Comparing Impact Assessments: Billing Analysis versus Self-Reporting and Engineering Algorithms

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ABSTRACT

This paper makes a direct comparison of two common methods of determining the energy impacts of an energy efficiency information program (Residential Personalized Energy Report Program) linked with a low-cost measure (Energy Efficiency Starter Kit) giveaway program. The program delivers seven popular energy efficiency measures (CFLs, weatherstripping, outlet gaskets, window shrink kit, low-flow showerheads, and aerators) and eighteen recommendations detailed in the Personalized Energy Report.

The Energy Efficiency Starter Kit and Personalized Energy Report were sent to thousands of Duke Energy customers. Six months later, mail surveys were sent to the participants. The results of the returned surveys were used in determining the energy impacts using engineering algorithms linked to the survey results and installation assumptions. In addition, a detailed billing analysis was conducted on the same customers to see if the installations and actions taken resulted in bill reductions.

This paper compares the two approaches and the resulting energy impact estimations and discusses the difference in the results. The paper shows the variability in the energy impacts using the two methods, and discusses which is more reliable for each of the measures and recommendations. The paper also discusses self-selection bias and false report bias in self-reported survey results.

Introduction

This paper presents the evaluation report for Duke Energy's Personalized Energy Report Program as it was administered in Kentucky. An impact analysis was performed for each of the measures in the Personalized Energy Report Kit. The impacts are based on the responses to customer survey. Energy savings impact estimations per measure and per recommendation adopted by participants are presented. The impact tables reporting total savings are based on the number of respondents indicating that they have taken actions as a result of their participation in the program. The number of customers installing the different measures varies widely, and estimates of the average savings per customer for each measure and/or recommendation are also provided.

The evaluation was based on a survey conducted with customers who participated in the PER program and who have received the kits mailed by the program. The study did not use on-site verification efforts to confirm if the survey information provided by the customer is accurate or if the measures taken were correctly installed, or used in a way that provides the projected savings. Because of the greater uncertainty around the two key biases associated with the installation of program-recommended measures (self-selection bias and false response bias) we do not consider the savings estimates based solely on the participant's responses to be a reliable indicator of actions taken. As a result, the authors have adjusted the estimated savings resulting from the participant's responses regarding the recommendations that were reported as being taken by the participants.

The evaluation was conducted by TecMarket Works and Architectural Energy Corporation (AEC) with assistance from Integral Analytics. The survey instruments were developed by TecMarket Works and AEC. The survey was administered by Integral Analytics via an automated response reading system. The survey was designed to be easily completed by participants by shading a box that best represents their response to the questions. Integral Analytics finalized the survey and formatted the instrument for electronic reading of survey results. The questions were designed to support energy savings calculations for actions that were taken as a result of the program.

Methodology

Development of the Customer Surveys

TecMarket Works and Duke Energy developed a customer survey for delivery to the Personalized Energy Report (PER) Program participants after they have had time to implement the actions and recommendations included in the kit and PER that was distributed to participants. The survey asks participants about the changes that they have made to their home as a result of their receipt of the kit and the recommendations contained in the PER distributed by the Program. The survey asked the customer for information specific to each of the measures included in the Energy Efficiency Starter Kit and each of the recommendations in the PER. For each measure that was installed and for each recommendation taken, the participant completed a short battery of questions to determine the degree to which that measure was effectively placed and used.

The customer surveys were electronic-scoring surveys. During the survey development process it was necessary to restrict questions so that they would fit on a set of double page paper that could be electronically scanned on each side of the page. This approach helped reduce the evaluation cost, but also reduced the number of questions that could be asked in order to calculate energy savings. However, this procedure did not result in overly restrictive questions and were structured to collect the data necessary to calculate savings.

