Beyond Bill History: Evaluating Commercial Sector Energy Impacts Through a Multiple Approach Strategy

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In 1993, Puget Sound Power & Light Company completed an extensive impact evaluation of its Commercial Energy Management program. This program offers customized rebates to its commercial customers for the retrofit installation of energy-efficient equipment.

The evaluation addressed energy savings attributable to the measures and the program, persistence of measures and savings over time, naturally occurring conservation, spillover, and rebound effect. The evaluation combined several different approaches, including statistically adjusted engineering billing analysis, binary choice modeling, customer site visits, and customer telephone surveys. The analysis focused on participant cohorts for the years 1987-1991.

This paper briefly discusses the results obtained from these analytical approaches, as well as the lessons learned from applying these approaches. Other utilities with similar programs will benefit from both the results obtained and the lessons learned for conducting similar research.

Introduction

Demand-side management programs and the evaluation of those programs have matured and evolved at an astonishing pace over the last 5-10 years. As the magnitude of DSM efforts have grown, program evaluations have scrambled to address increasingly sophisticated questions posed by decision makers. To what extent do energy conservation measures (ECMs) and their associated energy savings persist over time? How much load impact was caused by the program that would not have otherwise occurred? Why are the evaluation estimates of savings different from the program engineering estimates?

As a contribution to the growing body of research on these issues, this paper describes the experience of Puget Sound Power & Light Company (Puget Power) in conducting an evaluation of a commercial retrofit rebate program. Analysis findings and lessons learned about conducting such evaluations are presented.

In 1993, Puget Power completed a comprehensive impact and process evaluation of its Commercial Energy Management Services (CEMS) program. The focus of this paper is the impact evaluation. The CEMS program offers cash grants to all existing commercial customers for the retrofit installation of a wide variety of ECMs for all major end uses. The grant is based on a customized energy audit of commercial facilities by a Puget Power field engineer. Puget Power has offered this program since 1980.

The evaluation of this program was developed through Puget Power's Technical Collaborative Group, which includes representatives of the various regulatory, regional power planning, environmental and other organizations that are typically parties in the Company's conservation proceedings. The evaluation results are intended to be applied in a forward-looking manner, not as a retroactive justification for any shareholder incentive payment. Primary emphasis was placed on the gross energy savings achieved over time by the program measures and "lessons learned" to improve program design and cost effectiveness. Net savings attributable to the program was a secondary objective.

Energy savings was analyzed through econometric analysis of customer billing records. Telephone and on-site surveys collected information on the retention of measures over time, levels of naturally occurring conservation (i.e., free-ridership), installation of additional ECMs not directly funded by Puget Power, and business characteristics data. The survey and site visit data, along with some limited end use metering data, are combined with the statistical analysis to weave a story explaining the program impacts.

Approach

The CEMS impact evaluation analyzed the program years 1987-1991. This analysis period was selected because it was considered sufficiently long to permit an examination of energy savings persistence, program design and delivery were very similar to the current program, and billing records could be easily retrieved. Samples were selected to be representative of the basic measure categories and building types found in the 1987-1991 CEMS participant population.

The measures installed by program participants primarily concentrated on heating, ventilating and air conditioning (HVAC) and lighting system modifications, accounting for 84% of reported 1987-1991 CEMS energy savings. Participation was spread across all major commercial building categories, with 691 projects completed between 1987 and 1991. Average pre-program annual energy use was about 923,000 kWh per participating project[1]. The engineering estimates of savings averaged 9% of the total, or 85,000 kWh. Table 1 summarizes the number of projects and energy savings by measure category. Table 2 summarizes the number of projects, energy savings, and pre-program energy use by building type.

Table 1. 1987-1991 CEMS Participants Summary by Measure Category

Measure Category	Number of Projects	kWh Savings
HVAC	261	25,264,000
Lighting	399	24,094,000
Glass	71	2,035,000
Insulation	126	3,280,000
Other	29	3,742,000
Total	691	58,415,000

Note: Number of projects does not add to total because some projects installed multiple types of measures.

