Energy Trust Multi-Family Program Savings Methodology

For

Energy Trust of Oregon

By

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Executive Summary

Energy Trust of Oregon (ETO) earlier requested a review of the methodology used to estimate programs savings for multi-family projects. The review used billing data for a sample of recent projects to analyze actual consumption and savings. In addition, the review examined how savings estimates were developed and improvements recommended. This earlier review demonstrated that only about 20% of expected savings were achieved for the sample. The recommendation was to review a larger sample of projects and develop a simplified savings methodology that would be easy for staff to implement, as well as more accurate.

This report then completes that recommendation with the following conclusions:

- Key findings
    - Actual savings are highly variable and difficult to predict.
    - Results were too variable to allow conclusions about baseload measures such as CFL lights, showerheads and water heaters. The program should maintain current savings estimates of these measures.
        - There is reason to expect that, when large expected baseload savings are the result of major remodels, such a remodel may affect the underlying demographics of the tenants.
        - Predicted baseload savings look to be substantially higher than actual yields. Thus, the program should not seek to shift large amounts of resources to lighting/water heating savings as a means to maintain program cost effectiveness.
    - Realization rates for space heating related projects were 22% for electric and 48% for gas.
    - The proposed methodology for space heating measures provides savings that are consistent with the results of billing analysis. We have developed a spreadsheet tool to implement the method using standard assumptions for heat loss coefficients.
- Recommendations
    - Program should implement new savings methodology for space heating related measures based on the billing analysis findings for savings based on the change in UA[1]. Apply the Uo, (coefficient of thermal transfer) based on regional technical forum findings by specific component. The estimated value of energy savings per delta UA from this study were:
        - 5.85 kWh per delta UA/unit
        - 0.386 therm per delta UA/unit

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[1] Delta UA refers to the change in Uo value multiplied by component area

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MEMO

Date: February 4, 2010
To: Board of Directors
From: Jessica Rose, Business Sector Project Manager
Brien Sipe, Evaluation Project Manager
Subject: Staff response to Multi-family engineering review and impact evaluation

Several studies conducted on the Multi-family program during 2008 consistently found low overall realization rates for the multi-family program when examining program years 2003 through early 2007. These findings spurred additional research activities on the multi-family sector, including this study.

Results from this study indicate an average realization rate of electric weatherization savings of 22%, and 48% for gas measures. While no recommendations have been made for changes to estimated savings for ‘base load’ measures (e.g., lighting, showerheads/aerators, water heaters) there is considerable uncertainty about the current predicted savings for these measures.

Despite these low realization rates, actual space heating savings relative to total usage at these project sites were substantial (many project saved residents ~50% of total space heating loads). Overly optimistic predicted savings based on a small number of building simulations run at the inception of the program may have led to these high predicted savings. It should be noted that until 2008, Energy Trust did not have access to the unit level utility data needed to conduct an impact analysis.

The program is taking steps to utilize the new savings methodology developed by Stellar Processes to simplify the process of estimating savings. Currently, the program collects all the necessary data to utilize this new approach. The program is also reviewing the measures and services that it is offering to multifamily buildings.

Planning will begin to examine the impact of these savings estimates on cost effectiveness and work with the program to develop strategies to maintain program viability from a cost perspective. One avenue of potential research is to explore non-energy benefits of retrofits, specifically windows, to broaden the underlying economic basis for energy efficient investments.

Introduction

In order to obtain more reliable information about the multi-family program, Energy Trust of Oregon (ETO) previously asked Stellar Processes to review the process and methodology of estimating programmatic savings and data collection. The goal was to understand:

- The accuracy of predicted savings compared with actual savings from billing analysis.
- The method by which the initial estimates were prepared
- How can the accuracy of the predictions be improved?

Staff selected an initial study group of 25 multi-family projects for review. The sample was recent projects that represented large savings estimates and was not intended to be a random sample. Billing data were collected through about April, 2009. This meant that post-retrofit observations were few and the billing analysis generally constrained the post baseload to match the pre, unless there were sufficient actual data. Furthermore, there were few gas-heated projects in the study group.

