Enlightened Lighting Evaluation Tightening Up the Process

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This paper presents a portrait of the integrated and comprehensive evaluation of Pacific Gas & Electric Company's (PG&E's) Commercial Lighting Program. The evaluation approach began with samples drawn to meet the evaluation objectives, and the Protocols of the California Public Utilities Commission (CPUC), while maximizing data points with good billing data available. The evaluation effort implemented an integrated data collection strategy that used Computer-Aided Telephone Interviews (CATI) to collect data and schedule on-site audits. The on-site audits verified measure installation, collected evaluation data, placed lighting loggers and recorded startup date and placement location, and identified fixtures for a long-term retention base line study. On-site audits were conducted using pen-top data collection instruments for direct data entry. Data were downloaded nightly, via modem, for progress verification and data quality monitoring. This strategy improved data quality and simplified assembly of the final analysis dataset. The lighting evaluation results were reported by business segment and technology, allowing PG&E to identify successful business segment/technology combinations. This paper focuses on the integrated approach, final evaluation results, and identification of strength and weaknesses of the evaluation and program designs. This strategy has been successfully implemented here, with positive benefits for the quality of the results and improvement in their applicability for program planning and design.

INTRODUCTION

As the utility world becomes more competitive, and DSM programs fit firmly into their place as part of the long-term portfolio of economically viable services offered by utilities, cost-efficient integrated monitoring and evaluation strategies are developing to fill a multitude of data and information needs. This paper covers the impact evaluation of the commercial lighting technologies offered under the 1994 PG&E Commercial/Industrial/Agricultural (CIA) Retrofit Programs[1]. These technologies are covered by two separate program options, the Retrofit Express (RE) Program and the Customized Incentive (CI) Program. These programs are summarized below.

The PG&E Retrofit Express Program

The RE program offered fixed rebates to customers who installed specific gas or electric energy-efficiency equipment in their facilities. The program covered the most common energy saving measures, and spans lighting, air conditioning, refrigeration, motors, agricultural applications, and food service. Customers were required to submit proof-of- purchase with these applications, in order to receive rebates. The program was marketed primarily to small- and medium-sized commercial, industrial, and agricultural customers. The maximum rebate amount, including all measure types, was $300,000 per account. No minimum amount was required to qualify for a rebate. Specifically, the program offered rebates on the following technologies:

- Halogen lamps replacing existing lamps
- Compact fluorescent lamps replacing incandescent lamps
- Compact fluorescent and LED lamps replacing incandescent lamps in exit signs
- Electronic ballasts replacing electromagnetic ballasts
- Delamping with optical reflectors
- T8 lamps and electronic ballasts replacing T12 lamps and electromagnetic ballasts in various lengths and configurations
- High intensity discharge (HID) fixtures replacing incandescent or mercury vapor fixtures
- Installation of occupancy sensors, bypass or delay timers, photocells, and time clock controls for lighting applications

The PG&E Customized Incentives Program

The CI program offered financial incentives to customers who undertook large or complex projects that save gas or electricity. These customers were required to submit calculations for projected first-year energy savings with their applications and prior to installation of the project. The maximum incentive amount for the CI program was $500,000 per account, and minimum qualifying incentive was $2,500 per project. The total incentive payment for kW, kWh, and therm savings was limited to 50% of direct project cost for retrofit of existing systems. Since the program also applied to expansion projects, the new systems incentive was limited to 100% of the incremental cost to make new processes or added systems energy efficient. Customers were paid 4 cents per kWh, and 20 cents per therm for first-year annual energy savings. A $200 per peak kW incentive, and a $50 per peak kW early completion (October 31, 1994) bonus for peak demand savings required that savings be achieved during the hours PG&E experiences high power demand.

As a result of program design, many of the measures installed were similar to or the same as those for the RE program, but were installed in larger and more complex projects.

EVALUATION OVERVIEW

The impact evaluation described in this paper covers all lighting measures installed at commercial accounts, as determined by PG&E's Management Decision Support System (MDSS) sector code, which were included under the RE and CI programs, and for which rebates were paid during calendar year 1994.

The impact evaluation resulted in both gross and net impacts, and compares these estimates to the program design estimates.

Objectives

The objectives of the evaluation were as follows:

- Determine first-year gross energy and demand impacts for RE and CI lighting technologies paid in 1994, by technology and business type, and overall impacts for commercial and industrial sectors
- Investigate and explain differences between evaluation and program design estimates
- Assess free-ridership rates, and investigate and explain differences between evaluation and program design estimates
- Assess spillover rates, and investigate and explain differences between evaluation and program design estimates
- Provide recommendations to strengthen the realized impact of the RE program
- Create a panel of participants for future monitoring of equipment retention in Commercial and Industrial sectors.