Obtained and Cleaned Customer Information

The survey was sent to 5,401 PER Program participants – 3,562 customers that did not receive the kit, and 1,839 customers that did receive the Energy Efficiency Starter Kit. The data collection efforts resulted in 1,879 responses from PER participants who only received the PER (response rate = 52.8%), and 741 responses (response rate = 40.3%) from Kentucky PER participants who received the Energy Efficiency Kit. Once the data was delivered, TecMarket Works reviewed the data for accuracy and completeness, and readied the data for analysis in SPSS .

Engineering Impact Estimation

Using the measure-specific data collected from the customer surveys, we were able to extrapolate energy savings to the PER Program as a whole, and for each of the kit's eight measures individually. The per unit energy savings for each of the measures was determined through a method in which TecMarket Works and AEC assigned the estimates of energy savings for each of the measures included in the PER Energy Efficiency Starter Kit and for each of the recommended measures. Energy impacts are expressed in terms of annual kWh per unit, summer coincident peak demand (kW) and annual therm savings (for measures with gas impacts).

Non-Weather Dependent Measures. Simple engineering algorithms were used to estimate the energy and peak demand savings from non-weather dependent measures, such as CFLs, low-flow showerheads, faucet aerators, refrigerator replacement, water heater insulation, and cold-water laundry. Interactive effects of the measures with HVAC systems, both positive and negative, were included in the estimates as appropriate. The details of the engineering calculations are beyond the scope this paper, but the calculations generally follow the methodology presented in Engineering Methods for Estimating the Impacts of DSM Programs (EPRI, 1993) and the Efficiency Vermont Technical Reference Manual (Efficiency Vermont, 2003).

Weather Dependent Measures. The impact analysis of the weather dependent measures was based on DOE-2.2 simulations of a set of prototypical residential buildings. The prototypical simulation models were derived from the residential building prototypes used in the California Database for Energy Efficiency Resources (DEER) study (Itron, 2005), with adjustments make for local building practices and climate. Model inputs were derived from the DEER study and standard engineering references such as the ASHRAE Handbook of Fundamentals (ASHRAE, 2001). Weather-sensitive measures included attic and wall insulation, new furnaces, central air conditioning and heat pumps, duct insulation and repair, infiltration reduction measures such as weatherstripping, electrical outlet gaskets, and closing off fireplaces, lowering room temperatures, closing off rooms, drapery management, and window film shrink kits. Energy and summer peak demand savings were simulated and unit saving estimates were developed for each measure. The unit savings estimates were applied to the survey responses to estimate customer savings. Long-term average weather data from the Typical Meteorological Year (TMY-2) weather files for Covington, KY were used as the predictive weather.

Energy Efficiency Starter Kits. The items distributed in the kit, the reported installation rate and the total estimated savings for each measure is shown in Table 1. The table shows the relative "popularity" of each of the items for the recipients of the kits and the total savings for each of the measures based on those customers that indicated they installed the measure and did so in a manner that resulted in energy savings.

Table 1. Energy Efficiency Starter Kit Reported Installations and Saving Estimates

Kits	Percent Installed	Total kW Savings	Total kWh Savings	Therm Savings
15-watt CFL	88.3%	4.1	55,269	-159
20-watt CFL	79.6%	3.9	49,421	
Weather stripping	35.0%	0.5	1,791	41
Outlet gaskets	49.4%	1.5	5,259	106
Window shrink kit	13.6%	2.3	3,957	445
Showerhead	39.3%	4.1	36,983	3,725
Bathroom aerator	53.6%	0.04	2,651	150
Kitchen aerator	49.4%	0.03	2,083	135
Total Savings		**16.5**	**157,414**	**4,443**

Efficiency Recommendations. The recommendations in the PER, the reported recommendation adoption rate and the total estimated savings for each recommendation is shown in Table 2. The table shows the relative "popularity" of each of the recommendations and the total savings for each of the recommendations based on those customers that indicated they followed the recommendation and did so in a manner that resulted in energy savings.

