or wood pellets (either as their sole source of heat or in combination with another source) used on average 66 kWh per day during the winter months. Customers that did not heat with wood used 88 kWh per day on average.

After installation of a DHP, average daily electricity use during the winter increased to 72 kWh for customers that heated with wood (a difference of 6 kWh per day, while it decreased to 78 kWh for customers that did not heat with wood (a difference of 10 kWh per day).

IMPACT OF GAS SERVICE

The next significant survey result of note is the relationship between residential gas service and the change in electricity consumption after installing a DHP. Respondents were asked if they had natural gas service to their home, had propane or other bottled gas, or had no gas service. Table 32 shows the number of respondents by response and average drop in daily electricity usage during winter months. Most respondents (82) did not have any gas service and, while not statistically significantly different from zero, the average drop in daily electricity use for these sampled homes was about 3.7 kWh.

Table 32: Average change in electricity use during winter months by participants with and without gas service, 90% confidence interval

Response from Program Participant	*Sample Size*	*Mean Change in Daily kWh**	*Standard Error*	*Lower Bound*	*Upper Bound*
No Gas Service	82	-3.67	2.99	-1.31	8.65
Natural Gas Service (1)	20	-15.42	3.75	8.95	21.88
Propane or Other Bottled Gas (2)	26	9.88	4.66	-1.93	-17.83

1. Statistically significant reduction in average daily kWh during winter.
2. Statistically significant increase in average daily kWh during winter.
* Winter months (Dec, Jan, Feb) only.

The results for respondents with gas service are particularly interesting and, at least on the surface, seem contradictory. Participants with natural gas service decreased their electricity use on average by 15.4 kWh per day during the winter. This drop is highly statistically significant: the 90 percent confidence interval for the actual drop in electricity use ranged from about 9 kWh to nearly 22 kWh per day. In comparison, participants with propane (or other bottled gas) service *increased* their electricity use by nearly 10 kWh per day (90 percent confidence interval for actual increase ranges from about 2 kWh to nearly 18 kWh per day).

So why did participants with natural gas substantially reduce their electricity usage, while participants with propane increased their usage? Our assumption was that the difference was due to customers with propane service also heating with wood or wood pellets prior to installing a DHP. We did find that a larger proportion of homes with propane also heated with wood or wood pellets than did homes with natural gas (45% versus 15%). However, even when we recompute the change in electricity usage after first removing from the analysis customers that heat with wood or wood pellets, the results do not materially change.[17] Those with natural gas service decreased their electricity use, and customers with propane increased their usage. Customers with natural gas service did use more electricity prior to installing a DHP than did customers with propane service (87 kWh versus 75 kWh during the winter months). There was no discernable difference between the two groups of customers with respect to their responses regarding how they heated their homes prior to installing the DHP. Nearly all customers indicated that they heated with electric baseboards, wall fans, and space heaters in addition to other forms of heating such as a gas fireplace or wood-burning stove.

CHANGE IN ENERGY BILLS – PERCEPTION VERSUS REALITY

The survey also asked program participants how their energy bills changed during cooler and hotter times of the year after installing the DHP. Respondents were provided with five options ranging from "Much lower energy bill" to "Much higher energy bill." Table 33 shows the number of respondents that chose each option and the average daily drop in kWh based on our analysis of the

[17] For customers with natural gas service, change in daily electricity usage goes from -15.42 kWh to -16.40 kWh, and for customers with propane or other bottled gas, change in daily electricity usage goes from 9.88 kWh to -9.22 kWh. The precision of the estimates also does not materially change. For customers without any gas service, estimated electricity savings increased to 12.3 kWh per day during the winter and is highly statistically significant when excluding customers that heated with wood.

respondents' actual billing data. The results show that with respect to winter months, respondents on average were able to accurately determine if their energy bills changed, the direction their bill changed (up or down), and the magnitude of the change.

Table 33: Since installing the ductless heat pump, how have your energy bills changed during cooler times of the year? 90% confidence interval

Response from Program Participant	*Sample Size*	*Mean Change in Daily kWh**	*Standard Error*	*Lower Bound*	*Upper Bound*
1 - Much lower energy bill (1)	29	-10.70	4.57	2.94	18.46
2 - Slightly lower energy bill	37	-4.37	3.11	-0.88	9.62
3 - About the same	31	-2.25	5.45	-6.99	11.49
4 - Slightly higher energy bill (2)	18	7.42	4.22	-14.73	-0.11
5 - Much higher energy bill	11	9.97	9.48	-26.99	7.05

1. Statistically significant reduction in average daily kWh during winter.
2. Statistically significant increase in average daily kWh during winter.
* Winter months (Dec, Jan, Feb) only.

With the relatively small number of responses per option (ranging from 11 for "Much higher energy bill" to 37 for "Slightly lower energy bill"), the results are only statistically significant for respondents that reported *Much lower energy bill* or reported *Slightly higher energy bill*. Nevertheless, the results shown in Table 33 indicate that, at least during the heating season, participants generally understood the impact on their energy bills.

Table 34 shows the same information, but for hotter times of the year. Program participants tend to use much less electricity during the summer months as they do in the winter, which may explain why respondents were generally not able to determine the direction or magnitude of change in their energy use after installing a DHP. None of the results were statistically significant.

