Improving Billing Analysis Results Using On-site Follow-up Surveys

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Billing analyses using multiple regression models are often used to quantify savings from commercial retrofit programs. Outliers, sites that are not well explained by the regression equation, can adversely affect the estimates of program savings. In many cases, these outliers are dropped from the analysis or downweighted. Unfortunately, the affected sites can often account for a large amount of program savings, calling in to question the representativeness of the analysis.

This paper presents the results of a study that used follow-up on-site surveys of outlier sites to improve the billing analysis regression model. The study involved several steps. First, preliminary regression equations were developed, incorporating billing data, telephone survey data, weather data, and program tracking data. Second, regression residuals and influence diagnostics were examined to identify important outliers. Third, on-site surveys were conducted for the outlier sites to collect information regarding unexpected energy usage changes. Finally, the results of the on-site surveys were incorporated into the regression models to provide improved evaluation results.

Key uses of the on-site survey data included refining and correcting data telephone survey data, verification of program-related measures, and explicit quantification of nonprogram factors that altered electricity consumption. Regression statistics improved considerably as a result of the additional analysis, and program realization rates increased from 0.6 in the preliminary analysis to 0.8 for the final analysis.

INTRODUCTION

This paper is based on commercial retrofit programs provided by a consortium of utilities in the Pacific Northwest (XENERGY 1995a). The evaluation covered existing buildings that participated in the DSM programs during calendar years 1991 and 1992.

A key aspect of the retrofit evaluation was the development of techniques that could be used to evaluate impacts for smaller commercial DSM programs (i.e., programs with fewer than 500 participants). The primary approach used for this evaluation was a billing analysis of the change in electric consumption of program participants and nonparticipants.

An important element of this evaluation approach was the inclusion of on-site survey data to explain variations at outlier sites. Typically, outliers are either ignored, downweighted, or removed from billing analyses although the preferred approach is to further investigate these observations and to include the additional information in the model (Pindyck 1981 6–8, Schutte 1994, Violette 1991, XENERGY 1995b). This preferred approach was used in this evaluation. Based on the results of a preliminary analysis, sites with unexpected changes in energy use were identified and visited. Non-program factors affecting energy consumption and contributing to model error were quantified and incorporated into the final analysis. This final step yielded significant improvements in the evaluation results.

Background

In the Pacific Northwest, many commercial DSM programs implemented by utilities are based on Bonneville Power Administration's (BPA) Energy Smart Design (ESD) Program. The initial version of the ESD Program, which began in 1988, provided design assistance only. In subsequent years, the program was expanded to include financial incentive payments to customers for the installation of program-approved energy conservation measures. The 1991 and 1992 program years evaluated in this study may be characterized as a start-up period for the incentive portion of the program.

For the program, individual utilities make resource acquisition payments to their customers in the form of custom incentives and standardized DSM measure rebates. All commercial buildings and the non-process portion of industrial plants located within the service territory of participating BPA customer utilities are eligible to receive program services.

During the 1991–1992 startup period for the ESD Program, approximately 0.6 percent of the eligible buildings participated in the program. These buildings represented about 3.7

percent of the eligible floorspace. Overall, the 792 participating sites had expected savings of 53.6 GWh. The majority of measures installed under the program affected the lighting end use, with 660 sites installing lighting measures for expected savings of 41.4 GWh.

Scope

This paper focuses on the methodology and results of the billing analysis that were used to estimate energy savings impacts for the retrofit program. Particular attention is paid to the improvement of evaluation results through the incorporation of follow-up on-site survey data.

METHODOLOGY

The primary approach used for this evaluation was a billing analysis of the change in electric consumption of program participants and nonparticipants. This approach used an SAE (statistically-adjusted engineering) model that explained changes in energy use in terms of the engineering savings estimates from the installation of DSM measures, controlling for changes in weather, site characteristics, and market conditions. The primary components of the study included:

- sample design to select representative participant and comparable nonparticipant sites for the study;
- telephone surveying to collect site-specific data on factors affecting energy usage for use in the billing analysis models;
- billing data collected from the utilities involved in the study;
- preliminary billing analyses to produce initial evaluation results and to identify outlier sites for subsequent on-site surveys;
- on-site surveys of selected customers to quantify non-program factors causing changes in energy use; and
- final billing analyses incorporating the on-site survey data.

Ultimately, 347 sites were included in final study models (158 participants and 189 nonparticipants). A total of 77 sites received the follow-up on-site surveys.

Telephone Surveys

Telephone surveys were conducted to collect site-specific information on program participants and nonparticipants. Collected data were used to identify non-program factors affecting energy consumption that could confound the estimates of program energy savings. Because the evaluation method used for the study consisted of explaining the change in energy consumption for selected sites, the information gathered in the telephone surveys included:

- major equipment holding and operations behavior;
- events that caused consumption to change, such as changes in building operations and equipment additions/removals; and
- customer characteristics associated with the likelihood to change energy consumption including participating in the program.

