1994 Impact Evaluation of PG&E's Commercial-Sector HVAC Energy-Efficiency Programs

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This paper presents the methodology and results of an impact evaluation of 1994 commercial HVAC measures installed through Pacific Gas & Electric Company's (PG&E's) retrofit energy-efficiency programs. The objective of the evaluation was to determine the total first-year gross and net impacts of all commercial retrofit HVAC energy-efficiency measures for which PG&E provided rebates in 1994. A combination of engineering and statistical analysis techniques was used to achieve this objective. The evaluation was PG&E's first to address commercial retrofit HVAC measures under the California Protocols[1].

The gross impact evaluation consisted of both engineering and statistical components. The statistical analysis of gross savings utilized billing histories and telephone survey data obtained from a sample of 450 program participants. The engineering sample comprised 139 participant sites which constituted a subset of the statistical sample. DOE 2.1E simulations of varying degrees of detail were developed for each of these sites. Data for these simulations were collected through on-site audits and short-term metering when appropriate.

Three techniques were used to estimate the net-to-gross ratio. The first technique was based on participant self-reports obtained from telephone surveys. The second technique was a statistical analysis which utilized billing histories and telephone survey data gathered from 450 participants and 450 non-participants. The third technique was a discrete choice analysis based on the telephone survey data. Estimates of net savings were derived by combining the net-to-gross ratios with engineering and statistical estimates of gross savings.

INTRODUCTION

Pacific Gas and Electric (PG&E) offers rebates to its commercial customers for the adoption of energy-efficiency measures that reduce HVAC energy consumption and demand in existing buildings. In 1994 rebates were delivered through PG&E's Retrofit Express and Retrofit Customized Programs. PG&E provided rebates for 2,108 commercial-sector HVAC projects in 1994. These 2,108 projects were installed at approximately 1,152 premises (a premise is loosely defined as contiguous facilities belonging to a single customer).

Measures included technologies such as high-efficiency chillers and packaged air conditioners, HVAC adjustable speed drives, conversions to variable air volume (VAV) systems, reflective window film, cooling towers, resized HVAC motors and compressors, energy management systems (EMS), and programmable thermostats. SBW Consulting, Inc. was retained by PG&E to determine the energy and demand impacts associated with PG&E's investment in these measures.

The objectives of this impact evaluation were to: (a) determine the first-year gross impacts (kW, kWh, and therms) of the 1994 commercial HVAC measures installed through PG&E's Customized and Express retrofit incentive program; (b) determine the first-year net impacts (kW and kWh) of the 1994 commercial HVAC measures installed through PG&E's Customized and Express retrofit incentive program; and, (c) identify the basis for discrepancies between the evaluation results and PG&E's estimates of program impact.

METHODOLOGY

Both engineering and statistical analysis techniques were used to estimate first-year gross and net savings. Information from on-site surveys, one-time power measurements, and short-term end-use metering was used to create DOE 2.1E models for 139 participant sites. These models were run to derive engineering estimates of gross savings. Billing histories and telephone survey data obtained from 450 participants were fed to a regression model to develop statistical gross savings estimates. With a few exceptions, the sample for the statistical model of gross savings was a superset of the engineering analysis sample.

