Billing Analysis of HVAC Customized Rebates in the Nonresidential Sector

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Since July, 1990, Pacific Gas and Electric Company (PG&E) has administered a customized rebate program in the nonresidential sector. PG&E offers incentives up to $300,000 for nonresidential customers who take steps to significantly reduce their consumption of electricity or gas. More than 2,000 nonresidential customers participated in the customized rebate program during the first year of the program. Of these, more than 200 installed heating, ventilating, and air conditioning (HVAC) efficiency measures.

To estimate the savings attributable to the program, PG&E conducted a billing analysis of the HVAC customized rebate program participants. Included in this study were identification of matched non-participants, an on-site survey of both participants and non-participants, statistical modelling of the monthly bills of participants and non-participants on a building-specific basis, and comparison of the billing analysis results to the engineering estimates of savings contained in the rebate applications.

This paper reports on the results of this billing analysis, focusing on:

- Estimates of savings attributable to the HVAC customized rebate program that are identified through the billing analysis
- Comparison of the billing analysis savings estimates to engineering estimates of savings contained in the rebate applications
- Reconciliation of the two sets of estimates, including discussion of characteristics that explain identified differences.

The paper also includes a description of the methodology employed in the billing analysis.

Background

During 1990, Pacific Gas and Electric Company (PG&E) instituted customized rebate programs in the commercial, industrial, and agricultural (CIA) sectors to produce net avoided capacity, transmission, distribution, and energy costs. Customers select the energy efficiency improvements they wish to install, and submit an application to PG&E. After approval by PG&E, the measures are installed. PG&E pays incentives at the rate of $0.06 per kWh of expected (based on engineering estimates) first-year electric energy savings and $0.20 per therm of expected first-year gas savings. The maximum payment per application is $300,000 or 50 percent of direct project costs.

Heating, ventilating, and air conditioning (HVAC) efficiency improvements account for a substantial portion of the energy and demand savings in the customized rebate programs, especially for commercial and industrial customers. In the first year of program operations (July 1990 to June 1991) more than 200 of the 2,000 customized rebates PG&E paid to CIA customers were for HVAC efficiency improvements.

PG&E contracted with a private consulting firm to conduct a billing analysis of the CIA HVAC customized rebate participants. As part of this analysis, the consultant:

- recruited 150 participants to participate in the study, and conducted on-site surveys of these participants
- identified a non-participant match for each participant, and conducted on-site and telephone surveys of these customers

- analyzed the monthly billing data for each participant and its match using a multiple regression approach to estimate the annual savings attributable to the program for each participant

- compared the statistical savings estimates for the participants to the engineering estimates provided in the rebate applications.

This paper summarizes the methodology employed in the billing analysis (Methodology section), and the results of the billing analysis (Results section). Details about the statistical elements of the methodology are provided in an Appendix.

Methodology

The savings attributable to installations of HVAC efficiency measures were estimated by statistically analyzing pre- and post-installation monthly electric and gas bills, weather data, and detailed characteristics data for samples of program participants and non-participant controls. The sample design for the analysis is summarized in the Sample Design section, and the data development activities are described in the Data Development section. The statistical methods used in the analysis are summarized in the Data Analysis section and described in more detail in the Appendix.

Sample Design

Samples of participants and non-participants were surveyed and analyzed, as discussed further in the Effects of Other Changes on Statistical Savings Estimates section and the Other Factors Affecting Statistical Savings Estimates section. The sample of participants that was analyzed was selected in a straightforward manner. The approved applications for HVAC customized rebates were sorted according to the date PG&E issued the rebate check. Applicants were contacted in this order. The first 150 applicants who agreed to participate in the on-site survey (discussed in the Data Development section below) constituted the sample of participants.

For each surveyed participant, an attempt was made to identify and survey a non-participant match. The match for each participant was intended to reflect the "secular" (i.e., not related to major events that can be incorporated into a regression analysis) energy use trends (between the pre- and post-participation periods) the participant would most likely have experienced if it had not taken the conservation action for which it received a rebate. The match for each participant was in the same PG&E region and business type (six regions, 33 business types), and used the same fuels for space heating and air conditioning as the participant.