Table 34: Since installing the ductless heat pump, how have your energy bills changed during hotter times of the year? 90% confidence interval

Response from Program Participant	*Sample Size*	*Mean Change in Daily kWh**	*Standard Error*	*Lower Bound*	*Upper Bound*
1 - Much lower energy bill	15	2.70	3.67	-9.13	3.73
2 - Slightly lower energy bill	17	-3.43	2.69	-1.24	8.11
3 - About the same	46	0.11	1.31	-2.32	2.09
4 - Slightly higher energy bill	39	-1.19	1.35	-1.08	3.46
5 - Much higher energy bill	9	-2.89	4.47	-5.30	11.08

* Summer months (June, July, August) only.

CHARACTERISTICS THAT WERE NOT STATISTICALLY SIGNIFICANT

Equally important are some of the results that were not statistically significant. We found that customers that did not have cooling before adding a DHP did not increase their summertime electricity use after installing a DHP. This finding suggests that DHPs do not add to summertime loads in heating zones 2 and 3. We also found that there is not a clear distinction between the number of indoor DHP heads and the change in electricity usage after installing the DHP. Most customers (89) reported installing a single indoor head, while 23 reported installing two heads, and 12 reported installing three or four DHP heads.

We also found no difference in electricity savings between customers that continued to use their old heating system after installing a DHP and customers that stopped using their old heating system. Of the 44 customers that reported that they stopped using their old heating equipment, four indicated that the old equipment was removed from their home. On average, these customers reduced their daily electricity usage by 10.6 kWh, which, though seemingly substantial, is not statistically significantly different from participants that stopped using, but did not remove, their old heating equipment.

6 APPENDIX A: MODELING RESULTS FROM POST-ONLY BILLING REGRESSIONS

Table 35 through Table 42 show the estimated coefficients and standard errors for each regression model, as well as the number of participants, sample size, adjusted R2 and F-statistic.

Table 35: Modeling results for DHP replacing zonal heating

Variable	*Heating Zones 2 & 3*		*Heating Zone 2*		*Heating Zone 3*	
	Coefficient	*Std. Error*	*Coefficient*	*Std. Error*	*Coefficient*	*Std. Error*
Intercept	3.818	0.538	2.319	0.712	5.858	0.846
CDD	0.398	0.094	0.479	0.121	0.318	0.155
HDD	0.386	0.022	0.467	0.031	0.282	0.033
Pre-kWh * Jan	0.637	0.008	0.641	0.012	0.633	0.012
Pre-kWh * Feb	0.780	0.010	0.776	0.015	0.784	0.015
Pre-kWh * Mar	0.883	0.013	0.889	0.017	0.876	0.018
Pre-kWh * Apr	0.811	0.016	0.805	0.022	0.815	0.024
Pre-kWh * May	0.786	0.021	0.785	0.028	0.783	0.032
Pre-kWh * Jun	0.820	0.023	0.840	0.031	0.788	0.036
Pre-kWh * Jul	0.873	0.025	0.904	0.032	0.825	0.039
Pre-kWh * Aug	0.849	0.023	0.860	0.031	0.827	0.036
Pre-kWh * Sep	0.811	0.022	0.817	0.030	0.796	0.032
Pre-kWh * Oct	0.832	0.017	0.831	0.024	0.830	0.025
Pre-kWh * Nov	0.865	0.012	0.849	0.017	0.883	0.018
Pre-kWh * Dec	0.692	0.008	0.676	0.012	0.709	0.011
Part * Pre-kWh * Jan	-0.020	0.011	-0.027	0.015	-0.010	0.015
Part * Pre-kWh * Feb	-0.024	0.013	-0.046	0.018	0.005	0.019
Part * Pre-kWh * Mar	-0.074	0.016	-0.101	0.023	-0.039	0.024
Part * Pre-kWh * Apr	-0.070	0.021	-0.107	0.028	-0.021	0.030
Part * Pre-kWh * May	-0.060	0.027	-0.051	0.036	-0.071	0.040
Part * Pre-kWh * Jun	-0.071	0.029	-0.078	0.039	-0.062	0.045
Part * Pre-kWh * Jul	-0.072	0.029	-0.073	0.038	-0.075	0.044
Part * Pre-kWh * Aug	-0.022	0.029	-0.007	0.039	-0.043	0.043
Part * Pre-kWh * Sep	-0.024	0.028	0.006	0.039	-0.053	0.040
Part * Pre-kWh * Oct	-0.091	0.022	-0.092	0.030	-0.083	0.031
Part * Pre-kWh * Nov	-0.090	0.015	-0.069	0.021	-0.107	0.022
Part * Pre-kWh * Dec	-0.036	0.010	-0.022	0.014	-0.045	0.014
Participants	**450**		**256**		**194**	
Sample Size	**12,472**		**6,970**		**5,502**	
Adjusted R-Square	**0.73**		**0.73**		**0.74**	
F-Statistic	**1,329**		**716**		**609**	

