MEMO

Date: March 16, 2020
To: Board of Directors
From: Dan Rubado, Evaluation Project Manager
Subject: **Summary of Recurve Analysis of Ducted Heat Pump Conversion Impacts**

EXECUTIVE SUMMARY

Energy Trust used an impact analysis tool built by Recurve Analytics to evaluate energy savings from high efficiency ducted heat pumps installed in single-family and manufactured homes by trade ally contractors between 2013 and 2018. Energy savings for two primary installation scenarios were analyzed for each home type: homes replacing an existing heat pump (referred to as "upgrades") and conversions from an electric forced air furnace (referred to as "conversions"). This report focuses on the impact of heat pump conversion projects while heat pump upgrades will be reported on separately. Weather normalized annual energy usage prior to installation was compared with the year immediately following installation. Changes in annual energy usage were evaluated against changes in energy usage in a comparison group during the same time period.

Overall electricity savings for heat pump conversions were much lower than expected for both site-built (1,980 kWh/year) and manufactured homes (2,890 kWh/year). The overall realization rates were 48 percent for site-built homes and 73 percent for manufactured homes. Projects completed in heating zone 1 appeared to have higher savings than those in heating zone 2 and savings were higher for PGE customers than for Pacific Power customers. Smaller homes realized higher energy savings than larger homes. Although 75 percent of projects had some type of commissioning measure, they did not appear to result in significant additional electricity savings. Overall, savings for heat pump conversions declined slightly over time. Many of these findings may be reflective of program challenges. For instance, many poor performing projects may have supplemental heating fuels or undersized heat pumps that must rely on resistance backup heating during cold periods. In addition, program installation requirements and quality control may be less stringent outside of PGE territory. Lastly, many homes simply may not use enough electricity to realize much savings from a heat pump.

We recommend conducting a review of program rules and heat pump installation requirements to determine what is driving lower savings and identify potential improvements. We also recommend a review of heat pump commissioning activities, including controls, to better understand the savings potential and make improvements. Heat pump conversion projects may benefit lower income customers the most, so it may be worth investigating new offerings for small home or rental heat pump conversions to better reach low- and moderate-income customers. We recommend revisiting and adopting new deemed electric savings values for heat pump conversion measures, based on this analysis. Realized savings for heat pump conversions were much lower than expected and Energy Trust should adjust its savings claims to better reflect reality.

Introduction

Energy Trust used an impact analysis tool built by Recurve Analytics (Recurve) to evaluate electric savings from high efficiency ducted heat pumps[1] installed in single-family and manufactured homes between 2013 and 2018. Energy Trust's Residential program has provided incentives for ducted heat pump systems installed by trade ally contractors since 2005 to replace existing heat pumps (referred to as "upgrades") and to convert electric forced air furnace (eFAF) systems (referred to as "conversions"). This report focuses on the impact of heat pump conversion projects.

Heat pump installations are driven by trade ally contractors who promote the technology and use Energy Trust incentives to help make sales. Trade allies must meet certain requirements, agree to meet Energy Trust standards, and remain in good standing. Energy Trust provides trade allies with training, prescribes installation and commissioning requirements, and conducts quality assurance inspections to ensure that the expected energy savings are achieved. Energy Trust discontinued its incentives for residential heat pump upgrades in 2018—updated savings analysis from the Regional Technical Forum (RTF)[2], high installation costs, and utility avoided costs combined to make these projects no longer cost-effective. Energy Trust maintained incentives for heat pump conversions and has expanded its campaign to replace eFAF systems in recent years.

During the analysis period, there were several tiers of incentives and deemed savings values claimed by the program for heat pump conversions. Deemed savings varied significantly over time as measures were updated to align with RTF changes, to incorporate new information, or to better match evaluation results. Deemed savings also varied by the home type, heating zone, and efficiency level. For site-built homes in the 2013-2018 program years, the deemed savings claimed for heat pump conversions ranged from 2,531 to 5,553 kWh per year, with a weighted average, based on project volume, of 4,150 kWh. For manufactured homes, deemed savings for conversions ranged from 3,269 to 4,559 kWh per year, with a weighted average, based on project volume, of 3,950 kWh. The deemed savings values claimed for heat pump conversion projects in Energy Trust's project tracking database are summarized in Table 1.

Table 1: Heat pump conversion deemed savings values and project counts from project tracking data by installation scenario, from 2013-2018

Years in Effect	Project Type	Home Type	Incentive Design	Heating Zone	HSPF	Deemed Savings (kWh)	Project Count
2015-2016	Conversion	Manufactured	Fixed price	1	8.2+	4,202	57
2015-2016	Conversion	Manufactured	Fixed price	2	8.2+	4,559	53
2018-2019	Conversion	Manufactured	Fixed price	All	All	3,269	65
2018-2020	Conversion	Manufactured	Rebate	All	All	3,631	8
2010-2013	Conversion	Site-built	Rebate	All	9.0+	2,531	9
2012-2013	Conversion	Site-built	Rebate	All	9.0+	3,379	317
2014	Conversion	Site-built	Rebate	1	9.5+	3,816	109
2014	Conversion	Site-built	Rebate	2	9.5+	4,706	26
2013-2017	Conversion	Site-built	Rebate	1	9.0-9.49	3,379	625

[1] Residential ducted heat pumps are also known as air source heat pumps and central heat pump systems.
[2] https://rtf.nwcouncil.org

Years in Effect	Project Type	Home Type	Incentive Design	Heating Zone	HSPF	Deemed Savings (kWh)	Project Count
2014-2017	Conversion	Site-built	Rebate	1	9.5+	4,151	726
2013-2017	Conversion	Site-built	Rebate	2	9.0-9.49	4,167	106
2014-2017	Conversion	Site-built	Rebate	2	9.5+	4,939	125
2018-2020	Conversion	Site-built	Rebate	1	8.5+	5,252	502
2018-2020	Conversion	Site-built	Rebate	2	8.5+	5,553	84

In addition to the installation scenarios and deemed savings values listed above, heat pump projects may also receive additional incentives if the contractor performs commissioning activities or installs advanced controls in accordance with Energy Trust guidelines. These commissioning activities are associated with additional deemed savings that are claimed by the Residential program on top of the heat pump savings. Seventy-five percent of projects received incentives for commissioning activities during the time period analyzed. Deemed savings values for commissioning measures varied somewhat over time and depending on the activities completed and the heating zone. Deemed savings ranged from 452 to 1,211 kWh per year and had a weighted average, based on project volume, of 500 kWh. The weighted average deemed savings for commissioning activities were 474 kWh in heating zone 1 and 725 kWh in heating zone 2.

Electric savings for heat pump conversions were analyzed separately for site-built and manufactured homes[3]. The Recurve impact analysis tool uses monthly utility billing data to conduct pre/post billing analyses of whole home energy usage. Energy usage data are weather normalized using typical meteorological year data. Normalized annual energy usage in the year immediately preceding the installation is compared with that of the year immediately following installation. The change in normalized annual energy usage is then evaluated against changes in energy usage during the same time period for a comparison group— i.e., homes that received the same services in later years (future participants). These calculations provide an estimate of the average annual energy savings resulting from the measures, given typical weather conditions. Lastly, several standard data screens are applied to remove atypical homes and homes unsuitable for pre/post billing analysis from the analysis.

The Recurve snapshot reports that follow this memo, and the summary of results below, show that overall electricity savings for heat pump conversions were much lower than expected. Savings were generally higher in manufactured homes than site-built homes and decreased slightly over time. We analyzed heat pump projects along several other dimensions, including home size, heat pump commissioning status, electric utility, installer, and heating zone[4]. Many analyses spanned across heating zones due to a relatively low number of projects in heating zone 2

[3] Although heat pumps are frequently installed in manufactured homes, there were no measures or incentives specific to this market until a 2015 pilot study that used a fixed price incentive design and small pool of trade allies. The evaluation report summarizing that pilot can be found on Energy Trust's website: https://energytrust.org/wp-content/uploads/2017/12/XMH-Heat-Pump-Pilot-Eval-Final-Report-wSR.pdf. Measures and incentives specific to manufactured homes with distinct deemed savings didn't become available until 2018. Prior to that, the site-built heat pump measures and deemed savings values were used for manufactured homes.

[4] Heating zones are geographic areas defined by the Regional Technical Forum, based on the number of heating degree-days during a typical winter. Heating zone 1 represents areas of the state with relatively mild winters, such as Western Oregon. Heating zones 2 and 3 (combined hereafter into zone 2) represent areas of the state with cold winters, like the mountains and Central and Eastern Oregon.

Heat Pump Conversion Results

Overall savings

Heat pump conversion projects completed between 2013 and 2018 in site-built homes saved an average of 1,980 kWh per year (+/- 170) or 11 percent of baseline electricity usage. There were 1,302 site-built homes analyzed in the treatment group. These homes had average annual baseline electricity usage of 18,060 kWh, with estimated heating loads of 7,630 kWh (or 42 percent of usage). They were widely distributed across Energy Trust's electric service territory in Oregon. The weighted average deemed savings for these measures was 4,150 kWh per year, so the overall realization rate was 48 percent.

Heat pump conversion projects in manufactured homes saved an average of 2,890 kWh per year (+/- 330) or 18 percent of baseline electricity usage. There were 188 manufactured homes analyzed in the treatment group. These homes had average annual baseline electricity usage of 15,900 kWh, with estimated heating loads of 7,340 kWh (or 46 percent of usage). They were concentrated in the metro areas of Western and Central Oregon. The weighted average deemed savings for these manufactured home heat pump projects was 3,950 kWh per year, so the overall realization rate was 73 percent.

These results show that heat pump conversion savings were much lower than expected, overall, especially among site-built homes.

In the sections below, we examine the impact of the following factors on heat pump conversion savings:

- Heating zone
- Home size
- Installation contractor
- Electric utility
- Commissioning status

Heating Zone Impact

For site-built homes in heating zone 1, heat pump conversions saved an average of 2,020 kWh per year (+/- 190) or 11 percent of baseline electricity usage. There were 1,161 site-built homes analyzed in heating zone 1. These homes had average annual baseline electricity usage of 18,130 kWh with estimated heating loads of 7,680 kWh (or 42 percent of usage). They were distributed across heating zone 1 in Oregon. Heating zone 1 results were similar to the overall results because 89 percent of site-built homes in the treatment group were located in heating zone 1. The weighted average deemed savings for these measures was 4,170 kWh per year, so the realization rate for site-built homes in heating zone 1 was 48 percent.

For site-built homes in heating zone 2, heat pump conversions saved an average of 1,500 kWh per year (+/- 550) or 8 percent of baseline electricity usage. There were 126 site-built homes analyzed in heating zone 2. These homes had average annual baseline electricity usage of 17,670 kWh with estimated heating loads of 7,210 kWh (or 41 percent of usage). They were concentrated in Central Oregon. The weighted average deemed savings for these measures was 4,830 kWh per year, so the realization rate for site-built homes in heating zone 2 was just 31 percent.

The results by heating zone in site-built homes are shown in Chart 1, below.

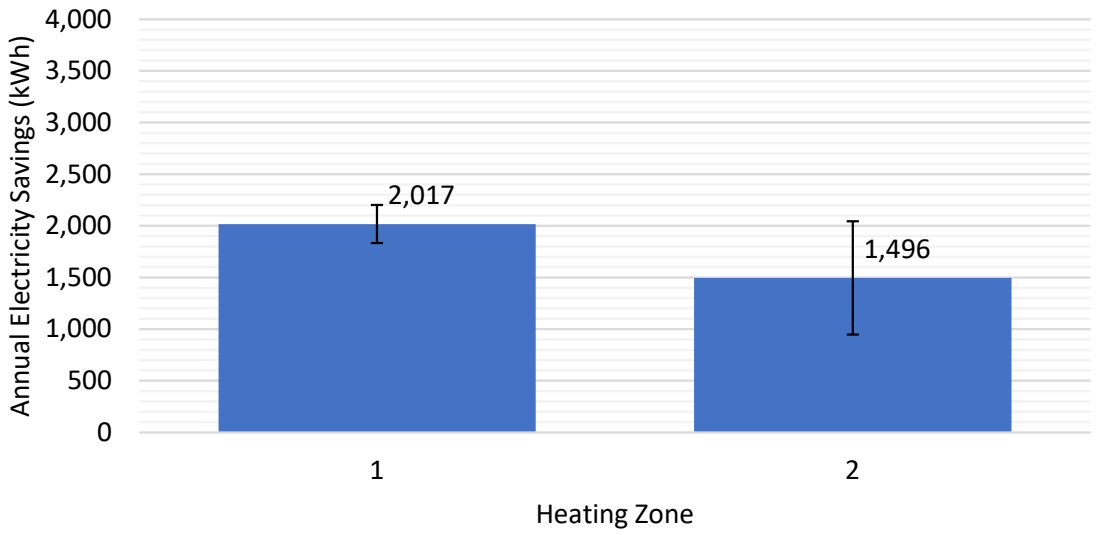


Chart 1: Electric savings for heat pump conversions in site-built homes by heating zone

For manufactured homes in heating zone 1, heat pump conversions saved an average of 2,930 kWh per year (+/- 340) or 19 percent of baseline electricity usage. There were 165 manufactured homes analyzed in heating zone 1. These homes had average annual baseline electricity usage of 15,570 kWh with estimated heating loads of 7,320 kWh (47 percent of usage). They were concentrated in the metro areas of Western Oregon. Heating zone 1 results were similar to the overall results because 87 percent of manufactured homes in the treatment group were located in heating zone 1. The weighted average deemed savings for these measures was 4,200 kWh per year, so the realization rate for manufactured homes in heating zone 1 was 70 percent. Electricity savings could not be assessed for manufactured homes in heating zone 2 due to a small number of projects.

Although savings and realization rates were low across the board, the results indicate that heat pump conversion projects achieved slightly higher electric savings in heating zone 1, contrary to our expectations based on the colder climate and deemed savings values. However, this discrepancy may be explained by a higher reliance on wood heat in heating zone 2, as well as reduced heat pump performance during cold periods due to an overreliance on backup resistance heating. Both of these issues would tend to decrease electricity savings and may not be fully captured in the engineering calculations underpinning the deemed savings values. Realization rates were especially low among site-built homes in heating zone 2, which also had the lowest absolute electricity savings.

Home Size Impact

For site-built homes, electricity savings for heat pump conversions decreased somewhat as home size increased, even though larger homes had much higher annual baseline electricity usage. Homes less than 1,200 square feet saved the most, with an average of 2,570 kWh per year (+/- 450) or 17 percent of baseline electricity usage. Homes from 1,200 to 2,000 square feet saved an average of 2,120 kWh per year (+/- 260) or 13 percent of baseline electricity usage. Homes from 2,000 to 3,000 square feet saved an average of 1,450 kWh per year (+/- 480) or 7 percent of baseline electricity usage. Homes larger than 3,000 square feet saved an average of 1,840 kWh per year (+/- 1,130) or 7 percent of baseline electricity usage. The average annual baseline electricity usage increased with home size, from 15,040 kWh for the

smallest homes to 26,540 kWh for the largest homes. The estimated annual heating loads increased similarly with size from 6,740 kWh to 8,520 kWh.

For the largest home size category, there were relatively few projects available for analysis (n=69) and the precision of the savings estimate was low, but the smaller home size categories had relatively robust sample sizes and at least moderate levels of precision. The results by home size in site-built homes are shown in Chart 2, below.

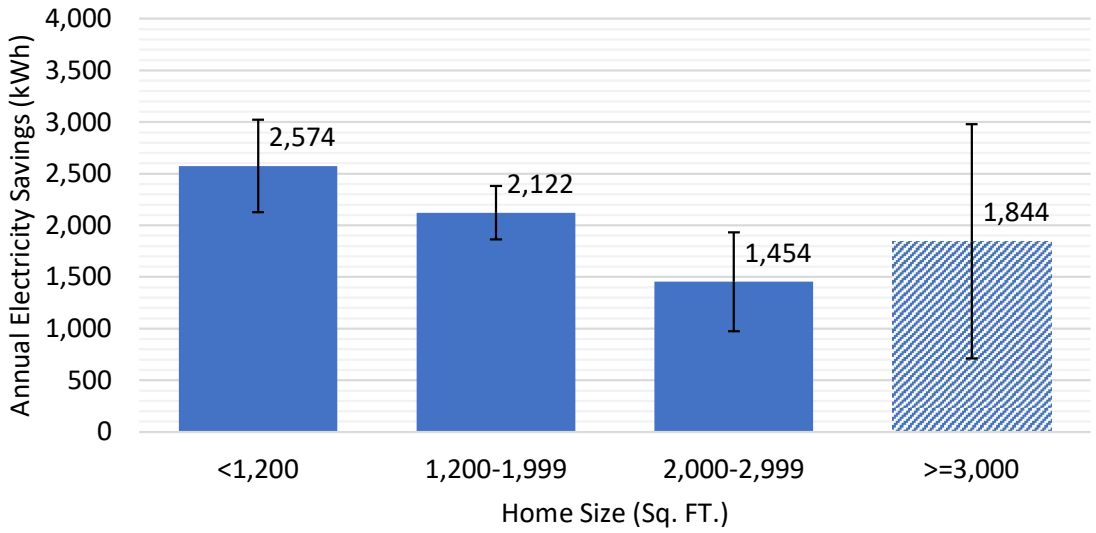


Chart 2: Electric savings for heat pump conversions in site-built homes by home size[5]

For manufactured homes, electricity savings for heat pump conversions was not assessed by home size, due to the relatively low number of projects.

For site-built homes, the results show that heat pump conversion savings in the smallest homes were 730 kWh higher than in the largest homes, while the percent savings were nearly 2.5 times higher. Although this result seems counterintuitive, since higher savings are generally found in homes with higher baseline energy usage, it could be related to sizing practices for heat pump systems and their ability to meet the full heating loads of larger homes with the compressor alone. If undersized systems are more commonly installed in larger homes, then these heat pumps may rely more on their electric resistance backup heat during cold periods, resulting in worse energy performance. Larger homes may also have more than one heating system present, so the impact of replacing one system may be lower than expected, especially if multiple fuels are used or the systems serve overlapping zones in the home.

Installation Contractor Impact

We analyzed electricity savings by installation contractor for site-built homes. However, there were many contractors active in this market and even those with the largest volume did not have enough projects available to properly assess differences between them. With that limitation in mind, we found that two of the top installation contractors may have realized somewhat lower savings, on average, than the rest.

[5] Note: the savings estimate for homes larger than 3,000 square feet has relatively low precision.

Electric Utility Impact

For site-built homes in Portland General Electric's (PGE's) service territory, heat pump conversions saved an average of 2,430 kWh per year (+/- 240) or 13 percent of baseline electricity usage, significantly higher than the overall results. There were 707 site-built homes analyzed in PGE territory—54 percent of the treatment group. These homes had average annual baseline electricity usage of 18,350 kWh, with estimated heating loads of 8,180 kWh. They were distributed across PGE's service territory in the Portland and Salem metro areas.

For site-built homes in Pacific Power territory, heat pump conversions saved an average of 1,440 kWh per year (+/- 250) or 8 percent of baseline electricity usage, significantly lower than the overall results. There were 594 site-built homes analyzed in Pacific Power territory—46 percent of the site-built homes in the treatment group. These homes had average annual baseline electricity usage of 17,650 kWh, with estimated heating loads of 6,990 kWh. They were distributed across Pacific Power's Oregon territory, with a concentration of projects in Southern Oregon. The results by electric territory in site-built homes are shown in Chart 3, below.

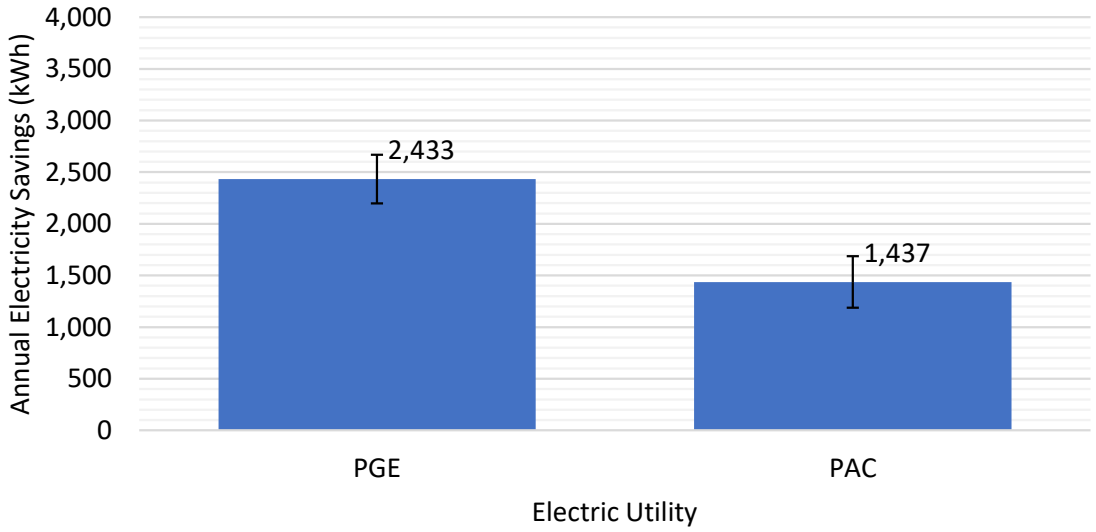


Chart 3: Electric savings for heat pump conversions in site-built homes by electric utility

For manufactured homes in PGE territory, heat pump conversions saved an average of 3,300 kWh per year (+/- 420) or 21 percent of baseline electricity usage, somewhat higher than the overall results. There were 85 manufactured homes analyzed in PGE territory—46 percent of the treatment group. These homes had average annual baseline electricity usage of 15,410 kWh, with estimated heating loads of 7,170 kWh. They were distributed across PGE's service territory in the Portland and Salem metro areas, with the notable exceptions of the cities of Portland and Beaverton.

For manufactured homes in Pacific Power territory, heat pump conversions saved an average of 2,550 kWh per year (+/- 500) or 16 percent of baseline electricity usage, somewhat lower than the overall results. There were 103 manufactured homes analyzed in Pacific Power territory—54 percent of the treatment group. These homes had average annual baseline electricity usage of 16,300 kWh, with

estimated heating loads of 7,480 kWh. They were concentrated in Southern Oregon. The results by electric territory in manufactured homes are shown in Chart 4, below.

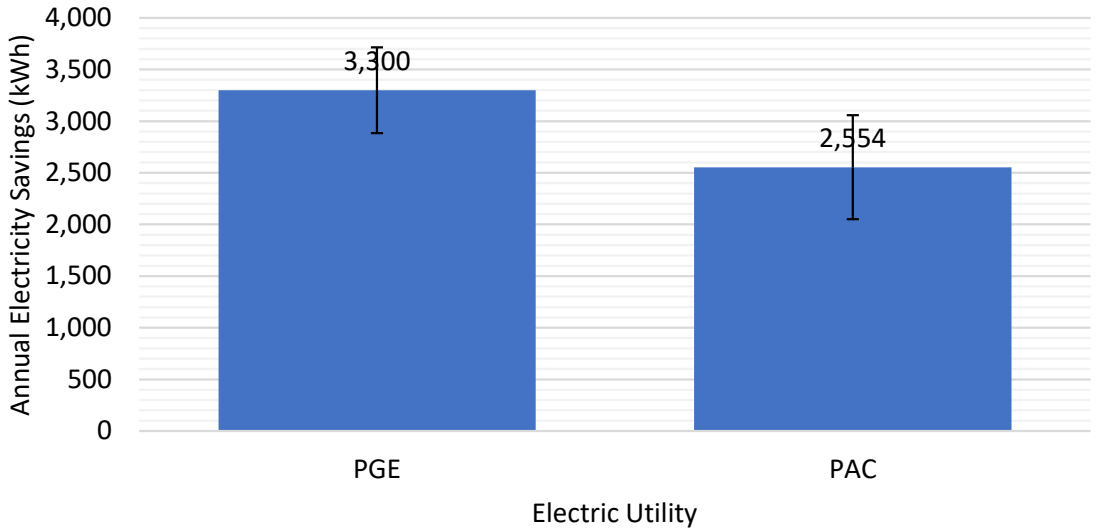


Chart 4: Electric savings for heat pump conversions in manufactured homes by electric utility

Electric utility impact in heating zone 1. For site-built homes within PGE territory in heating zone 1, heat pump conversions saved an average of 2,360 kWh per year (+/- 240) or 13% of baseline electricity usage. For site-built homes within Pacific Power territory in heating zone 1, heat pump conversions saved an average of 1,530 kWh per year (+/- 290) or 9 percent of baseline electricity usage.

Electric utility impact in heating zone 2. There were an insufficient number of site-built homes within PGE territory in heating zone 2 to produce a meaningful estimate of electricity savings. For site-built homes within Pacific Power territory in heating zone 2, heat pump conversions saved an average of 970 kWh per year (+/- 570) or 6% of baseline electricity usage. Although this savings estimate is based on more than 100 projects, it has relatively low precision.

For manufactured homes, electricity savings for heat pump conversions were not assessed by both electric utility and heating zone, due to the relatively low number of projects. The results by electric utility and heating zone in site-built homes are shown in Chart 5, below.

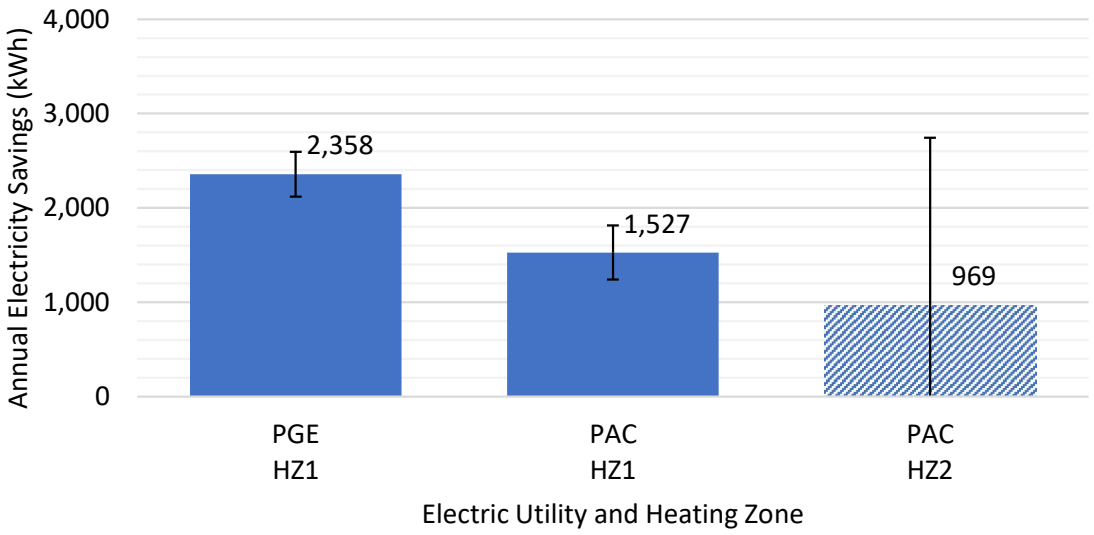


Chart 5: Electric savings for heat pump conversions in site-built homes by electric utility & heating zone[6]

These results show that heat pump conversion savings in PGE territory were nearly 1,000 kWh per year higher than in Pacific Power territory for site-built homes and 750 kWh higher for manufactured homes. These differences in savings are probably not due to differences in climate, at least not entirely. When the analysis was constrained to heating zone 1, site-built homes in PGE territory still saved 830 kWh per year more than those in Pacific Power territory. Within heating zone 2, site-built homes in Pacific Power territory saved 530 kWh per year less than heating zone 2 overall, although there was substantial variance.

The differences between utility territories may be explained by a higher reliance on wood heat in Pacific Power territory, particularly in Southern and Central Oregon, where most of the Pacific Power heat pump conversion projects were located.[7] When heat pump conversions are done in homes with wood heat, a portion of the savings are wood, not electricity, reducing the grid benefit. In addition, PGE has its own incentives and network of approved heat pump contractors that overlaps with Energy Trust's trade ally network.[8] PGE enforces somewhat more stringent installation requirements than Energy Trust does, aimed at maximizing energy savings. Heat pumps installed by PGE trade allies are also subject to a higher rate of quality control inspections. Pacific Power does not have a similar network of trade allies or additional requirements. Each of these issues could lead to lower observed electricity savings in Pacific Power territory and may not be fully captured in engineering-based savings calculations.

Commissioning Impact

In site-built homes, heat pump conversions where incentives were provided for commissioning services or advanced controls saved an average of 2,020 kWh per year (+/- 190) or 11 percent of baseline electricity usage. This estimate is very similar to the overall results for heat pump conversions. There were 976

[6] Note: the savings estimate for Pacific Power homes in heating zone 2 has relatively low precision. Savings could not be estimated for PGE homes in heating zone 2, due to a low sample size (n=18).

[7] Wood heat prevalence in Southern Oregon is roughly twice the statewide average, at approximately 13 percent. U.S. Census Bureau; American Community Survey, 2018 American Community Survey 5-Year Estimates, Table B25040. Retrieved on 1/20/2021 from: https://data.census.gov.

[8] https://portlandgeneral.com/save-money/save-money-home/more-ways/heating-cooling/ducted-heat-pumps

projects analyzed that received incentives for some type of commissioning—75 percent of treatment group homes. These site-built homes had average annual baseline electricity usage of 18,000 kWh, with estimated heating loads of 7,620 kWh. They were distributed across Energy Trust's electric territory in Western and Central Oregon. The weighted average deemed savings for heat pump commissioning measures was 500 kWh. When that is combined with the weighted average deemed savings for heat pump conversion projects in site-built homes of 4,150 kWh, the expected savings for these projects was 4,650 kWh. Thus, the realization rate for heat pump conversions with commissioning was 43 percent.

In site-built homes, heat pump conversions that did not receive incentives for commissioning services saved an average of 1,920 kWh per year (+/- 310), or 10 percent of baseline electricity usage, very similar to the overall results. There were 327 projects analyzed that did not receive any commissioning incentives—25 percent of treatment group homes. These site-built homes had average annual baseline electricity usage of 18,300 kWh, with estimated heating loads of 7,670 kWh. They were distributed across Energy Trust's electric service territory. Based on the weighted average deemed savings value of 4,150 kWh, the realization rate for heat pump conversions without commissioning in site-built homes was 46 percent. The results by commissioning status in site-built homes are shown in Chart 6, below.

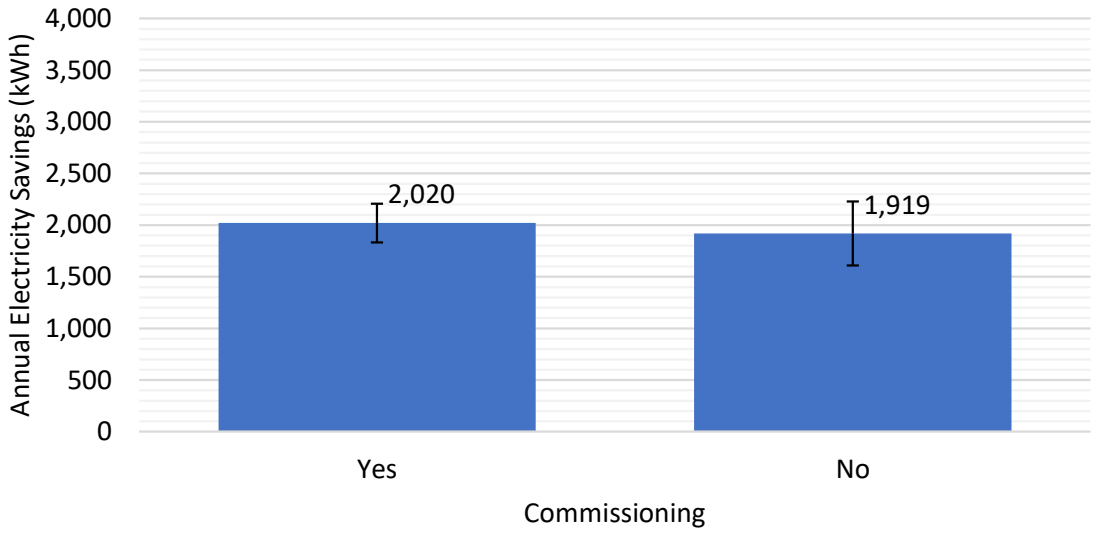


Chart 6: Electric savings for heat pump conversions in site-built homes by commissioning status

In manufactured homes, heat pump conversions that received incentives for commissioning services saved an average of 2,890 kWh per year (+/- 400), or 18 percent of baseline electricity usage, the same as the overall results. There were 109 projects analyzed that received some type of commissioning incentives—58 percent of treatment group homes. These manufactured homes had average annual baseline electricity usage of 15,880 kWh, with estimated heating loads of 7,250 kWh. They were distributed across Energy Trust's electric territory in Western and Central Oregon. The weighted average deemed savings for heat pump commissioning was 500 kWh. When combined with the weighted average deemed savings for heat pump conversion projects in manufactured homes of 3,950 kWh, the expected savings was 4,450 kWh for these projects. The realization rate for heat pump conversions with commissioning in manufactured homes was 65 percent.

In manufactured homes, heat pump conversions that did not receive incentives for commissioning services saved an average of 2,890 kWh per year (+/- 450), or 18 percent of baseline electricity usage. This estimate is the same as the overall results, however, it may be less reliable due to a relatively small sample size. There were 79 projects analyzed that did not receive any commissioning incentives—42 percent of treatment group homes. These manufactured homes had average annual baseline electricity usage of 15,920 kWh, with estimated heating loads of 7,470 kWh. They were concentrated in the Portland and Salem metro areas. Based on the weighted average deemed savings value of 3,950 kWh, the realization rate for heat pump conversions without commissioning in site-built homes was 73 percent. The results by commissioning status in manufactured homes are shown in Chart 7, below.

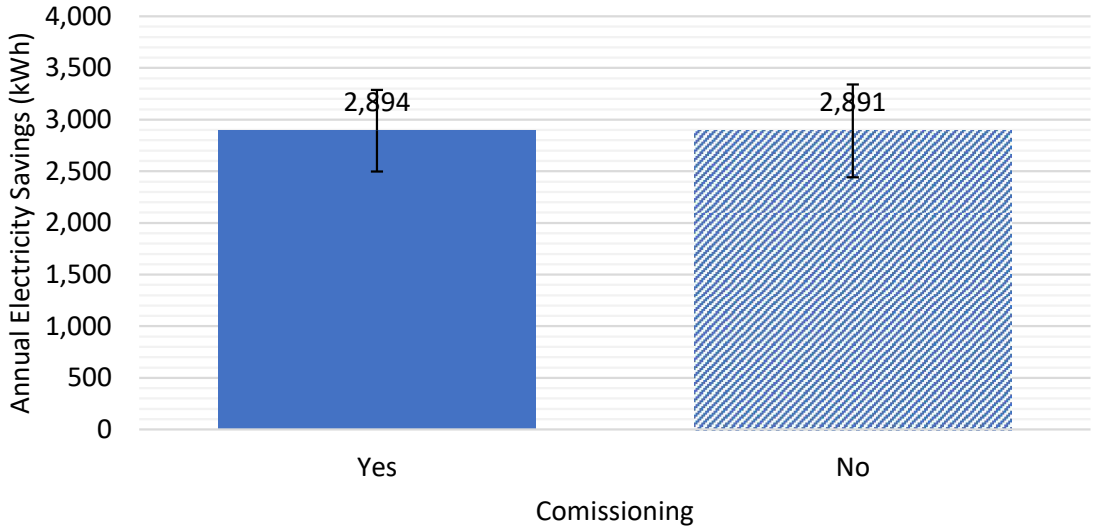


Chart 7: Electric savings for heat pump conversions in manufactured homes by commissioning status[9]

Commissioning impact in heating zone 1. For site-built homes in heating zone 1, heat pump conversions that received commissioning incentives saved an average of 2,020 kWh per year (+/- 200) or 11 percent of baseline electricity usage. Those that did not receive commissioning incentives saved an average of 2,020 kWh per year (+/- 330) or 11 percent of baseline electricity usage. These estimates are both essentially the same as the overall result for heating zone 1.

Commissioning impact in heating zone 2. For site-built homes in heating zone 2, heat pump conversions that received commissioning incentives saved an average of 1,660 kWh per year (+/- 590) or 9% of baseline electricity usage. This estimate is slightly higher than the overall result for site-built homes in heating zone 2. There were an insufficient number of site-built homes in heating zone 2 that did not receive heat pump commissioning incentives (n=44) to produce a meaningful estimate of electricity savings.

For manufactured homes, electricity savings for heat pump conversions were not assessed by both commissioning status and heating zone, due to the relatively low number of projects. The results for site-built homes by commissioning status and heating zone are shown in Chart 8, below.

[9] Note: the savings estimate for homes that did not receive commissioning incentives is based on a relatively small sample (n=79) and may not be reliable.

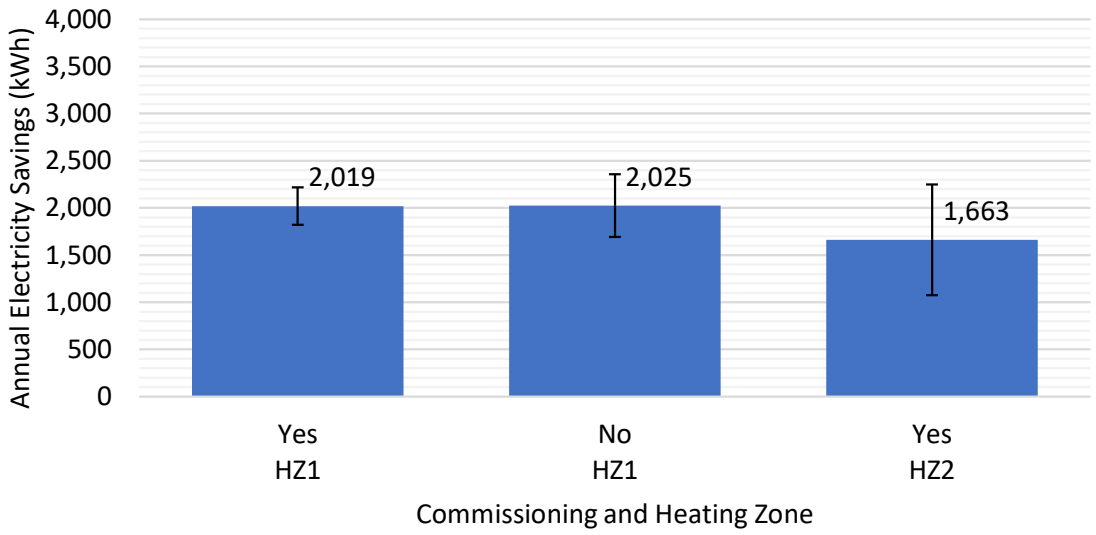


Chart 8: Electric savings for heat pump conversions in site-built homes by commissioning status and heating zone[10]

Commissioning impact for PGE customers. For site-built homes in PGE territory, heat pump conversion projects that received commissioning incentives saved an average of 2,470 kWh per year (+/- 260) or 14 percent of baseline electricity usage. Projects in PGE territory that did not receive commissioning incentives saved an average of 2,450 kWh per year (+/- 390) or 13 percent of baseline electricity usage. These estimates are very close to one another and are both similar to the overall result for PGE territory.

Commissioning impact for Pacific Power customers. For site-built homes in Pacific Power territory, heat pump conversion projects that received commissioning incentives saved an average of 1,500 kWh per year (+/- 270) or 8 percent of baseline electricity usage. Projects in Pacific Power territory that did not receive commissioning incentives saved an average of 1,350 kWh per year (+/- 490) or 7 percent of baseline electricity usage. Although projects that received commissioning appear to have slightly higher savings than those that did not, the difference is not significant and both estimates are similar to the overall result for Pacific Power territory.

Electricity savings for heat pump conversions in manufactured homes were not assessed by both commissioning status and electric utility, due to the relatively low number of projects. The results for site-built homes by commissioning status and utility territory are shown in Chart 9, below.

[10] Note: savings could not be reliably estimated for homes that received commissioning incentives in heating zone 2, due to a low sample size (n=44).

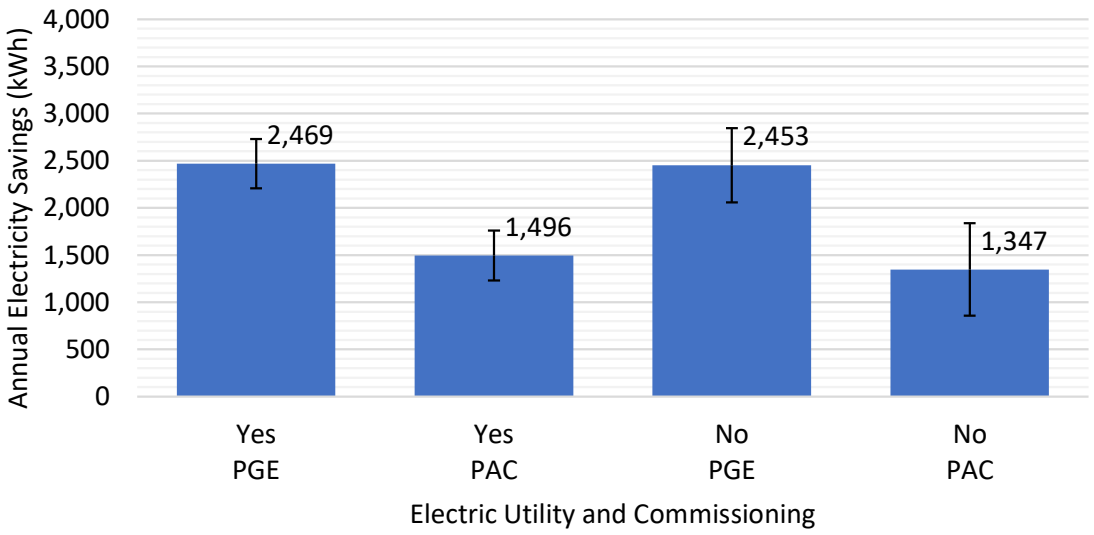


Chart 9: Electric savings for heat pump conversions in site-built homes by commissioning status and electric utility

These results show that heat pump conversion projects that received incentives for commissioning activities saved the same amount of electricity as those that did not. This was true for both site-built and manufactured homes. Constraining the analysis to heating zone 1, did not change this result. Within heating zone 2, site-built homes that received commissioning incentives saved 160 kWh per year more than in heating zone 2 overall, but this difference was well within the error bounds of the estimates. In addition, constraining the analysis to PGE customers showed no additional savings for commissioned projects. Within Pacific Power territory, site-built homes that received commissioning saved 150 kWh per year more than homes that did not, although this difference was not significant.