Results are segmented by technology and building type. Technologies are defined by measures offered by the RE and CI programs. Building segments for the commercial market sector, as defined by PG&E, are office, retail, college and university, schools, grocery, restaurant, health care, hotel/motel, and warehouse.

The difference between gross and net impacts is the behavior of the participants that affected their decision to participate. Adjustments were made to the gross estimate of savings for customers who would have installed energy-efficient measures anyway, despite the program (free-riders), and customers who installed energy efficient measures as a result of the presence of the program, resulting in savings that were beyond the program-related gross savings of the participants (spillover).

The evaluation investigated and, where possible, explains differences between program design estimates and evaluation results. This analysis resulted in recommendations for improving program design estimates (*ex ante*), which should, in turn, result in post-implementation evaluation savings (*ex post*) that are closer to *ex ante* estimated savings.

Role of Protocols

This evaluation was conducted under the rules specified in the ''Protocols and Procedures for the Verification of Cost, Benefits, and Shareholder Earnings from Demand Side Management Programs'' (the Protocols) as approved by the CPUC. The Protocols controlled most aspects of the evaluation. They specify the minimum sample sizes, the required precision, data collection techniques, certain minimum analysis approaches, and formats for documenting and reporting results to the CPUC. This evaluation endeavored to meet all Protocol requirements and, where possible, enhance evaluation techniques and results to supply added value for the design of future programs.

METHODOLOGY

This paper presents details of the evaluation approach, beginning with an overview of data sources and methods. This is followed by a discussion of the gross impact analysis. Gross impacts are derived through an integrated engineering and statistical analysis. Finally, the approach to estimating program net-to-gross (NTG) results is discussed.

DATA SOURCES

There were two types of data sources for this evaluation, PG&E supplied data and newly gathered evaluation data.

Existing PG&E Data

The PG&E C/I Lighting Evaluation approach used all data currently available, in particular PG&E's historical billing data, program participation data or MDSS, other program-related data, and industry standards information.

- *Program Participant Tracking System.* The participant tracking system data, maintained in the PG&E MDSS, contain program project information, and technical information about measure installation. It also provides expected impact estimates based upon the *ex ante* engineering algorithms. This information is used to create sample designs for data collection and leverage impact estimates from the telephone sample to the entire participant population.

- *Program Marketing Data.* PG&E program marketing data contain detailed descriptions of program marketing and application procedures, together with details on the measures offered. This data source also provides a general description of measures accepted by the program.

- *PG&E Billing Data.* The PG&E nonresidential billing database contains monthly energy-consumption information for all C/I customers in the PG&E service territory. It also contains demographic data for all customers, and the on-peak and off-peak monthly energy usage for customers who receive services on demand or time-of-use (TOU) rates. This information is used to calibrate the engineering estimates to actual pre- and post-installation energy usage.

- *Annual Earning Assessment Proceedings (AEAP) Report.* The AEAP Report documents the *ex ante* savings claims, including specific information on the derivation of per-unit *ex ante* savings estimates and the assumptions that go into those estimates. This documentation often includes assumptions such as operating hours and operating factors, by fixture type. This document supplies the best information available on *ex ante* estimates and assumptions, thus facilitating knowledge-based comparisons to *ex post* estimates.

- *Industry Standards/Information.* In order to establish baseline levels and new equipment performance levels, industry standards information from organizations such as the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) and American National Standards Institute (ANSI) was used, together with information from manufacturers.

New Data from Evaluation Surveys and Metered Data

For lighting in the RE and CI programs, the impact analysis plan is based upon a nested sample design, with a core of lighting-loggered sites supplying calibration for the on-site sample, and the on-site audit sample being leveraged with a larger, less expensive, telephone survey. Data between these samples are leveraged through ‘‘overlapping items’’ between the telephone and on-site instruments. The MDSS database, using program application information, is used to leverage results to the entire participant population. This approach, as shown in Figure 1, results in efficient use of all information contributing to the final impact results.