Table 36: Modeling results for DHP replacing electric forced-air furnace

Variable	*Heating Zones 3*	
	Coefficient	*Std. Error*
Intercept	3.222	2.371
CDD	1.017	0.421
HDD	0.782	0.086
Pre-kWh * Jan	0.564	0.029
Pre-kWh * Feb	0.635	0.036
Pre-kWh * Mar	0.706	0.045
Pre-kWh * Apr	0.629	0.060
Pre-kWh * May	0.679	0.094
Pre-kWh * Jun	0.741	0.115
Pre-kWh * Jul	0.731	0.123
Pre-kWh * Aug	0.756	0.113
Pre-kWh * Sep	0.726	0.091
Pre-kWh * Oct	0.649	0.060
Pre-kWh * Nov	0.657	0.042
Pre-kWh * Dec	0.518	0.027
Part * Pre-kWh * Jan	-0.098	0.037
Part * Pre-kWh * Feb	-0.080	0.044
Part * Pre-kWh * Mar	-0.150	0.058
Part * Pre-kWh * Apr	-0.093	0.078
Part * Pre-kWh * May	-0.103	0.115
Part * Pre-kWh * Jun	-0.031	0.142
Part * Pre-kWh * Jul	-0.104	0.128
Part * Pre-kWh * Aug	-0.081	0.126
Part * Pre-kWh * Sep	-0.114	0.109
Part * Pre-kWh * Oct	-0.115	0.077
Part * Pre-kWh * Nov	-0.071	0.055
Part * Pre-kWh * Dec	-0.067	0.033
Participants	**39**	
Sample Size	**1,036**	
Adjusted R-Square	**0.67**	
F-Statistic	**82**	

Table 37: Modeling results for VSHP with duct sealing

Variable	*Heating Zones 1 &2*	
	Coefficient	*Std. Error*
Intercept	-1.721	2.768
CDD	0.964	0.505
HDD	1.035	0.136
Pre-kWh * Jan	0.538	0.035
Pre-kWh * Feb	0.627	0.045
Pre-kWh * Mar	0.750	0.053
Pre-kWh * Apr	0.693	0.065
Pre-kWh * May	0.810	0.092
Pre-kWh * Jun	0.833	0.107
Pre-kWh * Jul	0.898	0.110
Pre-kWh * Aug	0.949	0.097
Pre-kWh * Sep	0.868	0.087
Pre-kWh * Oct	0.742	0.069
Pre-kWh * Nov	0.779	0.053
Pre-kWh * Dec	0.563	0.034
Part * Pre-kWh * Jan	-0.188	0.041
Part * Pre-kWh * Feb	-0.260	0.054
Part * Pre-kWh * Mar	-0.261	0.067
Part * Pre-kWh * Apr	-0.261	0.085
Part * Pre-kWh * May	-0.313	0.115
Part * Pre-kWh * Jun	-0.156	0.131
Part * Pre-kWh * Jul	-0.184	0.124
Part * Pre-kWh * Aug	-0.135	0.113
Part * Pre-kWh * Sep	-0.284	0.112
Part * Pre-kWh * Oct	-0.334	0.087
Part * Pre-kWh * Nov	-0.309	0.065
Part * Pre-kWh * Dec	-0.220	0.036
Participants	**22**	
Sample Size	**616**	
Adjusted R-Square	**0.71**	
F-Statistic	**60**	

Table 38: Modeling results for VSHP without duct sealing

Variable	*All Heating Zones*		*Heating Zone 1*		*Heating Zone 2 & 3*	
	Coefficient	*Std. Error*	*Coefficient*	*Std. Error*	*Coefficient*	*Std. Error*
Intercept	-2.380	1.598	3.056	1.682	-8.931	4.309
CDD	0.606	0.232	0.230	0.242	1.543	0.685
HDD	1.024	0.085	0.685	0.092	1.693	0.185
Pre-kWh * Jan	0.520	0.027	0.495	0.030	0.493	0.053
Pre-kWh * Feb	0.577	0.035	0.584	0.040	0.500	0.060
Pre-kWh * Mar	0.656	0.040	0.706	0.050	0.516	0.062
Pre-kWh * Apr	0.695	0.047	0.674	0.053	0.632	0.085
Pre-kWh * May	0.840	0.049	0.785	0.051	0.857	0.118
Pre-kWh * Jun	0.937	0.048	0.886	0.049	0.946	0.131
Pre-kWh * Jul	0.946	0.050	0.897	0.051	1.078	0.135
Pre-kWh * Aug	0.860	0.050	0.805	0.049	1.004	0.167
Pre-kWh * Sep	0.854	0.062	0.791	0.063	0.842	0.154
Pre-kWh * Oct	0.723	0.052	0.732	0.054	0.593	0.119
Pre-kWh * Nov	0.675	0.041	0.683	0.045	0.641	0.080
Pre-kWh * Dec	0.504	0.029	0.534	0.032	0.437	0.056
Part * Pre-kWh * Jan	-0.071	0.030	-0.105	0.035	-0.012	0.051
Part * Pre-kWh * Feb	-0.069	0.037	-0.139	0.044	0.032	0.059
Part * Pre-kWh * Mar	-0.045	0.048	-0.164	0.060	0.114	0.072
Part * Pre-kWh * Apr	-0.011	0.060	-0.021	0.068	0.021	0.104
Part * Pre-kWh * May	-0.094	0.062	-0.091	0.065	-0.045	0.136
Part * Pre-kWh * Jun	-0.054	0.060	-0.017	0.061	-0.229	0.151
Part * Pre-kWh * Jul	0.018	0.059	0.054	0.059	-0.360	0.179
Part * Pre-kWh * Aug	0.059	0.061	0.067	0.060	-0.114	0.229
Part * Pre-kWh * Sep	0.095	0.078	0.100	0.080	0.026	0.191
Part * Pre-kWh * Oct	0.020	0.065	0.002	0.068	0.036	0.144
Part * Pre-kWh * Nov	-0.095	0.046	-0.118	0.050	-0.074	0.091
Part * Pre-kWh * Dec	-0.055	0.029	-0.087	0.032	-0.006	0.055
Participants	**48**		**37**		**11**	
Sample Size	**1,320**		**1,014**		**306**	
Adjusted R-Square	**0.70**		**0.70**		**0.80**	
F-Statistic	**118**		**80**		**49**	