That commissioning activities did not appear to save much energy on top of the heat pump conversion savings could have several explanations. It may be that the commissioning activities associated with Energy Trust incentives are already standard practice in the industry, or at least among trade ally contractors. In this case, there would be no real-world difference between projects that received commissioning incentives and those that did not. Alternatively, it could be that the requirements for heat pump commissioning measures are not faithfully adhered to by the contractors doing the installations. In this case, homes where commissioning activities are performed do not receive the full benefit of commissioning. Lastly, it may be that heat pump commissioning measures simply do not save energy in heat pump conversion projects, particularly in heating zone 1. It is possible that heat pump commissioning activities in heating zone 2 produced a small amount of savings, but there were not enough projects completed to precisely estimate this impact.

Trends Over Time

We analyzed electric savings for heat pump conversions in site-built homes by installation year to see if there were changes occurring. To minimize year-to-year variance introduced by the comparison group, and better detect any trends, we analyzed only the treatment group's change in normalized annual electricity usage, as a proxy for savings. While there was no consistent trend, it appears that electric savings for heat pump conversions in site-built homes decreased slightly over time. This decline in savings

was associated with a slight decline in baseline annual electricity usage over the same period. The trend over time in savings is shown in Chart 10, below.

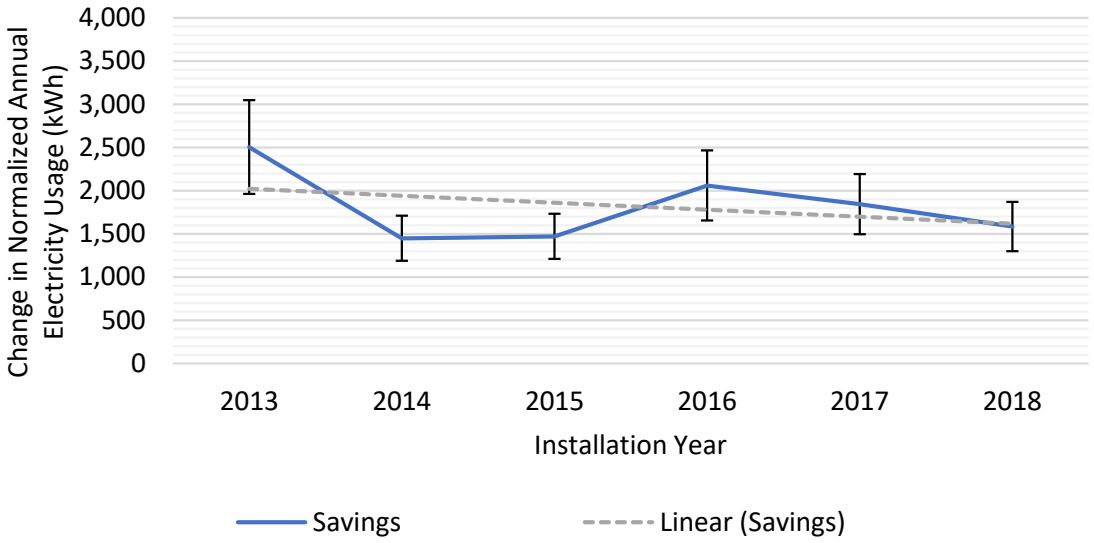


Chart 10: Electric savings for heat pump conversions in site-buit homes by installation year, 2013-2018

We next anlayzed the trend in electric savings by installation year in manufactured homes. Due to a relatively small number of projects overall, we combined annual estimates into two-year bins to improve the precision of the results. To minimize year-to-year variance introduced by the comparison group, and better detect any trends, we analyzed only the treatment group's change in normalized annual electricity usage, as a proxy for savings. Electric savings for heat pump conversions in manufactured homes were relatively flat over time. During the same period, there was a slight decline in baseline annual electricity usage. The trend over time in savings is shown in Chart 11, below.

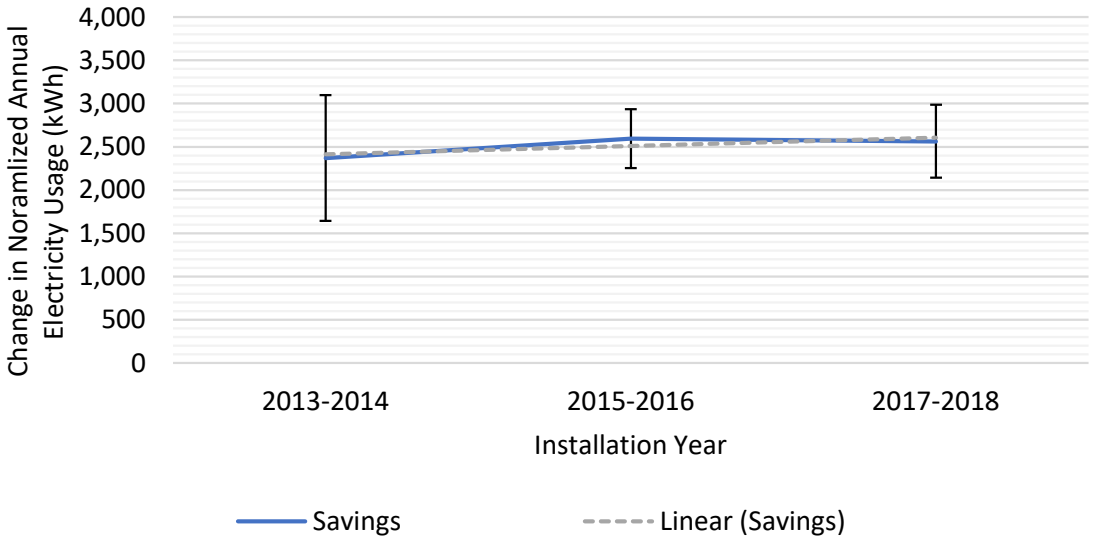


Chart 11: Electric savings for heat pump conversions in manufactured homes by installation year, 2013-2018

Reliability of Results

We assessed the results for each analysis scenario based on sample size, magnitude of savings, and relative precision, and assigned a confidence rating. While we have high or moderate confidence in many of the results, there are a few scenarios where we have low confidence in the value of the point estimate due to low precision, small sample size, or both. However, in most cases, the less reliable point estimates seem to fit roughly into a larger pattern of results. Scenarios with treatment group sample sizes less than 60 homes or very low precision were not assessed and are not reported here.

Summary of Results

In Table 2, below, we summarize the results of the various heat pump conversion scenarios analyzed in site-built homes. In Table 3, we summarize the results of heat pump conversion savings in manufactured homes. Results are provided in annual kWh savings for electrically heated homes that installed a heat pump between 2013 and 2018.

Table 2: Summary of heat pump conversion electric savings (kWh) in site-built homes, 2013-2018

Heating Zone	Utility	Cx Status	Home Size	N*	Baseline Energy Usage	Baseline Heating Usage	Average Savings†	Absolute Precision†	Percent Savings†	Realization Rate	Conf. Rating
All	All	All	All	1,302	18,063	7,634	1,977	±174	10.9%	48%	Very High
1	All	All	All	1,161	18,127	7,684	2,017	±185	11.1%	48%	Very High
2	All	All	All	126	17,673	7,215	1,496	±548	8.5%	31%	Moderate
All	PGE	All	All	707	18,346	8,177	2,433	±236	13.3%	--	Very High
All	PAC	All	All	594	17,648	6,994	1,437	±250	8.1%	--	High
All	All	Yes	All	976	18,002	7,623	2,020	±188	11.2%	43%	Very High
All	All	No	All	327	18,299	7,667	1,919	±309	10.5%	46%	High
All	All	All	<1,200	114	15,035	6,741	2,574	±448	17.1%	--	Moderate
All	All	All	1,200-1,999	518	16,975	7,477	2,122	±258	12.5%	--	High
All	All	All	2,000-2,999	204	20,234	7,998	1,454	±479	7.2%	--	Moderate
All	All	All	>=3,000	69	26,542	8,525	1,844	±1,134	6.9%	--	Low
1	PGE	All	All	680	18,330	8,151	2,358	±238	12.9%	--	High
1	PAC	All	All	481	17,910	7,048	1,527	±286	8.5%	--	High
2	PAC	All	All	108	17,317	6,646	969	±569	5.6%	--	Low
1	All	Yes	All	880	18,013	7,670	2,019	±199	11.2%	--	Very High
1	All	No	All	281	18,511	7,729	2,025	±332	10.9%	--	High
2	All	Yes	All	82	17,980	7,156	1,663	±587	9.2%	--	Moderate
All	PGE	Yes	All	526	18,274	8,098	2,469	±262	13.5%	--	High
All	PAC	Yes	All	450	17,740	7,071	1,496	±265	8.4%	--	High
All	PGE	No	All	183	18,927	8,405	2,453	±393	13.0%	--	High
All	PAC	No	All	146	17,984	6,759	1,347	±490	7.5%	--	Moderate

Note: results based on less than 60 treatment sites may be unreliable and were not assessed.

* N is the final treatment group sample size in the analysis.

† The savings, precision, and percent savings values are based on a future participant comparison group.

Table 3: Summary of heat pump conversion electric savings in manufactured homes, 2013-2018

Heating Zone	Utility	Cx Status	N*	Baseline Energy Usage	Baseline Heating Usage	Average Savings†	Absolute Precision†	Percent Savings†	Realization Rate	Conf. Rating
All	All	All	188	15,899	7,344	2,893	±328	18.2%	73%	High
1	All	All	165	15,567	7,320	2,931	±339	18.8%	70%	High
All	PGE	All	85	15,412	7,171	3,300	±415	21.4%	--	Moderate
All	PAC	All	103	16,301	7,485	2,554	±504	15.7%	--	Moderate
All	All	Yes	109	15,884	7,254	2,894	395	18.2%	65%	Moderate
All	All	No	79	15,920	7,467	2,891	448	18.2%	73%	Low

* N is the final treatment group sample size in the analysis.

† The savings, precision, and percent savings values are based on a future participant comparison group.

Conclusions and Recommendations

The Recurve analysis of heat pump conversion projects in electrically heated homes found that electric savings were substantially lower than expected across the board, although manufactured homes had higher savings and realization rates than site-built homes. Energy savings decreased slightly over time, which was accompanied by a slight decrease in average baseline energy usage. The relatively low overall baseline electricity usage and estimated heating loads may indicate that some homes simply do not use enough electricity to realize much savings from a heat pump conversion. This may be due to highly efficient homes with lower heating requirements than expected, or it could be due to the use of supplemental heating fuels, like wood, among other possibilities.

Projects completed in heating zone 1 appeared to have higher savings than those in heating zone 2, contrary to expectations, based on the colder climate of heating zone 2. In addition, savings were higher for PGE customers than for Pacific Power customers, a result that persisted after controlling for climate and commissioning status. In fact, the highest absolute savings were found among PGE customers in heating zone 1 and the lowest were among Pacific Power customers in heating zone 2. While it is not known why heat pump conversion savings are lower in heating zone 2, the possibilities include a higher prevalence of supplemental fuel use (e.g. wood heat) and an overreliance on backup resistance heating during cold periods. The lower savings observed in Pacific Power territory may be a result of a higher prevalence of wood heat, overreliance on backup resistance heating (especially in heating zone 2), and less stringent installation requirements and quality control than in PGE territory. Wood heating almost certainly plays a role in the lower electricity savings observed in those areas. As noted above, wood heat is much more prevalent in Southern and Eastern Oregon and the baseline electric heating loads were substantially lower than in the rest of the state, despite colder winter temperatures in heating zone 2.

Home size was an important factor in realized heat pump conversion savings in site-built homes. Smaller homes, less than 1,200 square feet, had the highest savings estimate. Percent savings decreased as home size increased. Absolute savings also decreased as home size increased, except that the largest two categories had roughly the same level of savings. This decrease in savings with home size was observed despite a large increase in electricity usage as home size increased. This trend may be a result of contractor heat pump sizing practices, where the capacity of installed heat pumps is not sized to meet the full heating load of larger homes. If a heat pump is undersized to the home, then it will require its backup resistance heating element more frequently during the heating season, reducing its energy performance. This makes

economic sense when considering the higher upfront cost of larger capacity heat pump units that would be able to meet the full heating load of a large home. To better assess the impact of heat pump sizing on energy performance, we would need more complete information than were available in the program data on system capacity, home size, and shell characteristics. Energy Trust needs to track these variables more completely in its program data. Alternatively, a follow-up study would be needed to collect and analyze the data needed to do this.

Commissioning and advanced control incentives were not associated with any additional electricity savings for heat pump conversion projects in site-built or manufactured homes. There may be a small amount of additional savings realized from commissioning activities in heating zone 2 and Pacific Power territory. However, the difference in savings estimates for heating zone 1 and PGE territory, respectively, are relatively small and not statistically significant.

Heat pump efficiency level (rated using the Heating Season Performance Factor (HSPF)) may be an important factor affecting energy performance and savings. Unfortunately, we were unable to analyze its impact due to a high degree of missing information in program data. However, some reports have suggested that HSPF rating does not play a large role in heat pump energy performance or savings. The RTF has stated that they do not "know of any studies that have isolated the real-world efficiency improvements of single-speed heat pumps with HSPF ratings higher than 8.5."[11] The type of heat pump system, such as single-stage, multi-stage, variable capacity, or cold climate, [12] may also have an impact on savings, but we were not able to assess this factor, due to lack of data. To further investigate the effects of HSPF and system type on heat pump conversion energy savings, Energy Trust needs to track these variables more completely in its program data. Alternatively, a follow-up study could be done to collect and analyze the data needed to assess the impacts of these factors.

We recommend conducting a thorough review of program rules and heat pump installation requirements to determine what is driving lower savings in heating zone 2 and Pacific Power territory. More thorough screening for supplemental fuels, like wood and gas, may be necessary to improve heat pump conversion savings. At the very least, offsets in wood use should be valued as non-energy benefits. In addition, sizing and control setting requirements should be reviewed to ensure that heat pumps can meet the full heating loads of the homes they are installed in and do not have an overreliance on backup resistance heating. Whether or not program rules and requirements are updated, we recommend a period of increased training and quality control visits to ensure that contractors are enforcing program rules and meeting installation requirements.

We also recommend conducting a thorough review of heat pump commissioning activities and advanced controls installations. This may involve collection of market data to understand how prevalent these services are and whether incentives are needed to improve the performance of heat pump projects. Further study of commissioning activities and advanced controls may also be needed to determine what the most effective practices are and how much energy they save. Although this analysis was unable to detect any savings from commissioning activities in general, there may be certain services that are more

[11] Regional Technical Forum. 2020. Single-speed Air Source Heat Pumps: Energy Impacts of Efficiency Program Design Elements. Retrieved on 1/20/2021 from: https://nwcouncil.box.com/v/ASHPWhitePaperCleanDraft.
[12] Also known as "extended capacity" variable speed heat pumps. Energy Trust researched this technology separately in a 2018/2019 pilot study summarized in this report: https://www.energytrust.org/wp-content/uploads/2020/04/ECHP-Pilot-Wrap-up-Memo-v4.pdf.

effective or that can be improved. The value of these services will most likely interact with any efforts to improve heat pump sizing requirements.

Heat pump conversion projects appear to save the most energy in situations that may benefit lower income customers the most: smaller, electrically-heated, site-built and manufactured homes. While Energy Trust already has offerings that focus on the manufactured homes market, it may be worth investigating new offerings for small home or rental home heat pump conversions. Not only could this be used to better reach low- and moderate-income customers, but it may be much more cost-effective, with higher energy savings at lower installed costs.

We recommend revisiting and adopting new deemed electric savings values for heat pump conversion measures in both site-built and manufactured homes, based on the findings of this analysis. The real-world savings for heat pump conversions are much lower than expected. This may be a result of lax program rules and installation requirements, or the deemed savings estimates may be unrealistically high, given recent heating loads of homes with electric forced air furnaces in Oregon. Whatever the cause, Energy Trust should adjust its savings claims to better reflect reality.

Appendix A: Recurve Impact Analysis Reports

List of Heat Pump Conversion Analysis Reports:

- Overall results
    - Site-built homes
    - Manufactured homes
- Results by heating zone
    - Site-built homes
        - Heating zone 1
        - Heating zone 2
    - Manufactured homes
        - Heating zone 1
        - Heating zone 2
- Results by utility territory
    - Site-built homes
        - PGE customers
        - Pacific Power customers
    - Manufactured homes
        - PGE customers
        - Pacific Power customers
- Results by commissioning and controls incentive status
    - Site-built homes
        - Commissioning incentives paid
        - Commissioning incentives not paid
    - Manufactured homes
        - Commissioning incentives paid
        - Commissioning incentives not paid

Impact Evaluation Report

Electricity Impact of Ductedheatpump-Manufactured in Program Year 2013, 2014, 2015, 2016, 2017, 2018

Result Summary

Measure: Ductedheatpump-Manufactured	Program Year: 2013, 2014, 2015, 2016, 2017, 2018		Fuel: Electricity	
Meter Data Filters:	DNAC: <100%	DNAC Percentile: Remove Top and Bottom 0.5%	Annual Consumption Percentile: Remove Top and Bottom 0.5%	*Last Consumption Data Update:* Q1 2020 *Last Participation Data Update:* Q1 2020
Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): All	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: All
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: All	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

188 Treatment Meters	2539 +/- 259 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	16 +/- 2 % Percent Normal Year Pre-Post Difference in Consumption per Participant	15,899 Mean Baseline Consumption (Electricity)	57% Realization Rate
296 Site-level Matched Meters	2492 +/- 343 kWh Average Savings Relative to Site-level Matched Comparison Group	16 +/- 2% Percent Savings Relative to Site-level Matched Comparison Group	14,339 Mean Baseline Consumption (Electricity)	56% Realization Rate
388 Future Participant Meters	2893 +/- 328 kWh Average Savings Relative to Future Participant Group	18 +/- 2% Savings Relative to Future Participant Group	15,499 Mean Baseline Consumption (Electricity)	65% Realization Rate

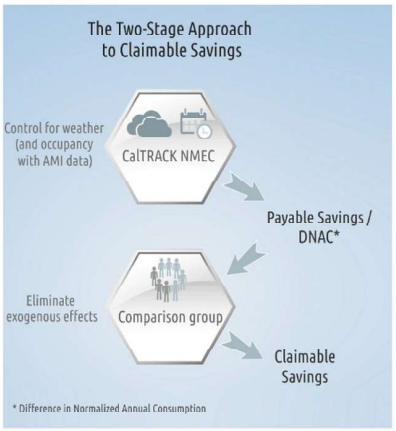
1. Introduction

This report contains the results of applying the two-stage approach (informed by the DOE's uniform methods chapter on whole building analysis) for calculating claimable savings to the selected portfolio of energy efficiency projects (see Figure). This approach begins with identification of two comparison groups for the treatment sample: (a) a site-level matched comparison group and (b) a future participant group. These groups are described below along with summary statistics (site locations, sample size, baseline consumption and baseline load disaggregation).

The CalTRACK methods are then applied to arrive at site-level savings, normalized for weather, and reflective of energy consumption changes for customers at the meter. Using a difference of differences for the treatment group with each comparison group accounts for population-level consumption changes (e.g. economic changes, rate changes, natural energy efficiency adoption etc.). The methods contained within this report are the outcome of a recent peer-reviewed study completed by Energy Trust of Oregon and Open Energy Efficiency (see "Methodology" section for more details).

The report includes the following sections:
Result Summary - Includes the overall portfolio results
Section 1. Introduction - Overview of report and the different groups included in the analysis
Section 2. Data Preparation - Data cleaning and sample attrition
Section 3. Modeling Results - CalTRACK model outputs and Difference in Normalized Annual Consumption (DNAC) results
Section 4. Methodology - Description of methods used in this report

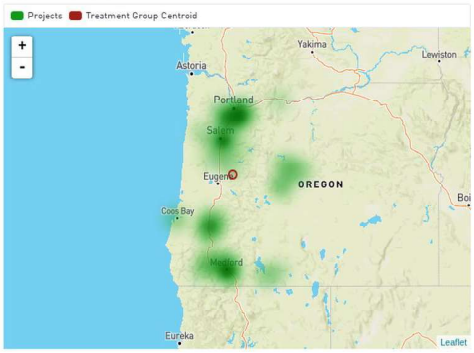
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations

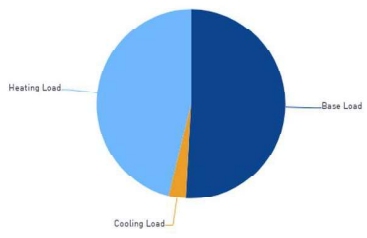


132.8 miles

80% of projects lie within this distance from treatment group centroid

188	15,899
Meters	Mean Baseline Consumption (Electricity)

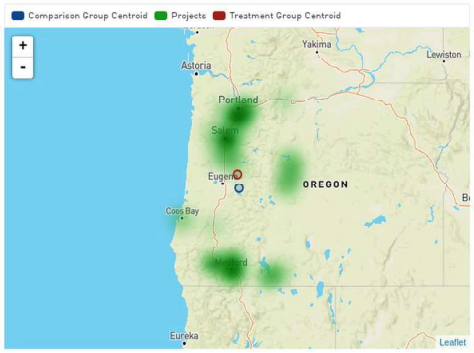
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations

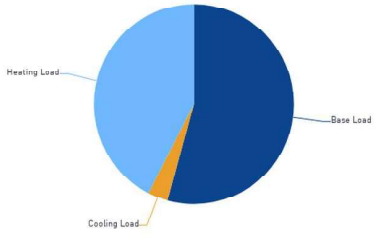


27.7 miles

Distance between treatment and comparison group centroids

296	14,339
Meters	Mean Baseline Consumption (Electricity)

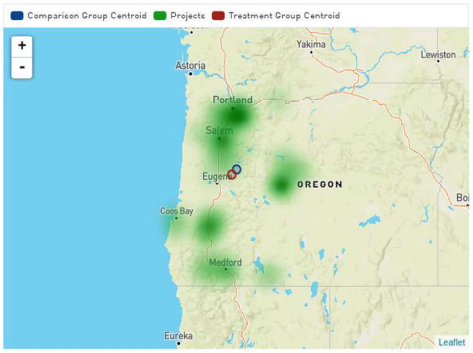
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

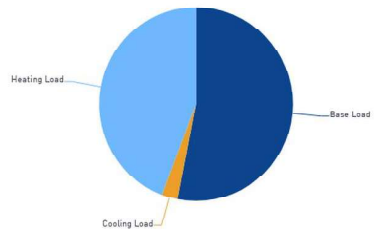


9.0 miles

Distance between treatment and future participant group centroids

388	15,499
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

710	188	26%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

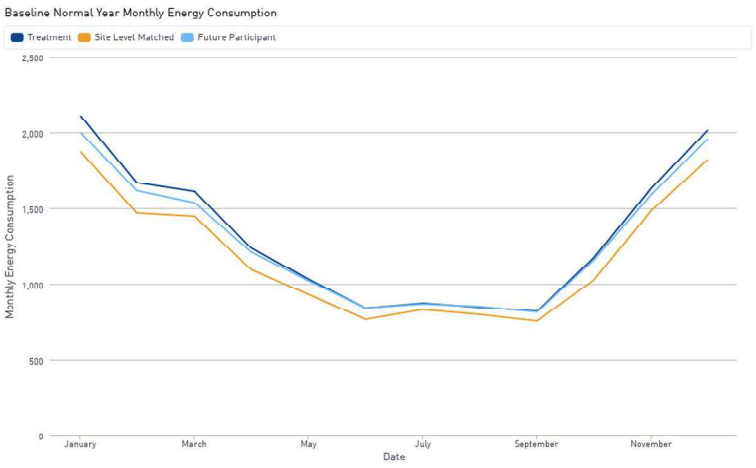
Sample Attrition Table

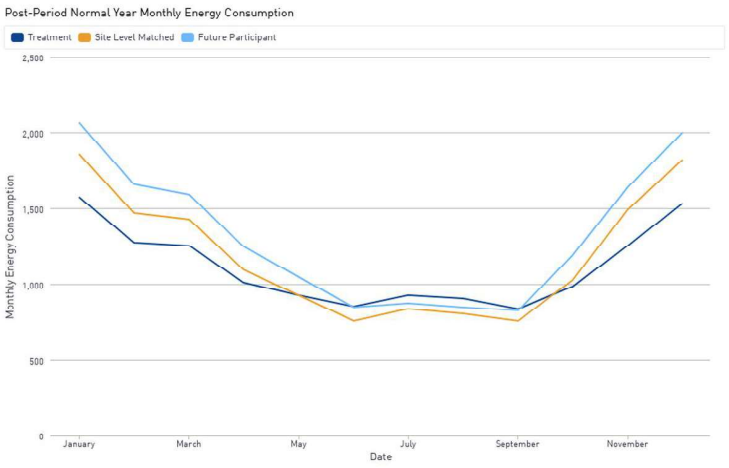
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-MANUFACTURED	115472	678
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	678
4	Fuel	Electricity	0	678
5	Valid consumption data in baseline and reporting periods	valid data	0	678
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	678
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	2	676
8	HeatingZone: Meters in selected heating climate zone.	--	0	676
9	CoolingZone: Meters in selected cooling climate zone.	--		676
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	236	440
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	440
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	2	438
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	2	436
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	0	436
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	50	386
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	386
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	386
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	386
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	386
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	386
21	Electricity Provider	--	0	386
22	Home Size [Sq Ft]	--	0	386
23	Water heating fuel type	--	0	386
24	Heat pump type	HEATPUMPREP	196	190
25	Contractor	--	0	190
26	Thermostat name	--		190
27	Heat pump baseline equipment	--	0	190
28	Heat pump manufacturer	--	0	190
29	Heat pump comissioning	--	0	190
30	Multi-measure elec	=false	2	188
31	Multi-measure gas	--	0	188

3. Modeling Results

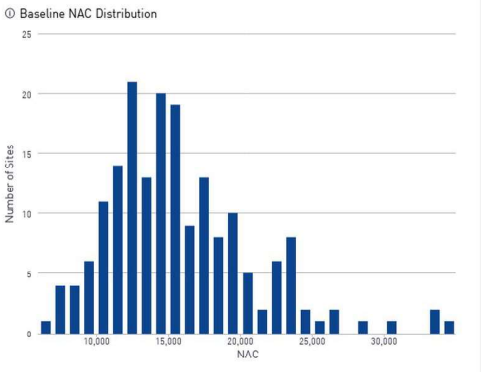
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

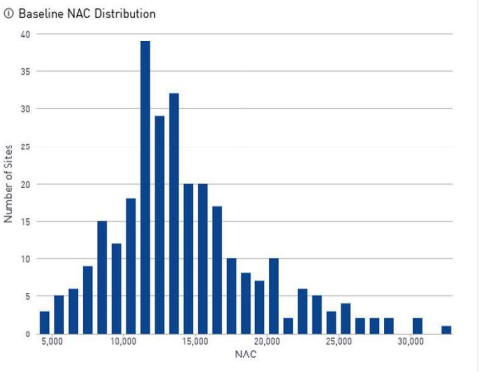




Treatment Group



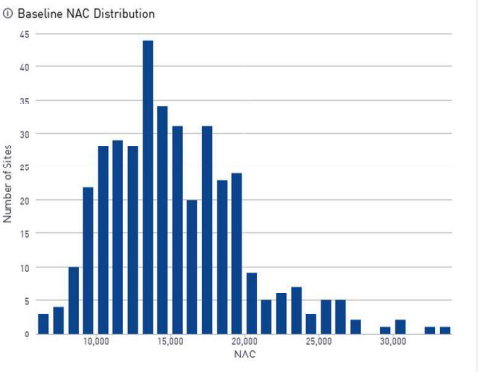
Site-level Matched Comparison Group



0.129

Annual Consumption p-value

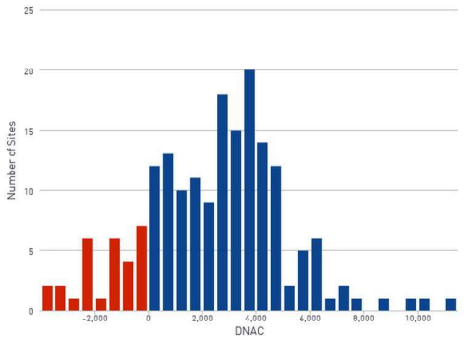
Future Participant Group



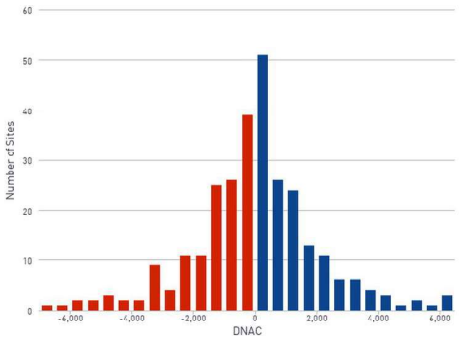
0.242

Annual Consumption p-value

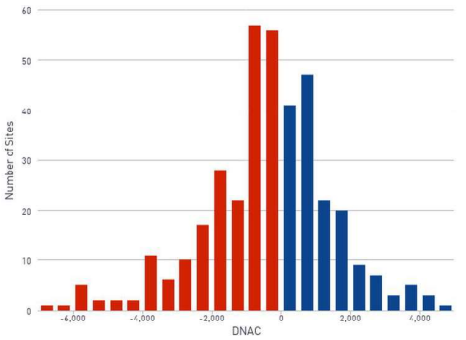
DNAC Distribution



DNAC Distribution



DNAC Distribution

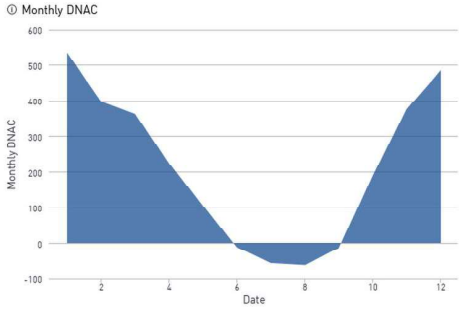


2539 +/- 259 kWh	16 +/- 2 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

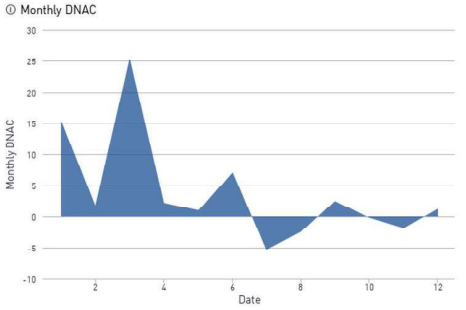
47 +/- 226 kWh	0 +/- 2 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

-354 +/- 202 kWh	-2 +/- 1 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

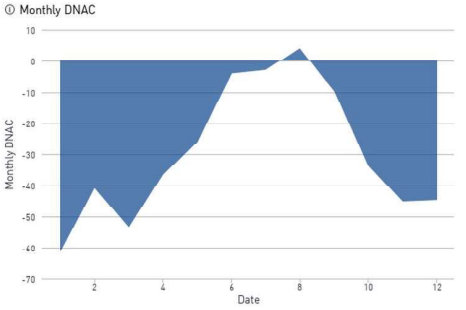
Monthly DNAC



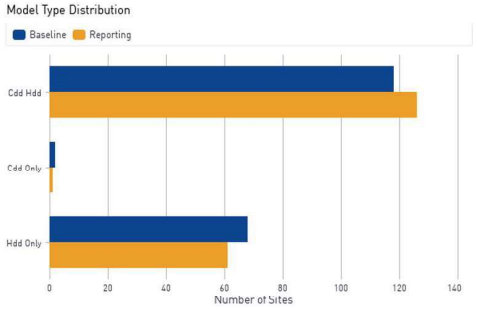
Monthly DNAC



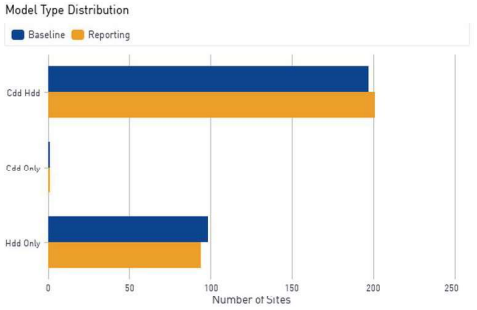
Monthly DNAC



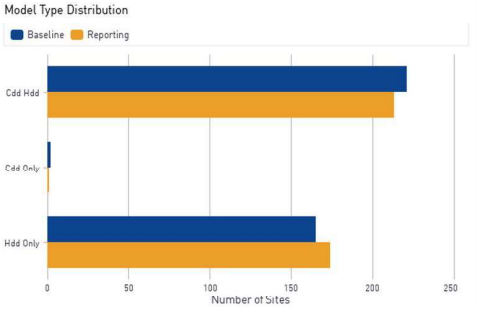
Model Type Distribution



Model Type Distribution



Model Type Distribution

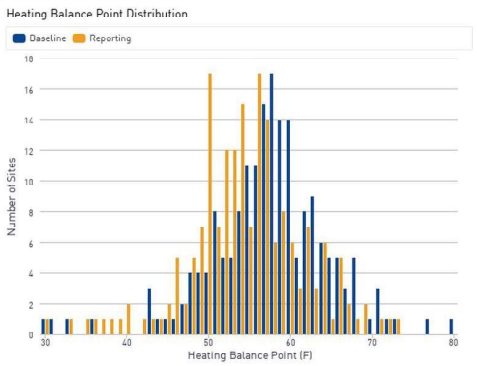


Treatment Group

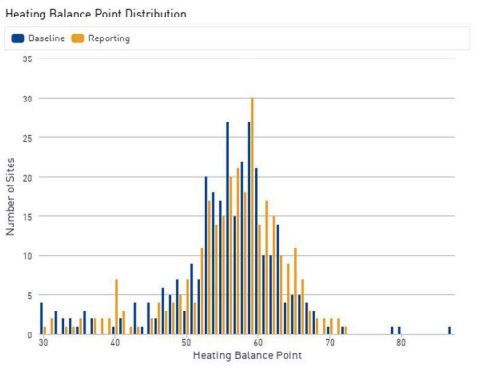
Site-level Matched Comparison Group

Future Participant Group

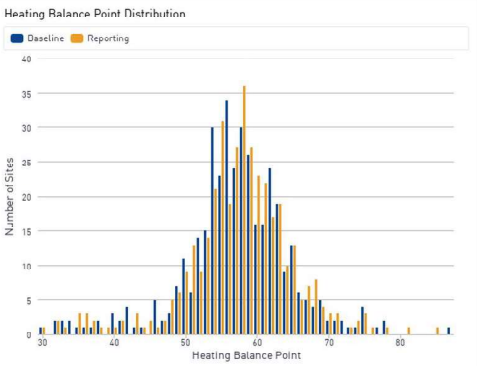
Heating Balance Point Distribution



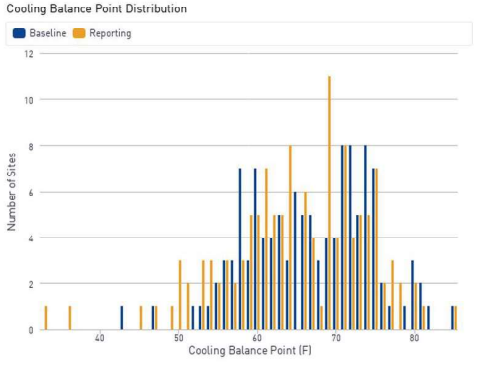
Heating Balance Point Distribution



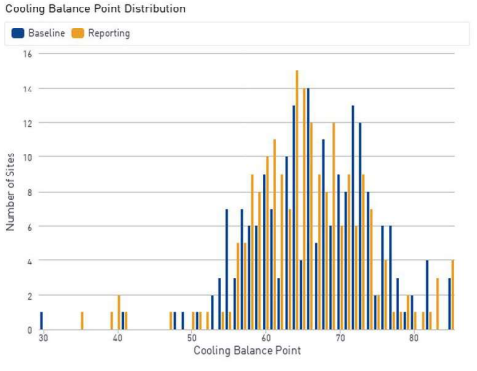
Heating Balance Point Distribution



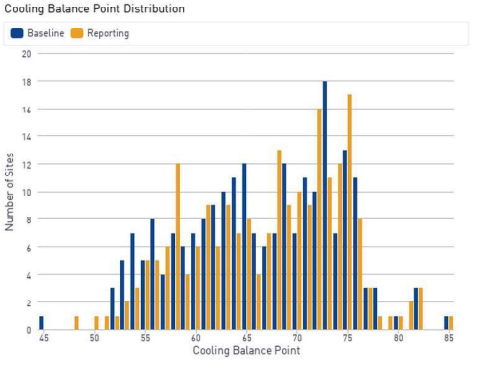
Cooling Balance Point Distribution



Cooling Balance Point Distribution



Cooling Balance Point Distribution



4. Methodology

CalTRACK and Comparison Group Methods
Documentation: docs.caltrack.org
Code: https://github.com/energy_market_methods/caltrack

Data Preparation

Baseline period: Since the predicted baseline may be unstable with different baseline period lengths, which may, in turn, affect calculated savings, the consensus of the CalTRACK 2.0 working group was to set the maximum baseline period at 12 months, since the year leading to the energy efficiency intervention is the most indicative of recent energy use trends and prolonging the baseline period increases the chance of other unmeasured factors affecting the baseline. In addition, CalTRACK uses a minimum 12-month baseline by default.

Blackout period: The blackout period refers to the time period between the end of the baseline period and the beginning of the reporting period. In this analysis, it is specified to coincide with the project installation time period, meaning that the billing period that contains the project installation date is dropped from the analysis.

Analysis periods: Different portions of the analysis used different time periods of consumption data, therefore, it is useful to clearly define these time periods and where they were used. Consider a project with an installation date on a particular day d in a particular month m in a particular program year y. The year before the program year is labelled as y-1, the year prior to that as y-2 and so on, while the years following the program year are labelled y+1, y+2 etc. In all cases, the billing period that contains the project installation was dropped from the analysis. Other sections of the analysis use the following time periods:
- *Treatment and site-level matched groups:* Baseline period includes the 12 months preceding the installation billing period. Reporting period includes the 12 months following the installation billing period.
- *Future participant group:* Baseline period is the calendar year preceding the program year (Year *y-1*). Reporting period is the program year itself (Year *y*).
- Site-level consumption matching was performed using the 12 months of data immediately prior to the project installation date.
- Equivalence tests were performed using data from the previous calendar year (y-1).

Modeling

Weather Normalization: Weather normalization of billing data in CalTRACK follows certain model foundations in literature (PRISM, ASHRAE Guideline 14, IPMVP Option C and the Uniform Methods Project for Whole Home Building Analysis). Building energy use is modeled as a combination of base load, heating load, and cooling load. Heating load and cooling load are assumed to have a linear relationship with heating and cooling demand, as approximated by heating and cooling degree days, beyond particular heating and cooling balance points. A number of candidate OLS models are fit to the consumption data using different combinations of heating and cooling balance points (ranging from 30 to 90 F) and different sets of independent variables. The model with the highest adjusted R-squared that contains strictly positive coefficients is selected as the final model and used to calculate normalized energy usage.

Model Types: CalTRACK specifies a linear relationship between energy use and temperature as reflected in the building consumption profile. In the most generic case, a model would include an intercept term, a heating balance point and heating slope coefficient, and a cooling balance point and a cooling slope coefficient. Depending on the fuel a building uses for heating or cooling or its consumption patterns, models with a single temperature coefficient and balance point (i.e., heating or cooling) may be more appropriate.

Difference in Normalized Annual Consumption (DNAC): The DNAC is calculated by using two CalTRACK regression models in conjunction with Typical Meteorological Year (TMY3) weather data, as follows:
- Two models are fit to the consumption data - one model for the baseline (pre-intervention) period and one for the reporting (post-intervention) period.
- Long-term heating and cooling degree days based on TMY3 data are substituted in both regression equations to calculate the Normalized Annual Consumption (NAC) for each period. TMY3 data is maintained by NREL and includes weather averages for 1020 locations in the US between 1991-2005.
- DNAC is determined by subtracting the two NACs (DNAC = Baseline NAC - Reporting NAC).

Disaggregation: Disaggregated loads are calculated from the different components of the statistical model fit. The weather sensitive components (heating and cooling load) are calculated by multiplying the relevant model coefficients (beta_hdd or beta_cdd) by the total degree days in a normal weather year (total HDD or CDD). For each site, the total HDD or CDD can be calculated using that site's estimated degree day balance points (also an output of the model) and the temperature for its closest weather station. The base load is estimated by multiplying the intercept of the statistical model by the number of days (365 for a full year).

Savings calculation: Savings are calculated by subtracting the DNAC for either comparison group from the DNAC for the treatment group.

Savings Uncertainty: Uncertainty presented in this analysis is calculated using the ASHRAE Guideline 14 formulation for aggregating the prediction uncertainty of point estimates in a time series. It is calculated at a 90% confidence level. The total uncertainty at the site-level is calculated using the sum of squares of the baseline and reporting models. Other aggregate uncertainty values (e.g. for a portfolio or for a difference-in-differences estimate) are also aggregated using the square root of the sum of squares.

Comparison Group Generation

Site-level Matching: In monthly consumption matching, a comparison group is constructed by selecting 20 matches from the comparison group pool with the shortest distance d to the treatment group customer under consideration. After applying the selected filters on the comparison group, the comparison group is filtered down to the closest 5 matches to each treatment group member. The pool is limited to non-participants within the same zipcode as the treatment group customer. The distance d is, in essence, a way to reduce 12 monthly consumption differences between any two customers to one metric (see Figure). In the present analysis, we selected twenty nearest neighbors for each treatment site based on the Euclidean distance of monthly consumption.

Future Participant Groups: Comparison groups comprising future participants are considered to be representative of participants in most aspects (observable and non-observable). For example, future participants are known to be eligible to receive the measure, and for some measures, they may have the same baseline equipment as the participants. Future participants have the same propensity to participate in the program as participants, thus reducing or eliminating self-selection bias, something that is otherwise difficult to control for in a quasi-experimental study. More comprehensive data is typically collected for future participants, allowing for potentially better matching and more insightful analysis. From a practical perspective, future participant groups may be difficult to construct for all measures, unless a program has been running for multiple years and is considered stable with sufficient data collection over the analysis period. Sample sizes for the comparison group may also be constrained if using future participants.

Stratified sampling is applied to future participant groups to attempt to replicate the distributions of the underlying variable (annual consumption) in the comparison group. Annual consumption of all treatment sites is first split into deciles, then a random sample is selected from within each corresponding bin in the comparison group pool of future participants.