Table 2. 1987-1991 CEMS Participants Summary By Building Type

Building Type	Number of Projects	kWh Savings
Office	149	18,110,000
School	137	11,684,000
Restaurant	48	1,180,000
Health	44	3,812,000
Retail	66	4,148,000
Hotel	15	3,814,000
Grocery	25	2,996,000
Public/Govt.	38	2,257,000
Bank	58	2,994,000
Other	111	7,420,000
Total	691	58,415,000

Statistically Adjusted Engineering (SAE) Model

Gross energy savings attributable to the installation of program ECMs among program participants, adjusted for differences in service levels before and after measure installation, was analyzed through a set of SAE models. The general approach for quantifying gross energy savings for this study was based on a pooled cross-sectional/time series analysis of energy consumption of those customers that installed conservation measures under the CEMS program between 1987 and 1991. Changes in daily energy consumption were analyzed, based on monthly bills for the period 1986-1992. This ensured one to five years of pre- and post-installation data for all locations. The basic research design is presented in Figure 1.

A notable aspect of these models was the use of generalized least squares (GLS) techniques incorporating analysis of covariance (ANCOVA). This is also referred to as a "fixed-effects" model. This model allows each individual location to act as its own control. The unique effects of weather and base energy use on the energy use at each location are the "fixed effects", included in the models as location-specific coefficients. This greatly controls the amount of variance or "noise" within the model. This approach also provides a much closer fit to the data than typical ordinary least squares models, without relying on direct inclusion of pre-retrofit consumption as an independent variable to predict post-retrofit consumption. The ANCOVA approach has not been widely used in the field of DSM evaluation, although a few such applications have been reported (see for example Megdal et al. 1993).

Another notable aspect of this analysis was testing of the stability of the model coefficients over time. Separate

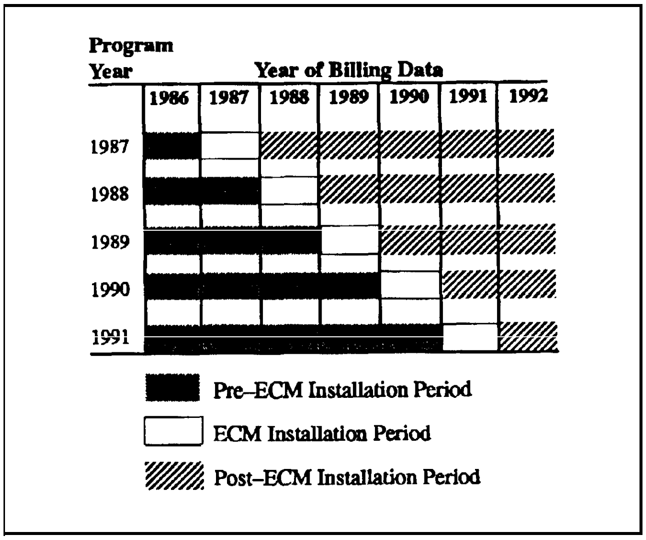

Figure 1. Research Design for Pre/Post Billing Analysis

models were estimated for 1987- 1990 participants, 1987 -1991 participants, and 1991 participants only. The model coefficients for 1991 participants were close to those for earlier years. This confirmed the stability and predictive value of this modeling approach. This paper presents the results from the 1987 - 1991 set of models.

