Customer Energy Efficiency Program
Measurement and Evaluation Program

EVALUATION OF PACIFIC GAS & ELECTRIC COMPANY'S 1995 NONRESIDENTIAL ENERGY EFFICIENCY INCENTIVES PROGRAM FOR COMMERCIAL SECTOR LIGHTING TECHNOLOGIES

PG&E Study ID number: 324

March 1, 1997

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PG&E STUDY ID#: 324

FINAL REPORT

March 1, 1997

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TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF EXHIBITS

LIST OF EXHIBITS

APPENDICES TABLE OF CONTENTS

SURVEY APPENDICES TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

This section presents a summary of the impact results for the commercial indoor lighting technologies offered under the Pacific Gas & Electric Company's (PG&E's) 1995 Nonresidential Energy Efficiency Incentive (EEI) Programs, referred to in this report as the Lighting Program. This evaluation covers indoor lighting technology retrofits that were performed at PG&E customer facilities, for all rebates paid in 1995. These retrofits were performed under two different PG&E programs, the Retrofit Express (RE) and the Customized Incentives Programs. The results are presented in three sections: evaluation results summary (covering the numerical results of the study), major findings, and major recommendations.

1.1 EVALUATION RESULTS SUMMARY

The evaluation results are summarized in terms of energy savings (kWh), demand savings (kW), therms impacts, and realization rates, the ratio of the evaluation results (ex post) to the program design estimates (ex ante). These results are presented on a gross and net basis (i.e., before and after accounting for customer actions outside the program). Exhibit 1-1 presents the gross energy and demand savings results (ex post and ex ante), together with each applicable gross realization rate.

Exhibit 1-1
Summary of Gross Evaluation and Program Design Results for Commercial Indoor Lighting Applications

	Gross Impacts						
	Energy			Demand			Therms
Program	Ex Ante (kWh)	Ex Post (kWh)	Realization Rate	Ex Ante (kW)	Ex Post (kW)	Realization Rate	Ex Post (therms)
Retrofit Express	138,069,793	132,760,708	0.96	25,486	30,682	1.20	-37,540
Customized Incentives	10,772,306	5,245,788	0.49	1,168	1,585	1.36	-1,272
Total	148,842,099	138,006,496	0.93	26,654	32,267	1.21	-38,812

The ex ante numbers presented above in Exhibit 1-1 and below in Exhibits 1-2, 1-3 and 1-4 were obtained from PG&E's Management Decision Support System (MDSS), PG&E's participant database. The values presented are identical to those filed in Table E-3 of the Technical Appendix of the Annual Summary Report on Demand Side Management Programs in 1995 and 1996, revised in December 1996.

These results illustrate the following key points about the gross commercial lighting impacts:

Lighting Retrofit Programs - Overall, the vast majority of the savings are from lighting technologies installed through the RE program, where RE retrofits represent more than 95 percent of the energy and demand impacts. Historically, participation has been significantly larger within the RE program. This is especially true with respect to recent participation, because the Customized Incentives Program was dropped from PG&E's DSM portfolio in 1995.

Gross Energy Impacts - The ex post gross energy impacts were just slightly lower than the ex ante gross estimates, following a significant reduction in the ex post impacts (after the application of SAE coefficients). These SAE coefficients ranged in magnitude from zero to 1.38, resulting overall in a 17 percent reduction to the engineering-based gross energy impact results. The SAE adjustment made to the Customized Incentives estimates was significant, resulting in a 49 percent reduction to the engineering-based gross energy impact results.

Gross Demand Impacts - The ex post gross impacts for demand, however, exceeded the ex ante estimates (overall, the gross demand estimates are 20 percent higher than the ex ante values). This is primarily the result of the ex post components of each applicable summer on-peak operating factor—the lighting system operating schedule and the open-period operating factors (as determined by field inspections). In addition, ex post HVAC savings were also applied (cooling savings result from the replacement of existing lighting systems with more efficient lights).

Customized Program Realization Rates - The above mentioned differences in realization rates for energy and demand are especially highlighted when examining the Customized Incentives Program results. The relatively low (0.49) realization rate for energy is due to the application of a statistically significant 0.51 SAE coefficient within the Customized Incentives Program. While the relatively high (1.36) realization rate for demand is driven by the factors mentioned under "Gross Demand Impacts" above.

Gross Therm Impacts - The heating penalty attributed to the installation of lower-wattage lighting by customers with gas heat was not included in the ex ante impact estimates, and therefore the ex-post impacts could not be compared using a realization rate.

Exhibits 1-2, 1-3, and 1-4 present the net energy, demand, and therm impact results, together with the net realization rates (for energy and demand only), at the same levels presented in Exhibit 1-1. A detailed presentation and discussion of the above findings can be found in *Section 4, Evaluation Results*.

The net ex post impacts exceed the net ex ante design estimates by 17 percent for energy and 54 percent for demand. To a certain extent, these results reflect the high gross realization rates, but they are really driven by the ex ante and ex post net-to-gross (NTG) ratios. The NTG adjustments apply equally to energy and demand impacts, since they represent behavioral effects regarding the decision to purchase energy-efficient equipment.

The ex ante NTG ratio was just 0.77 for the RE program and 0.75 for the Customized Incentives Program, while the ex post NTG ratio for all indoor lighting measures averaged 0.97. When compared to the ex ante NTG assumption, this results in an average 20 percent increase in realized savings, and therefore net realization rates that are consistently higher than gross realization rates.

