Impact Evaluation of Pacific Gas & Electric's Industrial Process, Refrigeration, and Miscellaneous Measures Programs

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This paper discusses the impact evaluation of Industrial Process and Miscellaneous measures for Pacific Gas & Electric Company's (PG&E) 1994 retrofit energy efficiency programs. The programs included industrial process, refrigeration, motors, and food service measures. This was PG&E's first evaluation of industrial process and miscellaneous measures under the constraints of the California Measurement and Evaluation Protocols. The evaluation addressed both gross and net impacts and was PG&E's largest evaluation to date to employ a ''project-specific'' engineering approach.

To determine gross impacts, projects were categorized into evaluation strata based on measure type, measure impact, and project-specific evaluation cost. Large impact projects typically received extensive project-specific evaluation, and smaller impact projects received simple verifications of installation. The net-to-gross analysis was project-specific as well, with each project in the evaluation sample receiving a project-specific net-to-gross analysis based on a series of customer interviews.

Evaluation results show gross realization rate of 0.75 to 1.25 for about half of the Retrofit Customized Program sites, indicating that site-specific analyses used during the application process provided reasonable accuracy. Retrofit Express measures not relying on site-specific analyses achieved realization rates in the 0.75 to 1.25 range less than 10 percent of the time. The net-to-gross analyses showed a high level of free ridership (about 50 percent). Larger projects had a greater tendency toward free ridership because customers were inclined to identify and implement these projects (for monetary savings or other strategic reasons) independent of motivation from PG&E.

INTRODUCTION

This paper summarizes results of a comprehensive impact evaluation of PG&E's 1994 Industrial Program activity (XENERGY 1996a, 1996b). The evaluation looked at industrial-sector applications of energy-efficiency measures in the end uses of process (including process boilers), refrigeration, motors, and food service. There were three primary objectives to this evaluation:

- Determine the first-year gross impacts (kW, kWh, and therms) for the industrial process, refrigeration, motors, and food service projects receiving incentives from PG&E in 1994.
- Compare the gross impact results to PG&E's estimates impacts and explain any discrepancies.
- Determine the level of free ridership among program participants.

The California Protocols (CPUC 1996) prescribe strict standards for the evaluation of measures in the process and motors end uses. Refrigeration and food service measures are categorized in the Protocols as ''miscellaneous measures'' and are therefore not subject to the same evaluation standards as process and motors measures. Because of their minimal relative impacts, however, motors measures were also considered ''miscellaneous measures'' for the purposes of this evaluation.

Table 1 presents PG&E's expected energy and demand impacts for the measure types included in the evaluation. As the table indicates, motor measures account for less than five percent of the electric energy and demand impacts of the four end uses. Table 1 also shows that the measures installed in the process end use account for approximately 80 percent the total impacts. For this reason, the evaluation focused, to a large extent, on the process end use. Process measures consist of varied measures related to changes in industrial processes, such as modifications to food processing systems, oil pumping systems, process boilers, compressors, pumps, dryers, and pollution control equipment.

The measures addressed in this evaluation were installed through two separate PG&E incentive programs:

The *Retrofit Express Program* provides incentives for commercial, industrial, and agricultural customers to ret-

Table 1. *Total Energy and Demand Impacts by Measure Type*

End Use	# of Projects	Annual kWh Amount	Annual kWh % of Total	Summer Peak kW Amount	Summer Peak kW % of Total	Annual Therms Amount	Annual Therms % of Total
Process	93	42,664,463	78%	6,286	78%	8,565,548	100%
Refrigeration	31	9,964,271	18%	1,424	18%	0	0%
Motors	486	2,019,675	4%	315	4%	0	0%
Food Service	2	3,105	0%	0	0%	0	0%
Total	612	54,651,514	100%	8,025	100%	8,565,548	100%

rofit their facilities with energy-efficient equipment from a pre-specified list of measures. Incentives are provided for equipment in the areas of air conditioning, agricultural, food service, refrigeration, lighting, and motors. All industrial motors and food service projects were installed through the Retrofit Express Program. A portion of the refrigeration projects were installed through the Retrofit Express Program.

