Commercial Facilities Contract Group
2006-2008 Direct Impact Evaluation

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Final Report

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ABSTRACT

The Commercial Facilities Contract Group evaluated two market-sector focused incentive programs (PGE2005 and PGE2007) and to two high-impact measures, a.k.a. "HIMs" (strip curtains and door gaskets in refrigerated reach-in coolers and warehouses). The overall objective was to determine the gross and net electricity and natural gas savings and demand (kW) reduction resulting from participation in the programs during the 2006 through 2008 program years. All gross impact results were based upon CPUC approved evaluation methodologies, policies and procedures for best practices. Net impact results were based upon customer self-report interviews on net-to-gross issues.

This report first presents the evaluation methodology and energy impact results for PG&E's High Tech (PGE2005) and Large Commercial (PGE2007) customer segments. The programs claimed savings through equipment retrofit, retrocommissioning and new construction activities with particular emphasis on providing design assistance for installing custom energy efficiency measures. Stratified random samples of participant sites were chosen from each program and primary data were collected and analyzed for the selected sites to determine gross savings. A survey of decision-makers was conducted to gather information with which to determine the net impacts. The sample was designed to achieve relative precision of 10% at the 90% confidence level for kWh savings. All gross impact results were based upon CPUC approved evaluation methodologies, policies and procedures for best practices including retrofit isolation engineering models and building energy simulation models that were calibrated to site-specific data. Net impact results were based upon customer self-report interviews.

This report also presents the evaluation methodology and statewide energy impacts results for two "high-impact" measures, door gaskets and strip curtains—that targeted energy savings in commercial facilities by reducing the infiltration of warm air from non-refrigerated spaces into reach-in coolers, freezers and refrigerated warehouses. The evaluation effort for the HIMs involved identifying the factors affecting infiltration, collecting data through field monitoring of freezers and coolers in different types of commercial facilities, and analyzing these data to determine how program-induced replacement of door gaskets and strip curtains affected infiltration and energy use.

A total of 41 projects were evaluated for the PG&E Hi-Tech Program and 61 projects were evaluated for the PG&E Large Commercial Program. The PGE2005 program achieved a gross realization rate for kWh of 0.446 and a net realization rate of 0.470 for an overall success of 0.249. The PGE2007 program achieved a gross realization rate for kWh of 0.795 and a net realization rate of 0.600 for an overall success of 0.657.

The evaluation team developed a novel, first principles-based engineering analysis approach utilizing a tracer gas to determine infiltration rates calibrated to pre/post data on 19 non-

participant sites. The models were then used to estimate energy usage for the HIM's based upon site-specific data collected at 40 commercial facilities. The strip curtain HIM achieved a gross realization rate for kWh of 0.42 and a net realization rate of 0.531 for an overall success of 0.23. The door gasket HIM achieved a gross realization rate for kWh of 0.03 and a net realization rate of 0.19 for an overall success of 0.01.

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1. EXECUTIVE SUMMARY

This report presents the results of the evaluation effort conducted by the Commercial Facilities Contract Group. The EM&V activities performed by the Commercial Facilities Contract Group pertained to two programs (PGE2005 and PGE2007) and to two high-impact measures (refrigeration strip curtains and refrigeration door gaskets). The overall objective for the evaluation was to determine the gross and net electricity and natural gas savings and demand (kW) reductions resulting from participation in the programs or from installing the HIMs.

The two programs evaluated were offered during 2006-2008 by Pacific Gas and Electric to its high tech (PGE2005) and large commercial (PGE2007) customers to provide assistance in installing energy efficiency measures. The approach for the impact evaluation of these programs had the following main features:

- Available documentation (e.g., audit reports, savings calculation work papers, etc.) was reviewed for samples of sites from both programs, with particular attention given to the calculation procedures and documentation for savings estimates.
- On-site data collection was conducted at sampled sites to provide the information needed for verifying savings and demand reductions. Monitoring was also conducted at some sites to obtain more accurate information on the operation of measures for which PG&E had claimed savings.
- Gross savings were estimated using proven techniques.
  - For PGE2005, many of the measures customers installed affected energy use for space conditioning. The impacts of these measures were analyzed using the eQuest energy analysis simulation model. HVAC measures installed by customers in PGE2007 were also analyzed using eQuest.
  - Analysis of savings from lighting measures was accomplished using information collected on-site on the equipment installed and, if appropriate, monitoring of hours of operation for lighting.
- A telephone survey was conducted of samples of participants from both programs to gather information on their decision making, their likes and dislikes of the programs, and other factors determining net-to-gross savings ratios for the programs. This information was used to determine net savings according to the standardized Large Nonresidential net-to-gross methodology used by several evaluation contract groups.

For PGE2005, the overall gross realization rate for kWh savings was estimated to be about 44.6 ± 6.3% (at the 90% confidence level). The relatively low realization rate is attributable to the importance that internal loads have in calculating energy usage and savings for high tech facilities. The EM&V effort revealed that the analyses underlying the claimed savings for projects were often made using a bin method, which is not a robust method when internal loads are high. Moreover, the data collection also revealed that the estimates of internal loads used in

the underlying analyses were often significantly higher than the internal loads actually observed at the facilities. In part, this resulted because facilities were being designed in expectation of higher demand than actually materialized.

The NTGR analysis for PGE2005 in this study showed a lower net-to-gross ratio (NTGR) than was used by PG&E in developing its claimed net savings estimates. PG&E used a NTGR of 0.94 for projects they classified as "process" and of 0.70 for most other projects. The weighted NTGR across all PGE2005 projects from these calculations was 0.84. Based on the information collected and analysis performed during this study, the NTGR for PGE2005 was calculated to be 0.47.

For PGE2007, the gross realization rate for kWh savings was estimated to be about 79.5 ± 13% (at the 90% confidence level), also less than 1, but not as low as for PGE2005. This was because most of the claimed energy savings for PGE2007 were attributable to lighting and HVAC measures that are more standardized than the measures receiving rebates under PGE2005.

In developing the net claimed savings for the projects in PGE2007, PG&E used a NTGR of 0.70 for most projects. The NTGR for PGE2007 that was calculated during this study was 60%, which was somewhat lower than the NTGR that was used by PG&E.

The two high-impact measures that were evaluated—door gaskets and strip curtains—affect the energy use for refrigeration in commercial facilities by reducing infiltration from non-refrigerated space into refrigerated space.[1] The evaluation effort for these two HIMs therefore involved identifying the factors affecting such infiltration, collecting data on these factors through field monitoring of freezers and coolers in different types of commercial facilities, and analyzing these data to determine how door gaskets and strip curtains affected infiltration and thereby energy use.

The gross impact evaluation for door gaskets utilized engineering calculations that were informed by detailed data collected at 40 sites. The gross impact evaluation of the strip curtains utilized a site-specific engineering methodology that consisted of retrofit isolation engineering models that were calibrated to and informed by detailed data collected at 150 sites. Estimates of NTGR were developed using information collected through interviews with decision-makers for 71 sites with door gaskets and 101 sites with strip curtains.

For door gaskets, a major finding from this evaluation effort is that the estimates of baseline gasket efficacy used by the IOUs in calculating claimed savings are too low, thereby inflating the ex ante estimates of savings from installing new gaskets. The realization rates on savings from

[1] HIMs are defined as those efficiency measures common across IOU programs that contribute greater than one percent to the entire IOU savings portfolio for reductions in electrical consumption, electrical demand, or natural gas consumption.

door gaskets are relatively low. The gross realization rate for kWh savings for door gaskets was 13% for SCE and 3% for PG&E and SDG&E.[2] The NTGR that was calculated for door gaskets during this study was 19%.

For strip curtains, the gross realization rate for kWh savings was 85% for SCE and 39% for PG&E and SDG&E. The NTGR that was calculated for strip curtains during this study was 40%.

Specific recommendations come out of this study regarding values for the ex-ante parameters used to calculate energy savings from strip curtains. It is recommended that the ex-ante estimations for the door-open time, the temperature differentials between the refrigerated and infiltrating airs, the difference in efficacy between the new and old strip curtains, the refrigeration system coefficients of performance, and the empirical discharge coefficients be updated with market-specific values developed during this study.

[2] The realization rates are reported separately for PG&E/SDGE and SCE because SCE had different ex-ante estimations than PG&E and SDG&E.

2. INTRODUCTION AND PURPOSE OF STUDY

As authorized by the California Public Utilities Commission (CPUC) in D.05-01-055[1], D.05-04-051[2], and D.05-11-011[3] the CPUC's Energy Division selected several contractor teams (designated as "contract groups") to conduct evaluation, measurement, and verification (EM&V) of the 2006-2008 energy efficiency programs implemented by California's investor-owned utilities (IOUs)[4]. The EM&V work performed by these contract groups is intended to increase the quality, reliability and objectiveness of the estimated energy impacts of the energy efficiency programs. The results of the EM&V work will be used in assessing the cost-effectiveness of the portfolio of California's energy efficiency programs.

The purpose of this report is to describe the EM&V activities undertaken by the Commercial Facilities Contract Group. These activities are summarized in Section 2.1, while Section 2.2 provides further detail on how the EM&V activities were grouped.

2.1 Description of EM&V Activities

The original focus of EM&V activities for the Commercial Facilities Contract Group was on evaluating savings from various energy efficiency programs that were offered by Pacific Gas and Electric Company (PG&E) to commercial and industrial customers. There were twelve programs to be evaluated, five of which were programs that PG&E implemented itself for targeted markets and seven of which were implemented by third-party entities. These programs are identified by Energy Efficiency Groupware Application (EEGA) number and name in Table 2-1.

Although the evaluation planning process initially took utility programs as a key organizational element, it was also emphasized by many evaluation teams that the portfolio should be examined from the perspective of key measures. In this evaluation, this approach is referred to as the high impact measure (HIM) approach. The philosophy behind the HIM approach organizes energy and demand impacts by measure groups and energy metrics (electric energy, electric demand, and gas energy) across programs at the utility level. The HIM approach sought to standardize the analytical methods and data collection approaches for key measures across programs and contract groups to increase consistency and accuracy.

[1] http://www.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/43628.htm

[2] http://www.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/45783.htm

[3] http://www.cpuc.ca.gov/PUBLISHED/FINAL_DECISION/51420.htm

[4] The investor-owned utilities are Pacific Gas and Electric, Southern California Edison, Southern California Gas, and San Diego Gas and Electric.

The first step in the HIM process was to identify which measures or like group of measures contributed most to each of the energy metrics for each of the utilities. The evaluation team developed a list of HIMs from the E3 calculators delivered by the IOUs covering program savings claims through the end of the second quarter of 2008 (Q2-2008). A single Access database containing the E3 measure line items from the Input tab of the E3 calculator was created. Each of the measures was assigned to a measure name using a consistent measure naming scheme. The savings claims for each IOU were tabulated for each named measure, and the contribution of each measure to the total IOU portfolio savings claim for kWh, kW and Therms was calculated. The list of HIMs was developed by identifying all measures that contributed more than 1% of the portfolio savings by IOU.

The Commercial Facilities Contract Group was assigned to be the lead contractor for evaluation of two refrigeration HIMs: strip curtains and door gaskets.

Table 2-1. PG&E Programs Originally Selected to be Evaluated in Commercial Facilities Contract Group

Targeted Market Programs	Third Party Programs
PGE2002 Schools and Colleges	PGE2050 Campus Housing Efficiency Solutions - Resource Solutions Group
PGE2005 High Technology Facilities	PGE2052 LodgingSavers - Ecology Action
PGE2006 Medical Facilities	PGE2055 Federal and State E5K Lighting - Energy Solutions
PGE2007 Office Buildings (Large Commercial)	PGE2063 Small Commercial Comprehensive Refrigeration Program (SCCRP) – KEMA
PGE2008 Lodging Facilities	PGE2066 Supermarket Controls (And Energy Smart Grocer) – PECI
	PGE2077 School Energy Efficiency Program – Resource Solutions Group
	PGE2086 HeatWise Program – Energy Solutions

In accordance Energy Division direction, the Commercial Facilities Contract Group re-examined its evaluation plan and budget in order to re-allocate resources to accommodate the evaluation of the HIM refrigeration measures (i.e., strip curtains and door gaskets). The subsequent re-allocation involved maintaining the scope of effort for full evaluation of two of the programs originally designated for evaluation, but eliminating further effort for evaluation of all other programs. The two programs for which the scope of effort was not reduced (i.e., PGE2005 and PGE2007) were chosen for full evaluation because of the expected magnitude of savings.

The final set of EM&V activities for the Commercial Facilities Contract Group that are reported on here is outlined in Table 2-2. EM&V activities were performed for two programs (i.e., PGE2005 and PGE2007) and for two HIMs (i.e., refrigeration strip curtains and refrigeration door gaskets).

Table 2-2. EM&V Activities for Commercial Facilities Contract Group

EM&V Activities	Realization Rates Anticipated (Based on EM&V activities)
PGE2005 - Non-HIM measures (EM&V for gross and net savings)	Verification, unit energy savings
PGE2007 - Non-HIM measures (EM&V for gross and net savings)	Verification, unit energy savings
Refrigeration Door gasket (EM&V for gross and net savings)	Verification, unit energy savings
Refrigeration strip curtain (EM&V for gross and net savings)	Verification, unit energy savings

The EM&V rigor levels for the two programs are identified in Table 2-3.

Table 2-3. Levels of Rigor for Evaluations of PGE2005 and PGE2007

Program ID	Evaluation Type	Energy Rigor	Energy M&V	kW Rigor	NTG Rigor
PGE2005	Protocol-Guided Direct Impact	Enhanced	B or D	Basic	Standard
PGE2007	Protocol-Guided Direct Impact	Enhanced	B or D	Enhanced	Standard

2.2 Rationale for Grouping of EM&V Activities

For the 2006-2008 program cycle, PG&E used a form of matrix management to implement programs for targeted markets in the commercial sector. With PG&E's approach, program offerings for a particular type of customer that were previously stand-alone were combined so that the resulting program was oriented to the unique needs of that type of customer. This approach was intended to resolve gaps and overlaps that previously existed among program elements so that energy efficiency could be marketed to the customers more effectively. The two programs being evaluated in the Commercial Facilities Contract Group were for such targeted markets (i.e., PGE2005 for high technology facilities and PGE2007 for Large Commercial facilities). The projects evaluated for these programs are primarily Custom Lighting, Custom HVAC, or Custom Other.

The two refrigeration HIMs evaluated (strip curtains and door gaskets) are separately enumerated as measures in the IOUs' tracking system data. However, the two measures are similar in that they reduce infiltration from non-refrigerated space into refrigerated space. An EM&V framework for evaluating the effects of strip curtains and door gaskets on electricity use was therefore provided by looking at the factors affecting such infiltration.

3. EVALUATION OF PGE2005

The PG&E program for high technology facilities (i.e., PGE2005) primarily addresses data centers, laboratories, and biotechnology facilities. Secondary targets include clean rooms, office space, and telecommunications. (Electronics manufacturing is not a major target of the program because this segment of the industry has mostly moved from the PG&E service territory to Asia and elsewhere.)

PG&E along with industry experts has developed techniques that can reduce the energy consumption of data centers by as much as 50 – 60 percent. Measures implemented include the use of outside air, improved air-conditioning systems, more efficient servers, and the introduction of virtualization technologies. (Virtualization allows more than one system to be run on a server, which can have the effect of increasing the load factor from five to 25 percent and thereby substantially reducing the number of servers.) Virtualization is expected to substantially reduce the energy consumption of existing data centers and slow the rate of growth in energy consumption in this sector.

The net kWh, kW and therm savings claimed for PGE2005 at the end of the 2006-2008 program period are summarized in Table 3-1, which shows the distribution of claimed savings by type of end use measure. (The classification by type of end use measure is according to the assignments made in the Standard Performance Tracking Databases.)