Potential matches for each participant were selected from previous PG&E commercial-sector surveys. If a match for a particular participant could not be identified from this source, potential matches were identified from the general population of PG&E nonresidential customers. If more than one potential match was identified for a single participant, the one with the annual energy consumption most similar to the participant was selected as the match.

Data Development

Three types of data were used in the savings estimation:

- Characteristics data

- Billing data

- Weather data.

The activities undertaken to develop these three types of data are described in the following paragraphs.

For each of the sampled participants, a detailed on-site survey/inspection was conducted. The following types of information were collected during each survey/inspection:

- Descriptions of the actions associated with the rebate, including the physical area affected by the rebate and the equipment that was both installed and removed in conjunction with the rebate

- Inspection of the rebated measures to verify that they were installed and are operated correctly

- The PG&E electric and gas accounts providing service to the area affected by the rebate

- Current characteristics of the facility, including floor area, an inventory of energy-using equipment, business types occupying the facility, and operating hours

- Descriptions of other conservation actions, renovations/remodels, and other major changes to energy-using equipment, between 1988 and 1991

- Changes in facility operating characteristics between 1988 and 1991, such as changes in business type, employment levels, operating hours, as well as periods of vacancy.

For each of the sampled non-participants who had not participated in a previous PG&E survey, a detailed on-site survey/inspection was also conducted. The same types of information were collected in these surveys as in the on-site surveys of participants, (including conservation actions they took on their own).

For each of the sampled non-participants who had participated in a previous PG&E survey, a telephone survey was conducted. This survey collected information about changes to the customer's facility or operations that had occurred during the 1988 - 1991 period, including conservation actions they had taken on their own.

For each sampled participant and non-participant, monthly electric and gas bills were obtained for all of the accounts associated with the facility's service address for the period January, 1988 - October, 1991. For facilities with multiple accounts for a single fuel, the accounts were aggregated, to form a single time series of monthly bills for each fuel and facility.

Finally, daily minimum and maximum temperature data were obtained for each of 21 weather stations in the PG&E service territory for the period January 1, 1988 - October 31, 1991. Each sampled participant and non-participant was assigned to a weather station. For each facility, heating and cooling degree days were calculated at various bases (25, 30, 35, 40 , 45, and 50 degrees Fahrenheit for heating; 35, 40, 45, 50, 55, 60 for cooling) for each of the facility's billing periods.

Data Analysis

Two approaches are frequently used to statistically estimate the savings attributable to energy efficiency programs, including programs in the nonresidential sector (Violette et al. 1991). The first approach is to calculate the difference between consumption in the year following participation and the year preceding participation for a sample of participants and, if possible, non-participants (Coates 1991; Dagang 1990). Consumption may be actual billed consumption, or weather-adjusted consumption computed using a method such as PRISM (Fels 1984). The difference between the two groups in the change in consumption between the pre- and post-participation periods constitutes the estimate of savings attributable to the program.

The second approach is to estimate a single regression equation using pre- and post-installation data for both participants and non-participants (Parti et al. 1991). The dependent variable in this regression is annual or monthly billed energy (possible divided by floor area); the explanatory variables include heating and cooling degree days, characteristics variables, and a variable representing program participation. The latter variable is equal to zero for non-participants, as well as for participants in pre-participation periods; it is equal to either one or expected savings for participants in post-participation periods. The estimated coefficient of this variable either constitutes or is used to calculate the estimate of savings attributable to the program.

When used to estimate the savings attributable to nonresidential programs, both approaches suffer from two shortcomings, which may lead to biased estimates of savings:

- Consumption in a particular nonresidential building varies substantially over time, due to a large number of factors in addition to changes in weather and program participation. The factors and their effects tend to be unique to the affected building. They are unlikely to occur in a control group, making use of such a group ineffective in controlling for these factors.

- Consumption varies substantially between nonresidential buildings, again due to a large number of factors. This makes selection of a control group that accurately reflects what the participants would have done in the absence of the program extremely difficult. In addition, only a few of these factors can typically be included in a cross-sectional or pooled analysis.

To overcome these two shortcomings, a new method was developed for this analysis. Details of this method are provided in the Appendix. The following paragraphs summarize the method.

