2009-2011 New Homes Billing Analysis:

Comparison of Modeled vs. Actual Energy Usage

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Executive Summary

This paper describes a utility billing analysis of newly constructed homes that received performance-based incentives through Energy Trust of Oregon's New Homes program. The Energy Performance Score track of the program uses energy modeling to compare home performance versus a code baseline, which determines the incentive amounts paid to builders and the energy savings claimed by the program. We obtained project tracking data, containing modeled annual energy usage, and monthly gas and electric billing data for homes built from 2009 to 2011. Gas and electric billing data were weather normalized. We analyzed the differences between the observed normalized and modeled energy use for the first full year post-occupancy and for subsequent years afterwards. We examined the distribution of differences and analyzed mean differences using paired t-tests.

For gas heated homes, the average differences between normalized and modeled gas use were less than 10 percent and individual differences were within 25 percent of the modeled usage for roughly two-thirds of homes. The average differences for electric base load usage were also less than 10 percent, although variability was much higher. For electric heated homes, sample sizes were too small to provide reliable results. Analysis of energy usage over time showed that the energy models consistently underestimated average annual gas and electric use by a small amount. In conclusion, energy models used by the program appear to be relatively accurate, on average, particularly for gas use, although they may slightly underestimate actual usage. However, there are substantial deviations from modeled usage in individual homes.

Introduction

Energy Trust's New Homes program has provided performance-based incentives to home builders for whole home efficiency upgrades through its Energy Performance Score (EPS™) track since 2009. To receive an EPS, a program verifier must inspect the home and model its energy usage with REM/Rate™ software (NORESCO, LLC, 2015). The modeled energy performance is compared to a baseline of what is required by state building code. The incentive provided to the builder is on a sliding scale, based on the estimated energy savings above code. Energy Trust developed the performance-based EPS track in 2008 in response to a more stringent state building code and the limitations of the prescriptive ENERGY STAR system. EPS was formally launched in mid-2009 along with an education and promotion campaign to recruit builders, verifiers and real estate professionals. Within the first six months of EPS, program builders were already exceeding the ENERGY STAR specifications (Stull & Youngblood, 2010).

This report describes a billing analysis that quantifies the average annual energy use of newly constructed, detached single family homes built in Oregon from 2009 to 2011. In particular, we analyzed the energy use of homes that received an EPS compared to their predicted energy use. Single family homes built from 2009 to 2011 were primarily constructed under Oregon's 2008 residential building code. We analyzed each year of home construction separately to account for some residual code differences, programmatic differences and changes in the market. The primary goal of this analysis was to determine how accurate the modeled energy use estimates were during these program years. Although similar analyses of REM/Rate's accuracy have been conducted in the past (Earth Advantage Institute, 2009) (Hassel, Blasnik, & Hannas, 2009), there has been no assessment of its accuracy for new homes in Oregon since it was deployed by Energy Trust.

The findings in this report provide feedback about the accuracy of the modeling software used by the New Homes program to claim savings. This may help to better calibrate the models to improve energy use and savings estimates in the future. The results will provide feedback to the Northwest Energy Efficiency Alliance and Northwest utilities that are investigating similar performance-based incentive programs for new residential construction. The report also offers a rare glimpse into residential energy use over several years and how modeled estimates perform in real world conditions.

From 2009 to 2011, according to market data that the program purchases from Construction Monitor (Construction Monitor, Inc., 2014), there were approximately 14,500 single family homes built in Energy Trust's service territory in Oregon and 2,130 of them received incentives from the New Homes program for whole home energy efficiency treatments. The number of homes that receive incentives through the New Homes program varies by year based on trends in home construction and the individual builders and subcontractors that are involved and active in the program. **Table 1** shows the number of homes constructed per year and the market share of program homes in the state.

Table 1. Overview of New Homes program activity: number of program homes, total program gas and electric savings, home characteristics, and program market share, 2009-2011

Year Built	Program Homes	Therm Savings Claimed	kWh Savings Claimed	% Gas Heat	% Electric Heat	Mean Sq.Ft.	Total New Homes in Market*	Program Market Share
2009	705	105,110	821,500	81%	18%	2,450	5,592	13%
2010	611	72,510	472,200	79%	21%	2,120	4,812	13%
2011	814	116,370	686,400	84%	16%	2,160	4,052	20%

Note: Numbers may not match official program results due to slight definitional differences.
* Numbers based on market data purchased by the New Homes program from Construction Monitor.

Methods

Weather Normalization of Usage Data

Electric and gas utility billing data from Energy Trust's participating utilities were obtained for all Oregon residences. The usage for every billing period was divided by the number of days in the period to arrive at the daily average usage. Data on daily average temperature were collected from the National Climatic Data Center for 13 weather stations dispersed across Energy Trust's service territory and matched to home addresses. Weather normalization was conducted using a method similar to the

PRInceton Score-keeping Method (PRISM) (Fels, 1986), where average daily energy use is a function of heating requirements of the home. The algorithm decomposes energy use into estimated heating and base load components. To do this, an optimum "set-point", or reference temperature, is found below which energy use for heating is detected. Reference temperatures ranging from 30 to 90 degrees Fahrenheit were calculated for each gas/electric billing period and a regression was run for each of the 61 possible reference temperatures. The regression for the reference temperature with the best fit and explanatory power (maximum R-squared) was used to calculate the weather normalized annual usage (NAU) using the latest typical meteorological year (TMY3) long run heating degree-days. The model specifications for weather normalization are:

$$\text{Average daily usage} = \alpha_{i1} + \beta_1 HDD_i(\tau_h) + \varepsilon_i$$
$$NAU_i = 365*\alpha_{i1} + \beta_1 LRHDD_i(\tau_h)$$

Where:
α_{i1} = Estimated average daily use, the "base load" in models
β_1 = Model predicted heating slope
$\beta_1 HDD_i(\tau_h)$ = Average daily heating degree days at reference temperature τ_h
ε_i = Unexplained error term
NAU_i = Normalized annual usage for site i
LRHDD= Long-run annual heating degree-days at reference temperature τ_h

Comparison of Modeled and Normalized Annual Energy Usage

The goal of this analysis was to determine the accuracy of the program's modeled energy usage estimates, which are used to calculate energy savings above code-level performance. We selected single family detached EPS homes that were built in Oregon from 2009 through 2011 from Energy Trust's project tracking database. Homes east of the Cascades were dropped from the analysis, due to the relatively low project volumes and lower availability of billing data. Next, we matched EPS homes to their normalized annual energy usage data based on address. To ensure that we only analyzed post-occupancy energy usage, we matched the energy data to homes beginning with the year of data following the completion year. The analysis was separated by year built, year of energy data, and primary heating fuel, which was determined for each home using the billing data and weather normalization regression results. The fuel with a regression heating signature (positive HDD regression coefficient, HDD R-squared value greater than 0.5, greater than 80 therms or 2,000 kWh normalized annual heating load) was selected as the heating fuel. Homes that indicated heating with both gas and electricity were not analyzed.