For those reasons, we repeated the study with an expanded study group and a longer period of billing data.

Aggregation of tenant bills for an apartment complex is often difficult. First, there is the problem of locating all the bills for a premise given that data inputs may have differences in how street addresses were entered. Then, there is the issue of tenant turnover – often a unit is vacant for a short interval between tenants. We collected the bills for units with a utility account and applied that average to any vacant or missing units. For example, if there are seven housing units but one month has only six billing records, we assume average consumption for the seventh unit and calculate an adjusted total for the facility. Thus, the analysis effectively assumes full occupancy. A small adjustment for partial occupancy should be applied to any programmatic estimate.

In part due to the difficulties of locating suitable multi-family projects, a control or reference group was not examined.

Billing analysis was successful for 38 electric cases and 13 gas cases. Of those cases, 6 of the electric and one of the case gases received only baseload measures that would not save space heating. Those cases were not used in subsequent space heat analysis. Billing analysis was not successful for another 15 cases due to occupancy changes or other interfering factors. For 5 cases, there was insufficient data for analysis. Sample attrition is shown in Table 1.

Table 1. Sample Attrition Table

	Electric Cases	Gas Cases	All Cases
Initial Sample	51	19	70
Insufficient Data	5		5
Interfering Factors	8	6	14
Successful Analysis	38	13	51
No Space Heat	6	1	7
Final Sample	32	12	44

Billing Analysis

Billing analysis used a temperature regression model similar to the PRInceton Scorekeeping Method (PRISM) to weather normalize the consumption data and to remove 'noise'. Estimates are reported as the Normalized Annual Consumption (NAC) after adjustment. The difference between NAC consumption before and after treatment represents the energy savings due to the program. PRISM-like models apply regression to separate the consumption into a baseload and seasonal, weather-dependent component. The baseload represents appliances while the weather dependent component is assumed to represent primarily space heating. Space heating occurs only below a balance temperature, which is unique to each home. The balance temperature depends on the thermal integrity of the house, the preferred thermostat setting of the customer and other behavioral factors.