Table 2. Efficiency Recommendations Reported Adoptions and Saving Estimates

Recommendation	Adoption Rate	Total kW Savings	Total kWh Savings	Therm Savings
CFLs	53.0%	31	197,260	-203
Clean baseboards	0.7%	0	91	0
Close off fireplace	25.8%	1	2,304	44
Install a new heat pump	2.2%	16	35,577	0
Install attic insulation	33.3%	57	72,482	1,125
Install new central air unit	7.8%	40	51,934	0
Install new furnace	17.7%	0	0	1,223
Install sidewall insulation	2.7%	13	16,370	338
Install window shrink kits	9.2%	4	4,534	68
Insulate ducts	5.5%	11	20,544	298
Insulate water heater	13.8%	2	14,560	1,255
Lower temp in winter - day	82.1%	0	586,087	9,982
Lower temp in winter - night	82.1%	0	153,106	3,858
Manage draperies	79.5%	0	132,744	6,013
Repair ducts	5.0%	15	20,663	152
Replace furnace filter	19.3%	-3	-8,551	20
Stop heating unused rooms	54.7%	168	158,596	1,707
Switch to cold water for laundry	52.1%	13	90,106	14,087
Total		**367**	**1,548,407**	**39,967**

Savings Distributions

There are substantial risks associated with relying on self-reported behavioral changes, because the foundation of the savings estimates are based solely on the participant's responses, with no means to verify that the respondent has installed the kit's measures or has actually taken the recommendation provided in the Personalized Energy Report. There are two main sources of bias with these types of surveys that directly impact the conclusions drawn from the responses. These sources of bias are Self-Selection Bias and False Response Bias. There is also an issue regarding the accuracy of the baseline energy use conditions used by AEC to develop the engineering estimates of savings in that many of these conditions need to be based on assumptions rather than specific data from surveys or on site observations. These three conditions significantly impact the evaluation contractor's ability to provide accurate estimates of energy impact. These issues are discussed in more detail in the following paragraphs.

Self-Selection Bias. The people that filled out and returned the survey are the participants that are more likely to install measures from the Energy Efficiency Kit and consider taking actions based on the recommendations from the Personalized Energy Report. That is, they self-selected themselves to return the survey because they have a higher interest in the subject matter than the people who did not. These individuals also will often respond to a survey in order to let it be known that they did the right thing, and that they are taking steps to be more energy efficient. The customers that did not return the survey are more likely to have a lower interest in the subject matter, and are less likely to take actions. Thus, the people who returned the survey are not the typical participant, but rather are the participant that is more likely to take actions. With 47.2% of the PER group and 59.7% of the Kit group not responding, we are setting the self-selection bias used to estimate the potential range of impacts at half of the non-response rate. As a result, all estimated energy impact estimates will be discounted 29.9% for customers that received the Energy Efficiency Kit and the Personalized Energy Report, and 23.6% for those that only received the Personalized Energy Report.

False Response Bias. False Response Bias is a problem with many self-reporting surveys. The participants respond not with the truth, but with the socially acceptable response. In short, they give the answer that they think is the right answer about what measures they installed or what actions they have taken as a result of the Personalized Energy Report. False response bias is typically not a large adjustment, depending on the controversy around the subject being discussed. False response bias adjustments typically range from a low of two or three percent to a high of 15 percent depending on the topic and the population being tested. The False Response Bias for this assessment was set at from a low of 10% to a high of 50% because of a specific rational relating to the conditions that act to increase or decrease this estimated average rate. A 10 % to 50% discount was applied to each kit and PER recommended measure impact estimate to calculate the low-end of the range of savings estimates for each measure and recommendation.

Baseline Energy Use Assumptions. When a mail survey is used to conduct an evaluation, the evaluation contractors are unsure of the actual conditions in the home that have experienced a change. For example, while a new showerhead may have been installed, it is impossible to estimate precise savings unless the flow rates and use conditions associated with the previous showerhead are well understood. For this study we established our baseline assumptions based on the survey results and our past research and experience with programs and program evaluations that have taken measurement of baseline conditions. We have also used computer models of prototypical residential buildings to estimate baseline conditions and behaviors. Due to the potential uncertainties associated with the baseline conditions and lack of resolution in the survey responses, a range of engineering estimates was developed. The false response bias, principle engineering assumptions and variations used to estimate a range of savings are shown in Tables 3 and 4.