For gas heated homes, we first analyzed gas usage and then analyzed the base load electric usage for homes where electric data were available. For electric heated homes, we analyzed electric usage only. Homes that could not be matched to billing data were dropped from the sample. When analyzing electric use, all homes with known solar photovoltaic (PV) systems were dropped. Homes with solar PV systems are difficult to use in electric billing analysis because the amount of on-site generation is not recorded by the utility meter. Homes that had incomplete or unreliable gas or electric billing data in a given year, and those that were outliers in usage (top or bottom one percent), were dropped from the sample.

To accomplish this, we directly compared the normalized annual energy usage to the modeled annual usage for each EPS home. We started by analyzing the energy data from the first full year of occupancy post-construction, then, each subsequent year of energy use data was analyzed through 2012. We then computed the differences between the normalized and the modeled annual gas and electric use for each home. Summary statistics and graphs were used to assess the distribution of differences. Paired, two-tailed t-tests were used to determine the magnitude and statistical significance (from p-values) of the mean differences for each construction year, fuel and year of billing data. A p-value of less than or equal to 0.05 is equivalent to statistical confidence of greater than or equal to 95 percent and was selected as our threshold to determine statistical significance for this analysis.

To model the annual energy use of an EPS homes with REM/Rate, a number of standards and assumptions are used. The program follows the Residential Energy Services Network (RESNET) Ratings Standards (RESNET, 2013) when modeling energy usage in REM/Rate, which includes guidelines related to housing characteristics, HVAC systems, water heating, lighting, appliances and assumptions about other end uses, such as TVs, refrigerators, cooking ranges, clothes washers and dryers, dishwashers, mechanical ventilation, ceiling fans and plug loads. One key assumption used in modeling is occupancy, which is set equal to the number of bedrooms plus one. Each version of REM/Rate contains updates and changes, some of which impact the modeled energy use estimates. Since the deployment of EPS, there have been several updates to REM/Rate. This analysis does not attempt to account for any of the inputs or assumptions used to model energy use in REM/Rate. We simply compared the modeled energy usage with normalized annual energy usage and did not attempt to determine the cause of any differences.

Results

The results of this billing analysis are organized into a sections pertaining to gas heated homes and electric heated homes. Within each section, sub-sections discuss attrition analysis, the comparison of modeled and first year normalized energy usage, and the comparison of modeled and normalized annual energy use over time.

Table 2 summarizes the results of our analysis to determine the heating system fuel for each EPS home in western Oregon. Six-hundred three homes out of 1,635 total could not be matched to energy usage data, particularly those built in 2011, due to missing data in Energy Trust's billing database. These homes could not be further analyzed and were removed during the attrition analysis described below. For both gas and electric heated homes, the large amount of attrition due to missing energy usage data could have introduced some bias into the study. Although the determination of heating fuel is included in the attrition below, it is not truly attrition, but a necessary step to sort homes into the appropriate analysis groups.

Table 2. Heating fuel for new EPS homes determined using energy usage data, 2009-2011

Year Built	Heating System Fuel				Total*
	Electric	Gas	Both	No billing data	
2009	35	377	16	115	557
2010	31	314	12	95	452
2011	48	147	2	393	626

* Total program homes shown here are restricted to western Oregon and thus are lower than the totals shown in Table 1.

Gas Heated Homes

Attrition Analysis. We started the analysis with EPS homes built in western Oregon from 2009 to 2011. The attrition tables in **Appendix A** summarize the number of homes removed at each step in the analysis and the raw annual gas and electric usage of homes remaining. Matching homes to gas use data to determine if they were heated with gas was a large source of attrition in all construction years. Some of this attrition was expected because 10-20 percent of new homes in Energy Trust territory do not have gas service. In addition, some homes could not be matched to gas data due to differences in address information between databases, further increasing attrition. In other cases, a match could not be made because the gas data were missing from Energy Trust's billing database. Of particular note was a very high level of attrition for homes built in 2011 due to missing 2012 gas data. It was found that the gas data for these homes were simply not present in Energy Trust's billing database, even though they had active accounts with Energy Trust's gas utilities. The reason for the missing data could not be determined. Once homes were matched to gas data (and electric data, if available), we determined if they were gas heated and removed all homes that were not.

In the next attrition step, homes were removed that did not have modeled gas use estimates available to compare with normalized annual usage. This was minor except in 2009 when the EPS track was just getting started. Small levels of attrition resulted from removing homes that had problems with their billing data in a particular year or were in the top or bottom one percent of annual energy use. Ultimately, the sample sizes available for analysis were robust, although smaller for 2011 homes. Of the 838 gas heated homes identified, 610 (73 percent) were available for the gas use analysis.

Once we arrived at the final sample of gas heated homes, we conducted the analysis of modeled versus first year gas usage. Then, we extended the analysis to look at the electric base load usage of gas homes. This caused additional attrition that left roughly 40 percent of the gas sample available. Many gas heated EPS homes are not served by one of Energy Trust's electric utilities, so we did not have access to billing data for these homes. Removing homes with solar PV from the electric analysis had a significant impact on attrition and the mean annual electric use. Minor attrition was also caused by removing homes with problems with their electric billing data and outliers in annual electric usage (top and bottom one percent). Much smaller, but sufficient samples remained for the electric base load analysis. Of the 838 gas heated homes identified, 226 (27 percent) remained for the electric analysis.

Table 3 summarizes the average characteristics of EPS homes in the final gas heat sample. The mean home size hovered around 2,000 square, but increased slightly from 2009 to 2011. EPS, first year gas heating and total gas usage also increased slightly over time. The mean heating reference temperature, the point below which gas heating was used, also appeared to increase slightly over time.

Table 3. Average characteristics of final sample of gas heated EPS home built from 2009-2011

Year Built	Analysis Year	N	Mean Sq.Ft.	Mean EPS	Mean Heating Reference Temp (ºF)*	Mean Normalized Therm Heating Usage**	Mean Normalized Annual Therm Usage
2009	2010	176	1,990	71	56	344	485
2010	2011	299	2,160	72	57	360	515
2011	2012	135	2,250	75	58	394	547

* The mean heating reference temperature refers to the best fit HDD reference temperature selected for each home during the PRISM weather normalization analysis.
** The mean annual heating load, calculated as the heating portion of the normalized annual usage (excluding base load) from the HDD regression coefficient for each home.

Comparison of Modeled and First Year Normalized Energy Use. Table 4 summarizes the results of the comparison between modeled and first year normalized gas use for gas heated EPS homes. The mean modeled gas use was very close to the mean normalized first year usage in all three years, with mean differences ranging from three therms higher than first year usage to 30 therms lower. These differences amount to less than 10 percent of the mean first year gas use. However, using the p-values from our paired t-tests, we found that the models significantly underestimated gas use for 2011 homes (p=0.023), on average, although the difference was slight (5.5 percent). **Figure 1** displays the mean differences between the modeled and first year gas use graphically.

Table 5 provides a summary of the variation between homes in the differences between modeled and first year gas use. For roughly one-third of homes modeled gas use was within 10 percent of first year usage and about two-thirds of homes were within 25 percent. This relatively low band of variability around the mean differences is illustrated in the scatterplots presented in **Figure 2**. To test whether there were any trends in the scatterplots displayed in **Figure 2**, we created a linear regression model of the deviations as a function of modeled usage. We found that 2010 homes did exhibit a slight trend in their deviations from modeled usage. For every 100 therms of modeled usage above 500, the 2010 gas models underestimated first year usage by 20 therms, on average, and vice versa. There were no significant trends in deviations for 2009 or 2011 homes.