Space Heat Savings

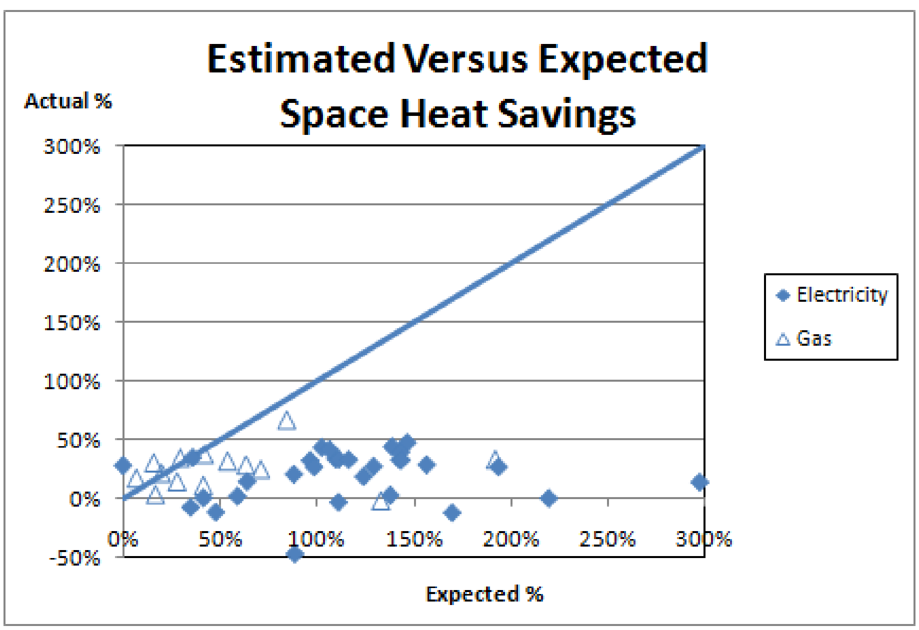

Figure 1. Expected versus Actual Space Heat Savings

Results from the expanded study are shown in Figure 1. This plot shows a comparison of the expected to actual total savings. Since the amount of savings varies widely due to project size, these results are presented as a percent savings. The y-axis shows the savings estimate derived from billing analysis while the x-axis shows the predicted savings. The sloping line is a reference, not a fit to the data. If there were perfect agreement between actual and predicted, the data points would align along the 45-degree reference line. Since space heating savings are the primary concern, it is instructive to look at just that end use. The predicted savings range beyond 300% of actual space heating – showing that the program estimates can be inconsistent with actual consumption. However, actual savings range up to 50% -- which is still a respectable amount of savings.

The results of the billing analysis are summarized in Table 2 and Table 3 Generally, one looks at the Normalized Annual Consumption (NAC) savings as the best estimate. For this study, we compared expected to actual savings for just the space-heating measures alone. For that purpose, the Space Heating (SH) savings are a better estimate since those expected savings are also based on the impact for space heating only. The R2 is an indicator on goodness-of-fit or the overall accuracy of the regression model. Most of the cases had a reasonably strong R2. As mentioned, the regression analysis assumes full occupancy so results should be adjusted by the occupancy rate factor. This is the average ratio used to increase monthly bills to a consistent total. Generally, the occupancy adjustment is not significant. The occupancy correction is applied to give the adjusted NAC and SH savings. Finally, the adjusted SH savings can be compared to the expected savings. The Realization Rate is the ratio of the final Adjusted Space Heat (SH) savings to the Expected savings.

Overall, only 22% of the expected savings were achieved for electric cases and 48% for gas.

Table 2. Billing Analysis Results – Electric Cases (n = 32)

Case Number	NAC Savings	SH Savings	R2	Average Occupancy	Adjusted NAC	Adjusted SH	Expected SH	Realization Rate
Case 1	10,634	-4,025	0.71	94%	9,978	-3,777	7,628	-53%
Case 2	52,725	563	0.93	99%	52,326	558	35,931	2%
Case 3	18,705	13,424	0.96	95%	17,725	12,721	58,368	23%
Case 4	38,492	-2,778	0.90	99%	37,923	-2,737	13,266	-21%
Case 5	23,615	19,878	0.99	98%	23,189	19,519	59,483	33%
Case 6	3,125	-2,301	0.80	97%	3,035	-2,235	9,637	-23%
Case 7	3,029	1,222	0.97	96%	2,917	1,177	62,732	2%
Case 8	45,519	34,703	0.98	99%	45,147	34,419	107,697	32%
Case 9	44,809	36,140	0.98	98%	43,875	35,387	133,005	27%
Case 10	12,827	-2,446	0.67	82%	10,571	-2,016	34,793	-6%
Case 11	5,924	4,896	0.87	98%	5,777	4,774	16,015	30%
Case 12	118,852	124,339	0.98	96%	113,741	118,993	294,391	40%
Case 13	8,143	2,129	0.92	97%	7,924	2,072	9,358	22%
Case 14	103,011	100,253	0.98	98%	100,636	97,942	334,947	29%
Case 15	54,420	21,943	0.96	99%	53,628	21,624	104,003	21%
Case 16	31,600	20,930	0.96	94%	29,773	19,720	138,488	14%
Case 17	27,616	11,772	0.43	96%	26,469	11,283	84,919	13%
Case 18	83,162	55,827	0.92	94%	78,322	52,578	176,590	30%
Case 19	11,700	-1,692	0.95	97%	11,301	-1,634	62,071	-3%
Case 20	157,412	34,939	0.98	96%	150,678	33,444	123,276	27%
Case 21	-3,521	606	0.93	95%	-3,348	577	17,055	3%
Case 22	12,527	9,758	0.87	82%	10,269	7,999	10,110	79%
Case 23	7,730	876	0.83	94%	7,303	827	41,050	2%
Case 24	41,459	52,536	0.92	98%	40,650	51,511	287,149	18%
Case 25	22,033	6,598	0.97	98%	21,657	6,485	141,325	5%
Case 26	11,791	9,159	0.94	94%	11,101	8,623	335,083	3%
Case 27	65,075	792	0.97	94%	60,912	741	570,162	0%
Case 28	86,163	35,019	0.96	93%	80,206	32,597	149,280	22%
Case 29	111,355	67,536	0.91	98%	108,740	65,950	245,394	27%
Case 30	40,130	53,997	0.94	92%	36,820	49,543	238,128	21%
Case 31	57,883	37,108	0.94	98%	56,853	36,448	95,452	38%
Case 32	3,285	-232	0.78	98%	3,226	-227	95,452	0%
Overall Electric Cases (n = 32)	**1,311,230**	**743,466**		**96%**	**1,259,323**	**714,884**	**4,092,238**	**17%**

