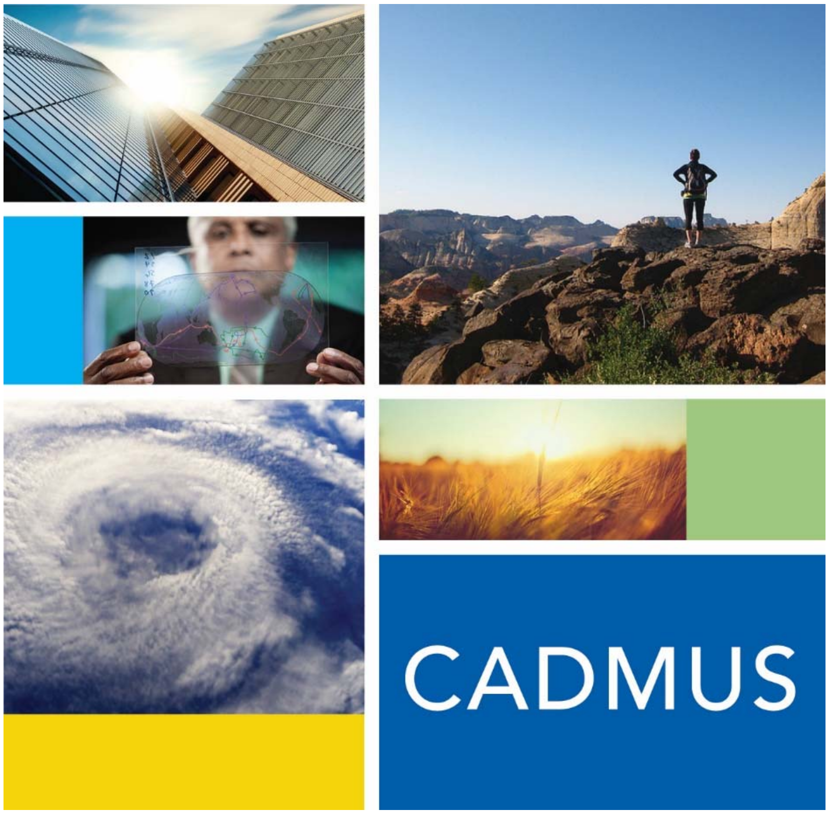

Comparison of Ductless and Ducted Heat Pump Retrofits in Manufactured Homes

January 5, 2018

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Table of Contents

CADMUS

Executive Summary

Energy Trust of Oregon considers ducted and ductless heat pump retrofits in manufactured homes to be a significant energy savings opportunity. In 2015 and 2016, Energy Trust ran a pilot to install ducted heat pumps in manufactured homes. In the fall of 2017, Cadmus conducted a billing analysis of these ducted heat pumps and found that they saved on average 3,269 kWh per year, or 21% of the pre-installation electricity use.

Following that study, Energy Trust commissioned Cadmus to conduct a similar billing analysis to evaluate the savings from ductless heat pumps in manufactured homes installed through its Existing Homes program in 2012–2016 and to compare the savings and costs between ductless and ducted heat pumps.

Cadmus' analysis of ductless heat pumps and ducted heat pumps in manufactured homes found that the two types of systems, on average, had very similar savings and installation costs despite differences in reported savings, as shown in Table 1. The differences between reported and evaluated savings resulted in realization rates that differ significantly —126% for ductless heat pumps and 75% for ducted heat pumps. Because ducted systems were installed in homes that previously had electric forced-air furnaces, we compared these against the subset of ductless heat pumps that had also been installed in homes with electric forced-air furnaces.

Table 1. Ductless and Ducted Heat Pump Average Savings and Cost Comparison

Heat Pump Type	Energy Savings					Installed Cost*		Savings per Dollar (kWh/$)
	Average kWh per unit	As a Percentage of Pre-NAC	n	Reported kWh per unit	Realization Rate	Average	n	
Ductless Heat Pumps**	3,324	22%	84	2,646	126%	$4,501	170	0.74
Ducted Heat Pumps	3,269	21%	78	4,367	75%	$4,511	103	0.72

*Installation costs include both the cost of labor and the costs of the equipment
** Installations in homes with electric forced-air furnaces

Cadmus reviewed Energy Trust's program data to analyze the cost profile of the ducted and ductless systems installed in manufactured homes. Installation costs for ductless heat pumps varied significantly; however, costs were not sensitive to a wide range of variables, including home size and age. One exception was the Portland Metro area, where ductless heat pump installation costs were higher than the rest of the state (likely due to a higher cost of living than elsewhere in Oregon). Installation costs for ducted heat pump systems installed through the pilot were clustered much more closely than ductless systems. This difference reflects the distinct designs of the two programs: the ducted heat pump pilot was designed with a tight cost structure, while the ductless heat pump incentive is applied to installation costs determined by the open market.

Cadmus also reviewed program data for ductless heat pumps to identify outliers and blank entries for key data fields. We requested original documents for 35 projects and received invoices and applications for 30 of these. Based on that documentation, we made two corrections to systems install cost, four corrections to home age, and seven corrections to system capacity.

Conclusions and Recommendations

Ducted and ductless heat pumps provide similar savings at comparable costs. The billing analysis for ducted and ductless heat pumps in manufactured homes showed almost identical savings on the basis of annual kWh and percentage of pre-installation usage for both system types. The annual savings for homes with electric forced-air furnaces were 3,324 kWh for ductless heat pumps and 3,269 kWh for ducted heat pumps. Despite, or perhaps due to the difference in program delivery, average costs and savings per dollar spent on system cost were also almost identical: $4,501 installed cost and 0.74 kWh per dollar for ductless heat pumps and $4,511 installed cost and 0.72 kWh per dollar for ducted heat pumps. Cadmus found greater variance in cost of the ductless heat pumps incentivized through the market-based program. Offering the ductless heat pump measure in conjunction with cost-controls, such as was done with the ducted heat pump pilot, should reduce the variance in cost and potentially lower the average cost.

- **Recommendation:** Offer incentives for both ducted and ductless heat pumps for manufactured homes. Work with the PMC to explore whether the cost of a ductless heat pump retrofit will respond to the same strategies used in the ducted heat pump pilot.

Although ducted and ductless heat pump savings are very similar, the realization rates for the two systems differ. The billing analysis of the two system types showed a realization rate of 126% for ductless heat pumps and 75% for ducted heat pumps in manufactured homes. This major difference suggests that Energy Trust underestimated the savings for ductless heat pumps and overestimated the savings of ducted heat pumps in manufactured homes.

- **Recommendation:** Revise *ex ante* savings estimates for ductless and ducted heat pumps for manufactured homes to more closely reflect evaluated savings.

Program design appears to significantly affect individual installation costs of ductless and ducted heat pumps. There was higher variance in installation costs for ductless heat pumps than for ducted heat pumps, despite the similarities in technology and housing stock. This variance is likely explained, in part, by the different program designs. The ducted heat pump pilot was delivered by four vetted contractors who were paid a fixed rate for the installation, whereas ductless heat pumps were installed by many contractors in a market-based program design. Although the average installation costs of these systems were similar, customers installing a ductless heat pump had much more uncertainty in the price they would pay. Such price inconsistency could affect uptake of this measure.

- **Recommendation:** If Energy Trust chooses to move forward in promoting ductless and ducted heat pumps in manufactured homes, it should consider the approach of its ducted heat pump pilot for both technologies. With more consistent pricing, and potentially lower retrofit costs, this design is likely to drive higher measure uptake than the market-based design currently used for ductless heat pumps.

Ductless heat pump program data contained some errors and missing information. Cadmus reviewed the program data for ductless heat pumps and selected a sample of projects that appeared to be outliers and in need of further investigation. We compared the program data for these projects against their original project documentation and found errors that indicate an opportunity for Energy Trust to improve its data entry process. Cadmus also found fields in the program data that were frequently missing information, such as the HSPF and SEER.

- **Recommendation:** Conduct quality review checks of the program data against project documents to improve the accuracy and completeness of the data. Consider prioritizing the review of project files with values that appear to be missing or outliers.

MEMO

Date: April 5, 2018
To: Board of Directors
From: Marshall Johnson, Residential Senior Program Manager
Dan Rubado, Evaluation Project Manager
Subject: Staff Response to the Comparison of Ductless and Ducted Heat Pump Retrofits in Manufactured Homes Report

After the completion of its successful pilot of ducted heat pump retrofits in manufactured homes with electric forced air furnaces, Energy Trust commissioned Cadmus to analyze ductless heat pumps (DHPs) supported by its Existing Homes program and compare the savings and costs to the heat pump pilot. This goal of the study was to help Energy Trust determine the most cost-effective electric heating system for manufactured homeowners and decide which technology to promote in this market. The study found that DHPs provided comparable savings to ducted heat pumps at a very similar cost. These findings led Energy Trust's Residential program to pursue a strategy to promote both technologies in manufactured homes. In addition, the DHP savings estimates from the study were significantly higher than Energy Trust's deemed savings. Thus, Energy Trust will adjust its deemed savings for DHPs in manufactured homes based on this study.

Given that the DHPs were installed through the open market, while the ducted heat pump pilot used a competitively selected pool of contractors and price controls to constrain costs, there is probably room to significantly reduce the installed costs of DHPs in manufactured homes. If the Residential program can bring down the cost of DHPs, using a similar strategy to the ducted heat pump pilot, DHPs will be the more cost-effective technology. The Residential program is currently planning a new campaign to promote DHPs and ducted heat pumps using the principles tested in the ducted heat pump pilot. This effort should drive down installation costs for both technologies, improving cost-effectiveness and driving higher uptake in the market. If successful, this strategy has the potential to reach a large number of manufactured homes across the state and achieve substantial energy savings.

Introduction

Given the potentially high energy savings that can be achieved with heat pump retrofits in electric-heated manufactured homes, Energy Trust of Oregon is interested in understanding the savings that can be achieved with two types of heat pump systems—ducted and ductless—and which of these technologies is more likely to be cost-effective. Energy Trust commissioned Cadmus to analyze and compare the installation costs and energy savings of these two measures.