Table 4. Comparison of mean modeled vs. first year normalized gas use (in therms) in gas heated EPS homes built from 2009-2011

Year Built	Analysis Year	N	Mean Modeled Usage	Mean Normalized Usage	Mean Difference	90% CI LB*	90% CI UB*	p-value
2009	2010	176	488	485	3	-15	21	0.797
2010	2011	299	504	515	-10	-24	3	0.211
2011	2012	135	517	547	-30	-52	-9	0.023**

* Lower and upper bounds of the 90 percent confidence interval for the mean difference.
** Statistically significant at the 0.05 level.

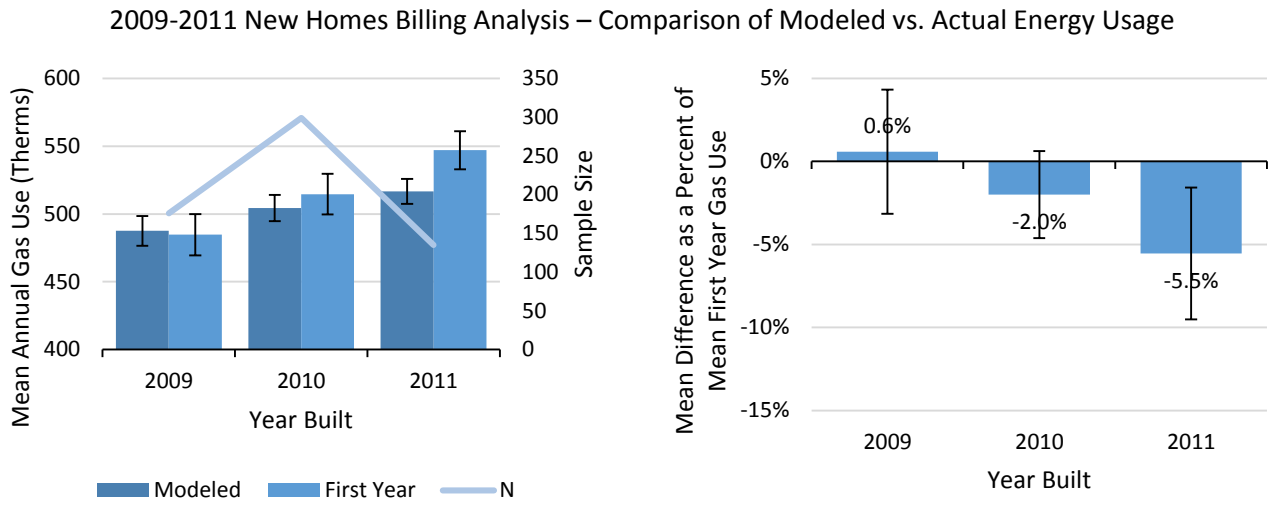

Figure 1. Comparison of mean modeled vs. first year normalized gas use (in therms) and mean differences as a percent of mean annual usage in gas heated EPS homes built from 2009-2011.
Note: positive values in the graph of differences indicate that models overestimated usage, on average, while negative values indicate that they underestimated it.

Table 5. Summary of differences for individual homes between modeled and first year normalized gas use as a percent of annual usage, in gas heated EPS homes built from 2009-2011

Year Built	Analysis Year	% Homes with <10% Difference	% Homes with <25% Difference	% Homes with <50% Difference
2009	2010	27%	65%	87%
2010	2011	28%	64%	92%
2011	2012	34%	75%	90%

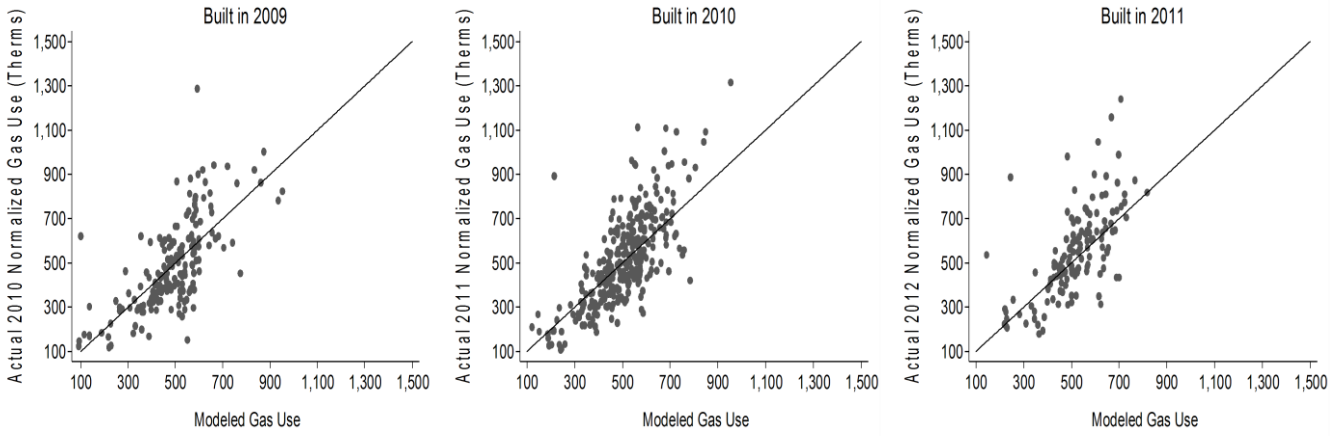

Figure 2. Scatterplots of modeled gas usage versus the deviation in first year normalized gas use from modeled usage (in therms) for individual gas heated EPS homes built from 2009-2011.
Note: the reference line indicates where first year and modeled gas use are equivalent; points above the line indicate homes where actual usage was higher than estimated and vice versa.

Table 6 shows the results of the comparison between the modeled and first year normalized electric base load usage for gas heated homes. In all three years, the models underestimated first year electric

use, on average, by 140 to 530 kWh. These differences are relatively small and represent less than 10 percent of the mean first year electric use. There were no statistically significant differences. **Figure 3** displays the mean differences between modeled and first year usage graphically.

Table 7 provides a summary of the variation between homes in the differences between modeled and first year electric use. Only about one-third of homes had modeled electric use within 50 percent of first year usage, indicating substantial variability around the mean differences in all three years. This relatively wide scatter is illustrated in the scatterplots presented in **Figure 4**. To test whether there were any trends in the scatterplots displayed in **Figure 4**, we created a linear regression model of the deviations as a function of modeled usage. We found that 2009 homes showed a slight trend in their deviations from modeled usage. For every 1,000 kWh of modeled usage above 6,000, the 2010 electric models overestimated first year usage by 500 kWh, on average, and vice versa. There were no significant trends in deviations for 2010 or 2011 homes.