Table 39: Modeling results for ASHP with duct sealing

Variable	*Heating Zones 1 & 2*		*Heating Zone 2*	
	Coefficient	*Std. Error*	*Coefficient*	*Std. Error*
Intercept	2.340	2.916	3.854	3.213
CDD	1.414	0.478	1.300	0.521
HDD	0.945	0.135	0.884	0.146
Pre-kWh * Jan	0.545	0.035	0.559	0.036
Pre-kWh * Feb	0.638	0.045	0.651	0.047
Pre-kWh * Mar	0.822	0.054	0.829	0.056
Pre-kWh * Apr	0.707	0.072	0.710	0.074
Pre-kWh * May	0.736	0.094	0.719	0.098
Pre-kWh * Jun	0.746	0.105	0.724	0.110
Pre-kWh * Jul	0.693	0.120	0.688	0.126
Pre-kWh * Aug	0.708	0.116	0.695	0.120
Pre-kWh * Sep	0.712	0.105	0.694	0.109
Pre-kWh * Oct	0.698	0.077	0.696	0.080
Pre-kWh * Nov	0.678	0.055	0.686	0.057
Pre-kWh * Dec	0.528	0.037	0.544	0.038
Part * Pre-kWh * Jan	-0.153	0.041	-0.165	0.042
Part * Pre-kWh * Feb	-0.220	0.050	-0.234	0.052
Part * Pre-kWh * Mar	-0.265	0.068	-0.269	0.070
Part * Pre-kWh * Apr	-0.152	0.090	-0.159	0.093
Part * Pre-kWh * May	0.019	0.116	0.017	0.120
Part * Pre-kWh * Jun	0.057	0.129	0.058	0.133
Part * Pre-kWh * Jul	0.015	0.133	0.015	0.138
Part * Pre-kWh * Aug	0.023	0.129	0.024	0.134
Part * Pre-kWh * Sep	0.019	0.125	0.023	0.129
Part * Pre-kWh * Oct	-0.040	0.096	-0.041	0.099
Part * Pre-kWh * Nov	-0.104	0.066	-0.112	0.069
Part * Pre-kWh * Dec	-0.124	0.039	-0.134	0.041
Participants	**35**		**32**	
Sample Size	**1,002**		**934**	
Adjusted R-Square	**0.58**		**0.58**	
F-Statistic	**54**		**50**	

Table 40: Modeling results for ASHP without duct sealing

Variable	*All Heating Zones*		*Heating Zone 1*		*Heating Zone 2 & 3*	
	Coefficient	*Std. Error*	*Coefficient*	*Std. Error*	*Coefficient*	*Std. Error*
Intercept	4.120	1.013	6.263	1.034	10.813	3.417
CDD	0.323	0.142	0.221	0.137	0.142	0.672
HDD	0.290	0.048	0.469	0.050	-0.273	0.137
Pre-kWh * Jan	0.610	0.013	0.518	0.014	0.772	0.032
Pre-kWh * Feb	0.799	0.017	0.682	0.018	0.982	0.041
Pre-kWh * Mar	0.955	0.023	0.794	0.024	1.186	0.052
Pre-kWh * Apr	0.900	0.028	0.741	0.030	1.107	0.067
Pre-kWh * May	0.852	0.033	0.815	0.034	0.713	0.090
Pre-kWh * Jun	0.851	0.032	0.820	0.031	0.681	0.110
Pre-kWh * Jul	0.880	0.032	0.866	0.030	0.727	0.126
Pre-kWh * Aug	0.831	0.032	0.800	0.030	0.742	0.122
Pre-kWh * Sep	0.847	0.034	0.782	0.033	0.800	0.106
Pre-kWh * Oct	0.941	0.028	0.829	0.030	1.001	0.063
Pre-kWh * Nov	0.935	0.019	0.795	0.020	1.156	0.047
Pre-kWh * Dec	0.705	0.013	0.587	0.013	0.954	0.032
Part * Pre-kWh * Jan	-0.140	0.016	-0.164	0.016	-0.069	0.038
Part * Pre-kWh * Feb	-0.219	0.020	-0.255	0.021	-0.099	0.048
Part * Pre-kWh * Mar	-0.278	0.029	-0.293	0.031	-0.254	0.065
Part * Pre-kWh * Apr	-0.224	0.037	-0.179	0.039	-0.315	0.084
Part * Pre-kWh * May	-0.089	0.042	-0.090	0.042	-0.029	0.109
Part * Pre-kWh * Jun	-0.129	0.040	-0.154	0.038	0.086	0.134
Part * Pre-kWh * Jul	-0.160	0.035	-0.187	0.033	0.090	0.130
Part * Pre-kWh * Aug	-0.132	0.037	-0.157	0.035	0.108	0.136
Part * Pre-kWh * Sep	-0.095	0.043	-0.099	0.041	-0.044	0.128
Part * Pre-kWh * Oct	-0.250	0.035	-0.243	0.037	-0.217	0.081
Part * Pre-kWh * Nov	-0.302	0.023	-0.280	0.023	-0.302	0.059
Part * Pre-kWh * Dec	-0.185	0.014	-0.174	0.014	-0.217	0.036
Participants	**176**		**147**		**29**	
Sample Size	**5,046**		**4,286**		**760**	
Adjusted R-Square	**0.68**		**0.64**		**0.79**	
F-Statistic	**418**		**299**		**114**	

Table 41: Modeling results for duct sealing (and no other measures)

