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Energy Trust of Oregon 2009 Existing Homes Gas Impact Analysis

Prepared by Brien Sipe
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Energy Trust of Oregon
421 SW Oak St., Suite 300
Portland, OR 97204

Executive Summary

The objective of this analysis is to estimate annual gas savings for participants in the 2009 Home Energy Solutions (HES) program, both at the household and measure level. As with previous impact evaluations, weather normalized annual consumption, similar to the PRInceton Scorekeeping Method (PRISM), is employed, allowing for more direct comparisons of results and exploration of trends in program savings over time.

In addition to weatherization measures, the Home Performance with Energy Star, Home Energy Review audit, Energy Saver Kits and tankless gas water heaters program offerings were also examined.

Gas savings estimates from this and previous studies are used in Energy Trust's annual true-up process, as well as being used to inform future expected measure savings and to identify potential issues with implementation that may not be detected via quality control inspections in the field. The following details highlights from the analysis, as well as a comparison of the most recent findings to the 2006-2008 estimated savings.

Of particular note, residential gas usage fell 14% in Northwest Natural territory from 2008 to 2010, resulting in a large change in consumption outside the influence of the program. Causes of the drop likely stem from both an exceptionally mild winter in 2010 as well as from the prevailing depressed economic conditions faced by households. We hypothesize that these factors led to lower estimates of savings per measure compared to prior program years' estimates. Energy Trust uses a three year rolling average estimate of savings to mitigate large short run deviations in savings estimates, thus, in the long run, periods of unusually high or low gas use have less influence on estimates used for project planning purposes.

Key Findings and Recommendations

Home Energy Solutions findings:

- Estimated average savings per household is 73 therms, or 10% of total household gas usage.
- The first measureable savings for air sealing were found in the 2009 program data, averaging 19 therms per project.
- Enhanced QC and implementation procedures, as well as an overhaul to the incentive structure for duct and air sealing are likely responsible for the measureable savings stemming from these measures in 2009.
- Savings estimates per CFM of duct and air leakage were estimated and can be used to calculate savings per project going forward.
- Returning to the 2008 analysis, removing one high volume contractor (subsequently removed from the program in 2009 due to consistently high quality control failure rates) yields statistically significant savings (per delta CFM) in line with 2006-07 and 2009 findings. Air sealing savings for 2008 were not found to be significantly different from zero, regardless of contractor level effects.

Recommendations:

- For true-up purposes, 2008 duct sealing savings should be de-rated based on the proportion of projects completed by the contractor whose work was found to be ineffective, allowing for savings to be booked for the remainder of projects which have been shown to be effective and averaged 24 therms per project (Contractor 'Z'

performed 56% of duct sealing projects in 2008 with no measureable savings, yielding a de-rating factor of 24/therms *0.56, or 13.5 therms per duct sealing project).
- Savings estimates for shell measures (e.g., ceiling/wall/floor insulation and windows), although slightly lower than previous years, are robust and appear consistent relative to the previous three years of impact evaluations.

Home Performance with Energy Star findings:
- Estimated savings for the Home Performance with Energy Star program averaged 148 therms per participating homes at the high end of the realization rate range, equivalent to 19% of average pre-treatment usage and 23% of estimated heating loads.
- Predicted savings for the Home Performance with Energy Star averaged 315 therms per home resulting in a realization rate of 35%-47%, depending on modeling approach.
- **Recommendation:** Calibrating estimates of energy savings to actual household energy usage could dramatically increase the accuracy of predicted measure calculated via the Home Performance program's modeling software.
- **Recommendation:** Given the significantly lower savings estimates than modeled, Energy Trust needs to recalculate the Home Performance program's cost-effectiveness.

Baseload measure findings:
- Tankless gas water heater savings were estimated to range from 59-65 therms, in line with previous studies on the 2008 program. These savings numbers put the measure significantly below a societal cost/benefit ratio of 1. Original engineering estimates put savings at ~110 therms annually, based on assumed water heating loads substantially higher than those found in Energy Trust service territory.
- **Recommendation:** Given that annual therm savings would have to double for tankless gas water heaters to be cost effective, consider removing incentive for the measure.
- The data indicates that directly installed measures, such as low flow aerators and showerheads, via the Home Energy Review audit process appear to be consistent with expectations, yielding average water heater savings of 36 ±6 therms, compared to the predicted savings of 38.
- Energy Saver Kits, which consumers can request and contain a variety of aerators, showerheads and CFLs, depending on housing characteristics, also had estimated savings of 12 ±7 therms relative to an assumed savings of 10.
- **Recommendation:** HER and ESK gas savings estimates appear reasonable and consistent with billing analysis findings and should be maintained at their current level.