Since 2008, Energy Trust has offered incentives for ductless heat pump system retrofits in electric-heated, single-family homes. Energy Trust currently provides incentives for nearly 2,000 single-family ductless heat pump retrofit projects in Oregon each year. This technology has been slower to catch on in manufactured homes, however, probably because of financial barriers. Nevertheless, the high prevalence of electric resistance heat and lower insulation levels in manufactured homes means there is a great opportunity for energy savings in this market.

Energy Trust provided incentives for just 16 and 18 ductless heat pumps in manufactured homes in 2012 and 2013, respectively. To accelerate the adoption of the technology in this market, Energy Trust's Existing Homes program, implemented by program management contractor (PMC) CLEAResult, offered a bonus incentive in 2014 and 2015. The bonus boosted ductless heat pump installations to 82 in 2015 and the increase was sustained, to some degree, even after the bonus ended.

In 2016, Energy Trust decided to test whether central, ducted heat pump retrofits could be affordably installed in manufactured homes with electric forced air furnaces as an alternative to a ductless heat pump. Energy Trust launched a pilot through its Existing Homes program to offer low-cost, flat-fee, ducted heat pump retrofits to owners of manufactured homes. The retrofits were installed by four vetted trade ally contractors, selected through a competitive process, who were paid a fixed rate per project. Cadmus' evaluation of the pilot showed that this strategy successfully drove demand for ducted heat pump retrofits in this market.[1] Cadmus also conducted a billing analysis to analyze the energy savings of these ducted heat pumps. The energy savings were 3,269 kWh per year, on average, or 21% of pre-installation electricity usage.

In the wake of this successful pilot, Energy Trust decided to explore which heat pump system – ducted or ductless – would be a more cost-effective technology in reducing electric loads in manufactured homes with electric forced air furnaces. Given the measures were offered under different program designs (limited contractor pilot vs. market-based program), the comparison should be interpreted with this context in mind as the pilot may have resulted in lowering the cost of ducted heat pump retrofits.

[1] Cadmus delivered the "Existing Manufactured Homes Heat Pump Evaluation Final Report" to the Energy Trust of Oregon on November 7, 2017.

Goals and Research Questions

The goal of this study was to analyze the electricity savings and cost of ductless heat pump retrofits in manufactured homes in Oregon that were heated by an electric forced air furnace or zonal electric heaters. The secondary goal was to compare the energy savings and installation costs between ductless and ducted heat pumps in similar homes with electric forced air furnaces.

The primary research questions for this study were these:

- What are the typical electricity savings of ductless heat pump systems installed in manufactured homes with either an electric forced-air furnace or zonal electric heat?
- Are there important differences in electric savings by system characteristics, region, housing characteristics, or other factors?
- What is the typical installation cost of ductless heat pump systems installed in homes with either an electric forced air furnace or zonal electric heat?
- Are there important differences in installation cost by system characteristics, region, housing characteristics, or other factors?
- How do electric savings and installation costs compare between the two system types in homes with electric forced air furnaces?
- Which type of heating system retrofit provides the most cost-effective energy savings in manufactured homes?

Methodology

In October 2017, Cadmus conducted a billing analysis of manufactured homes that had participated in the ductless heat pump incentive offering, analyzed program data, and compared the results from this study to the results from the 2015/2016 manufactured homes heat pump pilot.

Utility Billing Analysis

The billing analysis assessed the energy savings associated with the ductless heat pumps installed in manufactured homes from 2012 to 2016. Cadmus used a variable degree-day, household-level regression modeling method, similar to the Princeton Scorekeeping Method (PRISM).[2] We determined the final adjusted gross savings as the difference of the pre-/post-installation change in consumption of the ductless heat pump participants and a matched comparison group. We used the comparison group to account for exogenous factors that could have affected energy consumption during the 2011–2017 timeframe.

Cadmus created the final billing analysis dataset from the following:

- ***Ductless heat pump participant characteristics,*** collected and provided by Energy Trust (including installation dates, square footage, heat sources, baseline equipment, and expected savings for the entire ductless heat pump participant population).
- ***Comparison group customer characteristics,*** selected by Cadmus from customers who received an Energy Trust incentive for a minor measure, free duct-sealing service, or Energy Saver Kit for manufactured homes from 2008 through 2016. The initial comparison group comprised nearly 8,000 electric customers in Oregon. Of these, approximately 4,500 customers were located in the same cities as customers that received rebates from Energy Trust for installing ductless heat pumps in manufactured homes and were therefore considered for the final matched sample selection. We matched nonparticipant consumption to participant consumption at the quartile and heating zone levels. To ensure a more accurate representation of the nonparticipant change in usage, we selected four times more nonparticipants than participants in the heating zone and quartile matching process.
- ***Utility billing data***, provided by Energy Trust, including participant and nonparticipant billing data from 2011 through August 2017. The billing data also included customer information and incidental program participation information for other measures supported by Energy Trust. The final billing analysis sample consisted of 95 participants and 380 comparison homes.
- ***Oregon weather data***, including daily average temperatures from January 2011 to August 2017 for 22 weather stations, corresponding with Energy Trust participant locations. Cadmus also obtained typical meteorological year 3 (TMY3) normal weather values for these stations from

[2] Fels, M. "PRISM: An Introduction." *Energy and Buildings 9*, #1-2, pp. 5-18. 1986. Available online: www.marean.mycpanel.princeton.edu/~marean/images/prism_intro.pdf

the National Oceanic and Atmospheric Administration (NOAA). We used TMY3 data to calculate energy use under normal weather conditions.

Cadmus matched participant data with utility billing data, mapping daily heating degree-days (HDDs) and cooling degree-days (CDDs) to respective monthly billing periods using zip codes. For participants, we defined the billing analysis pre-period as the 12 months before the measure installation date and the post-period as the 12 months following the measure installation date (the month of installation was removed from the analysis). Participant installations occurred between 2012 and 2016.

For nonparticipants, we used the average participant installation dates by county as the nonparticipant pre/post cutoff dates.[3] These more detailed county-level averages assured that the nonparticipant pre/post periods more closely represented the participant pre-periods, rather than just using one overall average participant installation date.

Data Screening

Cadmus developed the final analysis samples by cleaning the data and selecting treatment and comparison group accounts that met the following criteria.

- Nonparticipants in the same cities as the participants
- A minimum of 300 days in each of the pre- and post-periods (i.e., before the earliest installation and after the latest reported installation)
- A consumption change of less than 70% of pre-pilot usage in either direction, removing large outlier homes with non-program related changes
- The same occupant was present throughout the pre- and post-periods
- No installation of other Energy Trust measures saving more than 10% of ductless heat pump savings in the analysis period by participants and nonparticipants[4]

Cadmus also screened individual monthly billing data to check for vacancies, outliers, and seasonal usage changes, and removed participants and non-participants from the sample if they would introduce a bias to the analysis. Table 2 shows participant and nonparticipant screening criteria and attrition used for the billing analysis.

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[3] The nonparticipant increases in usage by average participant installation year ranged between 89 kWh to 131 kWh. Thus, the nonparticipant change is stable by the average cutoff year selected.

[4] The evaluated ductless heat pump measures accounted for 99% of the savings claimed by Energy Trust at the participant sites. Cadmus removed participants who installed other Energy Trust measures that accounted for over 10% of the ductless heat pump *ex ante* savings in the analysis period. Because ductless heat pumps had a very large influence on electricity usage, the impact of other program measures was expected to be very minimal, at most 1%.

Table 2. Screen for Inclusion in Billing Analysis

Screen	Nonparticipant Attrition (n)	Participant Attrition (n)	Remaining Nonparticipant (n)	Remaining Participant (n)
Original DHP and Nonparticipant Population	-	-	7,819	197
Matched Billing Data Sample (keep only nonparticipant residential accounts in participant cities)	3,368	23	4,451	174
Less than 300 Days in Pre- or Post-Period	426	18	4,025	156
Changed Consumption by More Than 70% from Pre- to Post-Period	137	-	3,888	156
Remove Customers who Moved from Pre- to Post-Period	776	34*	3,112	122
Nonparticipants or Participants who Installed Measures in Analysis Period	357	19	2,755	103
Billing Data Outliers, Vacancies, and Seasonal Usage	389	8	2,366	95
Nonparticipant Heating Zone Quartile Matching	1,986	-	380	95
Final Sample			380	95

***** Cadmus also estimated savings including 23 of the 34 customers who moved and who passed all the screens. Eleven customers failed other screens and would have been dropped anyway. We found that the customers who moved had an unusually high realization rate of 152% and a low relative precision of +-39%. These customers were excluded because their savings were unusually high and the consumption behavior of the occupants were significantly different.

Nonparticipant and Participant Sample Distribution by Energy Trust Region and Pre-Retrofit Usage

Figure 1 shows the participant Energy Trust regional distribution and compares this against final paired nonparticipant groups. Although Cadmus created the nonparticipant group by matching the heating zone[5] and pre-period usage quartile, the figure shows good matching at the regional level as well.

[5] Nonparticipants were drawn from the same cities as the participants, although the matching to participants was not done at the city level.