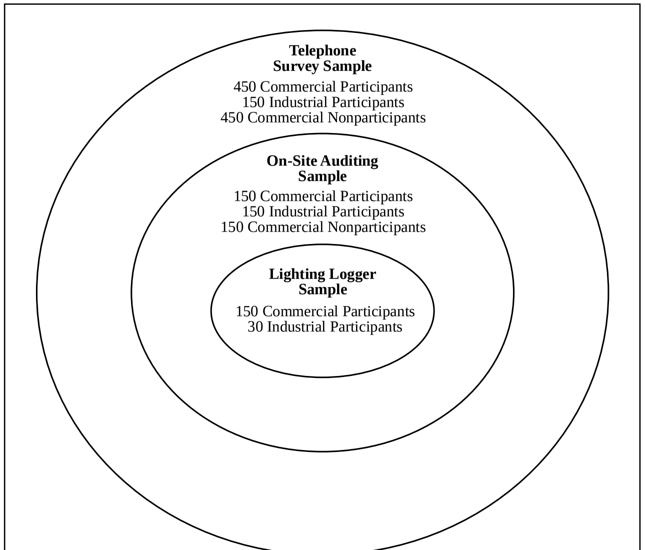
- The lighting logger data (represented by the innermost circle in Figure 1) supply the most accurate source of data for calibration of the engineering estimates. This metering registers the time and date the monitored fixture is turned on or off, for periods of up to two months in length. This information allows calibration of self-reported operating hours data collected during the telephone survey. In addition, it supplies operating information related to hours when facilities are closed, which cannot be collected during the on-site audit. When the lighting loggers are placed, one-time fixture operating wattage measurements (spot watt) are taken to confirm power consumption estimates of the operating fixtures.

- A relatively small on-site auditing sample (represented by the band around the innermost circle in Figure 1), is designed to support the telephone sample for the largest participation segments. This sample contributes equipment details that are site-specific, and better estimates of operating hours, operating factors, equipment efficiency, lamp burn-out rates, missed opportunities, and other technical factors that are difficult to collect over the telephone. The on-site sample is not designed to be statistically representative but to support the estimate of engineering parameters for the highest impact segments.

- A significantly larger telephone survey sample (represented in Figure 1 by the second band from the center), is designed to be representative of the participant population in terms of technology and business type. The telephone survey supplies information on participant decision-making, energy-related changes at each site for the billing period covered by the billing analysis, and data for estimating the NTG adjustments. The comparison group telephone surveys supply information on

- The engineering algorithms are calibrated to lighting logger data (to assess when the fixtures in the building are in use), and weekday operating factors collected based upon the number of lamps operating at the time of each on-site audit. In addition, data collected during the nonparticipant on-site audits, covering burned-out lamp rates and existing equipment saturation, are used to adjust engineering savings estimates.

Figure 1. Nested Sample Design Approach



- For smaller impact segments in which metered and on-site data are inadequate or present an obviously biased result, estimates are transferred from a similar segment, or industry standards are used for operating factors and average fixture wattage.

- The first step in estimating gross demand impacts is to estimate the per-unit demand impacts for each program segment. These represent savings achieved by prescribed conversion measures, assuming that single fixtures operate according to operating factors for installed equipment and the building schedule.

- Per-unit demand impacts are combined with the number of units installed, according to the participation matrices, to form the evaluation demand estimates for each segment. These results yield the estimated gross peak-demand impact for the program. They are presented as

Table 1. *Summary of Gross Evaluation Results Commercial Indoor and Outdoor Lighting Applications*

		Gross Impacts			
		Energy		Demand	
Program and Technology Group	Number of Units Paid*	(MWh)	Realization Rate	(kW)	Realization Rate
Indoor Total	2,826,393	277,688	0.99	62,389	1.19
Outdoor Total	16,363	18,058	0.87	782	6.31
Indoor and Outdoor Total	2,842,756	295,746	0.98	63,172	1.20

*Number of units paid refers to the number of measures installed: fixtures, ballasts or lamps.

- The *ex post* gross impacts equaled the *ex ante* gross estimate for energy, and exceeded it for demand. This is primarily the result of higher operating factors (as determined by field inspections), in conjunction with the inclusion of the HVAC interaction savings due to the more efficient lights, in the *ex post* impacts.

Table 2 and 3 present the net energy and demand impact results, together with the net realization rates, at the same levels presented in Table 1.

The net *ex post* energy impacts exceed the net *ex ante* design estimates by 39 percent for energy, and 73 percent for demand. To a certain extent, these results reflect the high gross realization rates, but they are really driven by the *ex ante* and *ex post* NTG ratios. The net to gross adjustments apply equally to energy and demand impacts, since they represent behavioral affects on the decision to purchase energy-efficient equipment. Thus the following points apply equally to Table 2 and 3.