Analysis on the 2009 program year revealed the first measureable savings from air and duct sealing at the 'per delta CFM' level (a measure of the change in the leakiness of homes and duct systems before and after treatment). Prior to 2009, issues with an exceptionally high volume contractor led to inconsistent and insignificant results stemming from the billing analysis.

Table 1 below shows average savings per measure installed with per unit of treated area (or delta CFM for air and duct sealing). Table 2 presents average project savings, based on 2009 treated areas or CFM reductions, stemming from these estimates.

Table 1 Single family estimated annual therm savings for typical project treated area by measure[†]

Measure	2006-2007	2008	2009
Air sealing (per 1000/CFM)	*0*	*5*	**15**
Duct sealing (per 500/CFM)	**24**	*6**	**12**
Gas furnace	**77**	**68**	**65**
Windows (per 200/sq. ft.)**	**22**	**39**	**38**
Ceiling insulation (per 1000/sq. ft.)	**52**	**52**	**45**
Floor insulation (per 1000/sq. ft.)	**35**	**51**	**36**
Wall insulation (per 1000/sq. ft.)	**52**	**62**	**38**
Duct insulation (per 200/Lft)***	**14**	**28**	-

[†]Average treated areas/delta CFMs for 'typical treatments' were used to create an average per project savings to facilitate comparison. Numbers in bold reflect statistically significant results, italics indicate not statistically different from zero.
*2008 duct sealing estimate contains ineffective contractor discussed above, removing them from 2008 yields an average savings of 24 therms/duct sealing project.
**Deemed windows savings are based on 'incremental' savings, impact estimates in this table represent 'replacement' savings and are not de-rated to account for baseline assumptions.
***The number of duct insulation projects in the final 2009 sample was inadequate to derive a meaningful estimate.

Introduction

The objective of this analysis is to estimate annual gas savings for participants in the 2009 Home Energy Solutions (HES) program, both at the household and measure level. This study follows on the 2006-07 and 2008 impact evaluations of gas weatherization. To provide flexibility in the data analysis, this study uses a weather normalized annual consumption approach, similar to the PRInceton Scorekeeping Method (PRISM). Utilizing a consistent modeling approach across studies allows for more direct comparisons of results and exploration of trends in program savings over time.

Gas savings estimates from this and previous studies are used in Energy Trust's annual true-up process, as well as being used to inform future expected measure savings and to identify potential issues with implementation that may not be detected via field quality control inspections.

This report provides a comprehensive analysis of both weatherization and baseload related energy conservation measures (infrequent measures or those with very small predicted savings were removed from the analysis) including tankless water heaters, Home Energy Review direct installs and Energy Saver Kits, as well as an analysis of the 2009 Home Performance with Energy Star gas savings.

Savings estimates are robust, and are in line with findings from previous impact evaluations, with the exception being duct sealing, where estimated savings appear to be negligible. As with the 2008 program year, one high volume contractor performed over 50% of air sealing and 36% duct sealing projects in 2009 was removed from the program mid-way through the program year after being placed on probation due to persistently high failure rates in quality control inspections. The program was aware of the quality control issues stemming from this contractor in 2008 and invested considerable time in training this contractor's staff to bring the quality of work up to par. Despite this effort, the contractor was removed mid-year; the findings section of this report examines this contractor's effect on the gas program.

It should be noted that in the time period of this analysis residential gas demand fell 14% (2008 to 2010), likely due to a combination of a mild heating season and the effects of the prevailing economic conditions. Thus, load and savings estimates during 2009 may have a downward bias.

Background & Methodology

Sample selection

Each site's pre and post treatment period consists of the full year prior to, and following, the year of program participation (2009 participant's pre and post years are 2008 and 2010, respectively). In addition, given the volume of participation in the last quarter of program year 2009 (40% of HES measures installed in Q4, and 22% installed in December) the 'post' period begins in February 2010, allowing a grace period for homes which may have partial occupancy during a retrofit, or inaccurate installation dates.

Households that participated in either the pre or post year (repeat participants) were removed from the analysis to eliminate the effect of prior or subsequent participation from influencing 2009 savings estimates. In addition, observations with treatment dates within a billing period which straddled the beginning or end of the treatment year were dropped. This approach

simplified the matching of the participant to comparison group, and aided in minimizing any weather related bias due to misalignment of the pre and post periods between groups.