Figure 1. Regional Distribution of Participant and Matched Nonparticipant Homes

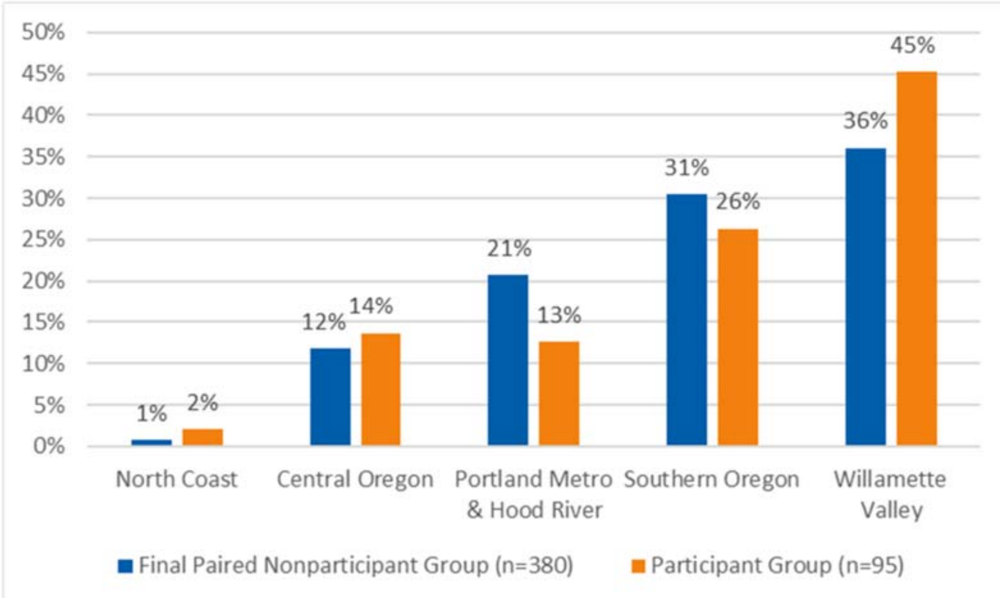
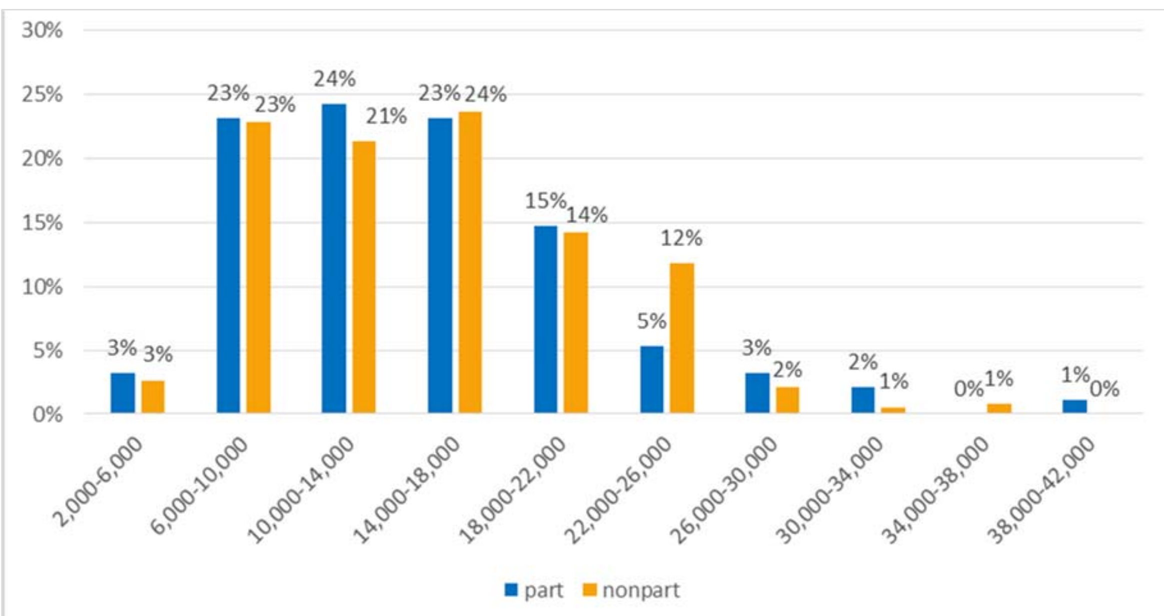


Figure 2 shows the distribution of pre-retrofit kWh usage for the participant and matched nonparticipant groups, which is similar across most of the usage bins. The average pre-period usage was nearly identical between participants and nonparticipants, 14,860 kWh and 14,858 kWh, respectively.

Figure 2. Pre-Retrofit Usage (kWh) for Participants and Nonparticipants



PRISM Models

Cadmus estimated site-level heating and cooling PRISM models for various heating and cooling base temperatures in both the pre- and post-period for each customer using the following specification:

$$ADC_{it} = \alpha_i + \beta_1 AVGHDD_{it} + \beta_2 AVGCDD_{it} + \varepsilon_{it}$$

Where for each customer '*i*' and monthly billing period '*t*':

ADC_{it}	=	Average daily kWh consumption
α_i	=	The participant intercept, representing the average daily kWh baseload
β_1	=	The model space heating slope (used only in the heating only, heating + cooling model)—average change in daily usage resulting from an increase of one daily heating degree-day (HDD)
$AVGHDD_{it}$	=	The base 45–65°F average daily HDDs for the specific location (used only in the heating only, heating + cooling model)
β_2	=	The model space cooling slope (used only in the cooling only, heating + cooling model)—average change in daily usage resulting from an increase of one daily cooling degree-day (CDD)
$AVGCDD_{it}$	=	The base 65–85°F average daily CDDs for the specific location (used only in the cooling only, heating + cooling model)
ε_{it}	=	The error term

Cadmus used a grid-search PRISM method that allowed the heating degree base temperatures to vary from 45 to 65 and the cooling base temperatures to vary from 65 to 85. If a heating and cooling model yielded incorrect negative coefficient signs for all models, we also estimated heating-only and cooling-only model specifications. We selected as the final model the one with positive coefficient signs for the heating and/or cooling slopes and the highest r-square. Using the above model, we computed weather-normalized annual kWh consumption for each site in both the pre- and post-pilot periods as:

$$NAC_i = \alpha_i * 365 + \beta_1 LRHDD_{it} + \beta_2 LRCDD_{it}$$

Where, for each customer '*i*' and for the annual pre- and post- Pilot time periods '*t*':

NAC_i	=	Normalized annual consumption (kWh)
$\alpha_i * 365$	=	Annual baseload kWh usage (non-weather sensitive)
$LRHDD_{it}$	=	Annual, long-term heating degree-days of a normal weather year from NOAA TMY3 data, based on home location
$\beta_1 LRHDD_{it}$	=	Weather-normalized, annual heating usage (kWh) (i.e., heat-NAC)

$LRCDD_{it}$ = Annual, long-term cooling degree-days of a normal weather year from NOAA TMY3 data, based on home location

$\beta_2 LRCDD_{it}$ = Weather-normalized, annual cooling usage (i.e., cool-NAC)

Savings Calculation

Cadmus derived adjusted gross energy savings using the following equation to adjust the evaluated participant savings based on changes in the comparison group energy use. This adjustment accounted for exogenous factors that occurred outside the effect of interest (all terms in the equation are averages). Similar to a straight difference-in-difference approach, this method accounted for potential discrepancies between each group's pre-treatment weather-normalized annual usage.

$$Adj.\, Gross\ Savings = (Pre\ Usage_{Treat.})\left(\frac{Change\ In\ Usage_{Treat.}}{Pre\ Usage_{Treat.}} - \frac{Change\ In\ Usage_{Comp.}}{Pre\ Usage_{Comp.}}\right)$$

Subgroup Analysis

Wherever an analysis subset variable was available for both participant and nonparticipant groups, Cadmus calculated the adjusted gross savings by comparing the participant subgroup with the same nonparticipant subgroup. However, we note that we did not match the nonparticipant group by pre-period usage to the participant group at the subgroup level. As a result, the pre-period nonparticipant usage may not match the participant usage within each subgroup. In addition, the weighted savings of subgroups may not match the overall results. If a variable was available only for participants, only the overall nonparticipant group change in usage was applied to obtain the adjusted gross savings.

Characteristics, System Costs, and Comparison of Heat Pump System Types

Cadmus reviewed Energy Trust's program data to analyze system characteristics and costs for ductless heat pumps. We first screened the data for outliers that could indicate errors in data entry and for blank fields for key variables. We then gave Energy Trust a targeted list of 35 projects and asked to review original project documents such as customer applications and contractor invoices. Energy Trust provided incentive application forms and invoices for 30 projects.

We reviewed the original project documents for a total of 140 items, or data fields, including system install cost, home age, home size, and ductless heat pump capacity. After correcting a number of errors in the program data, Cadmus analyzed the data to identify any trends in ductless heat pump system costs and characteristics. We conducted cross-tab analysis for a range of variables, including installation cost, number of indoor heads, installation year, existing heating system type (baseboard or electric furnace), ductless heat pump brand, participant region, home size, system efficiency and capacity, and home age.

We also compared the installation costs and energy savings of both ductless and ducted heat pump systems, drawing on results from the ducted heat pump analysis, by normalizing both groups' savings by system capacity, and including only the systems that replaced electric furnaces.

Utility Billing Analysis Results

This section presents the evaluated savings for ductless heat pump installations in absolute and percentage terms. Cadmus also calculates the realization rate as the evaluated savings divided by the Energy Trust's reported savings.[6]

Energy Savings – All Ductless Heat Pumps

Ductless heat pump participants achieved a 22% reduction in overall electric usage, an average of 3,294 kWh per year, as illustrated in Table 3. With reported savings averaging 2,711 kWh, this translates to a 122% realization rate. This table and all subsequent tables that show savings results include adjusted gross savings, which Cadmus calculated based on the difference in percentage change between participant and comparison homes. Additionally, we report savings as a percentage of pre-installation normalized annual consumption (Pre-NAC), which is a helpful metric for comparing and assessing the magnitude of measure impacts.

Table 3. Overall Ductless Heat Pump Energy Savings

Group	n	Pre-NAC (kWh)	Average Savings (kWh)		Realization Rate	Relative Precision at 90% Confidence	Savings as % of Pre-NAC	
			Evaluated	Reported			Evaluated	Reported
Comparison	380	14,858	-103	N/A	N/A	±193%	-1%	N/A
Participant	95	14,860	3,192	2,711	118%	±19%	21%	18%
Adj. Gross Savings	**95**	**14,860**	**3,294**	**2,711**	**122%**	**±19%**	**22%**	**18%**

Table 4 summarizes the changes in base load and weather-sensitive (heating + cooling) energy consumption from the pre- to post-installation periods. The results show that participants decreased their base loads by 438 kWh and their weather sensitive usage by 2,845 kWh. PRISM models, however, do not always accurately disaggregate the base, heating, and cooling loads.