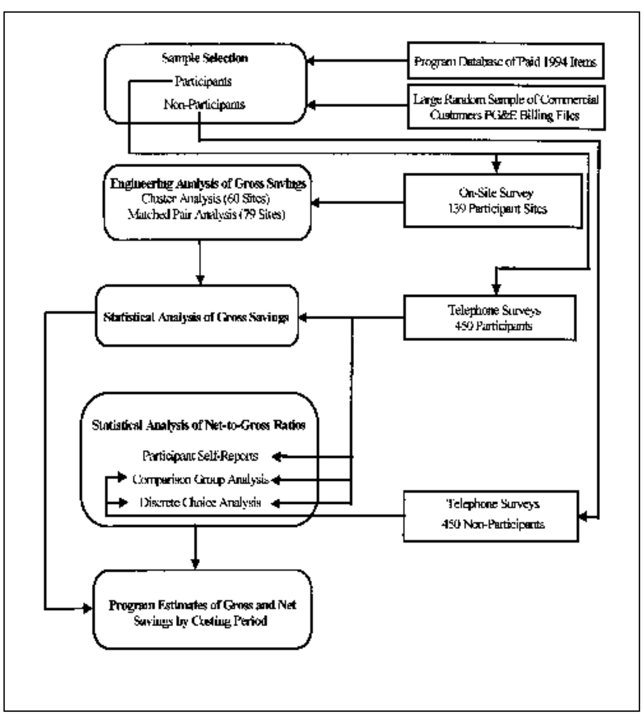
Net savings were estimated using three different approaches. The first approach was based on participant self-reports obtained from telephone surveys of 450 participating customers. The second approach was a statistical analysis which utilized billing histories and telephone survey data gathered from the same 450 participants and an additional 450 non-participants. The third approach was a discrete choice analysis based on the telephone survey data.

The flow of data through the analysis is graphically depicted in Figure 1. The methodology for each of these steps is described in more detail below.

Sources of Information

Data for both the statistical and engineering components of the evaluation were obtained from six sources: (1) PG&E Program Database, which provided a wide variety of information for each application processed by the program, including program estimates of savings for each project. (2) PG&E Program Files, consisting of paper files for each application, as well as additional documents, such as selected design drawings and equipment specifications, for certain applications. (3) PG&E Billing Files, which provided a history of monthly electric and gas consumption and electric peak demand for each affected account. This history provided benchmarks for calibrating the DOE 2.1E simulations, as well as inputs to statistical models for estimating gross savings and NTG ratios. (4) Weather Data the National Oceanic and Atmospheric Administration (NOAA) and PG&E. NOAA maintains seven long-term climatic measurement stations throughout PG&E service territory. PG&E maintains 33 stations that record temperature and relative humidity. Hourly data from these two sources provided actual and typical weather conditions for both the engineering and statistical analysis models. (5) Telephone Surveys, which collected data needed for the statistical analysis of gross and net savings and recruited sites for on-site surveys. Interviews were conducted with 450 participants and 450 non-participants. From both groups, a variety of information was collected about equipment stock, the efficiency of equipment added or replaced during the study period, whether the customer owns or rents the space, and any major changes during the study period that might affect energy. Participants also answered questions about how the PG&E rebate affected their purchases of efficient equipment. (6) On-Site Surveys, which provided information for the engineering analysis of gross impact. Surveyors gathered information about end use schedules, HVAC system configuration and operation, and envelope characteristics. There were two types of surveys, a more in-depth cluster survey, and a less detailed matched-pair survey. Surveyors at cluster sites also took one-time measurements of lighting and plug loads. Hourly end-use data recorders were installed for one to two weeks at five of the cluster survey sites.

Figure 1. *Data Flow for Impact Analysis*



Sample Selection

The study population for the 1994 Commercial HVAC retrofit program consists of those 2,108 projects included in applications with paid dates during 1994. However, by agreement with PG&E, 15 measures (comprising 104 projects) that collectively accounted for less than 5% of savings were eliminated from the study population. Projects with inadequate pre-retrofit electric billing history and those associated with sensitive customers were also removed, leaving a final study population of 1,646 projects.

In order to provide information useful for program design, the study population was divided into thirteen domains of study. Enhanced engineering estimates of gross savings for these domains were developed. Twelve domains were defined by specific measure. These are collectively referred to as the High Savings Domains, as they account for more than 80 percent of the program estimate of energy savings. All of the remaining measures are grouped in a single domain, referred to as the Other Measures domain. A stratified random sample of projects sufficient to complete on-site surveys for 139 sites and telephone surveys for 450 sites was drawn from the program database.