Billing data cleaning

- Energy Trust has developed a standardized procedure to 'clean' billing data prior to analysis. The major steps performed by the routine are:
- Estimated meter readings are added to next actual reading, to ensure meter begin and end dates accurately align with weather data.
- Sites with several consecutive estimates were removed if the number of observations in either the pre of post period fell below a minimum threshold.
- Excessively short or long readings are removed prior to weather normalization (less than 10 days, greater than 60).
- Sites with occupancy changes during the study period were flagged to allow an examination of influence, if any, on savings estimates (no significant changes were observed in the estimates when excluding sites with occupant turnover).

Comparison group

A random sample of 30,000 gas heated homes, which have not participated in Energy Trust programs, were used as a comparison group for the difference in differences estimates of this report. While using a future group of participants is considered superior to random non-participants, the timing of this study only allowed for an exceedingly small group of gas weatherization participants from 2011 to be used. Rather than forgoing a comparison group, a random group was selected. While this technique my raise the question of self selection bias, unexplained changes in consumption for the participant group were found to be in line with the change in consumption of the comparison group, lending support to the efficacy of this approach.

To ascertain overall attributable program savings, the comparison group was stratified based on region and consumption to bring the pre-period usage between the two groups into closer alignment, again assuming that future participating households in close proximity and with similar energy usage to 2009 participants allows for a more comparable estimate of savings. Comparison group sites are stratified based on consumption quintiles and region are proportionately matched to participants using a technique similar to a Monte Carlo simulation in order to minimize random sampling error. This matching approach may lead to considerably fewer than 30,000 non-participants being compared to the participant sample, as the smallest as the algorithm ensures equality across all strata, with the smallest strata filled determining the size of the others.

Weather normalization

Analysis was conducted using a method similar to the PRInceton Score-keeping Method (PRISM). The algorithm decomposes energy use into estimated heating, cooling and base load components. To do this, an optimum 'set-point' or reference temperature is found below (above) which energy use for heating (cooling) is detected. The reference temperature is a combination of consumer preference for thermostat settings, and the thermal integrity of the structure. Long-run average weather data is then used to calculate an estimate of annual

energy use in an 'average' year.[1] Model specifications for weather normalization can be found in Appendix A.

Post weather normalization data screening:

- Sites were flagged if pre to post change in total gas usage exceeded 65%, changes that could signify other major alterations to the household unrelated to energy conservation measure (ECM) installation.
- Gas sites were flagged if their pre or post normalized consumption model R^2 was less than 0.7
- Michael Blasnik provided guidance on additional screens to verify adequate variation in the model to estimate heating/base loads. Sites are flagged when the sum of HDD's for observed billing periods were less than 40% of the long run average, or Max-Min HDD/Day were less than Average HDD/day. Prior screens, assessing number of observations and R^2 tend to capture most of these sites.
- Sites with pre period consumption above the 99th or below the 1st percentile were removed.
- Non participant consumption was bounded based on the minimum and maximum participant consumption.
- Sites with less than 9 pre or post observations were flagged.

Savings estimation

Two approaches were used to estimate annual program and measure level gas savings. The first is a difference in differences model where the change in consumption from 2008 to 2010 between the participant and comparison group are subtracted, yielding average household savings. This technique can also be used to ascertain average savings for various groups of commonly installed measures. These findings are indicative and help to provide more insight into trends in savings across measures and examine the efficacy of particular contractors.

The second approach relies on a multivariate regression to estimate average measure level savings within the program. Three modeling approaches are used to allow an examination of the influence of outliers. Ordinary Least Squares (OLS) is the standard multivariate approach, supplemented with Robust regression and DFBETA estimates, with the latter two techniques intended to reduce the influence of outliers on the measure level savings estimates. Outliers may come in the form of inordinately large projects (shell insulation performed in homes over 4,000 sq. ft.).

[1] Energy Trust uses TMY3 weather data to align with the Northwest Power and Conservation Council's Regional Technical Forum methods.

The Data

Table 2 Sample attrition for 2009 participating gas heated homes

Attrition sources	2009 site attrition	Viable sample as a % of total 2009 program sites
Unique sites with gas savings	19,214	100%
Sites where bills were found and had no participation in pre-post period	12,082	63%
Sites with at least 6 observations pre and post	12,080	63%
Sites with less than a 65%+ change delta Pre/Post	11,611	60%
Sites with therm consumption between the 1st and 99th percentile in pre-period	11,467	60%
Eligible participant sites with R^2 > 0.7 & adequate weather variation	10,137	53%
Final gas site sample*	**10,137**	**-**
Eligible gas sites (infrequent/hard to evaluate measures removed)**	**7,344**	**-**

* Non-participants were screened using the same criteria.
**Tanked water heaters, boilers and homes with high efficiency appliances were screened out of the analysis.