Several model specifications were tested for each measure category to ensure a reasonable model with the fewest potential sources of bias from mis-specification or spurious correlation. These models were variations of the following basic model framework:

$$KWHPDAY_{it} = \beta_i EE1_{it} + \beta_2 EEP_{it} + \beta_3 EEH_{it} + \beta_4 EEC_{it} + \beta_5 EEP2_{it} + \beta_i HDD_t + \beta_i CDD_t + \beta_i YR_t + \beta_i + \beta_6 QTR2_t + \beta_7 QTR3_t + \beta_8 QTR4_t + \beta_9 HOL_t + \beta_{10} EMP_t + \beta_{11} EMP_{t-1} + \beta_{12} SVCS_t + \beta_{13} TNT2_t + \beta_{14} TNT3_t + \beta_{15} TNT4_t + \beta_{16} TNT5_t + \beta_{17} SQFT_i + \beta_{18} HRS_i + \beta_{19} EQPVAR_t + \beta_{20} OTVAR_t + \beta_{21} NHV1_t + \beta_{22} NHV2_t + \beta_{23} NHV3_t + \beta_{24} NLI1_t + \beta_{25} NLI2_t + \beta_{26} NGL1_t + \beta_{27} HVAR_t + e_{it}$$

where:

All ßi coefficients represent separate coefficients for each location i= 1...n.

All other ß coefficients represent all locations pooled (at the mean).

KWHPDAY = Energy use per day in time period t.

EE1, EEP, EEP2 = Engineering estimate of energy savings 0-12 months after measures installed, 12-24 months after measures installed, and more than 24 months after measures installed, respectively.

EEC, EEH = Engineering estimate of energy savings multiplied by average daily cooling degree days and heating degree days, respectively.

CDD, HDD = Average daily cooling degree days and heating degree days, respectively for time period t.

YR = Dummy variable to capture location-specific and year-specific differences not captured by other energy usage factors.

QTR2, QTR3, QTR4 = Dummy variables to capture seasonal usage impacts apart from weather differences.

HOL = Number of non-normal work days (e.g., weekends, holidays) in period t.

EMP = Employment by SIC code and county for time periods t and t-1.

SVCS = Number of meter services in effect in time period t.

TNT2, TNT3, TNT4, TNT5 = Dummy variables reflecting building tenant changes in period t.

SQFT = Square feet of conditioned floor area at location i.

HRS = Weekly business operating hours at location i.

EQPVAR, OTVAR = Dummy variables representing changes in electric non-process and process equipment, respectively, in period t.

NHV1 , NHV2, NHV3, NLI1 , NLI2, NGL1 = Dummy variables for installation of non-program measures, up to three HVAC measures, two lighting measures, and one glass measure, respectively, in period t.

HVAR = Dummy variable indicating a change in HVAC operations in period t.

Models were estimated separately for each type of measure, using data only for those locations that installed that type of measure and did not install other types of measures. This procedure allows for a "clean" estimation of energy savings from each type of measure, since the confounding effects of other types of measures, which might be taken at the same time, are avoided. For example, savings from HVAC measures were estimated from a model that includes only locations that installed an HVAC measure and did not install any other measures. Even though the models were estimated only on data for locations that installed one type of measure, the results can be reasonably generalized to all locations. Although the single measure models do not capture any interactive effects between HVAC and lighting, the effect of this bias was deemed negligible due to the limited number of affected participants and the temperate western Washington climate. The energy consumption levels and types of measures installed were found to be similar between single and multiple measure locations, further minimizing concerns about bias of model results.

Variables denoting changes in building space, business operation, equipment use and replacement, and installation of non-program measures were excluded from the final models because they had no significant effect on the resulting energy savings estimates.

The sample consisted of all projects that installed a single type of measure during the analysis period, stratified as follows:

- 151 HVAC-only locations (HVAC system or control modifications);
- 209 Lighting-only locations (lighting system or control modifications);
- 48 Insulation-only locations; and
- 24 Glass-only locations.

Other types of measures, such as refrigeration and other miscellaneous process modifications occurred too infrequently to permit meaningful analysis.

Net Savings Model

Net savings analysis is an attempt to estimate the program savings that would not have occurred in the absence of the program, excluding free-riders and including (in theory), additional "spillover" and "free-driver" savings. The CEMS analysis consisted of a quasi-experimental design, comparing the change in kWh consumption for a program participant group to that for a comparison group. Such analyses are vulnerable to self-selection bias, which is the possibility that the participant group is inherently more likely to install ECMs than the comparison group (for a more complete discussion of self-selection, see Violette et al. 1991; or Hirst and Reed 1991).