The statistical models used to estimate the Net-To-Gross (NTG) ratio required a non-participant sample of 450 sites. This sample was drawn from the population including all active 1994 commercial premises served by PG&E. Premises linked to control numbers associated with HVAC projects paid in 1994 were excluded from the sample, as were customers deemed to be sensitive by PG&E and customers who had been contacted for PG&E's evaluation of other retrofit measures.

Engineering Impact Evaluation

A building clustering approach was developed to leverage detailed information about one building by applying the information other similar buildings, thus maximizing the number of sites that could be analyzed. Prior to the on-site survey, the 139 sites chosen for the engineering impact evaluation were divided into two groups, a cluster group of 60 sites and a matched pair group of 79 sites. Sites in the cluster group received a more intensive on-site survey and a DOE 2.1E analysis calibrated to monthly bills. The initial analysis of the cluster sites was first completed, and then information from that analysis supported the matched pair analysis. An additional analysis was also performed to estimate the effect that rebated energy-efficient lighting had on HVAC impacts. These analyses are described in more detail below. The evaluation report (SBW Consulting, Inc., 1996, Chapter V) contains a full description of the engineering evaluation methodology.

Cluster Analysis. On-site surveys for the 60 cluster sites involved collecting data to characterize the as-built and pre-measure capacity, efficiency, and quantity of the measure-affected equipment. Surveyors also collected data on the type of HVAC system, operating schedule, control settings and other performance parameters, as well as the operating schedule for internal loads in the conditioned spaces served by the affected HVAC system, the power density of internal loads in those spaces, and the building envelope characteristics (conditioned floor area, number of floors, percent glazing, and glazing type). Survey information served two purposes: to provide inputs to a DOE 2.1E model, and to allow for correction of telephone survey measurement error.

Once the surveys were completed, the cluster sites were grouped into five sets according to key building characteristics. These groups were: (1) school, (2) retail, (3) hospital, (4) office with central A/C, and (5) office with packaged A/C. After the clusters were defined, one calibration site was selected from each of the five clusters. Using information from follow-up site visits and short-term end-use metering data, a site-specific DOE 2.1E model was developed for each of the calibration sites. These models were calibrated to 1994 weather, so that the simulations yielded HVAC use within 10% of a three-month summer HVAC target, maximum electric demand within 20% of billing data, and energy use within 10% of the bills for all fuels. From three of the five clusters, a test site was chosen. These three sites were used to test the impact of site specific envelope data on the estimate of savings for cluster sites. These sites were calibrated twice: as though they were a calibration site (except for end use metering) and as though they were a cluster site. Information from this test site analysis confirmed that DOE-2 modeling using a clustering approach yielded savings estimates reasonably close to those generated by detailed, site-specific DOE-2 models. For the three test sites combined, total savings in each case only differed by 11.7%.

Each of the remaining 52 cluster sites was matched with one of the eight calibration or test DOE 2.1E models, according to building and HVAC system characteristics. Key parameters in the model, such as thermal zoning, end-use schedules, and equipment efficiencies, were adjusted to match the cluster site characteristics. As-built consumption for each site was calibrated to within 10% of billed kWh and 20% of kW for a calibration period in 1994. After calibration, the cluster model was rerun using typical weather for the pre-condition, as-built, and when appropriate, Title 20 baseline cases. Gross savings were calculated by subtracting as-built consumption under typical weather conditions from pre-condition consumption.

Matched-Pair Analysis. On-site survey data for the 79 matched-pair sites were similar to those for the cluster sites, although with somewhat less detail about the specifics of the HVAC system. Based on data about building type, size, envelope characteristics and HVAC system type, each matched-pair site was paired with an appropriate cluster site. Key parameters of the DOE 2.1E model for that cluster site, such as HVAC schedules, setpoints, and glazing percentages, were then modified to reflect the matched-pair as-built and pre-measure conditions. As with the cluster analysis sites, gross savings were calculated by subtracting as-built consumption under typical weather conditions from pre-condition consumption.