Based on the site level sample attrition described above in Table 3, the following details the sample disposition of measures installed in 2009, and those included in the subsequent analysis. Measures which were infrequently installed were removed from the multiple variable regression analysis, as well as those where fuel switching (e.g. customers replacing electric water heaters with tankless gas water heaters, this measure is evaluated separately) is a known problem, were removed from the modeling. In addition, domestic hot water measures and energy saver kit savings are estimated in their own model.

Table 3 Sample disposition for 2009 gas weatherization impact analysis

Measure	2009 installs	2009 sample	Percent of totals eligible for analysis	Percent of program totals used in final models
Air sealing	1,475	992	67%	42%
Ceiling insulation	2,100	1,280	61%	37%
Domestic hot water measures	6,822	4,410	65%	25%
Duct insulation	465	253	54%	31%
Duct sealing	1,485	902	61%	40%
Energy Saver Kit	2,950	1,999	68%	-
Floor insulation	1,428	892	62%	37%
Gas furnace	7,918	4,636	59%	45%
Knee wall insulation	163	79	48%	-
Tankless water heater	1,169	609	52%	-
Wall insulation	782	490	63%	32%
Windows	809	439	54%	31%

Findings

Difference in differences estimates

Results from the difference in differences approach are presented below in Table 5. Average estimated therm savings for the 2009 program year, net of the comparison group, is 73 therms, or 10% of pre-treatment usage. This figure is slightly more than the average change found in 2008, at 62 therms per home. A non-programmatic fall in gas usage of 46 therms was estimated among the comparison group, likely influenced by mild weather and economic conditions.

Table 4 2009 Average annualized pre-treatment therm usage and savings for program participants and comparison group

Cohort	N	Pre-period therm usage	Base load	Heating load	Therm savings	Savings net of comparison group	95% CI
2009 participant	7,344	754	169	584	119	73	±3
2009 comparison group	13,920	744	168	573	46		

For frequently occurring measure or measure groupings (N>20), a difference in differences estimate was generated using a stratified comparison group. While these findings are indicative, they help to illustrate some of the trends observed in the multiple variable models to follow. Savings from these measure groupings do not represent program wide averages, as these groups, or standalone measures, don't necessarily reflect interactive effects that occur when various measures are installed concurrently (e.g., duct sealing savings would drop in the presence of ceiling insulation, as less conditioned air would need to pass through the ducts due to the increase in the home envelope's ability to retain heat). These measure combinations and savings net of the comparison group are shown in Table 6.

Air sealing projects conducted in 2009 are the first in the gas weatherization program's history to show significant savings. These findings likely correspond to several changes in implementation during 2009:

- Modification of the incentive structure, where incentives are capped as a fraction of installation cost, rather than paying per delta CFM.
- Extensive efforts to train and rigorous QC of high volume contractors. Eventual removal of one contractor likely had a positive impact on savings estimates. Use of checklists for air sealing to allow QC inspectors to verify location of air leaks which had been sealed.

Table 5 2009 HES measure grouping difference in differences savings estimates

Measure grouping	Participant N	Savings net of comparison group	95% CI	Participant pre use
Air sealing	69	53	±24	762
Ceiling insulation	335	86	±15	691
Ceiling and floor insulation	89	147	±35	735
Ceiling and wall insulation	59	116	±34	627
Ceiling insulation and windows	61	91	±31	637
Duct sealing	47	33	±37	828
Duct and air sealing	41	61	±52	693
Duct sealing and gas furnace	48	86	±38	754
Floor insulation	175	66	±20	766
Floor insulation and windows	31	107	±34	696
Gas furnace	3,291	79	±5	790
Wall insulation	89	75	±27	611

Multiple variable impact estimates
Sites receiving shell and duct insulation or glazing were limited to cases falling between the 5th and 95th percentile of the area treated. Obvious data errors as well as trivial projects (e.g., less than 100 sq. ft. of ceiling insulation or a project indicating 11,000 sq. ft. of window replacements) were eliminated.

To maintain consistency across program years, robust regression estimates are used as the 'final' savings estimates (Robust regression down weights outliers to prevent them from leveraging regression estimates) and are therefore used for program planning and the true-up process.