For each of a sample of participants, the customer's monthly consumption was regressed on weather, variables representing program participation, and variables representing other changes that occurred at the building. Monthly data for the January, 1988 - October, 1991 period were used in the regression. Vacancies, changes in employment, equipment changes, and installation of other conservation measures that occurred at the building were included in the regression equation.

A number of alternative specifications of the regression equation were tried for each participant, with and without the program participation variables. The specification that produced the smallest regression mean square error was selected as the final regression. Thus, the variables representing program participation were only included in the final regression equation if they contributed in a

statistically significant (i.e., F-statistic greater than one) way to explaining the variation in the participant's monthly consumption.

Following estimation, the regression coefficients were used to compute the "gross" annual savings for the participant. This estimate of gross savings corresponds to the difference between the participant's post- and pre-rebate annual consumption, controlling for differences in weather as well as other changes that occurred at the building between the pre- and post-participation years.

For each non-participant match, a similar regression equation was estimated, again using monthly data for the January, 1988 - October, 1991 period. The regression equation for each match included weather and variables representing non-program changes (vacancy, employment, other conservation actions, etc.) that occurred at the non-participant building. In addition, it included variables representing program participation that were defined in exactly the same manner as these variables were defined for the matching participant. For example, if the matching participant's rebate action occurred in August, 1990, the variable representing program participation was equal to zero prior to August, 1990, and equal to one after August, 1990, in the equation for this participant and for its non-participant match. Again, several alternative specifications of the regression equation were tried, and the specification that produced the smallest regression mean square error was selected as the final regression.

Following estimation, the coefficients of the non-participant regression equation were used to estimate the "trend" savings (or dis-savings) for the participant. The trend savings estimate corresponds to the difference between the non-participant's annual consumption in the post- and pre-participation periods, controlling for differences in weather as well as other changes that occurred at the non-participant building between the pre- and post-participation years.

Finally, net savings were computed for groups of participants as the difference between the sum of the gross savings for the participants and the sum of the trend savings for the participants' matching non-participants. Prior to this subtraction, the aggregated trend savings were multiplied by the ratio of the participants' to the non-participants' consumption in the 12 months prior to the rebate actions.

Results

The savings estimates generated from the billing analysis are summarized in the Statistical Savings Estimates section. The Effect of Other Changes on Statistical Savings Estimates section addresses the influence that the presence of other changes by participants and nonparticipants has on the savings estimates. Other factors that appear to affect the billing analysis savings estimates, as well as the relationship between the engineering and statistical estimates of savings, are explored in the Other Factors Affecting Statistical Savings Estimates section.

Statistical Savings Estimates

Estimates of annual electricity savings are summarized in Table 1. For participants, the table provides engineering estimates and the statistical estimates from the billing analysis of "gross" (not adjusted for non-participants) savings. For non-participants, the table provides statistical estimates from the billing analysis of "trend" savings.

Table 1. Estimates of Annual Electricity Savings (MWh)

Statistic	Participants	Non-Participants
# Sites	117	88
Prior Year Usage	228,919	141,065
Engineering Estimate of Savings	10,879	-
% Reduction	4.8	-
Statistical Estimate of Gross/Trend Savings	-2,403	-501
% Reduction	-1.0	-0.4

For the 117 participants who installed measures affecting electric loads, the engineering estimate of annual savings was 10,879 megawatt-hours (MWh), or 4.8 percent of the consumption of these customers in the 12 months prior to their participation. Gross savings for these 117 participants were estimated in the billing analysis to be -2,403 MWh per year (i.e., consumption increased after participation), equal to 1.0 percent of previous-year consumption. For the 88 non-participant matches, trend savings were estimated to be -501 MWh per year, equal to 0.4 percent of consumption by these customers in the 12 months prior to their matching participants' participation.

Estimates of annual gas savings are summarized in Table 2. For the 20 participants who installed measures affecting gas loads, the engineering estimate of annual savings was 126,409 therms, equal to 20.9 percent of prior-year consumption. Gross savings for these participants were estimated in the billing analysis to be -55,935 therms per year, equal to 9.3 percent of prior-year

Table 2. Estimates of Annual Gas Savings (Therms)

Statistic	Participants	Non-Participants
# Sites	20	14
Prior Year Usage	603,199	490,588
Engineering Estimate of Savings	126,409	-
% Reduction	20.9	-
Statistical Estimate of Gross/Trend Savings	-55,935	84,039
% Reduction	-9.3	17.1

consumption. For the 14 non-participant matches, trend savings were estimated in the billing analysis to be 84,039 therms per year, which represents 17.1 percent of consumption by these customers in the 12 months prior to their matching participants' participation.