Lighting Interaction Analysis. Of the 139 sites, 53 sites (comprising 70 projects) also received rebates for installing energy-efficient lighting measures during the study period. An analysis was performed to determine how much this efficient lighting affected estimates of HVAC measure savings. An additional on-site survey identified the extent of the rebated lighting that interacted with the HVAC measure(s) installed at the site. Based on this information, the original as-built and pre-condition DOE 2.1E models were modified to reflect the lighting in place prior to installation of the rebated lighting. These additional simulation runs yielded estimates of the HVAC impacts that would have occurred had efficient lighting not been installed.

Statistical Impact Evaluation

Statistical modeling techniques were used to prepare program-level estimates of gross savings and net-to-gross ratios.

Three techniques were used to estimate net-to-gross ratios: (1) participant self-reports obtained from telephone surveys, (2) comparison group analysis of billing histories and telephone survey data for 450 participants and 450 non-participants, and (3) discrete choice analysis. Estimates of net savings were derived by combining the net-to-gross ratios with engineering and statistical estimates of gross savings. An overview of the methods for correcting for measurement error, developing statistical gross estimates, and determining net estimates is presented below. The evaluation report (SBW Consulting, Inc., 1996, Chapters VI-IX) contains a full description of the statistical evaluation methodology.

Gross Impact. Various types of cross-sectional time-series model were estimated, beginning with a pool of 438 program participants who completed the telephone survey and whose data survived a variety of data screening activities. This pool also included 138 customers for which on-site surveys were completed. An important goal of this modeling effort was to use the best information available at the lowest level of aggregation.

The first specification incorporated separate engineering priors for HVAC installations. The advantage of this approach is that it attempted to use as much prior engineering information as possible. The information included the enhanced engineering priors provided by the engineering analysis as well as the engineering priors from the PG&E Program Database for measures not treated in the engineering analysis. The second specification, referred to as a mixed specification, used the enhanced engineering priors and dummy variables representing the other installations that did not receive new engineering analysis. This was done because there remained some concern regarding the amount of measurement error contained in these improved priors. The third model incorporated dummy variables indicating the installation of HVAC equipment. All three models included a variety of other data such as on-site and telephone survey data, data from the PG&E Program Database, economic data, and weather data. Neither the SAE nor the mixed models performed well. The third dummy variable model performed best and was used to develop the final statistical gross results.

Standard diagnostic checks were performed for outliers, heteroskedasticity, collinearity, and autocorrelation. Once the models were estimated, standard errors and confidence intervals around the impact estimates were calculated.

Net Impact. Three methods were used to estimate net-to-gross ratios and the associated net impacts of the HVAC efficiency measures. These three methods are as follows:

Participant Self-Report Analysis of NTG Ratio (Method 1): Telephone interviews of 450 participants were conducted in order to obtain self-reports on the effect of the rebates on their installations of energy efficient HVAC measures. The intent was to interview the person who played a role in the decision to participate in the program. This approach used stated intentions regarding the role played by the rebate in installing efficiency measures combined with additional consistency checks that overrode stated intentions where appropriate. The resulting net-to-gross ratio was weighted by avoided energy and capacity costs.

Comparison Group Analysis of NTG Ratio (Method 2): A non-equivalent control group design was used to estimate NTG ratios. This analysis compared billing histories associated with a sample of 450 participants and 450 non-participants to estimate how much energy consumption decreased after the program for participants compared to non-participants. These two groups are, in practice, never equivalent, because customers tend to self-select in the program. Until recently, the correction for self-selection has been the use of a technique developed by Heckman (1979) that involves the inclusion of, among other independent variables, an inverse Mills ratio which is used to mitigate the effects of self-selection. However, this traditional approach has been criticized in two simulation studies conducted by Train (1994) and Goldberg and Kademan (1995). All have concluded that this approach produced biased estimates while a nested logit approach produced unbiased estimates.