Table 3-1. Claimed Net Savings for PGE2005 by Type of End Use Measure

Type of End Use Measure (Per Standard Performance Tracking Database)	Claimed Net kWh Savings	Claimed Net kW Savings	Claimed Net Therm Savings
Building Shell	276,354	32	-
Compressed Air	2,351,548	362	-
Controls	4,630,900	411	266,123
Daylighting	18,082	10	-
Indoor Lighting	3,628,144	546	(1,975)
Motors	2,210,977	216	-
Office Equipment	4,446,042	453	-
Process	68,981,017	5,978	365,342
Process Cooling	735,858	84	-
Process Heat	-	-	39,054
Pumps	19,684	2	-
Refrigeration	1,336,977	97	-
Space Cooling	14,447,904	1,620	(98)
Water Heating	-	-	47,825
Whole Building	4,526,967	895	54,133
Totals	107,610,455	10,705	770,403

3.1 Objectives for Evaluation of PGE2005

The major parameters examined in the evaluation of PGE2005 are the gross savings realization rates and net-to-gross rates for the projects in the program. The savings achieved for such projects have been evaluated using Protocol-Guided Direct evaluation approaches. The levels of rigor for various aspects of the evaluation are shown in Table 3-2. Gross savings were evaluated with enhanced rigor. The net-to-gross evaluation accounts for the effects of free-ridership in the net savings' estimates.

Table 3-2. Levels of Rigor for Evaluation of PGE2005

Program ID	Evaluation Type	Energy Rigor	Energy M&V	kW Rigor	NTG Rigor
PGE2005	Protocol-Guided Direct Impact	Enhanced	B or D	Basic	Standard

3.2 Methods Used for Evaluation of Gross and Net Savings for PGE2005

The energy savings for PGE2005 were evaluated through the following activities:

- Preparing a sampling plan;.
- Obtaining and reviewing project documentation for sampled projects and preparing M&V site plans;
- Collecting data to inform analysis of savings
- Conducting analysis of ex post evaluated gross savings
- Conducting analysis of net savings

The details for these activities are discussed in Appendix A of the Non-HIM Appendices. Specific methods used for the evaluation of savings for PGE2005 are outlined here.

3.2.1 Sample Design

The sample design for the impact evaluation of PGE2005 was prepared in accordance with the guidelines provided in the California Evaluation Framework[1] (CEF) for a Protocol Guided Direct (PGD) evaluation with an "Enhanced" level of rigor. The goal in preparing the sample design was to meet the appropriate protocol precision/confidence targets.

The sample design for the evaluation of PGE2005 was originally developed in the first quarter of 2008. At that time, a sample frame was constructed using available project information extracted from the tracking system data for the program provided by PG&E. The design variable used in developing the sampling plan was *ex-ante* gross kWh savings. Sample strata were defined by applying the Dalenius-Hodges stratification procedure to the data on *ex ante* kWh savings. The

[1] The TecMarket Works Team, The California Evaluation Framework, Prepared for the California Public Utilities Commission and the Project Advisory Group, June 2004

efficacy of different allocations of sample points across strata was examined by considering the precision with which total kWh savings could be estimated at the 90% confidence level, with 10% precision being the target.

The population statistics for PGE2005 on which the initial sample design was based showed that the distribution of kWh savings for projects in PGE2005 was highly skewed. Given the skewness in the distribution of savings, an initial sample design was developed in which all of the projects in Stratum 5 (i.e., the stratum containing projects with the highest kWh savings) were chosen for the analysis sample with certainty with smaller numbers of projects to be chosen randomly from the other strata.

The initial sample design prepared in Q1 2008 provided the basis for beginning field work to collect the data needed to analyze actual savings from the sample projects. PG&E's final tracking database for PGE2005 became available in March 2009, at which point the final allocation of sample points across strata was determined.

The population statistics for the analysis sample as initially designed are shown in Table 3-3**,** which shows the distribution of the analysis sample across strata. Based on these statistics for the final population of projects, the distribution of the sample, and the *ex ante* claimed kWh savings values for the projects, it was estimated that total program kWh savings would be estimated with a precision of 6.3% at the 90% confidence level.

Table 3-3. Population Statistics for Achieved Sample for PGE2005

	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5	Overall
Strata boundaries (kWh)	< 57,000	57,001-171,000	171,001-315,000	315,000-764,000	> 764,001	
Number of projects	46	40	38	37	39	200
Total ex ante claimed gross kWh savings	1,138,567	3,959,252	9,049,566	19,286,109	94,293,475	127,726,970
Average kWh Savings	24,751	98,981	238,146	521,246	2,417,781	638,635
Standard deviation of kWh savings	16,550	30,888	41,236	157,407	2,257,027	1,333,038
Coefficient of variation	0.669	0.312	0.173	0.302	0.934	
Final design sample	2	2	2	3	31	41

3.2.2 Analysis of Gross Savings

For each project selected for the final analysis sample, available documentation (e.g., audit reports, savings calculation work papers, etc.) on the project was obtained from PG&E. Other, more general documentation was also reviewed, including program forms, billing and interval data, and weather data.

A site-specific M&V plan was prepared for each project in the analysis sample using the information presented in the documentation for a project. Each site-specific M&V plan was

submitted to the CPUC Energy Division and its Technical Advisors for review. After suggested revisions, each plan was submitted for approval by the Energy Division before on-site data collection was begun at a site.

On-site visits were used to collect data that were used in the analyses to determine what savings had been achieved with the sample projects.. During an on-site visit, the field staff accomplished three major things.

- First, they verified the implementation status of all measures for which PG&E had provided incentive payments through PGE2005.
- Second, they collected the physical data needed to analyze the energy savings that have been realized from the installed improvements and measures.
- Third, they interviewed the contact personnel at a facility to obtain additional information on the installed system to complement the data collected from other sources.

Estimates of energy use and savings for energy efficiency measures depend significantly on having accurate data for such factors as operating hours and usage patterns. Monitoring was not considered necessary for some sites. This included facilities where project documentation allowed for sufficiently detailed calculations or where this type of information was available from an energy management control system. For other facilities, information could be obtained through relatively simple monitoring using loggers. However, if a facility did not have an energy management control system or the measure being analyzed was relatively complex, monitoring of the affected equipment was conducted to gather more information to inform simulation analysis. The primary candidates for monitoring were sites where data could be collected that would allow a better analysis of savings to be developed.

The energy savings achieved through each project in the analysis sample were determined using a site-specific M&V approach. This involved determining the savings for each project by using one or more of the M&V Options defined in the IPMVP.[2]

- All HVAC measures were analyzed using IPMVP Option D. Review of the project documentation for many projects revealed that process measures for the high tech facilities participating in PGE2005 were often for space conditioning (e.g., to control space where servers were located). Thus, IPMVP Option D was also used for many of the measures that had been classified as “process” measures in PG&E’s tracking system. With IPMVP Option D, a Calibrated Simulation of energy use is made. For the analysis here, the eQuest energy analysis model was used to prepare computer simulations of energy use before and after the

[2] IPMVP refers to the International Performance Measurement and Verification Protocol, which specifies alternative measurement and analysis methods that can be used to estimate gross energy and demand savings from a measure installed under a program being evaluated. See www.evo-world.org .

HVAC measures were installed at a facility. The steps in the analysis are described in Appendix B of the Non-HIM Appendices.

- For process measures that did not involve space conditioning, the specificity of the process generally precluded using an energy analysis model for simulation analysis. Savings from these types of process improvement measures therefore were analyzed through engineering analysis of the process affected by the improvements, with monitoring used to supply information for important variables. The type of monitoring conducted for each site of this type was specified in the M&V plan for the site.
- Savings for lighting measures were assessed using IPMVP Option B, Retrofit Isolation. With IPMVP Option B, savings are calculated using short term or continuous measurement, and savings are determined by field post-measurements of the system(s) to which the measure(s) have been applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken during the post-retrofit period. In fact, however, only a small number of the projects for high tech facilities involved lighting measures (either retrofits or controls).

The evaluation of peak kW reduction for a facility was accomplished using the DEER-defined[3] peak definition period of 2:00 PM to 5:00 PM during the three consecutive weekday periods containing the weekday with the hottest temperature of the year for the climate zone where the facility was located. To identify these days, kW demand savings calculated from the 8,760 hourly loads generated through the eQuest modeling for a project were input to a spreadsheet that identified the three hottest days per the DEER definition and reported the peak demand savings for that three-day period. (The three days defining the peak demand periods for the climate zones where the facilities analyzed were located are reported in Appendix C of the Non-HIM Appendices.)

3.2.3 Analysis of Net Savings

The analysis of net savings for PGE2005 was conducted using the standard methodological framework that had been developed by the nonresidential net-to-gross working group formed by the Energy Division. This working group, which was composed of experienced evaluation professionals, developed a standard methodological framework, including decision rules, for integrating in a systematic and consistent manner the findings from both quantitative and qualitative information in estimating net-to-gross ratios. The approach was designed to fully comply with the *California Energy Efficiency Evaluation: Protocols: Technical,*

[3] The California Energy Commission and California Public Utilities Commission (CPUC) sponsors this database designed to provide estimates of energy and peak demand savings values, measure costs, and effective useful life (EUL) all with one data source. DEER has been designated by the CPUC as its source for deemed savings and impact costs for program planning.

Methodological, and Reporting Requirements for Evaluation Professionals (Protocols) and the *Guidelines for Estimating Net-To-Gross Ratios Using the Self-Report Approaches* (Guidelines).

Details of the net-to-gross method are discussed in Appendix A of the Non-HIM Appendices. The net-to-gross evaluation method used relies exclusively on a self-report approach (SRA) to estimate project and domain-level Net-to-Gross Ratios (NTGRs). This method was used because other available methods and research designs are generally not feasible for programs targeted at large nonresidential customers.

The NTGR as calculated through this procedure represents an averaging of three scores,.

- A *Timing and Selection* score reflects the influence of the *most important* of various program and program-related elements in the customer's decision to select the specific program measure at this time. Program influence through vendor recommendations is also incorporated in this score.
- A *Program Influence* score captures the perceived importance of the program (whether rebate, recommendation, training, or other program intervention) relative to non-program factors in the decision to implement the specific measure that was eventually adopted or installed. This score is determined by asking respondents to assign importance values to both the program and most important non-program influences so that the two total 10. The program influence score is adjusted (i.e., divided by 2) if respondents say they had already made their decision to install the specific program qualifying measure before they learned about the program.
- A *No-Program* score captures the likelihood of various actions the customer might have taken at this time and in the future if the program had not been available (the counterfactual). This score also accounts for deferred free ridership by incorporating the likelihood that the customer would have installed program-qualifying measures at a later date if the program had not been available.

3.2.4 Estimation of Program-Level Savings

Program-level ex post evaluated savings are developed by applying savings realization rates calculated for the analysis sample to program-level data for claimed savings. The procedure for estimating gross savings for the program is an application of ratio estimation. Given a stratified sample design, a gross realization rate (GRR) for a stratum is defined as the ratio of the sum of the ex post savings evaluated for the M&V sample to the sum of the *ex ante* claimed savings recorded in the tracking database for the same sample.

To estimate total ex post evaluated savings for a program, the estimates of ex post evaluated savings for the different strata are summed. Note that this will give a realization rate at the program-level that is a weighted average of the realization rates for the different strata, with claimed savings being the weights.

3.3 Validity and Reliability for Evaluation of PGE2005

There can be several sources of uncertainty associated with the estimates of the impacts of the PGE2005 program. Such sources include the following.

- Sample selection bias
- Physical measurement error (e.g., meter bias, sensor placement, non-random selection of equipment or circuits to monitor)
- Engineering analysis error (e.g., baseline construction, engineering model bias, modeler bias)
- Survey error (e.g., non-response bias)

Various steps were taken to reduce the uncertainty arising from these sources and thereby increase the validity and reliability of key measurements for the evaluation of savings for PGE2005. The details of these steps are discussed in Appendix D of the Non-HIM Appendices.

3.4 Detailed Findings for Evaluation of PGE2005

Detailed findings from the EM&V for PGE2005 are presented in this section. These findings are based on the sample of projects and measures chosen for detailed analysis. The discussion is focused on the results of the fieldwork and analysis as they pertain to the particular parameters that are most important in determining savings.

3.4.1 Findings from Analysis of Gross Savings for PGE2005

For each site in the final analysis sample used to analyze gross kWh savings for PGE2005, there are two estimates of gross kWh savings: the claimed gross kWh savings estimate (as reported in the program tracking system) and the estimate of ex post evaluated gross savings developed through the analysis. Figure 3-1 provides a summary comparison between the two values for the sample sites. The correlation between the two values across the sample sites is good with an R^2 of 0.28.

There are various reasons why ex post evaluated savings might not match ex ante claimed savings. For high tech facilities, an important consideration is how internal loads are addressed in the analysis. The review of savings calculations underlying the claimed savings showed that those calculations were often performed using a bin method. The bin method is adequate for most types of commercial buildings where operating schedules for equipment are important in estimating energy use and savings. By contrast, internal loads are more important for high tech facilities, which often house equipment that is "on" most of the time. When internal loads are dominant, the bin method is less applicable and the simulation analysis used in the M&V work becomes more useful.

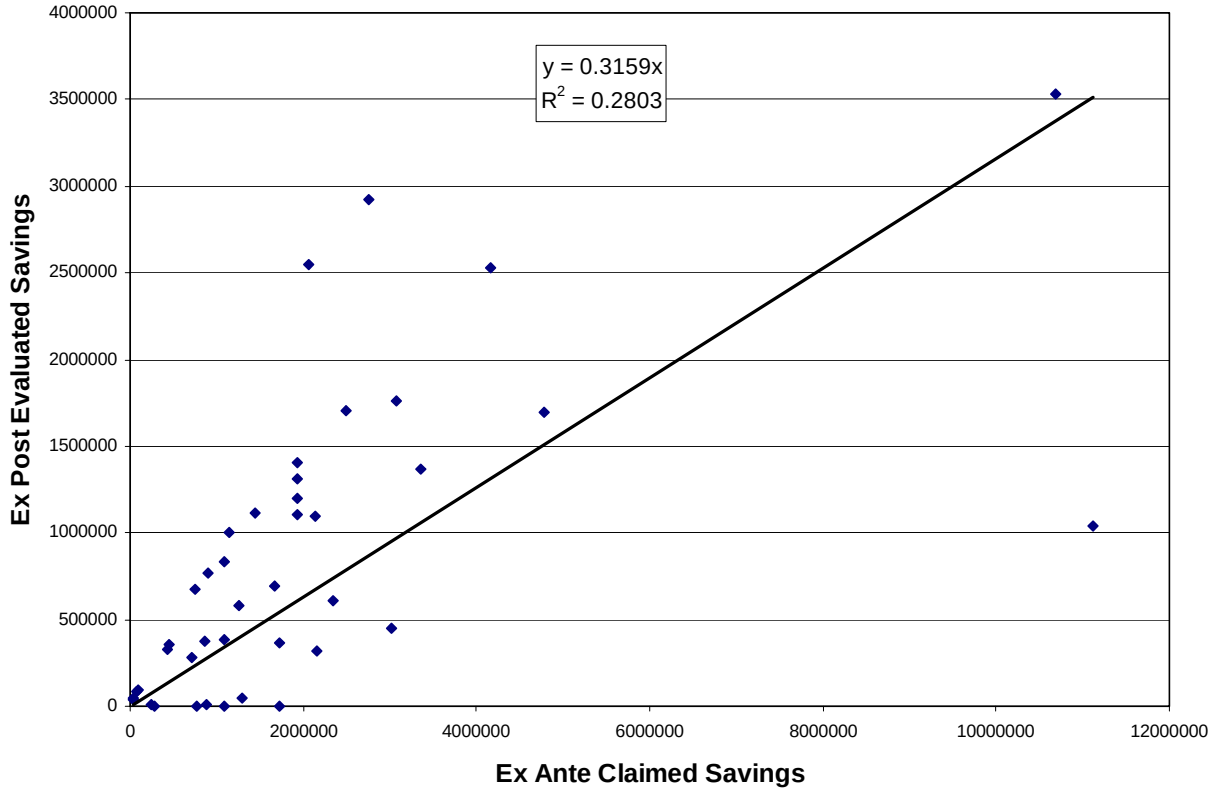

Figure 3-1. Comparison of Ex Post Evaluated Gross kWh Savings to Ex Ante Claimed Gross kWh Savings for PGE2005 Sample Sites

The importance of how internal loads are handled can be seen when the site in the sample with the largest claimed gross kWh savings is considered. Figure 3-1 shows that this site had claimed gross kWh savings over 10,000,000 kWh but with ex post evaluated gross kWh savings estimated to be much lower. This site was a data center and the measures installed were to provide space conditioning for the areas where equipment was installed. The claimed savings estimates for this site were based on assumptions of high internal loads, but actual loads as determined through the M&V effort were much lower. The claimed savings estimate for this site was developed on an assumption of internal loads being 5,800 kW, whereas the M&V work found the actual internal loads to be about 857 kW.