Table 6. Comparison of mean modeled vs. first year normalized electric use (in kWh) in gas heated EPS homes built from 2009-2011

Year Built	Analysis Year	N	Mean Modeled Usage	Mean Normalized Usage	Mean Difference	90% CI LB*	90% CI UB*	p-value
2009	2010	75	6,210	6,550	-340	-900	230	0.334
2010	2011	105	6,360	6,500	-140	-550	270	0.568
2011	2012	49	6,340	6,870	-530	-1,140	90	0.167

* Lower and upper bounds of the 90 percent confidence interval for the mean difference.

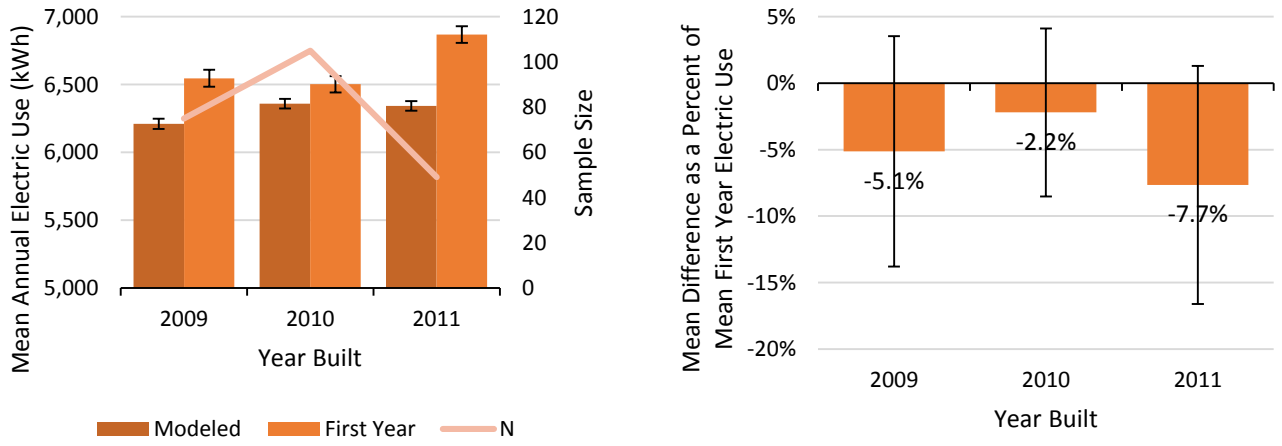

Figure 3. Comparison of mean modeled vs. first year normalized electric use (in kWh) and mean differences as a percent of mean annual usage in gas heated EPS homes built from 2009-2011.
Note: positive values in the graph of differences indicate that models overestimated usage, on average, while negative values indicate that they underestimated it.

Table 7. Summary of differences for individual homes between modeled and first year normalized electric use as a percent of annual usage, in gas heated EPS homes built from 2009-2011

Year Built	Analysis Year	% Homes with <10% Difference	% Homes with <25% Difference	% Homes with <50% Difference
2009	2010	10%	21%	32%
2010	2011	8.4%	20%	28%
2011	2012	4.4%	16%	31%

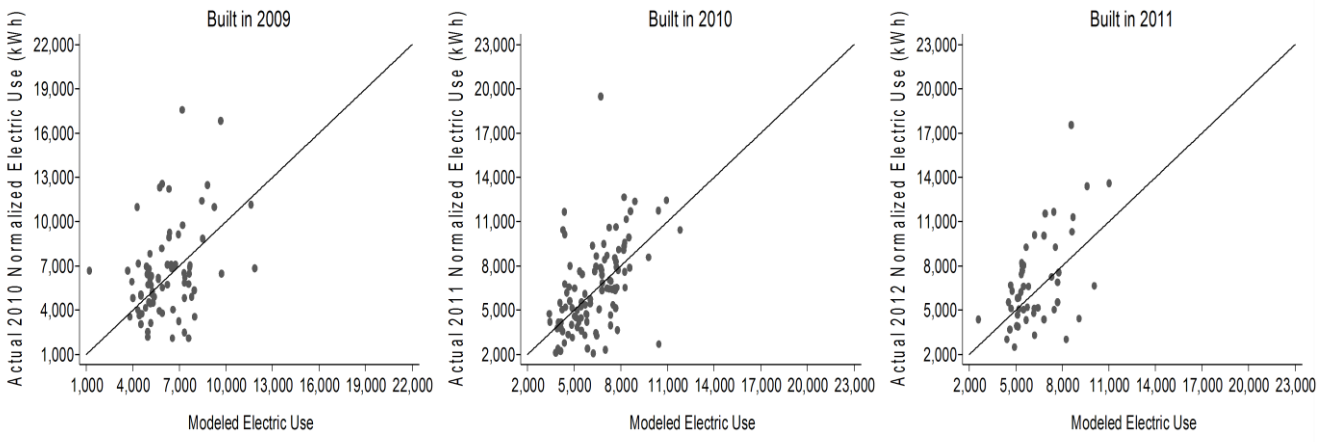

Figure 4. Scatterplots of modeled electric usage versus the deviation in first year normalized electric use from modeled usage (in kWh) in gas heated EPS homes built from 2009-2011.
Note: the reference line indicates where first year and modeled electric use are equivalent; points above the line indicate homes where actual usage was higher than estimated and vice versa.

Comparison of Modeled and Normalized Annual Energy Use over Time. We analyzed additional years of energy data for each year of gas heated home construction to see if any trends appeared. **Figure 5** displays the mean differences over time between modeled and normalized annual gas use as a percent of annual usage. Although the differences between mean modeled and first year gas use were relatively small, the gap appears to widen over time. This analysis does not cover enough years of energy data to identify whether there are any significant trends, but there is a consistent pattern of modeled usage slightly underestimating annual gas use, on average. Several years of usage data show mean differences where modeled gas use was significantly lower than the annual gas use. However, all of these differences are well below 10 percent of mean annual usage, so there is not a strong bias, on average.

Figure 6 displays the mean differences over time between the modeled and annual electric base load as a percent of annual usage. Modeled usage appeared to consistently underestimate annual electric usage, on average. The mean difference was only statistically significant for one year of energy data, but there was a clear pattern across all years. However, the differences were relatively small, on average, and were well below 10 percent of annual usage. **Appendix B** contains the tables of results for the comparisons of modeled and normalized annual energy use over time associated with the figures below.