However, Goldberg and Train (1996) have recently suggested a specification that, while resembling very closely the traditional approach, appears to produce both unbiased and reasonably efficient estimates. This specification uses two inverse Mills ratios: 1) an overall Mills ratio for both groups, and 2) a participant-specific Mills ratio. We employed this specification to correct for self-selection bias. This approach involved the estimation of both a discrete choice participation model and a multivariate regression model of energy savings. A regression equation was estimated in which the change in consumption from before the program to after the program is the dependent variable.

Discrete Choice Analysis of NTG Ratio (Method 3): This technique is an alternative method of handling the self-selection bias observed in net estimation. For the commercial incentive programs, each customer has a choice among three options regarding an eligible measure: (1) implement the measure within the program, (2) implement the measure outside the program, or (3) do not implement the measure. The customer chooses the option that provides it with the greatest ''utility.'' The utility that the customer obtains from each option depends on the investment cost, energy savings, and other factors associated with the option. Participants are customers who choose option 1, while non participants choose either option 2 or 3. To estimate NTG ratios for this method, a discrete choice model using a nested logit model was developed. This model describes customers' choices among these three options, using data on the actual choices that participants and non-participants made during the program period. Such a model recognizes the correlations in unobserved factors over different options available to any given customer.

RESULTS

Engineering estimates of gross savings

Tables 1a, 1b, and 1c show estimates of annual gigawatt-hour (GWh), coincident peak-period megawatt (MW), and kilotherm (kTherm) savings and realization rates, respectively. These savings estimates are broken down by PG&E program and HVAC measure and assume baseline conditions meeting Title 20 limits. Overall, it was estimated that the 1994 HVAC Retrofit Program yielded gross savings of:

- 49.4 GWh (76% of PG&E's estimate of 65.1 GWh)
- 17.7 coincident peak-period MW (116% of PG&E's estimate of 15.3 MW)
- 971 kTherm (178% of PG&E's estimate of 545 kTherm)

The Retrofit Custom Program, which accounted for 54% of PG&E's estimate of program savings, had a much higher realization rate (90%) than the Retrofit Express Program (59%). GWh realization rates for each measure varied dramatically. They tended to be high (84%-103%) in the custom program, although the relative error was correspondingly high because of the small number sampled. Certain Express Program measures, most notably cooling towers (26%), evaporative coolers (7%), and reflective window film (30%), had especially poor GWh realization rates. For these three measures, the program data base consistently overstated estimated savings. Larger discrepancies exist with coincident peak-period MW and kTherm realization rates. In some cases, PG&E claimed little or no electric demand or gas consumption savings, when in fact, engineering evaluations indicated they were significant. For instance, evaluated HVAC energy management system (EMS) measure savings were 5.46 MW, compared to the 0.56 MW PG&E claimed.

The DOE 2.1E simulations also produced hourly demand estimates over one year for each of the 139 engineering analysis sites. Aggregating these estimates yielded a program savings hourly load shape. Table 2 shows these results broken down and summarized into five PG&E costing periods. The highest GWh savings, as well as average and maximum MW savings, occur during the summer on-peak costing period.

Although engineering estimates indicate the program underestimated kW savings, it should be noted that DOE 2.1E is

Table 1A. *Electric Consumption Savings Realization Rates by Program and Measure*

			GWh Savings		
Program	Domain	PG&E Data Base Values	Evaluated	Realization Rate	RE @ 90% CL
Custom		35.46	31.96	0.90	28.25
	Convert to VAV	3.23	3.01	0.93	71.53
	Gas Absorption A/C	0.00	0.00	—	0.00
	HVAC Adjustable Speed Drive	4.99	4.27	0.85	49.33
	HVAC Resize Motor/Compressor	9.35	9.66	1.03	84.11
	Install HVAC EMS	17.88	15.02	0.84	16.84
Express		29.64	17.40	0.59	17.40
	A/C: Central Air Cooled	1.58	1.02	0.65	23.94
	Adjustable Speed Drive: HVAC Fan 50 HP	2.66	5.66	2.13	39.15
	Cooling Tower	4.56	1.20	0.26	33.42
	Evaporative Cooler	2.65	0.20	0.07	54.78
	Other	6.91	2.49	0.36	55.29
	Reflective Window Film	3.00	0.90	0.30	40.19
	Water Chiller Air Cooled	3.70	1.92	0.52	42.34
	Water Chiller Water Cooled	4.59	4.01	0.87	28.84
Total		65.10	49.36	0.76	19.29