Table 3. Kit Measures False Response Bias and Engineering Assumptions

Measure	False Response Bias	Principle Engineering Assumptions	Savings Range Assumptions
CFLs	10%	Common lamp sizes and mean operating hours for each survey response category used. Summer peak coincidence factor estimated at 0.1	Used ranges for wattage of bulb removed (as opposed to most common wattage in range) and hours of use for the lamp (as opposed to the mean of the range).
Weatherstripping	10%	Leakage area reductions based on ASHRAE Handbook of Fundamentals. Single story building with moderate wind shielding	Range of leakage area assumptions
Outlet gaskets	10%	Leakage area reductions based on ASHRAE Handbook of Fundamentals. Single story building with moderate wind shielding	Range of leakage area assumptions
Window shrink kit	10%	Window sizes estimated from qualitative “small, medium and large” responses from survey. Reductions in window conductance and solar heat gains simulated	Used a range of window sizes corresponding to small, medium and large windows
Showerhead	20%	3.1 gpm baseline showerhead, 5 minutes per shower	Adjusted baseline shower flow rates.

Measure	False Response Bias	Principle Engineering Assumptions	Savings Range Assumptions
Aerators	20%	Cold water temperature adjustments to Efficiency Vermont deemed values	Removed the savings from cases in which there was already an aerator installed for the low estimates.

Table 4. Efficiency Recommendation False Response Bias and Engineering Assumptions

Recommendation	False Response Bias	Principal Engineering Assumptions	Savings Range Assumptions
CFLs	50%	Common lamp sizes and mean operating hours for each survey response category used. Summer peak coincidence factor estimated at 0.1	Used ranges for wattage of bulb removed (as opposed to most common wattage in range) and hours of use for the lamp (as opposed to the mean of the range). Used ranges for wattage of CFL installed.
Clean electric baseboards	50%	Reduction in losses though R-11 exterior wall due to lower average temperature within baseboard unit. 8 ft unit assumed.	Range of baseboard unit size assumptions
Close off fireplace	50%	Leakage area reduction based on ASHRAE Handbook of Fundamentals estimate for closed damper leakage. Single story building with moderate wind shielding.	Range of leakage area assumptions
Install new central air unit	50%	Existing AC unit SEER = 8.5. Mean SEER from survey responses used	Low end of savings obtained by assuming half of new installations were normal replacement instead of early replacement.
Install new furnace	50%	Base furnace AFUE = 0.78; non-condensing furnace AFUE = 0.80; condensing furnace AFUE = 0.90	Low end of savings obtained by assuming half of new installations were normal replacement instead of early replacement.
Install a new refrigerator	50%	Existing refrigerator consumption = 2100 kWh/year, new standard efficiency unit = 590 kWh/year, Energy Star unit 500 kWh/year	Low end of savings based on existing refrigerator consumption of 1700 kWh/year
Install a new heat pump	50%	Existing heat pump SEER = 8.5 assumed for early replacement; SEER 13 assumed for normal replacement. Mean SEER from survey responses used.	Low end of savings obtained by assuming half of new installations were normal replacement instead of early replacement.
Install attic insulation	50%	Ceiling area estimated from number of rooms assuming 330 SF/room. Existing insulation R-value 3.5 per inch. Added insulation R value 3.5 per inch for fiberglass and cellulose, 5.6 per inch for foam	For survey responses indicating partial installation, used a range of 25% coverage to 50% coverage.