The *Retrofit Customized Program* provides incentives to commercial, industrial, and agricultural customers to install custom-designed energy-efficiency measures. Measures covered under the Retrofit Express Program cannot be included in the Retrofit Customized Program. All industrial process projects and a portion of the industrial refrigeration projects were installed through the Customized Program.

METHODOLOGY AND KEY ISSUES

Industrial energy-efficiency projects, especially those in the process end use, present a number of challenges to assessing actual energy impacts. Due to the customized nature of these projects, there is little consistency between projects, even within a single program. The size, operating schedule, and seasonality of the industrial facilities vary considerably. To complicate matters further, the impacts of industrial energy-efficiency projects are often very small in comparison to the total energy usage of large industrial facilities such that project impacts cannot be determined through utility billing records. All of these factors combine to pose difficulties for the ''pooled'' billing analysis evaluation techniques commonly employed in residential and commercial evaluations. For these reasons, this evaluation employed a project-specific engineering approach to determine gross impacts (kW, kWh, therms). Project-specific engineering analyses and associated on-site data collection were conducted for a sample of projects. The gross impact sample was drawn from the total population of 1994 industrial process energy-efficiency projects (1994 projects[1]) and was focused on the largest projects in the population. The project-specific evaluation results for the gross impact sample were used to develop a gross realization rate which was then extrapolated to the population as a whole.

Under the Protocols, a net-to-gross analysis for ''miscellaneous measures'' is not required. Rather, a default value of 0.75 is allowed. For this reason, the net-to-gross analysis only addressed process measures. Consistent with the gross impact analysis methodology, the overall approach to the net-to-gross evaluation was to determine the level of free ridership on a project-specific basis. That is, every project in the sample received a project-specific free-ridership assessment. The results of the project-specific assessments were then weighted to determine free ridership for the program's process measures.

Gross Impact Methodology

The research design was based on the principle that most of the expected savings come from a minority of the sites. Evaluation, field, and analytical resources were therefore allocated to measure type segments and sites[2] based on their expected resource value. Avoided costs were used as the basis for the sample design. Three levels of project-specific evaluation were developed as follows.

Analysis Sites. Analysis sites received detailed project-specific analyses of energy and demand impacts, includ-

ing detailed on-site surveys, engineering analysis and/or modeling, on-site monitoring where appropriate, and extensive documentation and reporting. In general, the approach consisted of the following steps:

- review the application documents to identify the technological mechanism through which the savings are achieved;
- identify an analytical methodology based on accepted engineering principles that would evaluate the savings;
- identify the key operating assumptions or measurements required to use the methodology with confidence;
- determine the best way to confirm the measurements or assumptions;
- conduct the site work to gather the required information; and
- analyze the results and present the results.

Only process and refrigeration projects received this detailed level of analysis. To ensure that the evaluation covered the majority of the energy and demand impacts in the population, a census of the largest projects was included in the Analysis Site sample. (For each end use, the 75th percentile, based on expected savings, was used to identify large projects.) Additionally, a sample of smaller projects was included in the analysis site sample.

Intermediate Sites. Motors and smaller refrigeration sites received an intermediate level of evaluation. For those sites slated for evaluation, site-surveys were carried out at the sampled sites to verify installation. Spot amperage measurements and discussions with facility personnel were used to determine schedule and load profiles of the sample group.

Verification Sites. Verification audits consisted of simply verifying that the program measures were still installed and were being operated consistent with the energy savings claim that was provided to PG&E with the incentive application. Verification audits were attempted for all process projects not in the analysis site sample. No refrigeration nor motors sites were included in the verification sample.

Avoided cost was an initial indicator of the level of detail planned for the data collection and the depth of analysis required to define savings to a reasonable degree of precision, and hence the amount of project budget allocated to each site. The technology (measure) guides the technical approach to the site review and the method of analysis.

Table 2 summarizes the gross impact research design. As the table indicates, food service was dropped from the sample due to the relatively small impacts resulting from these measures.