Survey responses in fact indicate that self-selection was not just a theoretical issue for the CEMS program. Building types and ages were found to differ between participants and nonparticipants. Two thirds of the nonparticipant sample also reported that they were aware of the CEMS program with 20% claiming they received a program energy audit, but did not get a grant. These findings may be subject to some response bias (respondents giving the interviewer what they think is the "right" answer) and should be treated as general indicators of systematic differences between the two groups.

An additional analytical problem, alluded to above, is inherent to the CEMS program. The program provides energy audits as a prerequisite to obtaining a grant. Not all customers who received audits also received grants, yet they could have installed some ECMs beyond what would have happened if the CEMS program never existed. Although Puget Power could identify which customers received audits, there is no information available regarding any non-grant measures installed and the associated estimates of energy savings. Unless audit-only savings can be separated from grant-only savings, the "participant" group must be defined as customers that received a CEMS audit and the "comparison" group as customers that received neither grants nor audits. Figure 2 illustrates the various degrees of possible participation in the program.

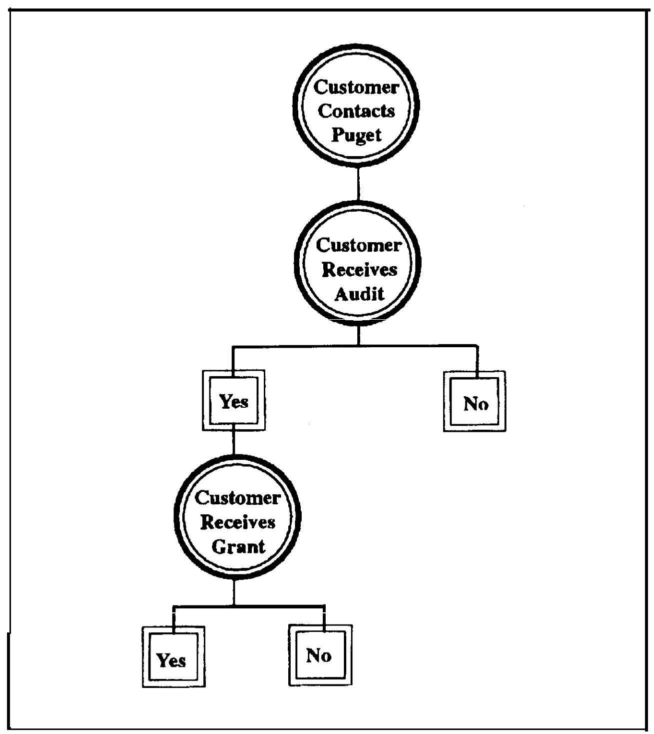

Figure 2. CEMS Participation Decision Points

Given that net savings was a secondary objective of the CEMS evaluation, it was decided that separating grant-only and audit-only impacts was beyond the scope of this study. Thus, the net savings analysis compares buildings that received a CEMS audit with those that were never audited. These results are not directly comparable to the gross savings for grant recipients, estimated by the SAE models.

A two-stage estimation procedure was implemented. First, a binary choice logit model was used to estimate the probability of a customer obtaining an audit. This step corrects for self-selection bias in the audit and non-audit groups. The probability of having an audit was modeled as a function of building type, change in tenant, and square feet of floor space. This probability was then included in a multiple regression model which estimated the change in total kWh per 1,000 square feet of floor area per day. The net savings model also includes building tenant changes, change in employment by SIC and county, and other location-specific factors (such as changes in energy equipment and business operations). Net kWh savings was calculated as the difference in the change in kWh per 1,000 square feet between the audit (treatment) group and the non-audit (comparison) group. The audit group included 395 locations and the non-audit group included 1,015 locations.