Table 6 2009 Multiple variable estimates of savings

Variables	Robust
Ceiling insulation (per sq. ft.)	0.0451***
Floor insulation (per sq. ft.	0.0362***
Wall insulation (per sq. ft.)	0.0382***
Duct insulation (per Lft.)	0.0290
Duct sealing (per delta CFM)	0.0240**
Air sealing (per delta CFM)	0.0153***
Gas furnace	65.16***
Windows (per sq. ft.)	0.191***
Home Energy Review	14.16***
'Z' duct impact	
'Z' air sealing impact	
Constant	56.86***
Observations	6,990
R-squared	0.064

*** p<0.01, ** p<0.05, * p<0.1

For the first time, impact estimates of 'per unit' (square/lineal foot, delta CFM) were estimated for all shell and sealing related measures. To give a sense of the total savings stemming from various weatherization measures, Table 8 below shows typical treated areas/CFM reduction, estimated coefficients and estimated total annual savings by shell and sealing measure. Savings from the multiple variable regression for insulation are significantly less than those that appear in the difference in differences modeling due to interactive effects, as more measures are installed at a site, incremental savings begin to fall (a home receiving insulation measures now needs less conditioned air delivered via the furnace and ducts, resulting in savings from those measures dropping).

In addition, we hypothesize that reductions in observed savings estimates relative to prior studies are likely being effected by constrained household incomes. As with interactive effects reducing marginal savings from each additional measure, as households take steps to reduce their energy costs (e.g., turning down thermostat set-points), the total pie of potential energy savings from installed energy conservation measures shrinks, leading to lower point estimates of savings.

Table 7 Measure estimated savings for typical treated areas*

Measure	Typical treated area/leakage reduction	Estimated savings per installed unit (Robust estimates)	Estimated average savings per installation
Ceiling insulation sq. ft.	1,000	0.045	45
Floor insulation sq. ft.	1,000	0.036	36
Wall insulation sq. ft.	1,000	0.038	38
Windows sq. ft.	200	0.19	38
Duct sealing (per delta CFM)	500	0.024	12
Air sealing (per delta CFM)	1,000	0.015	15

*Duct insulation N was too small to derive a meaningful estimate of savings in 2009.

Air and duct sealing discussion

Saving estimates for these two measures have proven elusive in the 2006 through 2008 program years. Several studies which examined the 2007 and early 2008 program years found negligible savings for air sealing in both years; these findings are confirmed by estimating energy savings per CFM in the tables below. Total savings by measure, year and projects performed with and without one high volume contractor are presented below in Table 9, with bold (italics) numbers indicating statistically significant (not significant) estimates of savings.

While air sealing savings appear to not drive gas savings in any year prior to 2009, removing one high volume contractor ('Z') from the analysis in 2008 yields an estimate of duct sealing savings comparable to the 2006 and 2007 estimate. As with prior in-house impact evaluation work, and research conducted by Blasnik and Associates, air sealing projects from 2006 through 2008 point toward a lack of measureable savings from air sealing. However, delta CFM numbers from 2009 indicate statistically significant savings from both air and duct sealing.

Table 8 Average estimated air and duct sealing therm savings by program year

Measure*	Program year	Estimated annual savings
Duct sealing	2009	**12**
	2009 no 'Z'	**14**
	2008	*9*
	2008 no 'Z'	**24**
	2006-07	**23**
Air sealing	2009	**19**
	2009 no 'Z'	**25**
	2008	*7*
	2008 no 'Z'	*4*
	2006-07	*15*

*For the sake of comparison, all savings estimates use average delta CFMs from the 2009 program year.

The 2009 program year saw the removal of contractor 'Z', along with a significant change in the implementation of both duct and air sealing, with incentives paid toward a fraction of cost, rather than the prior method of paying per delta CFM. Stricter quality control standards were also likely to contribute to the increased efficacy of air sealing projects.

Regression estimates indicate no significant difference in savings achieved by contractor 'Z' and the rest of the trade allies operating in 2009. Table 10 below shows these results, with contractor 'Z's work interacted with both the duct and air sealing variables. While the coefficients for this contractors' work are negative, there are not significantly different from estimated savings for the remainder of the work performed in 2009.