Variable	*All Heating Zones*	
	Coefficient	*Std. Error*
Intercept	2.296	0.859
CDD	0.350	0.142
HDD	0.614	0.039
Pre-kWh * Jan	0.561	0.011
Pre-kWh * Feb	0.691	0.015
Pre-kWh * Mar	0.836	0.019
Pre-kWh * Apr	0.822	0.023
Pre-kWh * May	0.842	0.029
Pre-kWh * Jun	0.884	0.031
Pre-kWh * Jul	0.935	0.033
Pre-kWh * Aug	0.904	0.030
Pre-kWh * Sep	0.821	0.030
Pre-kWh * Oct	0.778	0.024
Pre-kWh * Nov	0.802	0.017
Pre-kWh * Dec	0.616	0.011
Part * Pre-kWh * Jan	-0.107	0.013
Part * Pre-kWh * Feb	-0.105	0.018
Part * Pre-kWh * Mar	-0.136	0.023
Part * Pre-kWh * Apr	-0.213	0.029
Part * Pre-kWh * May	-0.128	0.037
Part * Pre-kWh * Jun	-0.253	0.037
Part * Pre-kWh * Jul	-0.122	0.038
Part * Pre-kWh * Aug	-0.126	0.035
Part * Pre-kWh * Sep	-0.027	0.037
Part * Pre-kWh * Oct	-0.032	0.031
Part * Pre-kWh * Nov	-0.115	0.022
Part * Pre-kWh * Dec	-0.090	0.012
Participants	**238**	
Sample Size	**6,570**	
Adjusted R-Square	**0.71**	
F-Statistic	**614**	

Table 42: Modeling results for duct sealing (and no other measures)

Variable	*Heating Zones 2 & 3*		*Heating Zone 2*		*Heating Zone 3*	
	Coefficient	*Std. Error*	*Coefficient*	*Std. Error*	*Coefficient*	*Std. Error*
Intercept	6.413	1.396	-0.033	1.200	4.393	2.836
CDD	0.039	0.225	0.388	0.191	1.040	0.528
HDD	0.699	0.071	0.614	0.054	0.718	0.115
Pre-kWh * Jan	0.462	0.021	0.595	0.013	0.519	0.043
Pre-kWh * Feb	0.601	0.029	0.722	0.018	0.583	0.057
Pre-kWh * Mar	0.702	0.036	0.881	0.022	0.724	0.069
Pre-kWh * Apr	0.704	0.044	0.868	0.028	0.680	0.087
Pre-kWh * May	0.797	0.048	0.874	0.037	0.702	0.117
Pre-kWh * Jun	0.822	0.047	0.935	0.041	0.697	0.130
Pre-kWh * Jul	0.893	0.052	0.989	0.043	0.585	0.189
Pre-kWh * Aug	0.882	0.046	0.937	0.040	0.713	0.135
Pre-kWh * Sep	0.740	0.051	0.864	0.038	0.731	0.116
Pre-kWh * Oct	0.638	0.043	0.830	0.029	0.697	0.091
Pre-kWh * Nov	0.695	0.033	0.841	0.021	0.704	0.063
Pre-kWh * Dec	0.494	0.020	0.675	0.014	0.466	0.038
Part * Pre-kWh * Jan	-0.102	0.025	-0.119	0.016	-0.032	0.053
Part * Pre-kWh * Feb	-0.128	0.033	-0.104	0.022	-0.036	0.066
Part * Pre-kWh * Mar	-0.227	0.044	-0.120	0.028	0.057	0.086
Part * Pre-kWh * Apr	-0.305	0.053	-0.175	0.036	-0.113	0.110
Part * Pre-kWh * May	-0.184	0.063	-0.103	0.047	-0.173	0.159
Part * Pre-kWh * Jun	-0.405	0.054	-0.094	0.051	-0.098	0.195
Part * Pre-kWh * Jul	-0.250	0.058	-0.048	0.048	-0.119	0.213
Part * Pre-kWh * Aug	-0.183	0.054	-0.040	0.047	-0.384	0.132
Part * Pre-kWh * Sep	0.130	0.065	-0.024	0.047	-0.376	0.123
Part * Pre-kWh * Oct	0.071	0.056	-0.053	0.038	-0.152	0.108
Part * Pre-kWh * Nov	-0.112	0.039	-0.104	0.027	-0.179	0.075
Part * Pre-kWh * Dec	-0.091	0.021	-0.098	0.015	-0.042	0.041
Participants	**66**		**145**		**27**	
Sample Size	**1,774**		**4,098**		**698**	
Adjusted R-Square	**0.67**		**0.74**		**0.60**	
F-Statistic	**137**		**460**		**42**	

7 APPENDIX A: DHP CUSTOMER MAIL SURVEY INSTRUMENT

The Survey Begins Here

1. Our records show that you purchased a ductless heat pump system for your home at some point between December 2016 and January 2018 and that you received a rebate from your utility. Is that correct?
   - ☐ Yes
   - ☐ No ➔ **Thank you**, please return this survey in the attached envelope.

If you answered "Yes" to Question 1, the following questions will ask you about your experiences with the ductless heat pump. Your input will help us better understand how customers use ductless heat pumps in their homes and help improve household utility programs going forward. Unless otherwise indicated, please select one answer for each question. Please watch for responses that include "skip to" instructions.

If you complete the survey and mail it back to us, we will send you an additional $25 check to thank you for your time.