Table 2. *Summary of Net Energy Results Commercial Indoor and Outdoor Lighting Applications*

		NTG Adjustments			Net	
Technology Group	Gross Impact (MWhr)	Free Ridership Adjustment (1-FR) (Unitless)	Participant Spillover Adjustment (Unitless)	Non-participant Spillover Adjustment (Unitless)	Net Impact without NP Spillover Adjustment (MWhr)	Net Impact with NP Spillover Adjustment (MWhr)
			Ex Ante			
Indoor Lighting	280,492	0.67	0.10		215,979	
Outdoor Lighting	20,756	0.67	0.10		15,982	
Indoor & Outdoor Lighting	301,248	0.67	0.10		231,961	
			Ex Post			
Indoor Lighting	277,688	0.70	0.20	0.19	249,919	302,680
Outdoor Lighting	18,058	0.77	0.20	0.10	17,516	19,322
Indoor & Outdoor Lighting	295,746	0.70	0.20	0.18	267,435	322,002
			Realization Rates (ex post/ex ante)			
Indoor Lighting	0.99	N.A.	N.A.	N.A.	1.16	1.40
Outdoor Lighting	0.87	N.A.	N.A.	N.A.	1.10	1.21
Indoor & Outdoor Lighting	0.98	N.A.	N.A.	N.A.	1.15	1.39

Table 3. *Summary of Net Evaluation Demand Results Commercial Indoor and Outdoor Lighting Applications*

		NTG Adjustments			Net	
Technology Group	Gross Impact (MWhr)	Free Ridership Adjustment (1-FR) (Unitless)	Participant Spillover Adjustment (Unitless)	Non-participant Spillover Adjustment (Unitless)	Net Impact without NP Spillover Adjustment (MWhr)	Net Impact with NP Spillover Adjustment (MWhr)
Ex Ante						
Indoor Lighting	52,428	0.67	0.10		40,370	
Outdoor Lighting	124	0.67	0.10		95	
Indoor & Outdoor Lighting	52,552	0.67	0.10		40,465	
Ex Post						
Indoor Lighting	62,389	0.70	0.20	0.21	56,150	69,252
Outdoor Lighting	782	0.77	0.20	0.20	759	915
Indoor & Outdoor Lighting	63,171	0.70	0.20	0.21	56,909	70,167
Realization Rates (ex post/ex ante)						
Indoor Lighting	1.19	N.A.	N.A.	N.A.	1.39	1.72
Outdoor Lighting	6.31	N.A.	N.A.	N.A.	7.94	9.58
Indoor & Outdoor Lighting	1.20	N.A.	N.A.	N.A.	1.41	1.73

- The *ex ante* NTG ratio was between 0.70 and 0.77, depending upon the business segment and technology, averaging about 0.76.

- The *ex post* NTG ratio for combined indoor and outdoor lighting averaged 1.08.

- When 1.08 is divided by 0.77, it results in an average 40 percent increase in realized savings.

- Free ridership rates were low for these programs, contributing a 17 percent overall reduction in energy and demand impacts.

- Participant spillover rates offset the free ridership to a small extent, contributing an average of 3 percent increase in impacts

- Nonparticipant spillover effects were detected in this evaluation, contributing a an average 18 percent increase in estimated savings for the combined indoor and outdoor impacts measured for the combined lighting programs.

Table 2 illustrates the following key points about the net commercial lighting energy impact results:

- The *ex post* net energy impact exceeded the *ex ante* net impact by 39 percent.

- A significant factor in the high *ex post* NTG ratio is nonparticipant spillover, which increased the NTG ratio by 18 percentage points. While this spillover effect is documented and believed to be appropriate, net realization rates without nonparticipant spillover are still 1.16.

Table 3 presents the net demand savings results, together with the net realization rates, at the same levels presented in Table 1.

These results illustrate the following key points about the net commercial lighting demand impact results:

- The net *ex post* energy impacts exceed the net *ex ante* design estimates 73 percent for demand. Like the energy estimates, a significant factor in the high *ex post* NTG ratio is nonparticipant spillover, which increased the NTG ratio by 18 percentage points.

- These high savings estimates reflect not only the high NTG ratios, but the conservative *ex ante* design estimates. The high operating factors that the evaluation identified in the commercial sector, and the inclusion of the HVAC savings in the *ex post* evaluation impacts, contributed to the high net demand savings.

- The high realization rates for outdoor lighting demand are a result of the on-site inspections identifying outdoor lighting that was operating during the day, and thus on-peak. The *ex ante* projections assumed very little outdoor fixture on-peak operation, and thus claimed very small on-peak impact. This resulted in division of the small impact found during the evaluation by a very much smaller *ex ante* value, yielding high realization rates.

FINDINGS

The key findings are summarized as follows:

- High NTG ratios combined with low program design NTG estimates to significantly increase net realized savings. This finding resulted from relatively low free-ridership rates in conjunction with significant participant and nonparticipant spillover.
- For the majority of business types and technologies, hours of operation and operating factors exceeded the *ex ante* estimated values by a significant margin. This was the main factor contributing to many high gross realization rates.
- The high participation technologies of T8/electronic ballast, optical reflectors with delamping, and HID replacement of less efficient technologies yielded strong realized savings.

ENDNOTES

1. The entire study covering the subject of this paper is available through PG&E by contacting Elsia Galawish at PG&E. Copy costs will be charged.