Table 9 Multiple variable regression estimates controlling for contractor 'Z'

Variables	Robust 'Z' impacts
Ceiling insulation (per sq. ft.)	0.0438***
Floor insulation (per sq. ft.)	0.0349***
Wall insulation (per sq. ft.)	0.0364***
Duct insulation (per Lft.)	0.0117
Duct sealing (per delta CFM)	0.0268**
Air sealing (per delta CFM)	0.0203***
Gas furnace	62.94***
Windows (per sq. ft.)	0.186***
Home Energy Review	11.99***
'Z' duct impact	-0.0136
'Z' air sealing impact	-0.000733
Constant	59.12***
Observations	6,990
R-squared	0.064

Home Performance with Energy Star analysis

The Home Performance with Energy Star (HPF) track aims to delivers participants a more comprehensive weatherization package. Participation begins with a home audit performed by the contractor, which includes diagnostic testing (blower door and duct blaster) as well as combustion safety testing.

Savings estimates are derived from the Real Home Analyzer modeling tool based on the inputs collected during the initial audit, rather than prescriptive savings used in the standard Home Energy Solutions program. Based on the inputs, modeled savings for recommended measures vary based on a particular home's characteristics.

An analysis of savings use two similar approaches as those used in above with a slight variation: a difference in differences estimate, and a regression aimed at estimating a realization rate for the total modeled savings at the home (a regression coefficient of 1 would imply that 100% of predicted savings were achieved).

Table 10 HPF gas heated homes sample attrition

HPF attrition	Count	Average measures installed
Total 2009 HPF gas homes	205	4.0
Homes passing data screens	101	4.2

Some HPF sites received HERs during the 2009 program year, resulting in 26 sites with directly installed domestic hot water measures (not listed below) and were included in the models. Homes with tankless water heater installations were also removed from the analysis, due to potential issues with fuel switching from electric water heaters.

Table 11 Measure counts in 2009 HPF homes

Measure	2009 installs	2009 sample	Sample percent of total installs
Air sealing	172	88	51%
Ceiling insulation	138	62	45%
Duct insulation	49	19	39%
Duct sealing	89	42	47%
Floor insulation	102	50	49%
Gas furnace	17	17	100%
Knee wall insulation	0	-	-
Tankless water heater	6	-	-
Wall insulation	111	38	34%
Windows	21	13	62%

A difference in differences approach yields an estimated average savings per site of 148 therms (Table 13), or 19% of total pre-treatment gas usage, compared to the average predicted savings of 314 therms per site, indicating a realization rate of 47%.

Table 12 2009 HPF difference in differences savings estimate

Cohort	N	Pre-period usage	Base load	Heating load	Therm savings	Savings net of comp	95% CI	Expected savings
2009 HPF participant	101	798	169	647	201	148	±31	314
2009 comparison group	7,834	797	168	633	53			

Given that HPF measure savings are calculated on a custom basis (modeling software estimates savings based on the changes in the home's characteristics before and after treatment) a realization rate can be estimated using a statistically adjusted engineering (SAE) modeling approach. Predicted savings per site are summed and the model is estimated with the change in consumption being a function of total predicted savings. A coefficient of '1' for the realization rate would indicate estimated savings were 100% of expected. Regression estimates across the models result in an average savings realization rate of 35%, or 111 therms per site. A measure level approach was also explored, but after removing extreme outliers (exceedingly large delta CFM and treated areas) the sample proved too small to deliver any meaningful estimates of savings at the measure level.

In addition, the entire comparison group was left in the model (without stratification as was used in Table 13) to illustrate the large 'non-programmatic' change in consumption occurring between 2008 and 2010. Comparison group changes in consumption in both the difference in differences and SAE model are relatively consistent, while the SAE model results in an unexplained change in the participant groups' consumption of nearly 30 therms (constant – comparison group coefficient). From the SAE model, these savings would appear to be changes in consumption over and above the treatments received from the HPF program, whilst the difference in differences estimator is likely attributing these savings to the program. Due to a lack of more data to explore this issue, our estimated realization rate range is 35%-47%

Table 13 2009 HPF realization rates

Variables	1 - OLS	2 -Robust	3 - DFBETA
HPF realization rate	0.350***	0.354***	0.352***
Comparison group	-57.64***	-57.27***	-63.93***
Constant	88.84***	81.95***	95.13***
Observations	27,853	27,853	27,846
R-squared	0.009	0.013	0.008
Predicted savings	314	314	314
Estimated realized savings	110	111	111

Gas baseload measure analysis
Several Energy Trust offerings provide energy savings measures aimed at reducing domestic hot water heating loads. Large volume offerings include directly installed low flow aerators and showerheads during the Home Energy Review (HER) audit program. For customers in rural areas where lead times for HERs can be longer, Energy Trust invited specific utility customer groups Energy Saver Kits, which consisted of measures that they could install themselves (a mixture of CFLs, showerheads and aerators, depending on their fuel mix). As of fall 2010, any customer served by a participating utility can request the kits.