Background

2. As of January 1, 2019, was the ductless heat pump still installed in your home?
   - ☐ Yes
   - ☐ No

3. We'd like to know about your home and where the ductless heat pump was installed. Is the home in which the ductless heat pump was installed a primary residence, a vacation/second home, or a rental property?
   - ☐ Primary residence
   - ☐ Secondary residence/vacation home
   - ☐ Rental property

4. As of January 1, 2019, did you own the home in which the ductless heat pump was installed?
   - ☐ Yes
   - ☐ No

5. Do you use the ductless heat pump for heating? Please select "Yes" even if you only use it rarely.
   - ☐ Yes
   - ☐ No

6. Do you use the ductless heat pump for air conditioning? Please select "Yes" even if you only use it rarely.
   - ☐ Yes
   - ☐ No

7. How many indoor units ("heads") does your ductless heat pump system have (see example)?
   - ☐ 1
   - ☐ 2
   - ☐ 3
   - ☐ More than 3
   - ☐ Don't know

Your Decision to Purchase a Ductless Heat Pump

8. What was your role in the household's decision to purchase a ductless heat pump?
   - ☐ I was the primary decision maker
   - ☐ I decided with other family members
   - ☐ I was not involved in the decision (please skip to Question 17)

9. In your own words, what was your main reason for seeking out a new system?

10. When you first started thinking about buying a new ductless heat pump, were you ***initially*** looking for something that would primarily provide heat, air conditioning, or both?
    - ☐ Heating
    - ☐ Air conditioning
    - ☐ Both Heating and Air conditioning

11. Did you purchase a ductless heat pump to replace an old heating system?
    - ☐ Yes
    - ☐ No (skip to Question 13)

12. What were the reasons you wanted to replace your old heating system? (Select YES or NO for each)

YES	NO	Old system did not work; beyond repair
YES	NO	Old system needed repairs; wasn't functioning properly
YES	NO	Old system was not providing adequate comfort
YES	NO	Old system's energy costs were too expensive
YES	NO	Wanted to take advantage of utility rebate for new system
YES	NO	Part of a larger home remodel
YES	NO	Wanted to heat a new part of home
YES	NO	Old system was not safe or healthy
YES	NO	Other _____

13. Did you purchase a ductless heat pump to replace an old cooling system?
    - ☐ Yes
    - ☐ No (skip to Question 15)

14. What were the reasons you wanted to replace an old cooling system? (Select YES or NO for each)
    - YES NO Old system did not work; beyond repair
    - YES NO Old system needed repairs; wasn't functioning properly
    - YES NO Old system was not providing adequate comfort
    - YES NO Old system's energy costs were too expensive
    - YES NO Wanted to take advantage of utility rebate for new system
    - YES NO Part of a larger home remodel
    - YES NO Wanted to cool a new part of home
    - YES NO Old system was not safe or healthy
    - YES NO Other _____

15. How important were ***each*** of the following when choosing a new system

	Extremely important	Very important	Somewhat important	A little important	Not at all important	NA
Wanting to replace an old system	☐	☐	☐	☐	☐	☐
Increasing comfort during the winter	☐	☐	☐	☐	☐	☐
Increasing comfort during the summer	☐	☐	☐	☐	☐	☐
Adding heating to an existing space that previously did not have it	☐	☐	☐	☐	☐	☐
Adding cooling to an existing space that previously did not have it	☐	☐	☐	☐	☐	☐
Adding heating to a newly built space	☐	☐	☐	☐	☐	☐
Adding cooling to a newly built space	☐	☐	☐	☐	☐	☐
Wanting to save energy or reduce your energy bills	☐	☐	☐	☐	☐	☐

16. If you had not purchased a ductless heat pump, what would you likely have done instead? (Select YES or NO for each)
    - YES NO Continued to use my old system for heating
    - YES NO Continued to use my old system for cooling
    - YES NO Purchased a central / ducted furnace to heat the house
    - YES NO Purchased space heater(s) to heat selected rooms
    - YES NO Purchased a central / ducted heat pump to heat the house
    - YES NO Purchased a central / ducted heat pump to cool the house
    - YES NO Purchased window air conditioner(s) to cool selected rooms
    - YES NO Purchased a through-the-wall room air conditioner
    - YES NO Purchased a through-the-wall mini-split air conditioner

Ductless Heat Pump Customer Survey

Where in Your Home You Use Your Ductless Heat Pump

17. Which rooms in your home are served by the ductless heat pump? (Check all that apply)
    - ☐ Whole house
    - ☐ Kitchen
    - ☐ Dining room
    - ☐ Living room/family room/den
    - ☐ Bedrooms(s)
    - ☐ Bathroom(s)
    - ☐ Office
    - ☐ Entry/foyer/mudroom
    - ☐ Laundry room
    - ☐ Other _____

18. Has the amount of square footage that is **cooled** in your home increased since you installed the ductless heat pump?
    - ☐ Yes (Amount of increased cooling area = _____ square feet)
    - ☐ No
    - ☐ Don't know

19. Has the amount of square footage that is **heated** in your home increased since you installed the ductless heat pump?
    - ☐ Yes (Amount of increased heating area = _____ square feet)
    - ☐ No
    - ☐ Don't know

20. How do you control your ductless heat pump? (Check all that apply)
    - ☐ Remote control
    - ☐ Controls on unit
    - ☐ Wall-mounted programmable thermostat
    - ☐ Wall-mounted manual (non-programmable) thermostat
    - ☐ Other _____

21. If you continue to use your old heating system, how do you control your old system? (Check all that apply)
    - ☐ Remote control
    - ☐ Controls on unit
    - ☐ Wall-mounted programmable thermostat
    - ☐ Wall-mounted manual (non-programmable) thermostat
    - ☐ Other _____
    - ☐ Not applicable, I no longer use my old heating system