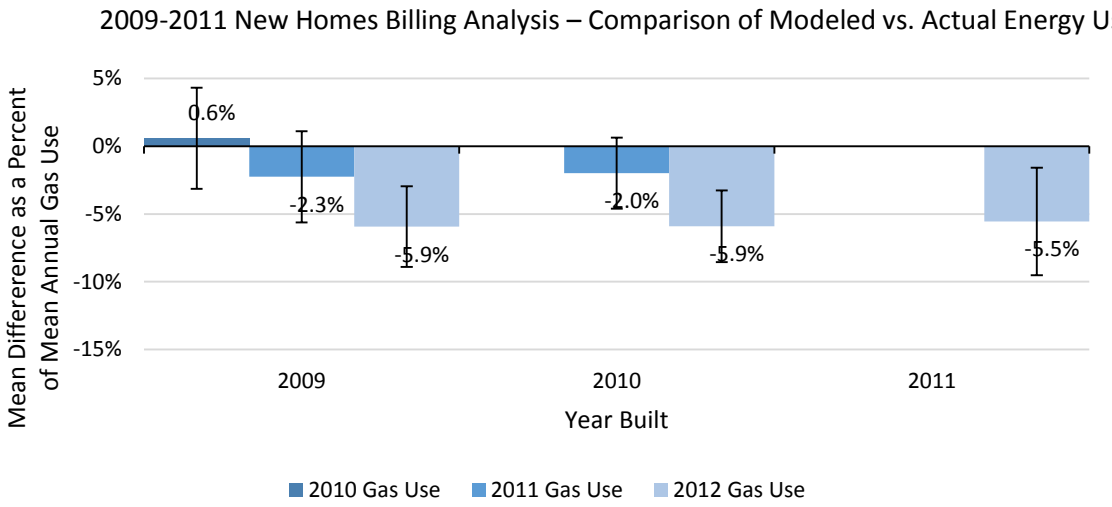

Figure 5. Mean differences in modeled vs. normalized annual gas use as a percent of mean annual usage over time, in gas heated EPS homes built from 2009-2011.
Note: positive values indicate that models overestimated usage, on average, while negative values indicate that they underestimated it.

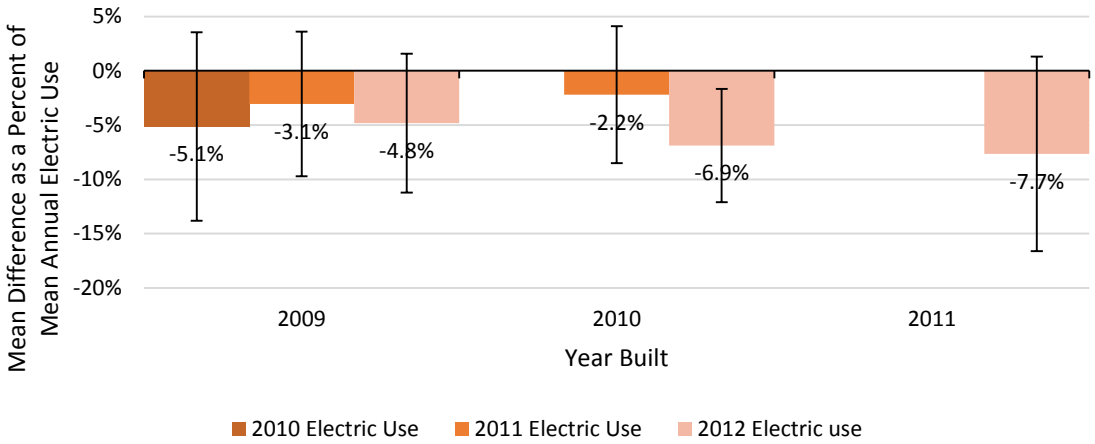

Figure 6. Mean differences in modeled vs. normalized annual electric use over time as a percent of mean annual usage, in gas heated EPS homes built from 2009-2011.
Note: positive values indicate that models overestimated usage, on average, while negative values indicate that they underestimated it.

Electrically Heated Homes

Attrition Analysis. The attrition tables in **Appendix A** summarize the number of homes removed at each step in the analysis and the raw annual electric usage of the remaining homes. We first matched EPS homes to electric usage data before we could determine if they were electrically heated. This was a large source of attrition in all construction years. Much of this attrition was expected because many new homes located in Energy Trust service territory are gas heated, in which case their electric usage data may not have been available. In addition, some homes could not be successfully matched to electric data based on slight address differences while others were simply missing from the utility billing database. Once homes were matched to electric data, we determined if they were electrically heated and excluded homes that were not. Selecting homes heated primarily with electricity caused a

large amount of attrition, based on the low prevalence of electric heating systems in new housing stock.

In the next step, homes were removed that did not have modeled electric usage estimates, which was a major source of attrition in 2009, the first year of the EPS track, but was essentially eliminated in later years. Removing homes with solar PV had a significant impact on attrition and on the mean annual electric use. Small levels of attrition resulted from removing homes that had problems with their billing data in a particular year or that were in the top or bottom one percent of electric use. The sample sizes available for the analysis of electric heated homes were much smaller than for gas heated homes and may not be sufficient to provide reliable results to gauge the accuracy of modeled electricity use.

Table 8 summarizes the average characteristics of EPS homes in the final electric heat sample. Mean square footage hovered around 2,000 square feet, but appeared to decrease over time. The mean EPS hovered around 53 and mean normalized annual electric use was around 12,000 kWh, with heating usage of about 4,000 kWh. Similar to gas heated homes, the mean heating reference temperature, below which heating usage was detected, increased slightly from 54 to 56 degrees over time.

Table 8. Average characteristics of final sample of electrically heated EPS homes

Year Built	Analysis Year	N	Mean Sq.Ft.	Mean EPS	Mean Heating Reference Temp (°F)*	Mean Normalized kWh Heating Usage**	Mean Normalized Annual kWh Usage
2009	2010	22	2,270	53	54	4,090	12,770
2010	2011	23	2,090	52	55	4,530	11,680
2011	2012	36	1,980	53	56	3,580	12,140

* The mean heating reference temperature refers to the best fit HDD reference temperature selected for each home during the PRISM weather normalization analysis.
** The mean annual heating load, calculated as the heating portion of the normalized annual usage (excluding base load) from the HDD regression coefficient for each home.

Comparison of Modeled and First Year Normalized Energy Use. Table 9 shows the results of the comparison between the modeled and first year electric use for electric heated homes. The mean differences for 2009 and 2010 homes were small and insignificant, less than 2 percent of first year electric use. However, for 2011 homes, the modeled usage underestimated first year electric use by 1,450 kWh, on average, or nearly 12 percent of usage. Using the p-values from our paired t-tests, we determined that this difference was statistically significant (p=0.036). **Figure 7** shows the mean differences graphically. However, due to the small sample sizes, these results may not be reliable.

Table 10 provides a summary of the variation between homes in their differences between modeled and first year electric use. Less than half of homes overall had modeled electric use within 50 percent of first year usage, indicating a large amount of variability. This relatively wide scatter is illustrated in **Figure 8** and is not surprising given the small sample sizes. It also appears that a few homes with large differences may have skewed the results for 2011 homes. To test whether there were any trends in the scatterplots displayed in **Figure 8**, we created a linear regression model of the deviations as a function of modeled usage. We did not find any significant linear trends in deviations from modeled usage for electric heated homes.

Table 9. Comparison of mean modeled vs. first year normalized electric use (in kWh) in electric heated EPS homes built from 2009-2011

Year Built	Analysis Year	N	Mean Modeled Usage	Mean Normalized Usage	Mean Difference	90% CI LB*	90% CI UB*	p-value
2009	2010	22	12,930	12,770	160	-1,280	1,610	0.853
2010	2011	23	11,870	11,680	190	-1,710	2,090	0.870
2011	2012	36	10,690	12,140	-1,450	-2,540	-360	0.036**

* Lower and upper bounds of the 90 percent confidence interval for the mean difference.
** Statistically significant at the 0.05 level.