The other major program offering in this category were tankless gas water heaters, with over 1,000 installations in 2009.. Tanked .62 energy factor water heaters were excluded from the analysis due to low volumes and small expected savings.

Home Energy Review direct installs

Given that these measure savings stem solely from baseload energy use, a difference in differences approach is used to estimate savings on those homes which received *only* HER direct installs. Table 15 below summarizes the average number of aerator and showerheads installs used in the sample compared to that of the program at large. Overall, the relative number of installs is comparable, and allows for generalizing to the program level.

Table 14 Home Energy Review 2009 summary

ISM type	2009 sample average installs (N=1,677)	2009 program average installs (N=4,024)
Showerheads	1.2	1.1
Aerators	2.1	2.1

The exceptionally large sample of homes receiving direct installs that reduce hot water usage via the HER allows for an analysis of savings despite the small predicted impact these ECMs have on total consumption (predicted savings averaged 5% of total gas usage). Net of changes in the comparison group usage, HER installed showerheads and aerators averaged modeled savings of 36 ±6 therms annually, compared to the predicted savings of 38 therms, suggesting that current engineering estimates are appropriate.

Table 15 HER savings net of comparison group

Measure grouping	Part N	Comp N	Part pre use	Comp pre use	Savings (therms)	±95%	Expected savings (therms)
Gas DHW HER savings	1,677	15,080	753	745	36	6	38

Energy Saver Kits
As with the HERs, ESKs were sent out to CNG customers in abundance during the 2009 program year, allowing for a robust sample from which to examine the effect on gas usage. The small N of the comparison group stems from the rather small number of CNG customers in the original comparison group draw. Despite predicted savings of 10 therms (~1.5% of total pre-

usage) the analysis points toward an average savings of 12 ±7 therms. In addition, the 2008-2009 HES process evaluation found install rates, via surveys of 2008 participants, which would result in savings in this range. As with the HER, the data seems to indicate good agreement between expected and estimated savings.

Table 16 Energy Saver Kits

Measure grouping	Part N	Comp N*	Part pre use	Comp pre use	Savings (therms)	±95%	Expected savings (therms)
ESK	1,441	1,030	704	702	12	7	10

*Comparison group N falls sharply due to most ESKs being delivered to CNG customers. The sampling methodology used for the comparison group drew proportionate numbers based on overall gas accounts in the state, being primarily filled by NWN customers.

Tankless gas water heaters

Tankless gas water heaters were last evaluated by several contractors in 2009, who examined energy savings during the 2006-2007 program years. Savings from the studies averaged 65 therms, significantly less than the original engineering estimate of 102 therms.

Evidence of significant numbers of homes fuel switching was evident in the 2009 sample, as with the previous studies. Keeping in line with previous studies, a cut-off of 80 therms was used as the minimum threshold for estimated 'baseload' usage when examining savings for the tankless water heaters. This threshold was identified as a balance between causing attrition to the sample and a reasonable floor to indicate whether a home actually had gas water heating prior to the tankless water heater installation.

A difference in differences approach is used to examine both the total loads in the participant and comparison sites, as well as a baseload comparison. Estimated savings, presented below in Table 18, averaged 58-66 therms depending on the approach used. Both estimates are comparable to the previous studies which found annual therm savings in the 55-70 range. These new findings consistent with previous results provide more confidence that tankless water heater savings are unlikely to change, and that the measure is simply not cost effective. As with any new product, incremental costs were expected to fall in the years following the introduction of the offering, which has not occurred. Currently, the program is shifting resources to generate demand and effect stocking practices of .67 energy factor (EF) tanked gas water heaters (.62 EF products are currently incented).

Table 17 Tankless gas water heating savings

Measure grouping	Participant N	Comp N	Part pre use	Comparison pre use	Savings (therms)	±95%	Expected savings (therms)
Tankless baseload only	230	2,470	229	228	**66**	13	65
Tankless total load comparison	230	150	776	764	**58**	29	65

Key Findings and Recommendations

Home Energy Solutions findings:

- Estimated average savings per household is 73 therms, or 10% of total household gas usage.
- The first measureable savings for air sealing were found in the 2009 program data, averaging 19 therms per project.
- Enhanced QC and implementation procedures, as well as an overhaul to the incentive structure for duct and air sealing are likely responsible for the measureable savings stemming from these measures in 2009.
- Savings estimates per CFM of duct and air leakage were estimated and can be used to calculate savings per project going forward.
- Returning to the 2008 analysis, removing one high volume contractor (subsequently removed from the program in 2009 due to consistently high quality control failure rates) yields statistically significant savings (per delta CFM) in line with 2006-07 and 2009 findings. Air sealing savings for 2008 were not found to be significantly different from zero, regardless of contractor level effects.