22. **Since installing the ductless heat pump,** how would you describe your comfort level on **cold days** compared to your comfort **prior** to having the ductless heat pump?
    - ☐ 1 – Much less comfortable since installing the ductless heat pump
    - ☐ 2 – Somewhat less comfortable since installing the ductless heat pump
    - ☐ 3 – About the same comfort level since installing the ductless heat pump
    - ☐ 4 – Somewhat more comfortable since installing the ductless heat pump
    - ☐ 5 – Much more comfortable since installing the ductless heat pump

23. **Since installing the ductless heat pump,** how would you describe your comfort level on **hot days** compared to your comfort **prior** to having the ductless heat pump?
    - ☐ 1 – Much less comfortable since installing the ductless heat pump
    - ☐ 2 – Somewhat less comfortable since installing the ductless heat pump
    - ☐ 3 – About the same comfort level since installing the ductless heat pump
    - ☐ 4 – Somewhat more comfortable since installing the ductless heat pump
    - ☐ 5 – Much more comfortable since installing the ductless heat pump

24. **Since installing the ductless heat pump**, which of the following statements apply to rooms heated and/or cooled by the ductless heat pump: (Select YES or NO)
    - YES NO I now heat rooms more frequently than before I installed my ductless heat pump.
    - YES NO I heat rooms at higher temperature than before I installed my ductless heat pump.
    - YES NO I air condition rooms more frequently than before I installed my ductless heat pump.
    - YES NO I air condition rooms at lower temperature than before I installed my ductless heat pump.

Heating Before and After you Installed your Ductless Heat Pump

25. Which of the following, if any, did you use to heat your home ***prior*** to installing the ductless heat pump? (Check all that apply)
    - ☐ I did not have any heating system (Skip to Question 34)
    - ☐ Electric furnace
    - ☐ Electric baseboard heating
    - ☐ Electric wall fan
    - ☐ Electric space heater
    - ☐ Electric heat pump
    - ☐ Gas furnace or boiler
    - ☐ Gas fireplace
    - ☐ Wood-burning stove
    - ☐ Wood-burning fireplace
    - ☐ Other _____

26. Prior to installing the ductless heat pump, on days when you needed to heat your home, how often did you use non-electric heat (e.g. gas furnace/boiler, gas fireplace, or wood stove/fireplace)?
    - ☐ Almost all of the time
    - ☐ Most of the time
    - ☐ About half of the time
    - ☐ Rarely
    - ☐ Almost never
    - ☐ I do not use non-electric heat

27. Please refer to your answers to Question 25. If you used more than one heating option in Question 25, which source did you use most frequently?

28. Do you use the ductless heat pump to heat the **exact same rooms of your house** as you did with your old heating system?
    - ☐ Yes
    - ☐ No (please explain) _____

29. Since you installed the ductless heat pump, have you **ever** used any of the following to heat your home? (Check all that apply)
    - ☐ Electric furnace
    - ☐ Electric baseboard heating
    - ☐ Electric wall fan
    - ☐ Electric Space heater
    - ☐ Electric heat pump
    - ☐ Gas furnace or boiler
    - ☐ Gas fireplace
    - ☐ Wood-burning stove
    - ☐ Wood-burning fireplace
    - ☐ Other _____

For the remainder of the survey, "old heating system" refers to the sources of heating you selected in Question 25

30. Which of the following best describes what you did with your old heating system after installing a ductless heat pump?
    - ☐ Stopped using the old heating system and removed it from my house (skip to Question 34)
    - ☐ Stopped using the old heating system but didn't remove it (skip to Question 34)
    - ☐ Continued to use other forms of heating in addition to my ductless heat pump (continue to Question 31)
    - ☐ Don't know (skip to Question 34)

31. When you are **heating** your home, how often do you use the old system in comparison to the ductless heat pump?
    - ☐ Significantly less than ductless heat pump (skip to Question 33)
    - ☐ Slightly less than ductless heat pump (skip to Question 33)
    - ☐ About the same as ductless heat pump (skip to Question 33)
    - ☐ Slightly more than ductless heat pump (continue to Question 32)
    - ☐ Significantly more than ductless heat pump (continue to Question 32)
    - ☐ I do not continue to use my old heating system (skip to Question 34)

32. If you use your old heating system more than your ductless heat pump, why do you typically use your old heating system more than your ductless heat pump?

33. How do you decide which heating system to use when you need to heat your home?

Cooling Before and After you Installed your Ductless Heat Pump

34. Which of the following, if any, did you use to air-condition (cool) your home prior to installing the ductless heat pump? (Check all that apply)
    - ☐ I did not have air conditioning (skip to Question 40)
    - ☐ Centrally ducted air conditioner
    - ☐ Room/window air conditioner
    - ☐ Electric heat pump
    - ☐ Other _____
    - ☐ Don't know (skip to Question 40)

35. Does the new ductless heat pump cool the **exact same rooms of your house** as your prior cooling system?
    - ☐ Yes
    - ☐ No (please explain) _____

36. What did you do with your old cooling system after installing the ductless heat pump?
    - ☐ Stopped using the old system and removed it from my house (skip to Question 40)
    - ☐ Stopped using the old system but didn't remove it (skip to Question 40)
    - ☐ Continued to use old cooling system in addition to my ductless heat pump (continue to Question 37)
    - ☐ Don't know (skip to Question 40)

37. When you are **cooling** your home, how often do you use the old cooling system in comparison to the ductless heat pump?
    - ☐ Significantly less than ductless heat pump (skip to Question 39)
    - ☐ Slightly less than ductless heat pump (skip to Question 39)
    - ☐ About the same as ductless heat pump (skip to Question 39)
    - ☐ Slightly more than ductless heat pump (continue to Question 38)
    - ☐ Significantly more than ductless heat pump (continue to Question 38)
    - ☐ I did not continue to use my old cooling system (skip to Question 40)

38. If you use your old cooling system more than your ductless heat pump, why do you typically use your old cooling system more often than your ductless heat pump?