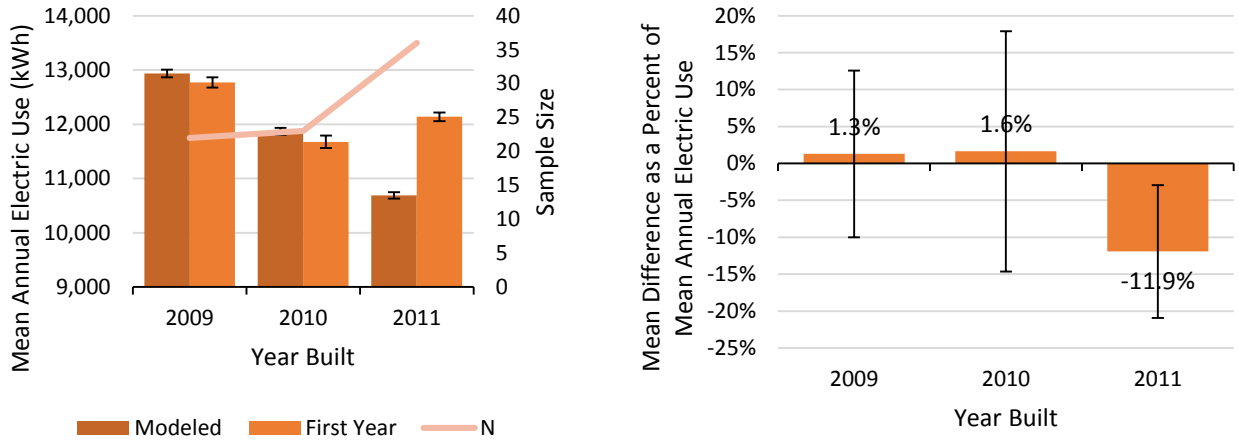

Figure 7. Comparison of mean modeled vs. first year normalized electric use (in kWh) and mean differences as a percent of mean annual usage in electric heated EPS homes built from 2009-2011. Note: positive values indicate that models overestimated usage, on average, while negative values indicate that they underestimated it.

Table 10. Summary of differences for individual homes between modeled and first year normalized electric use as a percent of annual usage in electric heated EPS homes built from 2009-2011

Year Built	Analysis Year	% Homes with <10% Difference	% Homes with <25% Difference	% Homes with <50% Difference
2009	2010	14%	50%	82%
2010	2011	9%	22%	70%
2011	2012	25%	61%	86%

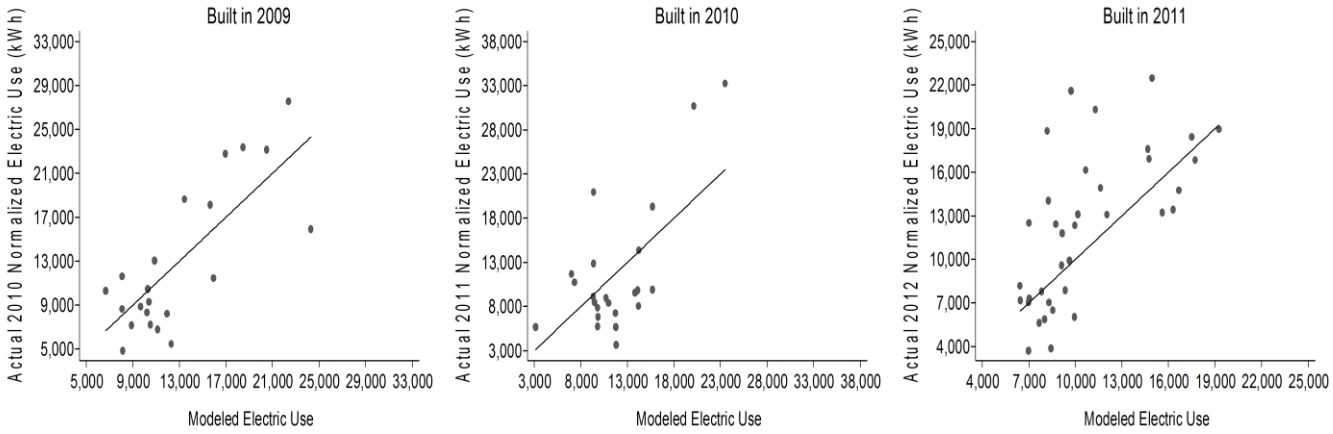

Figure 8. Scatterplots of modeled electric usage versus the deviation in first year normalized electric usage from modeled usage in electric heated EPS homes built from 2009-2011.
Note: the reference line indicates where first year and modeled electric use are equivalent; points above the line indicate homes where actual usage was higher than estimated and vice versa.

Comparison of Modeled and Normalized Annual Energy Use over Time. For each year of home construction, we analyzed additional years of electric data through 2012. **Figure 9** displays the mean differences over time between modeled and normalized annual electric use as a percent of annual usage. Although these differences varied from year to year, there is a discernable pattern of modeled usage slightly underestimating annual electric use, on average. All but one of the mean differences from modeled usage were less than 10 percent. For 2011 homes, the mean difference of 12 percent, as noted above, was statistically significant. Due to the small sample sizes, these results have a high degree of variability and uncertainty. **Appendix B** contains the table of results for the comparisons of modeled and normalized annual electric use over time associated with the figure below.

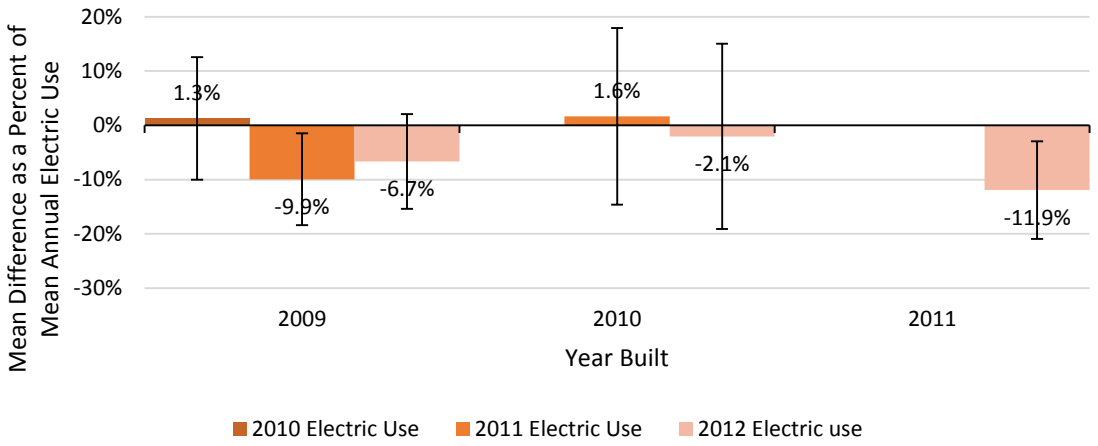

Figure 9. Mean differences in modeled vs. normalized annual electric use over time as a percent of mean annual usage, in electric heated EPS homes built from 2009-2011.
Note: positive values indicate that models overestimated usage, on average, while negative values indicate that they underestimated it.