Table 1B. *Electric Coincident Peak Demand Savings Realization Rates by Program and Measure*

Program	Domain	PG&E Data Base Values	MW Savings Evaluated	MW Savings Realization Rate	RE @ 90% CL
Custom		2.64	9.18	3.48	23.07
	Convert to VAV	0.61	1.08	1.79	90.95
	Gas Absorption A/C	0.00	0.00	—	0.00
	HVAC Adjustable Speed Drive	0.00	1.19	—	46.68
	HVAC Resize Motor/Compressor	1.47	1.44	0.98	45.17
	Install HVAC EMS	0.56	5.46	9.74	30.52
Express		12.70	8.57	0.67	20.81
	A/C: Central Air Colled	1.56	1.04	0.67	32.73
	Adjustable Speed Drive: HVAC Fan 50 HP	0.00	1.43	—	36.19
	Cooling Tower	3.75	0.95	0.25	35.04
	Evaporative Cooler	0.98	0.19	0.19	64.06
	Other	0.13	0.83	6.60	79.42
	Reflective Window Film	1.05	0.74	0.71	36.64
	Water Chiller Air Cooled	2.34	1.78	0.76	79.13
	Water Chiller Water Cooled	2.89	1.60	0.55	26.24
Total		15.34	17.75	1.16	15.60

Table 1C. *Gas Consumption Savings Realization Rates by Program and Measure*

Program	Domain	PG&E Data Base Values	kTherms Savings Evaluated	kTherms Savings Realization Rate	RE @ 90% CL
Custom		544.85	814.40	1.49	48.98
	Convert to VAV	44.18	203.92	4.62	102.16
	Gas Absorption A/C	133.79	71.46	0.53	0.00
	HVAC Adjustable Speed Drive	0.00	−6.84	—	70.00
	HVAC Resize Motor/Compressor	0.00	0.00	—	0.00
	Install HVAC EMS	366.87	545.86	1.49	62.31
Express		0.00	156.81	—	97.30
	A/C: Central Air Cooled	0.00	4.40	—	152.53
	Adjustable Speed Drive: HVAC Fan 50 HP	0.00	−60.27	—	82.63
	Cooling Tower	0.00	0.00	—	99.81
	Evaporative Cooler	0.00	1.20	—	107.39
	Other	0.00	226.70	—	63.26
	Reflective Window Film	0.00	−15.35	—	89.20
	Water Chiller Air Cooled	0.00	0.00	—	0.00
	Water Chiller Water Cooled	0.00	0.12	—	77.65
Total		544.85	971.21	1.78	43.97

Table 2. *Summary of Evaluation Results by Costing Period (Title 20 Baseline)*

PG&E Costing Period	Annual GWh Savings	Average MW Savings	Maximum MW Savings	Hour of Maximum MW Savings	Hour of PG&E System Maximum	MW Savings Coincident with System Max
Summer On-Peak						
May 1 to Oct 31 12 PM–6 PM	6.54	8.26	10.30	5:00 PM	3:30 PM	9.81
Summer Partial Peak						
May 1 to Oct 31 8:30 AM–noon 6 PM–9:30 PM	6.50	8.21	9.60	12:00 PM	6:00 PM	8.85
Summer Off-Peak						
May 1 to Oct 31 9:30 PM–8:30 AM All day weekends	14.74	5.21	9.79	1:00 PM	10:00 PM	5.22
Winter Partial Peak						
Nov 1 to Apr 30 8:30 AM–9:30 PM	12.93	5.95	8.92	4:00 PM	6:00 PM	5.06
Winter Off-Peak						
Nov 1 to Apr 30 9:30 PM–8:30 AM	8.65	3.98	7.13	9:00 AM	8:00 AM	4.21
Total/Maximum	**49.36**	**5.63**	**10.30**	**5:00 PM**	**3:30 PM**	**9.81**