On-site Surveys

On-site surveys were a key component of the final billing analysis. Information from the on-site surveys was incorporated into the billing analysis to better control for non-program factors, significantly improving modeling results.

During the preliminary billing analysis, outliers were targeted for on-site surveys. Outliers consisted of customers with unexpected changes in consumption or the lack of expected changes in consumption (participants whose bills were expected to decline). Outliers were identified using standard methods (Belsley 1980, Bollen 1990, Violette 1991) and statistical output (SAS 1990), including:

- examination of partial regression leverage plots to identify sites that were most influential in the energy use/expected savings relationship and the sites that stray farthest from the regression ‘‘line’’;
- examination of DFBETAS—influence diagnostics that indicate observations that are influential in estimating the realization rate parameter; and
- examination of regression residuals (using diagnostics such as Studentized residuals, DFFITS, and the Hat matrix)—large residuals indicated a poor overall fit of the model to these points.

The on-site surveys primarily were used to: (1) refine data collected in the telephone surveys, and (2) explicitly quantify non-program changes that altered electricity consumption and potentially masked program energy savings. The on-site surveys also were used to verify measure installation data obtained from the program tracking system at sites where energy savings were less than expected. Although a detailed verification of measure installations was not conducted at each site, it was found that program measures generally were still in place.

The surveys allowed for higher quality information than the telephone surveys as the surveyor and customer were able to discuss specific issues in detail. The surveyor had access to billing histories and information from the telephone survey and program tracking system so that unusual events could be identified and explained. Summary results of the on-site surveys are tabulated in Table 1.

Key findings from the on-site surveys included:

- The identification of five sites with major changes in occupants; these sites were dropped from the study.

- The identification of operations increases and equipment additions at a large number of participant sites. These increases tended to offset measure savings.

- The ability to calculate non-program kWh impacts associated with operations or equipment changes for 48 sites. These impacts were explicitly included in the final billing models.

Table 1. *On-site Survey Summary*

Sites visited	77
Factor influencing electricity usage	# Sites[1]
Total change in occupants	5
Equipment increases	21
Equipment decreases	3
Additional measures installed	8
Fewer measures installed	0
Operations increase	36
Operations decrease	4
Unusual occurrences	2
No explanation	17
kWh impacts calculated	48

[1]Sites do not sum to total due to multiple factor sites.

The non-program impacts were quantified on a site-by-site basis using methods that depended on the availability of site data. In some cases, the energy using characteristics of added equipment (kW input, wattage, horsepower, tons of cooling, etc.) and the operating profiles were collected and used in engineering equations to develop load changes. In other cases, site energy managers were able to provide estimates of the impact of specific site changes. Finally, in several sites with square footage additions, typical Northwest EUIs (energy use indices in kWh per square foot) for the given building type and end use were used to develop impact estimates.

Billing Analysis Model

The energy model regression analysis used a cross-sectional change-in-consumption model specification. Each customer's billing history was divided into three periods: a pre-retrofit period, a blackout period, and a post-retrofit period. The blackout period was chosen, on a site-specific basis, to be sufficiently large to ensure that the measure installation occurs within this period. Then pre- and post-retrofit billing data (viewed on an annual basis) were compared as part of the billing analysis. By using this approach, the timing of events was not as critical as with models that use monthly time-series data. Customers were usually able to recall the general timing of major facility events although they were often unable to pinpoint the exact month of an occurrence.

For the regression model, annual post-retrofit electric consumption per square foot of building was explained as a function of annual pre-retrofit consumption per square foot, a variable or variables identifying program participation, and ''other'' variables that explain changes in energy consumption:

$$\left(\frac{kWh}{SF}\right)_{i,Post} = \alpha + \beta_0 \left(\frac{kWh}{SF}\right)_{i,Pre} + \beta_1 \left(\frac{Eng}{SF}\right)_i + \sum \beta_j X_{ij} + \epsilon_i$$

where:

$kWh/SF_{i,Post}$	=	post-retrofit period consumption for customer *i*
$kWh/SF_{i,Pre}$	=	pre-retrofit period consumption for customer *i*
Eng/SF_i	=	the engineering-based estimate of rebate program savings from the program tracking system
X_{ij}	=	a vector of *j* other explanatory variables explaining changes in consumption

α, β's	=	estimated parameters
ϵ_i	=	random error term

The parameter of interest in these equations is $\beta1$, the coefficient for the program variable. This parameter represents the estimated realization rate, the fraction of tracking system savings realized in customer bills.

In addition to the program participation variables, ''other'' explanatory variables were developed from the survey data to explain non-program changes in energy consumption. A number of variables were investigated in the modeling process. Variables were included in final specifications based on their statistical significance and the reasonableness of their parameter estimate. Key ''other'' variables included the presence of an energy manager, increases in building floorspace, additions of equipment, installation of non-program conservation measures, and site-specific changes in energy use determined during the on-site surveys.