Gross savings impacts for both PG&E's initial savings estimates and the independent evaluation analysis relied on engineering-based techniques. A primary focus of the evaluation was therefore to identify areas in which the evaluation could consistently improve on PG&E's initial impact estimates while still employing engineering-based methods. The evaluation achieved this by focusing project resources on four key areas:

- *Verifying Installation:* As a first step, the evaluation confirmed that the rebated measures were installed in a manner consistent with the program application.
- *Enhancing Analytical Methodology:* At the next level, PG&E's impact methodologies were reviewed for adequacy on a project-by-project basis. Where appropriate, the evaluation improved on this methodology. It is important to note that the focus of the evaluation was not simply one of reviewing PG&E's methodologies. Improving the quality of key parameters (as discussed in the next two bullets) proved to be equally or more important than modifying or enhancing PG&E's methodologies.
- *Collecting Post-retrofit Data:* According to the Protocols, program impacts are to be calculated at the post-installation level of service. Because they were calculated prior to the retrofit, PG&E's estimated impacts were necessarily based on forecast or assumed post-retrofit operating conditions. The evaluation, on the other hand, was conducted during the post-retrofit period, actual operating conditions and equipment usage patterns. This was a key area in which the evaluation work improved on the PG&E estimates.
- *Measuring/Monitoring Key Assumptions:* In many cases, PG&E savings estimates were based on assumptions about key operating parameters. During the evaluation, measurements of these parameters were made on a site-specific basis using equipment logs, metering, monitoring, and manufacturer's performance specifications.

A number of important issues had to be addressed in this evaluation. Three of the most important issues are as follows.

Table 2. *Research Design Summary*

End Use	Site Type	Sample # of Sites	Sample Avoided Cost	Sample % of End Use	Population # of Sites	Population Avoided Cost
Process	Analysis	46	$43,913,665	92%	85	$47,785,593
Refrigeration	Analysis	14	$4,321,956	82%	26	$5,269,478
Food Service	—	0	$0	0%	1	$447
Motors	Intermediate	20	$313,836	27%	156	$1,174,932
Total		80	$48,549,457	90%	268	$54,230,450

Defining the Baseline Technology. Gross energy and demand impacts are defined as the difference between energy and demand levels in the post-retrofit period and those represented by the basecase. The basecase is represented by the basecase equipment operating at the post-retrofit level of service. Identifying the appropriate baseline equipment is an important component of the analysis. In terms of net impacts, the basecase equipment is that which would be in place were there no program. For a free rider, the basecase equipment would simply be the post-retrofit equipment and energy and demand savings therefore would be zero. For the analysis of gross impacts in this evaluation, PG&E chose to consider the basecase equipment to be the same as was used in PG&E's original rebate calculation. This approach was chosen to provide PG&E with important feedback about the accuracy of their gross savings calculations for the given baseline. In cases in which an inappropriate baseline equipment was used for PG&E's initial savings calculations, the net-to-gross analysis was used to account for the difference between the baseline equipment and what would have occurred without the program.

Normalizing Results to Post-retrofit Service Levels. Consistent with the Protocols, energy and demand impacts for this study were normalized to reflect post-retrofit levels of service. For the normalization process, energy and demand impacts were related to some measure of site activity (such as production levels, operating hours, or air/fluid flow rates). Then, using this relationship, baseline energy consumption was adjusted to the post-retrofit activity level.

In some cases, this approach was relatively straight forward, especially when the project was a straight retrofit with relatively similar equipment capacities and site activity levels. The availability of pre-retrofit and/or on-site personnel knowledgeable about pre-retrofit conditions greatly facilitated this effort. Many of the rebate projects were associated with significant production/operating changes at the site, however. In some of these cases, baseline operating levels were extrapolated past the physical limits of the pre-retrofit equipment by associating the pre-retrofit energy intensity with the new production/operating level. The guideline followed during this normalization process was to establish an adjusted baseline that maintained the efficiency of PG&E's initial baseline technology (which was usually developed based on pre-retrofit operating levels) but scaled energy usage to post-retrofit service levels.

Annualization of Results. In many cases, equipment performance and operating conditions could only be observed or monitored over a relatively short time frame, whereas the impacts must be extrapolated to provide annual results. Similar to the normalization process, energy and demand levels (or impacts) per unit of output during the observation period was multiplied by annual values.

At times, operating records were available to assist in the annualization process. In other cases, hourly load models were used in the analysis to relate building energy use to typical meteorological year conditions. For some sites, however, annualization of savings was based on interviews with the customers, sometimes adjusted by additional engineering analysis. Annualization with limited data increased the uncertainty of the evaluation results.