Recommendation	False Response Bias	Principal Engineering Assumptions	Savings Range Assumptions
Install sidewall insulation	50%	Floor area estimated from number of rooms assuming 330 SF/room. Wall area estimated from floor area and number of walls insulated. Assumes uninsulated wall in base case. Added insulation R value 3.5 per inch for fiberglass and cellulose, 5.6 per inch for foam	Varied assumptions on wall area to floor area ratios and square feet per room
Install window shrink kits	50%	Window sizes estimated from qualitative "small, medium and large" responses from survey. Reductions in window conductance and solar heat gains simulated	Used a range of window sizes corresponding to small, medium and large windows
Insulate or repair ducts	50%	Uninsulated ducts with 26% total leakage assumed in base case. Ducts insulated to R-19 and sealed to 8% total leakage.	Varied baseline insulation level and leakage rate assumptions
Insulate water heater	50%	Standby losses only. Tank loss assumptions by fuel and tank size per DOE appliance standards. 1 inch tank wrap, 140°F water heater setpoint temp, 75°F room temp	Varied insulation thickness and water heater setpoint assumptions
Lower temperature in winter	50%	Base case 70 heating setpoint with no setback, mean values of setback from survey responses. Night setback simulated from 10 pm to 5 am 7 days/week	Range of temperature setback instead of mean
Manage draperies	50%	Open drapes during winter daylight hours on south facing windows only	Reduced the savings to account for other window directions
Replace furnace filter	50%	5% maximum energy savings assumed, scaled based on mean number of filter changes reported. Most participants reported changing filter *less* frequently.	Range of reported filter changes
Stop heating unused rooms	50%	Average room size of 220 square feet	Reduced simulated savings to account for inability to completely shut off a room, and the conductive losses through the uninsulated walls.
Switch to cold water for laundry	50%	Mean savings per load taken from Efficiency Vermont deemed savings, mean number of loads from survey responses	Range of loads per week from survey

Engineering Analysis Results

Each of the Kit measures and PER recommendations was calculated to provide reasonable ranges of energy savings associated with each item. The tables below provide the mean, low and high estimates for each of the measures and recommendations provided to the Kentucky participants. Savings estimates are provided for only those participants who indicated that they installed the measure. For recommendations, savings are provided for only those who indicated that they took the action, and provided full details on follow-up questions on the survey.

Table 6. Engineering Analysis Results for Kit Measures

Measure	Watt Savings (per install)			kWh Savings (per install)			Therm Savings (per install)		
	Mean	Low	High	Mean	Low	High	Mean	Low	High
15-watt CFL	6	3	8	85	31	136	-0.1	-0.2	-0.0
20-watt CFL	7	3	9	84	32	141	0.0	-0.1	-0.0
Weatherstripping	2	1	3	7	3	9	0.2	0.1	0.2
Outlet gaskets	4.2	2	5	14	7	17	0.3	0.3	1.5
Window shrink kit	23	7	23	39	13	39	4.4	0.1	4.4
Showerhead	14	4	14	127	34	127	12.8	3.5	12.8
Bathroom aerator	0.1	0.1	0.1	7	4	7	0.4	0.2	0.4
Kitchen aerator	0.1	0.0	0.1	6	3	6	0.4	0.2	0.4
Total (adjusted for installation rate)	**22**	**9**	**27**	**213**	**76**	**306**	**6**	**2**	**7**