The estimated realization rates[4] for gross kWh savings for the strata in the PGE2005 analysis sample are shown in Table 3-4. (The realization rates defined for kWh, kW, and Therms for the

[4] A realization rate for a stratum is defined as the ratio of the sum of the ex post savings evaluated for the projects in the M&V sample to the sum of the *ex ante* claimed savings recorded in the tracking database for the same sample of projects.

sample strata are used with population weighting to develop overall realization rates. These overall realization rates are reported in Table 3-7.)

Table 3-4. Realization Rates for Gross kWh Savings by Sampling Strata for PGE2005 Analysis Sample

Stratum	Number of Sample Sites	Total Ex Ante Claimed Gross kWh Savings	Total Ex Post Evaluated Gross kWh Savings	Sample Realization Rates
1	2	75,978	77,666	102.2%
2	2	168,993	171,628	101.6%
3	2	525,428	6,416	1.2%
4	4	2,318,141	1,646,969	71.0%
5	31	79,492,946	31,613,044	40.1%
Overall	41	81,889,721	33,515,724	40.9%[5]

The estimated realization rates for gross kW reductions for the PGE2005 analysis sample are shown in Table 3-5.

Table 3-5. Realization Rates for Peak kW Reductions by Sampling Strata for PGE2005 Analysis Sample

Stratum	Number of Sample Sites	Total Ex Ante Claimed Peak kW Reductions	Total Ex Post Evaluated Peak kW Reductions	Sample Realization Rates
1-4	10	218.3	38.8	91.5%
5	31	7,444.9	3417.9	45.9%
Overall	41	7,663.2	3,617.6	47.2%

Table 3-6 lists the reasons for variances between ex-ante and ex-post energy savings. The number of occurrences of a given reason, the total ex-ante savings, total ex-post savings, the percentage of the overall program-level variance between ex-ante and ex-post, and average realization rate for all sites that fall under the given categories are also shown in the table.

[5] This is the un-weighted gross realization rate for the sample.

Table 3-6. Summary of variances between ex-ante and ex-post savings for PGE2005 analysis sample

Cause for Discrepancy	Number of Sites	Total Ex Ante Claimed Gross kWh Savings	Total Ex Post Evaluated Gross kWh Savings	Fraction of Total Variance between Ex-Ante and Ex-Post	Weighted Realization Rates
Ineligible measure	4	2,039,903	699,178	0.03	34%
Tracking database error	0	0	0	0.00	N/A
Noncompliant with program	2	2,489,651	0	0.05	0%
Measure not found	1	1,087,777	0	0.02	0%
Economic slowdown	1	4,787,719	1,695,864	0.06	35%
Incorrect code baseline	2	1,958,161	758,693	0.02	39%
Incorrect industry standard baseline	0	0	0	0.00	N/A
Inaccurate baseline parameters	6	12,102,801	4,559,839	0.15	38%
Measure parameters different from ex ante assumptions	12	31,230,755	11,937,894	0.39	38%
Measure operation changed	0	0	0	0.00	N/A
No major change (plus minus 10% of ex ante)	4	2,952,378	3,126,800	0.00	106%
Calculation errors in ex ante estimates	6	16,764,029	6,248,980	0.21	37%
Various (a single most important reason cannot be identified)	3	7,168,342	3,739,413	0.07	52%
Total	41	82,581,516	32,766,662	1.00	40%

The estimated realization rates for gross therm savings for the PGE2005 analysis sample are shown in Table 3-7.

Table 3-7. Realization Rate for Gross Therm Savings by Sampling Strata for PGE2005 Analysis Sample

Stratum	Number of Sample Sites	Total Ex Ante Claimed Therm Savings	Total Ex Post Evaluated Therm Savings	Realization Rates
Overall	5	152,617	19,454	12.8%

3.4.2 Findings from Analysis of Net Savings for PGE2005

The net-to-gross analysis for PGE2005 used a very slightly modified version of the standard net-to-gross battery of questions to take account of cases where one decision maker might be responsible for projects at several sites.

In developing the net claimed savings for PGE2005, PG&E used a NTG ratio of 0.94 for projects they classified as "process" and of 0.70 for most other projects. The ex ante weighted NTGR across all PGE2005 projects from these calculations was 0.84.

The NTGR analysis for PGE2005 in this study showed a lower NTGR than was used by PG&E in developing its claimed net savings estimates. The net-to-gross ratio (NTGR) for high tech facilities was calculated during this study using information obtained through interviews with five decision-makers for such facilities and applying the net-to-gross analysis procedure outlined in Section 3.2.3 and described in Appendix A of the Non-HIM Appendices. Based on this information and analysis, the NTGR for PGE2005 was calculated to be 47%.

3.4.3 Confidence and Precision of Key Findings for Evaluation of PGE2005

The estimated gross realization rates for kWh and therm savings and kW reductions for PGE2005 and the error bounds for these realization rates at 90% confidence level are shown in Table 3-8.

Table 3-8. Precision of Gross Savings Realization Rates for PGE2005

	Gross Savings		Gross Realization Rates	Error Bounds at 90% Confidence
	Ex Ante Claimed	**Ex Post Evaluated**		
kWh	127,726,970	56,941,515	44.6%	± 6.3%
kW	12,867	7,460	58.9%	± 13.5%
Therms	993,789	126,678	12.7%	± 19.6%

3.5 Program Specific Results from Evaluation of PGE2005

The findings for realization rates and net-to-gross ratios from Section 3.4 have been drawn on to prepare program-level estimates of ex post evaluated net savings for PGE2005. The program-level estimates of ex post evaluated gross and net savings are compared to the ex ante claimed values in Table 3-9.

Table 3-9. Gross and Net Savings: Ex Ante Claimed and Ex Post Evaluated for PGE2005

Type of Savings	**Gross Savings**		**Net Savings**	
	Ex Ante Claimed	**Ex Post Evaluated**	**Ex Ante Claimed**	**Ex Post Evaluated**
kWh	127,726,970	56,941,515	107,610,455	26,762,512
kW	12,867	7,460	10,705	3,506
Therms	993,789	126,678	770,403	59,539

For PGE2005, the gross realization rate was estimated to be 44.6% for kWh savings, 58.9% for kW demand reduction, and 12.7% for Therm savings,

3.6 Discussion of Findings and Recommendations from Evaluation of PGE2005

Table 3-10 provides data comparing net savings as projected in the PGE2005 Program Implementation Plan, as claimed at the end of the program cycle, and as verified achieved through this evaluation effort. As can be seen, the net savings claimed were significantly higher than the savings projected in the PIP. However, ex post evaluated savings were significantly lower than claimed. Net ex post evaluated savings fell below net claimed savings primarily because (1) the gross realization rates were significantly less than 1 and (2) the net-to-gross ratio was were lower than the values PG&E assigned to measures in determining claimed net savings.

Table 3-10. Comparison of Projected, Claimed and Evaluated Net Savings for PGE2005, by Type of Savings

Type of Savings	Net Savings as Projected in PIP*	Total Ex Ante Claimed Net Savings	Total Ex Post Evaluated Net Savings
kWh	46,659,000	107,610,455	26,762,512
kW	6,901	10,705	3,506
Therms	66,597	770,403	59,539

That the overall gross realization rate for kWh savings for PGE2005 was significantly less than 1 is attributable to the importance that internal loads have in calculating energy usage and savings for high tech facilities. The M&V effort revealed that the analyses underlying the claimed savings for projects were often made using a bin method, which is not a robust method when internal loads are high. Moreover, the data collection also revealed that the estimates of internal loads used in the underlying analyses were often significantly higher than the internal loads actually observed at the facilities. In part, this resulted because facilities were being designed in expectation of higher demand than actually materialized.

The net-to-gross ratio for PGE2005 as evaluated was also significantly lower than the values used by PG&E in calculating claimed net savings (e.g., 0.47 for kWh savings as evaluated versus approximately 0.84 for PG&E's claimed savings calculations). The information gathered through the net-to-gross interviews for the evaluation showed that most of the data center projects were initiated by customers. Indeed, customers were aware of the benefits of energy efficiency programs. Most were committed to doing efficiency projects and had project identification and implementation mechanisms in place. However, customers did find value in participating in PGE2005 because the utility program provided important technical information and helped to validate the projects and generate support with management.

Based on these findings, the following recommendations are made regarding implementation and evaluation of energy-saving projects for high tech facilities.

- *Require More Complete Documentation of Assumptions Underlying Specification of Baseline Conditions.* Understanding baseline conditions is important for any ex post evaluation of savings from a project, since savings from an energy efficiency measure are measured against the baseline. Because of the rapidity with which practices for high tech facilities can change, standard practices that determine baseline conditions can change noticeably over only a three-year period such as the 2006-2008 program period addressed in this evaluation. That is, baseline conditions as specified for a project completed in 2006 may not represent baseline conditions for a project being completed in 2008. Accordingly, it is recommended that more complete documentation be required of the assumptions underlying specification of baseline conditions for projects, particularly those for data centers and clean rooms where standard practice changes very rapidly. (Moreover, the implementation process may need to be more flexible to account for rapidly changing market conditions.)
- *Standardize Project Documentation.* Through the evaluation process, it became apparent that the manner in which projects were documented varied noticeably. The process of documenting energy savings from a project for a high tech facility should be standardized. This can be accomplished by using tools now available for identifying and evaluating energy efficiency opportunities in high tech facilities. For example, the Industrial Technologies Program of the U. S. Department of Energy has made available DC Pro Software Tool Suite, which includes a Profiling Tool and System Assessment Tools to perform and document energy assessments on data center systems.[6]
- *Re-emphasize Review and Inspection of Self-Sponsored Projects.* The above two recommendations take on even more importance with respect to self-sponsored projects (i.e., projects in which a customer is initiating and carrying a project forward). As noted above, most of the projects in PGE2005 were initiated by customers themselves. However, this often meant that a customer's project may not have received a complete third-party review of the baseline assumptions and calculations underlying the estimation of savings. PG&E should therefore re-emphasize working with customers to review and inspect self-sponsored projects so that assumptions and calculations are not being made that are overly optimistic regarding possible savings.
- *Ensure That Incentives Can Be Given for Savings for Measures Unique to High Tech Facilities.* The evaluation identified some measures that are implemented in high tech facilities that provide legitimate savings but that would not be eligible for incentives if implemented by other businesses. The most prominent example is the changing of HVAC

[6] For example, the Profiling Tool can provide information regarding the overall energy use and efficiency in a data center, breakout energy use by end use, and show potential areas for energy efficiency improvement. Such information can guide both implementation and evaluation of an energy efficiency project for a data center.

setpoints when "free cooling" is implemented. While setpoint changes in other settings are regarded as behavioral changes that do not receive incentives, setpoint changes for free cooling are an integral part of the hardware change used to affect that measure. For data centers implementing free cooling, changing (raising) the setpoint temperature for cooling is likely to persist, since there will be no everyday human intervention to motivate changing the setpoint settings. Instead, the increased cooling setpoint, when combined with any number of free cooling hardware implementations in some climate zones will deliver considerable savings that will motivate continued operation with the setpoint increase.

4. EVALUATION OF PGE2007

The Large Commercial program (PGE2007) was intended by PG&E to provide a cost effective and comprehensive portfolio of program elements for targeted customers in order to deliver the kWh and therm savings and kW reductions. The targeted customers included large buildings where capital expansion, capital renewal, and/or operations and maintenance products and services are procured through contracts with manufacturers and/or distributors.

4.1 Objectives for Evaluation of PGE2007

The major parameters examined in the evaluation of PGE2007 are the gross savings realization rates and net-to-gross rates for the projects in the program. The savings ex post evaluated for such projects have been evaluated using Protocol-Guided Direct evaluation approaches. The levels of rigor for various aspects of the evaluation are shown in Table 4-1.

Table 4-1. Levels of Rigor for Evaluation of PGE2007

Program ID	Evaluation Type	Energy Rigor	Energy M&V	kW Rigor	NTG Rigor
PGE2005	Protocol-Guided Direct Impact	Enhanced	B or D	Basic	Standard

Projects in PGE2007 could include not only retrofit projects but also new construction and retrocommissioning projects. However, the evaluation reported on here focused only on savings from retrofit projects. The new construction projects have been evaluated by the New Construction and Codes and Standards Contract Group, while the retrocommissioning projects have been evaluated by the Commercial Retrocommissioning Contract Group.

4.2 Methods Used for Evaluation of Gross and Net Savings for PGE2007

The energy savings for PGE2007 were evaluated through the following activities:

- Preparing a sampling plan
- Obtaining and reviewing project documentation for sampled projects and preparing M&V site plans
- Collecting data to inform analysis of savings
- Conducting analysis of ex post evaluated gross savings
- Conducting analysis of net savings

The particulars of these activities are discussed in Appendix A of the Non-HIM Appendices. Specific methods used for the evaluation of savings for PGE2007 are outlined here.

4.2.1 Sample Design

The sample design for the impact evaluation of PGE2007 was prepared in accordance with the guidelines provided in the California Evaluation Framework[1] (CEF) for a Protocol Guided Direct (PGD) evaluation with an "Enhanced" level of rigor. The goal in preparing the sample design was to meet the appropriate protocol precision/confidence targets.

The sample design for the evaluation of PGE2007 was originally developed in the first quarter of 2008. At that time, a sample frame was constructed using available project information extracted from the tracking system data for the program provided by PG&E. The design variable used in developing the sampling plan was *ex-ante* gross kWh savings. Sample strata were defined by applying the Dalenius-Hodges stratification procedure to the data on *ex ante* kWh savings. The efficacy of different allocations of sample points across strata was examined by considering the precision with which total kWh savings could be estimated at the 90% confidence level, with 10% precision being the target.

The population statistics for PGE2007 on which the initial sample design was based showed that the distribution of kWh savings for projects in PGE2007 was highly skewed. Given the skewness in the distribution of savings, an initial sample design was developed in which all of the projects in Stratum 5 were chosen for the analysis sample with certainty with smaller numbers of projects to be chosen randomly from the other strata.

The initial sample design prepared in Q1 2008 provided the basis for beginning field work to collect the data needed to analyze actual savings from the sample projects. PG&E's final tracking database for PGE2007 became available in March 2009, at which point the final allocation of sample points across strata was determined.

The population statistics for the analysis sample for PGE2007 as initially designed are shown in Table 4-2, which shows the distribution of the analysis sample across strata. Based on these statistics for the final population of projects, the distribution of the sample, and the *ex ante* claimed kWh savings values for the projects, it was determined that total program kWh savings would be estimated with a precision of 12.2% at the 90% confidence level.

[1] The TecMarket Works Team, The California Evaluation Framework, Prepared for the California Public Utilities Commission and the Project Advisory Group, June 2004

Table 4-2. Summary Statistics for PGE2007 Analysis Sample

	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5	Overall
Strata boundaries (kWh)	< 32,000	32,001 – 78,000	78,001- 165,000	165,001 – 300,000	> 300,000	
Number of projects	96	82	66	59	55	358
Total ex ante claimed kWh savings	1,280,897	4,084,052	7,727,937	12,650,468	32,609,317	58,352,671
Average kWh Savings	13,343	49,806	117,090	214,415	592,897	162,996
Standard deviation of kWh savings	8,892	13,529	24,183	34,118	465,729	267,267
Coefficient of variation	0.666	0.272	0.207	0.159	0.786	
Design sample	2	2	2	2	53	61

4.2.2 Analysis of Gross Savings

For each project selected for the analysis sample for PGE2007, available documentation (e.g., audit reports, savings calculation work papers, installation verification documentation, etc.) on the project was obtained from PG&E. Other, more general documentation was also reviewed, including program forms, billing and interval data, and weather data.