Table 4. Overall Ductless Heat Pump Savings (Weather Sensitive and Base Load)

Group	n	Pre-Base Load Usage (kWh)	Base Load Change	Base Load Change as % of Pre-Base Load Use	Pre-Weather Sensitive Usage (kWh)	Change in Weather Sensitive Use	Change in Weather Sensitive Use as % of Pre-Weather Sensitive Use	Relative Precision Weather Sensitive Savings at 90%
Comparison	380	7,449	-399	-5%	7,409	296	4%	±34%
Participant	95	7,336	45	1%	7,524	3,146	42%	±14%
Adj. Gross Savings	**95**	**7,336**	**438**	**6%**	**7,524**	**2,845**	**38%**	**±13%**

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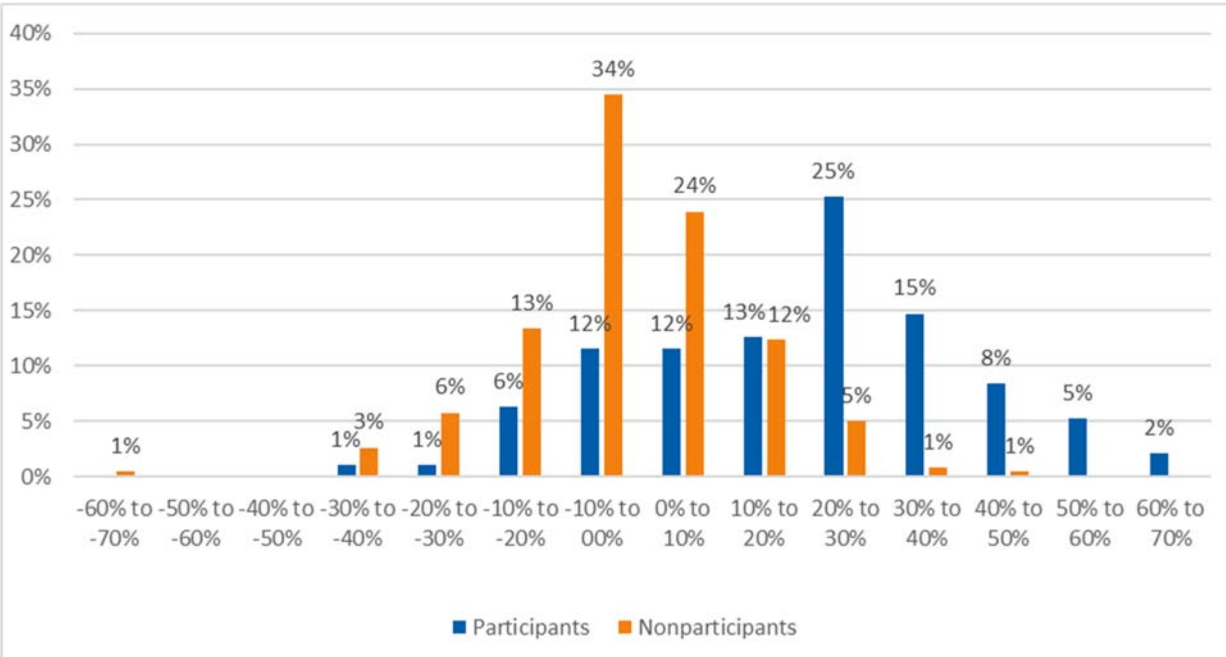
[6] Reported savings are obtained from the program data field called "working_kwh"

Figure 3 shows the distribution of savings for participants and nonparticipants. Nonparticipants increased their usage, on average, leading to a positive adjustment to participants' average savings.

Figure 3. Percentage Savings Distribution



Energy Savings by Existing Heating System

Cadmus also analyzed savings for participants based on the kind of electric heating equipment already in the home at the time participants had the ductless heat pumps installed. As shown in Table 5, the average savings and realization rates for participants with electric furnaces were similar to those of all participants.

Table 5. Participant Savings by Existing Heating System

Group	n	Pre-NAC	Average Savings (kWh)		Realization Rate	Relative Precision at 90% Confidence	Savings as % of Pre-NAC	
			Evaluated	Reported			Evaluated	Reported
Homes with Electric Furnaces								
Comparison	336	14,817	-207	N/A	N/A	±102%	-1%	N/A
Participant	84	14,815	3,117	2,646	118%	±21%	21%	18%
Adj. Gross Savings	**84**	**14,815**	**3,324**	**2,646**	**126%**	**±21%**	**22%**	**18%**
Homes with Zonal Electric Heat (Participant only)								
Comparison	380	14,858	-103	N/A	N/A	±193%	-1%	N/A
Participant	11	15,203	3,762	3,205	117%	±41%	**25%**	21%
Adj. Gross Savings	**11**	**15,203**	**3,867**	**3,205**	**121%**	**±40%**	**25%**	**21%**

Although savings were slightly higher for participants with zonal (baseboard) electric heating systems, the relative precision of these estimates was ±40%, significantly worse than for all participants. In this analysis, Cadmus selected a separate nonparticipant group with electric furnaces that was matched only to the group of participants with electric furnaces, which had an increase in usage of 207 kWh (compared to the increase of 103 kWh in the overall comparison group in Table 3). The difference between nonparticipant groups is not statistically significant. There was insufficient sample to obtain a matched nonparticipant group for zonal heating, so Cadmus used the comparison group from the overall analysis.

Among ductless heat pump retrofits in homes with electric forced-air furnaces, 71 installations had a single indoor unit and 13 installations had two indoor units. The adjusted gross savings by number of heads are shown in Table 6.

Table 6. Adjusted Gross Savings by Number of Heads (Forced-Air Furnace Replacement Only)

Number of Heads	n	Pre-NAC	Average Savings (kWh)		Realization Rate	Relative Precision at 90%	Savings as % of Pre-NAC	
			Evaluated	Reported			Evaluated	Reported
1	71	14,403	3,085	2,630	117%	10%	21%	18%
2	13	17,063	2,990	2,738	109%	25%	18%	16%

Energy Savings – Savings by Heating Zone

The following tables summarize savings by heating zone.[7] Ductless heat pump participants were either in heating zone 1 or in heating zone 2. Table 7 shows that participants in heating zone 1 achieved a 24% reduction in electric usage, saving an average of 3,389 kWh per year.

Table 7. Savings by Heating Zone

Group	n	Pre-NAC	Average Savings (kWh)		Realization Rate	Relative Precision at 90% Confidence	Savings as % of Pre-NAC	
			Evaluated	Reported			Evaluated	Reported
Heating Zone 1								
Comparison	308	14,342	96	N/A	N/A	±229%	1%	N/A
Participant	77	14,342	3,485	2,736	127%	±20%	24%	19%
Adj. Gross Savings	**77**	**14,342**	**3,389**	**2,736**	**124%**	**±22%**	**24%**	**19%**
Heating Zone 2								
Comparison	72	17,067	-954	N/A	N/A	±43%	-6%	N/A
Participant	18	17,077	1,936	2,607	74%	±48%	11%	15%
Adj. Gross Savings	**18**	**17,077**	**2,890**	**2,607**	**111%**	**±35%**	**17%**	**15%**

With reported savings of 2,736 kWh, this translates to a 124% realization rate. Participants in heating zone 2 achieved a 17% reduction in electric usage, saving an average of 2,890 kWh per year. With

7 Heating zone 1 has fewer HDDs than Oregon's other two heating zones and is where most of the population of Oregon lives. The list of heating zone by county is provided in Appendix B.

reported savings of 2,607 kWh, this translates to a 111% realization rate. The savings, realization rate, and percent savings are not significantly different between zones 1 and 2 at the 90% confidence level.

Energy Savings – Savings by Pre-Usage Quartile

Table 8 shows savings by pre-usage quartiles. Participants achieved 17% to 25% reductions in electric usage depending on the quartile. Savings by quartile increased from 1,368 kWh in quartile 1 to 5,064 kWh in quartile 4. With reported savings ranging from 2,827 kWh to 2,619 kWh, the lowest quartile achieved a 48% realization rate while the highest quartile achieved a 193% realization rate. In the lowest quartile, the average reported savings of 2,827 kWh is 34% of the entire pre-period usage; as such, the reported savings appear to be overstated. Although the difference between quartiles 1 and 4 for kWh savings and realization rate appear substantial, the actual percent savings are not statistically different.

Table 8. Savings by Pre-Usage Quartile

Group	Pre-Usage Quartile	n	Pre-NAC	Average Savings (kWh)		Realization Rate	Relative Precision at 90% Confidence	Savings as % of Pre-NAC	
				Evaluated	Reported			Evaluated	Reported
Comparison	1	100	8,263	-480	N/A	N/A	±43%	-6%	N/A
	2	92	11,789	-352	N/A	N/A	±83%	-3%	N/A
	3	92	16,209	-169	N/A	N/A	±202%	-1%	N/A
	4	96	23,374	593	N/A	N/A	±103%	3%	N/A
Participant	1	25	8,260	889	2,827	31%	±66%	11%	34%
	2	23	11,789	2,591	2,691	96%	±34%	22%	23%
	3	23	16,223	3,724	2,701	138%	±26%	23%	17%
	4	24	23,371	5,657	2,619	216%	±28%	24%	11%
Adj. Gross Savings	**1**	**25**	**8,260**	**1,368**	**2,827**	**48%**	**±45%**	**17%**	**34%**
	2	**23**	**11,789**	**2,943**	**2,691**	**109%**	**±32%**	**25%**	**23%**
	3	**23**	**16,223**	**3,893**	**2,701**	**144%**	**±26%**	**24%**	**17%**
	4	**24**	**23,371**	**5,064**	**2,619**	**193%**	**±34%**	**22%**	**11%**

Cadmus conducted additional analysis for various subgroups, including analysis by utility service territory, housing vintage, and home size. The results from this additional analysis can be found in Appendix A.