Telephone and On-Site Surveys

Telephone and on-site surveys were designed to accomplish a variety of objectives related to the impact evaluation, including the collection of:

Telephone and On-Site Surveys

Telephone Business characteristics data to inform the SAE and net savings models;

- Retention data for program-funded ECMs (measures still installed and operational);
- The level of naturally occurring conservation (free-riders) within the program; and
- Additional non-grant (100% customer funded) ECMs installed.

Two sets of telephone surveys and one set of on-site surveys were conducted. Phone and on-site surveys were conducted for 1987-1990 participants and nonparticipants, with the smaller on-site survey acting as a validity check on the larger telephone survey. A phone survey only was used for 1991 participants and nonparticipants. These will be treated as a single group in the discussion of findings because they covered many of the same objectives and phone survey responses were nearly identical to the on-site findings. Samples were selected to be representative of geographic location, measure category, and building type. All participant survey responses were weighted by the proportion of ECM type by geographic division for the sample to the 1987-1990 and 1991 program populations, in order to extrapolate survey findings to the entire program. Table 3 outlines the key objectives and Table 4 shows the sample sizes associated with each survey.

Findings

Gross Energy Savings and Persistence

The results of the HVAC, lighting, and glass SAE models generally confirm the engineering estimates of savings and are consistent with the measure persistence findings from the surveys. There is no apparent degradation of energy savings over the first five years of measure installation and very few ECMs have been removed or rendered inoperable over the same period.

The key finding from the pooled 1987-1991 SAE analysis is that the HVAC, lighting, and glass models estimated an overall realized savings rate of 90% of the original engineering estimate. Realization rates by measure category are 94% for HVAC, 86% for lighting, and 74% for glass. Inclusion of persistence variables for measures 2 - 5 years after installation had no significant impact on realized savings beyond the second year. Thus, for ECMs which account for over 90% of program savings, there is no statistically measurable decline in savings three to five

Table 3. Survey Sample Sizes

	On-Site 1987-1990	Telephone 1987-1990	Telephone 1991
Participants	101	199	100
	95% response	71% response	82% response
Nonparticipants	44	101	203
	90% response	52% response	46% response

Table 4. Survey Research Objectives

	On-Site 1987-1990	Phone 1987-1990	Phone 1991
Participants & Nonparticipants			
Business & Building Characteristics	X	X	X
Changes in Equipment & Operations	X	X	X
Installation of Non-Program Measures	X	X	X
Program Awareness	-	X	X
Participants Only			
Measure Persistence	X	X	-
Naturally Occurring Conservation	-	X	X

years after installation. The high savings persistence rate corresponds to a high measure retention rate, discussed later in this paper.

Table 5 summarizes the realized savings rates and statistical performance for the HVAC, lighting, and glass models. Savings persistence of the CEMS program is somewhat higher than what was found in a three-year savings persistence study conducted for Bonneville Power Administration's Commercial Incentives Pilot Program (Coates 1992). The difference in persistence appears to be due to differences in the mix of measures and customer characteristics participating in the Bonneville and Puget Power programs (Weisbrod et al. 1993).

Results for insulation do not reflect the engineering estimates of expected savings. In fact, the SAE model showed that energy consumption increased after insulation was installed. It is hypothesized that the results were driven by unobserved changes to the building that occurred at the same time that the measures were installed, possibly reductions in outside air leakage or business expansion. More work, probably including on-site field measurements, would be needed to identify any savings resulting from insulation.

The phone and on-site surveys of 1987-1990 participants indicate very high levels of equipment persistence as well. Among the CEMS measures installed during this period, 97% of HVAC, 96% of lighting, 100% of glass, and 99% of insulation measures were still in place and working as of late 1992. Similarly high measure persistence rates have recently been reported by other utilities (Velcenbach and Parker 1993; Jacobson et al. 1993). A year-by-year breakdown of equipment persistence rates is presented in Table 6.

The surveys also provided rates of equipment malfunctions and repairs, shown in Table 7. It is notable that while customers reported malfunctions occurred in 26% of the HVAC projects and 17% of the lighting projects, almost all the malfunctioning units were subsequently repaired and found to be working properly.