not a particularly good tool for estimating peak demand. DOE 2.1E simulations yield hourly demand results, while utility demand metering typically occurs at 15 minute intervals. The simulations cannot model very short-term energy consumption patterns, such as air conditioning equipment cycling on and off several times in an hour. Maximum peak demand often occurs over a very short period of time (less than an hour), when high loads for several end uses coincide. For example, the peak load in a building for a particular month might occur once that month for a twenty minute period, when most building lights are on, the HVAC system is operating at full load, and miscellaneous equipment (such as welding machines or process equipment) is in use. DOE 2.1E cannot always capture such short-term events, and thus does not always provide an accurate picture of peak demand.

Over a longer period such as a year, though, such fluctuations in demand tend to average out, so that DOE 2.1E can provide good estimates of annual consumption. Estimates for a period less than a year, consequently, may have higher uncertainty. For the costing periods above, the summer on-peak period estimates of savings might be expected to have the highest uncertainty, because the lowest number of hours occurs during that period. Conversely, the winter partial-peak and off-peak periods have the highest number of hours and thus the highest degree of certainty.

Table 3 shows how efficient lighting retrofits affected estimates of HVAC program savings. The engineering analysis of the effect of lighting on HVAC savings overall found the effect to be very small: savings increased 0.35%, 0.27%, and 0.77%, respectively. Savings increased, rather than decreased, because of the significant effect of HVAC fan measures, which typically show greater HVAC savings with reduced lighting loads. These fan measures showed an increase of savings of 3.6% with efficient lighting, more than offsetting the 3.2% reduction in savings for other lighting-affected HVAC measures.

Statistical estimates of gross savings

Both the engineering and statistical estimates of gross savings and realization rates are summarized in Table 4. The statistical analyses resulted in gross savings estimates of:

- 59.9 GWh (92% of PG&E's estimate of 65.1 GWh)

Table 3. Effects of Interaction between HVAC and Efficient Lighting, by Program

	GWh Savings			MW Savings			kTherm Savings		
Program	Post (with Eff. Lights)	Pre (without Eff. Lights)	% Diff.	Post (with Eff. Lights)	Pre (without Eff. Lights)	% Diff.	Post (with Eff. Lights)	Pre (without Eff. Lights)	% Diff.
Custom	31.96	31.80	0.52	9.18	9.08	1.10	814.40	808.38	0.74
Express	17.40	17.39	0.04	8.57	8.62	0.62	156.81	155.33	0.95
Total	49.36	49.19	0.35	17.75	17.70	0.27	971.21	963.71	0.77

- 16.8 MW (109% of PG&E's estimate of 15.3 MW)

The study did not attempt to estimate statistical gross therm savings. The corresponding statistical gross realization rate for annual energy consumption (the ratio of evaluation gross savings to program gross savings) is 0.92. The engineering analysis found that the primary reason for differences between program and evaluation savings estimates was discrepancies in assumed operating hours, rather than differences in equipment capacity. The engineering analysis, because it estimates demand more or less independently of operating hours, should yield a more accurate realization rate. Because of this, the statistical gross realization rate was adjusted upwards to 1.09 for MW to bring it in line with the engineering MW realization rate of 1.16. The statistical analysis of the lighting/HVAC interaction did not yield a statistically significant estimate of the interaction effect. Despite the relatively large sample size the billing regression model was unable to quantify the effect.

The net-to-gross ratios for the self-report and discrete-choice analyses were 0.57 and 0.55, respectively. To calculate the net-to-gross ratio for the billing regression analysis, By dividing the billing regression net savings were divided by the statistical-results by those of the billing regression gross savingsresults, yielding a net-to-gross ratio of 0.7065 was derived. The threeThe self-report and discrete-choice net-to-gross ratios were applied to both the GWh and MW billing regression estimates of gross savings to estimate net savings. The corresponding net GWh realization rates (defined as the evaluation estimate of net savings divided by the program estimate of net savings) were 0.73, and 0.71, and 0.90, respectively.