Conclusions

Energy Trust's New Homes program appears to have modeled annual energy use with relatively good accuracy, on average, for EPS homes built from 2009 to 2011. Differences in modeled versus normalized annual energy usage were less than 10 percent for gas heated homes on average, and within 25 percent of the modeled usage for roughly two-thirds of homes. For electric heated homes, differences in modeled versus normalized annual electric use were between 1 percent and 12 percent, on average, with wide confidence intervals due to the small sample sizes. Slightly less than half of electric heated homes had normalized usage within 25 percent of the modeled usage value. Across the board, there was a consistent pattern of modeled gas and electric use being slightly underestimated, on average, although most of these differences were not statistically significant. The accuracy of modeled electric base loads, which are influenced more by human factors such as behavior and plug loads, varied substantially between homes. However, it is difficult to draw any conclusions from the limited number of electric heated homes in our sample. Further analysis with a larger sample of electric heated homes would be required to better understand the accuracy of modeled electric use.

There were several limitations to this analysis. We were not able to obtain energy usage data for all program homes and saw attrition of greater than half the original sample. Therefore, the results are indicative but may not be quantitatively representative of the population of homes in Energy Trust territory. Although we weather normalized the energy data for each home using standard methods, it is possible that there were residual weather effects, particularly because we used monthly data with only 12 data points per home on which to run the weather regression models. This could have factored into the small differences in results we observed between years of construction and energy data. In addition, because we were only able to analyze whole home gas and electric use, we were unable to identify the source of any deviations from modeled usage or assess how accurately different end uses were modeled.

In spite of these limitations, the findings of this analysis validate that REM/Rate is a reliable tool, on average, for estimating energy use in gas heated EPS new homes and provides a sound basis for calculating energy savings. Small calibrations may further improve modeled usage estimates. However, the variability we observed in the accuracy of modeled usage means that the models frequently miss the mark for individual homes. This analysis does not provide information about how accurately the program estimates energy savings for EPS homes. We are currently undertaking a follow up analysis to evaluate program energy savings claims by comparing normalized annual energy use between EPS homes and similar homes built to code that did not receive incentives from the program.

References

Construction Monitor, Inc. (2014). Building Permit Data. Cedar City, Utah. Retrieved from http://www.constructionmonitor.com

Earth Advantage Institute. (2009). *Energy Performance Score 2008 Pilot: Findings & Recommendations Report.* Portland, OR: Energy Trust of Oregon. Retrieved March 5, 2015, from http://www.earthadvantage.org/assets/documents/EPSPilotReport_2008.pdf

Fels, M. (1986). PRISM: An Introduction. *Energy and Buildings, 9*, 5-18. Retrieved from http://www.marean.mycpanel.princeton.edu/~marean/images/prism_intro.pdf

Hassel, S., Blasnik, M., & Hannas, B. (2009). *Houston Home Energy Efficiency Study.* Raleigh, NC: Advanced Energy. Retrieved March 5, 2015, from http://www.resnet.us/blog/wp-content/uploads/2012/08/Houston-Energy-Efficiency-Study-2009-Final.pdf

NORESCO, LLC. (2015). REM/Rate Software. Boulder, CO. Retrieved from http://www.remrate.com

RESNET. (2013). *Mortgage Industry National Home Energy Rating Systems Standards.* Oceanside, CA: Residential Energy Services Network, Inc. (RESNET). Retrieved March 5, 2015, from http://www.resnet.us/standards/RESNET_Mortgage_Industry_National_HERS_Standards.pdf

Stull, B., & Youngblood, K. (2010). Savings beyond Energy Star with Energy Performance Scores. *ACEEE 2010 Summer Study on Energy Efficiency in Buildings.* Washington, D.C.: American Council for an Energy-Efficient Economy. Retrieved March 5, 2015, from http://aceee.org/files/proceedings/2010/data/papers/1957.pdf

Appendix A: Attrition Tables

Gas Heated Homes

Table 11. Attrition of 2009 gas heated EPS homes used for comparison of modeled vs. normalized annual gas usage

Attrition Step	Analysis Year	N Removed	% Removed	N Remaining	Annual Gas Usage*	Annual Electric Usage*
All EPS homes in western Oregon	--	0	0%	557	--	--
Not matched to gas usage data	2010	107	19%	450	511	6,833
	2011	107	19%	450	595	7,140
	2012	112	20%	445	551	7,346
Not primarily gas heated	2010	91	20%	359	524	6,723
	2011	87	19%	363	607	6,931
	2012	78	18%	367	562	7,163
Missing modeled annual gas usage†	2010	182	51%	177	475	6,203
	2011	182	50%	181	558	6,361
	2012	182	50%	185	520	6,710
Major problem with gas data	2010	0	0%	177	475	6,203
	2011	0	0%	181	558	6,361
	2012	1	0%	184	522	6,725
Top and bottom 1% of gas users	2010	1	1%	176	469	6,135
	2011	1	1%	180	553	6,291
	2012	2	1%	182	519	6,733

***** Raw annual energy use for all homes that remain after each attrition step. Gas usage is reported in therms per year and electric usage is reported in kilowatt-hours per year.
† The EPS track began in mid-2009, so not all program homes had their energy use modeled in this year, explaining the high level of attrition in this step.

Table 12. Attrition of 2010 gas heated EPS homes used for comparison of modeled vs. normalized annual gas usage

Attrition Step	Analysis Year	N Removed	% Removed	N Remaining	Annual Gas Usage*	Annual Electric Usage*
All EPS homes in western Oregon	--	0	0%	452	--	--
Not matched to gas usage data	2011	85	19%	367	547	6,816
	2012	92	20%	360	516	7,275
	2011	63	17%	304	565	6,279

Not primarily gas heated	2012	54	15%	306	530	6,868
Missing modeled annual gas usage	2011	1	0%	303	566	6,276
	2012	1	0%	305	531	6,868
Major problem with gas data	2011	4	1%	299	568	6,325
	2012	2	1%	303	532	6,891
Top and bottom 1% of gas users	2011	0	0%	299	568	6,325
	2012	1	0%	302	529	6,808

***** Raw annual energy use for all homes that remain after each attrition step.

Table 13. Attrition of 2011 gas heated EPS homes used for comparison of modeled vs. normalized annual gas usage

Attrition Step	Analysis Year	N Removed	% Removed	N Remaining	Annual Gas Usage*	Annual Electric Usage*
All EPS homes in western Oregon	--	0	0%	626	--	--
Not matched to gas usage data†	2012	415	66%	211	521	6,639
Not primarily gas heated	2012	25	12%	186	527	6,575
Missing modeled annual gas usage	2012	0	0%	186	527	6,575
Major problem with gas data	2012	51	27%	135	547	6,657
Top and bottom 1% of gas users	2012	0	0%	135	547	6,657

***** Raw annual energy use for all homes that remain after each attrition step.

† The high level of attrition observed at this step is a result of a large number of gas billing records that were missing from Energy Trust's historical billing database for homes constructed in 2011.