39. How do you decide which air conditioning system to use when you need to cool your home?

Satisfaction with your Ductless Heat Pump

40. Overall, how satisfied are you with the quality of the **heating** provided by the ductless heat pump?
    - ☐ Extremely satisfied
    - ☐ Very satisfied
    - ☐ Somewhat satisfied
    - ☐ A little satisfied
    - ☐ Not at all satisfied
    - ☐ I do not use my ductless heat pump for heating

41. Overall, how satisfied are you with the quality of the **cooling** provided by the ductless heat pump?
    - ☐ Extremely satisfied
    - ☐ Very satisfied
    - ☐ Somewhat satisfied
    - ☐ A little satisfied
    - ☐ Not at all satisfied
    - ☐ I do not use my ductless heat pump for cooling

42. Since installing the ductless heat pump, how have your energy bills changed **during cooler times of the year**?
    - ☐ Much higher energy bill
    - ☐ Slightly higher energy bill
    - ☐ About the same
    - ☐ Slightly lower energy bill
    - ☐ Much lower energy bill

43. Since installing the ductless heat pump, how have your energy bills changed **during hotter times of the year**?
    - ☐ Much higher energy bill
    - ☐ Slightly higher energy bill
    - ☐ About the same
    - ☐ Slightly lower energy bill
    - ☐ Much lower energy bill

44. Since installing the ductless heat pump, have you noticed an improvement in the air quality in your home?
    - ☐ Yes
    - ☐ No

45. Since installing the ductless heat pump, which of the following have you noticed? (Select YES or NO for each)

YES	NO	An increase in overall comfort
YES	NO	An increase in safety compared to other heating systems you have used in the past or are currently using now

46. Have you noticed any other effects (positive or negative)?

Household Characteristics

47. In the 12 months immediately **after** you installed your ductless heat pump, how many people moved into your home?
    - ☐ 0 people moved in
    - ☐ 1-2 people moved in
    - ☐ 3 or more people moved in

48. In the 12 months immediately **after** you installed your ductless heat pump, how many people moved out of your home?
    - ☐ 0 people moved out
    - ☐ 1-2 people moved out
    - ☐ 3 or more people moved out

49. During the 12 months immediately **before and after** you installed your ductless heat pump, did you add square footage to your home that is heated and/or cooled (check all that apply)?
    - ☐ Yes, added square footage prior to installation of ductless heat pump
    - ☐ Yes, added square footage after installation of ductless heat pump
    - ☐ No, did not add square footage heated and/or cooled square footage

50. In the 12 months immediately **after** you installed your ductless heat pump, did you replace any old appliances with new appliances?
    - ☐ Yes (please list) _____
    - ☐ No

51. Which best describes the home in which you installed the ductless heat pump?
    - ☐ Single Family Detached
    - ☐ Single Family Attached
    - ☐ Small Multifamily (building contains 2-4 units)
    - ☐ Multifamily (building contains more than 4 units)
    - ☐ Manufactured or pre-built home
    - ☐ Other

52. Approximately what year was this home built?
    - ☐ Prior to 1920
    - ☐ 1920-1939
    - ☐ 1940-1959
    - ☐ 1960-1979
    - ☐ 1980-1999
    - ☐ 2001-2019

53. Approximately how long have you occupied this home?
    - ☐ Less than 3 years
    - ☐ 3 – 6 years
    - ☐ 7 – 10 years
    - ☐ 10 – 15 years
    - ☐ More than 15 years

54. Approximately how big is this home?
    - ☐ 0 – 999 Sq. ft.
    - ☐ 1000 – 1999 sq. ft.
    - ☐ 2000 – 2999 sq. ft.
    - ☐ 3000 – 3999 sq. ft.
    - ☐ 4000+ sq. ft.

55. Does the home have gas service?
- ☐ Yes; natural gas
- ☐ Yes; propane or other bottled gas
- ☐ No
- ☐ Don't know

56. Approximately what percentage of the windows in your home are double (or triple) pane?
- ☐ 0% - 24%
- ☐ 25% - 49%
- ☐ 50% - 74%
- ☐ 75% - 99%
- ☐ 100%. All windows are double (or triple) pane.
- ☐ Don't know

57. Which of the following does your home have?

	Yes	No	Not Sure	NA
Attic insulation	☐	☐	☐	☐
Floor insulation	☐	☐	☐	☐
Wall insulation	☐	☐	☐	☐
Door / window weather-stripping	☐	☐	☐	☐

58. Are solar panels installed at this home?
- ☐ Yes, installed prior to 2018
- ☐ Yes, installed in 2018
- ☐ Yes, installed in 2019 or later
- ☐ No

Thank you for completing the survey! Please put the completed survey into the included envelope. Once we receive your survey, we will send a check for $25 to person and address you list below.

What is the name that should appear on the check for $25?

Where should we send the $25 check?
- ☐ To the address listed to the right
- ☐ To the address listed below:

According to our records, your current address is:

This section can be used for any additional comments