Sampling method: In all cases where sampling was required from the comparison group, sampling was performed without replacement.

Impact Evaluation Report

Electricity Impact of Ductedheatpump-Site-Built in Program Year 2013, 2014, 2015, 2016, 2017, 2018

Result Summary

Measure: Ductedheatpump-Site-Built	Program Year: 2013, 2014, 2015, 2016, 2017, 2018		Fuel: Electricity	
Meter Data Filters:	DNAC: <100%	DNAC Percentile: Remove Top and Bottom 0.5%	Annual Consumption Percentile: Remove Top and Bottom 0.5%	*Last Consumption Data Update:* Q1 2020 *Last Participation Data Update:* Q1 2020
Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): All	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: All
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: All	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

1,302 Treatment Meters	1769 +/- 133 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	10 +/- 1 % Percent Normal Year Pre-Post Difference in Consumption per Participant	18,063 Mean Baseline Consumption (Electricity)	40% Realization Rate
3,726 Site-level Matched Meters	1720 +/- 145 kWh Average Savings Relative to Site-level Matched Comparison Group	10 +/- 1% Percent Savings Relative to Site-level Matched Comparison Group	13,766 Mean Baseline Consumption (Electricity)	39% Realization Rate
1,930 Future Participant Meters	1977 +/- 174 kWh Average Savings Relative to Future Participant Group	11 +/- 1% Savings Relative to Future Participant Group	17,998 Mean Baseline Consumption (Electricity)	44% Realization Rate

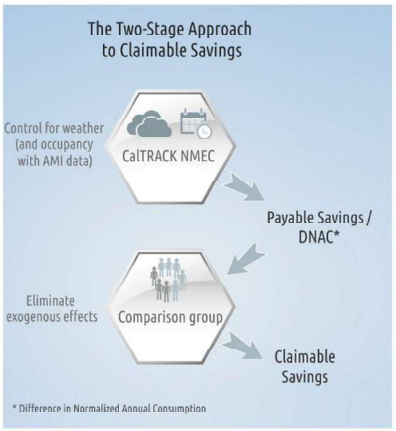
1. Introduction

This report contains the results of applying the two-stage approach (informed by the DOE's uniform methods chapter on whole building analysis) for calculating claimable savings to the selected portfolio of energy efficiency projects (see Figure). This approach begins with identification of two comparison groups for the treatment sample: (a) a site-level matched comparison group and (b) a future participant group. These groups are described below along with summary statistics (site locations, sample size, baseline consumption and baseline load disaggregation).

The CalTRACK methods are then applied to arrive at site-level savings, normalized for weather, and reflective of energy consumption changes for customers at the meter. Using a difference of differences for the treatment group with each comparison group accounts for population-level consumption changes (e.g. economic changes, rate changes, natural energy efficiency adoption etc.). The methods contained within this report are the outcome of a recent peer-reviewed study completed by Energy Trust of Oregon and Open Energy Efficiency (see "Methodology" section for more details).

The report includes the following sections:
Result Summary - Includes the overall portfolio results
Section 1. Introduction - Overview of report and the different groups included in the analysis
Section 2. Data Preparation - Data cleaning and sample attrition
Section 3. Modeling Results - CalTRACK model outputs and Difference in Normalized Annual Consumption (DNAC) results
Section 4. Methodology - Description of methods used in this report

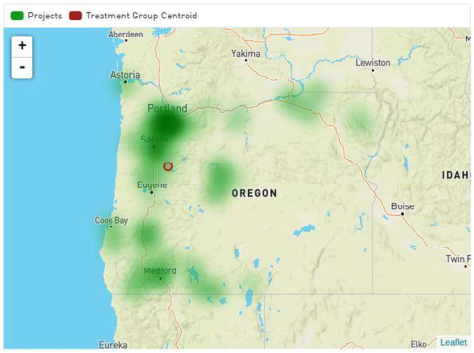
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations

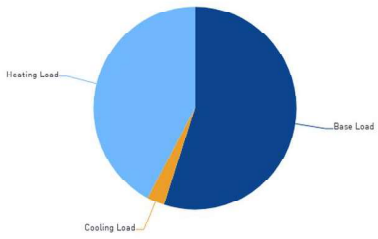


152.4 miles

80% of projects lie within this distance from treatment group centroid

1,302	18,063
Meters	Mean Baseline Consumption (Electricity)

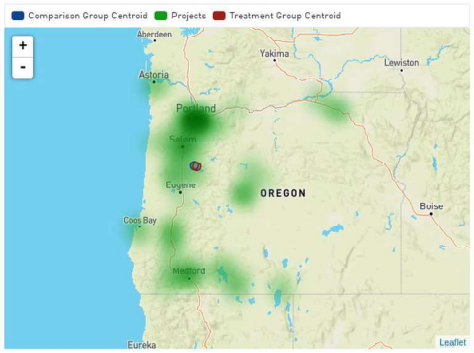
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations

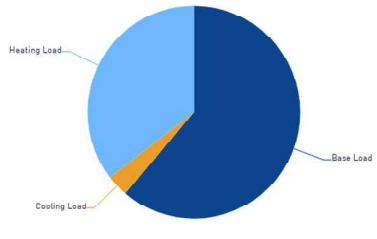


3.8 miles

Distance between treatment and comparison group centroids

3,726	13,766
Meters	Mean Baseline Consumption (Electricity)

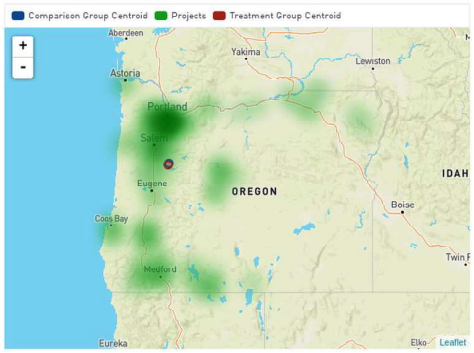
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

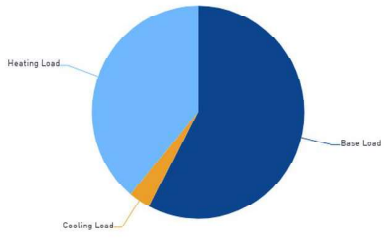


2.2 miles

Distance between treatment and future participant group centroids

1,930	17,998
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

7,398	1,302	18%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

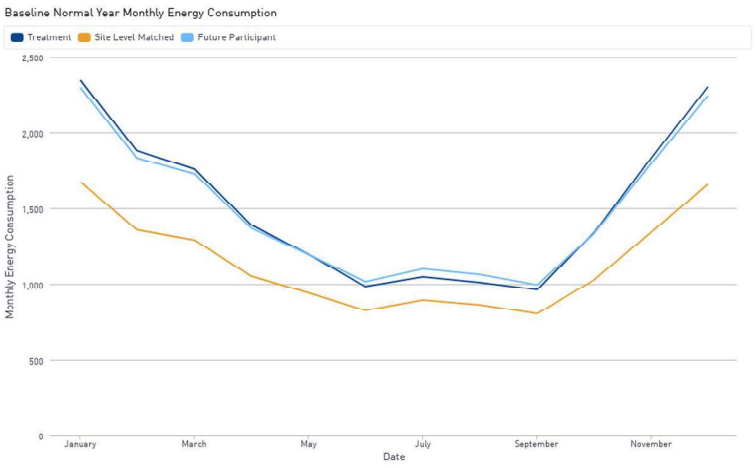
Sample Attrition Table

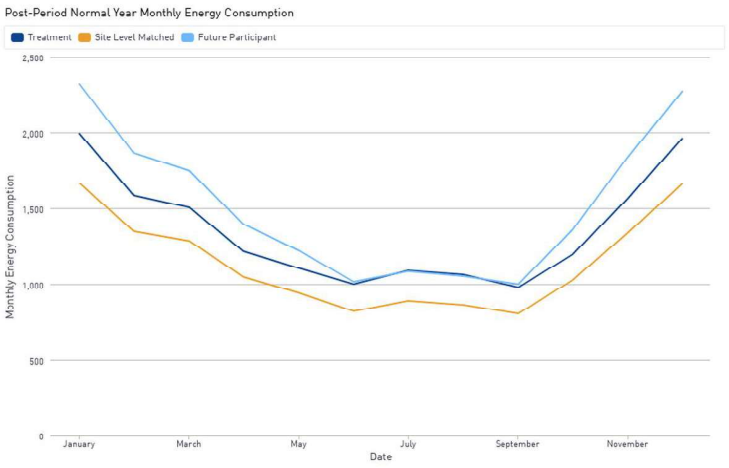
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-SITE-BUILT	108901	7249
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	7249
4	Fuel	Electricity	0	7249
5	Valid consumption data in baseline and reporting periods	valid data	0	7249
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	7249
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	91	7158
8	HeatingZone: Meters in selected heating climate zone.	--	0	7158
9	CoolingZone: Meters in selected cooling climate zone.	--		7158
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	1742	5416
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	5416
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	104	5312
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	26	5286
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	20	5266
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	701	4565
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	4565
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	4565
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	4565
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	4565
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	4565
21	Electricity Provider	--	0	4565
22	Home Size (Sq Ft)	--	0	4565
23	Water heating fuel type	--	0	4565
24	Heat pump type	HEATPUMPREP	3226	1339
25	Contractor	--	0	1339
26	Thermostat name	--		1339
27	Heat pump baseline equipment	--	0	1339
28	Heat pump manufacturer	--	0	1339
29	Heat pump comissioning	--	0	1339
30	Multi-measure elec	=false	37	1302
31	Multi-measure gas	--	0	1302

3. Modeling Results

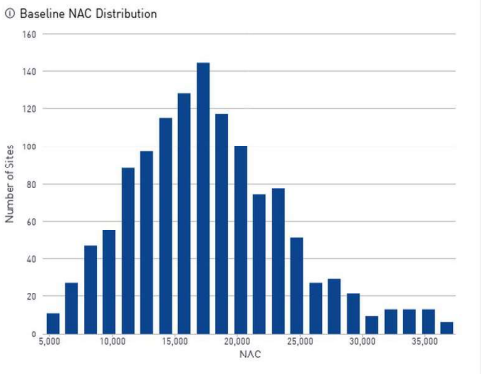
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

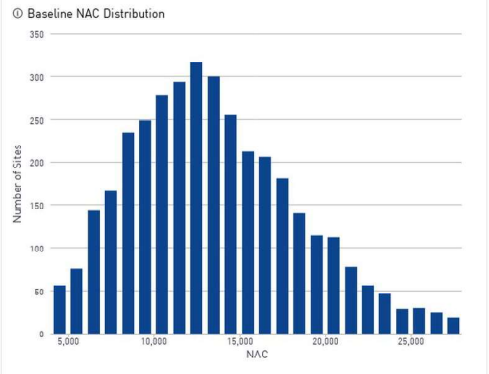




Treatment Group



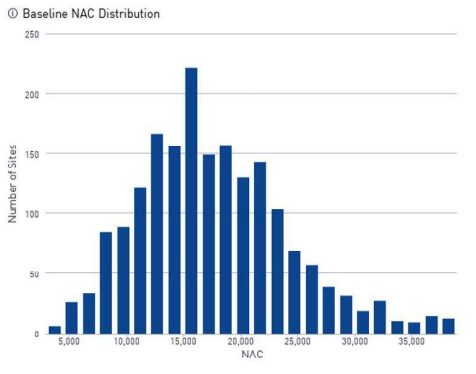
Site-level Matched Comparison Group



0.0397

Annual Consumption p-value

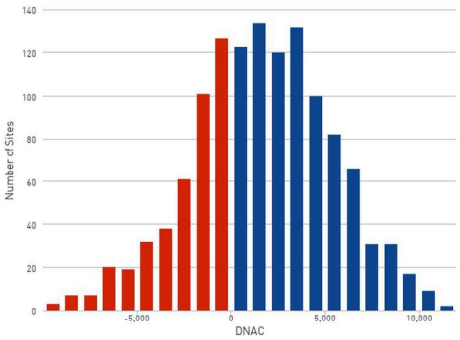
Future Participant Group



0.128

Annual Consumption p-value

DNAC Distribution



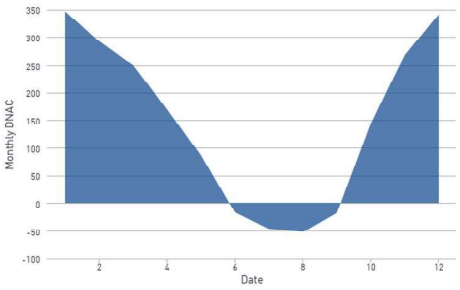
1769 +/- 133 kWh

Average Difference in Normalized Annual Consumption per Participant

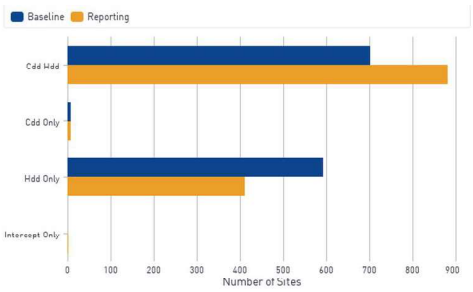
10 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

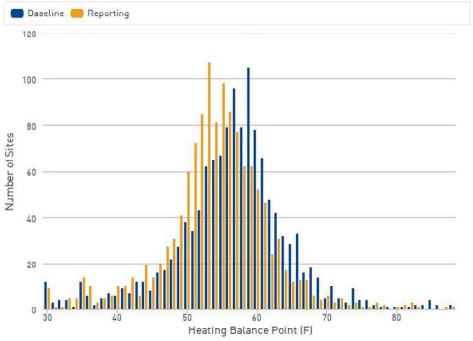


Model Type Distribution

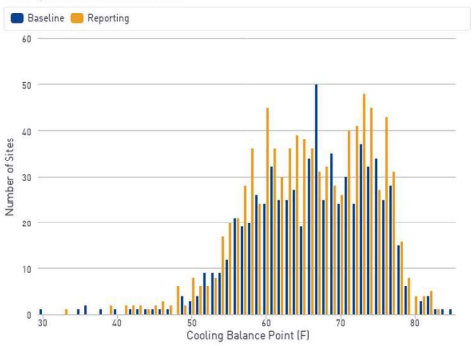


Treatment Group

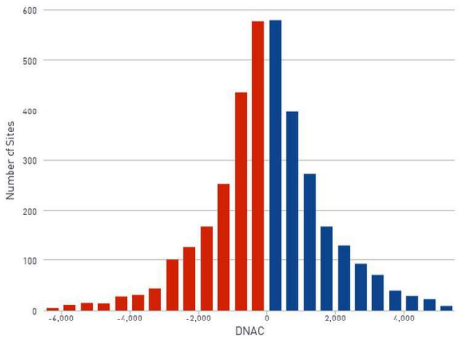
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



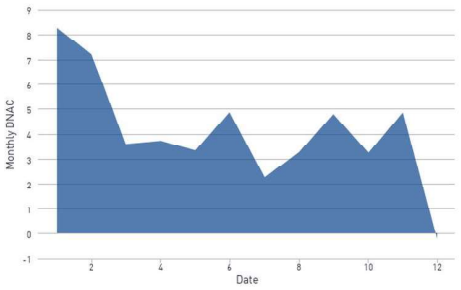
49 +/- 57 kWh

Average Difference in Normalized Annual Consumption per Participant

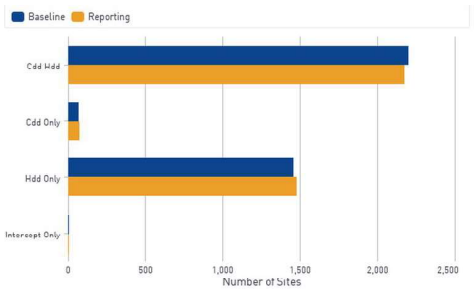
0 +/- 0 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

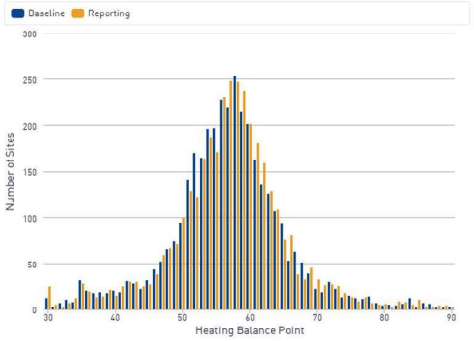


Model Type Distribution

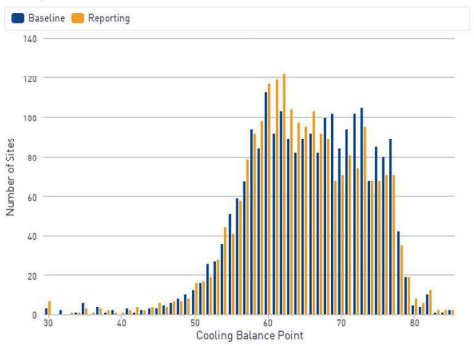


Site-level Matched Comparison Group

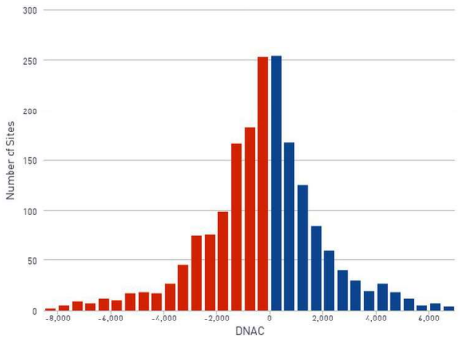
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



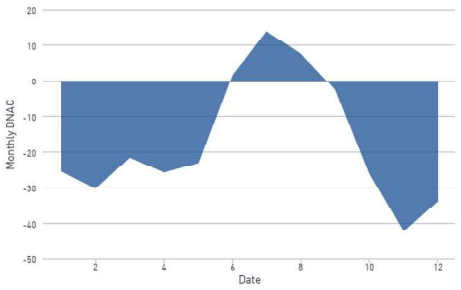
-208 +/- 112 kWh

Average Difference in Normalized Annual Consumption per Participant

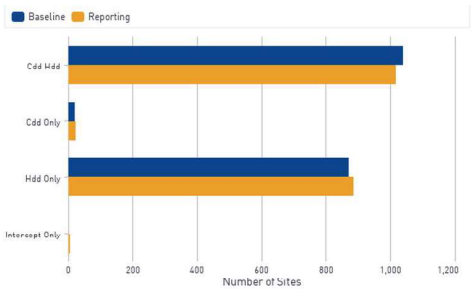
-1 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

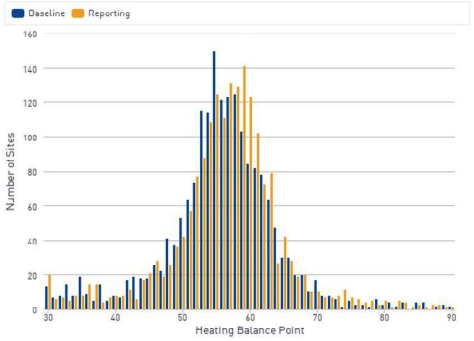


Model Type Distribution

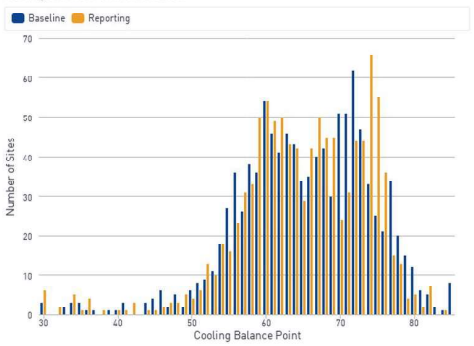


Future Participant Group

Heating Balance Point Distribution



Cooling Balance Point Distribution



Impact Evaluation Report

Electricity Impact of Ductedheatpump-Manufactured in Program Year 2013, 2014, 2015, 2016, 2017, 2018

Result Summary

Measure: Ductedheatpump-Manufactured	Program Year: 2013, 2014, 2015, 2016, 2017, 2018		Fuel: Electricity	
Meter Data Filters:	DNAC: <100%	DNAC Percentile: Remove Top and Bottom 0.5%	Annual Consumption Percentile: Remove Top and Bottom 0.5%	*Last Consumption Data Update:* Q1 2020 *Last Participation Data Update:* Q1 2020
Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): 1 - Hdd <= 6000	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: All
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: All	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

165 Treatment Meters	2607 +/- 268 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	17 +/- 2 % Percent Normal Year Pre-Post Difference in Consumption per Participant	15,567 Mean Baseline Consumption (Electricity)	60% Realization Rate
263 Site-level Matched Meters	2642 +/- 355 kWh Average Savings Relative to Site-level Matched Comparison Group	17 +/- 2% Percent Savings Relative to Site-level Matched Comparison Group	14,205 Mean Baseline Consumption (Electricity)	61% Realization Rate
314 Future Participant Meters	2931 +/- 339 kWh Average Savings Relative to Future Participant Group	19 +/- 2% Savings Relative to Future Participant Group	15,112 Mean Baseline Consumption (Electricity)	67% Realization Rate

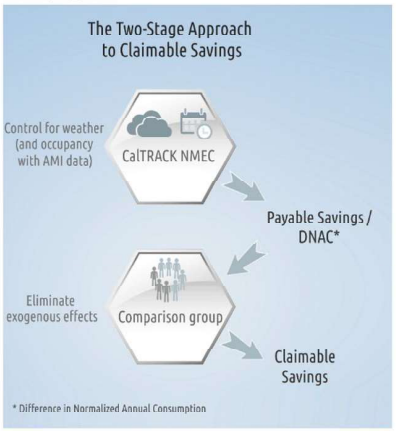
1. Introduction

This report contains the results of applying the two-stage approach (informed by the DOE's uniform methods chapter on whole building analysis) for calculating claimable savings to the selected portfolio of energy efficiency projects (see Figure). This approach begins with identification of two comparison groups for the treatment sample: (a) a site-level matched comparison group and (b) a future participant group. These groups are described below along with summary statistics (site locations, sample size, baseline consumption and baseline load disaggregation).

The CalTRACK methods are then applied to arrive at site-level savings, normalized for weather, and reflective of energy consumption changes for customers at the meter. Using a difference of differences for the treatment group with each comparison group accounts for population-level consumption changes (e.g. economic changes, rate changes, natural energy efficiency adoption etc.). The methods contained within this report are the outcome of a recent peer-reviewed study completed by Energy Trust of Oregon and Open Energy Efficiency (see "Methodology" section for more details).

The report includes the following sections:
Result Summary - Includes the overall portfolio results
Section 1. Introduction - Overview of report and the different groups included in the analysis
Section 2. Data Preparation - Data cleaning and sample attrition
Section 3. Modeling Results - CalTRACK model outputs and Difference in Normalized Annual Consumption (DNAC) results
Section 4. Methodology - Description of methods used in this report

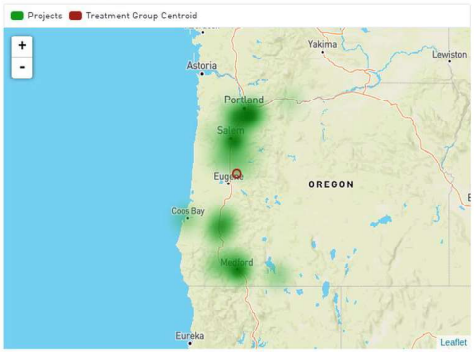
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations

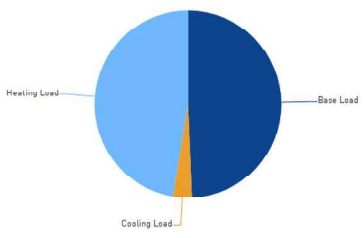


133.5 miles

80% of projects lie within this distance from treatment group centroid

165	15,567
Meters	Mean Baseline Consumption (Electricity)

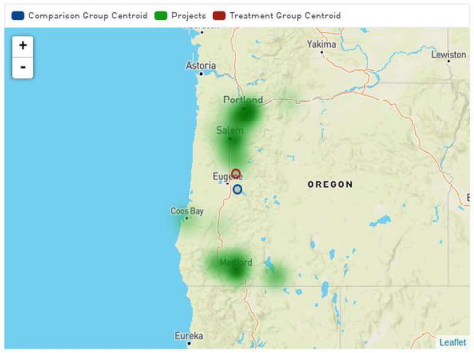
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations

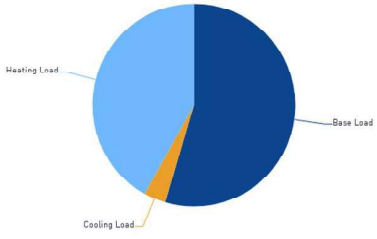


32.1 miles

Distance between treatment and comparison group centroids

263	14,205
Meters	Mean Baseline Consumption (Electricity)

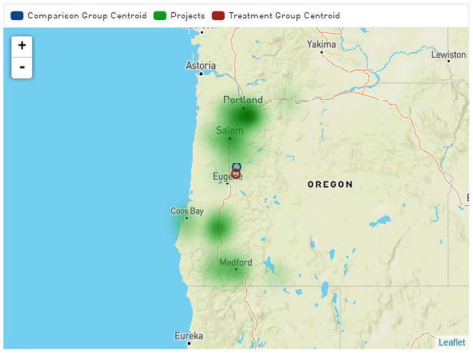
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

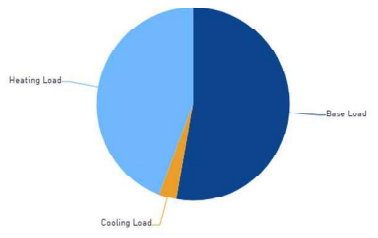


8.7 miles

Distance between treatment and future participant group centroids

314	15,112
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

710	165	23%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

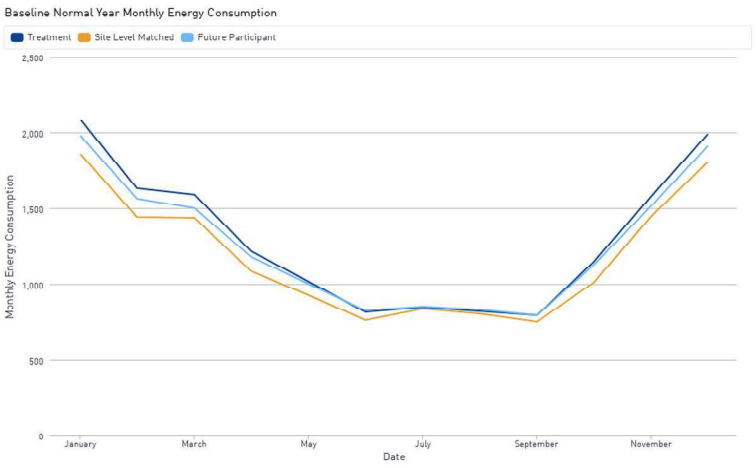
Sample Attrition Table

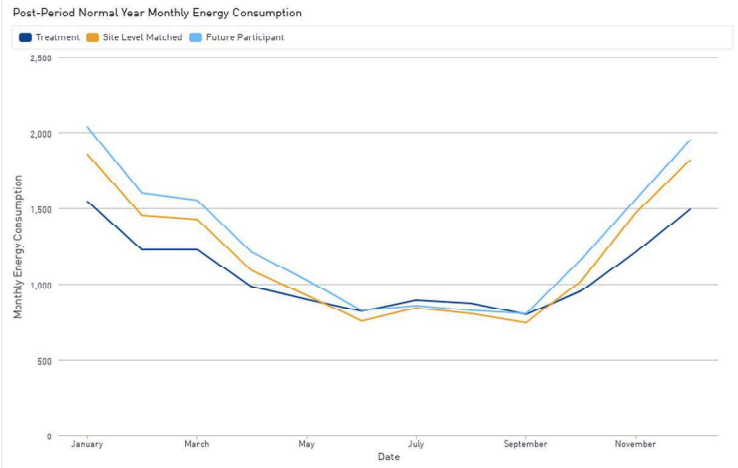
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-MANUFACTURED	115472	678
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	678
4	Fuel	Electricity	0	678
5	Valid consumption data in baseline and reporting periods	valid data	0	678
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	678
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	2	676
8	HeatingZone: Meters in selected heating climate zone.	1	119	557
9	CoolingZone: Meters in selected cooling climate zone.	--		557
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	165	392
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	392
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	2	390
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	1	389
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	0	389
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	45	344
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	344
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	344
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	344
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	344
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	344
21	Electricity Provider	--	0	344
22	Home Size [Sq Ft]	--	0	344
23	Water heating fuel type	--	0	344
24	Heat pump type	HEATPUMPREP	177	167
25	Contractor	--	0	167
26	Thermostat name	--		167
27	Heat pump baseline equipment	--	0	167
28	Heat pump manufacturer	--	0	167
29	Heat pump comissioning	--	0	167
30	Multi-measure elec	=false	2	165
31	Multi-measure gas	--	0	165

3. Modeling Results

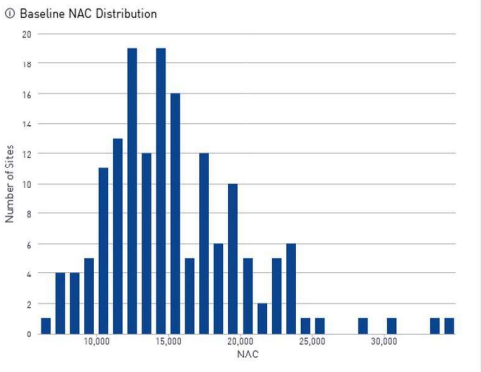
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

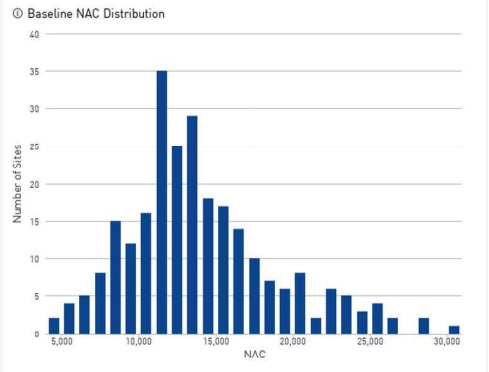




Treatment Group



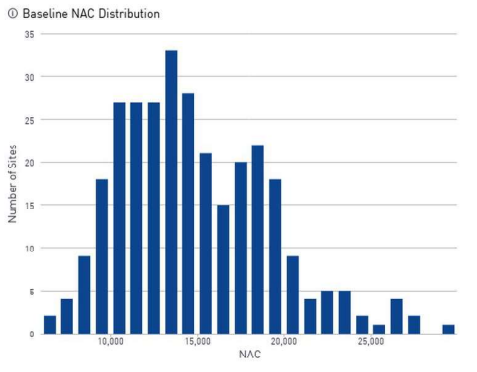
Site-level Matched Comparison Group



0.214

Annual Consumption p-value

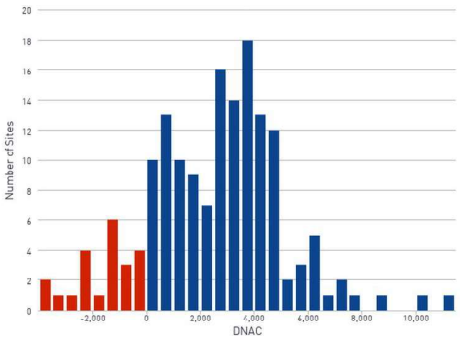
Future Participant Group



0.26

Annual Consumption p-value

DNAC Distribution



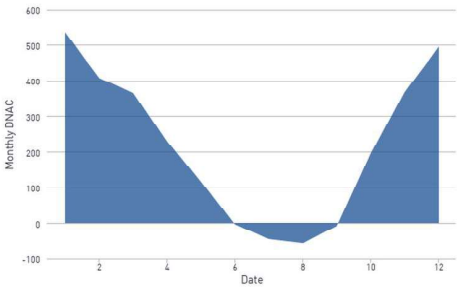
2607 +/- 268 kWh

Average Difference in Normalized Annual Consumption per Participant

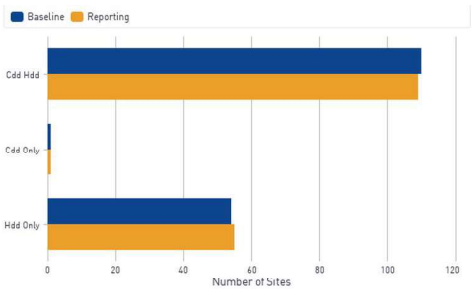
17 +/- 2 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

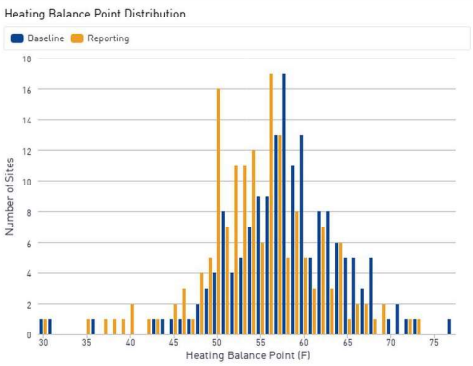


Model Type Distribution

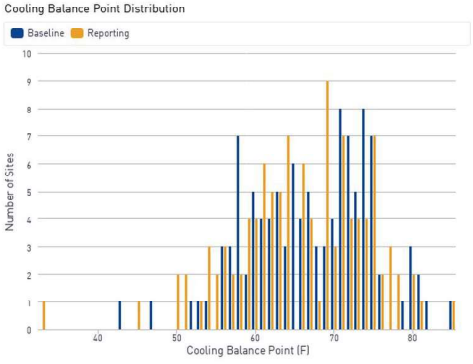


Treatment Group

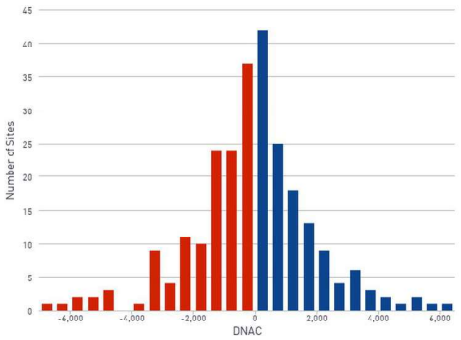
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



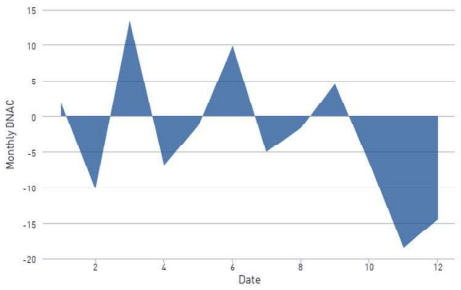
-35 +/- 233 kWh

Average Difference in Normalized Annual Consumption per Participant

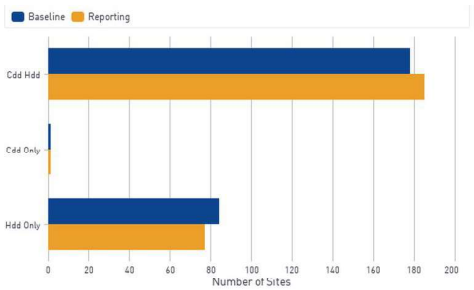
-0 +/- 2 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

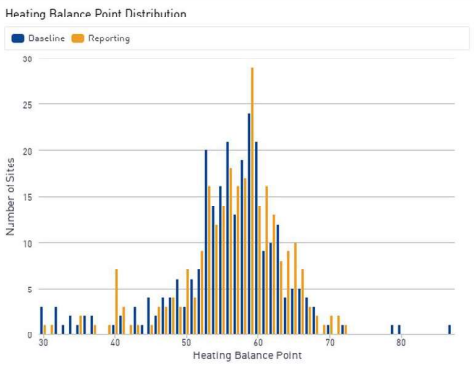


Model Type Distribution

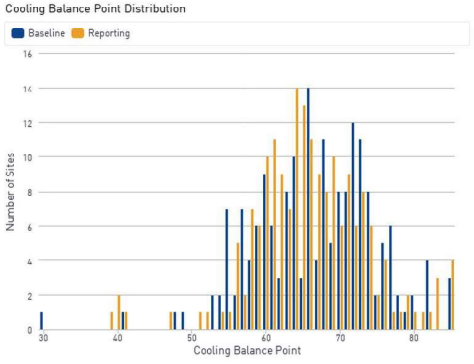


Site-level Matched Comparison Group

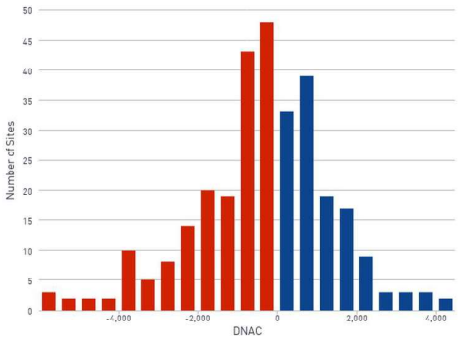
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



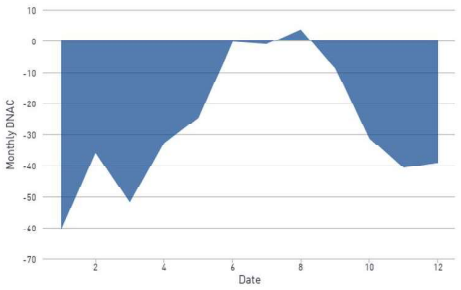
-324 +/- 208 kWh

Average Difference in Normalized Annual Consumption per Participant

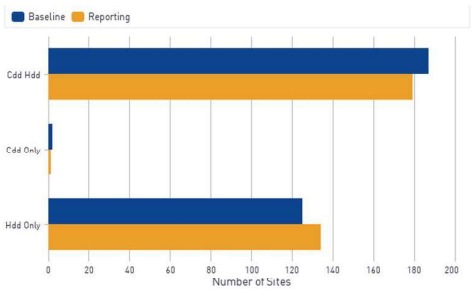
-2 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

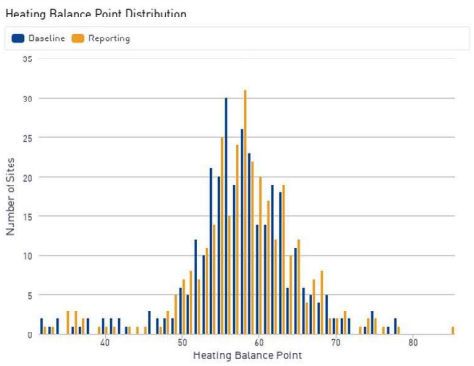


Model Type Distribution

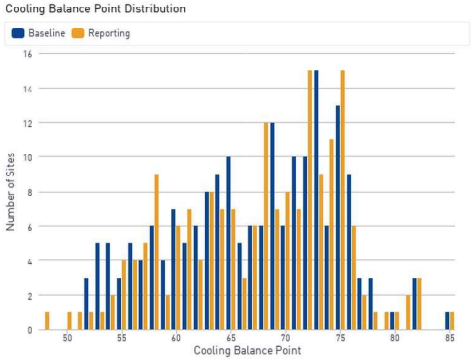


Future Participant Group

Heating Balance Point Distribution



Cooling Balance Point Distribution



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Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): 2 - 6000 < Hdd < 7500	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: All
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: All	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

21 Treatment Meters	2384 +/- 957 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	13 +/- 5 % Percent Normal Year Pre-Post Difference in Consumption per Participant	18,700 Mean Baseline Consumption (Electricity)	49% Realization Rate
31 Site-level Matched Meters	1821 +/- 1260 kWh Average Savings Relative to Site-level Matched Comparison Group	10 +/- 7% Percent Savings Relative to Site-level Matched Comparison Group	14,419 Mean Baseline Consumption (Electricity)	37% Realization Rate
69 Future Participant Meters	2952 +/- 1138 kWh Average Savings Relative to Future Participant Group	16 +/- 6% Savings Relative to Future Participant Group	17,382 Mean Baseline Consumption (Electricity)	61% Realization Rate

1. Introduction

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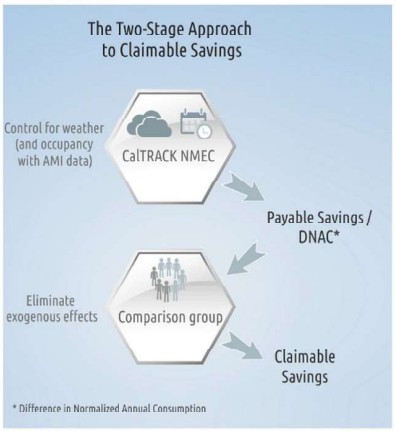
Section 4. Methodology - Description of methods used in this report

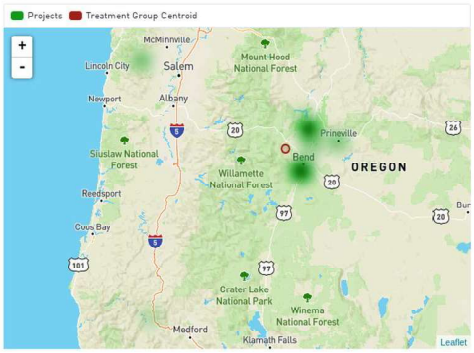
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations

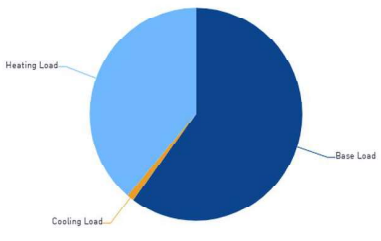


113.2 miles

80% of projects lie within this distance from treatment group centroid

21	18,700
Meters	Mean Baseline Consumption (Electricity)

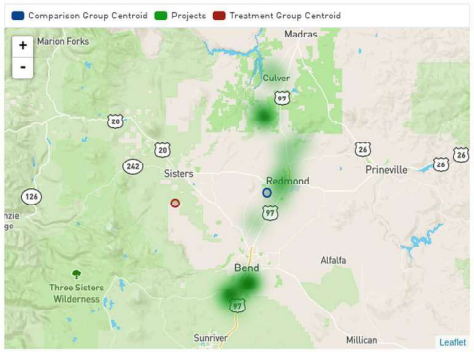
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations

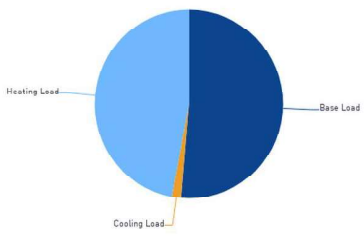


15.7 miles

Distance between treatment and comparison group centroids

31	14,419
Meters	Mean Baseline Consumption (Electricity)