Table 3. Billing Analysis Results – Gas Cases (n = 12).

Case Number	NAC Savings	SH Savings	R2	Average Occupancy	Adjusted NAC	Adjusted SH	Expected SH	Realization Rate
Case 1	2,859	2,280	0.96	91%	2,591	2,066	6,652	31%
Case 2	2,243	1,858	0.96	97%	2,182	1,807	1,734	104%
Case 3	433	276	0.97	98%	426	271	550	49%
Case 4	619	771	0.98	71%	441	550	670	82%
Case 5	665	1,019	0.93	80%	532	816	1,152	71%
Case 6	190	-15	0.71	95%	180	-14	886	-2%
Case 7	595	234	0.98	91%	544	214	93	230%
Case 8	8,598	6,575	0.95	100%	8,576	6,558	14,870	44%
Case 9	1,091	1,490	0.96	57%	625	854	780	109%
Case 10	1,456	1,216	0.94	100%	1,456	1,216	1,552	78%
Case 11	671	536	0.95	71%	476	380	2,042	19%
Case 12	183	366	0.99	93%	171	341	626	54%
Overall Gas Cases (n =12)	**19,604**	**16,605**		**93%**	**18,200**	**15,058**	**31,607**	**48%**

Baseload Savings

The primary focus of this review was not baseload measures. However, the billing analysis does provide observations on such measures. The baseload measures are CFL lights, showerheads, water heater upgrades and similar measures that are generally too small to measure through billing analysis. Savings for these measures have been "deemed" based on direct measurements and other previous studies. The results from billing analysis do not show correlation with the expected baseload savings. Figure 2 and Figure 3 show expected versus actual baseload savings for electricity and gas respectively. These plots are normalized to savings per housing unit. One should be aware that, since space heat tends to dominate consumption, the baseload estimates derived from billing analysis include more relative uncertainty.

One might expect that, if there is an underlying trend towards increased consumption, the plots would be consistently biased downward (negative actual savings). While this occurs in some cases, it is not consistent. This suggests that the renovations may sometimes result in demographic changes. For example, low-income rental units may sometimes -- but not always -- be renovated to upper-income condos. Such demographic changes could interfere with billing analysis that assumes comparable pre- and post-retrofit conditions. Another general observation is that, while there may be small baseload savings, the very large expected savings do not appear to materialize. This could be a similar demographic change since the large expected savings would occur with a major remodel.