Characteristics, System Costs, and Comparison with Ducted Heat Pumps

After reviewing Energy Trust's program data, Cadmus made two corrections to systems install cost, four corrections to home age, and seven corrections to system capacity. We were unable to verify data for 23 items in the participant dataset, because these items were not included in the original documents. The results of this data cleaning exercise are not indicative of the overall quality of the data, since we requested documents to verify outliers and missing values, and not based on a random sample.

Using the updated ductless heat pump dataset, Cadmus conducted cross-tab analysis for a range of variables, including installation cost, number of indoor heads, installation year, existing heating system type (baseboard or electric furnace), manufacturer, participant region, home size, system efficiency and capacity, and home age.

We also compared the installation costs and energy savings of both ductless and ducted heat pump systems, drawing on results from the ducted heat pump pilot impact evaluation.

Ductless Heat Pump System Characteristics

Cadmus analyzed ductless heat pump project characteristics, such as home age, home size, type of existing heating equipment, number of installations over time, system manufacturer, system efficiency level, and where in the home equipment was installed. Table 9 shows the majority of units were single indoor unit installations in slightly smaller and older homes than the installations with two indoor units.

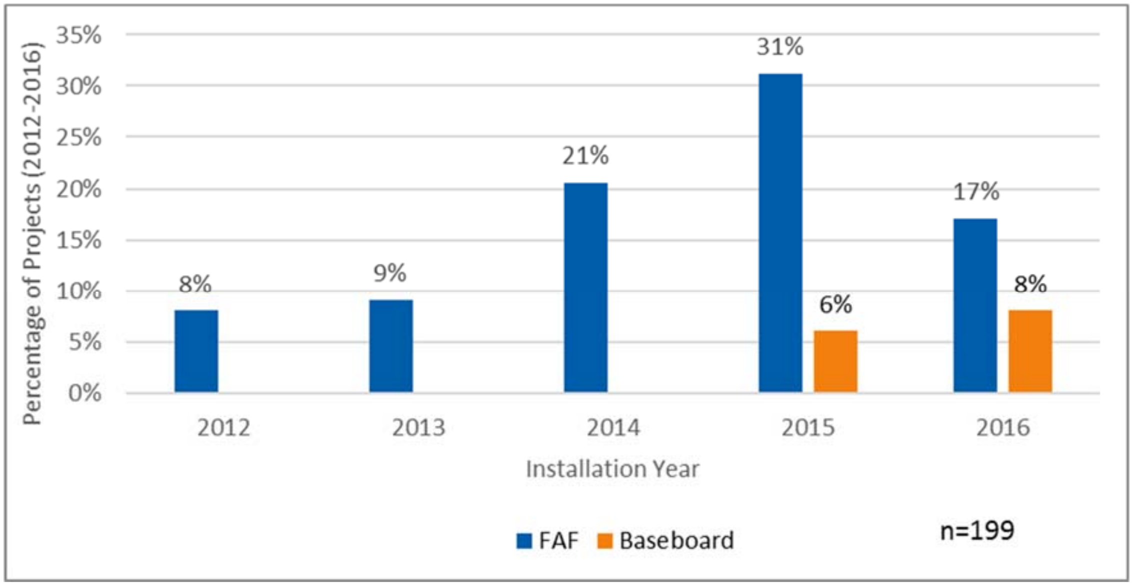
Table 9. Summary of Ductless Heat Pump System Characteristics

Number of Indoor Units*	Average Cost ($)	Average Capacity (BTU)	Average SEER	Average HSPF	Average Home Size (Square footage)	Average Home Age (years)	Percent of systems replacing furnaces
All (n=199)	$ 4,582	19,691	20.0	11.0	1,195	33.5	85.9%
1 (n=148)	$ 4,256	18,371	20.4	11.1	1,179	33.8	85.8%
2 (n=30)	$6,102	25,935	17.5	10.7	1,234	31.0	80.0%

*n for variables will vary depending on the data that was available for each. For example, the program data only had SEER for 50 installations, HSPF for 94 installations, and capacity for 183 installations out of a total of 199 retrofits.

As shown in Figure 4, most participants installed ductless heat pump systems in 2015, and a large majority of homes originally had electric furnaces, whereas the others had zonal heat (baseboard) heat.

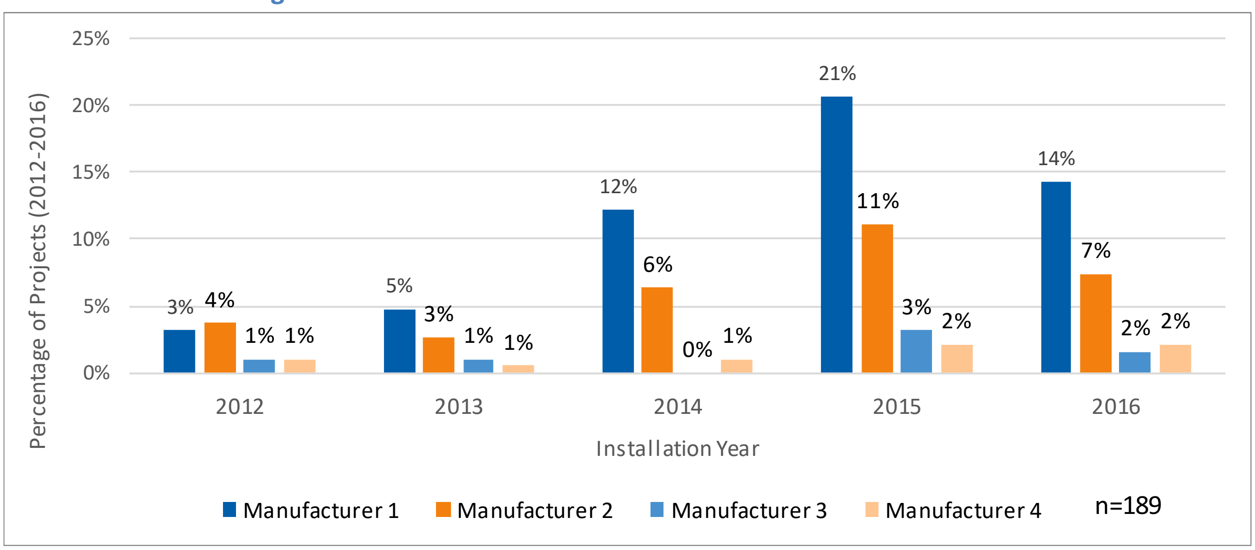
Figure 4. Installation Year of Ductless Heat Pump and Existing Heating Equipment



FAF = forced air furnace

Figure 5 shows that one manufacturer has been the most popular since 2013, accounting for 55% of Energy Trust-incentivized installations from 2012 to 2016.

Figure 5. DHP Installation Manufacturers and Installation Year



As shown in Figure 6, most single-head ductless heat pumps had a capacity of between 15,000 BTU and 19,999 BTU (the average was 18,371 BTU), whereas two-head systems tended to be higher capacity systems, as expected (the average was 25,935 BTU).

Figure 6. System Capacity for Single-Head and Two-Head Ductless Heat Pumps

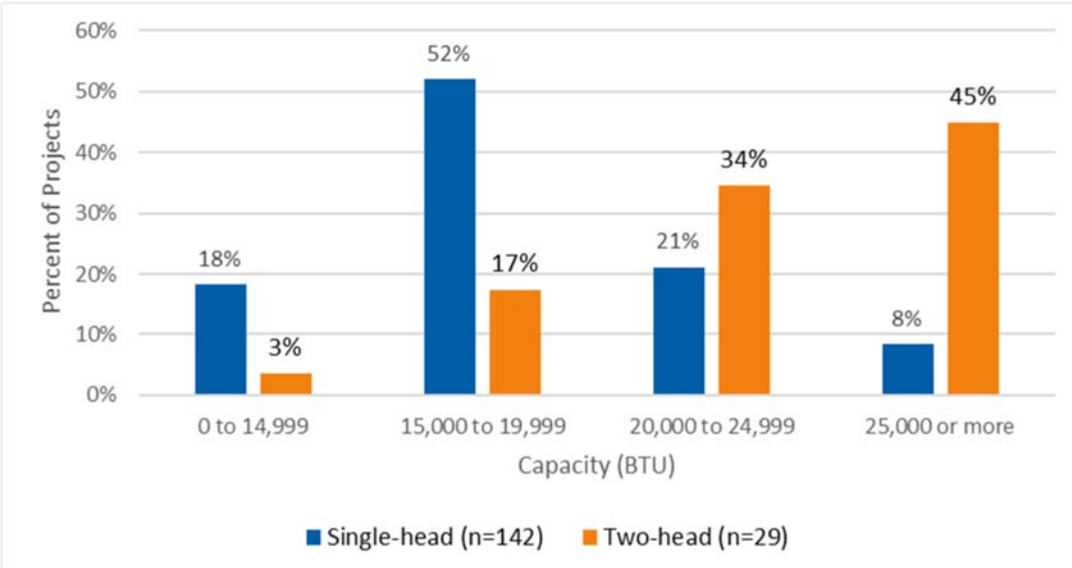
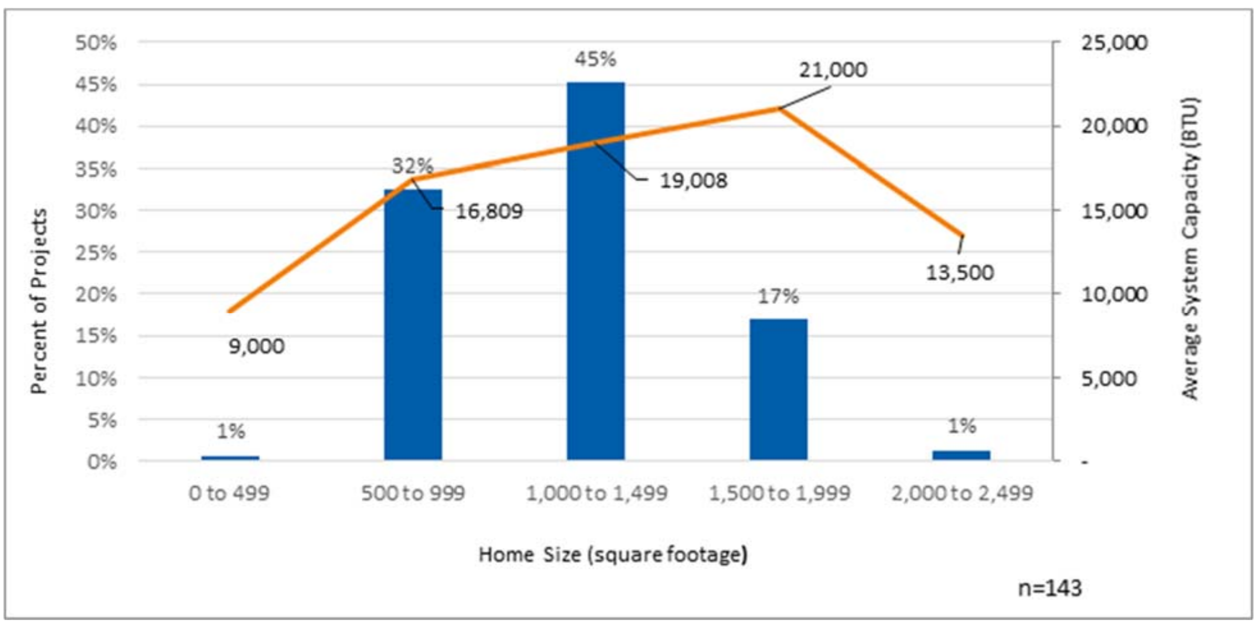