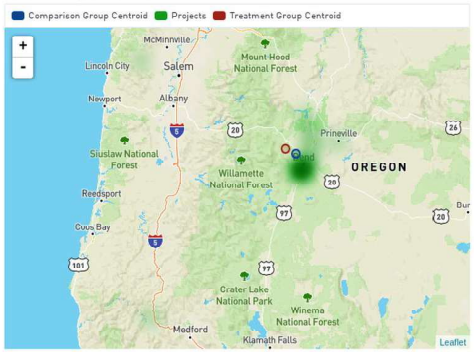
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

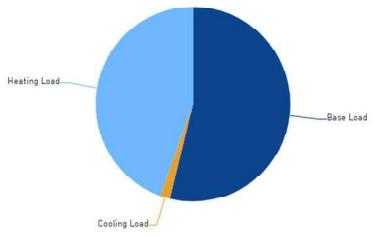


7.7 miles

Distance between treatment and future participant group centroids

69	17,382
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

710	21	3%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

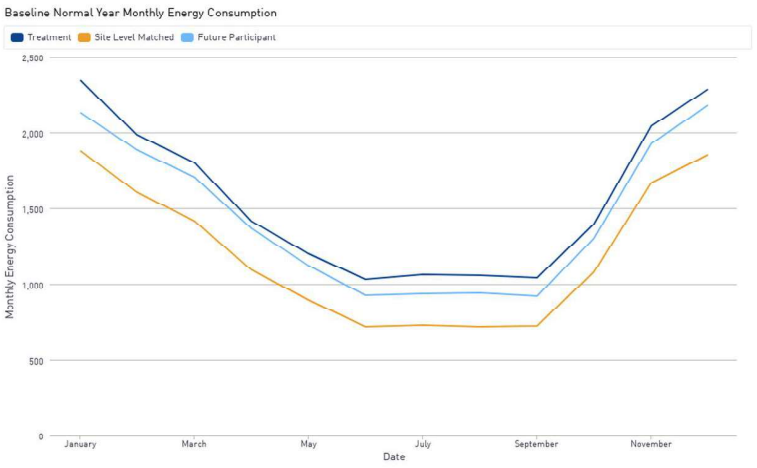
Sample Attrition Table

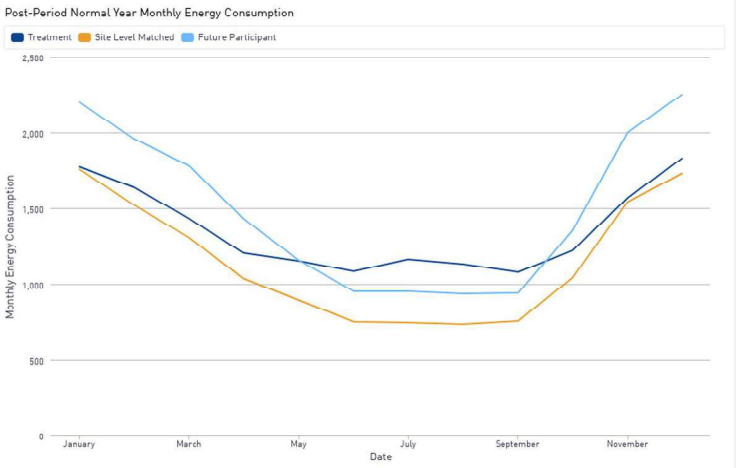
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-MANUFACTURED	115472	678
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	678
4	Fuel	Electricity	0	678
5	Valid consumption data in baseline and reporting periods	valid data	0	678
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	678
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	2	676
8	HeatingZone: Meters in selected heating climate zone.	2	561	115
9	CoolingZone: Meters in selected cooling climate zone.	--		115
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	69	46
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	46
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	0	46
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	0	46
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	0	46
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	6	40
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	40
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	40
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	40
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	40
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	40
21	Electricity Provider	--	0	40
22	Home Size [Sq Ft]	--	0	40
23	Water heating fuel type	--	0	40
24	Heat pump type	HEATPUMPREP	19	21
25	Contractor	--	0	21
26	Thermostat name	--		21
27	Heat pump baseline equipment	--	0	21
28	Heat pump manufacturer	--	0	21
29	Heat pump comissioning	--	0	21
30	Multi-measure elec	=false	0	21
31	Multi-measure gas	--	0	21

3. Modeling Results

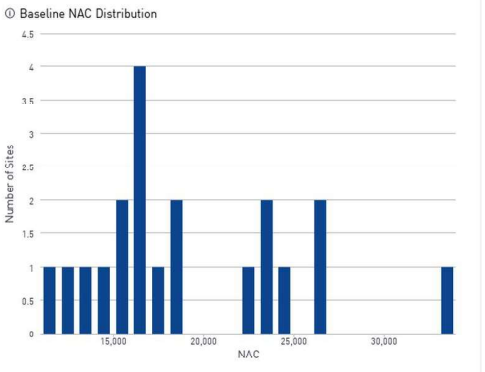
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

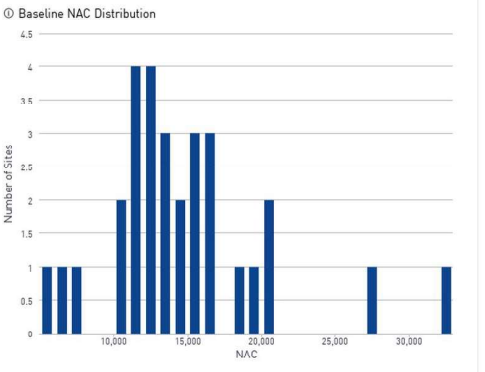




Treatment Group



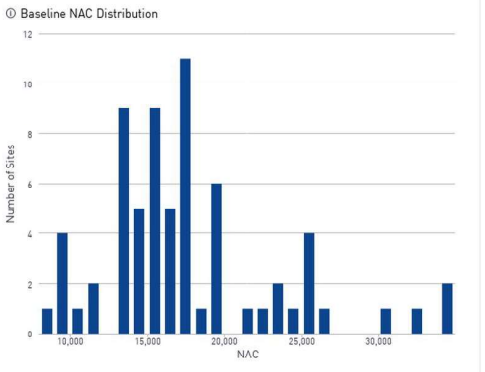
Site-level Matched Comparison Group



0.0752

Annual Consumption p-value

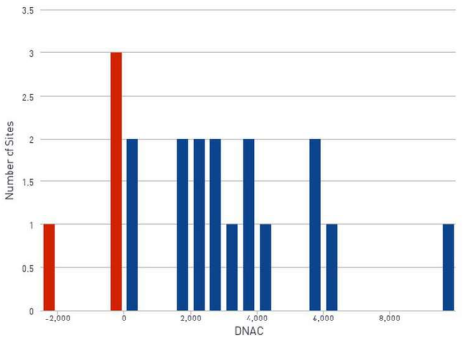
Future Participant Group



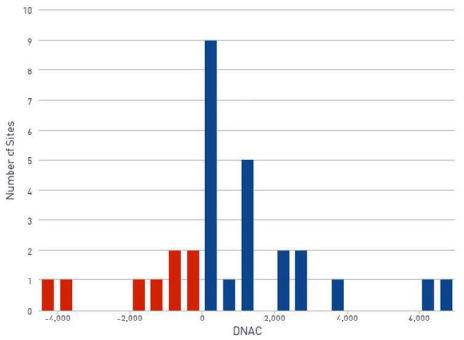
0.383

Annual Consumption p-value

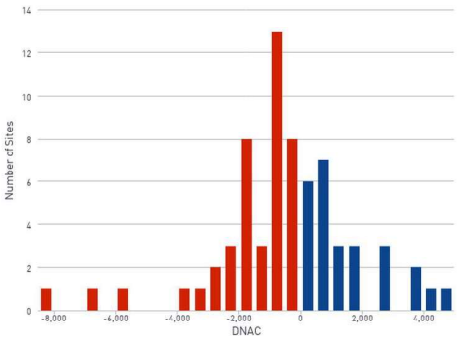
DNAC Distribution



DNAC Distribution



DNAC Distribution

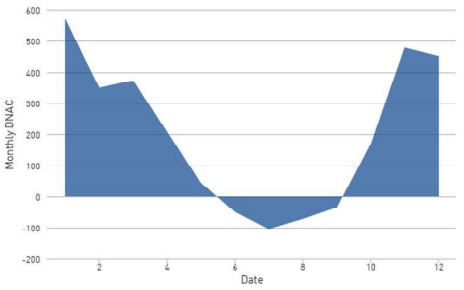


2384 +/- 957 kWh	13 +/- 5 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

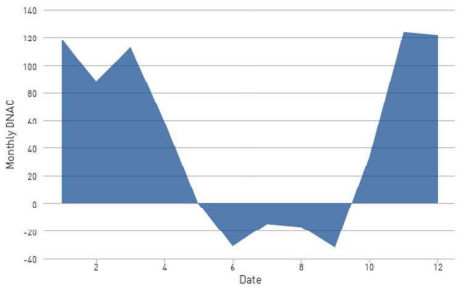
564 +/- 819 kWh	4 +/- 6 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

-568 +/- 616 kWh	-3 +/- 4 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

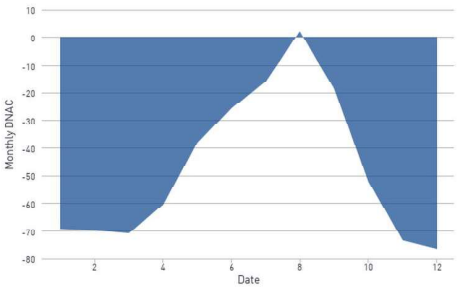
Monthly DNAC



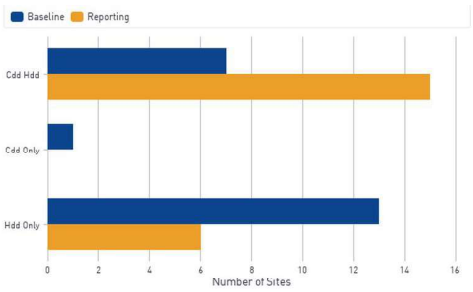
Monthly DNAC



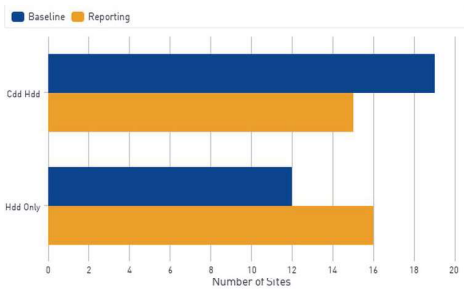
Monthly DNAC



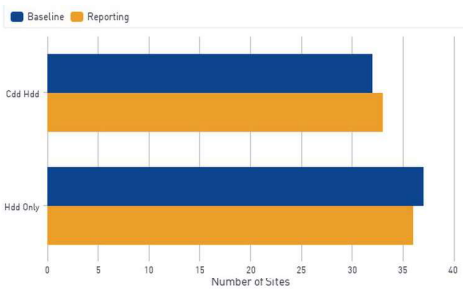
Model Type Distribution



Model Type Distribution



Model Type Distribution

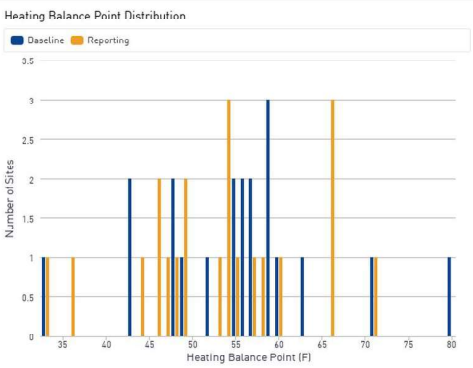


Treatment Group

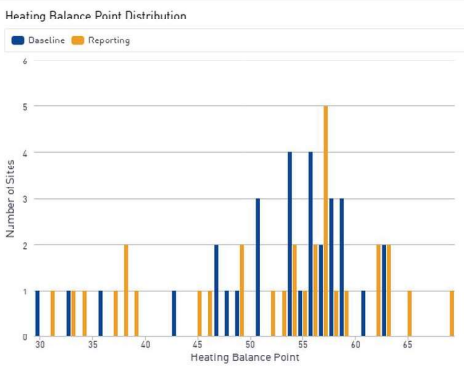
Site-level Matched Comparison Group

Future Participant Group

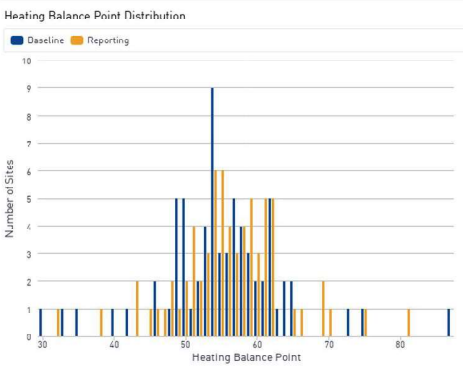
Heating Balance Point Distribution



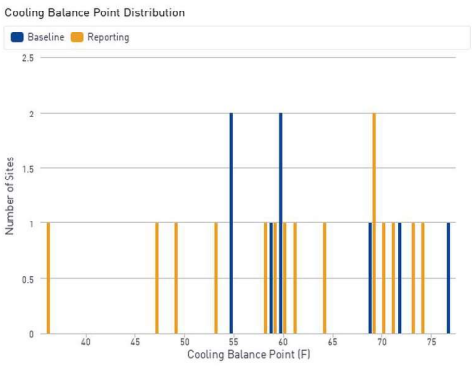
Heating Balance Point Distribution



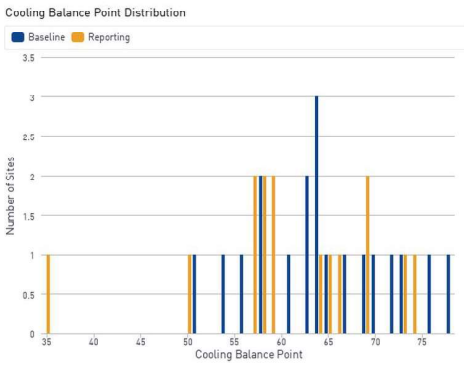
Heating Balance Point Distribution



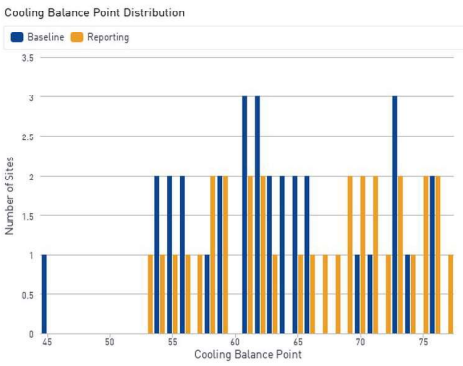
Cooling Balance Point Distribution



Cooling Balance Point Distribution



Cooling Balance Point Distribution



Impact Evaluation Report

Electricity Impact of Ductedheatpump-Site-Built in Program Year 2013, 2014, 2015, 2016, 2017, 2018

Result Summary

Measure: Ductedheatpump-Site-Built	Program Year: 2013, 2014, 2015, 2016, 2017, 2018		Fuel: Electricity	
Meter Data Filters:	DNAC: <100%	DNAC Percentile: Remove Top and Bottom 0.5%	Annual Consumption Percentile: Remove Top and Bottom 0.5%	*Last Consumption Data Update:* Q1 2020 *Last Participation Data Update:* Q1 2020
Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): 1 - Hdd <= 6000	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: All
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: All	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

1,161 Treatment Meters	1855 +/- 142 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	10 +/- 1 % Percent Normal Year Pre-Post Difference in Consumption per Participant	18,127 Mean Baseline Consumption (Electricity)	42% Realization Rate
3,438 Site-level Matched Meters	1789 +/- 153 kWh Average Savings Relative to Site-level Matched Comparison Group	10 +/- 1% Percent Savings Relative to Site-level Matched Comparison Group	13,685 Mean Baseline Consumption (Electricity)	41% Realization Rate
1,721 Future Participant Meters	2017 +/- 185 kWh Average Savings Relative to Future Participant Group	11 +/- 1% Savings Relative to Future Participant Group	18,029 Mean Baseline Consumption (Electricity)	46% Realization Rate

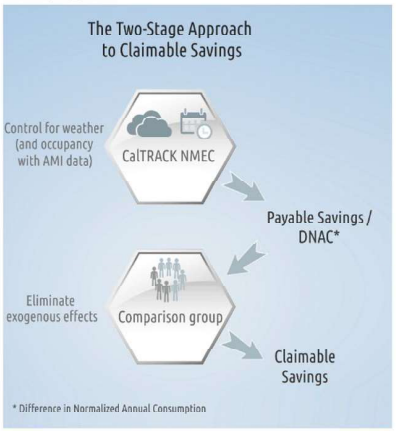
1. Introduction

This report contains the results of applying the two-stage approach (informed by the DOE's uniform methods chapter on whole building analysis) for calculating claimable savings to the selected portfolio of energy efficiency projects (see Figure). This approach begins with identification of two comparison groups for the treatment sample: (a) a site-level matched comparison group and (b) a future participant group. These groups are described below along with summary statistics (site locations, sample size, baseline consumption and baseline load disaggregation).

The CalTRACK methods are then applied to arrive at site-level savings, normalized for weather, and reflective of energy consumption changes for customers at the meter. Using a difference of differences for the treatment group with each comparison group accounts for population-level consumption changes (e.g. economic changes, rate changes, natural energy efficiency adoption etc.). The methods contained within this report are the outcome of a recent peer-reviewed study completed by Energy Trust of Oregon and Open Energy Efficiency (see "Methodology" section for more details).

The report includes the following sections:
Result Summary - Includes the overall portfolio results
Section 1. Introduction - Overview of report and the different groups included in the analysis
Section 2. Data Preparation - Data cleaning and sample attrition
Section 3. Modeling Results - CalTRACK model outputs and Difference in Normalized Annual Consumption (DNAC) results
Section 4. Methodology - Description of methods used in this report

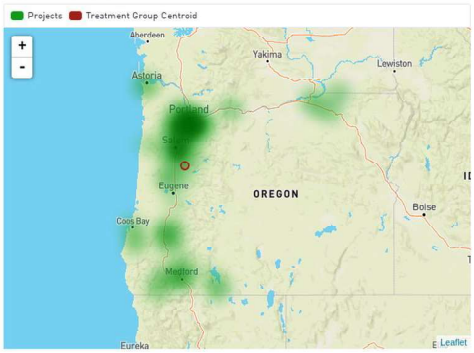
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations

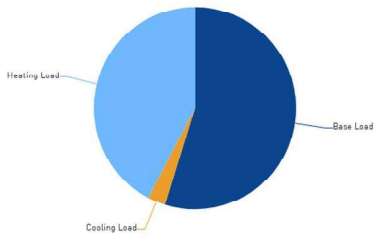


154.2 miles

80% of projects lie within this distance from treatment group centroid

1,161	18,127
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



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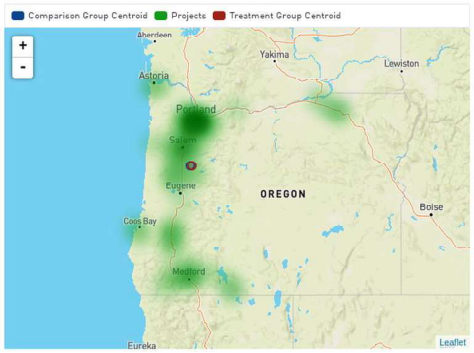
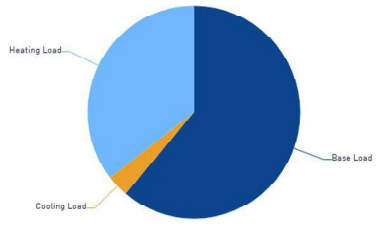


2.2 miles

Distance between treatment and comparison group centroids

3,438	13,685
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



Future Participant Group

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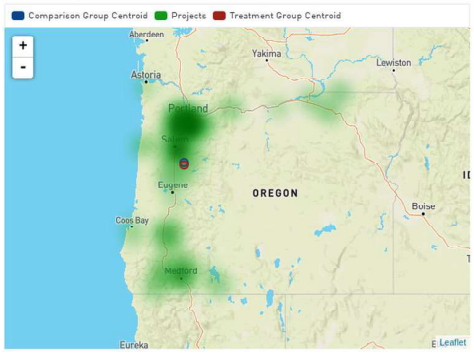
Future Participant Site Locations

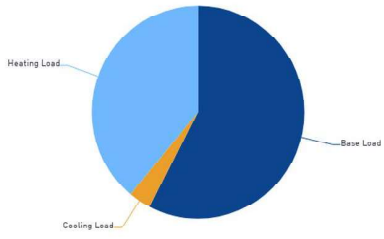


2.9 miles

Distance between treatment and future participant group centroids

1,721	18,029
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

7,398	1,161	16%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

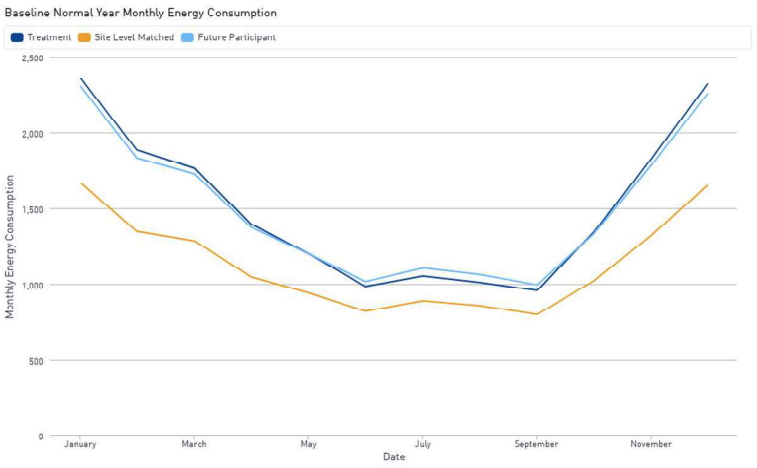
Sample Attrition Table

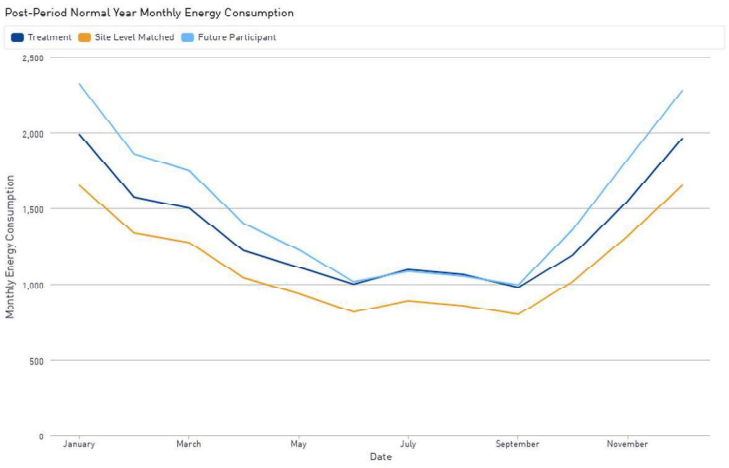
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-SITE-BUILT	108901	7249
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	7249
4	Fuel	Electricity	0	7249
5	Valid consumption data in baseline and reporting periods	valid data	0	7249
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	7249
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	91	7158
8	HeatingZone: Meters in selected heating climate zone.	1	797	6361
9	CoolingZone: Meters in selected cooling climate zone.	--		6361
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	1377	4984
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	4984
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	97	4887
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	24	4863
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	18	4845
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	641	4204
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	4204
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	4204
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	4204
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	4204
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	4204
21	Electricity Provider	--	0	4204
22	Home Size [Sq Ft]	--	0	4204
23	Water heating fuel type	--	0	4204
24	Heat pump type	HEATPUMPREP	3011	1193
25	Contractor	--	0	1193
26	Thermostat name	--		1193
27	Heat pump baseline equipment	--	0	1193
28	Heat pump manufacturer	--	0	1193
29	Heat pump comissioning	--	0	1193
30	Multi-measure elec	=false	32	1161
31	Multi-measure gas	--	0	1161

3. Modeling Results

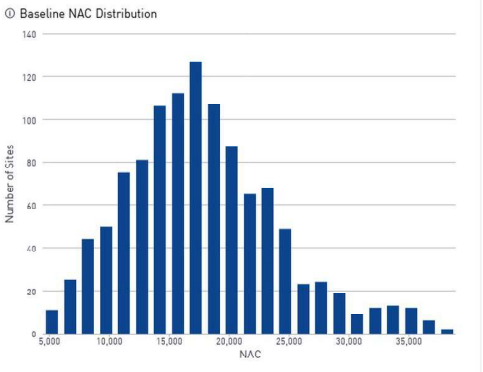
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

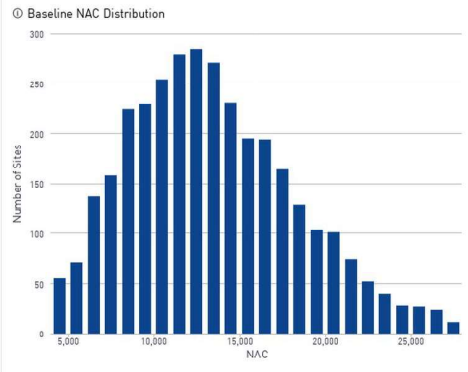




Treatment Group



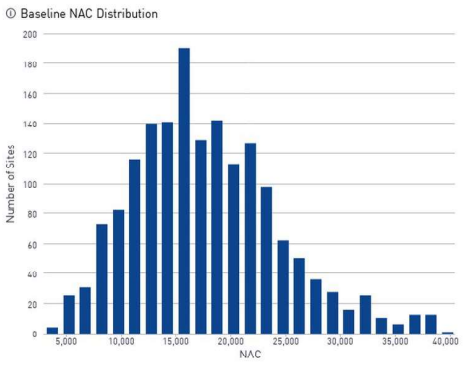
Site-level Matched Comparison Group



0.0566

Annual Consumption p-value

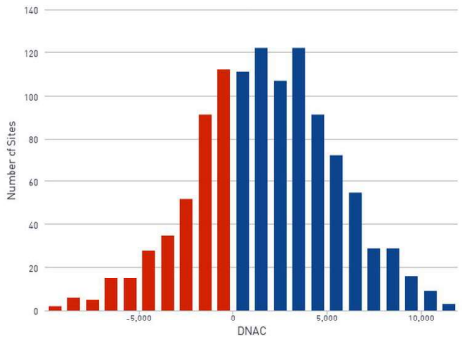
Future Participant Group



0.151

Annual Consumption p-value

DNAC Distribution



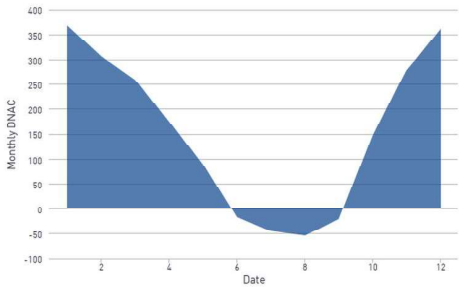
1855 +/- 142 kWh

Average Difference in Normalized Annual Consumption per Participant

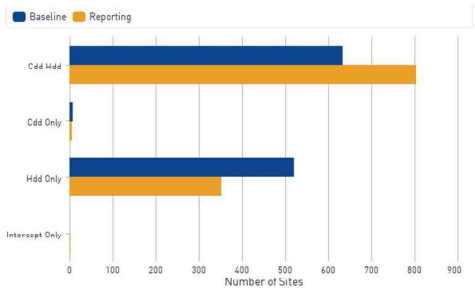
10 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

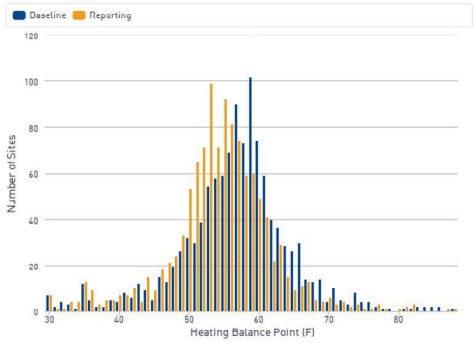


Model Type Distribution

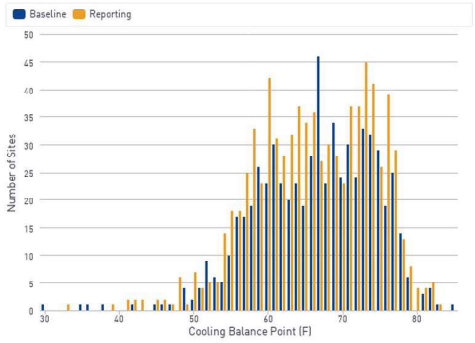


Treatment Group

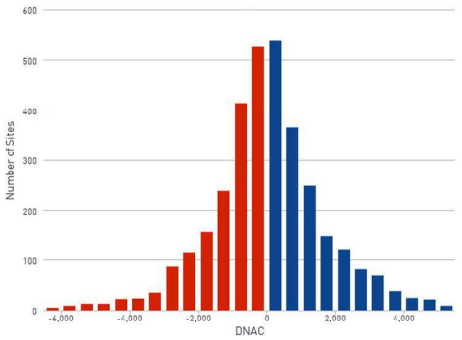
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



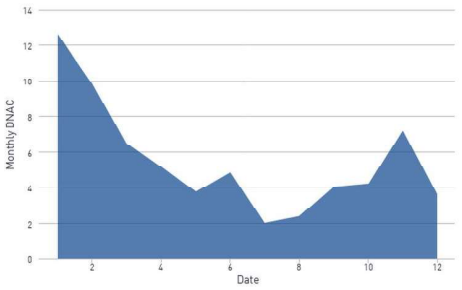
66 +/- 59 kWh

Average Difference in Normalized Annual Consumption per Participant

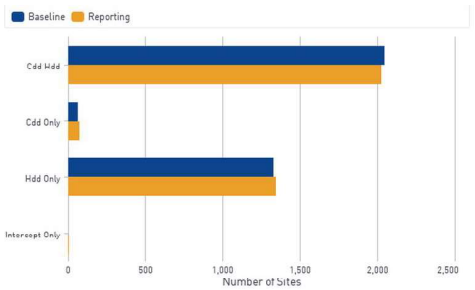
0 +/- 0 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

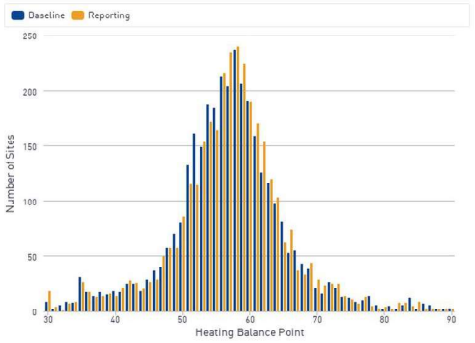


Model Type Distribution

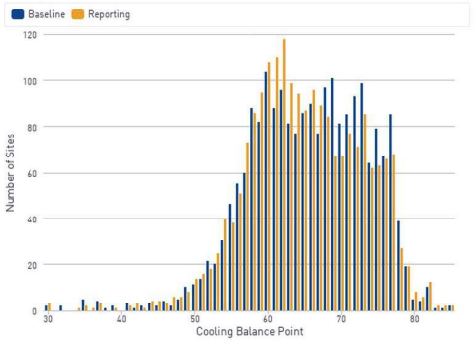


Site-level Matched Comparison Group

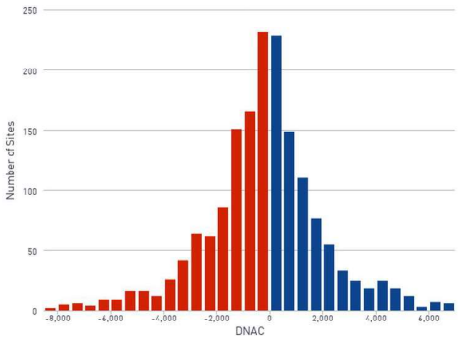
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



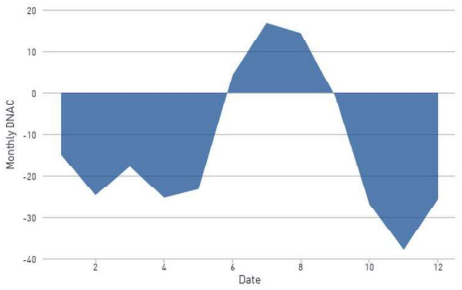
-161 +/- 119 kWh

Average Difference in Normalized Annual Consumption per Participant

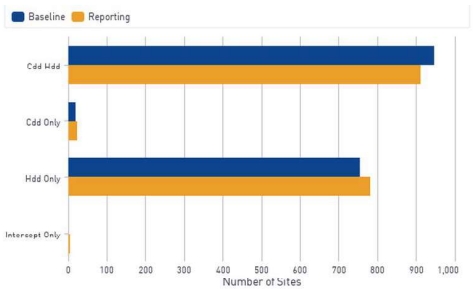
-1 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

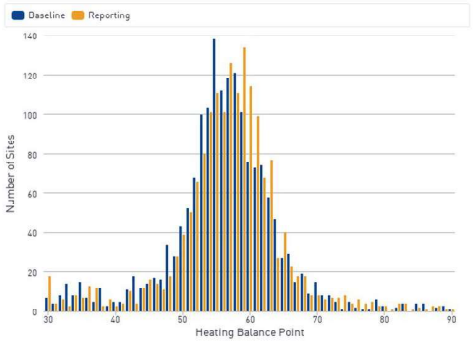


Model Type Distribution

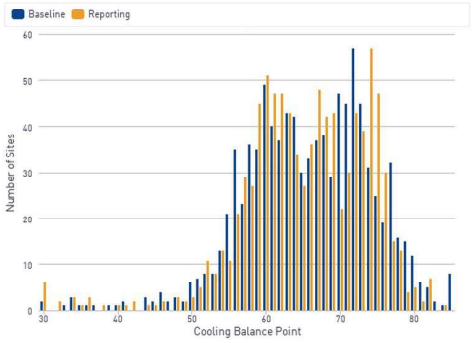


Future Participant Group

Heating Balance Point Distribution



Cooling Balance Point Distribution



Impact Evaluation Report

Electricity Impact of Ductedheatpump-Site-Built in Program Year 2013, 2014, 2015, 2016, 2017, 2018

Result Summary

Measure: Ductedheatpump-Site-Built	Program Year: 2013, 2014, 2015, 2016, 2017, 2018		Fuel: Electricity	
Meter Data Filters:	DNAC: <100%	DNAC Percentile: Remove Top and Bottom 0.5%	Annual Consumption Percentile: Remove Top and Bottom 0.5%	*Last Consumption Data Update:* Q1 2020 *Last Participation Data Update:* Q1 2020
Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): 2 - 6000 < Hdd < 7500	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: All
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: All	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

116 Treatment Meters	825 +/- 406 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	5 +/- 2 % Percent Normal Year Pre-Post Difference in Consumption per Participant	17,657 Mean Baseline Consumption (Electricity)	16% Realization Rate
214 Site-level Matched Meters	938 +/- 493 kWh Average Savings Relative to Site-level Matched Comparison Group	5 +/- 3% Percent Savings Relative to Site-level Matched Comparison Group	14,837 Mean Baseline Consumption (Electricity)	19% Realization Rate
173 Future Participant Meters	1289 +/- 552 kWh Average Savings Relative to Future Participant Group	7 +/- 3% Savings Relative to Future Participant Group	18,266 Mean Baseline Consumption (Electricity)	26% Realization Rate

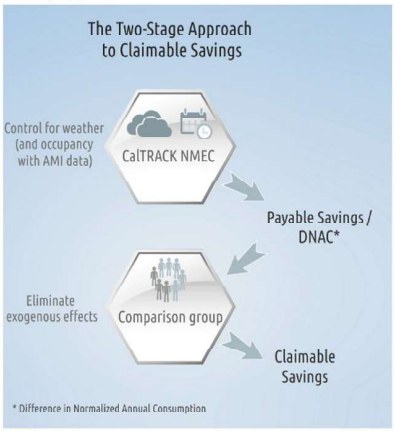
1. Introduction

This report contains the results of applying the two-stage approach (informed by the DOE's uniform methods chapter on whole building analysis) for calculating claimable savings to the selected portfolio of energy efficiency projects (see Figure). This approach begins with identification of two comparison groups for the treatment sample: (a) a site-level matched comparison group and (b) a future participant group. These groups are described below along with summary statistics (site locations, sample size, baseline consumption and baseline load disaggregation).

The CalTRACK methods are then applied to arrive at site-level savings, normalized for weather, and reflective of energy consumption changes for customers at the meter. Using a difference of differences for the treatment group with each comparison group accounts for population-level consumption changes (e.g. economic changes, rate changes, natural energy efficiency adoption etc.). The methods contained within this report are the outcome of a recent peer-reviewed study completed by Energy Trust of Oregon and Open Energy Efficiency (see "Methodology" section for more details).