A site-specific M&V plan was prepared for each project in the analysis sample using the information presented in the documentation for a project. Each site-specific M&V plan was submitted to the CPUC Energy Division and its Technical Advisors for review. After suggested revisions, each plan was submitted for approval by the Energy Division before on-site data collection was begun at a site.

On-site visits were used to collect data that were used in the analyses to determine what savings had been achieved with the sample projects. During an on-site visit, the field staff accomplished three major things.

- First, they verified the implementation status of all measures for which PG&E had provided incentive payments through PGE2007.
- Second, they collected the physical data needed to analyze the energy savings that have been realized from the installed improvements and measures.
- Third, they interviewed the contact personnel at a facility to obtain additional information on the installed system to complement the data collected from other sources.

Estimates of energy use and savings for energy efficiency measures depend significantly on having accurate data for such factors as operating hours and usage patterns. Monitoring was not considered necessary for some sites. This included facilities where project documentation allowed for sufficiently detailed calculations or where this type of information was available from an energy management control system. For other facilities, information could be obtained through relatively simple monitoring using loggers. However, if a facility did not have an energy

management control system or the measure being analyzed was relatively complex, monitoring of the affected equipment was conducted to gather more information to inform simulation analysis. The primary candidates for monitoring were sites where data could be collected that would allow a better analysis of savings to be developed.

The energy savings achieved through each project in the analysis sample were determined using a site-specific M&V approach. This involved determining the savings for each project by using one or more of the M&V Options defined in the IPMVP.

- Savings for lighting measures were assessed using IPMVP Option B, Retrofit Isolation. With IPMVP Option B, savings are calculated using short term or continuous measurement, and savings are determined by field post-measurements of the system (s) to which the measure(s) have been applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken during the post-retrofit period.
- All HVAC measures were analyzed using IPMVP Option D. With this option, a Calibrated Simulation of energy use is made. For the analysis here, the eQuest energy analysis model was used to prepare computer simulations of energy use before and after the HVAC measures were installed at a facility.

The evaluation of peak kW reduction for a facility was accomplished using the DEER-defined peak definition period of 2:00 PM to 5:00 PM during the three consecutive weekday periods containing the weekday with the hottest temperature of the year for the climate zone where the facility was located. To identify these days, kW demand savings calculated from the 8,760 hourly loads generated through the eQuest modeling for a project were input to a spreadsheet that identified the three hottest days per the DEER definition and reported the peak demand savings for that three-day periods. (Further details on the peak demand analysis are provided in Appendix B of the Non-HIM Appendices.)

4.2.3 Analysis of Net Savings

The analysis of net savings for PGE2007 was conducted using the standard methodological framework that had been developed by the nonresidential net-to-gross working group formed by the Energy Division. This working group, which was composed of experienced evaluation professionals, developed a standard methodological framework, including decision rules, for integrating in a systematic and consistent manner the findings from both quantitative and qualitative information in estimating net-to-gross ratios. The approach was designed to fully comply with the *California Energy Efficiency Evaluation: Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals* (Protocols) and the *Guidelines for Estimating Net-To-Gross Ratios Using the Self-Report Approaches* (Guidelines).

The NTG method relies exclusively on the self-report approach (SRA) to estimate project and domain-level Net-to-Gross Ratios (NTGRs), since other available methods and research designs are generally not feasible for large nonresidential customer programs.

The NTGR as calculated through this procedure represents an averaging of three scores,

- A *Timing and Selection* score reflects the influence of the *most important* of various program and program-related elements in the customer's decision to select the specific program measure at this time. Program influence through vendor recommendations is also incorporated in this score.
- A *Program Influence* score captures the perceived importance of the program (whether rebate, recommendation, training, or other program intervention) relative to non-program factors in the decision to implement the specific measure that was eventually adopted or installed. This score is determined by asking respondents to assign importance values to both the program and most important non-program influences so that the two total 10. The program influence score is adjusted (i.e., divided by 2) if respondents say they had already made their decision to install the specific program qualifying measure before they learned about the program.
- A *No-Program* score captures the likelihood of various actions the customer might have taken at this time and in the future if the program had not been available (the counterfactual). This score also accounts for deferred free ridership by incorporating the likelihood that the customer would have installed program-qualifying measures at a later date if the program had not been available.

4.2.4 Estimation of Program-Level Savings

Program-level ex post evaluated savings are developed by applying savings realization rates calculated for the analysis sample to program-level data for claimed savings. The procedure for estimating gross savings for the program is an application of ratio estimation. Given a stratified sample design, a gross realization rate (GRR) for a stratum is defined as the ratio of the sum of the ex post savings evaluated for the M&V sample to the sum of the *ex ante* claimed savings recorded in the tracking database for the same sample.

To estimate total ex post evaluated savings for a program, the estimates of ex post evaluated savings for the different strata are summed. Note that this will give a realization rate at the program-level that is a weighted average of the realization rates for the different strata, with claimed savings being the weights.

4.3 Validity and Reliability for Evaluation of PGE2007

There can be several sources of uncertainty associated with the estimates of the impacts of the PGE2007 program. Such sources include the following.

- Sample selection bias
- Physical measurement error (e.g., meter bias, sensor placement, non-random selection of equipment or circuits to monitor)
- Engineering analysis error (e.g., baseline construction, engineering model bias, modeler bias)

- Survey error (e.g., non-response bias)

Various steps were taken to reduce the uncertainty arising from these sources and thereby increase the validity and reliability of key measurements for the evaluation of savings for PGE2005. The details of these steps are discussed in Appendix D in the Non-HIM Appendices.

4.4 Detailed Findings for Evaluation of PGE2007

Detailed findings from the EM&V for PGE2007 are presented in this section. These findings are based on the sample of projects and measures chosen for detailed analysis. The discussion is focused on the results of the fieldwork as it pertains to the particular parameters that are most important in determining savings.

4.4.1 Findings from Analysis of Gross Savings for PGE2007

For each site in the final sample used to analyze gross kWh savings there are two estimates of gross kWh savings: the claimed gross kWh savings estimate (as reported in the program tracking system) and the estimate of ex post evaluated gross savings developed through the analysis. Figure 4-1 provides a summary comparison between the two values for the PGE2007 sample sites. The correlation is close with an R^2 of 0.84 between the two values across the sample sites.

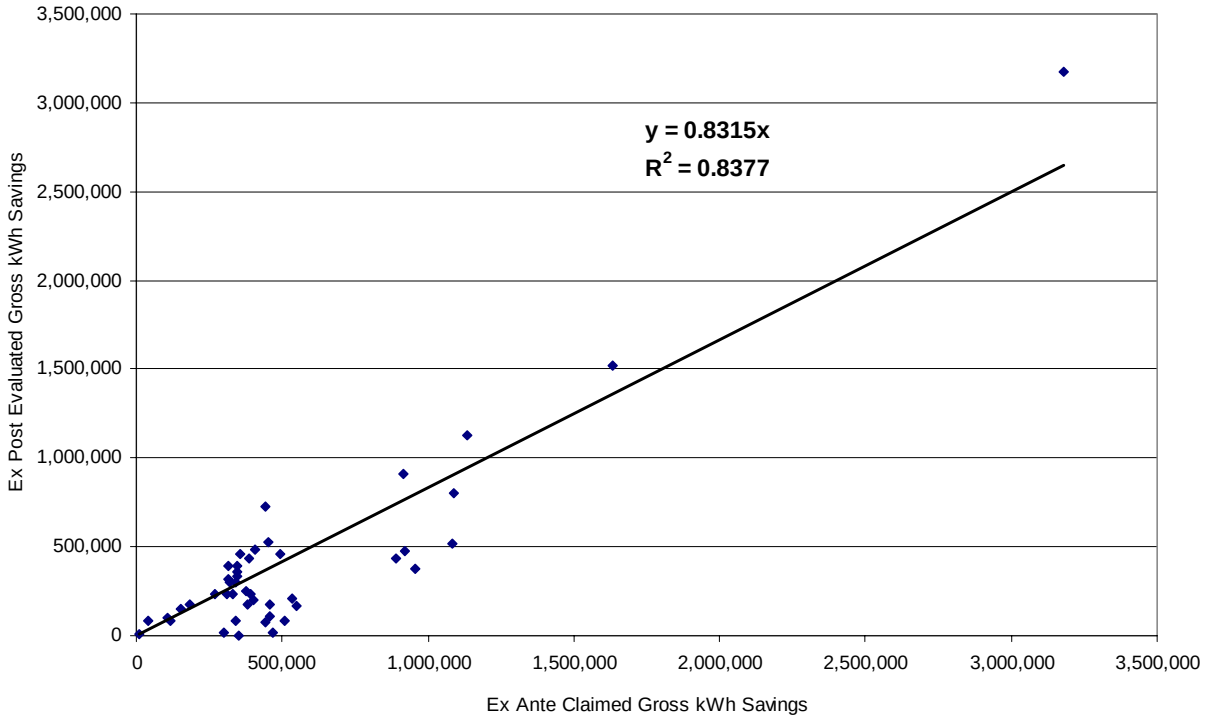

Figure 4-1. Comparison of Achieved Gross kWh Savings to Claimed Gross kWh Savings for PGE2007 Sample Sites

The estimated realization rates for gross kWh savings for the strata in the PGE2007 analysis sample are shown in Table 3-5. Realization rates for the larger projects in Stratum 5 are somewhat lower than those for projects in other strata. (The realization rates defined for kWh, kW, and Therms for the sample strata are used with population weighting to develop overall realization rates. These overall realization rates are reported below in Table 4-6.)

Table 4-3. Realization Rates for Gross kWh Savings by Sampling Stratum for PGE2007 Analysis Sample

Stratum	Number of Sample Sites	Total Claimed Gross kWh Savings	Total Achieved Gross kWh Savings	Sample Realization Rates
1	1	8,640	6,815	78.9%
2	2	94,006	64,835	69.0%
3	2	269,418	235,124	87.3%
4	2	454,255	410,731	90.4%
5	38	23,391,305	17,191,200	73.5%
Overall	46	24,217,624	17,908,705	73.9%

The realization rates for peak kW reductions by sampling stratum for the PGE2007 analysis sample are shown in Table 4-4.

Table 4-4. Realization Rates for Peak kW Reductions for PG2007 Analysis Sample, by Sampling Strata

Stratum	Number of Sample Sites	Total Ex Ante Claimed Peak kW Reductions	Total Ex Post Evaluated Peak kW Reductions	Sample Realization Rates
1-4	7	266	115	43.2%
5	39	3,210	2,651	82.6%
Overall	46	3,475	2,766	79.6%

The realization rates for gross therm savings for the PGE2007 analysis sample are shown in Table 4-5.

Table 4-5. Realization Rate for Gross Therm Savings for PGE2007 Analysis Sample

Stratum	Number of Sample Sites	Total Ex Ante Claimed Gross Therm Savings	Total Ex Post Evaluated Gross Therm Savings	Sample Realization Rates
Overall	3	96,637	8,516	8.8%

Table 4-6 lists the reasons for variances between ex-ante and ex-post energy savings. The number of occurrences of a given reason, the total ex-ante savings, total ex-post savings, the percentage of the overall program-level variance between ex-ante and ex-post, and average realization rate for all sites that fall under the given categories are also shown in the table.

Table 4-6. Summary of variances between ex-ante and ex-post savings for PGE2007 analysis sample

Cause for Discrepancy	Number of Sites	Total Ex Ante Claimed Gross kWh Savings	Total Ex Post Evaluated Gross kWh Savings	Fraction of Total Variance between Ex-Ante and Ex-Post	Weighted Realization Rates
Ineligible measure	0	0	0	0.00	N/A
Tracking database error	0	0	0	0.00	N/A
Noncompliant with program	0	0	0	0.00	N/A
Measure not found	0	0	0	0.00	N/A
Economic slowdown	1	379,051	179,410	0.03	47%
Incorrect code baseline	3	1,262,481	467,027	0.11	37%
Incorrect industry standard baseline	0	0	0	0.00	N/A
Inaccurate baseline parameters	12	6,941,259	2,746,194	0.56	40%
Measure parameters different from ex ante assumptions	13	5,488,686	4,876,492	0.08	89%
Measure operation changed	1	52,297	-19,158	0.01	-37%
No major change (plus minus 10% of ex ante)	9	8,351,724	8,266,676	0.01	99%
Calculation errors in ex ante estimates	3	683,723	325,488	0.05	48%
Various (a single most important reason cannot be identified)	3	1,498,903	327,950	0.16	22%
Total	**45**	**24,658,124**	**17,170,079**	**1.0**	**70%**

4.4.2 Findings from Analysis of Net Savings for PGE2007

For the analysis of net savings attributable to PGE2007, it is important to recognize that the commercial market is divided into a number of submarkets. These include large office, government, retail, data centers, high tech facilities, etc. It is also important to recognize that there are multiple players. There are the owners, the building managers, the facility engineering staff, and others. In many instances buildings are managed for their owners by professional management firms that perform the traditional owner functions and involve the owners in instances where there are major capital decisions.

In addition, there are other firms that provide facility engineering services that may work for the management firms or the owners. A trend that has occurred over the last four years is that property management firms are becoming much more involved in providing facilities engineering services and are competing with the traditional facilities engineering services providers. Representatives of major national property management firms that were interviewed mentioned that they now have national directors of energy engineering and that energy

engineering is "on the map." They now sell efficiency analysis and services as part of their offerings. This is likely an important influence for energy efficiency.

A further consideration in analyzing net savings for the large commercial market is that firms often have multiple sites. For example, for one large national retail firm, there were PGE2007 lighting projects at nine locations. Multiple sites were also sampled for a manufacturer of networking equipment. Thus, one decision maker might be responsible for projects at several sites.

To account for these characteristics of the large commercial buildings market, the net-to-gross analysis for PGE2007 used a very slightly modified version of the standard net-to-gross battery of questions. Detailed findings from the net-to-gross data collection and analysis for PGE2007 are provided in Appendix F of the Non-HIM Appendices. A summary of those findings is presented here.

In developing the net claimed savings for the projects in PGE2007 evaluated here, PG&E used a NTG ratio of 0.7 for most projects. The net-to-gross ratio (NTGR) for PGE2007 was calculated during this study using information obtained through interviews with fourteen decision-makers for large commercial facilities and applying the net-to-gross analysis procedure outlined in Section 3.2.3 and described in Appendix A in the Non-HIM Appendices. Based on this information and analysis, the NTGR for PGE2007 was calculated to be 60%, which was somewhat lower than the NTGR that was used by PG&E in developing its claimed net savings estimates.

4.4.3 Confidence and Precision of Key Findings for Evaluation of PGE2007

The estimated gross realization rates for kWh and therm savings and kW reductions for PGE2007 and the error bounds for these realization rates at 90% confidence level are shown in Table 4-7.

Table 4-7. Precision of Gross Savings Realization Rates for PGE2007

	Gross Savings		Gross Realization Rates	Error Bounds at 90% Confidence
	Ex Ante Claimed	**Ex Post Evaluated**		
kWh	58,352,671	46,374,538	79.5%	± 12.2%
kW	9,684	8,181	84.5%	± 68.8%
Therms	287,995	60,377	21.0%	±33.8%

4.5 Program Specific Results from Evaluation of PGE2007

The findings for realization rates and net-to-gross ratios from Section 4.4 were drawn on to prepare program-level estimates of ex post evaluated savings for PGE2007 according to the procedure described in Appendix of the Non-HIM Appendices.

The program-level estimates of savings for PGE2007 are shown in Table 4-8.

Table 4-8. Gross and Net Savings for PGE2007: Ex Ante Claimed and Ex Post Evaluated

Type of Savings	Gross Savings		Net Savings	
	Ex Ante Claimed	Ex Post Evaluated	Ex Ante Claimed	Ex Post Evaluated
kWh	58,352,671	46,374,538	42,342,316	27,824,723
kW	13,785	8,181	7,035	4,908
Therms	287,995	60,377	201,597	36,226

4.6 Discussion of Findings and Recommendations from Evaluation of PGE2007

Table 4-9 provides data comparing net savings as claimed at the end of the program cycle and as evaluated as being achieved through this evaluation effort.