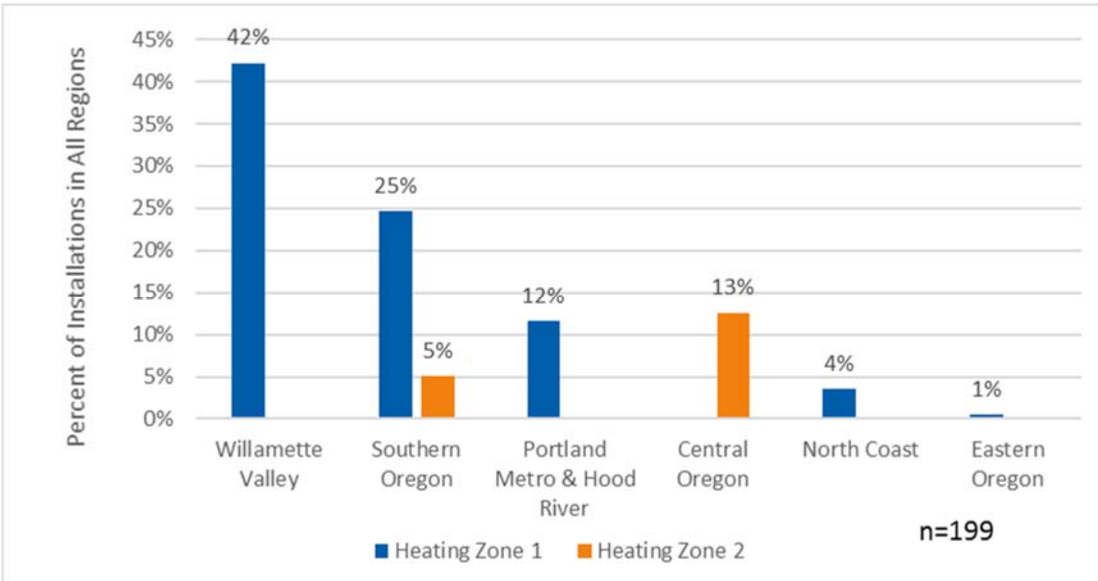
Figure 7. Shows the average system capacity for single-head units in various home-size bins.

Figure 7. Average System Capacity by Home Size (Single-head units)



Most ductless heat pump installations (82%) occurred in heating zone 1, which has fewer HDDs than Oregon's other two heating zones and is where most of the population of Oregon lives. Heating zone 1 includes the Willamette Valley and Portland Metro area (including Hood River). See Appendix B for a full list of counties in each heating zone. The other 18% of ductless heat pump installations occurred in heating zone 2, which includes parts of Southern Oregon and Central Oregon (see Figure 8, below).

Figure 8. Ductless Heat Pump Installation by Region



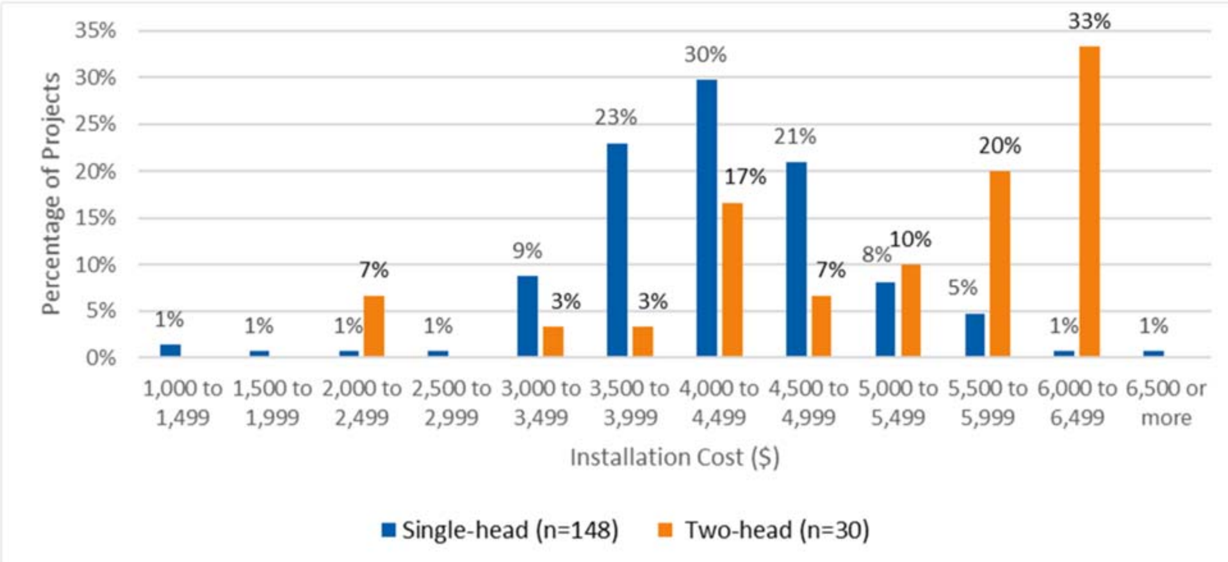
Ductless Heat Pump System Costs

Whether participants installed one or two indoor units with their ductless heat pump system has a strong impact on the cost of the system. The average cost of installation was $4,582 across all systems (n=198). The average cost was $4,256 for systems with a single indoor unit (n=148) and $6,102 for systems with two indoor units (n=30).[8] As shown in Figure 9, ductless heat pump system costs varied significantly. For single-head systems the minimum installation cost was $1,208 and the maximum was $6,975, with a standard error of $88.[9] For two-head systems the maximum cost was $9,397. Cadmus presents results for systems with a single indoor unit in much of the following analysis.

[8] The program data did not include the number of indoor units for 19 systems and one system included four indoor units. The installation cost for the project with four indoor units was $8,715.

[9] Although Cadmus did not verify the installation cost for the minimum cost retrofit, we did verify a similar installation priced at $1,474, which suggests that some units really are installed at a very low cost.

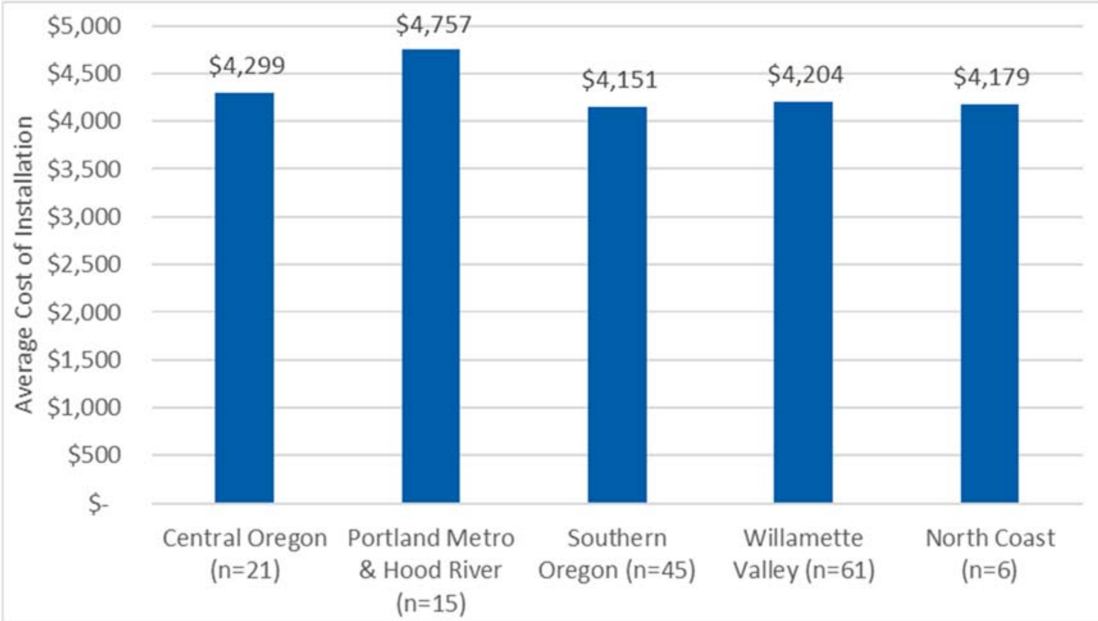
Figure 9. Installation Costs for Single-Head and Two-Head Ductless Heat Pumps



We also analyzed cost by installation year, system manufacturer, existing heating system, home size, home age, ductless heat pump system capacity, HSPF, and region. Although relatively steady over time, across home sizes, home age, brands, and system efficiency levels, we discovered notable trends in installation costs by region and system capacity.