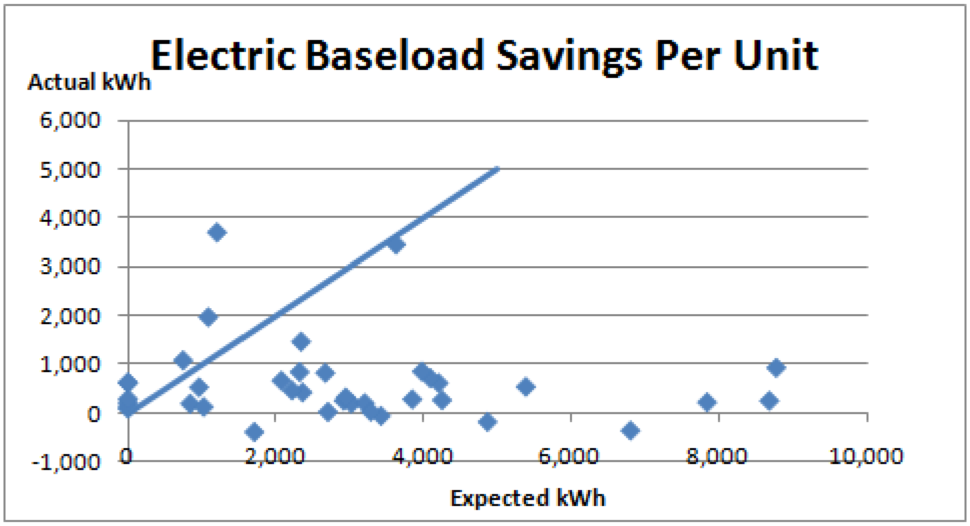

Figure 2. Per Unit Baseload Savings -- Electric

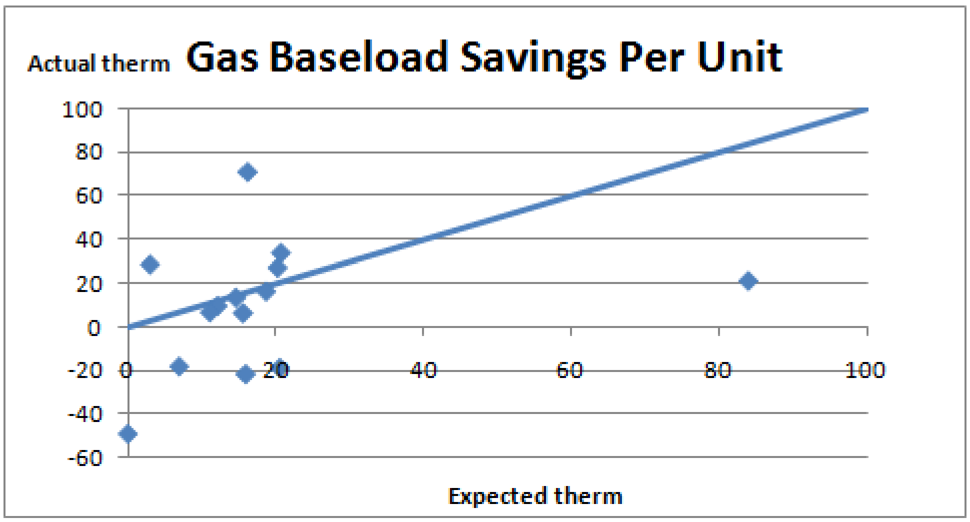

Figure 3. Per Unit Baseload Savings – Gas

We attempted to compare the actual to expected baseload savings using a single-variable Conditional Demand Model (CDM). However, the model was not statistically significant for either the electric or gas cases. Table 4 shows regression results. The overall models show poor significance based on R2 or F values. The intercept represents a trend variable that reflects underlying consumption change. While the trend is significant for electric cases, the overall poor fit of the model mitigates against any conclusions. The Coefficient represents the Realization Rate for expected savings. It is not significant for either fuel. Thus, we have no recommendations for baseload measures from this study. Given the variability of results, there is no reason to revise "deemed" savings estimates that were based on more careful experimental design.