RESULTS

Regression modeling results are presented in Table 2. The first two columns of numbers show parameter estimates and t-statistics for the preliminary model, the model that was developed before on-site surveys were conducted. The last two columns of numbers show parameter estimates and t-statistics for the final model. Below the parameter estimates are summary regression statistics, including adjusted R2 and root mean square error.

Key differences between the two models are highlighted next:

(1) The root mean square error is much lower for the final model, indicating that unexplained model error has been reduced significantly.

(2) More observations are included in the final model; a number of outliers was removed from the preliminary model to obtain reasonable parameter estimates, but only five sites with significant tenant changes were removed from the final model.

(3) The R2 statistic is higher for the preliminary model and the t-statistic is much higher for the pre-retrofit kWh variable. Initial errors in building floorspace estimates led to large variations in the dependent variable that were explained by the pre-retrofit usage variable. Errant floorspace estimates were corrected for the final model, leading to one fewer source of variation.

(4) The on-site survey variable explicitly quantifying non-program factors that changed energy use has a parameter estimate near 1.0 (0.94) with a high t-statistic (11.8), indicating that the nonprogram impact estimates from the survey were fairly accurate and fit the billing data well.

(5) The program realization rate increased (from 0.63 to 0.84) and its t-statistic also increased (from 8.3 to 11.2).

(6) The final model is much less sensitive to the influence of outliers. Exclusion of the most influential sites from the final regression model causes only minor changes in the results, whereas outliers exerted considerable influence on the preliminary model.

Overall, the final model was much more stable and provided superior ''fit'' statistics versus the preliminary model.

CONCLUSIONS

This project demonstrated an alternative technique for dealing with billing analysis ''outlier'' observations. Instead of excluding these sites from the final results, additional data collection activities were used to understand why they were ''outliers.'' A variable was developed from the on-site surveys that effectively explained nonprogram changes in energy use that had initially obscured estimates of program savings.

The approach outlined above provides a more intensive analysis of each site included in the study. When study size is constrained by a limited number of program participants, this approach is likely to provide improved results over studies that rely only on standardized forms of data collection. We have found that customers often misreport or only partially report non-program factors that affect energy consumption when completing standardized telephone surveys. These ''errors'' can significantly affect the evaluation results for smaller studies (as demonstrated in Table 2).

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REFERENCES

Belsley, D.A, Kuh, E., and Welsh, R.E. 1980. *Regression Diagnostics: Identifying Influential Data and Sources of Collinearity*. New York: John Wiley.

Bollen, K.A., and Jackman. R.W. 1990. ''Regression Diagnostics: An Expository Treatment of Outliers and Influential

Table 2. Regression Results: Dependent Variable = Post Retrofit kWh/sqft

Independent Variables	Preliminary Model Parameter Estimate	Preliminary Model t-statistic	Final Model Parameter Estimate	Final Model t-statistic
Intercept	−0.58	−0.8	0.15	0.4
Pre retrofit kWh/sqft	1.01	203.6	0.99	122.3
Mills ratio	−0.50	−1.0	−0.19	−0.8
kWh savings/sqft	**−0.63**	**−8.3**	**−0.84**	**−11.2**
On-site change: kWh/sqft			0.94	11.8
Have energy manager	−5.89	−2.3	−0.41	−1.3
New tenants	2.55	1.7		
Remodeled site	2.67	1.6	1.07	1.8
Floor space increase	1.43	1.3	0.67	2.1
Decrease in hours	−8.72	−2.3	−0.90	−1.7
n	332		347	
Root Mean Square Error	6.5		2.8	
Adjusted R^2	0.9932		0.9789	

Cases,'' *Modern Methods of Data Analysis,* edited by Fox, J., and Long, J.S. Newburry Park, Calif.: SAGE Publications Inc.

Pindyck R.S., and Rubinfeld, D.L. 1981. *Econometric Models and Economic Forecasts,* Second Edition. New York: McGraw-Hill.

SAS Institute Inc. 1989. *SAS/STAT User's Guide,* Version 6, Fourth Edition, 2: Cary, N.C.: SAS Institute Inc.

Schutte, J.M., and Violette, D. 1994. ''The Treatment of Outliers and Influential Observations in Regression-Based Impact Evaluation.'' *In Proceedings of the ACEEE 1994 Summer Study on Energy Efficiency in Buildings,* 8:171–176. Washington D.C.: American Council for an Energy-Efficient Economy.

Violette, D., Ozog, M,. Keneipp, M., Stern, F., and Hanser P. 1991. *Impact Evaluation of Demand-Side Management Programs, Volume I: A Guide to Current Practice*. EPRI.

XENERGY. 1995. *Northwest Commercial Evaluation Project: Draft Retrofit Report*. EPRI. (a)

XENERGY. 1995. *Performance Impacts: Evaluation Methods for the Nonresidential Sector,* edited by Violette, D., Keneipp, M., and Obstfeld, I. EPRI. (b)