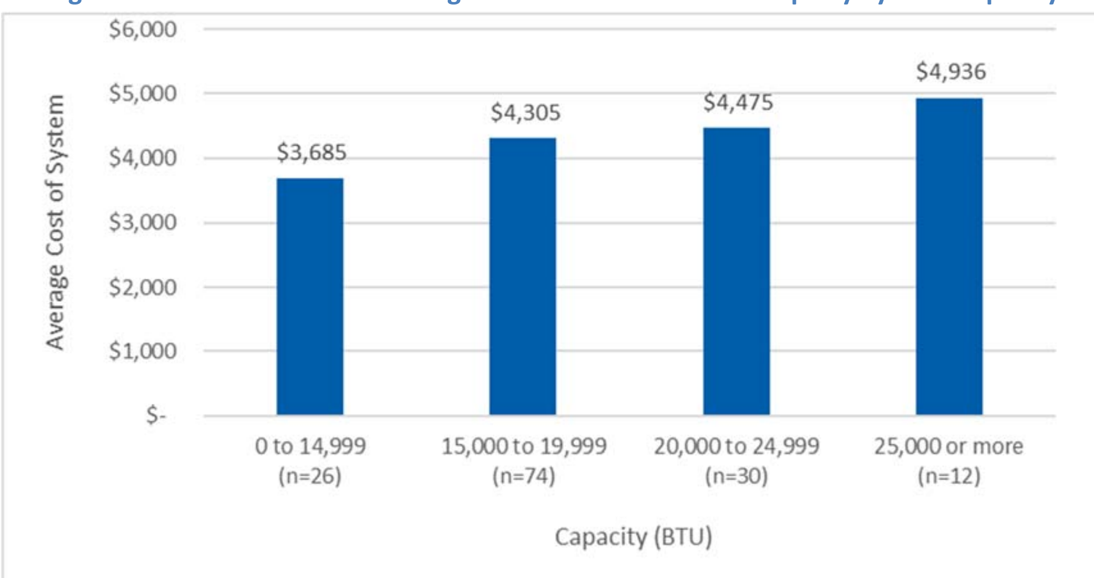
As shown in Figure 10, installation costs for ductless heat pumps in the Portland Metro region were on average more than $557 (or 12%) higher than in the rest of Oregon (where the average installation cost was $4,200). Most participants lived in the Willamette Valley and Southern Oregon and relatively few lived in the North Coast or Portland Metro region.

Figure 10. Installation Cost of Single-Head Ductless Heat Pumps by Region



Average system costs increased with system capacity, as shown in Figure 11. Lower capacity systems were on average over $1,000 cheaper than the highest capacity systems.

Figure 11. Installation Cost of Single-Head Ductless Heat Pumps by System Capacity



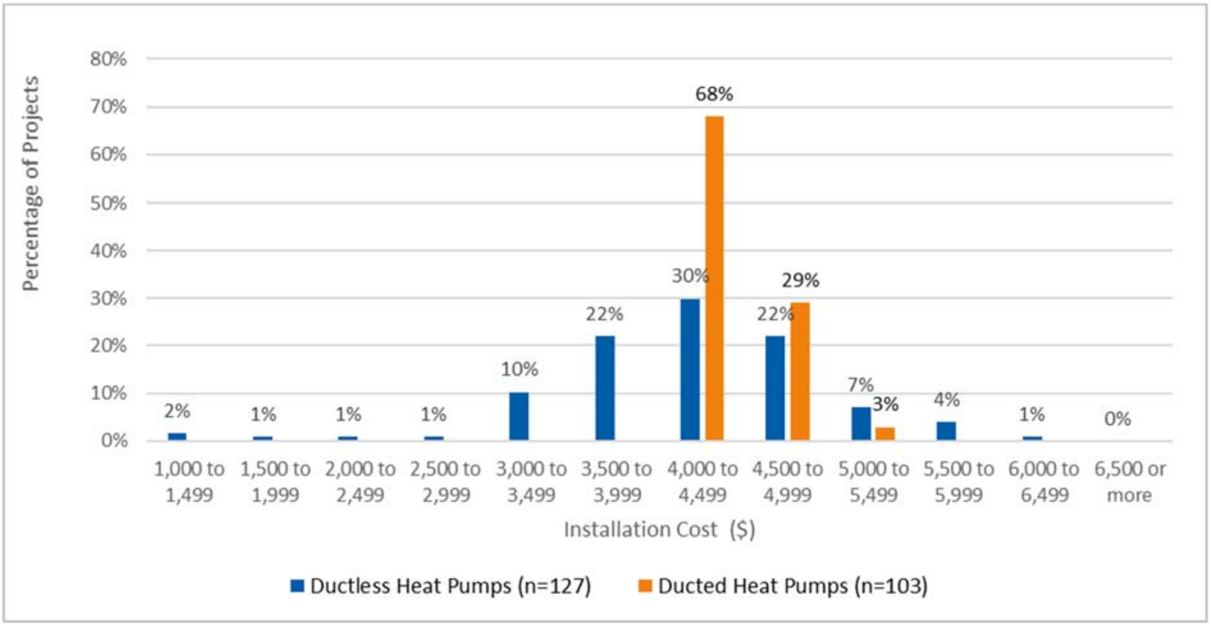
Comparison of Ductless Heat Pumps with Ducted Heat Pumps

Cadmus compared the costs and savings (performance) of the two types of heat pump systems. Because ducted systems were installed only in homes with electric furnaces, we compared these only with the ductless heat pumps that had been installed in homes with forced-air electric furnaces. Given the measures were offered under different program designs and not intended to be a perfect comparison, the results should be interpreted with this context in mind.

Cost Comparison

Costs for ductless and ducted heat pumps in homes with electric furnaces were almost identical. Average installation costs (in nominal dollars) were $4,501 for a ductless heat pump system with an electric furnace and $4,511 for a ducted heat pump. However, we found that costs were much more narrowly distributed for ducted systems than for ductless systems, as shown in Figure 12. The standard error was $70 for the cost of ductless heat pumps in homes with electric furnaces and $22 for ducted heat pumps.

Figure 12. Cost Comparison of Ductless and Ducted Heat Pumps



Four vetted trade ally contractors, selected through a competitive process, installed the ducted heat pumps during the pilot. Customers paid a flat fee of $1,000, and Energy Trust paid contractors a flat rate, based on the system size, for the balance of the installation.

Seventy-two contractors installed the ductless heat pumps we analyzed. Energy Trust provided an incentive of either $800 or $1,000 and the customer paid the remainder of the cost. One of the 72 contractors that installed ductless heat pumps was also a vetted contractor of Energy Trust's ducted heat pump pilot. This contractor installed one ductless heat pump.

Performance Comparison

Cadmus compared the energy savings from 84 ductless heat pumps[10] installed in homes with electric furnaces to the energy savings of 78 ducted heat pumps and found that, across both heating zones, they performed very similarly in terms of overall savings and savings per dollar of installed cost. However, they had significantly different realization rates and savings per ton of installed capacity, as illustrated in Table 10. We also analyzed the relative performance of ducted and ductless heat pumps in heating zones 1 and 2. The performance of both types of heat pump was similar across the heating zones in terms of annual savings, savings as a percentage of pre-installation usage, and savings per dollar spent on installation.

Table 10. Heat Pump Savings Comparison for Homes with Electric Furnaces

Heat Pump Type	Savings Per Unit (kWh)	Savings as % of Pre-NAC	Realization Rate	n[a]	Average Cost ($)	Average Capacity (Tons)	n[b]	Savings per Ton	Savings per $ (kWh/$)
Overall Sample									
Ductless Heat Pumps	3,324	22%	126%	84	$4,501	1.5	170	2,274	0.74
Ducted Heat Pumps	3,269	21%	75%	78	$4,511	2.2	103	1,461	0.72
Heating Zone 1									
Ductless Heat Pumps	3,321	23%	124%	69	$4,492	1.5	30	2,254	0.74
Ducted Heat Pumps	3,077	20%	73%	42	$4,403	2.3	51	1,324	0.70
Heating Zone 2									
Ductless Heat Pumps	3,333[c]	19%	133%	15	$4,542	1.4	140	2,363	0.73
Ducted Heat Pumps	3,447	21%	76%	36	$4,617	2.2	52	1,600	0.75

[a] n for savings analysis

[b] n for average cost

[c] The participant unadjusted savings and percent savings are nearly identical between the overall Zone 2 results (Table 6) and for the electric furnace subgroup shown here, both at 11% savings and approximately 1900 kWh savings. The difference between this value and the value reported in Table 6 is that the comparison group from Table 6 increased usage 954 kWh or 6%, while it increased by 1,364 kWh or 8% in this electric furnace sub-group. The sample sizes are small, and it is uncertain why the comparison groups differed in usage.

[10] Eleven installations in manufactured homes with zonal electric heat were removed from this part of the analysis.

Conclusions and Recommendations

Ducted and ductless heat pumps provide similar savings at comparable costs. The billing analysis for ducted and ductless heat pumps in manufactured homes showed almost identical savings on the basis of annual kWh and percentage of pre-installation usage for both system types. The annual savings for homes with electric forced-air furnaces were 3,324 kWh for ductless heat pumps and 3,269 kWh for ducted heat pumps. Despite, or perhaps due to the difference in program delivery, average costs and savings per dollar spent on system cost were also almost identical: $4,501 installed cost and 0.74 kWh per dollar for ductless heat pumps and $4,511 installed cost and 0.72 kWh per dollar for ducted heat pumps. Cadmus found greater variance in cost of the ductless heat pumps incentivized through the market-based program. Offering the ductless heat pump measure in conjunction with cost-controls, such as was done with the ducted heat pump pilot, should reduce the variance in cost and potentially lower the average cost.

- **Recommendation:** Offer incentives for both ducted and ductless heat pumps for manufactured homes. Work with the PMC to explore whether the cost of a ductless heat pump retrofit will respond to the same strategies used in the ducted heat pump pilot.