The high levels of energy savings and measure persistence are most likely a function of CEMS program design. Measures eligible for CEMS funding are typically durable and difficult to remove. For example, T-8 fixtures are eligible for funding, but re-lamping with 32 watt T-12 tubes is not. The program also requires that a significant portion of measure costs be shared by participating customers. Thus stable businesses interested in long term commitment to receiving the energy savings are payback are the most likely type of customer to be attracted to the CEMS program.

Why are realized savings for lighting or glass measures not as close to 100% as HVAC measures when equipment persistence is over 95% for all three measure categories?

In the case of lighting, the answer appears to be inaccurate assumptions of system operating hours. The evaluation literature is full of examples where operating hours were pinpointed as the culprit in lower than expected commercial lighting energy savings (see for example Nadel and Keating 1991; Jacobson et al. 1992), This national experience was reflected in a very limited case study analysis conducted by Puget Power in 1993. Logging devices that measure cumulative on-time of lighting were installed at three CEMS lighting projects for approximately four weeks. Although the sample is much too small to draw any statistically defensible conclusions, it is

Table 5. Statistical Performance of SAE Models

Statistical Performance Measure	Effect on Energy Consumption (sign and significance) HVAC Model	Lighting Model	Glass Model
Savings Realization Rate	94.17%	85.59%	74.20%
R-squared: proportion of observed variation in monthly energy consumption which is explained by the model	0.994	0.984	0.936
Precision of Key Parameters (at 90% confidence level)			
EEI: Program Impact: Engineering Estimate	-(***)	-(***)	-(NS)
EEP: Persistence (one year)	-(**)	NA	-(**)
EEP2: Persistence (two year)	-(**)	-(*)	-(**)
EEH: Eng. Est. of Savings* Heating Degree Days	-(*)	NA	+(*)
EEC: Eng. Est. of Savings* Cooling Degree Days	NA	-(*)	NA
90% Confidence Interval for Energy Savings Realization Rate	+/-.010	+/-.009	+/-.042

90% confidence intervals:
(*) 50 to 100%
(**) 25 to 50%
(***) 12 to 25%
(****) 0 to 12%
(NS) = Not statistically significant (i.e., +/- more than 100%).

worth noting that measured operating hours were substantially less than assumed operating hours in all three cases.

In the case of glass, the reasons for lower than expected savings are readily apparent. However, since glass measures account for only 2% of total program savings, there is little cause for alarm. A review of project files indicates that many glass participants were small, pre-1980 vintage buildings. Several files had notes indicating that the occupants complained of draftiness and inability to keep the space warm, and as a result, did not bother trying to run the heater to achieve their desired comfort level. Discussions with several field engineers led to a similar conclusion. Thus it is possible that the reduced level of savings may be an indication of rebound effect, resulting from turning up the heat in some of these buildings to improve occupant comfort, now that the building is perceived to hold the heat better.

Net Program Impacts

As discussed earlier, the net savings for CEMS grant participants could not be directly determined because the data did not permit separation of grant-only savings from audit-only savings. A discrete-continuous modeling approach was used to estimate net savings for grant participants by calculating a net-to-gross ratio as the proportion of average net savings per 1,000 square feet of floor area for the audit group (audit-only plus grant recipients) to average gross savings per 1,000 square feet for grant recipients only.

Table 6. Percentage of Installed Measures Which are Still in Place, by Year Installed

Type of Measure	Installed Number of Years Ago			
	2	3	4	5
HVAC	100%	100%	91%	94%
Lighting	100%	97%	93%	96%
Insulation	100%	94%	100%	100%
Glass	100%	100%	100%	100%
Other	100%	100%	100%	100%

Table 7. Malfunction and Repair of Measures Installed

Type of Measure	Percentage of all Measures Installed	
	Malfunctioned	Repaired
HVAC	26%	25%
Lighting	17%	17%
Insulation	3%	3%
Glass	2%	1%
Process/Other	23%	23%