Table 4-9. Comparison of Ex Ante Claimed and Ex Post Evaluated Net Savings for PGE2007, by Type of Savings

Type of Savings	Total Ex Ante Claimed Net Savings	Total Ex Post Evaluated Net Savings
kWh	42,342,316	27,824,723
kW	7,035	4,908
Therms	201,597	36,226

Net ex post evaluated savings for PGE2007 fell below ex ante claimed net savings primarily because (1) gross realization rates were less than 1 and (2) the net-to-gross ratio was somewhat lower than the values assigned to the measures by PG&E in determining claimed net savings.

For PGE2007, the gross realization rate for kWh savings was estimated to be 79.5%. This realization rate is higher than the 44.6% calculated for PGE2005. The higher realization rate is due mostly to the higher evaluated savings for lighting and HVAC measures in PGE2007 that are relatively more standardized than the measures receiving rebates under PGE2005.

The NTGR for PGE2007 that was calculated during this study was 0.60, which was somewhat lower than the NTGR of 0.70 that was used by PG&E in developing net claimed savings. However, that owners and managers of commercial office properties are now paying attention to energy efficiency appears to be in part an effect of pre-2006 PG&E programs. As an example, a pre-2006 project completed in a headquarters building resulted in that firm letting and even encouraging energy efficiency projects to compete with other projects for funding. The facilities engineering manager said that they have completed approximately 100 projects of which 75 may have received incentives. Those that haven't received incentives likely had paybacks that were too short to qualify for the program. The incentive does improve the chances of projects that have marginal paybacks. The program also serves to highlight the importance of energy with the owners and the owners value the PG&E imprimatur associated with the program. The chances

are greater that the project would have gone forward in the IOU service territory with more competitive rebate programs.

Based on these findings, the following recommendations are made regarding implementation and evaluation of energy-saving projects for large commercial facilities.

- *Ensure Complete Documentation of Assumptions Underlying Specification of Baseline Conditions.* Understanding baseline conditions is important for any ex post evaluation of savings from a project, since savings from an energy efficiency measure are measured against the baseline. Accordingly, it is recommended that PG&E ensure full and complete documentation be required of the assumptions underlying specification of baseline conditions for any particular project.

5. EVALUATION OF REFRIGERATION DOOR GASKETS HIM

5.1 Evaluation Objectives for Evaluation of Refrigeration Door Gaskets HIM

This evaluation was aimed at assessing the gross and net energy savings attributable to door gaskets, a refrigeration measure for which PG&E, SCE, and SDG&E provided rebates during the 2006-2008 program cycle.

Door gaskets are placed on doors of refrigerated display cases in supermarkets, convenience stores, and some eateries to ensure proper sealing of closed doors. Door gaskets reduce the overall refrigeration load by preventing infiltration of warm, moist air into refrigerated space. Virtually all doors in refrigerated display cases and even main doors for walk-in coolers and freezers have door gaskets by design. However, the gaskets need periodic replacement to ensure proper sealing of closed doors.

The IOUs rebated the replacement of old gaskets with new ones in grocery stores, convenience stores, and restaurants. Most of the rebated gaskets were placed on refrigerated display cases in supermarkets (i.e. gaskets on the glass doors in the frozen food section).

The specific objectives for the evaluation of savings from door gaskets included the following.

- A key objective of the evaluation was to identify, measure, and quantify the most significant parameters that influence the energy savings achievable with door gaskets.
- A second objective was to form recommendations for adjustments to ex-ante savings estimations and to the assumptions and/or methodologies employed to develop the ex-ante savings estimations.
- A third objective was to make recommendations to increase the cost effectiveness and accuracy of future evaluations on refrigeration door gaskets.

5.2 Methodology and Specific Methods Used for Evaluation of Refrigeration Door Gaskets HIM

The gross impact evaluation for door gaskets was conducted at the enhanced level of rigor according to the CA Evaluators' Protocols[1]. The energy savings attributable to door gaskets on coolers and freezers were determined through a three-step process:

1) Determine the infiltration through door gaskets of varying conditions (e.g. newly installed, damaged, nearing the end of useful life, etc.) through in situ tracer gas measurements at supermarkets.

[1] Hall, et al. *California Energy Efficiency Evaluation Protocols: Technical, Methodological and Reporting Requirements for Evaluation Professionals*, California Public Utility Commission (April 2006) p.26.

2) Monitor the temperature and relative humidity patterns inside and directly outside the refrigerated cases and the door-usage patterns. The sample should be large enough to describe the temperature and door operation patterns for groceries and supermarkets with 10% relative precision at the 90% confidence interval.

3) Compute the annual savings achieved by door gaskets using a custom-made computer model that calculates and sums the savings for each hour of the year accounting for factors such as weather dependence of refrigeration systems' performances, interactions between the exfiltrated air and the HVAC systems that condition the sales floors, and the prevalent door usage patterns determined through the monitoring process determined in step (2) above.

5.2.1 Literature Review

This study began with a literature review of the utility program tracking data and work papers that detailed the energy savings estimation calculations associated with door gaskets. The sampling plan and field measurement approaches were devised according to the findings of the literature review. Major findings of the literature review are summarized here.

The initial calculation review found significant differences in *ex-ante* energy savings calculation methodologies. This has led to widely disparate in *ex-ante* energy savings estimations. The difference in the results of the IOU calculations is due to differing assumptions regarding the infiltration rate through poor gaskets.

PG&E estimated that the infiltration rate is 3% that of the infiltration rate through a fully open door. For most reach-in units, 3% of the door area is 40 to 45 square inches. The engineers involved in the literature review found it difficult to accept that degraded gaskets on a single door can allow as much air to pass through as an opening that is approximately half the size of a standard letter size sheet of paper. In fact, for most reach-in refrigerator doors, the area of the gap that would result by completely *removing* the gaskets is less than 100 square inches[2]. Our literature review found that the energy penalty due to damaged gaskets, as claimed by the PG&E work paper, is higher than the increased energy usage that results from removing gaskets entirely – in other words, the ex-ante claims are non-physical[4].

SCE directly measured the refrigeration load with new gaskets and with degraded gaskets that were missing a 1-foot section in the lab. To scale the lab results to field gasket conditions (most gaskets are not so severely damaged as the one tested in the lab), SCE conducted field inspections of supplanted gaskets to assess that, out of every 45 feet of gaskets, one foot of gasket is ineffective. This is a far more rigorous approach, yet it is subject to any bias that may

[2] Perhaps the "3% of door area" estimation was motivated by certain claims (by implementers) that damaged gaskets can actually prevent proper door closure. Although this seems feasible, our field effort, which involved visual inspections of over 1000 doors, and detailed, inch-by-inch description of over a mile of potentially "baseline" gaskets, did not find any evidence of torn gaskets impeding door closure.

result from sampling just one unit[3]. After all, the leakage through damaged gaskets is a function of both the gaskets and of the unit on which the gaskets are installed.

Most of the remaining assumptions among the IOUs were in agreement. The baseline gasket condition was identified as a likely to dominate the uncertainty in the ex-post energy savings estimations.

5.2.2 Sample Selection

Savings from door gaskets result from replacing deteriorated gaskets with new gaskets, thereby reducing infiltration. Developing the sample design for door gaskets therefore required taking into account the data that can be obtained regarding the impacts of door gasket replacements on infiltration. One source of such data was the laboratory testing of door gaskets that has been performed for the Pacific Northwest Regional Technical Forum.[4] This laboratory testing provided results for how differences in gasket conditions affect the energy usage of walk-in coolers and freezers under controlled conditions. However, the sampling for the analysis of door gaskets as a HIM needed to address how field measurements of infiltration could be made for coolers and freezers with door gaskets.

Tracking system data provided by the IOUs provided a sampling frame for identifying sites that had deteriorated door gaskets replaced. However, these sites will have gaskets fully in place. For the field measurements, sites with deteriorated door gaskets also had to be included to gauge the change in infiltration that results from replacing the deteriorated gaskets. It is possible to remove door gaskets to simulate door gaskets in a deteriorated state when taking infiltration field measurements. Removing just two or three gaskets in an isle of reach-ins can establish the far upper limit of energy savings achievable by door gaskets.

For taking field measurements of how door gasket conditions affect infiltration, two complementary sampling approaches were used.

The first approach, which is similar to that used for strip curtains, involved conducting with and without monitoring of infiltration for sites with deteriorated door gaskets that participated in the IOU programs. In particular, because the effective useful life of door gaskets is relatively short (i.e., 4 years), it might be expected that there would be some door gasket deterioration for sites that had door gaskets replaced in 2006. Two infiltration tests were performed for sample sites: first, as-is with the deteriorated gaskets and second, as repaired (by sealing up the deteriorated

[3] The SCE approach to ex-ante savings estimation is sound, but there are limitations to the data obtained through the lab tests. Please see Appendix I for a more detailed discussion.

[4] See the reports prepared by Design Services Network for the Bonneville Power Administration (BPA) and Portland Energy Conservation, Inc. (PECI): *Energy Usage of a Walk-in Freezer with Various Gasket Conditions*, September 28, 2008 and *Energy Usage of a Walk-in Cooler with Various Gasket Conditions*, October 20, 2008

section of door gaskets). Essentially, this approach would provide paired data for each site similar to that obtained through the field testing performed for strip curtains.

The second approach, which was used to complement the first, was to take field measurements of infiltration for a comparison group of non-participant sites. For this second approach, sites were recruited that did not participate in the IOU programs and that were identified as having deteriorated door gaskets. Field testing of infiltration was then conducted for this sample of sites.

The sample sizes associated with the field measurement work for these two approaches include 20 participants and 10 non-participants each for freezers in supermarkets, coolers in supermarkets, and coolers in convenience stores. Upon reviewing infiltration test results, the 'post-only' gaskets were found to be virtually perfect infiltration barriers. Our sensitivity tests showed that the energy savings would be over-estimated by a negligible amount if the post-only leakage was deemed to be identically zero. As such, the post-only sample for convenience stores was dropped from the study, and the rebated gaskets for convenience stores were deemed to be perfect.

5.2.3 Field Measurement Methodology

5.2.3.1 Tracer Gas Measurements

The infiltration rates through the gaskets were determined using data collected through tracer gas measurements. The process is described in detail in the Appendix B of the HIM Appendices. At least three separate tests were conducted at each site:

- Measurement of infiltration with the doors closed as in normal operation.
- Measurement of infiltration with the doors closed and taped shut.
- Measurement of infiltration every third or fourth gasket removed.
- Additional tests are discussed in Appendix B of the HIM Appendices. The leakage through the gaskets is defined as the difference in infiltration rates between test #1 and test #2. The third test was used to capture the absolute maximum infiltration rates. Both the baseline an and post-measure infiltration rates were expected to be small fractions of the infiltration rates determined by test #3. The test results were analyzed by fitting the observed CO_2 decay rates with an exponential function and converting the results to a flow rate in cubic feet per minute, based on the measured volume of the display case.

5.2.3.2 Short Term Monitoring

In addition to tracer gas measurements, refrigerated cases were monitored for at least a two-week period. The following data were collected:

- Door Open/Close states for two to four doors were monitored with state-loggers installed at both the handle and hinge of the door, to capture small-angle and relatively large-angle openings, respectively.

- Temperature and relative humidity were monitored with HOBO loggers, both inside the unit, outside the unit (placed appropriately to characterize the air that infiltrates the walk-in of interest), and outdoors.

5.2.3.3 Analysis of Short Term Monitoring Data

The data collected during short term monitoring established the times and durations of door openings and the conditions of the refrigerated and infiltrating airs. This data was extrapolated into a year-long, hourly binned calculation in a spreadsheet. The general approach was to describe weather-dependent quantities as functions of calibration constants and outdoor temperature and humidity. The calibration constants were automatically determined for each site individually for each site using a least squares approach.

The resulting calibrated temperature functions were then seeded with typical meteorological year weather data. The two week door-opening and freezer defrost temperature patterns were taken to be repeating patterns over the 52-week period.

In the strip curtain evaluation (discussed in Chapter 6), the analysis was done on a site-by site basis for 154 sites, and the results were aggregated according to walk-in types and business types. This was the initial plan for the door gasket analysis as well. However, early analysis findings and results indicated that the variations in door-open times, sales floor temperatures, freezer/cooler temperatures, and post-install gasket efficacies are quite small and make minimal contribution to the overall uncertainty in the *ex post* savings estimation. Accordingly, the analysis for the door gasket evaluation involved making a total of 32 archetypal 8760-hour calculations—one for coolers and one for freezers in each of the 16 climate zones[5].

5.2.3.4 Estimation of Baseline Gasket Efficacy

Measurements on "baseline" gaskets prior to retrofit could not be made during this study. However, there was an opportunity to inspect and record the conditions of over 5,300 feet of gaskets prior to replacement. Using these data, three complementary approaches were used in an attempt to determine the baseline gasket efficacy.

- First, gaskets from comparison groups that were non-participants in the gasket rebate programs were compared with the "post only" sample.
- Second, as with the strip curtains, it was expected that the "baseline gasket" might exist in the "post-only" sample.

[5] This is the same approach that would be used if eQuest or DOE2 were to be used in the analysis. Late in the contract cycle, ADM received a new version of eQuest Refrigeration that calculates infiltration between spaces due to the stack effect. We have started to replicate our binned calculations with the eQuest software. Although there was not sufficient time for full results of the study to be included in this report, initial findings are that the two methods are in good agreement.

- Third, field observations from early "pre-post" field visits were used to determine the severity of the gaps and tears in gaskets that were replaced in 2008. This data were coupled with the results from test #3 (described above) that was used to assess the infiltration through poor gaskets as some fraction of the infiltration that occurs in the absence of gaskets.

The first and second method revealed that the "post only" and "comparison group" samples contained essentially perfect gaskets. The third method is the only methodology that utilized actual observations of "baseline" gaskets. Ultimately, this method was used to establish the baseline gasket efficacy.

5.2.4 Conducting Analysis of Net Savings

The analysis of net savings for door gaskets was conducted using the standard methodological framework that had been developed by the nonresidential net-to-gross working group formed by the Energy Division. This working group, which was composed of experienced evaluation professionals, developed a standard methodological framework, including decision rules, for integrating in a systematic and consistent manner the findings from both quantitative and qualitative information in estimating net-to-gross ratios.

The NTG method relies exclusively on the Self-Report Approach (SRA) to estimate project and domain-level Net-to-Gross Ratios (NTGRs), since other available methods and research designs are generally not feasible for large nonresidential customer programs. The approach was designed to fully comply with the *California Energy Efficiency Evaluation: Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals* (Protocols) and the *Guidelines for Estimating Net-To-Gross Ratios Using the Self-Report Approaches* (Guidelines).

The net-to-gross survey for door gaskets, which was conducted with participants who had door gaskets installed through an IOU program, was a modified version of the standard net-to-gross battery. The modifications were required because:

- Program participants may have had maintenance contracts for door gasket replacements.
- Participants may have had an internal program for maintaining door gaskets.
- Door gaskets were provided at no charge. Since the customer is not paying for the measure, payback, which is the total cost of the measure to the customer us divided by annual cost savings is zero and therefore not meaningful.

For the survey, convenience stores and supermarkets were stratified into three groups each: according to the savings. Stores and supermarkets with large savings were sampled with certainty. Stores and supermarkets with medium and small savings were randomly sampled in accordance with the variance in the estimates of the savings.

The logic for the net-to gross for the replacement of door gaskets is as follows.