Recommendations:

- For true-up purposes, 2008 duct sealing savings should be de-rated based on the proportion of projects completed by the contractor whose work was found to be ineffective, allowing for savings to be booked for the remainder of projects which have been shown to be effective and averaged 24 therms per project (Contractor 'Z' performed 56% of duct sealing projects in 2008 with no measureable savings, yielding a de-rating factor of 24/therms *0.56, or 13.5 therms per duct sealing project).
- Savings estimates for shell measures (e.g., ceiling/wall/floor insulation and windows), although slightly lower than previous years, are robust and appear consistent relative to the previous three years of impact evaluations.

Home Performance with Energy Star findings:

- Estimated savings for the Home Performance with Energy Star program averaged 148 therms per participating homes, equivalent to 19% of average pre-treatment usage.
- Predicted savings for the Home Performance with Energy Star averaged 315 therms per home resulting in a realization rate of 35%-47%, depending on modeling approach.
- **Recommendation:** Calibrating estimates of energy savings to actual household energy usage could dramatically increase the accuracy of predicted measure calculated via the Home Performance program's modeling software.
- **Recommendation:** Given the significantly lower savings estimates than modeled, Energy Trust needs to recalculate the Home Performance program's cost-effectiveness.

Baseload measure findings:

- Tankless gas water heater savings were estimated to range from 59-65 therms, in line with previous studies on the 2008 program. These savings numbers put the measure significantly below a societal cost/benefit ratio of 1. Original engineering estimates put savings at ~110 therms annually, based on assumed water heating loads substantially higher than those found in Energy Trust service territory.
- **Recommendation:** Given that annual therm savings would have to double for tankless gas water heaters to be cost effective, consider removing incentive for the measure.

- The data indicates that directly installed measures, such as low flow aerators and showerheads, via the Home Energy Review audit process appear to be consistent with expectations, yielding average water heater savings of 36 ±6 therms, compared to the predicted savings of 38.
- Energy Saver Kits, which consumers can request and contain a variety of aerators, showerheads and CFLs, depending on housing characteristics, also had estimated savings of 12 ±7 therms relative to an assumed savings of 10.
- **Recommendation:** HER and ESK gas savings estimates appear reasonable and consistent with billing analysis findings and should be maintained at their current level.

Appendix A: Model specifications

Normalized annual consumption (NAC) and measure level savings model specifications:

1. Pre/Post heating model: $NAC_i = \alpha_{i1} + \beta_1 HDD_i(\tau_h) + \varepsilon_i$
2. Measure level savings model: $DeltaNAC_i = \alpha_{i2} + \beta_m ECM_i + \varepsilon_i$
3. Difference in differences estimation:

   $DeltaNAC_p = (PreNAC_p - PostNAC_p) - (PreNAC_c - PostNAC_c)$

   With the estimated standard error calculated using:

   $SE(DeltaNAC) = (SE^2_{DeltaNAC,p} + SE^2_{DeltaNAC,c})^{1/2}$

Where:

α_{i1} = Estimated average daily use, the 'base load' in models (1) and (2)

α_{i2} = Savings not attributable to measures installed at participant sites in model (3)

NAC_i = Normalized annual consumption for site i

$DeltaNAC_p$ = Participant savings net of comparison group's change in consumption

PreNAC/PostNAC = Pre/post normalized annual consumption (calculated for both participants and comparison group)

$HDD_i(\tau_h)$ = Model predicted heating slope at reference temperature τ_h

ECM_{mi} = Vector of ECMs installed at site i

ε_i = Unexplained error term

Multiple variable model descriptions

Ordinary least squares (OLS) estimate – Estimates coefficients by minimizing the sum of squared errors. This approach is susceptible to outliers.

Robust regression – model down-weights cases with large residuals to reduce the influence of outliers on estimated savings coefficients.[2]

DFBETA – Cases exerting a large influence on individual coefficients are screened out of the analysis.[3]

[2] Down-weighting occurs when a case's absolute residual value exceeds a distance from the median absolute deviation from the median residual described by the literature. Extremely large outliers are given weights of 0.

[3] DFBETA values over $2/\sqrt{n}$ are considered by the literature to be an acceptable tolerance for deeming an observation as 'influential' (Belsley, Kuh and Welsch 1980).