The report includes the following sections:
Result Summary - Includes the overall portfolio results
Section 1. Introduction - Overview of report and the different groups included in the analysis
Section 2. Data Preparation - Data cleaning and sample attrition
Section 3. Modeling Results - CalTRACK model outputs and Difference in Normalized Annual Consumption (DNAC) results
Section 4. Methodology - Description of methods used in this report

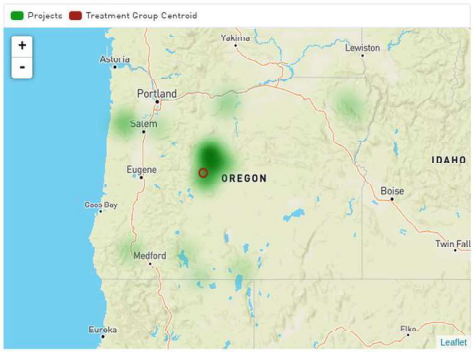
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations



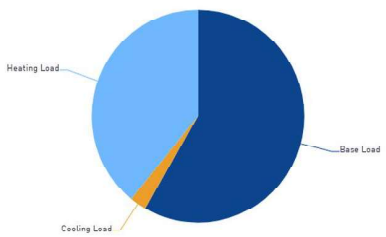
144.4 miles

80% of projects lie within this distance from treatment group centroid

116
Meters

17,657
Mean Baseline Consumption (Electricity)

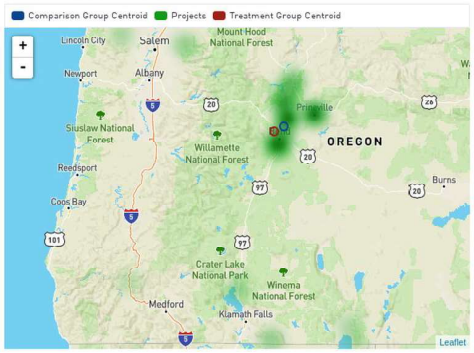
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations



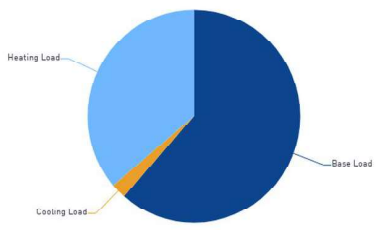
10.4 miles

Distance between treatment and comparison group centroids

214
Meters

14,837
Mean Baseline Consumption (Electricity)

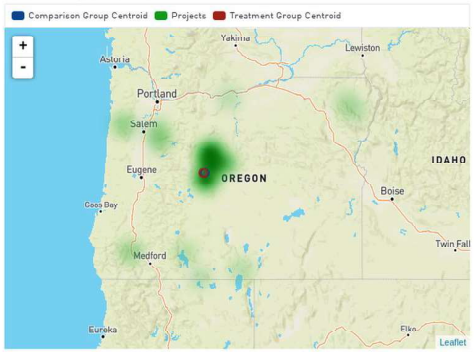
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations



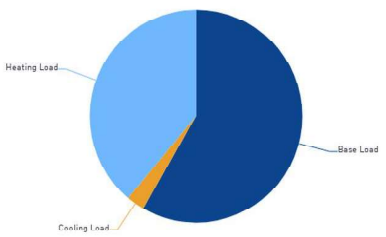
2.2 miles

Distance between treatment and future participant group centroids

173
Meters

18,266
Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

7,398
Meters in Treatment Population

116
Final Sample Size

1.6%
Percent of Treatment Population Represented by Sample

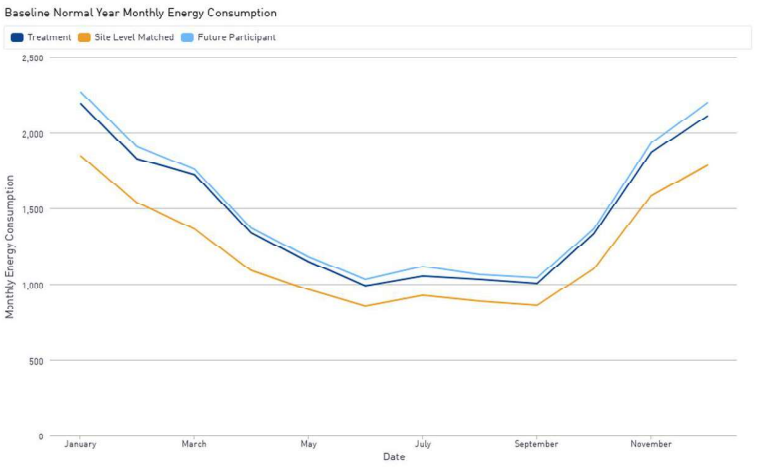
Sample Attrition Table

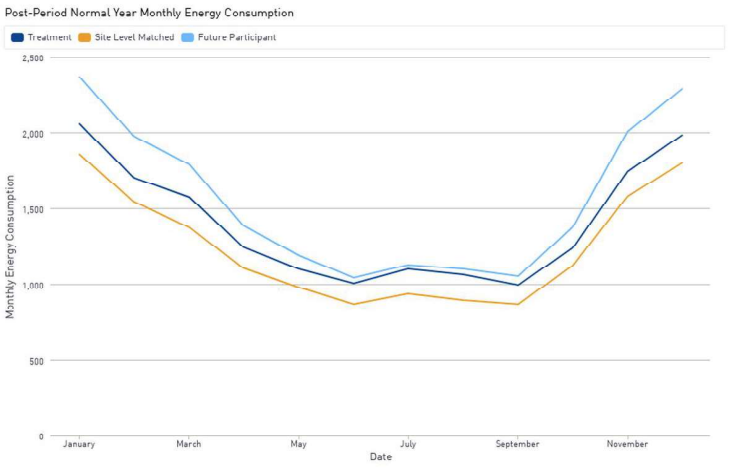
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-SITE-BUILT	108901	7249
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	7249
4	Fuel	Electricity	0	7249
5	Valid consumption data in baseline and reporting periods	valid data	0	7249
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	7249
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	91	7158
8	HeatingZone: Meters in selected heating climate zone.	2	6515	643
9	CoolingZone: Meters in selected cooling climate zone.	--		643
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	283	360
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	360
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	4	356
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	1	355
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	1	354
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	55	299
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	299
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	299
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	299
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	299
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	299
21	Electricity Provider	--	0	299
22	Home Size (Sq Ft)	--	0	299
23	Water heating fuel type	--	0	299
24	Heat pump type	HEATPUMPREP	181	118
25	Contractor	--	0	118
26	Thermostat name	--		118
27	Heat pump baseline equipment	--	0	118
28	Heat pump manufacturer	--	0	118
29	Heat pump comissioning	--	0	118
30	Multi-measure elec	=false	2	116
31	Multi-measure gas	--	0	116

3. Modeling Results

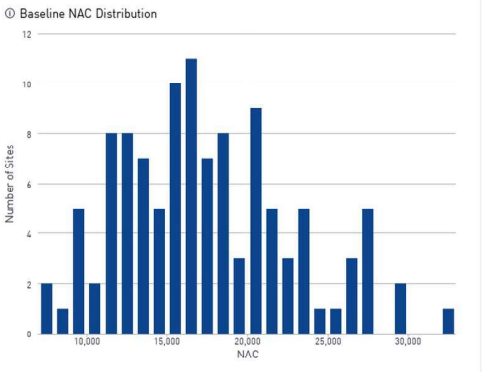
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

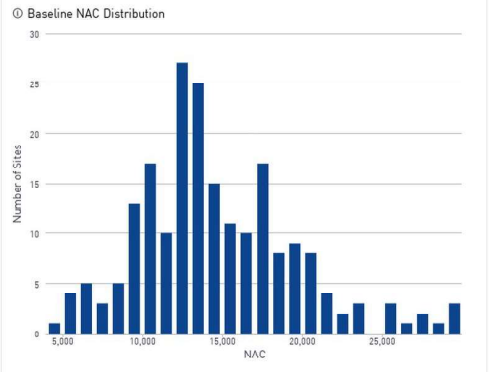




Treatment Group



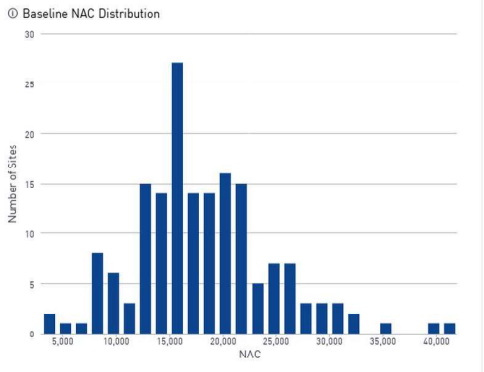
Site-level Matched Comparison Group



0.209

Annual Consumption p-value

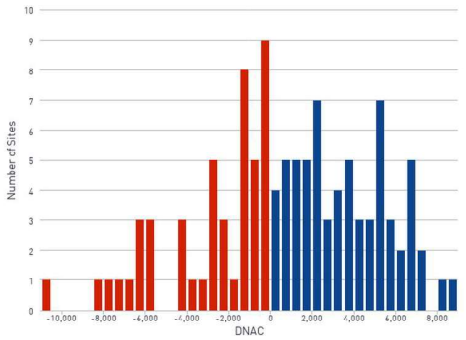
Future Participant Group



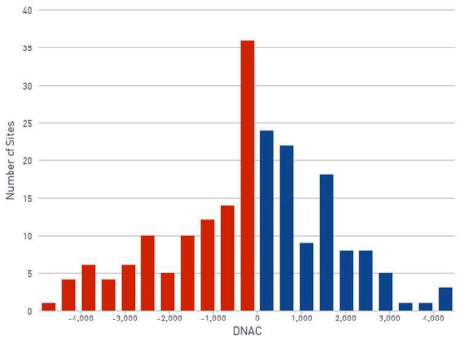
0.303

Annual Consumption p-value

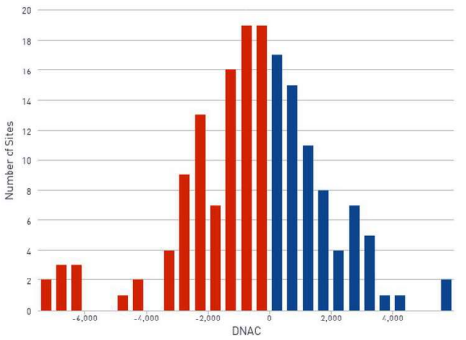
DNAC Distribution



DNAC Distribution



DNAC Distribution



825 +/- 406 kWh

Average Difference in Normalized Annual Consumption per Participant

5 +/- 2 %

Difference in Normalized Annual Consumption as a Percent of Baseline

-114 +/- 280 kWh

Average Difference in Normalized Annual Consumption per Participant

-1 +/- 2 %

Difference in Normalized Annual Consumption as a Percent of Baseline

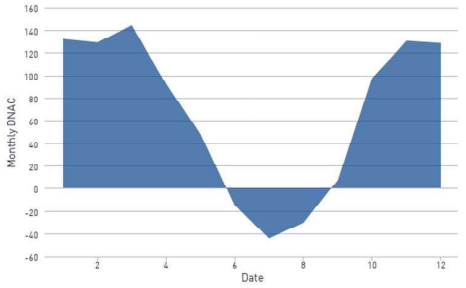
-464 +/- 373 kWh

Average Difference in Normalized Annual Consumption per Participant

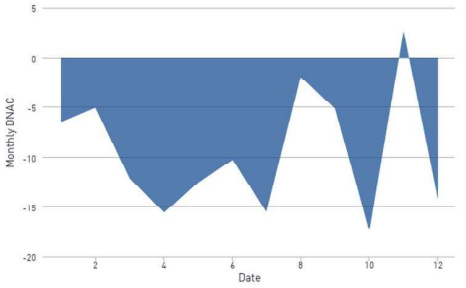
-3 +/- 2 %

Difference in Normalized Annual Consumption as a Percent of Baseline

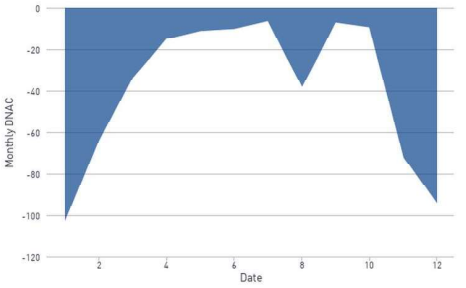
Monthly DNAC



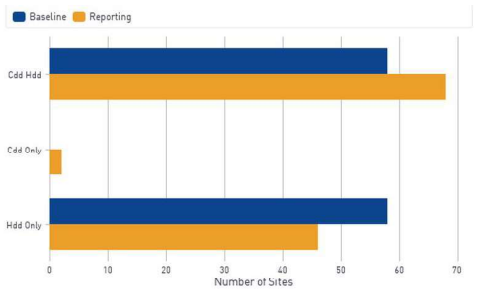
Monthly DNAC



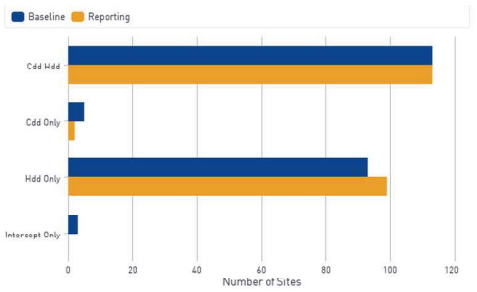
Monthly DNAC



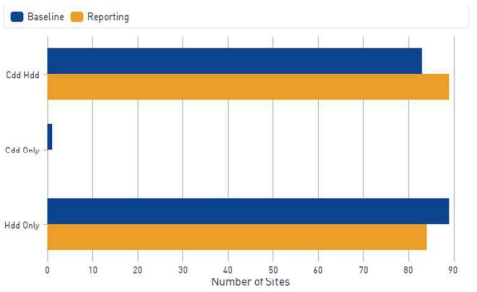
Model Type Distribution



Model Type Distribution



Model Type Distribution

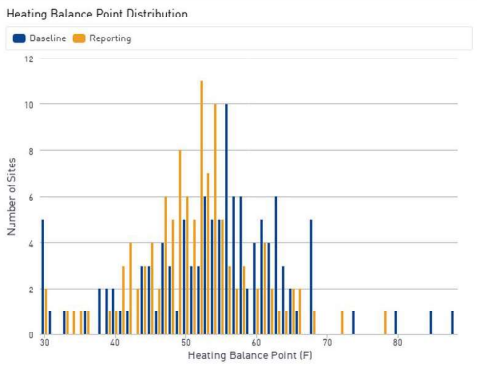


Treatment Group

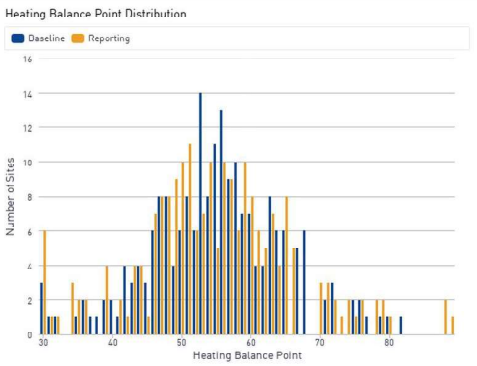
Site-level Matched Comparison Group

Future Participant Group

Heating Balance Point Distribution



Heating Balance Point Distribution



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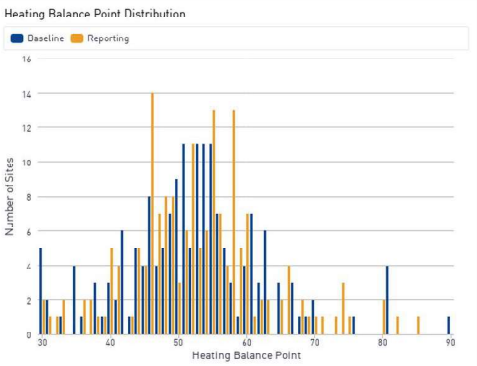
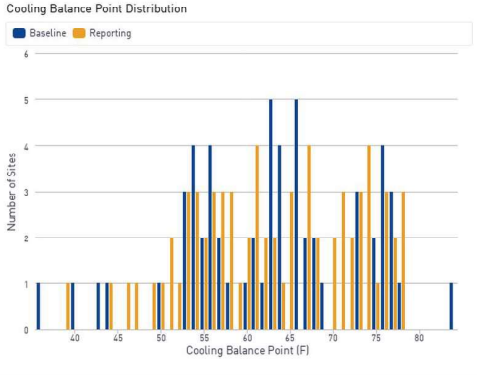


Cooling Balance Point Distribution



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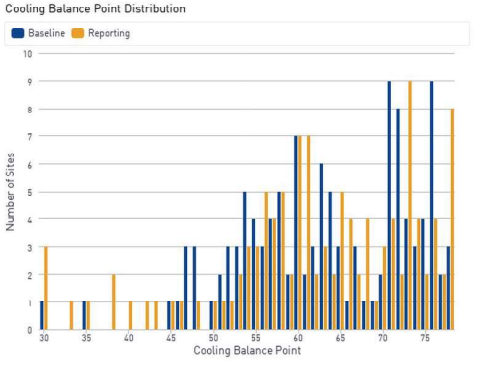
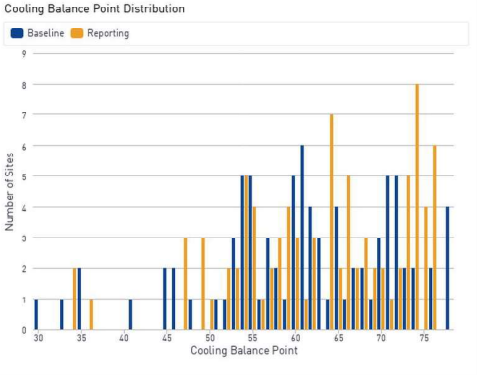


Cooling Balance Point Distribution



Impact Evaluation Report

Electricity Impact of Ductedheatpump-Manufactured in Program Year 2013, 2014, 2015, 2016, 2017, 2018

Result Summary

Measure: Ductedheatpump-Manufactured	Program Year: 2013, 2014, 2015, 2016, 2017, 2018		Fuel: Electricity	
Meter Data Filters:	DNAC: <100%	DNAC Percentile: Remove Top and Bottom 0.5%	Annual Consumption Percentile: Remove Top and Bottom 0.5%	*Last Consumption Data Update:* Q1 2020 *Last Participation Data Update:* Q1 2020
Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): All	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: All
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: Pac	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

103 Treatment Meters	2239 +/- 412 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	14 +/- 3 % Percent Normal Year Pre-Post Difference in Consumption per Participant	16,301 Mean Baseline Consumption (Electricity)	49% Realization Rate
184 Site-level Matched Meters	2198 +/- 491 kWh Average Savings Relative to Site-level Matched Comparison Group	13 +/- 3% Percent Savings Relative to Site-level Matched Comparison Group	14,375 Mean Baseline Consumption (Electricity)	48% Realization Rate
209 Future Participant Meters	2554 +/- 504 kWh Average Savings Relative to Future Participant Group	16 +/- 3% Savings Relative to Future Participant Group	15,705 Mean Baseline Consumption (Electricity)	56% Realization Rate

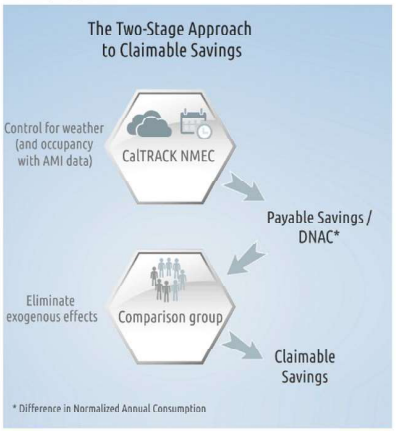
1. Introduction

This report contains the results of applying the two-stage approach (informed by the DOE's uniform methods chapter on whole building analysis) for calculating claimable savings to the selected portfolio of energy efficiency projects (see Figure). This approach begins with identification of two comparison groups for the treatment sample: (a) a site-level matched comparison group and (b) a future participant group. These groups are described below along with summary statistics (site locations, sample size, baseline consumption and baseline load disaggregation).

The CalTRACK methods are then applied to arrive at site-level savings, normalized for weather, and reflective of energy consumption changes for customers at the meter. Using a difference of differences for the treatment group with each comparison group accounts for population-level consumption changes (e.g. economic changes, rate changes, natural energy efficiency adoption etc.). The methods contained within this report are the outcome of a recent peer-reviewed study completed by Energy Trust of Oregon and Open Energy Efficiency (see "Methodology" section for more details).

The report includes the following sections:
Result Summary - Includes the overall portfolio results
Section 1. Introduction - Overview of report and the different groups included in the analysis
Section 2. Data Preparation - Data cleaning and sample attrition
Section 3. Modeling Results - CalTRACK model outputs and Difference in Normalized Annual Consumption (DNAC) results
Section 4. Methodology - Description of methods used in this report

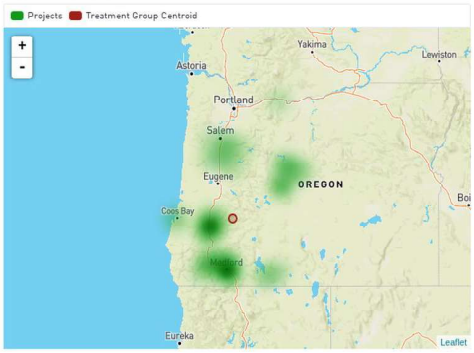
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations

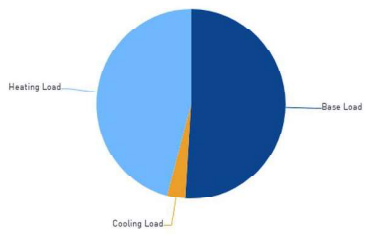


102.6 miles

80% of projects lie within this distance from treatment group centroid

103	16,301
Meters	Mean Baseline Consumption (Electricity)

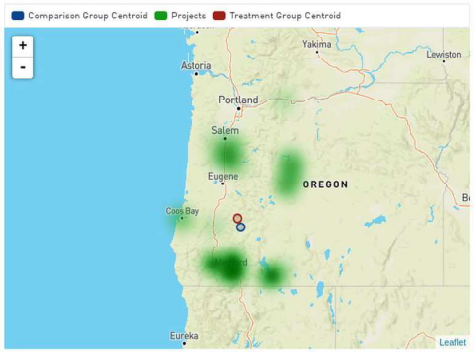
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations

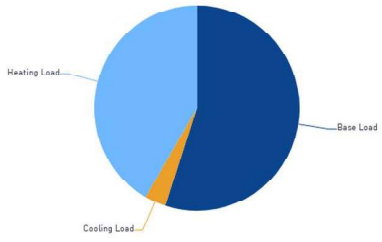


14.9 miles

Distance between treatment and comparison group centroids

184	14,375
Meters	Mean Baseline Consumption (Electricity)

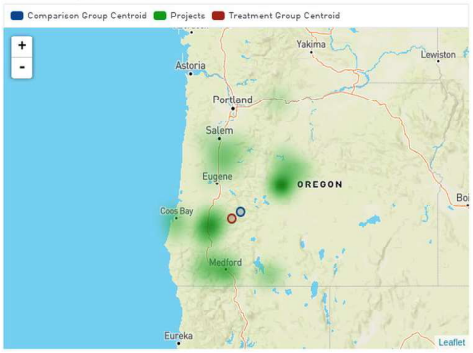
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

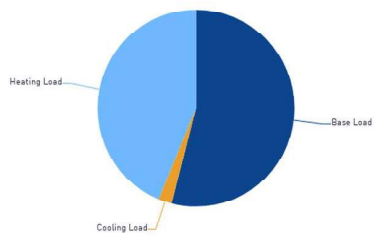


15.4 miles

Distance between treatment and future participant group centroids

209	15,705
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

710	103	15%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

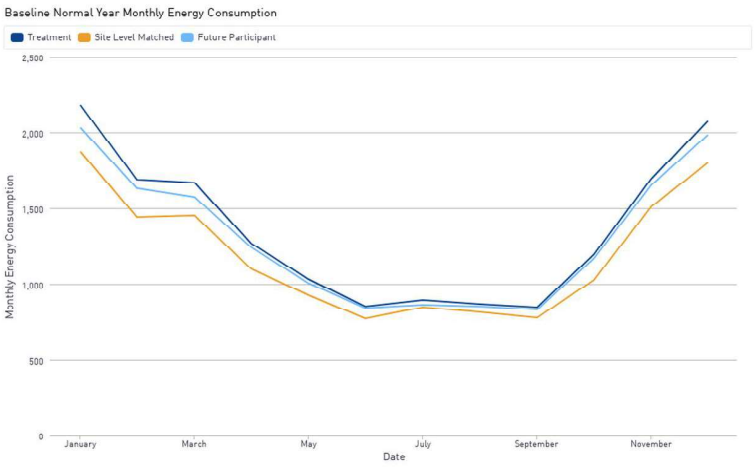
Sample Attrition Table

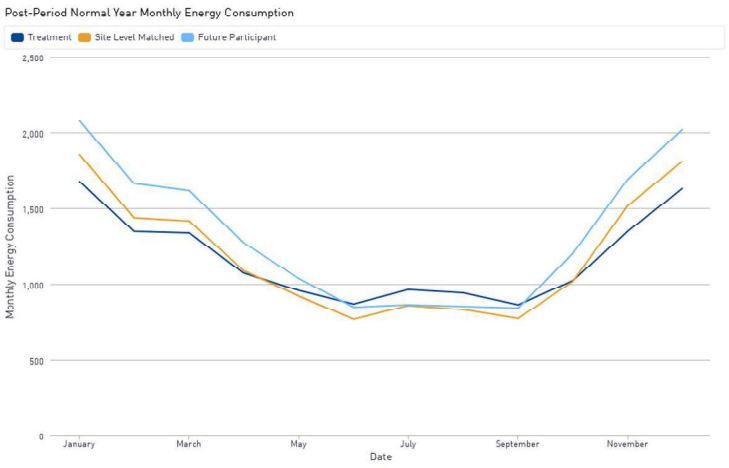
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-MANUFACTURED	115472	678
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	678
4	Fuel	Electricity	0	678
5	Valid consumption data in baseline and reporting periods	valid data	0	678
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	678
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	2	676
8	HeatingZone: Meters in selected heating climate zone.	--	0	676
9	CoolingZone: Meters in selected cooling climate zone.	--		676
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	236	440
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	440
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	2	438
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	2	436
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	0	436
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	50	386
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	386
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	386
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	386
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	386
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	386
21	Electricity Provider	PAC	149	237
22	Home Size [Sq Ft]	--	0	237
23	Water heating fuel type	--	0	237
24	Heat pump type	HEATPUMPREP	132	105
25	Contractor	--	0	105
26	Thermostat name	--		105
27	Heat pump baseline equipment	--	0	105
28	Heat pump manufacturer	--	0	105
29	Heat pump comissioning	--	0	105
30	Multi-measure elec	=false	2	103
31	Multi-measure gas	--	0	103

3. Modeling Results

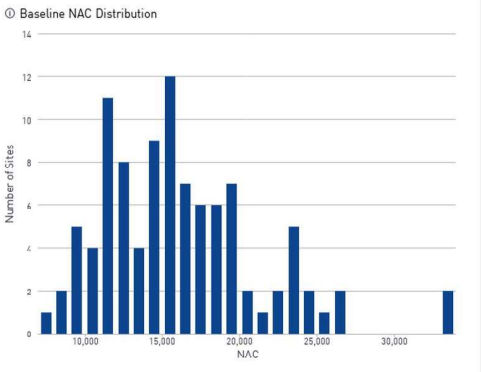
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

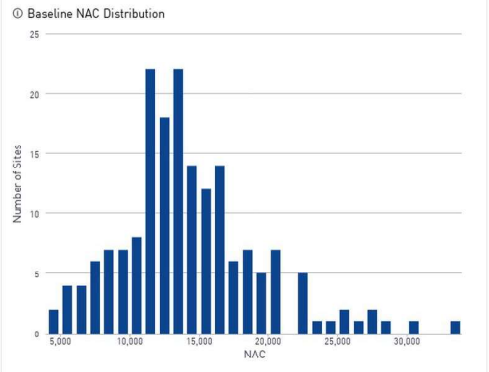




Treatment Group



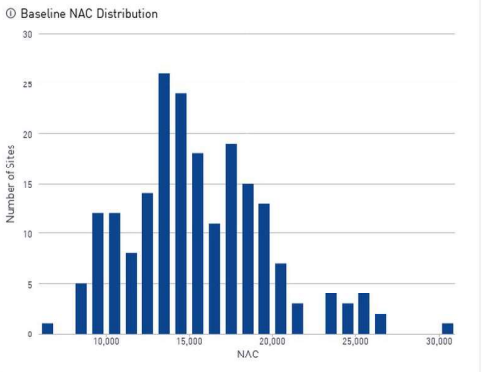
Site-level Matched Comparison Group



0.214

Annual Consumption p-value

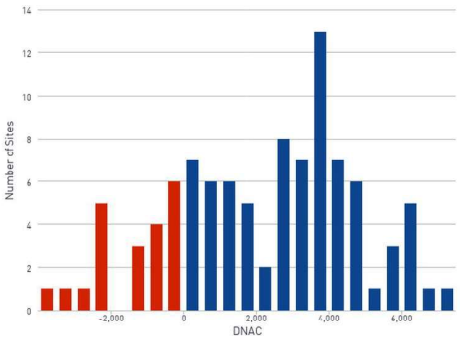
Future Participant Group



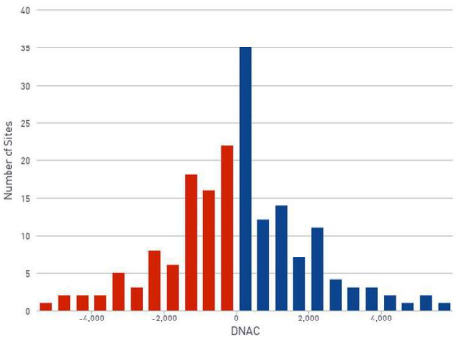
0.0125

Annual Consumption p-value

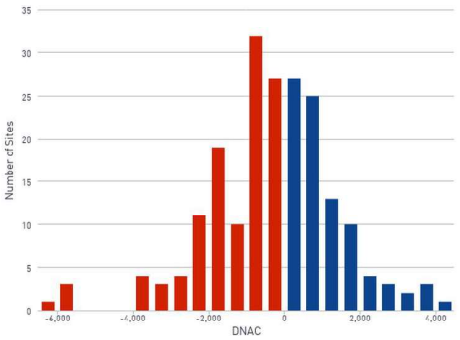
DNAC Distribution



DNAC Distribution



DNAC Distribution

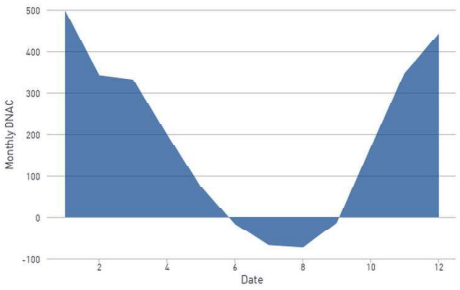


2239 +/- 412 kWh	14 +/- 3 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

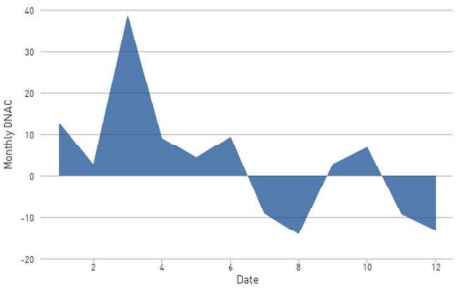
41 +/- 267 kWh	0 +/- 2 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

-315 +/- 290 kWh	-2 +/- 2 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

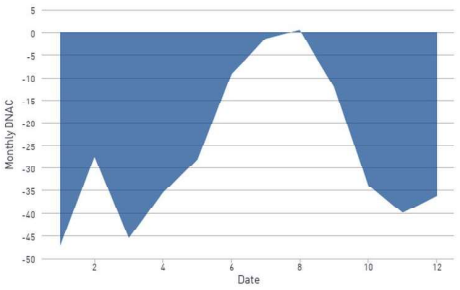
Monthly DNAC



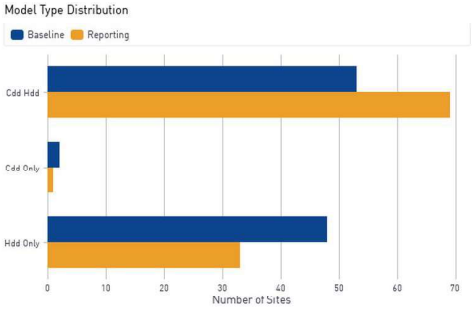
Monthly DNAC



Monthly DNAC



Model Type Distribution



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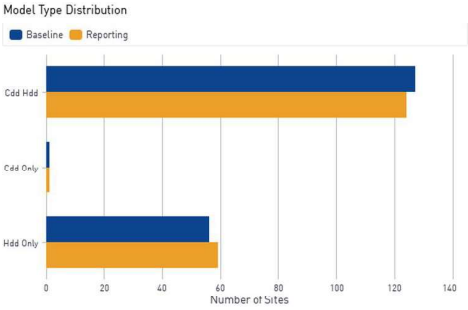

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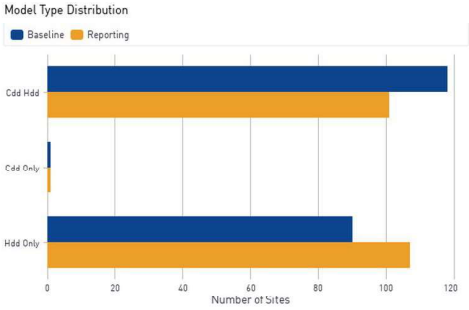
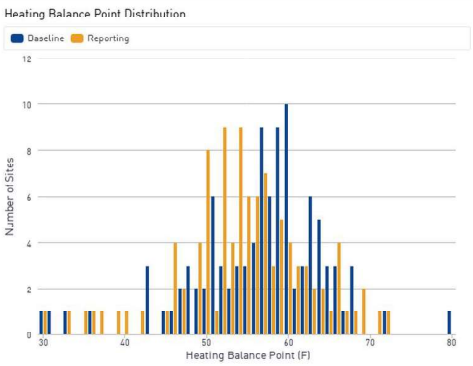


Treatment Group

Site-level Matched Comparison Group

Future Participant Group

Heating Balance Point Distribution



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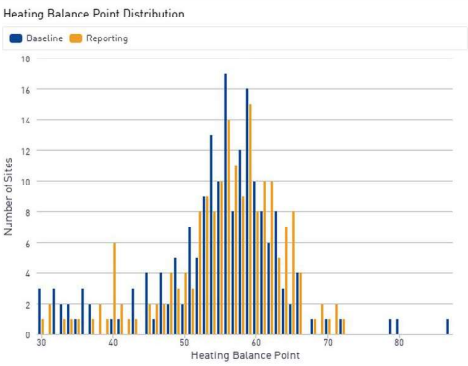

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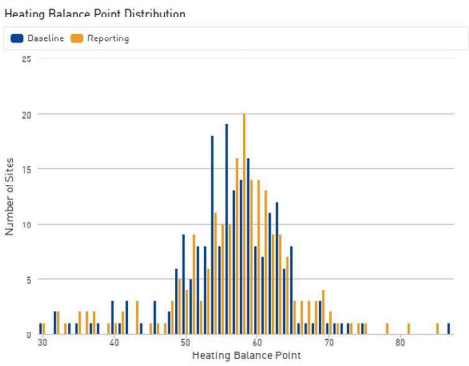

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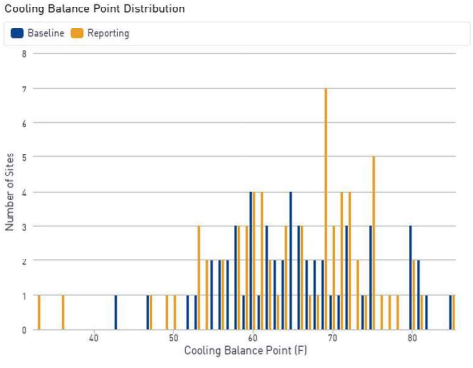

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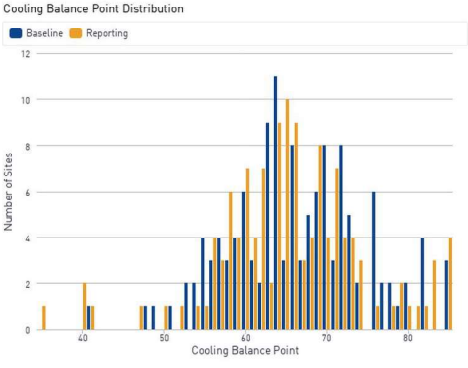

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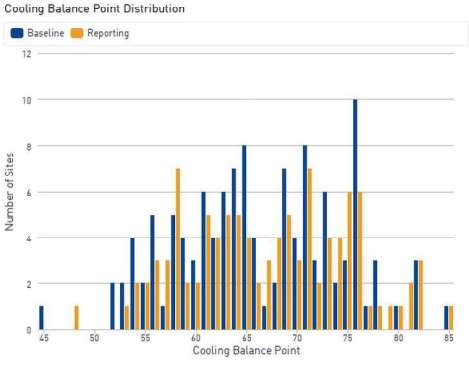

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	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: All
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: Pge	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

85 Treatment Meters	2902 +/- 279 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	19 +/- 2 % Percent Normal Year Pre-Post Difference in Consumption per Participant	15,412 Mean Baseline Consumption (Electricity)	69% Realization Rate
111 Site-level Matched Meters	2908 +/- 486 kWh Average Savings Relative to Site-level Matched Comparison Group	19 +/- 3% Percent Savings Relative to Site-level Matched Comparison Group	14,118 Mean Baseline Consumption (Electricity)	69% Realization Rate
179 Future Participant Meters	3300 +/- 415 kWh Average Savings Relative to Future Participant Group	21 +/- 3% Savings Relative to Future Participant Group	15,257 Mean Baseline Consumption (Electricity)	79% Realization Rate

1. Introduction

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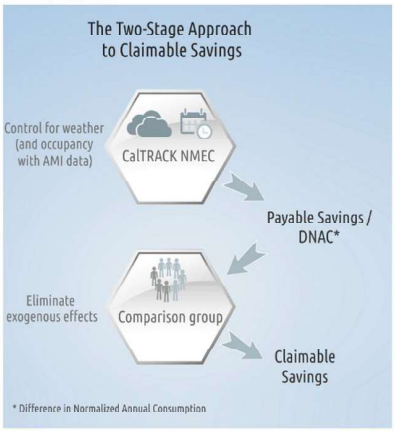
Two-Stage Approach



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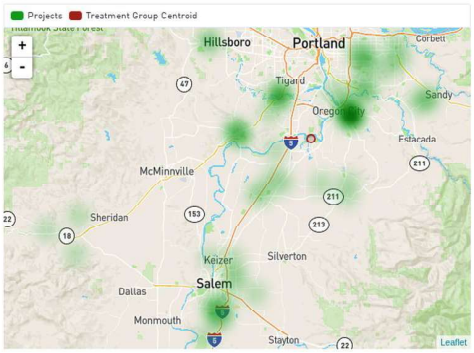
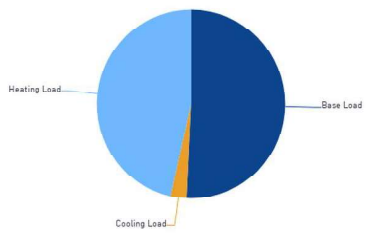


32.4 miles

80% of projects lie within this distance from treatment group centroid

85	15,412
Meters	Mean Baseline Consumption (Electricity)

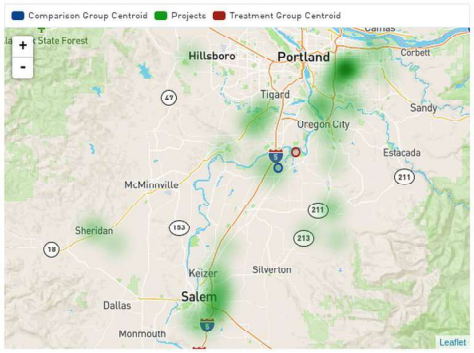
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations

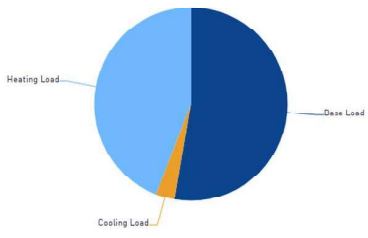


5.3 miles

Distance between treatment and comparison group centroids

111	14,118
Meters	Mean Baseline Consumption (Electricity)

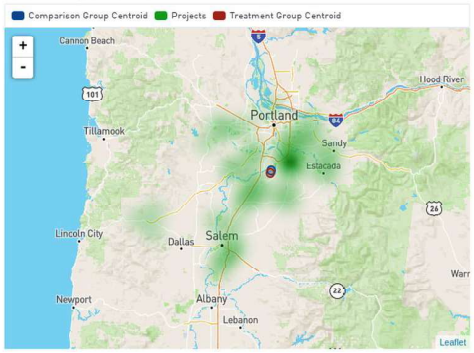
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

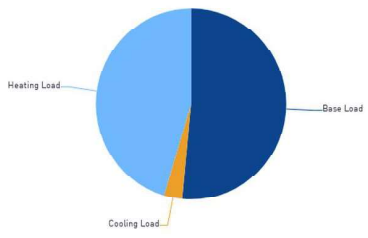


0.9 miles

Distance between treatment and future participant group centroids

179	15,257
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

710	85	12%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

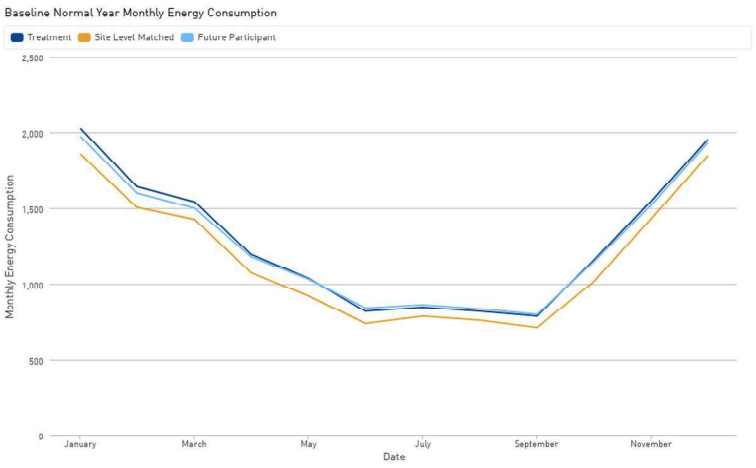
Sample Attrition Table

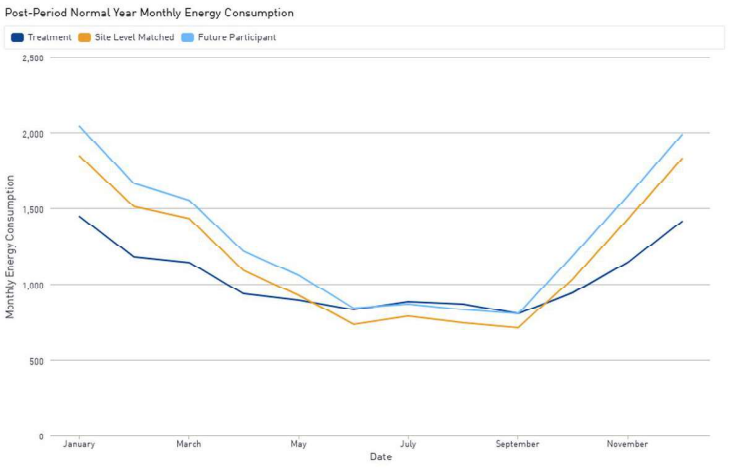
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-MANUFACTURED	115472	678
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	678
4	Fuel	Electricity	0	678
5	Valid consumption data in baseline and reporting periods	valid data	0	678
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	678
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	2	676
8	HeatingZone: Meters in selected heating climate zone.	--	0	676
9	CoolingZone: Meters in selected cooling climate zone.	--		676
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	236	440
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	440
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	2	438
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	2	436
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	0	436
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	50	386
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	386
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	386
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	386
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	386
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	386
21	Electricity Provider	PGE	238	148
22	Home Size [Sq Ft]	--	0	148
23	Water heating fuel type	--	0	148
24	Heat pump type	HEATPUMPREP	63	85
25	Contractor	--	0	85
26	Thermostat name	--		85
27	Heat pump baseline equipment	--	0	85
28	Heat pump manufacturer	--	0	85
29	Heat pump comissioning	--	0	85
30	Multi-measure elec	=false	0	85
31	Multi-measure gas	--	0	85

3. Modeling Results

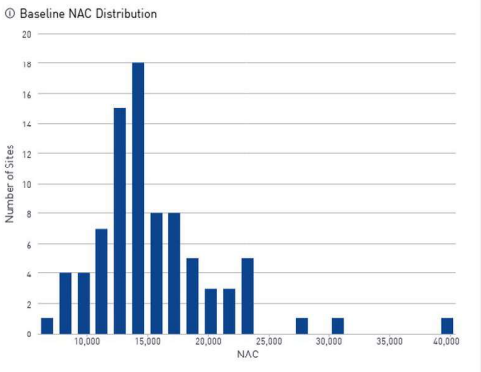
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

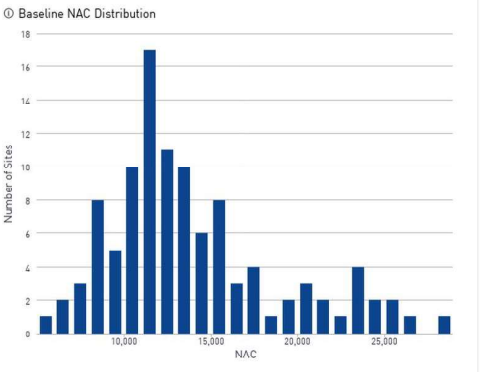




Treatment Group



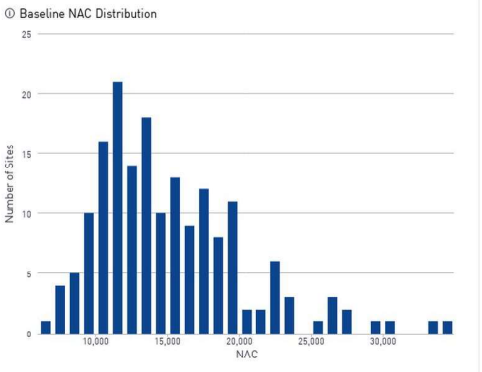
Site-level Matched Comparison Group



0.239

Annual Consumption p-value

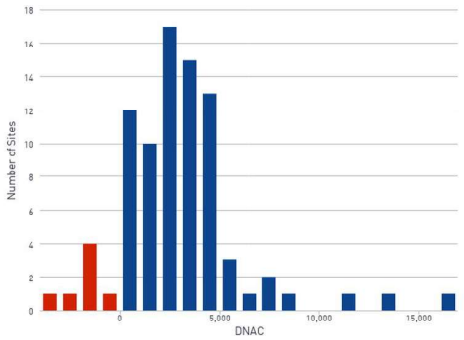
Future Participant Group



0.266

Annual Consumption p-value

DNAC Distribution



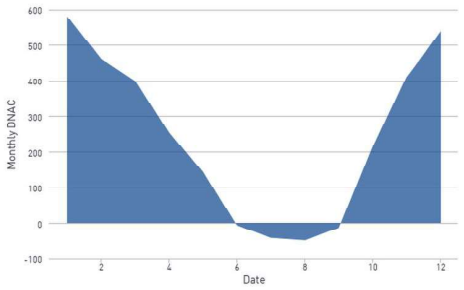
2902 +/- 279 kWh

Average Difference in Normalized Annual Consumption per Participant

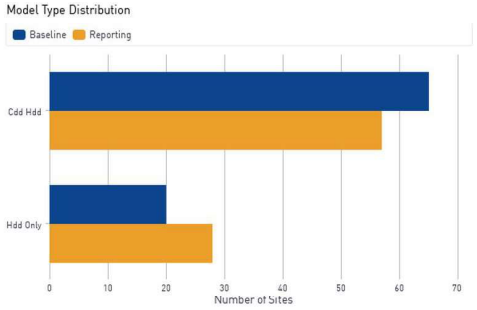
19 +/- 2 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