- If the respondent had a maintenance contract and the maintenance contract was less than the assumed measure life (four years) of a door gasket, the respondent was identified as a free rider, in other words, the net-to-gross ratio for these respondents is zero. Any respondents with contract maintenance with a periodicity greater than the measure life were identified as a non-free-riding participant and were administered the net-to-gross battery.
- If the respondent reported that they regularly maintained door gaskets (on there own without a maintenance contract), and the periodicity of the maintenance was less than the assumed measure life (four years), the respondent was assumed to be the a free rider with a net-to-gross ratio of zero. Any respondents who maintained door gaskets with a periodicity greater than the measure life were identified as non-free-riding participants and were administered the net-to-gross battery.
- The remaining participants either did not report maintaining gaskets and did not have maintenance contracts, had maintenance contracts but were not replacing gaskets within the expected lifetime of the gaskets, or reported doing maintenance but reported that they were doing the maintenance at intervals greater than the life of the gaskets. The full net-to-gross battery was administered to this group of participants.

5.3 Confidence and Precision of Key Findings for Evaluation of Refrigeration Door Gaskets HIM

The goals of this study were to assess the energy savings due to door gaskets curtains with 10% relative precision at the 90% confidence interval and to identify market-specific factors that affect the energy savings potential of door gaskets in various applications. Table 5-1 lists the quantities measured as part of this evaluation. The relative precision at the 90% confidence interval is shown for each quantity and includes all statistical, instrumentation, and computational uncertainties. (See description in Section 5.4).

Table 5-1. Summary of Sample Savings, Precision, and Confidence.

	Number of Sites in Sample	Ex-Post Energy Savings (kWh/ft)	Relative Precision (Including Statistical, Measurement, and Computational Uncertainties)
Supermarket Freezer	20	3.32	154%
Supermarket Cooler	20	0.45	154%

We note that the large relative precision is not a sign of a flawed study, but is rather a large *relative* uncertainty on a small number. The ex-ante annual savings estimations ranged from 10 kWh to 100 kWh per linear foot of strip curtain. Our absolute uncertainties range from 0.7 kWh/ft to 5.1 kWh/ft, which would be well under ten percent, had the ex-post energy savings been close to the ex-ante estimations. In other words, the uncertainty in the discrepancy between the ex-ante and ex-post energy savings is quite small. As explained in Section 5.4, the uncertainty is due almost entirely to uncertainty in assessing the efficacy of baseline gaskets.

The final sample was smaller than originally intended for two primary reasons.

- First, the quantities obtained by the site visits showed very little variation. Freezer and cooler temperatures, door opening patterns, and even the efficacies of the rebated gaskets were known to much better than 10% relative precision with the sample size shown in Table 5-1. The uncertainty in the ex-post energy savings was set almost entirely by the uncertainty in the baseline gasket leakage.
- Secondly, it was unexpectedly difficult to gain access to supermarkets. Unlike the walk-in units, which are typically in loading bays, the gaskets are all on the sales floor. Stores that did not have 24-hour operation were not receptive to requests to carry out infiltration tests after hours. Access was eventually gained to about 40 supermarkets that had 24-hour operation, but only after long negotiations.

5.4 Validity and Reliability for Evaluation of Refrigeration Door Gaskets HIM

Table 5-2 lists the contributions of various measurements and calculations to the overall uncertainty in the gross impact calculation. This process is discussed in more detail in Appendix F of the HIM Appendices. The results are discussed below.

Table 5-2. Contributions of Various Calculation and Extrapolation Uncertainties to Estimate of Overall Site-specific Energy Savings

Measured/Assessed Quantity	Absolute Uncertainty: (σ_x)	Relative Uncertainty: $\frac{(\sigma_x \times \frac{\partial kWh}{\partial x})}{kWh}$
Delta Gasket Efficacy	154% of the baseline value	154%
Refrigerated Air Temp	1.2 °F	2.5%
Infiltrating Air Temp	0.8 °F	2.5%
Refrigerated Air RH	2.4 % RH	0.7%
Infiltrating Air RH	1 % RH	0.0%
Refrigeration COP	0.125 for freezers, 0.25 for coolers	9%
Overall Uncertainty		**154%**

The uncertainty in this study is driven by the uncertainty in the baseline door gasket. There were no badly damaged gaskets in the post-only sample. Furthermore, the comparison group also did not have any leaky gaskets. As such, resort had to be made to records of baseline gasket conditions (see Table 5-4) prior to retrofit. The baseline gasket efficacy is defined as the ratio of the overall gasket length that was removed by the installers to the gasket length that was replaced. The results of the infiltration tests with the gaskets removed were scaled accordingly to simulate badly damaged gaskets. Unfortunately, such a small percentage of the overall

observed gasket length was significantly damaged that the ratio of missing gasket length to overall door perimeter has a large statistical uncertainty. This ratio is consistent with the ratio determined through similar methods in the SCE work paper[6].

As a check on the results of the infiltration tests with the gaskets removed, the energy savings for the sites in our sample were calculated as if the baseline gasket efficacy was zero. The annual energy savings that would result are approximately 230 kWh per linear foot of gasket installed. This compares well with the results of lab tests conducted in 2008[7]. Most of the uncertainty in the measurement for this study, then, comes from assessing the fraction of the baseline gaskets that are effectively missing. As previously discussed, the PG&E *ex ante* estimations correspond to unreasonably large fractions of ineffective gaskets.

5.5 Detailed Findings for Evaluation of Refrigeration Door Gaskets HIM

Findings from the evaluation of the door gaskets HIM are presented in this section.

5.5.1 Gross Energy Savings for Door Gaskets

5.5.1.1 Various Baseline Gasket Efficacy Scenarios

Our tracer gas measurements found that there is virtually no leakage through gaskets that are in good or moderate condition. The tracer gas tests are sensitive to leakages as little as 0.005 CFM leakage per liner foot of gasket, yet no significant leakage was detected in the post-only sample or in the non-participant comparison group. The energy savings, then, depend almost entirely on the leakage through the baseline gaskets. Energy savings attributable to door gaskets are shown in or various scenarios regarding baseline gasket efficacies are shown in Table 5-3.

The limiting scenario is if the baseline gaskets are completely missing. The energy savings achievable under this scenario are 230 kWh/ft for freezers and 30 kWh/ft for coolers. However, the energy savings that can *actually be achieved* are a small fraction of the savings that would result under this scenario.

[6] SCE determined that every 45 feet of replaced gasket corresponded to 1 foot of ineffective gasket. This translates to 2.2% of ineffective gasket by length. Our field observations resulted in an estimation of 1.5%, though, due to the large uncertainty, the value is entirely consistent with 2.2%. See Southern California Edison, Design and Engineering Services, *Infiltration Barriers-Strip Curtains,* SCE Work Paper WPSCNRRN0002.1, November 2007.

[7] *Energy Usage of a Reach In Freezer With Various Gasket Conditions*, Steve Pfister and George Kazachki (August 2008), p.7.

Table 5-3 Energy Savings Achievable for New Gaskets Replacing Baseline Gaskets of Various Efficacies

	PGE Ex-Ante Savings (kWh/ft)	SCE Ex-Ante Savings (kWh/ft)	Savings if Baseline Gaskets are 0% Effective	Savings if Baseline Gaskets are 50% Effective	Savings if Baseline Gaskets are 90% Effective	Ex-Post Savings (Baseline Gaskets 98.5% Effective)
Freezers	105	21.7	228	114	23	3.3
Coolers	105	10.2	30	15	3	0.4

The IOU e*x ante* estimations are also listed in Table 5-3. Note that the PG&E *ex ante* energy savings estimations for coolers are approximately three times higher than the savings in the limiting scenario. The reason for this disparity is most likely the assumption in the work paper that the "Weak gaskets on coolers and freezers allow loss of 3% of the open door heat loss."[8] The *ex ante* savings estimations from SCE are much more conservative, yet the energy savings correspond to the savings against a baseline gasket that is just 90% effective[9].

5.5.1.2 Post Retrofit Gasket Efficacy

One noteworthy finding from the study regards the efficacy of door gaskets. Most of the reach-in units tested had insignificant leakage through the gaskets. There were no significant differences in gasket leakage between program participants and the non-participant comparison group, despite the fact that some of the gaskets in the comparison group were installed up to three years ago. This suggests that unless novel, catastrophic failure modes manifest in large numbers late in the door gasket service lives, the "baseline" door gaskets are actually quite effective infiltration barriers. Only a small fraction of door gaskets would be legitimate targets for replacement.

5.5.1.3 Implementer's Approach

A second important finding of this study is that the implementers tend to target the worse 15% of gaskets for replacement. The findings in Table 5-4 suggest that the direct install implementers are targeting the leakiest and most unsightly gaskets for replacement. However, the ratio of unsightly to leaky gaskets is very large. This is important, as the previous section indicated that only a small fraction of gaskets truly merit replacement from a strict energy savings criteria[10].

[8] PG&E Non Residential Work Paper R50/R90, *Door Gaskets Coolers or Freezers, Solid or Glass Doors*, page 1.

[9] See Appendix I for a discussion on the disparity between the SCE ex-ante savings estimation and the ex-post findings.

[10] Often, the door gaskets may be appear tattered and dilapidated, but are functional infiltration barriers nonetheless. Net-to-Gross findings presented below may suggest that the gaskets are replaced aesthetic grounds rather than from an energy savings standpoint.

During the field work in 2008, field staff recorded the conditions of 5,311 linear feet of gaskets (19 cases, 360 doors) prior to retrofit. On average, about 16% of gaskets were replaced. All of the gaskets that had missing sections were replaced, and about half of the gaskets that had tears were replaced. The infiltration tests showed that torn gaskets do not appreciably increase the infiltration rate into the refrigerated cases. The findings in Table 5-4 suggest that the direct install implementers are using improper criteria in choosing which gaskets to replace. For example, if the "threshold" for gasket replacement were raised to six inches of gaskets missing, then the energy savings would double. The issue presented in Table 5-4 is that the IOUs appear to be rebating not just the gaskets that merit replacement from an energy savings standpoint, but also many, many more gaskets that are replaced chiefly on a cosmetic basis.

Table 5-4. Conditions of Baseline Gaskets That Were and Were Not Replaced by Implementers.

	Total Length (ft)	% Missing	% Torn Through
Observed by ADM field staff prior to replacement	5,311	0.23%	0.53%
Replaced by Implementers	850	1.47%	3.32%
Not Replaced by Implementers	4,311	0.00%	0.27%

5.5.2 Net Savings Impacts for Door Gaskets

The results from the net-to-gross analysis for door gaskets are presented in this section for the population of customers who had door gaskets installed through an IOU program. Details for the net-to-gross analysis for door gaskets are discussed in Appendix J of the HIM Appendices.

Through the analysis of the survey data, net-to-gross ratios were assigned to three groups of customers who received door gaskets through an IOU program.

A first group consisted of participants with a maintenance contract who replaced door gaskets within a four-year period (i.e., the assumed life of door gaskets). Survey data for this group suggested that half of these customers maintain gaskets at least annually and sixty-four percent replace them within two years. Because there is a near certainty that door gaskets within these establishments would have been replaced without the program, customers in this group were assigned a net-to-gross ratio of zero.

A second group consisted of participants who did not have maintenance contracts but who maintained gaskets on a schedule that was more frequent than the lifetime of the gasket. Sixty-three percent of these participants claimed to maintain gaskets on a cycle that was less than three years. There is a high probability that door gaskets within these establishments would have been replaced without the program. One might argue that the program might have accelerated the replacement of door gaskets for these respondents. On the other hand, it is likely that linear feet of compromised door gaskets for these firms is not large and that the losses from compromised gaskets sufficiently low replacement might not have been cost effective. Accordingly, customers in this second group were also assigned a net-to-gross ratio of zero.

A third group consisted of participants who did not have maintenance contracts and who did not regularly maintain gaskets. A very high percentage of these firms thought replacement too costly, was not needed, or tended to defer maintenance. It is clear that these establishments could substantially benefit from this program. Ultimately, the question for this group was would they have replaced door gaskets without the program.

A net-to-gross ratio for the third group was calculated using three scores:

- A factor-specific program influence score.
- A summary program-influence score
- A likelihood score that door gaskets would not have been replaced without the program.

The factor-specific program influence score was derived from program and non-program factors. An average factor specific program influence score and a factor specific non-program influence score was calculated for each respondent. The average factor specific influence score was then divided by the sum of the average of the program and non-program specific factor influence scores. This resulted in a program influence ratio ranging between 0 and 1. If program specific factors had higher average ratings than the non-program specific factors then the factor specific program influence score is above 0.5. Alternatively, if the program factors had a lower average rating in comparison to the non-program ratings, then the program influence would be less than 0.5. If there were program specific factors but no specific non-program factors, then the program specific factor influence score would be 1. Likewise if there were only non-program specific factors, then the program influence score would be zero.

Respondents were also asked provide a summary program influence score by distributing 10 points to what they understood to be "program factors" and "non-program factors." The summary program influence score was calculated by dividing the number of points that respondent gave to "program factors" by 10. This results in a score between 0 and 1.

The likelihood that the action was program induced was calculated as well. The likelihood score was based on the question about the likelihood that the respondent would have installed door gaskets in the absence of the program. The likelihood that the respondent would have taken action without the program was calculated as 10 minus the likelihood of taking the action in the absence of the program divided by 10.

The factor specific program influence score and the summary program influence score were combined to form a composite program summary score. The composite program influence score is the average of the two program influence scores.

The net-to-gross ratio was formed by averaging the composite program summary influence score and likelihood score. In a situation where one or the other score is missing, only the one score is used.

The results are shown in Table 5-5. The overall weighted net-to-gross ratio for door gaskets is 19%.

Table 5-5 Overall Results of Net to Gross Survey for Door Gaskets

Category of respondent	Count	Percent	Group Net-to-Gross	Weighted Net-to-Gross
Maintenance contract	12	17	0	0
No maintenance contract but claiming to maintain within the lifetime of the gasket	33	47	0	0
Did not maintain gaskets	26	37	0.50	0.19
Total/weighted total	71	101	-	0.19

5.6 Program Specific Results for Evaluation of Refrigeration Door Gaskets HIM

The IOUs provided incentives for installing door gaskets through a variety of programs. The results for gross kWh savings for these various programs are summarized in Table 5-6. The SCE programs generally had higher realization ratios because their ex-ante assumptions were more conservative than those of PG&E and SDG&E.

Table 5-6. Program Gross Impact Realizations and Realization Ratios*

Program	Linear Feet of Gaskets Installed in 2006-2008	Ex-Ante Claimed Gross kWh Savings	Ex-Post Evaluated Gross kWh Savings	Realization Ratio (%)
PGE2020	15,413	1,611,741	45,335	2.8%
PGE2021	58	6,090	171	2.8%
PGE2026	174	18,270	512	2.8%
PGE2029	12,631	1,320,619	37,154	2.8%
PGE2051	37,641	3,935,404	110,718	2.8%
PGE2063	114,018	11,971,936	335,374	2.8%
PGE2066	431,940	45,353,734	1,270,511	2.8%
PGE2080	161,730	16,981,645	475,713	2.8%
SCE2511	9,161	138,459	13,585	9.8%
SCE2517	469,932	7,548,119	977,276	12.9%
SCE2566	1,250	30,000	4,540	15.1%
SDGE	146,261	15,291,588	542,222	2.8%

*The relative precision, which is limited by the uncertainty in the assessment of the baseline gaskets, is 154% for all programs.

5.7 Discussion of Findings and Recommendations for Evaluation of Refrigeration Door Gaskets HIM

5.7.1 Recommendations on Efficacy of Baseline Gaskets

Although the estimation of the baseline gasket efficacy in this study has a very high relative uncertainty, it is known with a much higher degree of certainty that the PG&E estimates of baseline gasket efficacy are too low. Laboratory testing can accurately assess the savings due to replacing a particular gasket on a particular display case, but the extrapolation from a single unit to the entire population of gaskets and display cases is a perilous process.

Accordingly, a first recommendation is that there be a significant upward revision in the assumed efficacy of baseline gaskets. In this evaluation, a baseline infiltration rate of 0.0023 CFM per foot of baseline gasket per square root of the temperature differential (in Fahrenheit or Rankine) between the sales floor and refrigerated case temperatures was used. At a 70 °F temperature differential, the infiltration rate is 0.02 CFM per linear foot of baseline gasket. The typical case door experienced 1.35 CFM per linear foot of door perimeter when the gaskets were removed.