Effect of Other Changes on Statistical Savings Estimates

More than one-third of the participants installed other conservation measures, remodeled, renovated, or experienced major employment changes within one heating or cooling season of receiving the rebate under analysis. Similarly, one-third of the non-participant matches also experienced major events within one heating or cooling season of the time their matching participants received rebates. It was not possible statistically to distinguish between the effect of the rebate action and these other events, so the variables representing these other events were dropped from the analysis. The statistical estimates of gross/trend savings from the billing analysis for these participants and non-participants therefore include the effects of these other events.

Nearly one-half of the changes other than program participation that participants experienced within one heating/cooling season of participation caused electric consumption to increase (e.g., one-time employment increases, floorspace expansions, installation of additional equipment); the remaining changes were primarily installation of conservation actions. Conversely, nearly all of the changes experienced by non-participants within one heating/cooling season of their matching participants' rebate action caused consumption to decrease (e.g., one-time employment decreases, installation of conservation actions). (Interestingly, participants installed more conservation measures during the 1988 - 1991 period, not counting the rebate actions, than non-participants did.)

Table 3 summarizes the estimates of annual electricity savings separately for participants and non-participant matches (1) who did not make or experience any other change within one heating or cooling season of receiving the rebate and (2) who did make or experience such a change. For the 77 participants who did not experience other changes, gross savings were estimated in the billing analysis to be 1,775 MWh per year. This corresponds to 1.4 percent of previous-year consumption, or 27.0 percent of the engineering estimate of savings, for these participants. For the 58 non-participants who did not experience other changes, trend savings were estimated in the billing analysis to be -1,389 MWh per year, equal to 2.0 percent of previous-year consumption for these customers.

Table 3. Estimates of Annual Electricity Savings, by Presence of Changes Other Than Program Participation (MWh)

	Sites Making No Other Changes	
Statistic	Participants	Non-Participants
# Sites	77	58
Prior Year Usage	126,184	69,979
Engineering Estimate of Savings	6,567	-
% Reduction	5.2	-
Statistical Estimate of Gross/Trend Savings	1,775	-1,389
% Reduction	1.4	-2.0
% of Engineering Estimate	27.0	-

	Sites Making Other Changes	
Statistic	Participants	Non-Participants
# Sites	40	30
Prior Year Usage	102,735	71,086
Engineering Estimate of Savings	4,312	-
% Reduction	4.2	-
Statistical Estimate of Gross/Trend Savings	-4,178	888
% Reduction	-4.1	-1.2

Note: Changes include other conservation measures, remodels, renovations, or one-time major employment changes within one heating or cooling season of the rebate action.

The gross/trend savings estimates for these 77 participants and 58 non-participants were combined to generate an estimate of net savings for these 77 participants of 4,280 MWh per year. This corresponds to 3.4 percent of

prior-year consumption (1.4 percent gross savings plus 2.0 percent trend dis-savings), and 65.2 percent of the engineering estimate of annual savings, for these 77 participants.

For the 40 participants who did experience other changes within one year of participation, gross savings were estimated in the billing analysis to be -4,178 MWh per year, equal to 4.1 percent of prior-year consumption. Trend savings for the 30 non-participants who experienced other changes were estimated in the billing analysis to be 888 MWh per year, equal to 1.2 percent of consumption in the 12 months prior to their matching participants' participation.

Table 4 provides similar information concerning the estimates of gas savings. For the 12 participants who did not experience any other change within one heating season of the rebate, gross savings were estimated in the billing analysis to be 21,328 therms per year, which was 5.2 percent of prior-year usage. Trend savings were estimated in the billing analysis to be -1,606 therms per year for the 10 non-participants who did not experience other changes, equal to 0.6 percent of previous-year usage for these customers. Net savings were estimated to be 23,786 therms per year for these 12 participants. This corresponds to 5.8 percent of previous-year usage (5.6 percent gross savings plus 0.2 percent trend dis-savings), and 40.6 percent of the engineering estimate of savings for these participants.