Table 4. Baseload CDM Model Results

	Adjusted R2	F	Significance F	Intercept (trend)	Intercept t-Stat	Coefficient	Coefficient t-Stat

Electric	-0.016	0.418	0.522	699.0	3.15	-0.039	-0.646
Gas	-0.008	0.889	0.363	2.40	0.243	0.362	0.943

Revised Savings Methodology

The earlier study reviewed the techniques used for estimating savings during program implementation. We suggested a relatively simple approach that would be based on the actual savings derived from billing analysis. Space heating consumption appears to be linear with respect to the building's heat loss coefficient or UA. The change in consumption (savings) should then be linear with regard to the change in UA (Delta UA). Figure 4 and Figure 5 show that this is roughly correct. In these figures, the sloping line is not a reference line but represents a fit to the data forced through the zero point. In both plots, the data observations are averaged to savings per dwelling unit to avoid bias by large projects. The observations lead to a simple estimation approach – just multiply the change in UA by the slope coefficient as shown in the figures.

The appropriate regression slopes are:

5.85 kWh per UA unit (R2 = .53)

0.386 therm per UA unit (R2 = .39)

To assure consistency, we developed a simplified worksheet to compute UAs using standard estimates of the heat loss values (source: Tom Eckman for RTF, reswxmf.xls, 1/25/02.)