5.7.2 Recommendations Regarding Ex-Ante Parameters That Describe Store Conditions

Another recommendation coming out of the study results is that the *ex ante* estimations for the door-open time and for the temperature differentials between the refrigerated and infiltrating airs should be updated with values listed in Table 5-7.

Table 5-7. Results from Monitoring at Supermarkets

	Sales Floor Temperature (F)	Sales Floor RH (%)	Freezer Case Temperature (F)	Freezer Case RH (%)	Cooler Case Temperature (F)	Cooler Case RH (%)	Minutes Door Closed Per Day
Average	70.0	37.5	0.8	63.5	40.2	78.3	1,435
90% Confidence Interval	±1.3	±3.9	±0.0	±2.0	±1.5	±6.3	±1.6

5.7.3 Recommendations for Future EM&V Efforts on Door Gaskets

It is recommended that any future EM&V activities on door gaskets focus mainly on the efficacy of the baseline door gaskets. The following methodology is suggested.

1. First, obtain from the implementer all gaskets that were replaced with new ones for a store.
2. Take a random sample of 30 or replaced gaskets and install them all on 30-door case, and carry out the infiltration testing procedure as described in this report.
3. Carry out this process on at least five coolers and five freezer cases, with no more than one cooler or freezer tested from any given supermarket chain.

As stated in table 5-4, a typical freezer case with gaskets that are three to four years old will have gaskets that are approximately 99.8% effective. However, the gaskets that were targeted and replaced by the contractors were just 98.5% effective. The process above would yield a direct and accurate measurement of the infiltration rates through baseline door gaskets.

A second approach is to supplement the current lab tests on gasket leakage with various types of baseline gaskets installed on several different types of walk-in cases. As mentioned, the leakage through gaps in gaskets is a function of both the gasket and the case, so that the population of display cases encountered in rebate programs must be represented in an unbiased fashion in lab tests.

6. EVALUATION OF REFRIGERATION STRIP CURTAINS HIM

6.1 Evaluation Objectives for Evaluation of Refrigeration Strip Curtains HIM

This evaluation aims to assess the gross and net energy savings attributable to strip curtains installed through PG&E, SCE, and SDG&E programs in the 2006-2008 program cycle. Strip curtains are placed in doorways of walk-in freezers and coolers, and in doorways of refrigerated warehouses. Strip curtains reduce the overall refrigeration load by preventing infiltration of warm, moist air into refrigerated space while the door is open. The IOUs have rebated the installation of new strip curtains on the entrances of refrigerated spaces. Some programs targeted doors that had no strip curtains installed prior to the rebate process, while other programs also replaced old, degraded strip curtains.

A key goal of the evaluation effort has been to identify, measure, and quantify the most significant parameters that influence the energy savings achievable with strip curtains. Based on the results, recommendations have been developed for adjustments to ex-ante savings estimations and to the assumptions and methodologies employed to develop the ex-ante savings estimations. Another evaluation objective is to make recommendations to increase to cost effectiveness and accuracy of future evaluations of refrigeration strip curtains.

6.2 Methodology and Specific Methods Used for Evaluation of Refrigeration Strip Curtains HIM

The gross impact evaluation for strip curtains is conducted at the enhanced level of rigor according to the California Evaluators' Protocols[1]. The energy savings attributable to strip curtains on coolers and freezers are determined through a three-step process:

1) Determine the infiltration through strip curtains of varying conditions (e.g. newly installed, damaged, nearing the end of useful life, etc.) through in situ tracer gas measurements at supermarkets, convenience stores, restaurants, and refrigerated warehouses.
2) Monitor the temperature and relative humidity patterns inside and directly outside the walk-in units and the door-usage patterns. The sample should be large enough to describe the temperature and door operation patterns for walk-in units with 10% relative precision at the 90% confidence interval.
3) Compute the annual savings achieved by strip curtains using a custom-made computer model that calculates and sums the savings for each hour of the year accounting for factors such as weather dependence of refrigeration systems' performances, interactions between the

[1] Hall, et al. *California Energy Efficiency Evaluation Protocols: Technical, Methodological and Reporting Requirements for Evaluation Professionals*, California Public Utility Commission (April 2006) p.26.

exfiltrated air and the HVAC systems that condition the sales floors, and the door usage patterns determined through the monitoring process determined in step (2) above.

6.2.1 Literature Review

This study began with a literature review of utility program tracking data and "work papers" that detailed the energy savings estimation calculations associated with strip curtains. The sampling plan and field measurement approaches were developed using the findings of the literature review. The literature review also included a review of the basic theoretical predictions of air infiltration due to temperature differentials between two spaces. The theory is discussed in Appendix A of the HIM Appendices.

The key finding of this part of the literature review is that the theoretical equations need an empirical scale factor, often called the *Discharge Coefficient* (C_D), that maps the theoretical predictions to actual measured infiltration rates. This empirical scale factor typically takes on values between 0.4 and 0.6. One of the goals of this effort is to provide updated values and formulations of the empirical scale factor.

The initial review of calculations of energy use and savings associated with use of strip curtains found that the overall approach can potentially yield satisfactory results. However, the resulting savings estimations are quite sensitive to input variables that are based on informed assumptions rather than survey data. For example, PG&E assumed that the refrigerator doors are open 300 minutes per day while SCE assumed that the doors were open 64 minutes per day. To understand the key drivers of the savings calculations, various input parameters were varied by 10%. Table 6-1 lists the relative changes in the calculated energy savings that result from 10% variations of key input parameters.

Table 6-1. Relative Changes in Calculated Energy Savings That Result from 10% Variations in Values of Key Input Parameters.

10% Variation in Input Parameter	Corresponding Variation in Savings
Temperature Differential ($T_{infiltrating} - T_{refrigerated}$)	20.90%
Post-Measure Curtain Efficacy	17.70%
Time Door Open per Day	10.00%
Refrigeration System COP	10.00%
Baseline Curtain Efficacy	7.70%
Relative Humidity of Infiltrating Air	4.20%

Table 6-1 helps to identify the measurable quantities that influence energy savings, but does not assess the inherent variation and measurement uncertainty associated with those quantities. Certain factors are expected to abide by natural constraints. For example, the temperatures of units that contain frozen goods are likely grouped in a relatively narrow band. Likewise, the efficacies of the new strip curtains are determined mostly by the laws of physics. The condition or even the prior existence of the baseline curtains is more difficult to assess. Most importantly,

the time that a walk-in door is open per day depends on many factors and particularly depends on the behavior of the employees at a given site.

These facts are reflected in the IOU work papers. The two ex-ante assumptions that are most disparate among the different IOUs are the efficacies of the old strip curtains and the amount of time that the walk-in doors spend in the open position.

6.2.2 Sample Selection

In statistical terms, a domain of study is a major segment of the population that is identified in the overall sample design as one for which a certain level of detail and certain data reliability are required. The number and types of domains that are defined have an important bearing on the size and distribution of the sample. For the analyses of strip curtains, domains of study were defined by three criteria:

- Type of business (Supermarket, Convenience store, Restaurant, Refrigerated Warehouse);
- Type of refrigeration unit to which the measures are applied (Walk-In Cooler, Walk-In Freezer); and
- Geographical location.

Geographical location of the sites where the measures are installed was considered in defining domains of study for two reasons. One reason, which is based on an administrative point of view, is that taking account of geographical location in defining domains allows consideration of utility service territory. However, there is also an analytical reason for considering geographical location in defining domains. The climate zone can affect the refrigeration systems' efficiencies, and may also influence the temperature of the infiltrating air in cases where the refrigeration unit opens to unconditioned space.

For this study of strip curtains, a sample design was developed using the concept of a paired study as the analytical framework. With a paired study, two measurements of infiltration are made for each site: with strip curtains in place and with strip curtains not in place. The sample design indicated that a total of 140 units were suitable for the overall sample, split approximately evenly among the domains of study. The sample is summarized in Table 6-2.

Table 6-2. Sample Sizes for Strip Curtain Field Measurements by Business Type and Type of Refrigeration Unit

Type of Business	Type of Refrigeration Unit	
	Freezers	Coolers
Supermarkets	20	20
Convenience Stores	20	20
Restaurants	20	20
Refrigerated Warehouses	20	n/a

6.2.3 Field Measurement Methodology

6.2.3.1 Tracer Gas Measurements

The infiltration rates through the strip curtains were determined by tracer gas measurements. The process is described in detail in Appendix B of the HIM Appendices. Up to six tests were conducted at each site, but the minimal set of tests included the following:

- Measurement of infiltration with the door open and the strip curtains in place
- Measurement of infiltration with the door open and the strips removed
- Measurement of infiltration with the door closed and sealed – to capture any leakage through other orifices and cracks (e.g. gaskets of reach-in doors for walk-in/reach-in units)

The test results were analyzed by fitting the observed CO_2 decay rates with an exponential function and converting the results to a flow rate in cubic feet per minute based on the measured volume of the walk-in unit. The efficacy of the strip curtains was then determined by the ratio of the infiltration rates in tests #1 and #2, both normalized for any leakage discovered in test #3. The discharge coefficient is determined by comparing the results in test #2 to theoretical calculations.

6.2.3.2 Short Term Monitoring

In addition to tracer gas measurements, units were monitored for at least a two-week period. The following data were collected:

- Door Open/Close states were monitored with state-loggers installed at both the handle and hinge of the door to capture small-angle and relatively large-angle openings, respectively.
- Temperature and relative humidity were monitored both inside the units, outside the units (placed appropriately to characterize the air that infiltrates the walk-in of interest), and outdoors.
- Activity inside the coolers was monitored with passive infrared motion sensors, and logged with HOBO loggers.

The framework for analyzing the monitoring data was developed early in the evaluation process and was refined in consultation with ED Technical Advisors. In brief, the data collected during the short term monitoring was used to establish the times and durations of door openings and the conditions of the refrigerated and infiltrating airs. These data were extrapolated into an 8760-hour binned calculation in a spreadsheet. The general approach was to describe weather-dependent quantities as functions of calibration constants and outdoor temperature and humidity. The calibration constants were automatically determined individually for each site using a least

squares approach[2]. The resulting calibrated temperature functions were then seeded with typical meteorological year weather data. The two week door-opening and freezer defrost temperature patterns were taken to be repeating patterns over the 52-week period.

6.2.4 Conducting Analysis of Net Savings

The analysis of net savings for strip curtains was conducted using the standard methodological framework that had been developed by the nonresidential net-to-gross working group formed by the Energy Division. This working group, which was composed of experienced evaluation professionals, developed a standard methodological framework, including decision rules, for integrating in a systematic and consistent manner the findings from both quantitative and qualitative information in estimating net-to-gross ratios.

The NTG method relies exclusively on the Self-Report Approach (SRA) to estimate project and domain-level Net-to-Gross Ratios (NTGRs), since other available methods and research designs are generally not feasible for large nonresidential customer programs. The approach was designed to fully comply with the *California Energy Efficiency Evaluation: Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals* (Protocols) and the *Guidelines for Estimating Net-To-Gross Ratios Using the Self-Report Approaches* (Guidelines).

The net-to-gross survey for strip curtains, which was conducted with participants who had strip curtains installed through an IOU program, was a modified version of the standard net-to-gross battery. The modifications were required because:

- Program participants may have had maintenance contracts.
- Participants may have had an internal program for maintaining strip curtains.
- Strip curtains were provided at no charge. Since the customer is not paying for the measure, payback, which is the total cost of the measure to the customer is divided by annual cost savings is zero and therefore not meaningful.

For the survey, convenience stores and supermarkets were stratified into three groups each: according to the savings. Stores and supermarkets with large savings were sampled with certainty. Stores and supermarkets with medium and small savings were randomly sampled in accordance with the variance in the estimates of the savings.

[2] This increases analysis efficiency and also decreases the potential bias that would result if the analysts were left to determine the best match according to their own criteria.

6.3 Confidence and Precision of Key Findings for Evaluation of Refrigeration Strip Curtains HIM

The goals of this study were to assess the energy savings due to strip curtains with 10% relative precision at the 90% confidence interval and to identify market-specific factors that affect the energy savings potential of strip curtains in various applications.

Table 6-3 lists the sample size, the average energy savings per square foot of strip curtains, the standard deviation of savings, the relative precision at the 90% confidence interval, the measurement and computational uncertainty, and the final relative precision at the 90% confidence interval that includes statistical, instrumentation, and computational uncertainties.

Table 6-3. Summary of Sample Savings, Precision, and Confidence.

	Number of Sites in Sample	Ex-Post Evaluated Energy Savings (kWh/ft^2)	Standard Deviation of Savings (kWh/ft^2)	Relative Precision at 90% CI	Measurement and Computational Uncertainty	Relative Precision (Including Statistical, Measurement, and Computational Uncertainties)
Supermarket Freezer	9	409	237	32%	10%	33%
Supermarket Cooler	14	159	57	16%	8%	18%
Restaurant Freezer	20	77	152	73%	7%	73%
Restaurant Cooler	22	18	13	25%	6%	26%
Convenience Freezer	17	16	18	44%	7%	44%
Convenience Cooler	54	14	27	43%	4%	43%
Refrigerated Warehouse	14	177	116	29%	8%	30%

The overall relative precision for the energy savings of all strip curtains installed in the 2006-2008 cycle among all IOU programs is 27%.

6.4 Validity and Reliability for Evaluation of Refrigeration Strip Curtains HIM

Table 6-3 indicates that the overall uncertainty in the ex-post gross impact evaluation is driven by statistical uncertainties. Three approaches were used to reduce the statistical uncertainty associated with the evaluation.

- First, more coolers were tested and more sites monitored than originally planned.
- Second, there was redundancy in the monitoring equipment installed. Two state sensors and two temperature sensors were used for each walk-in unit.

- Third, data were post stratified to maximize the utility of the data that were gathered through the field efforts.

The research plan prepared at the start of the evaluation effort called for the monitoring of a total of 140 walk-in units and refrigerated warehouses categorized according to the distribution summarized in Table 6-2[3]. In fact, however, a total of 181 walk-in coolers, walk-in freezers, and refrigerated warehouses were monitored during the course of the project.

Over the course of the project, it was recognized that there were significant subcategories within the business types being studied. For example, the Supermarket business type consists of major chain supermarkets and small, independent grocers. The convenience store sample also included some small grocers and specialty markets. Additionally, some of the sites that had NAICS descriptions consistent with refrigerated warehouses were found to be large walk-in coolers or freezers rather than compartments within refrigerated facilities.

The usage patterns in the original business type classifications were often bimodal. For example walk-in refrigerators in supermarkets see an order of magnitude more traffic than freezers in small grocers. On the other hand, freezers in small grocers have similar usage patterns as freezers in general convenience stores and marts.

In light of these findings, the sample was post stratified along the delineations presented in Table 6-4. The supermarket category now strictly represents chain supermarkets. The smaller markets have been grouped with convenience stores[4].

Table 6-4. Sample Sizes for Strip Curtain Field Measurements by Business Type and Type of Refrigeration Unit

Type of Business	Type of Refrigeration Unit	
	Freezers	Coolers
Supermarkets	9	14
Convenience Stores	17	54
Restaurants	20	22
Refrigerated Warehouses	14	n/a

[3] The number of monitored units exceeds the number of analyzed units for the following reasons. 1) Five sites were used solely to test our field techniques. 2) 18 walk-in units were monitored early on in the evaluation cycle, prior to the approval of our final monitoring plan. These sites were not monitored in accordance to the same protocol as the other units in our evaluation, and we removed them from consideration. 3) Eight sites had severe data acquisition failures (e.g. lost/stolen loggers, loggers removed from original placement) and could not be used in the evaluation.

[4] Additionally, two walk-in coolers that were part of the warehouse sample were moved to the restaurant category because they were in a retail bakery and a catering business. Two other walk-in units encountered in the warehouse sample were moved into the Grocer and Convenience store category because they were inside a liquor store and a community food pantry.

6.5 Findings for Evaluation of Refrigeration Strip Curtains HIM

The major findings from the analysis of the data collected on strip curtains are presented and discussed in this section, first pertaining to gross impacts and then to net impacts.