Electric Heated Homes

Table 14. Attrition of 2009 electric heated EPS homes used for comparison of modeled vs. normalized annual electric usage

Attrition Step	Analysis Year	N Removed	% Removed	N Remaining	Annual Electric Usage*
All EPS homes in western Oregon	--	0	0%	557	--
Not matched to electric usage data	2010	115	21%	442	8,006
	2011	115	21%	442	8,511
	2012	114	20%	443	8,569
Not primarily electric heated**	2010	406	92%	36	13,189
	2011	407	92%	35	15,350
	2012	399	90%	44	14,299
Missing modeled annual electric usage†	2010	4	11%	32	12,978
	2011	5	14%	30	15,547
	2012	9	20%	35	13,676
Homes with solar PV	2010	5	16%	27	13,948
	2011	5	17%	25	17,154
	2012	6	17%	29	15,069
Major problem with electric data	2010	2	7%	25	14,601
	2011	0	0%	25	17,154
	2012	0	0%	29	15,069
Top and bottom 1% of electric users	2010	3	12%	22	12,103
	2011	1	4%	24	16,182
	2012	1	3%	28	14,133

* Raw annual electric use for all homes that remain after each attrition step.
** Only a small portion of new homes built in Energy Trust's service territory use electric heating systems, so the high attrition in this step is simply reflective of the housing stock.
† The EPS track began in mid-2009, so not all program homes had their energy use modeled in this year, explaining the high level of attrition in this step.

Table 15. Attrition of 2010 electric heated EPS homes used for comparison of modeled vs. normalized annual electric usage

Attrition Step	Analysis Year	N Removed	% Removed	N Remaining	Annual Electric Usage*
All EPS homes in western Oregon	--	0	0%	452	--
Not matched to electric usage data	2011	94	21%	358	7,743
	2012	85	19%	367	8,137
Not primarily electric heated**	2011	328	92%	30	14,356
	2012	340	93%	27	13,622

Missing modeled annual electric usage	2011	0	0%	30	14,356
	2012	0	0%	27	13,622
Homes with solar PV	2011	5	17%	25	15,129
	2012	6	22%	21	14,676
Major problem with electric data	2011	0	0%	25	15,129
	2012	0	0%	21	14,676
Top and bottom 1% of electric users	2011	2	8%	23	11,639
	2012	2	10%	19	11,225

* Raw annual electric use for all homes that remain after each attrition step.
** Only a small portion of new homes built in Energy Trust's service territory use electric heating systems, so the high attrition in this step is simply reflective of the housing stock.

Table 16. Attrition of 2011 electric heated EPS homes used for comparison of modeled vs. normalized annual electric usage

Attrition Step	Analysis Year	N Removed	% Removed	N Remaining	Annual Electric Usage*
All EPS homes in western Oregon	--	0	0%	626	--
Not matched to electric usage data	2012	127	20%	499	7,608
Not primarily electric heated**	2012	458	92%	41	12,269
Missing modeled annual electric usage	2012	0	0%	41	12,269
Homes with solar PV	2012	5	12%	36	11,919
Major problem with electric data	2012	0	0%	36	11,919
Top and bottom 1% of electric users	2012	0	0%	36	11,919

* Raw annual electric use for all homes that remain after each attrition step.
** Only a small portion of new homes built in Energy Trust's service territory use electric heating systems, so the high attrition in this step is simply reflective of the housing stock.

Appendix B: Data Tables for Comparisons over Time

Gas Heated Homes

Table 17. Comparison of mean modeled vs. normalized annual gas use (in therms) over time, in gas heated EPS homes built from 2009-2011

Year Built	Analysis Year	N	Mean Modeled Usage	Mean Normalized Usage	Mean Difference	90% CI LB*	90% CI UB*	p-value
2009	2010	176	488	485	3	-15	21	0.799
	2011	180	490	501	-11	-28	6	0.271
	2012	182	493	524	-31	-47	-16	0.001**
2010	2011	299	504	515	-10	-24	3	0.211
	2012	302	501	533	-31	-45	-17	<0.001**
2011	2012	135	517	547	-30	-52	-9	0.023**

* Lower and upper bounds of the 90% confidence interval for the mean difference.
** Statistically significant at the 0.05 level.

Table 18. Summary of differences between modeled and normalized gas use over time, as a percent of annual usage, in gas heated EPS homes built from 2009-2011

Year Built	Analysis Year	% Homes with <10% Difference	% Homes with <25% Difference	% Homes with <50% Difference
2009	2010	27%	65%	87%
	2011	30%	68%	91%
	2012	36%	71%	93%
2010	2011	28%	64%	92%
	2012	31%	66%	91%
2011	2012	34%	75%	90%

Table 19. Comparison of mean modeled vs. normalized annual electric use (in kWh) over time, in gas heated EPS homes built from 2009-2011

Year Built	Analysis Year	N	Mean Modeled Usage	Mean Normalized Usage	Mean Difference	90% CI LB*	90% CI UB*	p-value
2009	2010	75	6,210	6,550	-340	-900	230	0.334
	2011	86	6,020	6,210	-190	-600	220	0.453
	2012	74	6,050	6,350	-300	-710	100	0.220
2010	2011	105	6,360	6,500	-140	-550	270	0.568
	2012	130	6,410	6,880	-470	-830	-110	0.032**
2011	2012	49	6,340	6,870	-530	-1,140	90	0.167

* Lower and upper bounds of the 90 percent confidence interval for the mean difference.

** Statistically significant at the 0.05 level.

Table 20. Summary of differences between modeled and normalized electric use over time, as a percent of annual usage, in gas heated EPS homes built from 2009-2011

Year Built	Analysis Year	% Homes with <10% Difference	% Homes with <25% Difference	% Homes with <50% Difference
2009	2010	10%	21%	32%
	2011	14%	29%	40%
	2012	10%	26%	35%
2010	2011	8%	20%	28%
	2012	9%	22%	36%
2011	2012	4%	16%	31%

Electric Heated Homes

Table 21. Comparison of mean modeled vs. normalized annual electric use over time, in electric heated EPS homes, built from 2009-2011

Year Built	Analysis Year	N	Mean Modeled Usage	Mean Normalized Usage	Mean Difference	90% CI LB*	90% CI UB*	p-value
2009	2010	22	12,930	12,770	160	-1,280	1,610	0.853
	2011	24	14,280	15,860	-1,580	-2,920	-230	0.066
	2012	28	13,340	14,290	-950	-2,200	300	0.221
2010	2011	23	11,870	11,680	190	-1,710	2,090	0.870
	2012	19	11,270	11,500	-230	-2,200	1,730	0.845
2011	2012	36	10,690	12,140	-1,450	-2,540	-360	0.036*

* Lower and upper bounds of the 90 percent confidence interval for the mean difference.
** Statistically significant at the 0.05 level.

Table 22. Summary of differences between modeled and normalized electric use over time, as a percent of annual usage, in electric heated EPS homes built from 2009-2011

Year Built	Analysis Year	% Homes with <10% Difference	% Homes with <25% Difference	% Homes with <50% Difference
2009	2010	14%	50%	82%
	2011	25%	67%	100%
	2012	25%	57%	93%
2010	2011	9%	22%	70%
	2012	5%	32%	68%
2011	2012	25%	61%	86%