This analysis indicates that the net impacts of the CEMS program are 85% - 100% of the gross impact estimates. This means that free ridership effects (which reduce net impact) could be offset by spillover effects (which increase net impact). The exact comparison has an element of uncertainty, since the estimates of gross energy savings per square foot were based on all grant recipients, while the estimates of net energy savings per square foot were necessarily based on all audit recipients. In effect, the estimates of net energy saving per square foot are "watered down" by the inclusion of audit-only customers. At a minimum, the net impact of the program was 85 percent of the gross impact, as determined by the ratio of net to gross energy savings per 1,000 square foot, indicated above. This minimum would be correct if we assume that the audit-only customers had as much savings per square foot as the recipients of CEMS financial grants. To the extent that the CEMS grant recipients had a higher net savings than the audit-only customers, which would be expected but cannot be confirmed, then the actual ratio of net-to-gross savings is also higher by an unknown amount.

Naturally Occurring Conservation

Naturally occurring conservation (NOC) is that portion of the energy saving actions taken by participants that would have occurred without the program. The rate of naturally occurring conservation among participants is sometimes also referred to as "free ridership."

One of the most common techniques for determining naturally occurring conservation is through surveys. There were three questions in the telephone surveys used to estimate NOC. These asked whether, without the program, the customer would have purchased similar equipment, would this equipment have been as efficient, and would the purchase have occurred at the same time. The grant program can accelerate the timing of purchasing efficient equipment, or increase the efficiency of the equipment they otherwise would purchase, or do both. Puget Power defines NOC as the latter case, where equally efficient equipment would have been purchased within the same time period regardless of receiving a program grant.

Obtaining stated intentions to a hypothetical situation is subject to two potentially significant errors. Respondents may be unable to guess how they actually would have responded to a hypothetical situation (without the grant program). There is also the possibility of a bias towards over-reporting that they would have done the same action. The latter can come about because they think that if conservation is good, they'll appear to be a better person. This is a classic source of internal invalidity called testing or experimental interaction. These errors tend to result in upward bias of survey-based NOC estimates (Hirst and Reed, 1991).

Given these cautions, survey responses indicate that 16% of 1987-1990 participants and 20% of 1991 participants, accounting for about 10%-12% of program energy savings, would have bought equally efficient equipment at the same time without the grant program. NOC responses were most commonly associated with participants that installed HVAC-only or combinations of multiple measures. Schools were the most common building type associated with NOC. The NOC level reported by the surveys is consistent with the results of the net savings analysis.

Although Puget Power takes these NOC estimates with a (large) grain of salt, they do indicate that a relatively low level of NOC occurs within the CEMS program, with higher levels in certain measure and building types. This information is useful when reviewing program design and implementation procedures.

Installation of Non-Program Measures

The CEMS evaluation also attempted to assess installation of ECMs not funded by a program grant, for participants and nonparticipants. This data could then be used in an analysis of spillover effects among participants and free-driver/market transformation effects among nonparticipants.

There are two measurement issues associated with estimating these effects. The first is identifying the additional non-grant ECMs installed. The second issue is attributing causality to the program. As discussed below, Puget Power encountered enough difficulties with the first issue that the second issue was never addressed.

Measures were reported installed without an incentive by 35 of the 100 participants surveyed for program year 1991. Because the installation rate for non-grant measures was unexpectedly high, Puget Power reviewed the project files for each of these participants. For all but five projects, the measures reported installed without a grant, in fact were actually funded by a grant in a year other than 1991. Obviously, respondents misunderstood the question or simply did not remember that they received a grant for the other measures. Because serious doubts had been raised about the accuracy of the participant survey responses, no further analysis of spillover or free-ridership was conducted. However, the small difference between gross and net energy savings provides some indication that these effects may be of a magnitude that roughly offset NOC.