Other Factors Affecting Statistical Savings Estimates

The other major factor affecting the savings estimates is the type of HVAC conservation measure installed. Table 5 compares the statistical and engineering estimates of annual electricity savings for the participants who did not make or experience any other changes, according to the type of HVAC conservation measure installed. The table shows that the statistical and engineering estimates vary less for measures involving replacement or significant modification to air conditioning equipment than measures involving changes to the building shell, ventilating equipment, or HVAC controls.

The ratio of statistical to engineering estimates may also vary according to other factors, such as geographic area (e.g., climate) or business type. However, there was not enough variation across these categories among participants with "clean" estimates to explore these relationships in a meaningful way.

Table 4. Estimates of Annual Gas Savings, by Presence of Changes Other Than Program Participation (Therms)

	Sites Making No Other Changes	
Statistic	Participants	Non-Participants
# Sites	12	10
Prior Year Usage	407,092	265,998
Engineering Estimate of Savings	58,545	-
% Reduction	14.4	-
Statistical Estimate of Gross/Trend Savings	21,328	-1,606
% Reduction	5.2	-0.6
% of Engineering Estimate	36.4	-

	Sites Making Other Changes	
Statistic	Participants	Non-Participants
# Sites	8	4
Prior Year Usage	196,107	224,590
Engineering Estimate of Savings	67,864	-
% Reduction	34.2	-
Statistical Estimate of Gross/Trend Savings	-77,263	85,645
% Reduction	-39.3	38.2

Note: Changes include other conservation measures, remodels, renovations, or one-time major employment changes within one heating season of the rebate action.

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Table 5. Estimates of Annual Electricity Savings, by Type of Measure Installed--Participants Making No Other Changes (MWh)

Statistic	Multiple Measures	Air Conditioning Only	Ventilation Only	HVAC Controls Only	Building Shell Only
# Sites	31	14	5	20	7
Prior Year Usage	32,625	22,055	28,720	25,550	17,234
Engineering Estimate of Savings	1,042	749	440	4,026	310
% Reduction	3.2	3.4	1.5	15.8	1.8
Statistical Estimate of Gross Savings	-280	215	16	1,698	126
% Reduction	-0.9	1.0	0.1	6.6	0.7
% of Engineering Estimate	-	28.7	3.6	42.2	40.6
Statistical Estimate of Net Savings	368	653	586	2,205	468
% Reduction	1.1	3.0	2.0	8.6	2.7
% of Engineering Estimate	35.3	87.2	133.2	54.8	151.0

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Appendix: Details of the Statistical Method

For each participant for which the rebated HVAC efficiency improvement affected electric loads, the following regression equation was estimated:

$$kWh_t = b_0 + b_1 * HDD_t + b_2 * CDD_t + b_3 * VACANCY_t + b_4 * EMPLOY_t + b_5 * UNEMP_t + b_6 * OTHEREB_t + b_7 * DUMMY1_t + b_8 * DUMMY2_t + b_9 * PROG_t + b_{10} * PROG\_HDD_t + b_{11} * PROG\_CDD_t \quad (1)$$

where

kWh_t = Electric consumption by participant during billing period t, divided by number of days in billing period t

HDD_t = Heating degree days at participant's weather station during billing period t, divided by number of days in billing period t

CDD_t = Cooling degree days at participant's weather station during billing period t, divided by number of days in billing period t

$VACANCY_t$ = Participant's vacancy rate during period t

$EMPLOY_t$ = Participant's employment during period t

$UNEMP_t$ = Unemployment rate in PG&E service territory during period t

$OTHEREB_t$ = Dummy variable representing other rebate received by participant, = 0 before other rebate, = 1 after rebate received

$DUMMY1_t$ = Dummy variable representing first other major change made or experienced by participant, = 0 before change, = 1 after change

$DUMMY2_t$ = Dummy variable representing second other major change made or experienced by participant, = 0 before change, = 1 after change

$PROG_t$ = Dummy variable representing installation of rebated measure by participant, = 0 before installation, = 1 after installation

$PROG\_HDD_t$ = $PROG_t * HDD_t$

$PROG\_CDD_t$ = $PROG_t * CDD_t$

$b_0 - b_{11}$ = Parameters to be estimated.