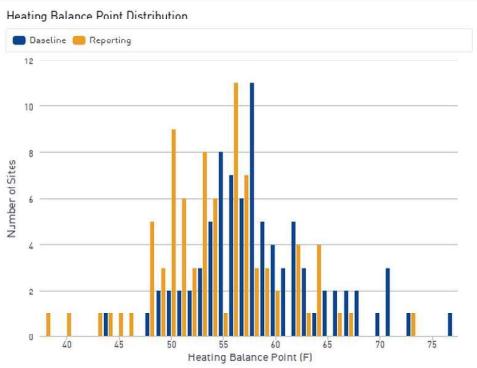


Model Type Distribution

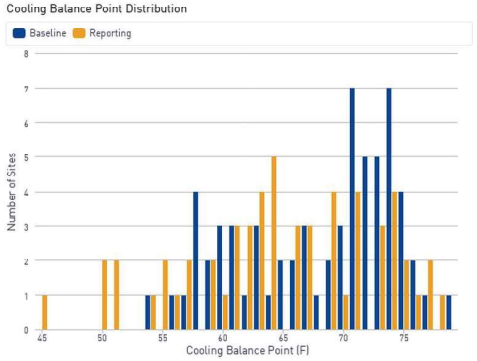


Treatment Group

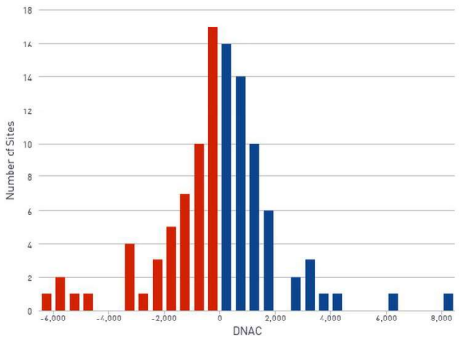
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



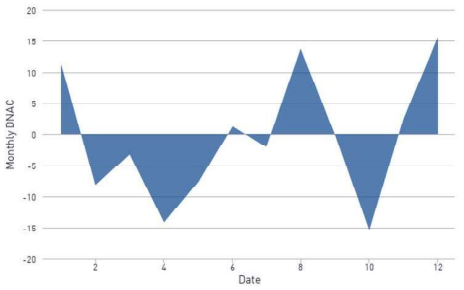
-6 +/- 398 kWh

Average Difference in Normalized Annual Consumption per Participant

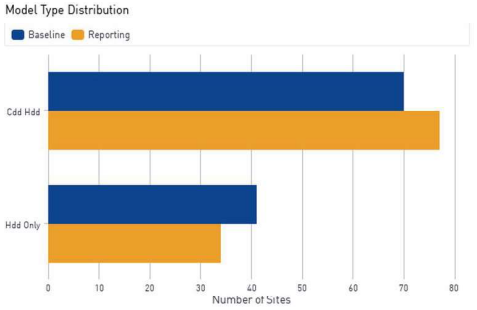
-0 +/- 3 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

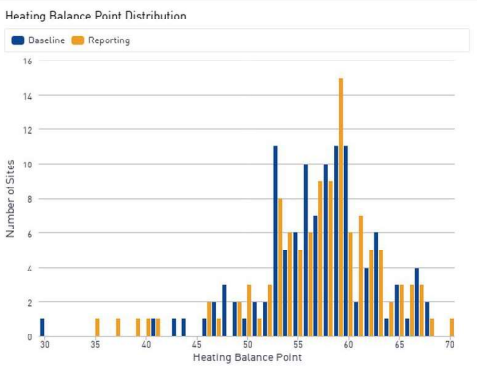


Model Type Distribution

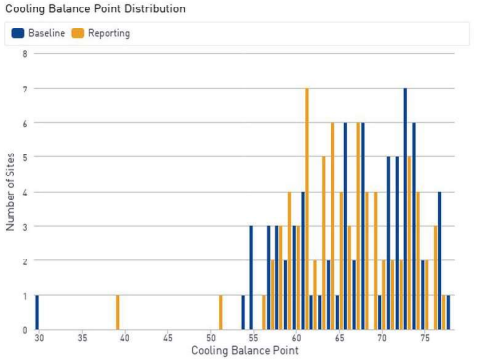


Site-level Matched Comparison Group

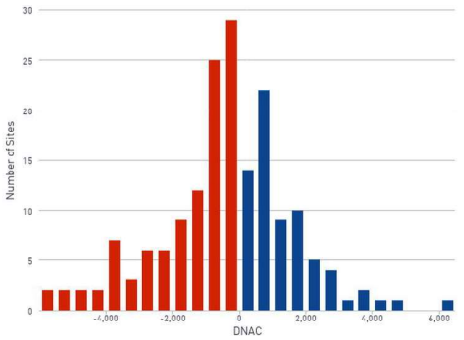
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



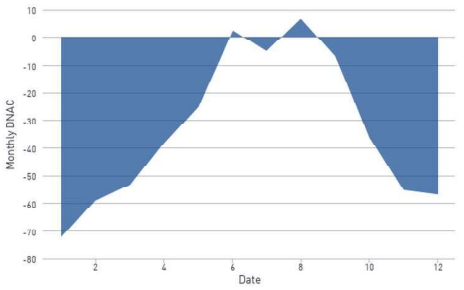
-398 +/- 307 kWh

Average Difference in Normalized Annual Consumption per Participant

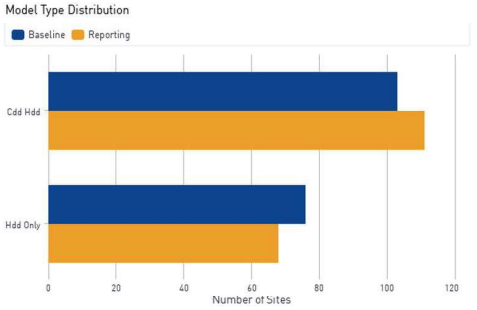
-3 +/- 2 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

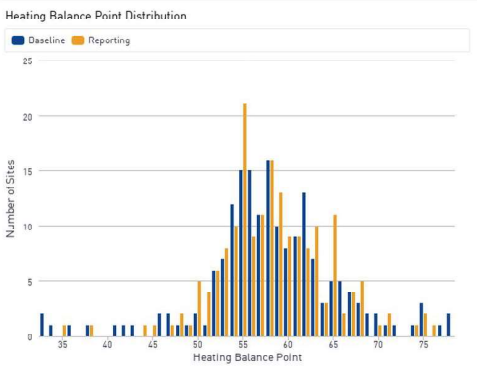


Model Type Distribution

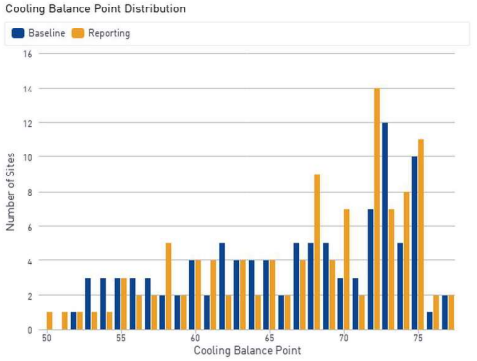


Future Participant Group

Heating Balance Point Distribution



Cooling Balance Point Distribution



Impact Evaluation Report

Electricity Impact of Ductedheatpump-Site-Built in Program Year 2013, 2014, 2015, 2016, 2017, 2018

Result Summary

Measure: Ductedheatpump-Site-Built	Program Year: 2013, 2014, 2015, 2016, 2017, 2018		Fuel: Electricity	
Meter Data Filters:	DNAC: <100%	DNAC Percentile: Remove Top and Bottom 0.5%	Annual Consumption Percentile: Remove Top and Bottom 0.5%	*Last Consumption Data Update:* Q1 2020 *Last Participation Data Update:* Q1 2020
Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): All	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: All
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: Pac	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

594 Treatment Meters	1311 +/- 189 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	7 +/- 1 % Percent Normal Year Pre-Post Difference in Consumption per Participant	17,648 Mean Baseline Consumption (Electricity)	28% Realization Rate
1,598 Site-level Matched Meters	1321 +/- 209 kWh Average Savings Relative to Site-level Matched Comparison Group	7 +/- 1% Percent Savings Relative to Site-level Matched Comparison Group	13,891 Mean Baseline Consumption (Electricity)	29% Realization Rate
858 Future Participant Meters	1437 +/- 250 kWh Average Savings Relative to Future Participant Group	8 +/- 1% Savings Relative to Future Participant Group	17,618 Mean Baseline Consumption (Electricity)	31% Realization Rate

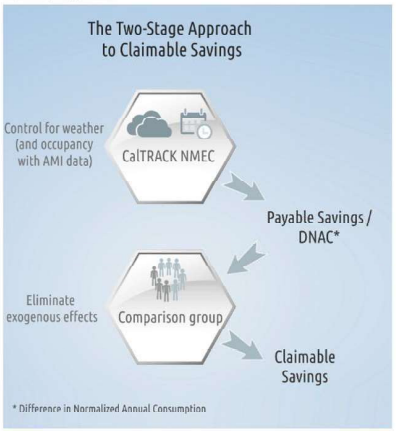
1. Introduction

This report contains the results of applying the two-stage approach (informed by the DOE's uniform methods chapter on whole building analysis) for calculating claimable savings to the selected portfolio of energy efficiency projects (see Figure). This approach begins with identification of two comparison groups for the treatment sample: (a) a site-level matched comparison group and (b) a future participant group. These groups are described below along with summary statistics (site locations, sample size, baseline consumption and baseline load disaggregation).

The CalTRACK methods are then applied to arrive at site-level savings, normalized for weather, and reflective of energy consumption changes for customers at the meter. Using a difference of differences for the treatment group with each comparison group accounts for population-level consumption changes (e.g. economic changes, rate changes, natural energy efficiency adoption etc.). The methods contained within this report are the outcome of a recent peer-reviewed study completed by Energy Trust of Oregon and Open Energy Efficiency (see "Methodology" section for more details).

The report includes the following sections:
Result Summary - Includes the overall portfolio results
Section 1. Introduction - Overview of report and the different groups included in the analysis
Section 2. Data Preparation - Data cleaning and sample attrition
Section 3. Modeling Results - CalTRACK model outputs and Difference in Normalized Annual Consumption (DNAC) results
Section 4. Methodology - Description of methods used in this report

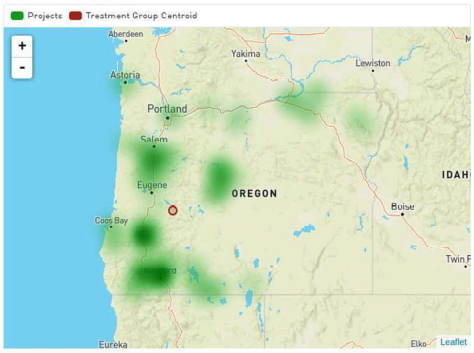
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations

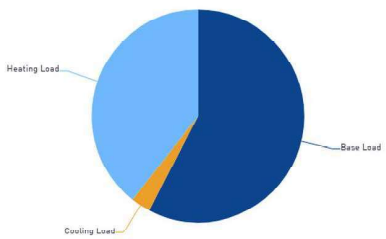


127.6 miles

80% of projects lie within this distance from treatment group centroid

594	17,648
Meters	Mean Baseline Consumption (Electricity)

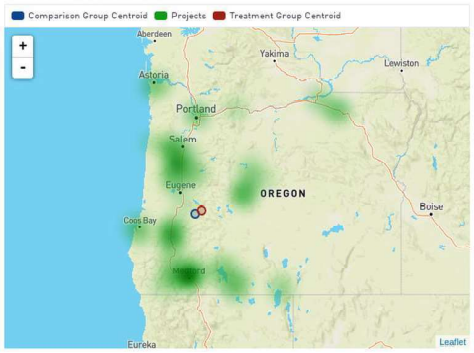
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations

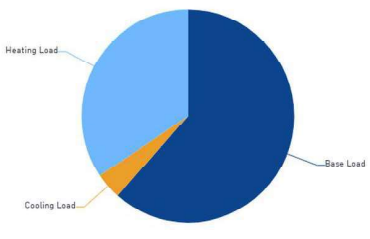


8.1 miles

Distance between treatment and comparison group centroids

1,598	13,891
Meters	Mean Baseline Consumption (Electricity)

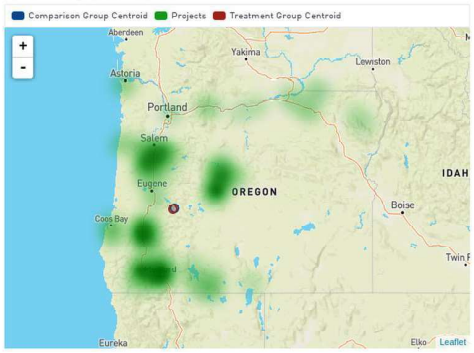
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

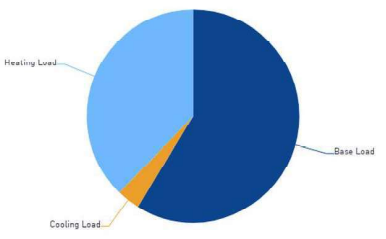


2.4 miles

Distance between treatment and future participant group centroids

858	17,618
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

7,398	594	8%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

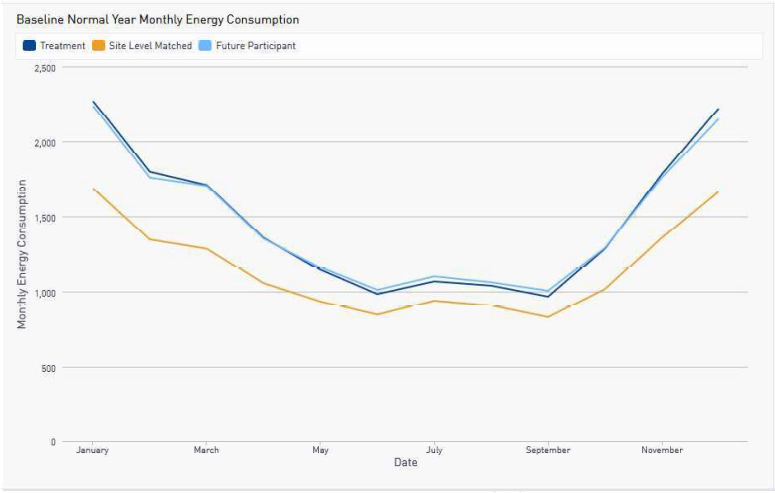
Sample Attrition Table

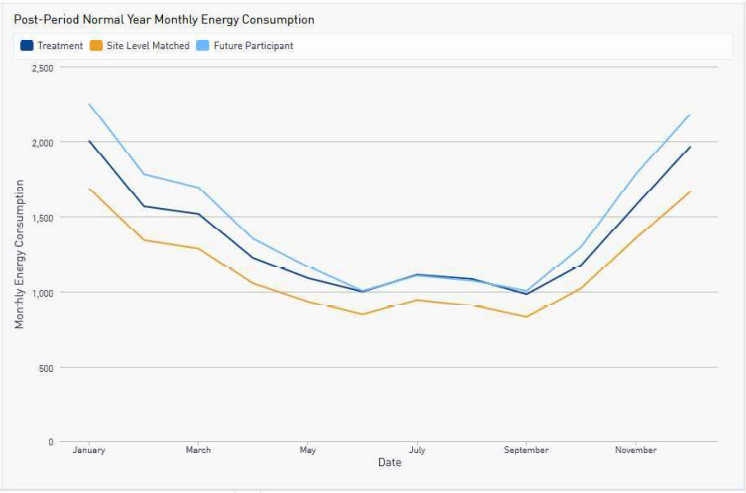
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-SITE-BUILT	108901	7249
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	7249
4	Fuel	Electricity	0	7249
5	Valid consumption data in baseline and reporting periods	valid data	0	7249
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	7249
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	91	7158
8	HeatingZone: Meters in selected heating climate zone.	--	0	7158
9	CoolingZone: Meters in selected cooling climate zone.	--		7158
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	1742	5416
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	5416
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	104	5312
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	26	5286
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	20	5266
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	701	4565
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	4565
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	4565
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	4565
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	4565
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	4565
21	Electricity Provider	PAC	2554	2011
22	Home Size [Sq Ft]	--	0	2011
23	Water heating fuel type	--	0	2011
24	Heat pump type	HEATPUMPREP	1403	608
25	Contractor	--	0	608
26	Thermostat name	--		608
27	Heat pump baseline equipment	--	0	608
28	Heat pump manufacturer	--	0	608
29	Heat pump comissioning	--	0	608
30	Multi-measure elec	=false	14	594
31	Multi-measure gas	--	0	594

3. Modeling Results

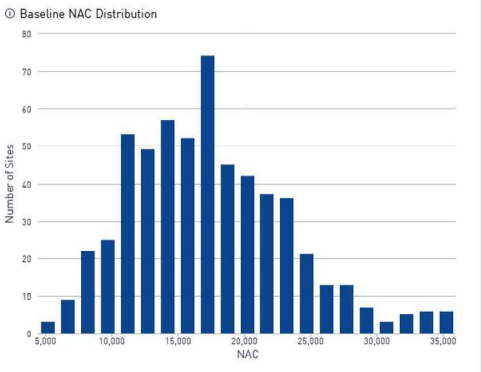
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

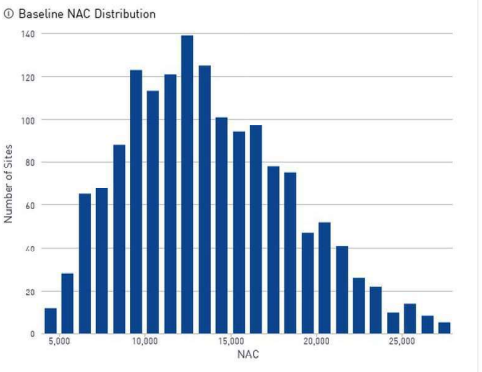




Treatment Group



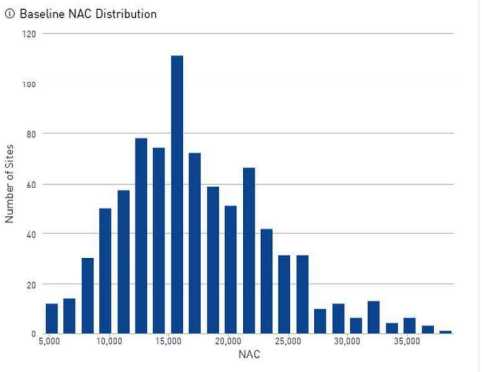
Site-Level Matched Comparison Group



0.00683

Annual Consumption p-value

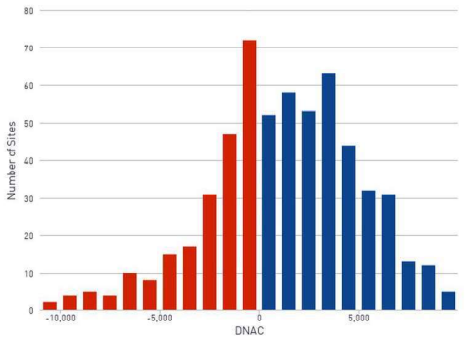
Future Participant Group



0.169

Annual Consumption p-value

DNAC Distribution



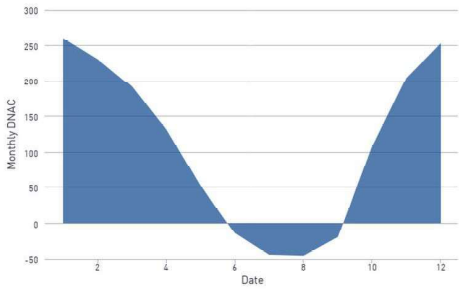
1311 +/- 189 kWh

Average Difference in Normalized Annual Consumption per Participant

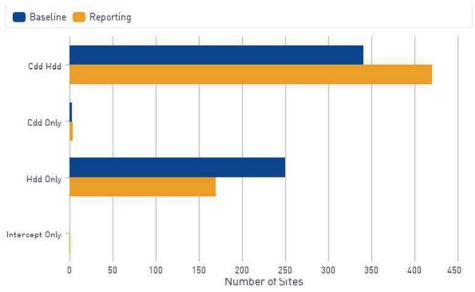
7 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

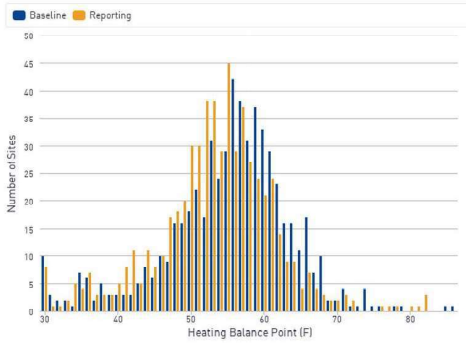


Model Type Distribution

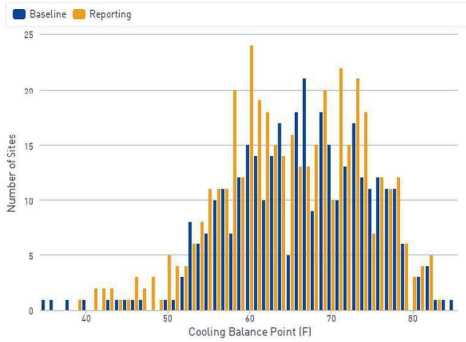


Treatment Group

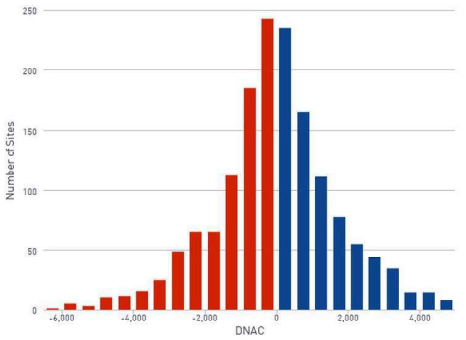
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



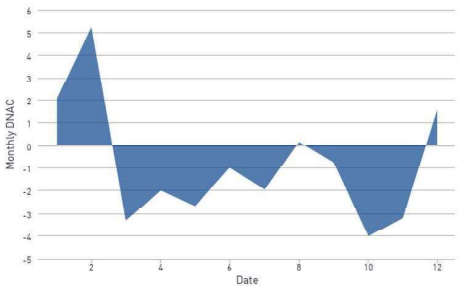
-10 +/- 90 kWh

Average Difference in Normalized Annual Consumption per Participant

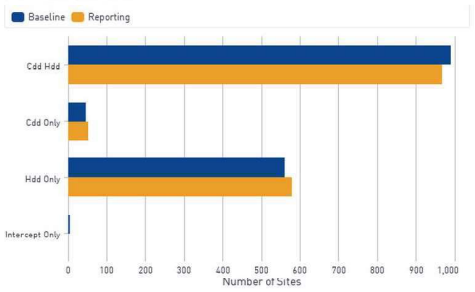
-0 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

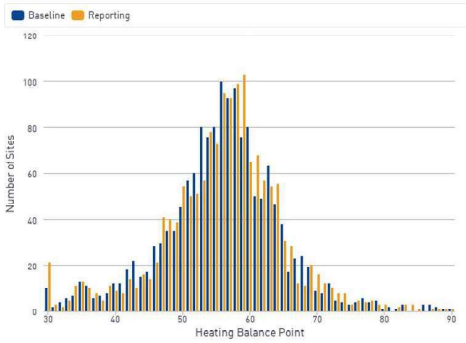


Model Type Distribution

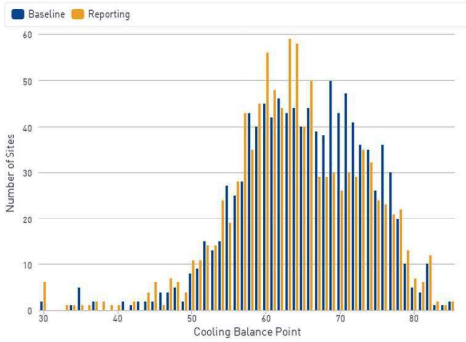


Site-level Matched Comparison Group

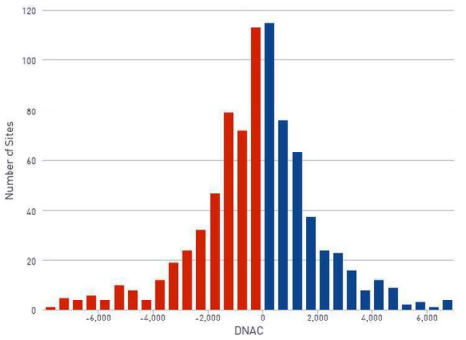
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



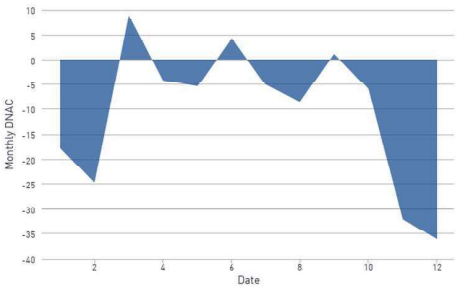
-125 +/- 164 kWh

Average Difference in Normalized Annual Consumption per Participant

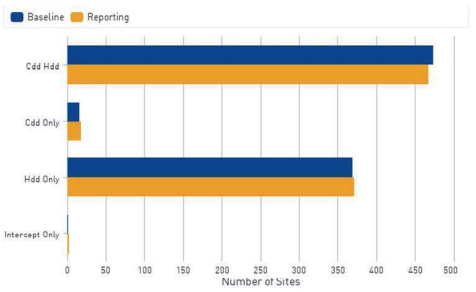
-1 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

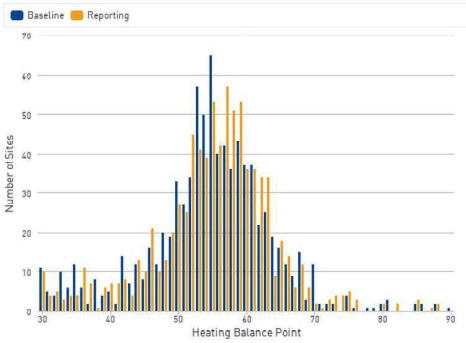


Model Type Distribution

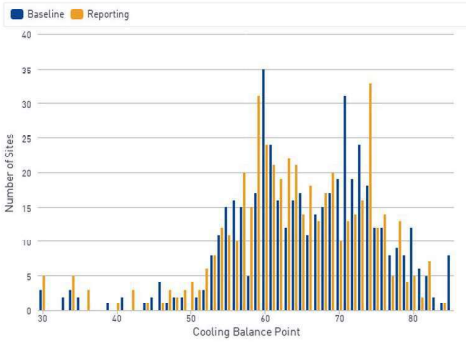


Future Participant Group

Heating Balance Point Distribution



Cooling Balance Point Distribution



Impact Evaluation Report

Electricity Impact of Ductedheatpump-Site-Built in Program Year 2013, 2014, 2015, 2016, 2017, 2018

Result Summary

Measure: Ductedheatpump-Site-Built	Program Year: 2013, 2014, 2015, 2016, 2017, 2018		Fuel: Electricity	
Meter Data Filters:	DNAC: <100%	DNAC Percentile: Remove Top and Bottom 0.5%	Annual Consumption Percentile: Remove Top and Bottom 0.5%	*Last Consumption Data Update:* Q1 2020 *Last Participation Data Update:* Q1 2020
Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): All	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: All
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: Pge	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

707 Treatment Meters	2170 +/- 180 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	12 +/- 1 % Percent Normal Year Pre-Post Difference in Consumption per Participant	18,346 Mean Baseline Consumption (Electricity)	50% Realization Rate
2,125 Site-level Matched Meters	2044 +/- 196 kWh Average Savings Relative to Site-level Matched Comparison Group	11 +/- 1% Percent Savings Relative to Site-level Matched Comparison Group	13,695 Mean Baseline Consumption (Electricity)	47% Realization Rate
1,073 Future Participant Meters	2433 +/- 236 kWh Average Savings Relative to Future Participant Group	13 +/- 1% Savings Relative to Future Participant Group	18,316 Mean Baseline Consumption (Electricity)	56% Realization Rate

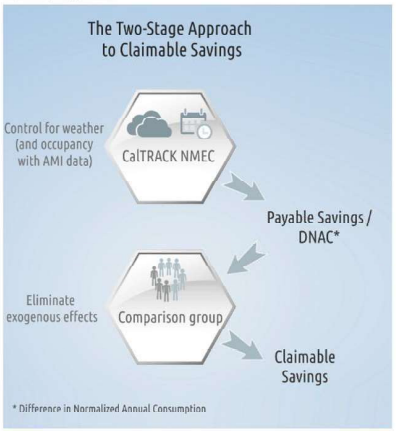
1. Introduction

This report contains the results of applying the two-stage approach (informed by the DOE's uniform methods chapter on whole building analysis) for calculating claimable savings to the selected portfolio of energy efficiency projects (see Figure). This approach begins with identification of two comparison groups for the treatment sample: (a) a site-level matched comparison group and (b) a future participant group. These groups are described below along with summary statistics (site locations, sample size, baseline consumption and baseline load disaggregation).

The CalTRACK methods are then applied to arrive at site-level savings, normalized for weather, and reflective of energy consumption changes for customers at the meter. Using a difference of differences for the treatment group with each comparison group accounts for population-level consumption changes (e.g. economic changes, rate changes, natural energy efficiency adoption etc.). The methods contained within this report are the outcome of a recent peer-reviewed study completed by Energy Trust of Oregon and Open Energy Efficiency (see "Methodology" section for more details).

The report includes the following sections:
Result Summary - Includes the overall portfolio results
Section 1. Introduction - Overview of report and the different groups included in the analysis
Section 2. Data Preparation - Data cleaning and sample attrition
Section 3. Modeling Results - CalTRACK model outputs and Difference in Normalized Annual Consumption (DNAC) results
Section 4. Methodology - Description of methods used in this report

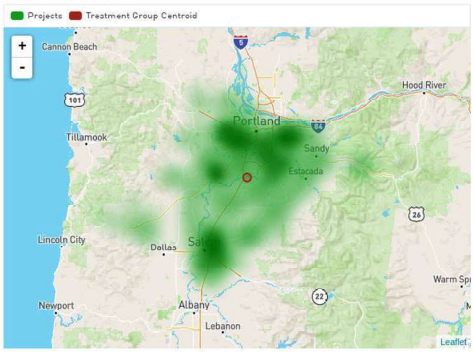
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations

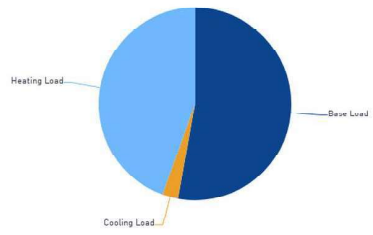


28.2 miles

80% of projects lie within this distance from treatment group centroid

707	18,346
Meters	Mean Baseline Consumption (Electricity)

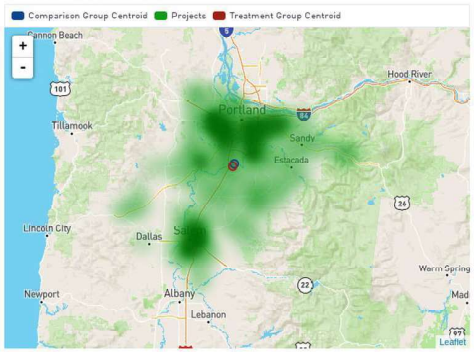
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations

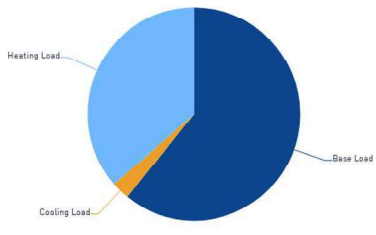


0.6 miles

Distance between treatment and comparison group centroids

2,125	13,695
Meters	Mean Baseline Consumption (Electricity)

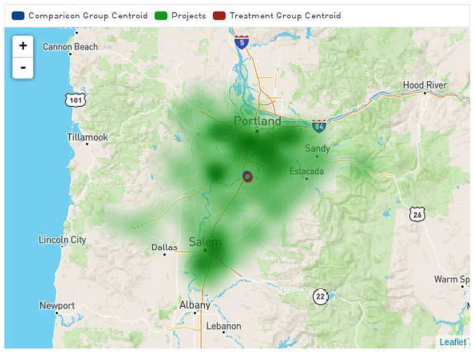
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

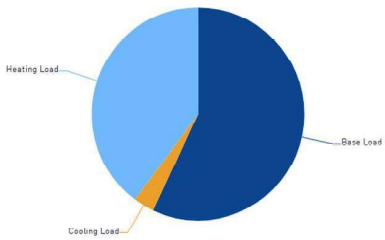


0.8 miles

Distance between treatment and future participant group centroids

1,073	18,316
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

7,398	707	9.6%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

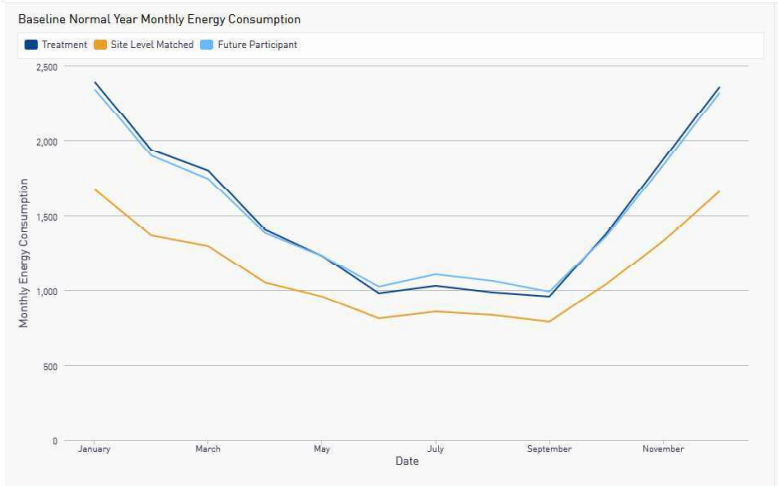
Sample Attrition Table

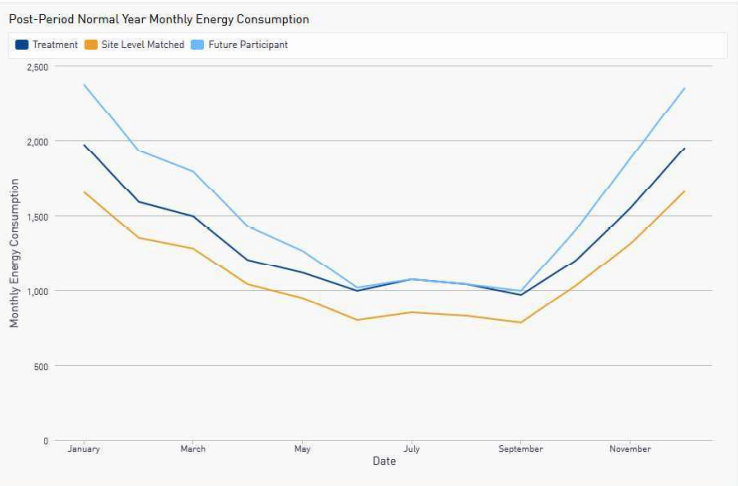
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-SITE-BUILT	108901	7249
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	7249
4	Fuel	Electricity	0	7249
5	Valid consumption data in baseline and reporting periods	valid data	0	7249
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	7249
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	91	7158
8	HeatingZone: Meters in selected heating climate zone.	--	0	7158
9	CoolingZone: Meters in selected cooling climate zone.	--		7158
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	1742	5416
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	5416
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	104	5312
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	26	5286
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	20	5266
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	701	4565
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	4565
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	4565
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	4565
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	4565
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	4565
21	Electricity Provider	PGE	2010	2555
22	Home Size [Sq Ft]	--	0	2555
23	Water heating fuel type	--	0	2555
24	Heat pump type	HEATPUMPREP	1825	730
25	Contractor	--	0	730
26	Thermostat name	--		730
27	Heat pump baseline equipment	--	0	730
28	Heat pump manufacturer	--	0	730
29	Heat pump comissioning	--	0	730
30	Multi-measure elec	=false	23	707
31	Multi-measure gas	--	0	707

3. Modeling Results

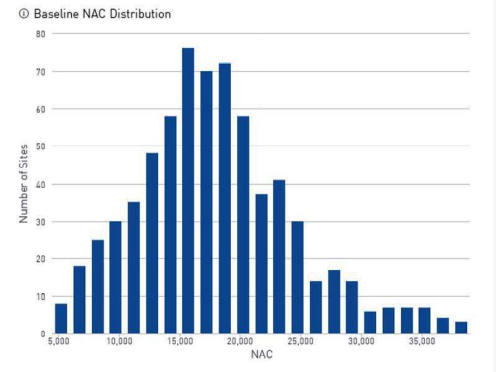
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

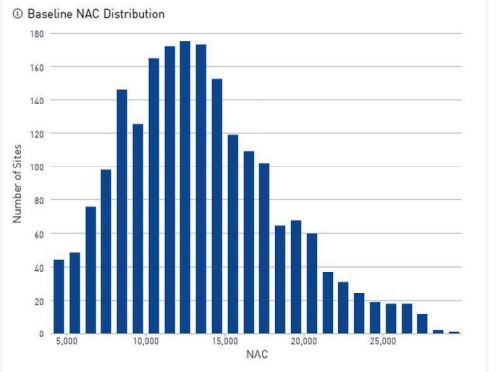




Treatment Group



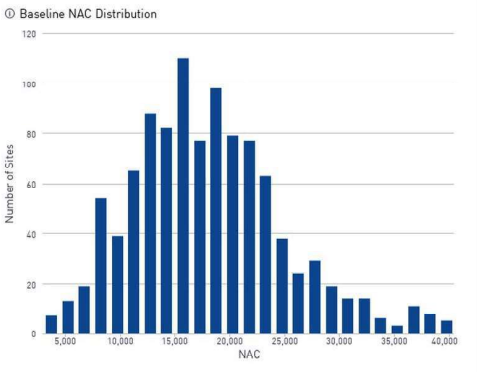
Site-Level Matched Comparison Group



0.000318

Annual Consumption p-value

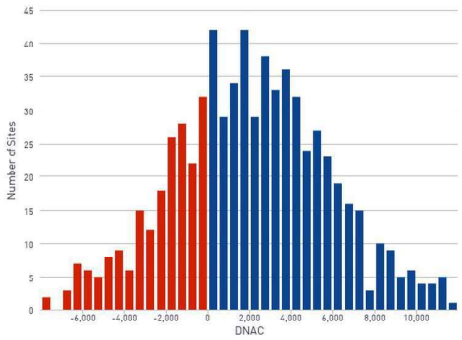
Future Participant Group



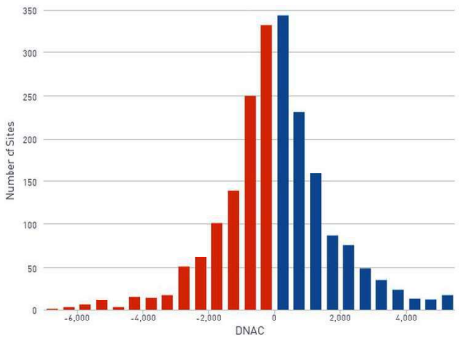
0.18

Annual Consumption p-value

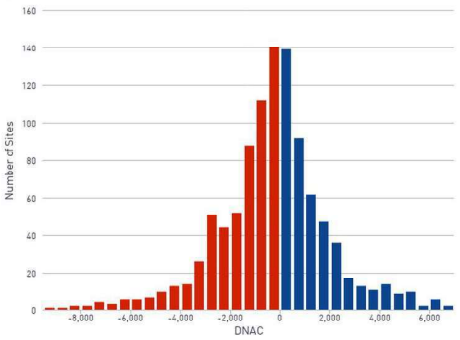
DNAC Distribution



DNAC Distribution



DNAC Distribution

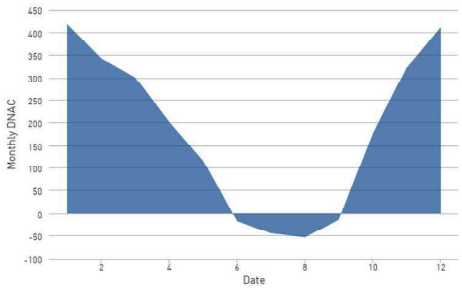


2170 +/- 180 kWh	12 +/- 1 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

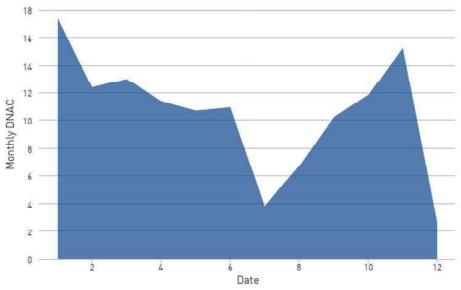
126 +/- 76 kWh	1 +/- 1 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