Net-to-Gross Methodology

The net-to-gross analysis was conducted only for process measures and only for analysis sites. A separate net-to-gross ratio was estimated for each project based on a number of data sources, but relied most heavily on self-reports. The program net-to-gross ratio was calculated by averaging the

separate net-to-gross ratios weighted by the first-year avoided costs for each project. For this evaluation, spillover effects were assumed to be small relative to the primary program impacts, and the net-to-gross analysis focused on measuring the impacts of free ridership.

Net-to gross information was collected from three sources:

(1) *Application File Review:* The initial data source was from a review of the documentation in the PG&E hard copy file of the retrofits. Many of the files contain memos and other information that provide insight into the reasoning behind the retrofit and the decision process.

(2) *On-site Interview:* The second source of data was an informal discussion with facility staff during the on-site survey. The purpose of the on-site interview was to collect information regarding the background of the installation and potentially significant technical factors that may have influenced the project purchase decision. Additionally, the site visit was used to identify the name and contact information of the decision maker for the follow-up telephone interview.

(3) *Follow-up Telephone Interview:* The third source of information was a set of follow-up telephone interviews with the decision makers identified through the on-site interview. Although the survey instrument employed a small number of traditional net-to-gross questions, the telephone interview was for the most part conducted in an informal discussion type format. The individual survey instruments were customized for each project by using the project descriptions and preliminary net-to-gross data collected during the on-site surveys. The interviewers focused the discussion on the key issues concerning how, and to what degree, the PG&E rebate program influenced each project.

Based on the data collected from these three sources, a net-to-gross ''story'' was developed for each project in the sample. Based on these stories, each project received one of four net-to-gross classifications:

- *Pure Free Rider*: a participant who would have installed all program-related measures at the same time even without the program;

- *Partial or Incremental Free Rider*: a participant for whom PG&E did not use the appropriate basecase equipment in the estimate of gross impacts. That is, the customer would have installed something anyway, but not of the same efficiency or type as the rebated equipment.

- *Deferred Free Rider*: a participant who still would have installed program-related measures, but at a later date, if not for the program. Customers who would have installed measures anyway within a year were included in this category. Customers who would have deferred their projects more than one year were considered program-induced participants.

- *Program-induced Participant:* a participant who would not have installed the energy-efficiency measure in the absence of the program.

Net-to-gross values were assigned to each project based on these classifications. Pure free riders received a net-to-gross value of zero. The net-to-gross ratio for deferred free riders was based on the number of months that the project was moved forward due to the rebate. The net-to-gross ratio for incremental free riders was based on the ratio of energy and demand impacts based on PG&E's basecase equipment and that equipment that would have been installed in the absence of the program. Program-induced participants received a net-to-gross value of 1.0.

Key Issues. By nature, a net-to-gross analysis based on self reported data is prone to subjectivity and ambiguity. In practice, the distinction between a free rider and a program-induced participant can frequently be obscure. In many cases, there are elements of both program-induced participation and free ridership in a customer's decision to implement a single energy-efficiency project. Often numerous factors contribute to the decision to implement an energy-efficiency project rather than a single deciding factor. The evaluation attempted to limit this ambiguity in two primary ways:

- *Develop a Story:* Instead of relying simply on the answers to a limited number of generic questions, project-specific net-to-gross evaluations focused on developing the story behind the retrofit. This story was customized to each project and was based on the totality of information collected during the evaluation, not simply during the telephone interview. Other key parameters might include the life of the pre-retrofit equipment, the role of PG&E in identifying the retrofit equipment, the magnitude of the rebate amount compared to the rebate cost, and any facility-wide efficiency or related programs undertaken by the customer independent of the rebate program.

- *Reduce Uncertainty:* For projects that didn't clearly fit into one net-to-gross category or where inconsistent data was obtained from the multi-staged analysis, the follow-up telephone surveyor attempted to clarify the relevant issues during their discussion with the decision maker. Inconsistencies in the net-to-gross ''story'' were

brought to the decision maker's attention for purposes of reconciliation. For most sites, the decision maker was able to provide a clear indication of the appropriate net-to-gross ratio. In limited cases (especially where the original decision maker was not available) uncertainties in the appropriate net-to-gross ratio were addressed by averaging the possible net-to-gross estimates.