The parameters for each participant were estimated using only monthly observations between January, 1988 and October, 1991 of the dependent and explanatory variables for the participant. The parameters were estimated using standard econometric methods that correct for the autocorrelation of regression residuals usually observed in analyzing time series of monthly energy consumption.

Each of the variables VACANCY, EMPLOY, OTHEREB, DUMMY1, and DUMMY2 were included in the equation for a particular participant only if it was relevant to that participant, i.e., if the participant experienced periods of vacancy, variations in employment, received another rebate, etc. during the 1988 - 1991 period. In addition, the variables HDD and CDD were only included in the equation if electricity was used at the facility for space heating and air conditioning, respectively. Similarly, the variable PROG_HDD was only included if electricity was used at the facility for space heating and the rebated measure affected space heating loads (similarly for PROG_CDD).

Separate equations were estimated for each participant with and without each of the variables HDD, CDD, PROG, PROG_HDD, PROG_CDD, and UNEMP. The final set of explanatory variables for a participant was selected as the set whose equation explained the greatest proportion of the variation in the dependent variable. Similarly, the heating and/or cooling degree day bases for each participant were selected by estimating a separate equation for each base (or combination of bases), and selecting the base(s) whose equation explained the greatest proportion of the variation in the dependent variable.

For each participant for which the rebated HVAC efficiency improvement affected gas loads, a regression equation similar to Equation (1) was estimated, except that (1) the equation did not include the cooling degree day variables (CDD and PROG_CDD) and (2) the dependent variable was gas consumption in therms during the billing period divided by the number of days in the period.

Equation (1) was also estimated for each non-participant match. Each of the variables VACANCY, EMPLOY, OTHERREB, DUMMY1, and DUMMY2 were included in the equation for the non-participant only if it was relevant to that non-participant, i.e., if the non-participant experienced periods of vacancy, variations in employment, received a non-HVAC rebate, etc. during the 1988 - 1991 period. In addition, the variables HDD and CDD were only included in the equation if electricity was used at the non-participant facility for space heating and air conditioning, respectively.

For each non-participant, the variable PROG was defined identically to the way it was defined for the participant it matches. Prior to the participant's participation in the program, PROG was equal to zero for the non-participant match; following the participant's participation, PROG was equal to one.

Again, separate equations were estimated for each non-participant with and without each of the variables HDD, CDD, PROG, PROG_HDD, PROG_CDD, and UNEMP. The final set of explanatory variables for a non-participant was selected as the set whose equation explained the greatest proportion of the variation in the dependent variable. Similarly, the heating and/or cooling degree day bases for each participant were selected by estimating a separate equation for each base (or combination of bases), and selecting the base(s) whose equation explained the greatest proportion of the variation in the dependent variable for the non-participant.

Following estimation of Equation (1), and its gas variant, for each participant and non-participant, the estimated parameters were used to compute the annual gross savings for each participant as:

$$G\_SAV = -365 * (b_9 + b_{10} * AVG\_HDD + b_{11} * AVG\_CDD) \quad (2)$$

where AVG_HDD and AVG_CDD are the average (for the four years for which weather data were obtained) annual (per day) heating and cooling degree days for the participant, using the heating and cooling degree bases selected for the participant, and the other parameters are defined as in Equation (1).

Similarly, Equation (2) was applied to the parameters estimated for each participant's non-participant match, using the heating and cooling degree bases selected for the non-participant, to estimate the annual trend savings for the non-participant.

Finally, estimates of net savings were computed for groups of participants in four steps. First, the estimates of gross savings were aggregated across the participants. Second, the estimates of trend savings were aggregated across the non-participant matches. Third, the aggregate trend savings were multiplied by the ratio of (a) the sum of participants' consumption in the 12 months prior to their rebate actions to (b) the sum of non-participants' consumption in the 12 months prior to their matching participants' rebate actions. Finally, the "net" savings attributable to the program were computed as the difference between the results of steps 1 and 3.