-263 +/- 153 kWh	-1 +/- 1 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

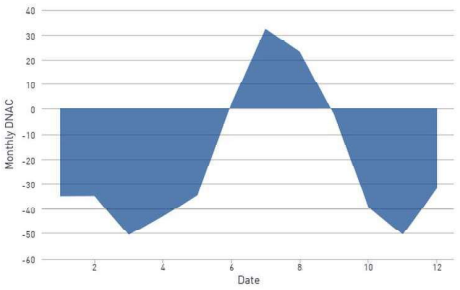
Monthly DNAC



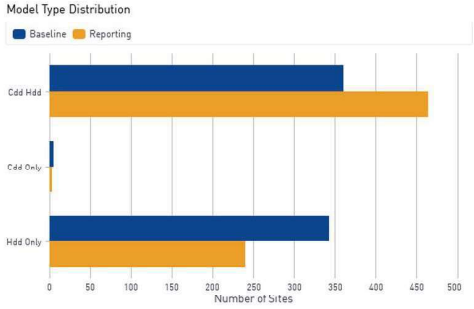
Monthly DNAC



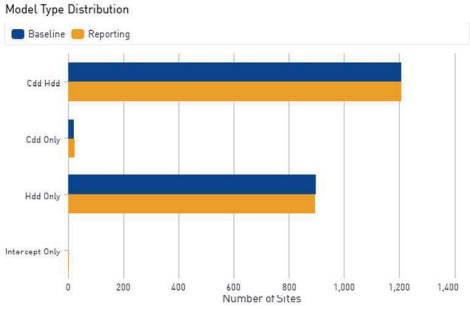
Monthly DNAC



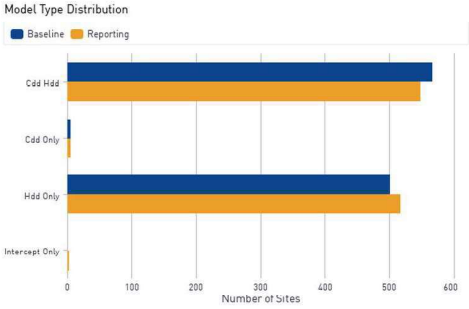
Model Type Distribution



Model Type Distribution



Model Type Distribution

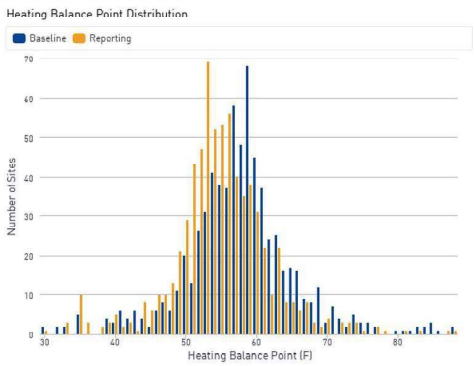


Treatment Group

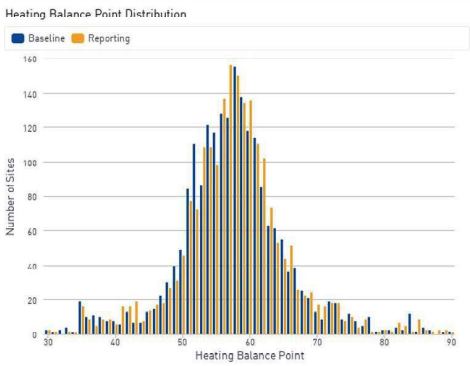
Site-level Matched Comparison Group

Future Participant Group

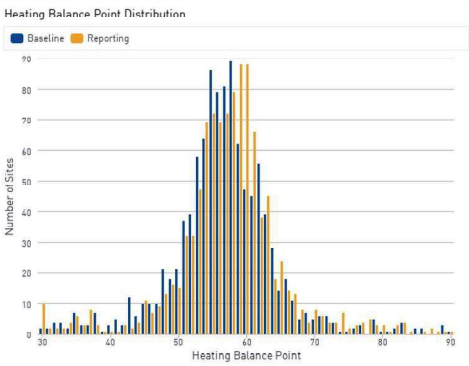
Heating Balance Point Distribution



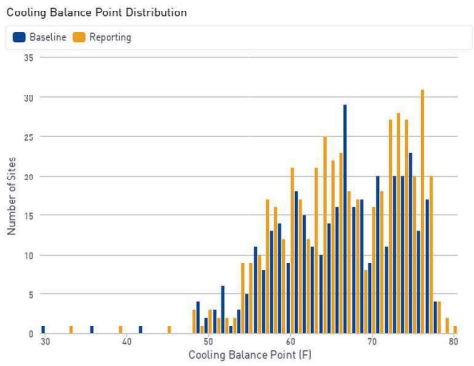
Heating Balance Point Distribution



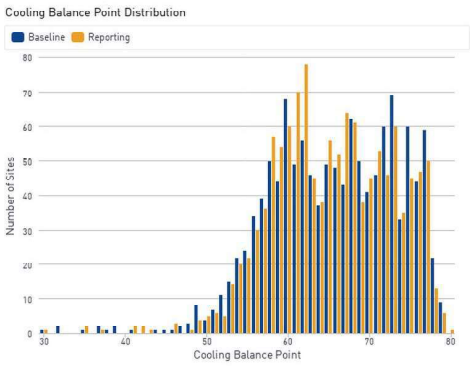
Heating Balance Point Distribution



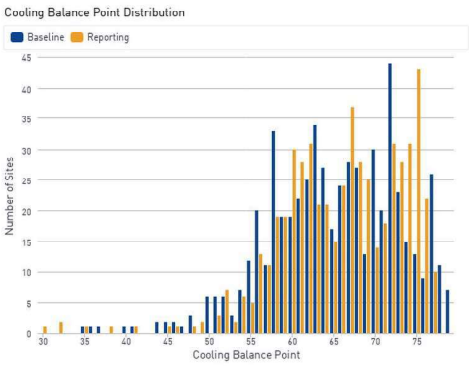
Cooling Balance Point Distribution



Cooling Balance Point Distribution



Cooling Balance Point Distribution



Impact Evaluation Report

Electricity Impact of Ductedheatpump-Manufactured in Program Year 2013, 2014, 2015, 2016, 2017, 2018

Result Summary

Measure: Ductedheatpump-Manufactured	Program Year: 2013, 2014, 2015, 2016, 2017, 2018		Fuel: Electricity	
Meter Data Filters:	DNAC: <100%	DNAC Percentile: Remove Top and Bottom 0.5%	Annual Consumption Percentile: Remove Top and Bottom 0.5%	*Last Consumption Data Update:* Q1 2020 *Last Participation Data Update:* Q1 2020
Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): All	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: No
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: All	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

79 Treatment Meters	2536 +/- 400 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	16 +/- 3 % Percent Normal Year Pre-Post Difference in Consumption per Participant	15,920 Mean Baseline Consumption (Electricity)	64% Realization Rate
95 Site-level Matched Meters	2287 +/- 603 kWh Average Savings Relative to Site-level Matched Comparison Group	14 +/- 4% Percent Savings Relative to Site-level Matched Comparison Group	14,988 Mean Baseline Consumption (Electricity)	57% Realization Rate
388 Future Participant Meters	2891 +/- 448 kWh Average Savings Relative to Future Participant Group	18 +/- 3% Savings Relative to Future Participant Group	15,499 Mean Baseline Consumption (Electricity)	72% Realization Rate

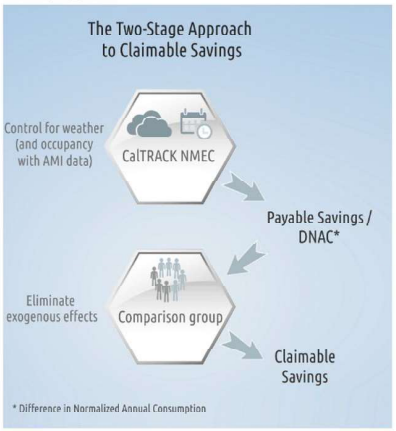
1. Introduction

This report contains the results of applying the two-stage approach (informed by the DOE's uniform methods chapter on whole building analysis) for calculating claimable savings to the selected portfolio of energy efficiency projects (see Figure). This approach begins with identification of two comparison groups for the treatment sample: (a) a site-level matched comparison group and (b) a future participant group. These groups are described below along with summary statistics (site locations, sample size, baseline consumption and baseline load disaggregation).

The CalTRACK methods are then applied to arrive at site-level savings, normalized for weather, and reflective of energy consumption changes for customers at the meter. Using a difference of differences for the treatment group with each comparison group accounts for population-level consumption changes (e.g. economic changes, rate changes, natural energy efficiency adoption etc.). The methods contained within this report are the outcome of a recent peer-reviewed study completed by Energy Trust of Oregon and Open Energy Efficiency (see "Methodology" section for more details).

The report includes the following sections:
Result Summary - Includes the overall portfolio results
Section 1. Introduction - Overview of report and the different groups included in the analysis
Section 2. Data Preparation - Data cleaning and sample attrition
Section 3. Modeling Results - CalTRACK model outputs and Difference in Normalized Annual Consumption (DNAC) results
Section 4. Methodology - Description of methods used in this report

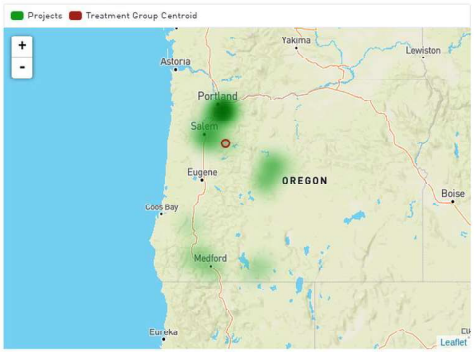
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations

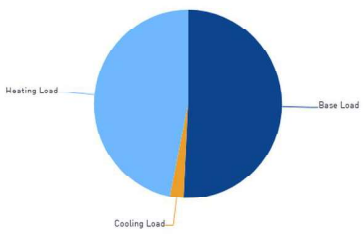


165.0 miles

80% of projects lie within this distance from treatment group centroid

79	15,920
Meters	Mean Baseline Consumption (Electricity)

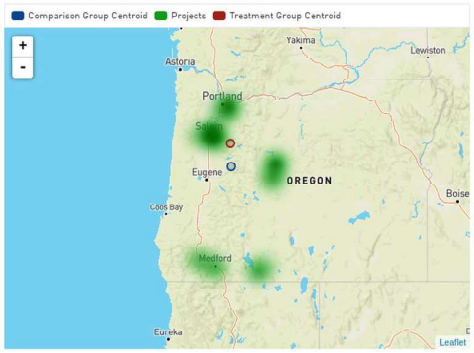
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations

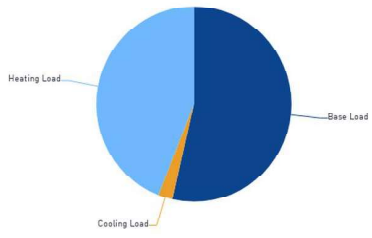


36.9 miles

Distance between treatment and comparison group centroids

0	14,988
Meters	Mean Baseline Consumption (Electricity)

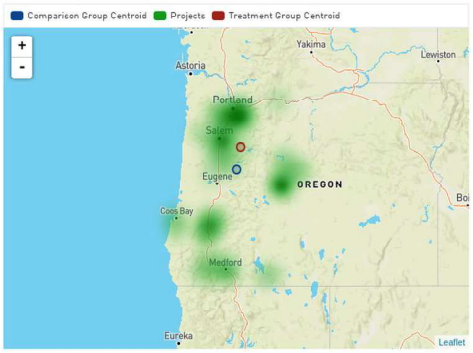
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

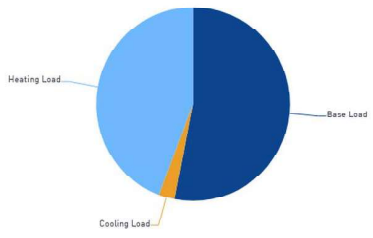


31.1 miles

Distance between treatment and future participant group centroids

388	15,499
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

710	79	11%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

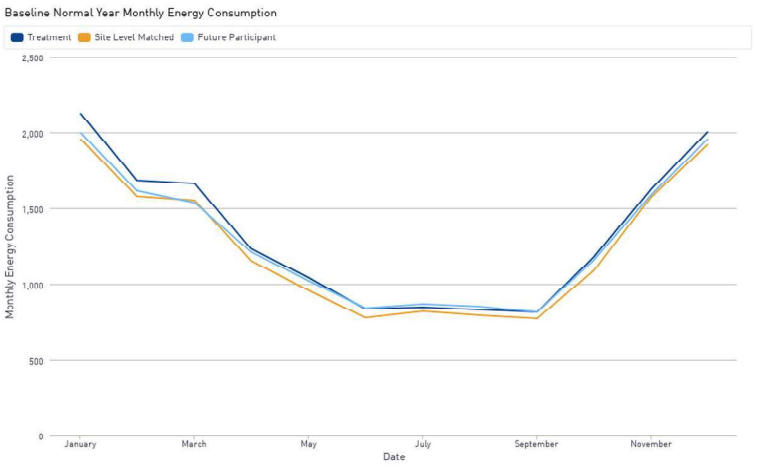
Sample Attrition Table

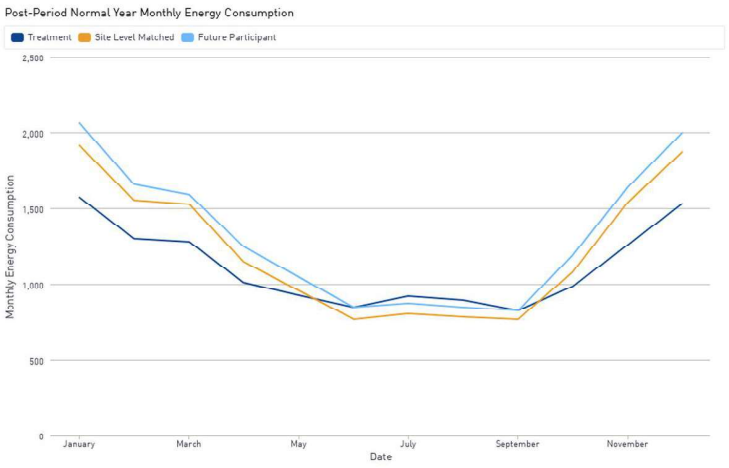
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-MANUFACTURED	115472	678
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	678
4	Fuel	Electricity	0	678
5	Valid consumption data in baseline and reporting periods	valid data	0	678
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	678
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	2	676
8	HeatingZone: Meters in selected heating climate zone.	--	0	676
9	CoolingZone: Meters in selected cooling climate zone.	--		676
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	236	440
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	440
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	2	438
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	2	436
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	0	436
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	50	386
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	386
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	386
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	386
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	386
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	386
21	Electricity Provider	--	0	386
22	Home Size [Sq Ft]	--	0	386
23	Water heating fuel type	--	0	386
24	Heat pump type	HEATPUMPREP	196	190
25	Contractor	--	0	190
26	Thermostat name	--		190
27	Heat pump baseline equipment	--	0	190
28	Heat pump manufacturer	--	0	190
29	Heat pump comissioning	No	111	79
30	Multi-measure elec	=false	0	79
31	Multi-measure gas	--	0	79

3. Modeling Results

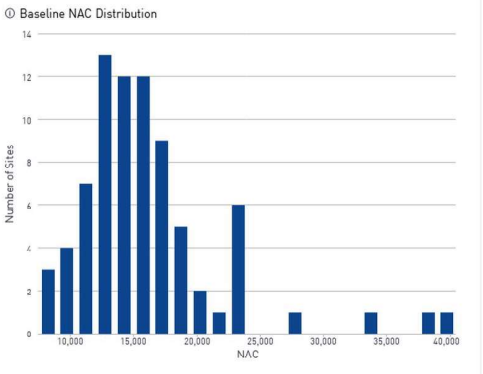
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

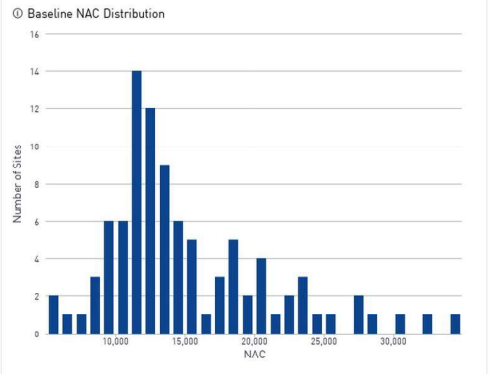




Treatment Group



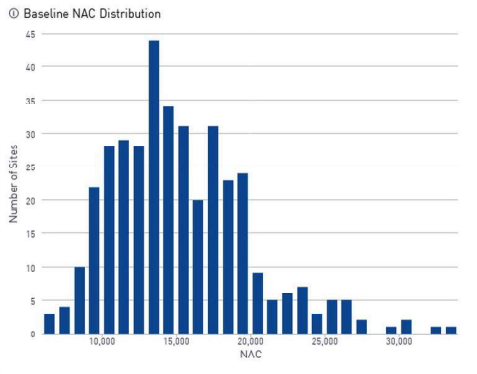
Site-Level Matched Comparison Group



0.234

Annual Consumption p-value

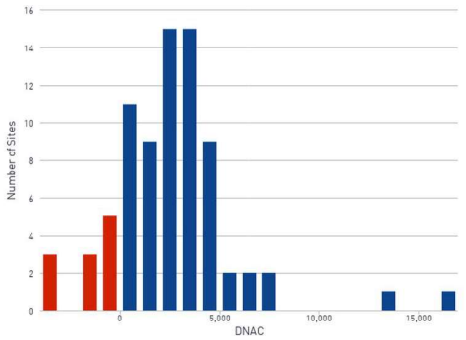
Future Participant Group



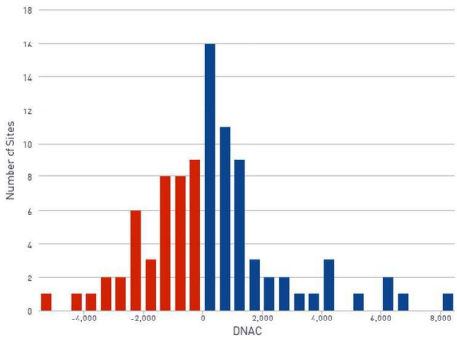
0.26

Annual Consumption p-value

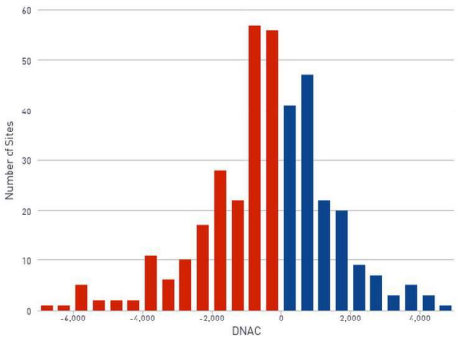
DNAC Distribution



DNAC Distribution



DNAC Distribution

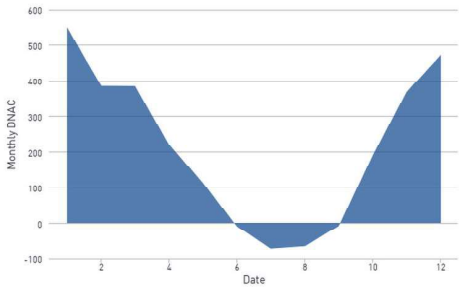


2536 +/- 400 kWh	16 +/- 3 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

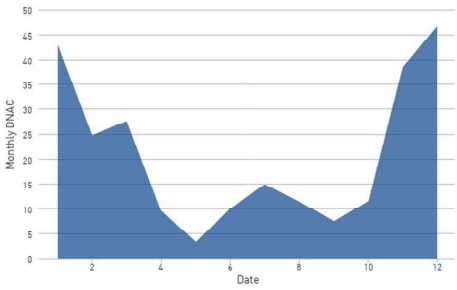
249 +/- 451 kWh	2 +/- 3 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

-354 +/- 202 kWh	-2 +/- 1 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

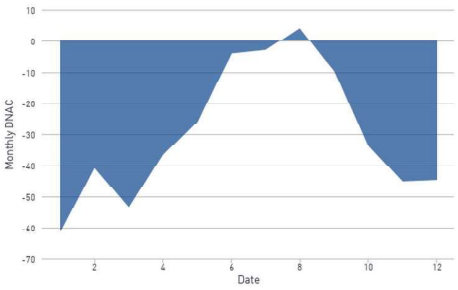
Monthly DNAC



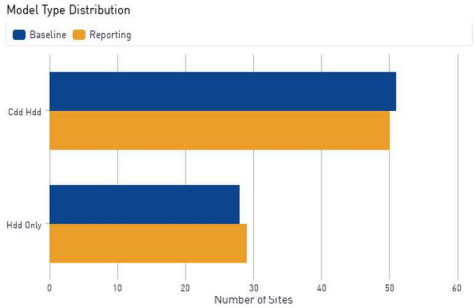
Monthly DNAC



Monthly DNAC



Model Type Distribution



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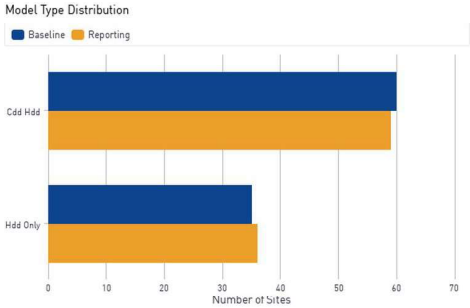
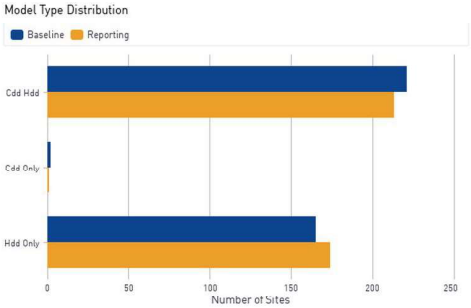


Model Type Distribution

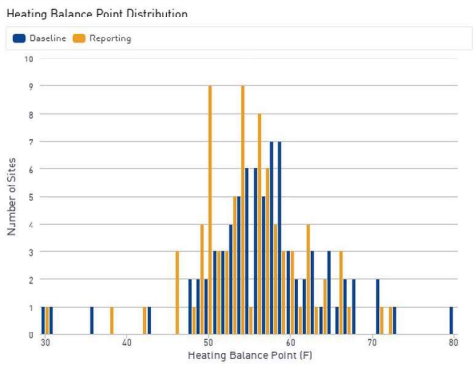


Treatment Group

Site-level Matched Comparison Group

Future Participant Group

Heating Balance Point Distribution



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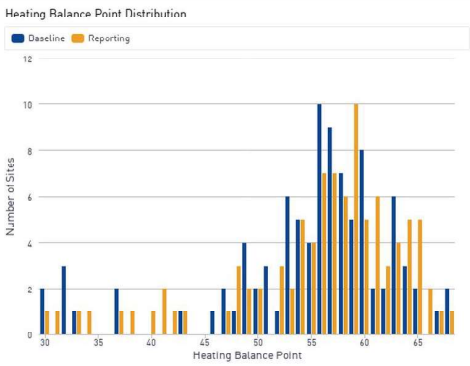

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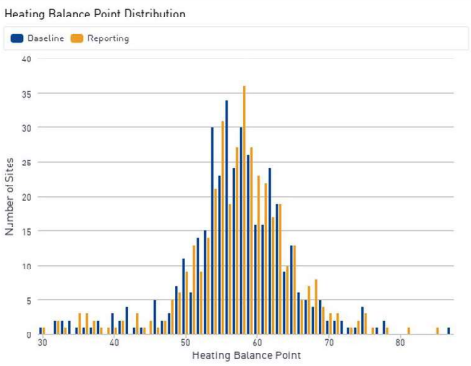

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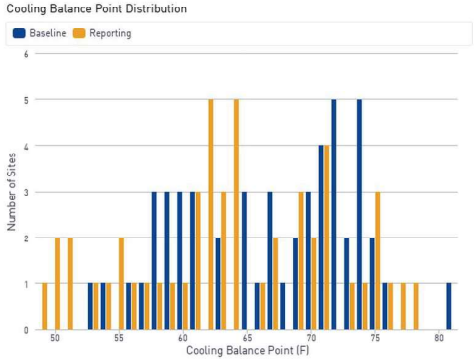

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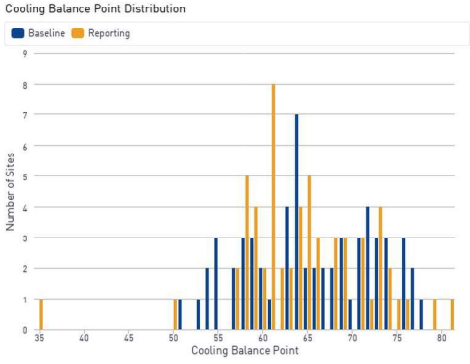

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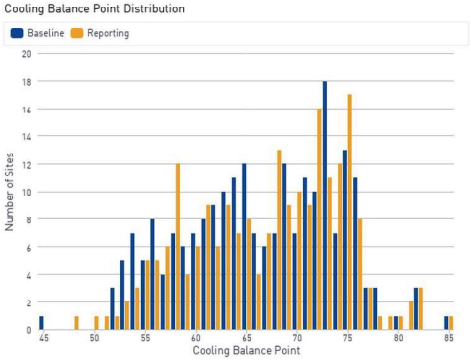

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	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: Yes
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: All	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

109 Treatment Meters	2540 +/- 339 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	16 +/- 2 % Percent Normal Year Pre-Post Difference in Consumption per Participant	15,884 Mean Baseline Consumption (Electricity)	54% Realization Rate
201 Site-level Matched Meters	2589 +/- 425 kWh Average Savings Relative to Site-level Matched Comparison Group	16 +/- 3% Percent Savings Relative to Site-level Matched Comparison Group	14,032 Mean Baseline Consumption (Electricity)	55% Realization Rate
388 Future Participant Meters	2894 +/- 395 kWh Average Savings Relative to Future Participant Group	18 +/- 2% Savings Relative to Future Participant Group	15,499 Mean Baseline Consumption (Electricity)	61% Realization Rate

1. Introduction

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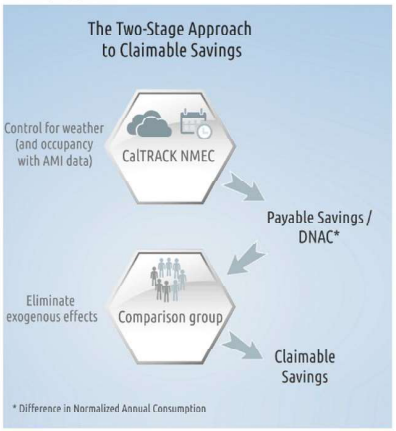
Two-Stage Approach



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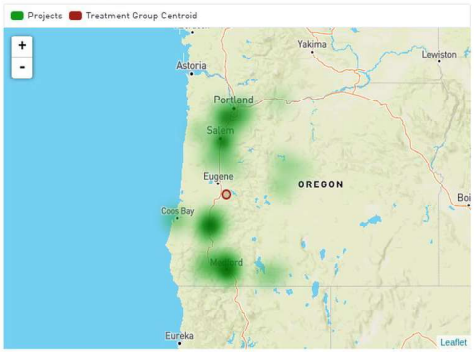
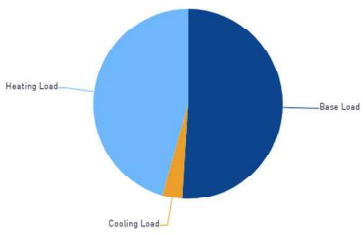


115.1 miles

80% of projects lie within this distance from treatment group centroid

109	15,884
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



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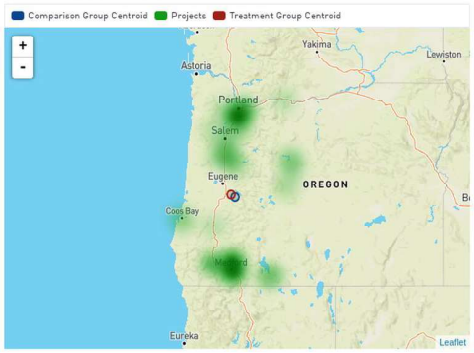
Site-level Matched Site Locations

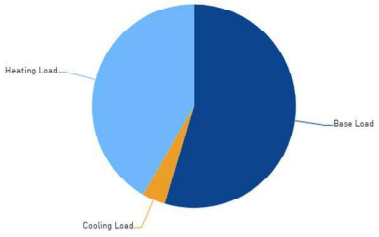


15.2 miles

Distance between treatment and comparison group centroids

0	14,032
Meters	Mean Baseline Consumption (Electricity)

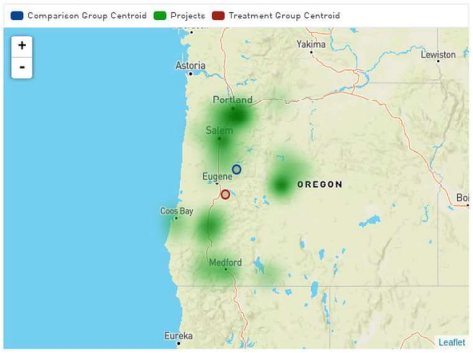
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

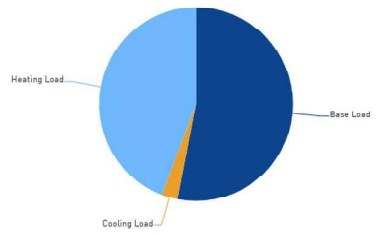


36.3 miles

Distance between treatment and future participant group centroids

388	15,499
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

710	109	15%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

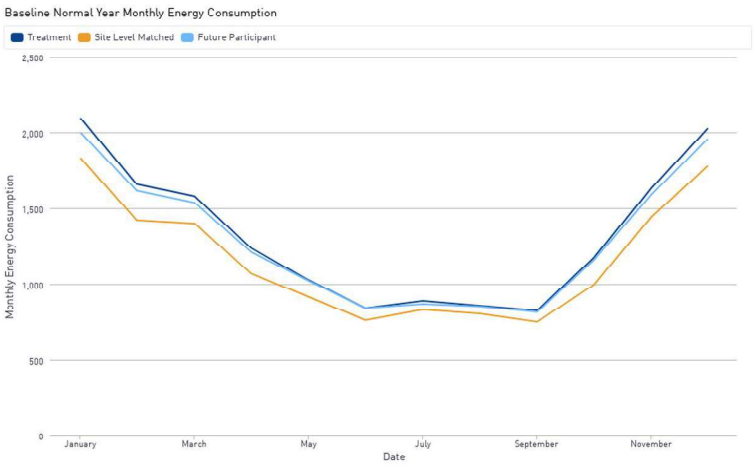
Sample Attrition Table

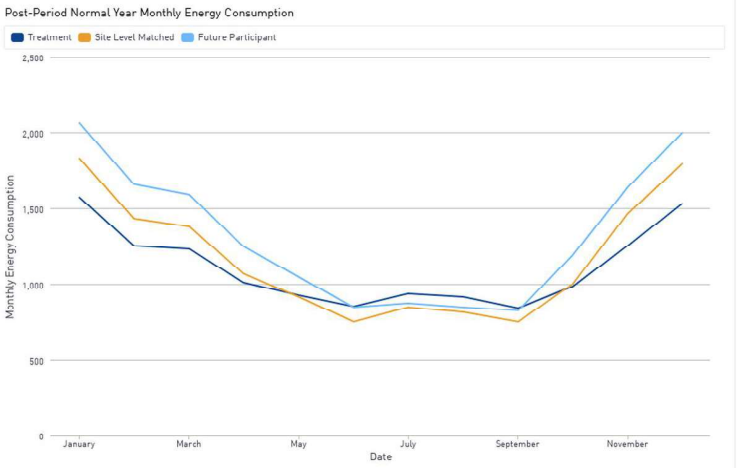
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-MANUFACTURED	115472	678
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	678
4	Fuel	Electricity	0	678
5	Valid consumption data in baseline and reporting periods	valid data	0	678
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	678
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	2	676
8	HeatingZone: Meters in selected heating climate zone.	--	0	676
9	CoolingZone: Meters in selected cooling climate zone.	--		676
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	236	440
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	440
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	2	438
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	2	436
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	0	436
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	50	386
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	386
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	386
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	386
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	386
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	386
21	Electricity Provider	--	0	386
22	Home Size [Sq Ft]	--	0	386
23	Water heating fuel type	--	0	386
24	Heat pump type	HEATPUMPREP	196	190
25	Contractor	--	0	190
26	Thermostat name	--		190
27	Heat pump baseline equipment	--	0	190
28	Heat pump manufacturer	--	0	190
29	Heat pump comissioning	Yes	79	111
30	Multi-measure elec	=false	2	109
31	Multi-measure gas	--	0	109

3. Modeling Results

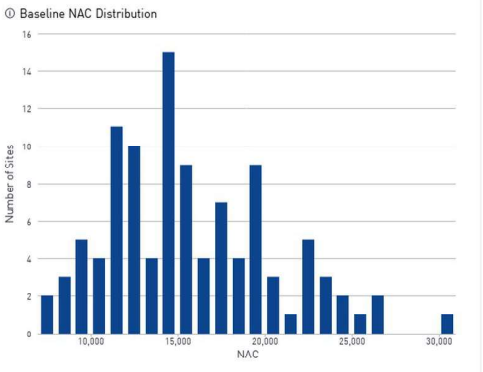
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

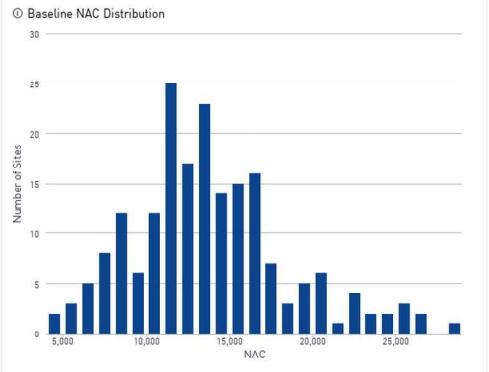




Treatment Group



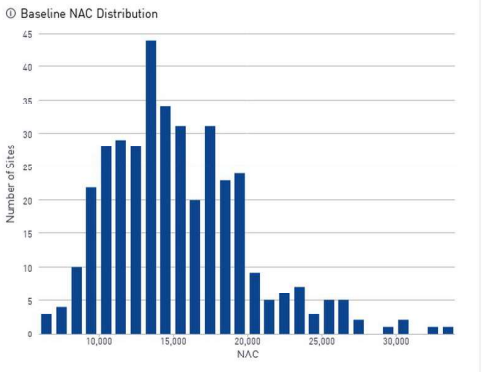
Site-level Matched Comparison Group



0.231

Annual Consumption p-value

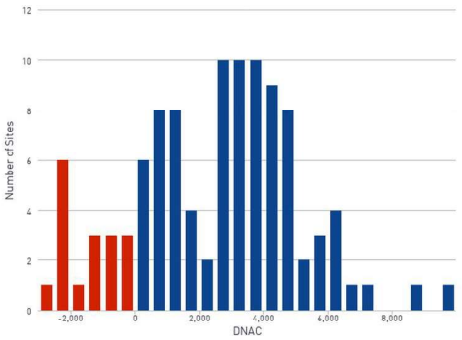
Future Participant Group



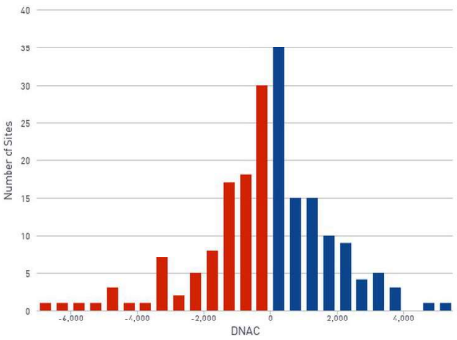
0.258

Annual Consumption p-value

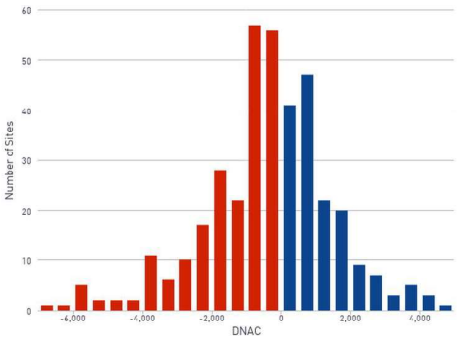
DNAC Distribution



DNAC Distribution



DNAC Distribution

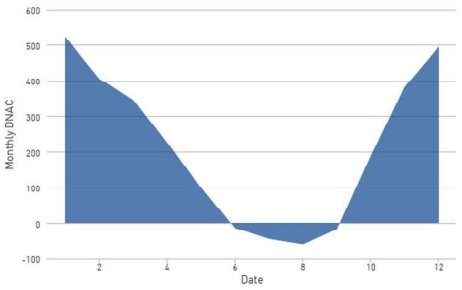


2540 +/- 339 kWh	16 +/- 2 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

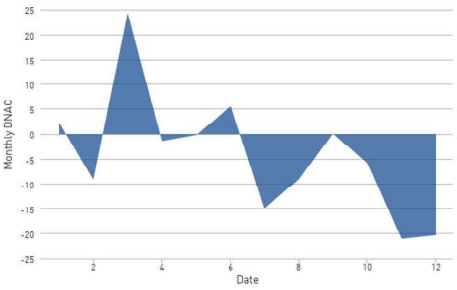
-49 +/- 255 kWh	-0 +/- 2 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

-354 +/- 202 kWh	-2 +/- 1 %
Average Difference in Normalized Annual Consumption per Participant	Difference in Normalized Annual Consumption as a Percent of Baseline

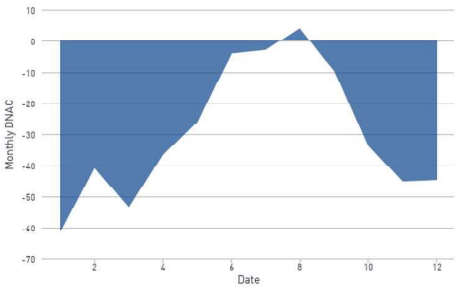
Monthly DNAC



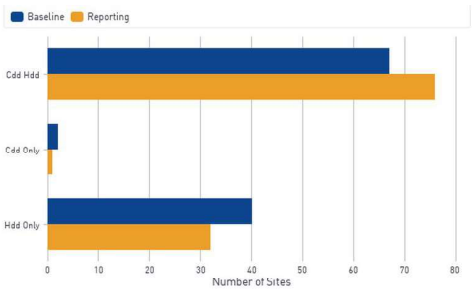
Monthly DNAC



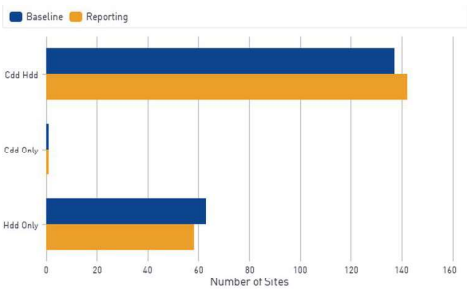
Monthly DNAC



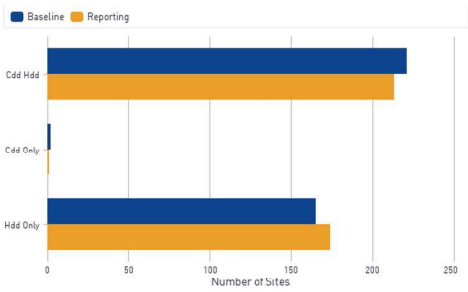
Model Type Distribution



Model Type Distribution



Model Type Distribution

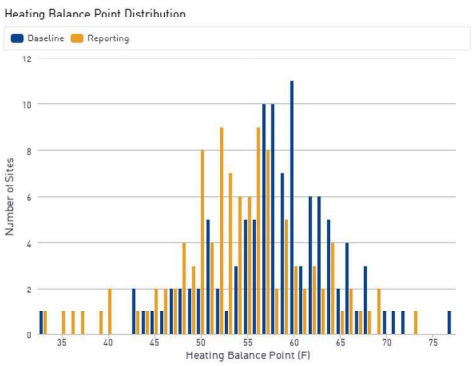


Treatment Group

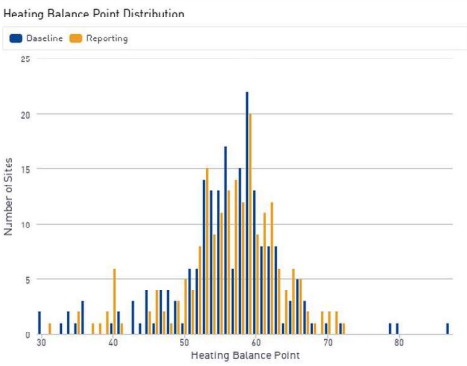
Site-level Matched Comparison Group

Future Participant Group

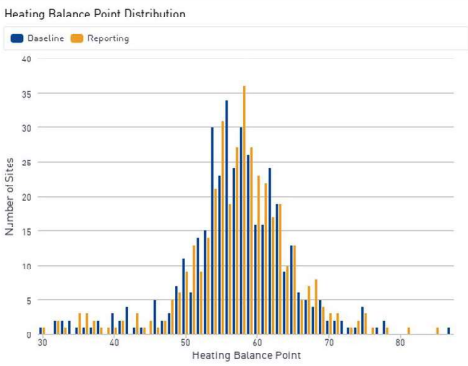
Heating Balance Point Distribution



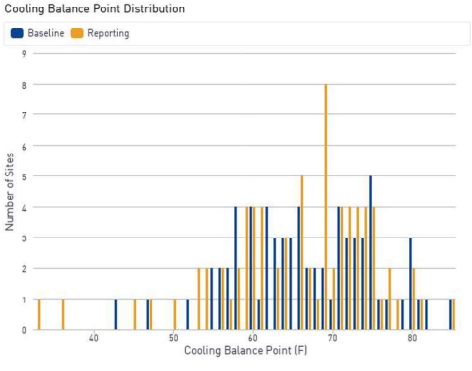
Heating Balance Point Distribution



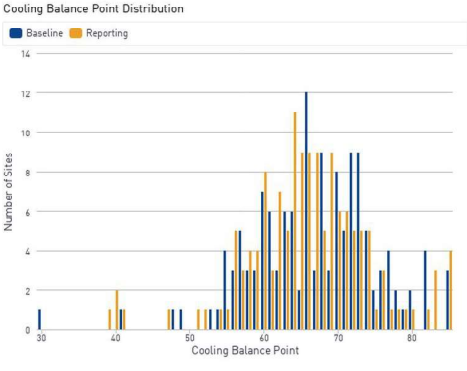
Heating Balance Point Distribution



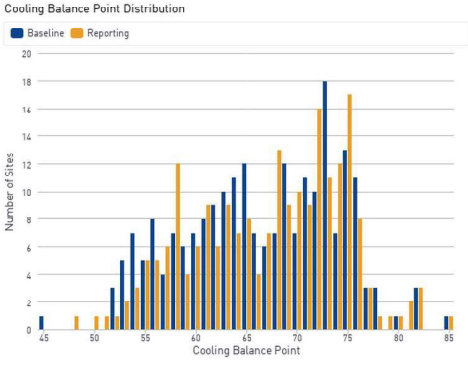
Cooling Balance Point Distribution



Cooling Balance Point Distribution



Cooling Balance Point Distribution



Impact Evaluation Report

Electricity Impact of Ductedheatpump-Site-Built in Program Year 2013, 2014, 2015, 2016, 2017, 2018

Result Summary

Measure: Ductedheatpump-Site-Built	Program Year: 2013, 2014, 2015, 2016, 2017, 2018		Fuel: Electricity	
Meter Data Filters:	DNAC: <100%	DNAC Percentile: Remove Top and Bottom 0.5%	Annual Consumption Percentile: Remove Top and Bottom 0.5%	*Last Consumption Data Update:* Q1 2020 *Last Participation Data Update:* Q1 2020
Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): All	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: No
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: All	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

327 Treatment Meters	1712 +/- 288 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	9 +/- 2 % Percent Normal Year Pre-Post Difference in Consumption per Participant	18,299 Mean Baseline Consumption (Electricity)	42% Realization Rate
980 Site-level Matched Meters	1631 +/- 308 kWh Average Savings Relative to Site-level Matched Comparison Group	9 +/- 2% Percent Savings Relative to Site-level Matched Comparison Group	14,290 Mean Baseline Consumption (Electricity)	40% Realization Rate
1,930 Future Participant Meters	1919 +/- 309 kWh Average Savings Relative to Future Participant Group	10 +/- 2% Savings Relative to Future Participant Group	17,998 Mean Baseline Consumption (Electricity)	47% Realization Rate

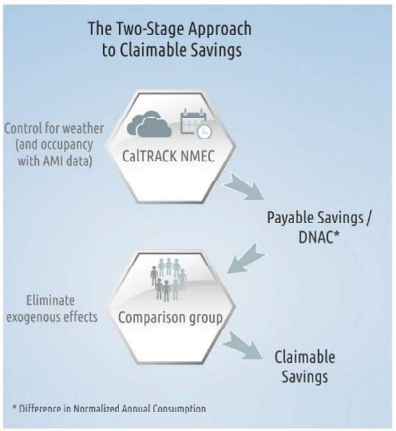
1. Introduction

This report contains the results of applying the two-stage approach (informed by the DOE's uniform methods chapter on whole building analysis) for calculating claimable savings to the selected portfolio of energy efficiency projects (see Figure). This approach begins with identification of two comparison groups for the treatment sample: (a) a site-level matched comparison group and (b) a future participant group. These groups are described below along with summary statistics (site locations, sample size, baseline consumption and baseline load disaggregation).