Table 7. Engineering Analysis Results for PER Recommendations

Recommendation	Watt Savings (per install)			kWh Savings (per install)			Therm Savings (per install)		
	Mean	Low	High	Mean	Low	High	Mean	Low	High
CFLs (all sizes)	6	6	12	385	385	1,629	-0.2	-0.2	-2.5
Clean baseboards				8	8	23	-	-	-
Close off fireplace	3	3	5	6	6	17	0.1	0.1	0.4
Install a new heat pump	320	320	1828	706	706	4,025	-	-	-
Install attic insulation	102	102	163	64	64	273	1.1	1.1	4.7
Install new central air unit	791	791	1266	300	300	1,713	-	-	-
Install new furnace				-	-	-	2.9	2.9	16.6
Install sidewall insulation	347	347	556	133	133	1,140	3.1	3.1	27.7
Install window shrink kits	31	31	56	15	15	85	0.3	0.3	1.6
Insulate ducts	99	99	159	95	95	542	2.1	2.1	12.3
Insulate water heater	11	11	20	32	32	176	3.5	3.5	18.3
Lower temp in winter - day				200	200	571	4.5	4.5	12.8
Lower temp in winter - night				93	93	266	1.8	1.8	5.1
Manage draperies				62	62	75	2.8	2.8	3.6
Repair ducts	203	203	324	119	119	680	1.6	1.6	9
Replace furnace filter	-18	-18	-18	-36	-36	-36	-0.12	-0.1	-0.1
Stop heating unused rooms	213	213	213	87	87	309	1.1	1.1	3.9
Switch to cold water for laundry	14	14	23	71	71	203	10	10	28.6
Total (adjusted for adoption rate)	**247**	**247**	**352**	**628**	**628**	**2,214**	**15**	**15**	**43**

Billing Data Analysis

This section of the paper presents the billing data analysis of the PER program which is contrasted with the engineering analysis conducted by TecMarket Works and AEC which relied upon customer self-reports and engineering analysis to estimate program impacts.

Methodology.

For this analysis, data are available both across households (i.e., cross-sectional) and over time (i.e., time-series). With this type of data, known as "panel" data, it becomes possible to control, simultaneously, for differences across households as well as differences across periods in time through the use of a "fixed-effects" panel model specification. The fixed-effect refers to the model specification aspect that differences across homes that do not vary over the estimation period (such as square footage, heating system, etc.) can be explained, in large part, by customer-specific intercept terms that capture the net change in consumption due to the program, controlling for other factors that do change with time (e.g., the weather).

Because the consumption data in the panel model includes months before and after the installation of measures through the program, the period of program participation (or the participation window) may be defined specifically for each customer. This feature of the panel model allows for the pre-installation months of consumption to effectively act as controls for post-participation months. In addition, this model specification, unlike annual pre/post-participation models such as annual change models, does not require a full year of post-participation data. Effectively, the participant becomes their own control group, thus eliminating the need for a non-participant group. We know the exact month of participation in the program for each participant, and are able to construct customer specific models that measure the change in usage consumption immediately before and after the date of program participation, controlling for weather and customer characteristics.

The fixed effects model can be viewed as a type of differencing model in which all characteristics of the home, which (1) are independent of time and (2) determine the level of energy consumption, are captured within the customer-specific constant terms. In other words, differences in customer characteristics that cause variation in the level of energy consumption, such as building size and structure, are captured by constant terms representing each unique household.

Algebraically, the fixed-effect panel data model is described as follows:

$$y_{it} = \alpha_i + \beta x_{it} + \varepsilon_{it},$$

where:

- y_{it} = energy consumption for home *i* during month *t*
- α_I = constant term for site *i*
- β = vector of coefficients
- x = vector of variables that represent factors causing changes in energy consumption for home *i* during month *t* (i.e., weather and participation)
- ε = error term for home *i* during month *t.*

With this specification, the only information necessary for estimation is those factors that vary month to month for each customer, and that will affect energy use, which effectively are weather conditions and program participation. Other non-measurable factors can be captured through the use of monthly indicator variables (e.g., to capture the effect of potentially seasonal energy loads).

The effect of the program, in the case the Personal Energy Report kit, is done by including a variable which is equal to one for all months after the customer received the kit. The coefficient on this variable is the monthly savings associated with the kit. The effect of the recommended measures was captured by totaling all the engineering estimates for the measures recommended for each customer (from the TecMarket analysis). As for the kit variable, this variable was set to zero for the months prior to the PER report, and then equal to the customer-specific engineering estimate for the months after the customer received the report. The coefficient on this case is the "realization rate" of the engineering estimate, i.e., the percentage of the engineering estimate realized by participants.