Although ducted and ductless heat pump savings are very similar, the realization rates for the two systems differ. The billing analysis of the two system types showed a realization rate of 126% for ductless heat pumps and 75% for ducted heat pumps in manufactured homes. This major difference suggests that Energy Trust underestimated the savings for ductless heat pumps and overestimated the savings of ducted heat pumps in manufactured homes.

- **Recommendation:** Revise *ex ante* savings estimates for ductless and ducted heat pumps for manufactured homes to more closely reflect evaluated savings.

Program design appears to significantly affect individual installation costs of ductless and ducted heat pumps. There was higher variance in installation costs for ductless heat pumps than for ducted heat pumps, despite the similarities in technology and housing stock. This variance is likely explained, in part, by the different program designs. The ducted heat pump pilot was delivered by four vetted contractors who were paid a fixed rate for the installation, whereas ductless heat pumps were installed by many contractors in a market-based program design. Although the average installation costs of these systems were similar, customers installing a ductless heat pump had much more uncertainty in the price they would pay. Such price inconsistency could affect uptake of this measure.

- **Recommendation:** If Energy Trust chooses to move forward in promoting ductless and ducted heat pumps in manufactured homes, it should consider the approach of its ducted heat pump pilot for both technologies. With more consistent pricing, and potentially lower retrofit costs, this design is likely to drive higher measure uptake than the market-based design currently used for ductless heat pumps.

Ductless heat pump program data contained some errors and missing information. Cadmus reviewed the program data for ductless heat pumps and selected a sample of projects that appeared to be outliers and in need of further investigation. We compared the program data for these projects against their original project documentation and found errors that indicate an opportunity for Energy Trust to improve its data entry process. Cadmus also found fields in the program data that were frequently missing information, such as the HSPF and SEER.

- **Recommendation:** Conduct quality review checks of the program data against project documents to improve the accuracy and completeness of the data. Consider prioritizing the review of project files with values that appear to be missing or outliers.

Appendix A – Additional Subgroup Analysis

Table 11 provides additional subgroup analysis for ductless heat pumps by various subgroups. The table shows that participants in PGE's service territory experienced higher energy savings than participants in PacifiCorps' service territory. The table also shows that energy savings remain relatively even across home sizes, but are larger for the oldest homes.

Table 11. Additional Subgroup Analysis

Group	Sub-Group	n	Pre-NAC	Average Savings (kWh)		Realization Rate	Relative Precision at 90% Confidence	Savings as % of Pre-NAC	
				Evaluated	Reported			Evaluated	Reported
Overall	Overall	95	14,860	3,294	2,711	122%	19%	22%	18%
Zone	Zone 1	77	14,342	3,389	2,736	124%	22%	24%	19%
Zone	Zone 2	18	17,077	2,890	2,607	111%	35%	17%	15%
Utility	PAC	59	14,903	2,558	2,693	95%	29%	17%	18%
Utility	PGE	36	14,789	4,499	2,740	164%	25%	30%	19%
Pre Quartile	Pre Q=1 All	25	8,260	1,368	2,827	48%	45%	17%	34%
Pre Quartile	Pre Q=2 All	23	11,789	2,943	2,691	109%	32%	25%	23%
Pre Quartile	Pre Q=3 All	23	16,223	3,893	2,701	144%	26%	24%	17%
Pre Quartile	Pre Q=4 All	24	23,371	5,064	2,619	193%	34%	22%	11%
Pre Quartile by Zone	Pre Q=1 Zone 1	20	7,465	1,141	2,798	41%	62%	15%	37%
Pre Quartile by Zone	Pre Q=2 Zone 1	19	11,108	2,763	2,732	101%	36%	25%	25%
Pre Quartile by Zone	Pre Q=3 Zone 1	19	15,643	4,098	2,744	149%	27%	26%	18%
Pre Quartile by Zone	Pre Q=4 Zone 1	19	23,512	5,671	2,666	213%	33%	24%	11%
Pre Quartile by Zone	Pre Q=1 Zone 2	5	11,441	2,277	2,942	77%	54%	20%	26%
Pre Quartile by Zone	Pre Q=2 Zone 2	4	15,022	3,797	2,501	152%	73%	25%	17%
Pre Quartile by Zone	Pre Q=3 Zone 2	4	18,977	2,920	2,501	117%	72%	15%	13%
Pre Quartile by Zone	Pre Q=4 Zone 2	5	22,836	2,755	2,441	113%	89%	12%	11%
Pre Quartile by Utility	Pre Q=1 PAC	15	7,530	1,177	2,701	44%	65%	16%	36%
Pre Quartile by Utility	Pre Q=2 PAC	14	12,125	1,888	2,953	64%	69%	16%	24%
Pre Quartile by Utility	Pre Q=3 PAC	16	16,586	4,118	2,576	160%	26%	25%	16%

Group	Sub-Group	n	Pre-NAC	Average Savings (kWh)		Realization Rate	Relative Precision at 90% Confidence	Savings as % of Pre-NAC	
				Evaluated	Reported			Evaluated	Reported
Pre Quartile by Utility	Pre Q=4 PAC	14	23,659	3,182	2,559	124%	64%	13%	11%
Pre Quartile by Utility	Pre Q=1 PGE	9	8,048	1,660	2,934	57%	71%	21%	36%
Pre Quartile by Utility	Pre Q=2 PGE	9	11,596	3,884	2,601	149%	30%	33%	22%
Pre Quartile by Utility	Pre Q=3 PGE	9	15,707	5,240	2,714	193%	18%	33%	17%
Pre Quartile by Utility	Pre Q=4 PGE	9	23,804	7,243	2,711	267%	46%	30%	11%
Sqft Quartile	Sqft Q=1 All	24	13,742	3,540	2,771	128%	32%	26%	20%
Sqft Quartile	Sqft Q=2 All	23	13,577	3,512	2,698	130%	48%	26%	20%
Sqft Quartile	Sqft Q=3 All	25	14,086	2,843	2,718	105%	36%	20%	19%
Sqft Quartile	Sqft Q=4 All	23	18,150	3,347	2,655	126%	39%	18%	15%
Sqft Quartile by Zone	Sqft Q=1 Zone 1	21	13,591	3,059	2,756	111%	38%	23%	20%
Sqft Quartile by Zone	Sqft Q=2 Zone 1	18	13,773	4,342	2,764	157%	49%	32%	20%
Sqft Quartile by Zone	Sqft Q=3 Zone 1	16	11,619	2,313	2,805	82%	58%	20%	24%
Sqft Quartile by Zone	Sqft Q=4 Zone 1	22	17,503	3,789	2,642	143%	33%	22%	15%
Sqft Quartile by Zone	Sqft Q=1 Zone 2	5	13,006	2,171	2,725	80%	96%	17%	21%
Sqft Quartile by Zone	Sqft Q=2 Zone 2	3	14,568	4,475	2,319	193%	30%	31%	16%
Sqft Quartile by Zone	Sqft Q=3 Zone 2	4	22,260	3,669	2,396	153%	75%	16%	11%
Sqft Quartile by Zone	Sqft Q=4 Zone 2	6	18,268	2,017	2,792	72%	92%	11%	15%
Sqft Quartile by Utility	Sqft Q=1 PAC	16	13,458	2,323	2,774	84%	63%	17%	21%
Sqft Quartile by Utility	Sqft Q=2 PAC	13	11,858	2,292	2,795	82%	56%	19%	24%
Sqft Quartile by Utility	Sqft Q=3 PAC	11	16,253	2,738	2,552	107%	61%	17%	16%
Sqft Quartile by Utility	Sqft Q=4 PAC	19	17,423	2,794	2,638	106%	56%	16%	15%
Sqft Quartile by Utility	Sqft Q=1 PGE	10	13,512	3,766	2,713	139%	29%	28%	20%
Sqft Quartile by Utility	Sqft Q=2 PGE	8	17,183	7,746	2,546	304%	48%	45%	15%
Sqft Quartile by Utility	Sqft Q=3 PGE	9	10,685	2,455	2,933	84%	73%	23%	27%
Sqft Quartile by Utility	Sqft Q=4 PGE	9	18,182	4,532	2,751	165%	30%	25%	15%
Energy Trust Region	Central Oregon	13	16,281	3,070	2,694	114%	34%	19%	17%

Group	Sub-Group	n	Pre-NAC	Average Savings (kWh)		Realization Rate	Relative Precision at 90% Confidence	Savings as % of Pre-NAC	
				Evaluated	Reported			Evaluated	Reported
Energy Trust Region	North Coast	2	8,010	1,633	3,013	54%	170%	20%	38%
Energy Trust Region	Portland Metro & Hood River	12	13,252	3,498	2,758	127%	41%	26%	21%
Energy Trust Region	Southern Oregon	25	16,542	2,721	2,647	103%	51%	16%	16%
Energy Trust Region	Willamette Valley	43	14,220	3,678	2,726	135%	28%	26%	19%
Vintage	1960-1969	9	16,093	4,847	2,617	185%	42%	30%	16%
Vintage	1970-1979	38	14,055	3,088	2,674	116%	39%	22%	19%
Vintage	1980-1989	22	14,262	3,376	2,859	118%	37%	24%	20%
Vintage	1990-1999	21	14,372	3,032	2,623	116%	32%	21%	18%
Vintage	2000-2014	5	23,436	3,135	2,884	109%	91%	13%	12%

Appendix B. Oregon Heating Zone by County

County	Oregon Heating Zone	County	Oregon Heating Zone
Baker	2	Malheur	1
Benton	1	Marion	1
Clackamas	1	Morrow	1
Clatsop	1	Multnomah	1
Columbia	1	Polk	1
Coos	1	Sherman	2
Crook	2	Tillamook	1
Curry	1	Umatilla	1
Deschutes	2	Union	2
Douglas	1	Wallowa	3
Gilliam	1	Wasco	1
Grant	2	Washington	1
Harney	3	Wheeler	2
Hood River	1	Yamhill	1
Jackson	1		
Jefferson	2		
Josephine	1		
Klamath	2		
Lake	2		
Lane	1		
Lincoln	1		
Linn	1		