The CalTRACK methods are then applied to arrive at site-level savings, normalized for weather, and reflective of energy consumption changes for customers at the meter. Using a difference of differences for the treatment group with each comparison group accounts for population-level consumption changes (e.g. economic changes, rate changes, natural energy efficiency adoption etc.). The methods contained within this report are the outcome of a recent peer-reviewed study completed by Energy Trust of Oregon and Open Energy Efficiency (see "Methodology" section for more details).

The report includes the following sections:
Result Summary - Includes the overall portfolio results
Section 1. Introduction - Overview of report and the different groups included in the analysis
Section 2. Data Preparation - Data cleaning and sample attrition
Section 3. Modeling Results - CalTRACK model outputs and Difference in Normalized Annual Consumption (DNAC) results
Section 4. Methodology - Description of methods used in this report

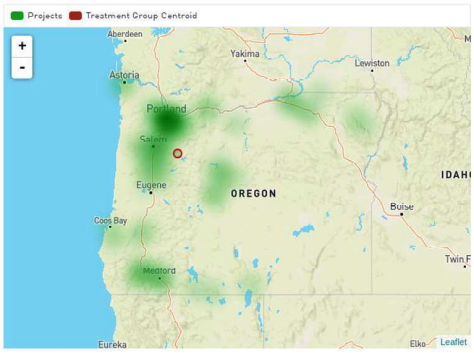
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations

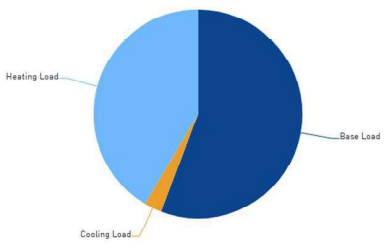


173.2 miles

80% of projects lie within this distance from treatment group centroid

327	18,299
Meters	Mean Baseline Consumption (Electricity)

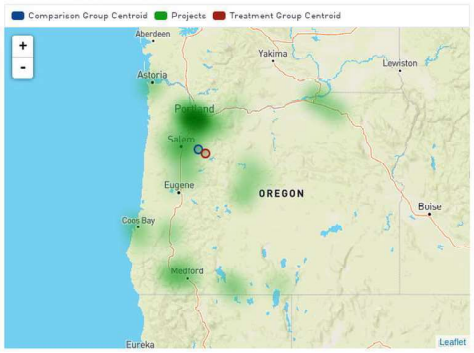
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations

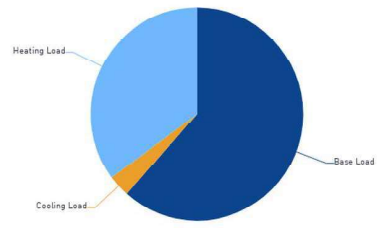


9.6 miles

Distance between treatment and comparison group centroids

0	14,290
Meters	Mean Baseline Consumption (Electricity)

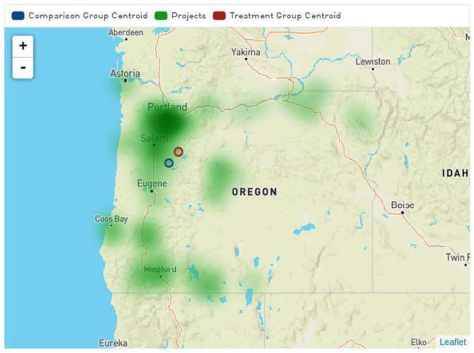
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

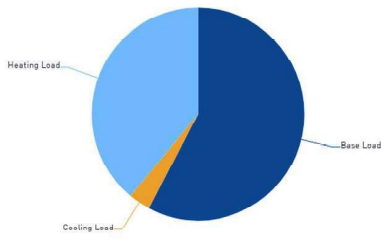


20.1 miles

Distance between treatment and future participant group centroids

1,930	17,998
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

7,398	327	4.4%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

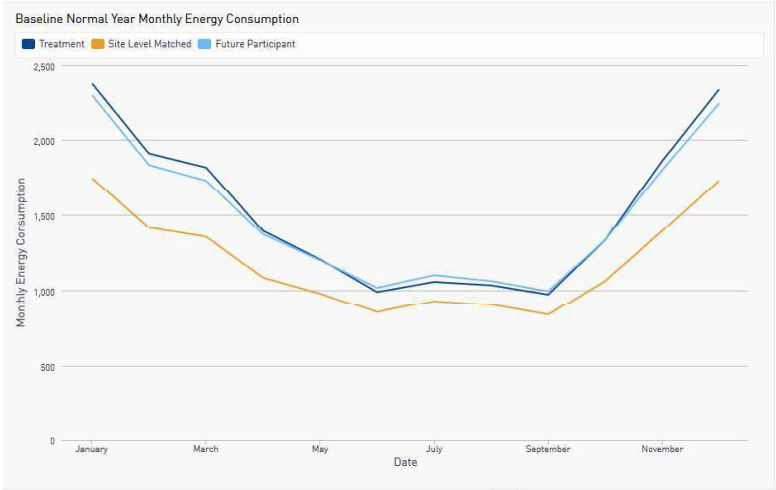
Sample Attrition Table

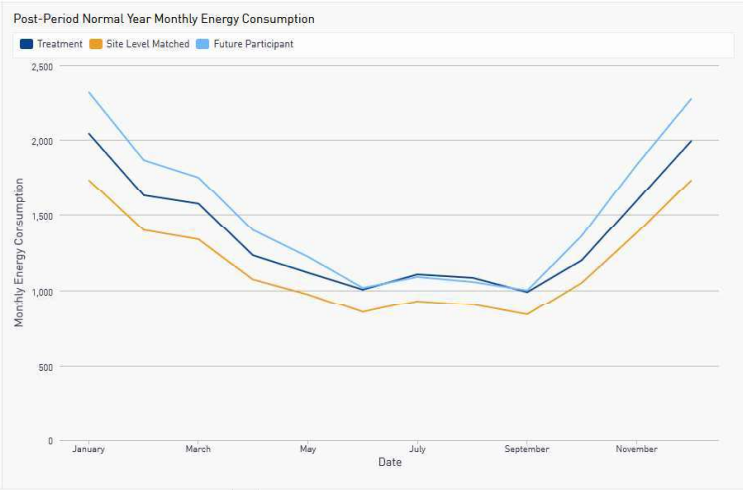
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-SITE-BUILT	108901	7249
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	7249
4	Fuel	Electricity	0	7249
5	Valid consumption data in baseline and reporting periods	valid data	0	7249
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	7249
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	91	7158
8	HeatingZone: Meters in selected heating climate zone.	--	0	7158
9	CoolingZone: Meters in selected cooling climate zone.	--		7158
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	1742	5416
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	5416
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	104	5312
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	26	5286
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	20	5266
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	701	4565
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	4565
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	4565
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	4565
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	4565
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	4565
21	Electricity Provider	--	0	4565
22	Home Size [Sq Ft]	--	0	4565
23	Water heating fuel type	--	0	4565
24	Heat pump type	HEATPUMPREP	3226	1339
25	Contractor	--	0	1339
26	Thermostat name	--		1339
27	Heat pump baseline equipment	--	0	1339
28	Heat pump manufacturer	--	0	1339
29	Heat pump comissioning	No	999	340
30	Multi-measure elec	=false	13	327
31	Multi-measure gas	--	0	327

3. Modeling Results

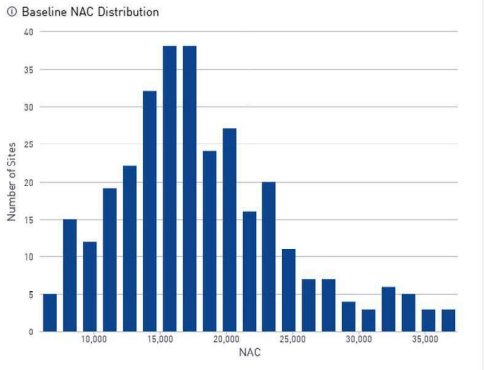
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

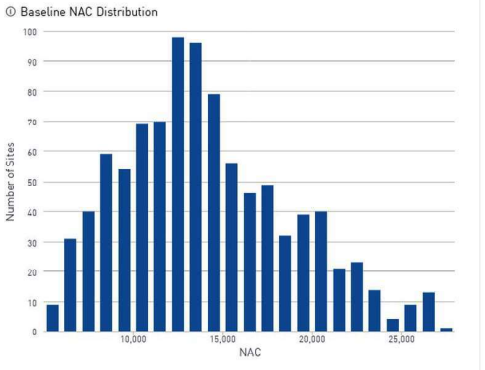




Treatment Group



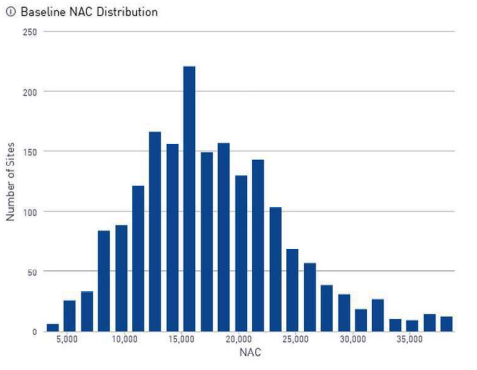
Site-Level Matched Comparison Group



0.107

Annual Consumption p-value

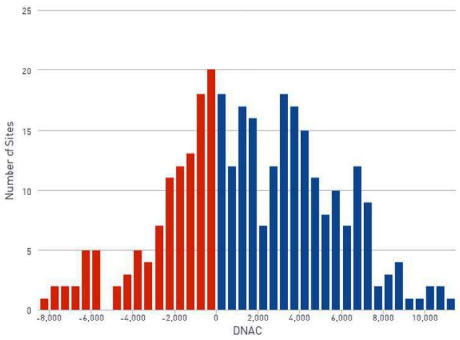
Future Participant Group



0.174

Annual Consumption p-value

DNAC Distribution



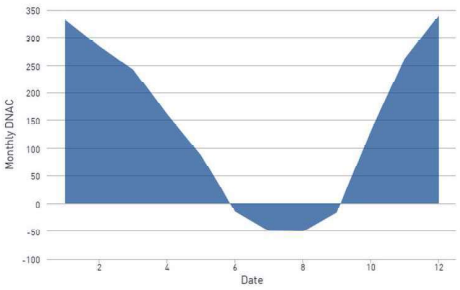
1712 +/- 288 kWh

Average Difference in Normalized Annual Consumption per Participant

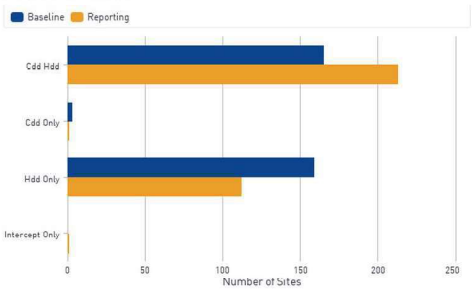
9 +/- 2 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

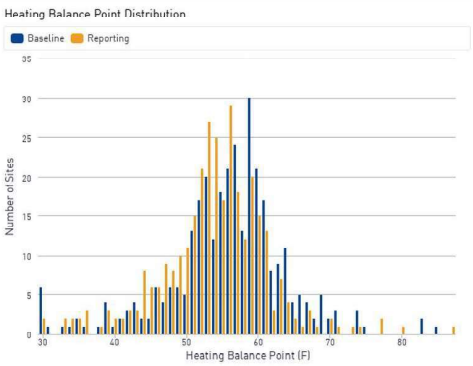


Model Type Distribution

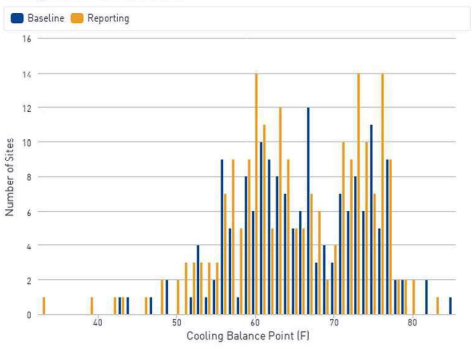


Treatment Group

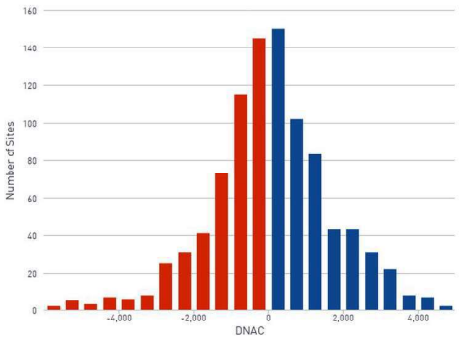
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



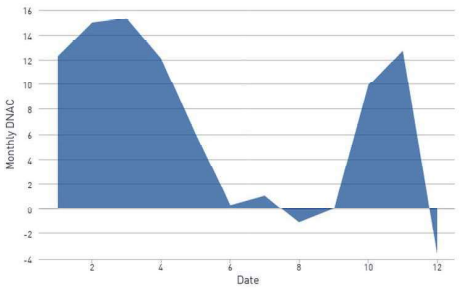
80 +/- 110 kWh

Average Difference in Normalized Annual Consumption per Participant

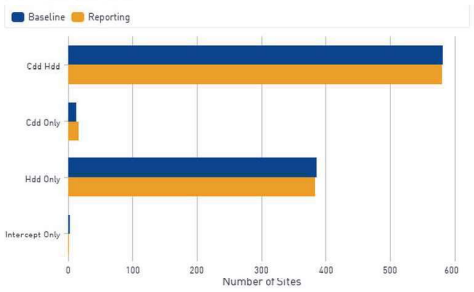
1 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

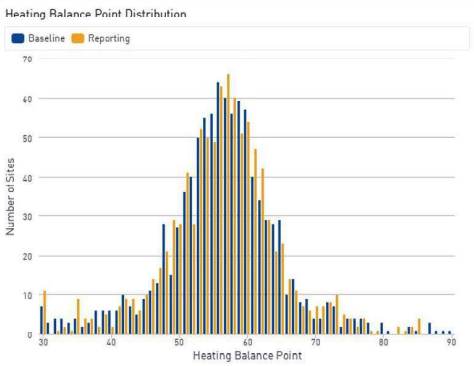


Model Type Distribution

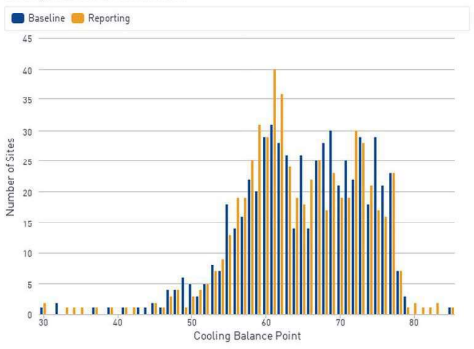


Site-level Matched Comparison Group

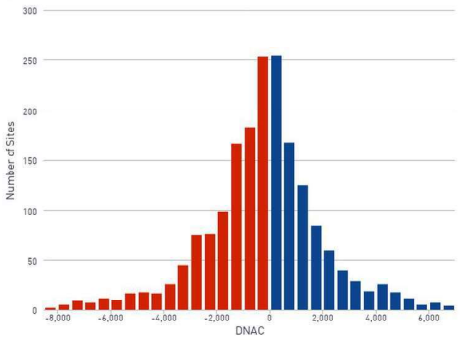
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



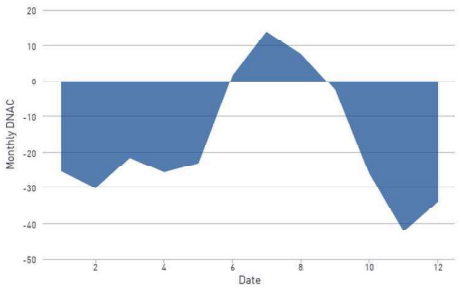
-208 +/- 112 kWh

Average Difference in Normalized Annual Consumption per Participant

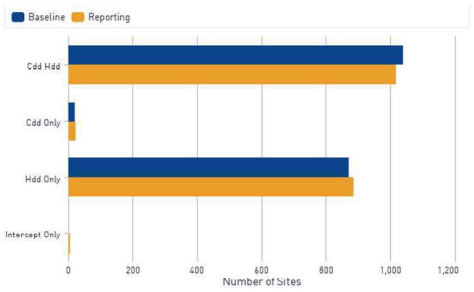
-1 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

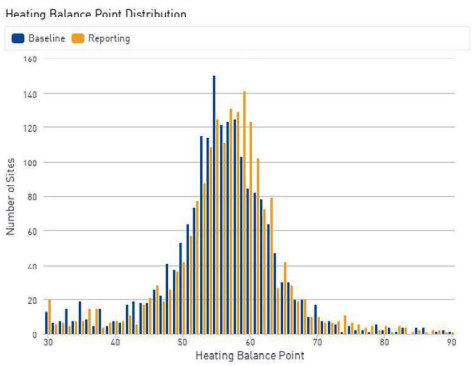


Model Type Distribution

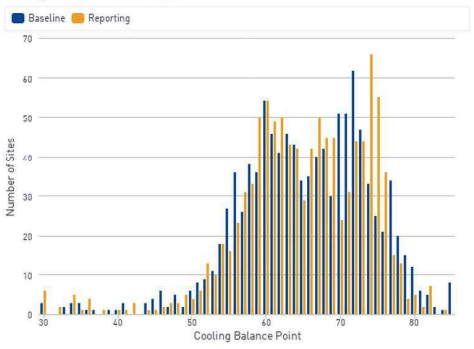


Future Participant Group

Heating Balance Point Distribution



Cooling Balance Point Distribution



Impact Evaluation Report

Electricity Impact of Ductedheatpump-Site-Built in Program Year 2013, 2014, 2015, 2016, 2017, 2018

Result Summary

Measure: Ductedheatpump-Site-Built	Program Year: 2013, 2014, 2015, 2016, 2017, 2018		Fuel: Electricity	
Meter Data Filters:	DNAC: <100%	DNAC Percentile: Remove Top and Bottom 0.5%	Annual Consumption Percentile: Remove Top and Bottom 0.5%	*Last Consumption Data Update:* Q1 2020 *Last Participation Data Update:* Q1 2020
Model Filters:	Period Length: 11 Months or Longer	R-Squared: >0.5	CV(RMSE): < 1	*CalTRACK Version:* 2.0
Metadata Filters:	Cooling Zone(s): All	Heating Zone(s): All	Heating Fuel: Electricity	Heat Pump Manufacturer: All
	Thermostat Name: All	Heat Pump Baseline: All	Multi Measure Filter: Single Measure Only	Heat Pump Adv. Controls or Commissioning: Yes
	Air / Duct type: All	Home size: All	Complex Duct Sealing: All	LikelyGasWaterHeating: All
Electric Provider: All	Contractor: All	Water Heating Fuel: All	Home Size (SqFt): All	Ducted heat pump type: Heatpumprep

976 Treatment Meters	1812 +/- 151 kWh Average Normal Year Pre-Post Difference in Consumption per Participant	10 +/- 1 % Percent Normal Year Pre-Post Difference in Consumption per Participant	18,002 Mean Baseline Consumption (Electricity)	39% Realization Rate
2,756 Site-level Matched Meters	1742 +/- 165 kWh Average Savings Relative to Site-level Matched Comparison Group	10 +/- 1% Percent Savings Relative to Site-level Matched Comparison Group	13,620 Mean Baseline Consumption (Electricity)	38% Realization Rate
1,930 Future Participant Meters	2020 +/- 188 kWh Average Savings Relative to Future Participant Group	11 +/- 1% Savings Relative to Future Participant Group	17,998 Mean Baseline Consumption (Electricity)	44% Realization Rate

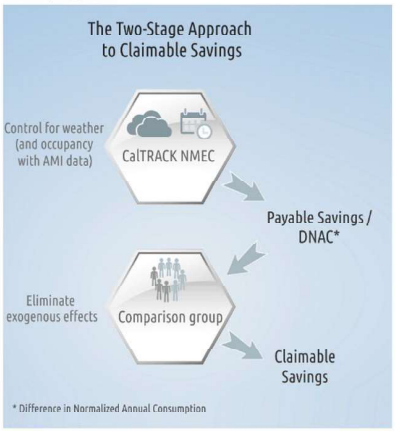
1. Introduction

This report contains the results of applying the two-stage approach (informed by the DOE's uniform methods chapter on whole building analysis) for calculating claimable savings to the selected portfolio of energy efficiency projects (see Figure). This approach begins with identification of two comparison groups for the treatment sample: (a) a site-level matched comparison group and (b) a future participant group. These groups are described below along with summary statistics (site locations, sample size, baseline consumption and baseline load disaggregation).

The CalTRACK methods are then applied to arrive at site-level savings, normalized for weather, and reflective of energy consumption changes for customers at the meter. Using a difference of differences for the treatment group with each comparison group accounts for population-level consumption changes (e.g. economic changes, rate changes, natural energy efficiency adoption etc.). The methods contained within this report are the outcome of a recent peer-reviewed study completed by Energy Trust of Oregon and Open Energy Efficiency (see "Methodology" section for more details).

The report includes the following sections:
Result Summary - Includes the overall portfolio results
Section 1. Introduction - Overview of report and the different groups included in the analysis
Section 2. Data Preparation - Data cleaning and sample attrition
Section 3. Modeling Results - CalTRACK model outputs and Difference in Normalized Annual Consumption (DNAC) results
Section 4. Methodology - Description of methods used in this report

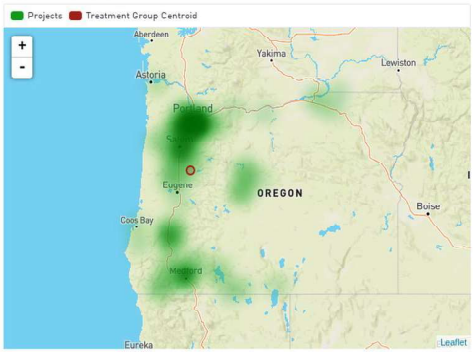
Two-Stage Approach



Treatment Group

The treatment group consists of sites that participated in the specified energy efficiency projects in the specified program year. Only sites that installed single measures are included in the treatment group. And this group includes the subset of sites that had sufficient data quality for modeling.

Treatment Site Locations

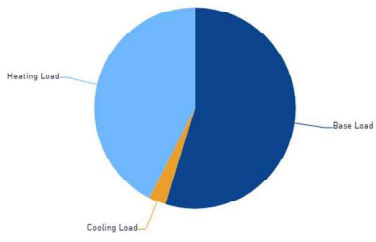


144.5 miles

80% of projects lie within this distance from treatment group centroid

976	18,002
Meters	Mean Baseline Consumption (Electricity)

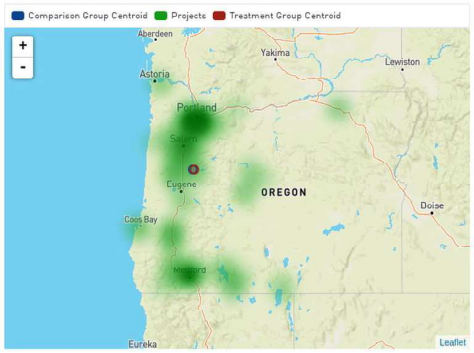
Load Disaggregation



Site-level Matched Comparison Group

This group includes comparison group sites that were matched at the site-level to treatment group sites. Each treatment group site is matched to five comparison group sites from the same zipcode, but only the sites with sufficient data quality were included in the group. Matching was performed using monthly consumption in the baseline period as detailed in the Methodology section.

Site-level Matched Site Locations

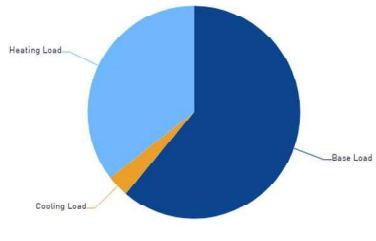


2.0 miles

Distance between treatment and comparison group centroids

0	13,620
Meters	Mean Baseline Consumption (Electricity)

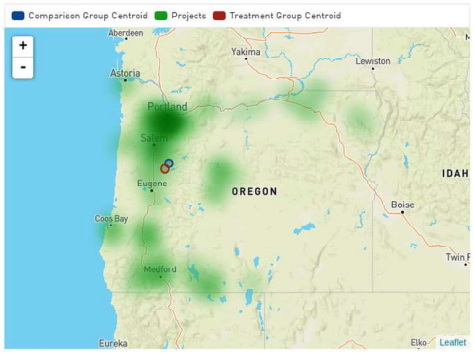
Load Disaggregation



Future Participant Group

The pool of sites that was used to create this group was composed of sites that installed the same measure in the year following the specified program year. The final sites were selected by stratified sampling using deciles of annual energy consumption.

Future Participant Site Locations

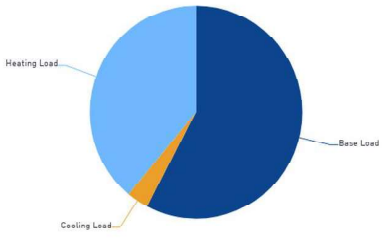


9.5 miles

Distance between treatment and future participant group centroids

1,930	17,998
Meters	Mean Baseline Consumption (Electricity)

Load Disaggregation



2. Data Preparation

Consumption data preparation and cleaning followed best practices defined in the CalTRACK 2.0 billing methods. Some key aspects of the data cleaning process are highlighted here; please see the resources section for links to more detailed documentation. The initial and final sample sizes are shown below along with the percent of the treatment population that is represented by the sample. The sample attrition table shows the impact of each filtering criterion on sample size.

7,398	976	13%
Meters in Treatment Population	Final Sample Size	Percent of Treatment Population Represented by Sample

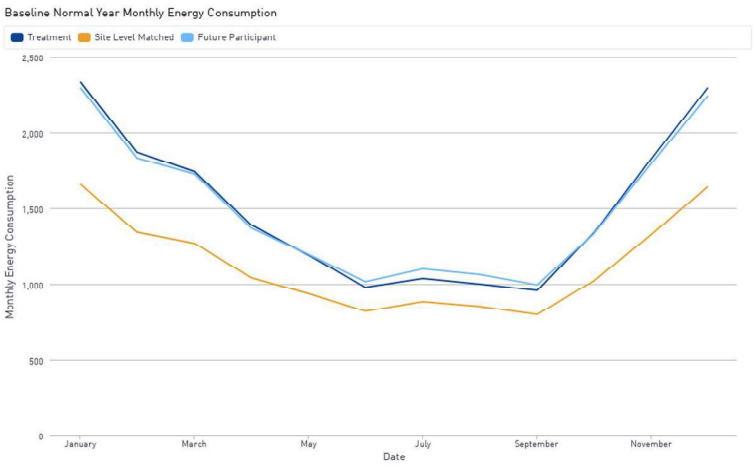
Sample Attrition Table

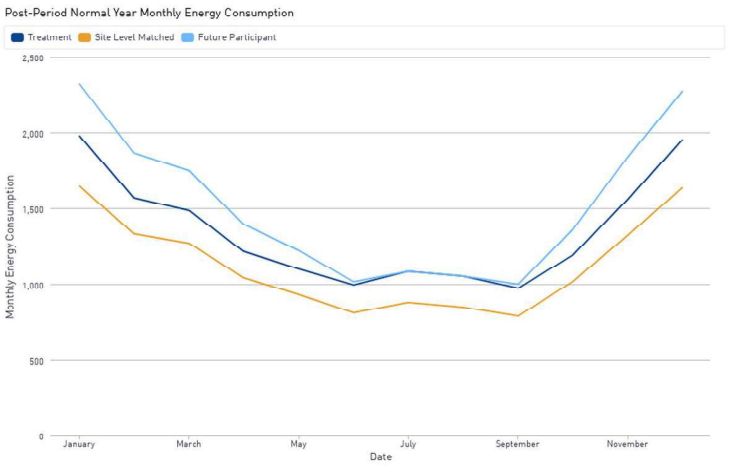
	FILTER NAME	FILTER VALUE	TREATMENT METERS DROPPED	TREATMENT METERS REMAINING
1	Initial treatment population			116150
2	Measure	DUCTEDHEATPUMP-SITE-BUILT	108901	7249
3	Year	2013, 2014, 2015, 2016, 2017, 2018	0	7249
4	Fuel	Electricity	0	7249
5	Valid consumption data in baseline and reporting periods	valid data	0	7249
6	MultiMeasure_Filter: Meters with single/multiple measure installations in baseline and/or reporting periods	--	0	7249
7	HeatingFuel: Meters with a valid heating fuel that corresponds to the selected filter value.	='ELE'	91	7158
8	HeatingZone: Meters in selected heating climate zone.	--	0	7158
9	CoolingZone: Meters in selected cooling climate zone.	--		7158
10	PeriodLength_Threshold: Meters meeting a threshold number of months of valid consumption data.	>=11	1742	5416
11	Meters with at least 5 site-level matched meters from the comparison group pool		0	5416
12	DNAC_Threshold: Meters with normalized change in annual energy consumption under a specified threshold	<1	104	5312
13	DNACPercentile_Threshold: Meters within specified percentile bands of normalized change in annual consumption	Between 0.5 and 99.5	26	5286
14	ConsumptionPercentile_Threshold: Meters within specified percentile bounds of annual energy consumption.	Between 0.5 and 99.5	20	5266
15	R2_Threshold: Meters with valid model R-squared for the baseline and reporting periods that meet a specified threshold. ...	> 0.5	701	4565
16	CVRMSE_Threshold: Meters with valid model CV(RMSE) for the baseline and reporting periods that meet a specified threshol...	< 1	0	4565
17	home_size: Meters with manufactured home size meeting a specific criteria (single-wide, double-wide, or triple-wide)	--	0	4565
18	complex_duct_sealing: Meters with the 'MH Complex Add-On' measure	--	0	4565
19	airduct_type: Meters that used specific measures relevant to Air and Duct Sealing programs	--	0	4565
20	likely_gas_water_heating: Metrs with more than 0.2 therms per day average gas consumption in August.	--	0	4565
21	Electricity Provider	--	0	4565
22	Home Size (Sq Ft)	--	0	4565
23	Water heating fuel type	--	0	4565
24	Heat pump type	HEATPUMPREP	3226	1339
25	Contractor	--	0	1339
26	Thermostat name	--		1339
27	Heat pump baseline equipment	--	0	1339
28	Heat pump manufacturer	--	0	1339
29	Heat pump comissioning	Yes	340	999
30	Multi-measure elec	=false	23	976
31	Multi-measure gas	--	0	976

3. Modeling Results

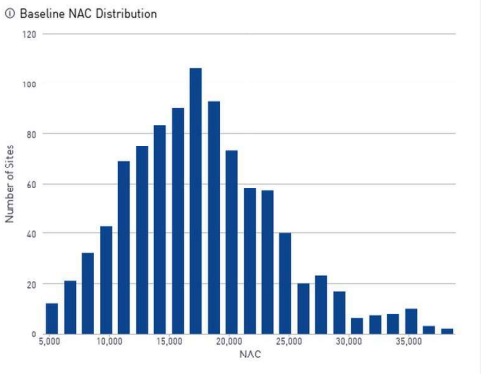
This section includes summaries of the Difference in Normalized Annual Consumption (DNAC) results for the treatment and comparison groups. The time series of monthly energy consumption illustrates the similarities and/or differences in energy consumption for the different groups in the baseline and reporting periods.

Below, you will find a breakdown of the DNAC results by group, showing the histograms of DNAC as well as the mean value expressed in raw units and as a percent of baseline annual consumption. Finally, the distribution of model types in the baseline and reporting periods are also provided as an additional layer of analysis.

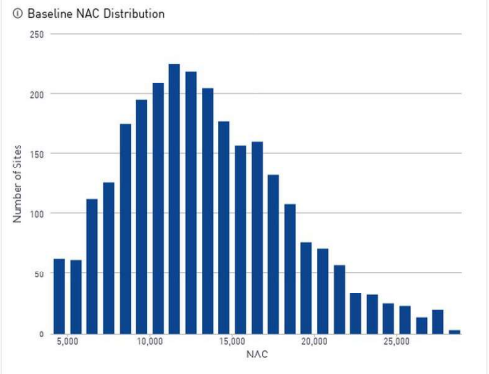




Treatment Group



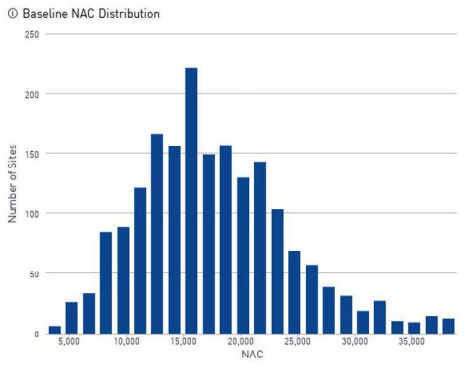
Site-level Matched Comparison Group



0.000153

Annual Consumption p-value

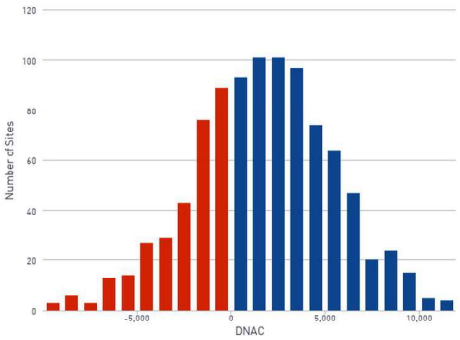
Future Participant Group



0.18

Annual Consumption p-value

DNAC Distribution



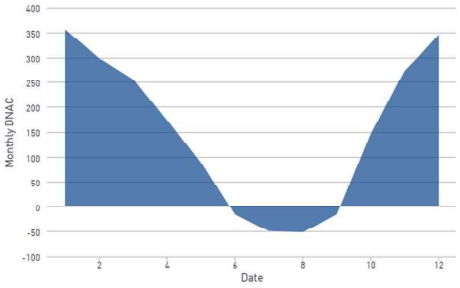
1812 +/- 151 kWh

Average Difference in Normalized Annual Consumption per Participant

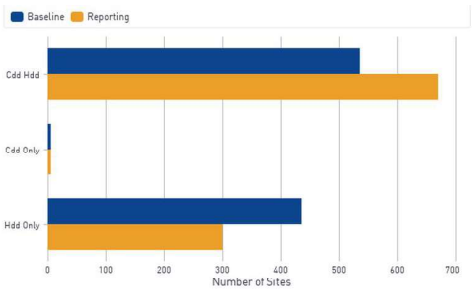
10 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

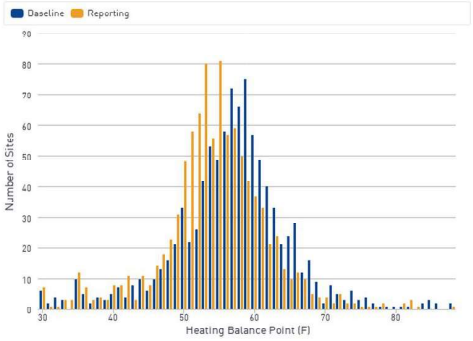


Model Type Distribution

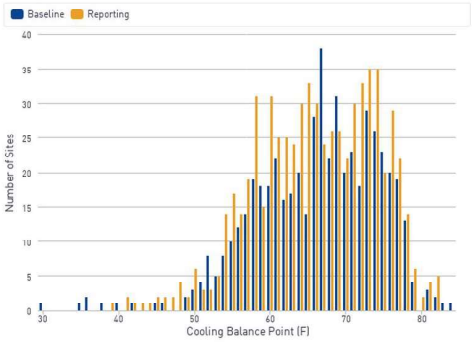


Treatment Group

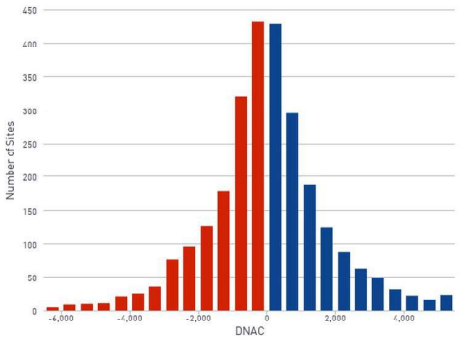
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



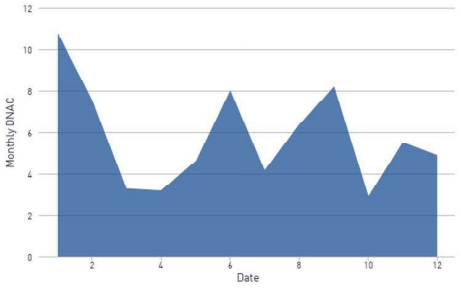
70 +/- 68 kWh

Average Difference in Normalized Annual Consumption per Participant

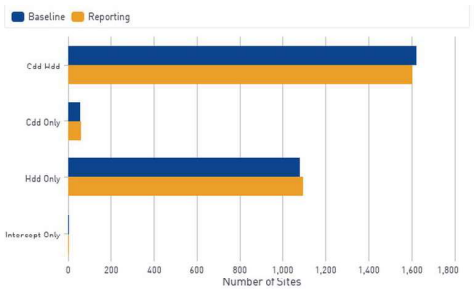
1 +/- 0 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

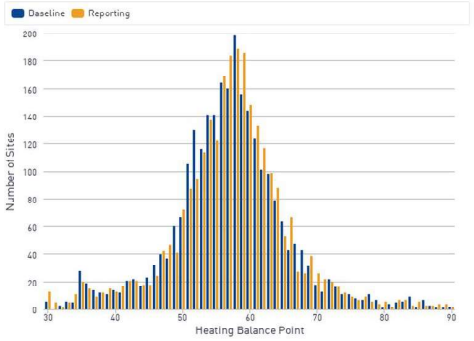


Model Type Distribution

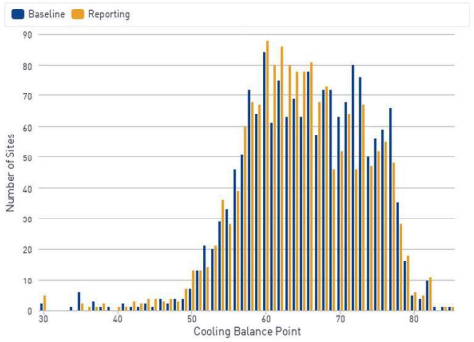


Site-level Matched Comparison Group

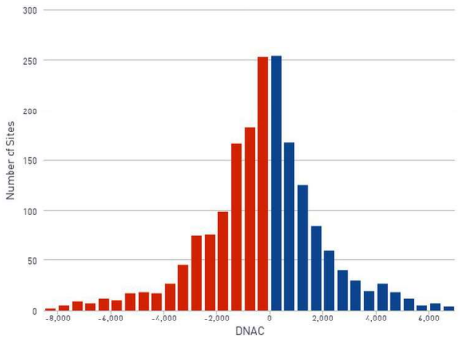
Heating Balance Point Distribution



Cooling Balance Point Distribution



DNAC Distribution



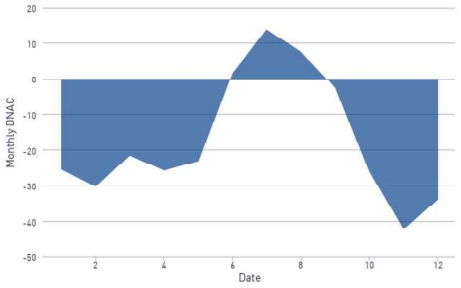
-208 +/- 112 kWh

Average Difference in Normalized Annual Consumption per Participant

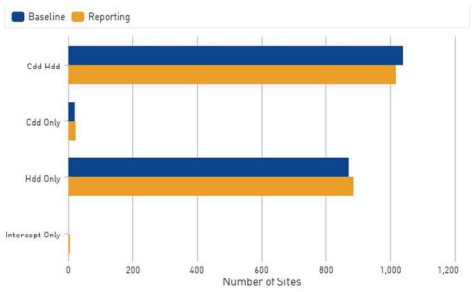
-1 +/- 1 %

Difference in Normalized Annual Consumption as a Percent of Baseline

Monthly DNAC

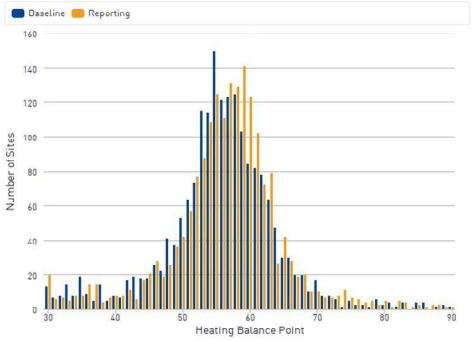


Model Type Distribution



Future Participant Group

Heating Balance Point Distribution



Cooling Balance Point Distribution