RESULTS

Gross impact results for the evaluation are presented next, followed by net-to-gross results.

Gross Impact Results

Table 3 presents aggregate energy and demand impacts and realization rates for the industrial-sector end uses covered in this evaluation. As these numbers indicate, the realization rate was highest for therm savings, followed by kWh savings and kW savings.

Table 4 provides a distribution of kWh realization rates by program delivery type (Customized vs. Express). The Customized Program was associated with a much higher percentage of projects with realization rates that were close to one. This demonstrates that the site-specific analyses used in the customized application process provided reasonable accuracy. Site-specific factors that differed from the Express Program average assumptions were the primary reasons for deviations in Express Program realization rates.

A primary objective of this study was to identify the basis for discrepancies between the evaluation results and PG&E's estimated impacts. As part of the site-specific analyses, key factors leading to discrepancies between evaluation results and PG&E's estimated impacts were identified. These factors are summarized in Table 5 and are discussed below in their relative order of importance.

Table 4. *Distribution of kWh Realization Rates*

Realization Rate	Program Type	
	Customized	Express
>1.75	8%	41%
1.26–1.75	8%	11%
0.76–1.25	**47%**	**4%**
0.25–0.75	25%	22%
<0.25	11%	22%

1. **Equipment/ System Performance Different from Projections.** PG&E's energy and demand estimates are based on predictions of how installed measures will perform. The evaluation was able to improve on the initial estimates by using actual versus assumed performance in savings calculations/models. The evaluation found that access to post-installation performance data was an important factor causing differences between the evaluation results and PG&E's impact estimates at 32 of the sites in the analysis sample. In the vast majority of these cases, equipment performance did not meet expectations.

Table 3. *Summary of Gross Impact Results*

Segment	Number of Program Sites	Annual kWh		Summer Peak kW		Annual Therms	
		PG&E Estimate	Realiz. Rate	PG&E Estimate	Realiz. Rate	PG&E Estimate	Realiz. Rate
Process	81	42,664,463	0.76	6,286	0.72	8,565,548	1.18
Motors	156	2,019,675	2.33	315	1.91	0	—
Refrigeration	26	9,964,271	0.75	1,424	1.62	0	—
Food Service	2	3,105	—	0	—	0	—
Totals	263	54,651,514	0.82	8,025	0.93	8,565,548	1.18

Table 5. *Summary of Discrepancy Factors*

Discrepancy Factor	# Sites
Equipment/system performance	32
Operating conditions	22
Production/service level	16
Operation hours	22
Different methodology	7
Secondary impacts	10
Inappropriate methodology	5

2. **Different Operating Conditions.** Different operating conditions reflect the fact that equipment is being operated in a manner that is different from initial PG&E assumptions. In many cases the desired outcome from the equipment does not change, just the strategy used to produce that outcome. Examples of different operating conditions include use of different chiller or economizer setpoints, different pressure setting for compressors, and different operation of upstream or downstream equipment. Different operating conditions were found to be an important factor for 22 sites in the analysis sample. Changes in operating conditions contributed to both under- and overestimation of impacts.

3. **Different Production Quantity/Level of Service.** This factor refers to the level of output required for the retrofitted equipment to perform the required function. For example, the level of cooling required for an associated production load might be different than assumed. This was found to be a factor at 16 sites.

4. **Operating Hours Different from Initial Assumptions.** An important part of the evaluation was to determine actual operating schedules. In a number of cases, these schedules differed from those initially assumed. For Retrofit Express Program measures, operating hours reflected typical building usage and could differ considerably from actual usage. Different operating hours were found to be a factor at 22 sites and contributed to both over- and under-prediction of energy and demand impacts.

5. **Evaluation Methodology Different than PG&E's Methodology.** The project-specific evaluations used the most appropriate analytical methodology available. In the majority of cases, the evaluation methodology was in some way different from that used by PG&E, either in overall methodological approach or in level of methodological detail. All told, the use of different and more detailed methodologies in the project-specific evaluations contributed to significant differences between the evaluation results and PG&E's estimated impacts in only seven cases.