Billing Analysis Results

This estimated model for electricity shows that the PER kits results in a savings of 17.00 kWh/month, or 204 kWh a year. This estimate is precisely estimated, with the 90% confidence interval extending from savings of 14.8 kWh/month to 19.2 kWh/month. The savings associated with the recommended non-kit measures is very small and not statistically significant. The estimated electric model statistics are presented in Table 8.

Table 8. Electricity Billing Data Model Statistics

Independent Variable	Coefficient	t-value
Customer received kit	-17.00	-12.37
Engineering estimate of stated installed measured	0.01	1.44
Sample Size	7,476 obs (267 homes)	
R-Squared With fixed effect terms W/O terms	 65% 39%	

This estimated model for natural gas shows that the PER kits results in a savings of 0.93 Therms/month, or 11.2 Therms a year. This estimate is relatively well estimated, with the 90% confidence interval extending from savings of 0.06 Therms/month to 1.80 Therms/month. As was the case in the electricity model, there are no statistically significant non-kit savings. The statistics for the natural gas model are presented in Table 9.

Table 9. Gas Billing Data Model Results

Independent Variable	Coefficient	t-value
Customer received kit	-0.93	-1.71
Engineering estimate of stated installed measured	0.32	1.21
Sample Size	143,972 obs (4,050 homes)	
R-Squared With fixed effect terms W/O terms	 76% 71%	

Savings Comparison

A comparison of the energy savings for electricity and natural gas between the engineering analysis and the billing analysis for the energy efficiency starter kits and the efficiency recommendations taken from the PER report are shown in Table 10.

Table 10. Savings Results Comparison between Engineering Estimates and Billing Analysis

	Kits		Recommendations	
Method	**Electricity (kWh/year)**	**Gas (therms/year)**	**Electricity (kWh/year)**	**Gas (therms/year)**
Engineering	213	6	628	15
Billing	204	11	0	0

For the efficiency starter kits, the engineering and billing data analysis estimates of kWh savings are quite comparable. Gas savings estimated through both approaches are small, though comparable. Energy savings associated with PER efficiency recommendations, while making up the majority of the engineering estimates of savings for the program, were not detected through the billing analysis.

Discussion

The billing results for efficiency starter kits are very similar to the engineering results when one includes factors which account for self-selection bias and false response bias. It is also important to note that the billing analysis may be underestimating savings from the efficiency recommendation component of the program because the survey did not capture the timing of additional program induced changes in the household. While responders may have stated that they did undertake additional energy efficiency actions, these may have been undertakes some time after the PER event, so they would not have been captured in the statistical model. Customers may be conducting other remodeling actions at the same time which may overshadow any energy efficiency gains..

The self-report adjustment approach was subjective, and was not based on the evaluation literature or on completed research within the energy program evaluation field. Within the energy program evaluation field there is a substantial lack of research indicating the range of self-selection bias associated with energy efficiency programs. As a result, the authors of this study elected to apply a significant self-selection bias factor in order to be conservative in our estimates of program impacts. Setting the factor at half of the non-response rate was based on professional conservative judgment from conducting surveys and metering studies of energy efficiency programs for over 28 years and interacting with the evaluation community regarding these rates, but we can point to no research that objectively assesses if this level of self-selection bias is too high or too low.

The wide discrepancy between the engineering and the billing data analysis approaches for the PER energy efficiency recommendations indicates the difficulty in applying either engineering analysis or billing analysis to this problem. The lack of data inherent in a simple mail-back survey requires many assumptions regarding existing equipment efficiencies and customer behavior. Since the efficiency recommendations were implemented by homeowners over a period of time, it is difficult to establish a measure installation date for a billing analysis. All these results show that determining the effect of educational/audit program is challenging and requires careful survey design and interpretation, and should include on-site visits on a statistically selected sample of customers to confirm key engineering assumptions.

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