6.5.1 Findings from Analysis of Gross Impacts

This section presents the results from the gross impact analysis. Four major topics are discussed.

- First, it is demonstrated that the calculated ex-post energy savings have a strong correlation to a handful of simple predictive parameters, such as the time that the walk-in door is open per day and the temperature differential between the refrigerated and infiltrating airs.
- Second, the ex-ante assumptions and ex-post measured values of the parameters found among various market sectors are presented.
- Third, there is a discussion of the measured empirical constants that relates the measured infiltration rates to those predicted by simple physical models based on Bernoulli's principle (i.e. ASHRAE Refrigeration Handbook Equation 12.5-10). An empirical discharge *function* is proposed that can be applied to the physical models to describe infiltration rates due to the stack effect in walk-in coolers, freezers, and refrigerated warehouse facilities.
- Fourth, findings are presented and discussed regarding the useful lives of the strip curtains, based on field observations and interviews with site contacts.

6.5.1.1 Predictive Parameters for Energy Savings

As discussed in the previous section, there are four parameters that have the greatest influence on the energy savings achieved per square foot of strip curtain installed on a cooler or freezer door[5]. These parameters are:

- Door open time.
- Temperature differential between infiltrating and refrigerated airs.
- $\delta_{Efficacy}$: the difference between efficacies of the new strip curtains and of the old infiltration barriers, if any existed prior to installation of the rebated strips.
- Efficiency of the refrigeration system.

However, these four influential factors can be reduced to one factor by simple multiplication of the first three factors, and division by the refrigeration system efficiency. The resulting variable

[5] Other factors that influence savings include the average duration of door-openings (independent of, and of secondary significance to the overall door-open-time), the moisture content of the refrigerated and infiltrating airs, the efficiencies of the refrigeration equipment, and to a lesser extent, the efficiencies of any systems that condition the area surrounding the walk-in door, the door height, the aerodynamic resistance of objects within the paths of the infiltrating and exfiltrating airs, and the effects of any fans that may blow air out the door. These are all considered in our formal site-by-site calculations. In this discussion, however, a simple functional form for the expected energy savings is distilled from the results of this work.

is described in Appendix E of the HIM Appendices. The correlation between the ex-post calculated energy savings, and a 'back of the envelope' savings calculation based on the above four parameters is 0.96. All other variables, such as climate zone, for example, are relatively insignificant predictors for the energy savings due to strip curtains. *It is important to note that the explanation for gross impact realization ratios that stray far from unity must come from a mismatch between ex-ante assumptions and ex-post determinations of the four predictive parameters listed above.* Values of these parameters that are specific to walk-in coolers, freezes, and refrigerated facilities are presented in Appendix E of the HIM Appendices. In particular, comparison of Table E-8 and E-10 will show that a substantial overestimation of the door-open time is the primary cause of the low realization rates for the PG&E and SDG&E programs. The ex-ante assumption of 300 minutes of door-open time per day is appropriate for a mix of supermarkets and warehouses, but according to the tracking data many of the strip curtains were installed in restaurants, convenience stores, and small grocers. The second largest cause for the discrepancy between ex-ante and ex-post savings estimations is the ex-ante assumption that the strip curtains are installed solely in doorways that did not have pre-existing strip curtains. Our evaluation found that in most programs, about 50% of the rebated strip curtains replaced existing strip curtains.

6.5.1.2 Comparison of Usage Patterns to IOU Ex-Ante Assumptions

The significant assumptions in the ex-ante estimations developed in the IOU work papers are compared to the field findings from this study in Table 6-5. The last two columns pertain to the empirical constant that relates the infiltration equation to the actual infiltration rates. (The empirical constant for the infiltration equation was discussed in Section 6.2 and in Appendix D of the HIM Appendices.) Specific recommendations are made in Section 6.7 regarding modifications to the ex-ante assumptions in the IOU work papers.

6.5.1.3 Analysis of Measured Empirical Constants

The infiltration equations are based on a simple physical analysis based on Bernoulli's equation. They describe steady-state air flow through an unobstructed doorway due to temperature differential between the two spaces on the opposing sides of the doorway. Real world conditions differ significantly from this simple model. For example, the air flow may be hindered by products that are stacked inside the walk-in cooler. The evaporator fans may also influence the infiltration rate. An empirical scale factor, often called the *discharge coefficient,* is used to scale the theoretical predictions of the infiltration rate to measured data. The infiltration rate for a particular set of conditions at a site is difficult to predict with high accuracy even by computational fluid dynamics[6]. However, proper formulation of a discharge coefficient can sufficiently describe the infiltration rates on an aggregate level. As part of this study, a new

[6] *Experimental verification of analytical and CFD predictions of infiltration through cold store entrances,* A.M. Foster, M.J. Swain, R. Barrett, S.J. James, **International Journal of Refrigeration** Volume 26, Issue 8, December 2003, Pages 918-925

formulation for the discharge coefficient was developed that is suitable for a broad range of applications. The results are presented in the Appendix D of the HIM Appendices.

Table 6-5 Comparison of Ex-Ante Estimations Used in IOU Work Papers to Measured Ex-post Parameters that Affect Energy Savings Attributable to Strip Curtains

	Minutes Open		Delta Temp		Delta Efficacy		C_D	
	Measured	PGE/SCE	Measured	PGE/SCE	Measured	PGE/SCE	Measured/Fit	All IOU
Supermarket Cooler	132	300/64	34	35/37	0.88	0.8/0.52	0.366	0.531
Supermarket Freezer	102	300/64	58	80/75	0.88	0.8/0.52	0.415	0.531
Mart Cooler	38	300/64	31	35/37	0.46	0.8/0.52	0.348	0.531
Mart Freezer	9	300/64	57	80/75	0.52	0.8/0.52	0.421	0.531
Restaurant Cooler	45	300/64	33	35/42	0.46	0.8/0.52	0.383	0.531
Restaurant Freezer	38	300/64	58	80/80	0.55	0.8/0.52	0.442	0.531

6.5.1.4 Findings from Field Visits and Interviews with Site Contacts

There are two noteworthy findings from the field work.

The first is regarding the general condition of the strip curtains that were rebated in the 2006-2008 program cycle. Although this study was technically a "post-only" study, baseline strip curtains were extant in the "post-only" sample. Approximately 16% of the strip curtains in the sample qualified as "baseline" curtains because they had at least 15% of the overall area missing or had substantial gaps between the strips. The measured efficacy of these curtains was 0.541, compared to over 0.80 for strip curtains in good repair. The most common failure mode was strips that were intentionally cut. The failure of the strip curtains is most likely to occur as a catastrophic event, such as some strips being hacked off, or torn off by a fork lift, rather than as a gradual decrease in efficacy over time.

A second, related finding is that three of seventeen warehouses that were visited indicated that they replace strip curtains in cycles of one year or shorter. This is significantly lower than the four-year estimated useful life of the strip curtains.

6.5.2 Findings from Net Impact Analysis

The results from the net-to-gross analysis for strip curtains are presented in this section for the population of customers who had strip curtains installed through an IOU program.[7] The Net to Gross study is discussed in detail in Appendix K of the HIM Appendices.

The net-to-gross analysis is based on data collected through net-to-gross strip curtain survey that was conducted with decision-makers at convenience stores, supermarkets, restaurants, and warehouses. The convenience store and supermarket submarkets were stratified for customers with high, medium, and low savings. The high savings customers were sampled with certainty and the medium and low savings customers were randomly sampled.

Through the analysis of the survey data, net-to-gross ratios were assigned to three groups of customers who received strip curtains through an IOU program.

A first group consisted of participants with a maintenance contract who replaced strip curtains within a four-year period (i.e., the assumed life of strip curtains). There were three customers in the group in the survey. Because there is a near certainty that strip curtains within these establishments would have been replaced without the program, customers in this group were assigned a net-to-gross ratio of zero.

A second group consisted of participants who did not have maintenance contracts but who maintained gaskets on a schedule that was more frequent than the lifetime of the gasket. Seventy-five percent of these participants claimed to maintain strip curtains on a cycle that was four years or less. There is a high probability that curtains within these establishments would have been replaced without the program. Accordingly, customers in this second group were also assigned a net-to-gross ratio of zero.

A third group consisted of participants who did not have maintenance contracts and who did not regularly maintain gaskets. A very high percentage of these firms thought replacement too costly, was not needed, or tended to defer maintenance. It is clear that these establishments could substantially benefit from this program. Ultimately, the question for this group was would they have replaced strip curtains without the program.

A net-to-gross ratio for the third group was calculated using three scores:

- A factor-specific program influence score.
- A summary program-influence score
- A likelihood score that strip curtains would not have been replaced without the program.

[7] Third party and mass market programs offered replacement or installation of strip curtains in convenience stores, supermarkets and warehouses. The measures were recommended by auditors who visited customer facilities or were requested by customers who learned about the program and made arrangements to participate.

The factor-specific program influence score was derived from program and non-program factors. An average factor specific program influence score and a factor specific non-program influence score was calculated for each respondent. The average factor specific influence score was then divided by the sum of the average of the program and non-program specific factor influence scores. This resulted in a program influence ratio ranging between 0 and 1. If program specific factors had higher average ratings than the non-program specific factors then the factor specific program influence score is above 0.5. Alternatively, if the program factors had a lower average rating in comparison to the non-program ratings, then the program influence would be less than 0.5. If there were program specific factors but no specific non-program factors, then the program specific factor influence score would be 1. Likewise if there were only non-program specific factors, then the program influence score would be zero.

Respondents were also asked provide a summary program influence score by distributing 10 points to what they understood to be "program factors" and "non-program factors." The summary program influence score was calculated by dividing the number of points that respondent gave to "program factors" by 10. This results in a score between 0 and 1.

The likelihood that the action was program induced was calculated as well. The likelihood score was based on the question about the likelihood that the respondent would have installed strip curtains in the absence of the program. The likelihood that the respondent would have taken action without the program was calculated as 10 minus the likelihood of taking the action in the absence of the program divided by 10.

The factor specific program influence score and the summary program influence score were combined to form a composite program summary score. The composite program influence score is the average of the two program influence scores.

The net-to-gross ratio was formed by averaging the composite program summary influence score and likelihood score. In situations where one score is missing, only the remaining score is used.

The results are shown in Table 6-6. The overall weighted net-to-gross ratio is 40%.

Table 6-6. Overall Results of Net to Gross Survey for Strip Curtains

Category of respondent	Count	Percent	Group Net-to-Gross	Weighted Net-to-Gross
Maintenance contract	3	3	0	0
No maintenance contract but claiming to maintain within the lifetime of the strip curtains	15	15	0	0
Did have or did not maintain strip curtains	81	81	0.49	0.40
Indeterminate	2	2		0
Total/weighted total	101	101	-	0.40

6.6 Program Specific Results for Evaluation of Refrigeration Strip Curtains HIM

The program-specific results are summarized in Figure 6-1 and Table 6-8. The SCE programs generally had the highest realization ratios because their ex-ante assumptions were more conservative. Moreover, SCE's programs tended to target supermarkets and warehouses, which had the highest ex-post savings per square foot of strip curtains.

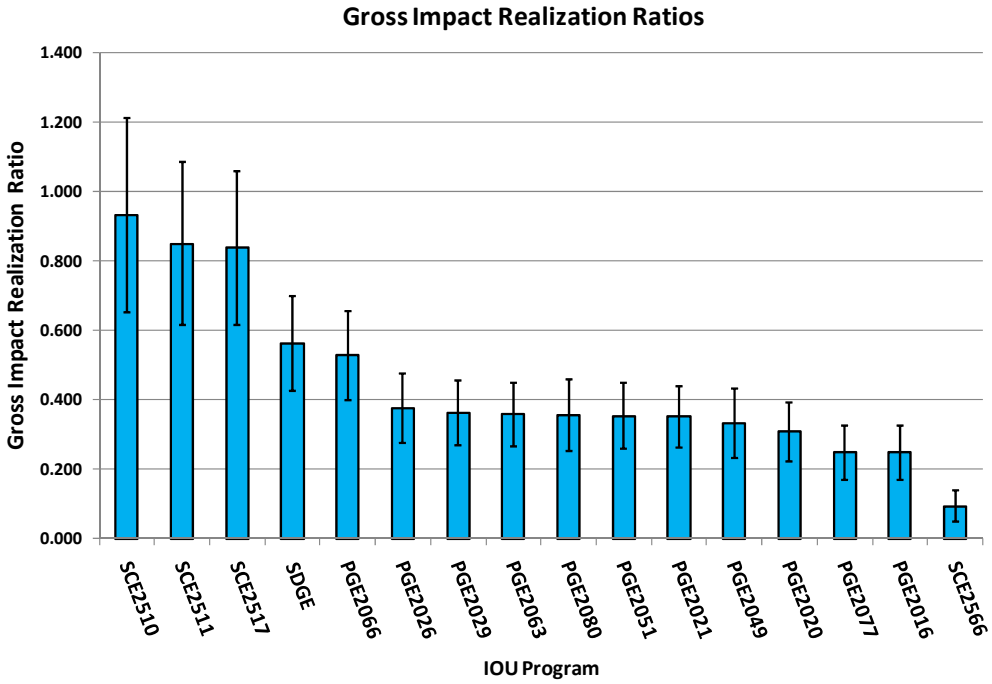

Figure 6-1. Program Specific Gross Realization Ratios

6.7 Discussion of Findings and Recommendations from Evaluation of Refrigeration Strip Curtains HIM

Specific recommendations come out of this study regarding the ex-ante parameters used to calculate energy savings from strip curtains. It is recommended that the ex-ante estimations for the door-open time, the temperature differentials between the refrigerated and infiltrating airs, the difference in efficacy between the new and old strip curtains, the refrigeration system coefficients of performance, and the empirical discharge coefficients be updated with market-specific values listed in Table 6-8 below.

Table 6-7. Program Gross Impact Realization Ratios

Program	Gross Impact Realization Ratios	Relative Precision at 90% CI
SCE2510	0.93	0.28
SCE2511	0.85	0.23
SCE2517	0.84	0.22
SDGE	0.56	0.14
PGE2066	0.53	0.13
PGE2026	0.38	0.10
PGE2029	0.36	0.09
PGE2063	0.36	0.09
PGE2080	0.36	0.10
PGE2051	0.35	0.10
PGE2021	0.35	0.09
PGE2049	0.33	0.10
PGE2020	0.31	0.09
PGE2077	0.25	0.08
PGE2016	0.25	0.08
SCE2566	0.09	0.04

In updating the assumptions, it must be recognized that the relatively high difference between the post and baseline curtain efficacies for the supermarkets is not due to a market difference but is rather due to program design. The PGE2066 program was a direct install program with the requirement that the strips must be placed on doorways which did not have existing infiltration barriers. In updating the discharge coefficient, care must be taken to replace the product of the 0.8 doorway flow factor and the implicit 0.663 included in the model equation[8] with the values listed in the table below. For example, for supermarket coolers, the IOU model equations would be multiplied by a factor of 0.366/0.663, and the doorway flow factor of 0.8 would be dropped as it is effectively replaced by the new discharge coefficient.

The recommendations in Table 6-8 are applicable to all IOUs. The updates would tend to result in much higher ex-ante energy savings estimates for supermarkets and warehouses than for small grocers, convenience stores, and restaurants. The resulting disparity in the ex-ante savings estimations for strip curtains in different markets will help IOU program managers optimize their programs through market-specific rebate amounts, for example.

[8] The model equation is taken from American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2006. *ASHRAE Handbook*, Refrigeration: 13.4.

Table 6-8. Recommended Updates to Ex-Ante Estimations Used in IOU Work Papers

	Minutes Door Open per Day	Delta Temp	Delta Efficacy	Nominal COP	Empirical Constant for Infiltration Equation
Supermarket Cooler	132	34	0.88	2.5	0.366
Supermarket Freezer	102	58	0.88	1.5	0.415
Mart Cooler	38	31	0.46	2.5	0.348
Mart Freezer	9	57	0.52	1.5	0.421
Restaurant Cooler	45	33	0.46	2.5	0.383
Restaurant Freezer	38	58	0.55	1.5	0.442
Warehouse	494	32	0.35	1.5	0.425