Conclusions

Used and useful impact evaluation requires more than just billing data and a statistical estimation model. Surveys and metering results add depth and color to model results. The evaluation can construct an image of the program that includes not only the magnitude of energy impacts, but also explains why those impacts occurred and separates the effects of factors like naturally occurring conservation, which may be of particular interest to decision-makers.

Puget Power conducted such an evaluation of its CEMS program with generally good success. The primary objective of the evaluation was to quantify actual savings from program measures over the first five years of installation. This is one of the first commercial program evaluations to analyze energy impacts over such a long period. Secondary objectives were to estimate the net energy savings attributable to the program and identify the levels of naturally occurring conservation and spillover within the program. These priorities dictated the level of effort directed at each study objective.

Gross annual average measure savings were successfully estimated with statistically adjusted engineering models, for those measures that represent over 90% of program savings. The evaluation found that 90% of the program engineering estimates were realized for HVAC, lighting, and glass measures, up to five years after installation. No significant decline in savings over time was observed by the analysis. Surveys found almost all program measures were still installed and operational after two to five years, confirming the statistical model results. The high persistence rate is apparently a result of the CEMS program design.

Of course, it is too early to draw conclusions about persistence of measures and savings beyond five years. Most CEMS program measures have estimated useful lives of 10 - 20 years and the analysis period for this study is too short to detect changes that may occur later. Persistence must be analyzed over a longer period to draw definitive conclusions.

HVAC results were in closest agreement with the engineering estimates, followed by lighting and glass, respectively. Estimates for insulation were inconclusive and counter-intuitive. Metering results and review of the evaluation literature indicate that discrepancies in lighting savings were due to differences between assumed and actual hours of operation. The reasons for discrepancy between the evaluation and engineering estimates of savings for glass are less clear. A review of project files and interviews with program field staff indicate that a rebound effect may be associated with this measure.

It was not possible to obtain a point estimate of net program savings because significant self-selection bias exists between CEMS grant participants and nonparticipants and because the analysis was confounded by the inability to separate audit-only participants from grant participants. These constraints were results of the basic program design, in which receiving an energy audit is a prerequisite for receiving a grant, and the maturity of the program, which results in many nonparticipants becoming aware of the program over time, even though no direct marketing of the program is done.

However, the net savings analysis does provide an indication that a very large percentage of the energy savings from CEMS grant-funded measures would not have been achieved in the absence of the program. A comparison of net audit recipient savings with gross grant recipient savings yielded a net-to-gross ratio ranging from 85% to 100%. Puget Power has determined that gross savings is the most appropriate measure of program savings because: (1) there appears to be little difference between net and gross savings estimates, (2) considerable additional effort would be required to refine the net savings estimates, and (3) there is no external or internal requirement to develop and use precise point estimates of net savings.

Obtaining estimates of naturally occurring conservation and spillover effects based on customer surveys were problematic, at best. The estimate obtained for naturally occurring conservation within the CEMS program is best interpreted as a general indication that the magnitude of the effect is relatively small, in the neighborhood of 15%-20%. Survey responses tend to produce upwardly biased estimates of free-ridership. It was not possible to develop estimates of spillover and free-driver effects. Review of program records indicate that survey-based estimates of non-program measure installation can be very inaccurate. The net savings analysis indicates that these effects may be roughly the same magnitude as NOC. In short, quantifying these effects is a worthy concept that is extremely difficult to put into practice. Utilities that wish to pursue these issues more thoroughly should be extremely careful in their research design and administration and use more sophisticated techniques than surveys alone.

Acknowledgments

The authors wish to acknowledge Andrew Hub of Cambridge Systematic, Rich Mazzucchi of SBW Consulting, and Dr. Kenneth Train of the University of California at Berkeley for producing much of the analysis discussed in this paper.

Endnote

1. It is important to distinguish between projects and locations, *Location* refers to an individual building premise, which has a unique identification number assigned to it and is the basic analysis unit used by the gross and net energy savings models. *Project* refers to the entire set of energy efficiency modifications installed at a customer's facility, which can affect single or multiple locations and can involve single or multiple types of measures.

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