6. **''Secondary'' Impacts not Estimated by PG&E.** For a significant number of projects, PG&E estimated the primary project impacts, but did not estimate ''secondary'' impacts. For example, PG&E's impact estimate might have addressed only kWh when there were significant kW impacts that should have been investigated. Another common example would be one where PG&E did not estimate the kW and kWh impacts of gas related projects. Secondary impacts were not an important factor in the evaluation. Only minimal impacts associated with 10 sites were found.

7. **Inappropriate Methodology.** Use of the inappropriate methodology affected savings estimates at nine sites. Inappropriate methodologies ranged from not considering all equipment affected by the rebate to use of simple ''percent savings'' calculations for complex processes. The inappropriate models consistently over-predicted savings at the five sites associated with this discrepancy.

Net Impact Results

The objective of the net-to-gross analysis is to determine what would have occurred without the PG&E programs. As discussed earlier, the net-to-gross analysis focused on estimating free ridership and looked only at process measures. The approach taken was a site-by-site assessment of free ridership using data from the program files, information collected during on-site surveys, and most importantly, data from telephone interviews of key decision makers.

As a result of the free rider assessment, site-specific net-to-gross ratios were estimated for 42 of the 46 analysis sites included in the gross savings study. (Decision makers at the other four sites could not be reached to complete the analysis.) For sites where there was some uncertainty about the net-to-gross ratio estimate, upper and lower bound estimates were developed. Table 6 presents net-to-gross ratios based on a simple average and on a weighted average of study respondents. Weights were based on first-year avoided cost savings to reflect relative project impacts.

Two important conclusions can be drawn from these results. First, significant free ridership was associated with the industrial process projects in the net-to-gross sample. Without

Table 6. *Summary of Net-to-Gross Results*

	Net-to-gross Ratio
Unweighted	0.68
Weighted	0.47

weighting, approximately 30 percent of the projects exhibited some level of free ridership. Second, the larger projects have a greater tendency toward free ridership. When avoided cost weights are applied to the results, the level of free ridership is more than 50 percent.

There are a number of reasons why larger projects might tend more toward free ridership. Large impact projects are commonly initiated by facility personnel as opposed to PG&E representatives. One reason for this is that, because of the potentially larger monetary savings, facility personnel are able to identify the project and develop an interest in it independent of PG&E. A second reason is that the largest impact projects are often very customized to the customer's process (as opposed to projects such as simply adding a variable-frequency drive on a process motor), and the utility simply may not have the expertise to identify these projects for the customer.

CONCLUSIONS

Ex-ante engineering estimates can be accurate predictors of energy and demand impacts under the right conditions. Realization rates were in the 0.75–1.25 range for about half of the customized program sites, indicating that the site-specific analyses employed during the application process provided reasonable but not overwhelming accuracy. Changes in post-retrofit operating conditions were the primary contributor to inaccuracies. For the Express measures, which did not use site-specific ex-ante estimates, realization rates were outside the 0.75–1.25 range more than 90 percent of the time. This demonstrates the importance of incorporating site-specific conditions into ex-ante savings estimates.

Different performance/operations limit the accuracy of ex-ante estimates. A large part of the errors in the ex-ante estimates occurred as a result of changes at the site. Often the rebated equipment was installed during a facility expansion, and the post-retrofit operating levels did not reach ''steady state'' until some months after the measures were installed. For these sites, the evaluation results were liable to differ considerably from the initial estimates. For some sites differences in equipment performance from initial assumptions were determined via on-site measurements during the evaluation. For these sites, a requirement for post-retrofit measurements as part of the rebate application could considerably improve initial savings estimates.

Free ridership is high and program design/implementation should investigate ways to improve net-to-gross levels. Customer representatives should work more closely with program participants to identify new ways to save energy. Reps should also try to determine if projects are so cost-effective that customers would install them even without rebates. In lieu of attempts to limit free ridership, PG&E should incorporate lower net-to-gross ratios into their planning process.

ENDNOTES

1. For the purposes of this evaluation, a ''1994 project'' is defined as one that received an incentive payment from PG&E in 1994. The installation dates for 1994 projects range from 1992 to 1994.

2. In the evaluation, sites refer to one or more program projects assigned to a PG&E control number.

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