While the three net-to-gross ratios shown in Table 4 are not statistically different, they were produced by very different approaches, each with its own set of advantages and disadvantages. This is a classic case of triangulation in which the uncertainty surrounding a given estimate is reduced by obtaining additional points of comparison using complementary techniques. Thus, in the current study, while the uncertainty surrounding the individual estimates can be quite large, the uncertainty surrounding the ''true'' estimate is reduced by virtue of the strong agreement among the three estimates. These three estimates can be said to converge on the ''true'' estimate. Although the M&E Protocols do not allow NTG ratios based on self-reports, these NTG ratios can be used to provide a sanity check on those methods that are allowed by the Protocols. The self-report-based NTG ratio of 0.57 has clearly provided such a sanity check. While the discrete choice model, which examined the choices made by customers, was a somewhat unstable model, it did arrive independently at an estimate that was reasonably close to the other two. The billing regression analysis produced the highest NTG ratio estimate (0.70), but one that was still close to the Retrofit Customized and Express Program NTG ratios (0.75 and 0.67 respectively).

ENDNOTES

1. Also known as the ''Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand-Site Management Programs.''

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Table 4. Summary of Program-Level Evaluation Results

	Electric Usage		Electric Demand		Gas Usage	
	GWh/yr (9)	90% CI (1)	MW (9)	90% CI (1)	kTherms/ yr (9)	90% CI (1)
PG&E's PROGRAM DATA BASE						
Gross Savings	65.10	—	15.34	—	544.9	—
Net-to-Gross Ratio (2)	0.71	—	0.68	—	0.75	—
Net Savings	46.45	—	10.49	—	408.6	—
EVALUATION RESULTS						
Gross Realization Rate (3)						
Engineering	0.76	0.61 to 0.90	1.16	0.98 to 1.34	1.78	1.00 to 2.57
Statistical	0.92	0.72 to 1.12	1.09 (4)	—	—	—
Gross Savings						
Engineering	49.36	39.8 to 58.9	17.75	15.0 to 20.5	971.2	544 to 1398
Statistical	59.89	47.1 to 72.7	16.77	—	—	—
Net-to-Gross Ratio						
Self-Report	0.57	0.32 to 0.82 (5)	0.57	0.32 to 0.82 (5)	0.57	—
Discrete Choice	0.55	0.23 to 0.87	0.55	0.23 to 0.87	0.55	—
Billing Regression	0.70	−4.1 to 5.5	0.70	−4.1 to 5.5	0.70	—
Net Savings (6)						
Self-Report	34.14	—	9.56	—	553.6 (8)	—
Discrete Choice	32.94	—	9.22	—	534.2 (8)	—
Billing Regression	41.92	—	11.74	—	679.8 (8)	—
Net Realization Rate (7)						
Self-Report	0.73	—	0.91	—	1.35	—
Discrete Choice	0.71	—	0.88	—	1.31	—
Billing Regression	0.90	—	1.12	—	1.66	—

NOTES

1. Confidence interval (CI) at a 90% confidence level.
2. Assumes a net-to-gross ratio of 0.75 for Customized Program measures, 0.67 for Express Program measures.
3. Evaluation gross savings / program gross savings.
4. The statistical gross realization rate of 0.92 was adjusted upwards towards the engineering MW realization rate of 1.16 since the major reason for program/evaluation discrepancies was a difference in assumed operating hours.
5. This is an uncertainty range, rather than a confidence interval.
6. Based on statistical gross savings estimates.
7. Evaluation net savings / program net savings.
8. Estimates of net therm savings were derived by multiplying electrical net-to-gross ratios and the engineering estimate of gross savings.
9. These units apply to all number below except for realization rates and net-to-gross ratios.

Approaches.'' Report submitted by Xenergy to the California DSM Measurement Advisory Committee.

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