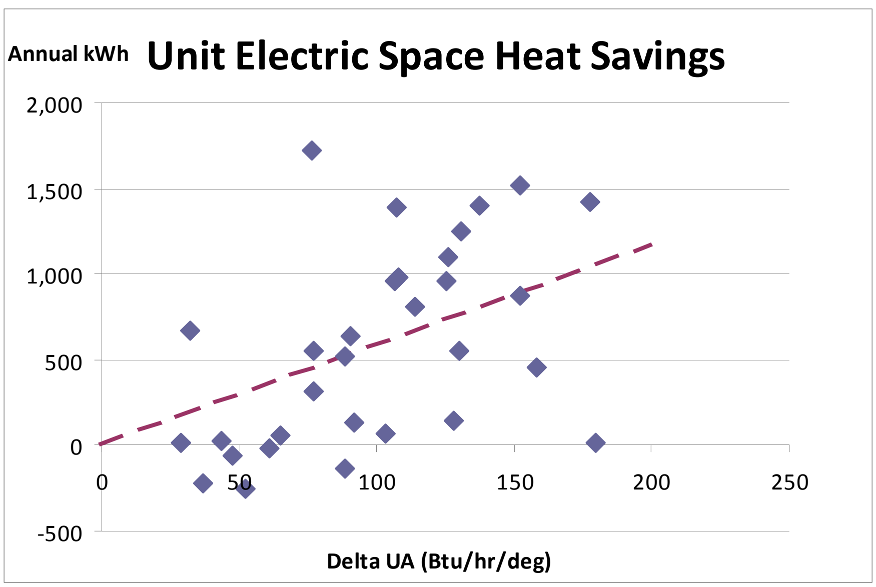

Figure 4. Per Unit Space Heat Savings Versus Change in UA -- Electric

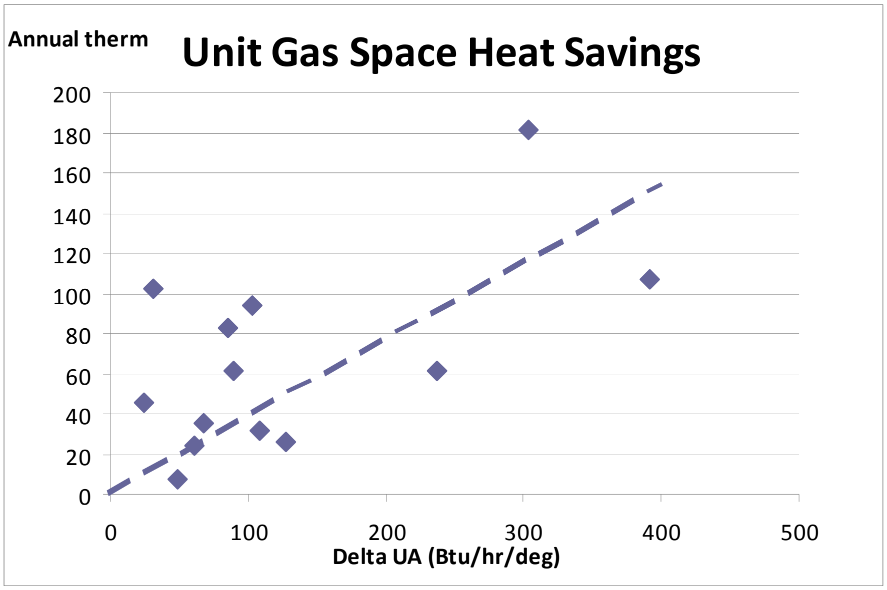

Figure 5. Per Unit Space Heat Savings Versus Change in UA – Gas

As a verification check one might ask to what extent would program savings estimates have been improved using this method? Table 5 and Table 6 show the estimated savings that would be predicted using the new method. Overall, total electric space heat savings are 95% of predicted and total gas savings are 104% of predicted. The fact that the realization rates are not exactly 100% is due to the variability introduced into the average by a few large projects.

Table 5. Predicted versus Actual Savings – Electric Cases

Case Number	Predicted SH Savings	Actual SH Savings	Realization Rate
Case 1	1,704	-3,777	-222%
Case 2	8,029	558	7%
Case 3	10,554	12,721	121%
Case 4	3,369	-2,737	-81%
Case 5	11,246	19,519	174%
Case 6	2,153	-2,235	-104%
Case 7	5,997	1,177	20%
Case 8	8,917	34,419	386%
Case 9	29,295	35,387	121%
Case 10	7,774	-2,016	-26%
Case 11	3,116	4,774	153%
Case 12	53,934	118,993	221%
Case 13	2,067	2,072	100%
Case 14	74,844	97,942	131%
Case 15	17,531	21,624	123%
Case 16	27,305	19,720	72%
Case 17	16,244	11,283	69%
Case 18	32,042	52,578	164%
Case 19	7,793	-1,634	-21%
Case 20	21,507	33,444	156%
Case 21	3,811	577	15%
Case 22	2,259	7,999	354%
Case 23	10,244	827	8%
Case 24	52,556	51,511	98%
Case 25	25,862	6,485	25%
Case 26	74,875	8,623	12%
Case 27	68,292	741	1%
Case 28	66,608	32,597	49%
Case 29	44,184	65,950	149%
Case 30	36,363	49,543	136%
Case 31	21,329	36,448	171%
Case 32	3,941	-227	-6%
Overall Electric Cases (n = 32)	**755,746**	**714,884**	**95%**

Table 6. Predicted versus Actual Savings – Gas Cases

Case Number	Predicted SH Savings	Actual SH Savings	Realization Rate
Case 1	3,025	2,066	68%
Case 2	212	1,807	852%
Case 3	260	271	104%
Case 4	317	550	173%
Case 5	551	816	148%
Case 6	306	-14	-5%
Case 7	46	214	467%
Case 8	7,112	6,558	92%
Case 9	936	854	91%
Case 10	461	1,216	263%
Case 11	979	380	39%
Case 12	263	341	129%
Overall Gas Cases (n =12)	**14,468**	**15,058**	**104%**

Conclusions

- Actual savings are highly variable and difficult to predict.
- The proposed methodology provides savings that are consistent with the results of billing analysis. We have developed a spreadsheet tool to implement the method using standard assumptions for heat loss coefficients.
- Results were too variable to allow conclusions about baseload measures.
    - There is reason to expect that, when large expected baseload savings are the result of major remodels, that remodel may affect the underlying demographics of the tenants.
    - Predicted baseload savings look to be substantially higher than actual yields. Thus, the program should not seek to shift large amounts of resources to lighting/water heating savings as a means to maintain program cost effectiveness.