High NTG rates detected in the discrete choice NTG analysis for high-participation measures help account for the generally high net realization rates. For example, the combined NTG adjustment (free-ridership and spillover) of 1.05 was applied to the RE Programs' primary fluorescent retrofits. These retrofits alone make up 67 percent of the gross indoor lighting end-use energy impacts and 71 percent of demand.

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

Exhibit 1-2
Summary of Net Evaluation and Program Design Energy Results For Commercial Indoor Lighting Applications

Program	Gross (kWh)	Net-to-Gross Adjustments: Free Ridership (1-FR)	Net-to-Gross Adjustments: Spillover	Net-to-Gross Adjustments: NTG Ratio (Unitless)	Net (kWh)
		EX ANTE			
Retrofit Express	138,069,793	0.67	0.10	0.77	106,313,738
Customized Incentives	10,772,306	0.65	0.10	0.75	8,079,230
Total	148,842,099	0.67	0.10	0.77	114,392,967
		EX POST			
Retrofit Express	132,760,708	0.88	0.10	0.98	129,891,251
Customized Incentives	5,245,788	0.78	0.00	0.78	4,107,452
Total	138,006,496	0.88	0.09	0.97	133,998,703
		REALIZATION RATES (Ex Post/Ex Ante)			
Retrofit Express	0.96	NA	NA	NA	1.22
Customized Incentives	0.49	NA	NA	NA	0.51
Total	0.93	NA	NA	NA	1.17

Exhibit 1-3
Summary of Net Evaluation and Program Design Demand Results For Commercial Indoor Lighting Applications

Program	Gross (kW)	Net-to-Gross Adjustments: Free Ridership (1-FR)	Net-to-Gross Adjustments: Spillover	Net-to-Gross Adjustments: NTG Ratio (Unitless)	Net (kW)
		EX ANTE			
Retrofit Express	25,486	0.67	0.10	0.77	19,624
Customized Incentives	1,168	0.65	0.10	0.75	876
Total	26,654	0.67	0.10	0.77	20,501
		EX POST			
Retrofit Express	30,682	0.88	0.11	0.99	30,251
Customized Incentives	1,585	0.78	0.00	0.78	1,241
Total	32,267	0.87	0.10	0.98	31,492
		REALIZATION RATES (Ex Post/Ex Ante)			
Retrofit Express	1.20	NA	NA	NA	1.54
Customized Incentives	1.36	NA	NA	NA	1.42
Total	1.21	NA	NA	NA	1.54

In Exhibit 1-4, net therm impacts are presented. Because no ex ante therm impacts were calculated it was not possible to compare the ex ante and ex post results.

Exhibit 1-4
Summary of Net Evaluation Therm Results
For Commercial Indoor Lighting Applications

Program	Gross (therm)	Net-to-Gross Adjustments			Net (therm)
		Free Ridership (1-FR)	Spillover	NTG Ratio (Unitless)	
		EX ANTE			
Retrofit Express	0	NA	NA	NA	0
Customized Incentives	0	NA	NA	NA	0
Total	0	NA	NA	NA	0
		EX POST			
Retrofit Express	-37,540	0.89	0.11	1.00	-37,526
Customized Incentives	-1,272	0.78	0.00	0.78	-996
Total	-38,812	0.88	0.11	0.99	-38,522
		REALIZATION RATES (Ex Post/Ex Ante)			
Retrofit Express	NA	NA	NA	NA	NA
Customized Incentives	NA	NA	NA	NA	NA
Total	NA	NA	NA	NA	NA

Overall, the net therm impacts do not differ significantly from the gross impacts, because gross gas impacts were concentrated within technologies with high NTG ratios.

1.2 MAJOR FINDINGS

The key findings are summarized as follows:

Overall, PG&E's ex ante estimates for the commercial lighting technologies paid under the 1995 programs were conservative, resulting in net realization rates exceeding one.

For many of the business types and technologies, hours of operation and operating factors exceeded the ex ante values by a significant margin. This was the main factor contributing to many high gross realization rates.

High NTG ratios, combined with low program design NTG estimates, significantly increased the net realized savings.

The high participation technologies of T-8/electronic ballast, optical reflectors with delamping, and HID replacement of less efficient technologies yielded large realized savings. For the fluorescent technologies mentioned in this list, NTG spillover rates (that were applied to this particular group of measures) partially account for the solid result in these segments.

1.3 MAJOR RECOMMENDATIONS

Trade on Established Information in Future Evaluations - This evaluation developed extensive observed and measured operating factor and operating hours information on the highest participation segments. There is no reason to believe that the operating factor and operating hours information developed in this evaluation will change significantly from year to year. QC recommends that PG&E develop an understanding with the California Public Utilities Commission (CPUC) on the validity and use of this information in subsequent evaluations, thus minimizing the need to replicate operating hours and operating factor data for sectors where this information is unlikely to change. This will allow PG&E and the CPUC to maximize return on money invested in future evaluations, resulting in better estimates for sectors that have yet to be definitively documented.

Other detailed recommendations concerning measures offered and the CPUC Protocols are covered in detail in *Section 5*.

2. INTRODUCTION

This report summarizes the impact evaluation of Pacific Gas & Electric Company's (PG&E's) Nonresidential Energy Efficiency Incentive (EEI) Program for commercial sector lighting technologies (the Lighting Evaluation). These technologies are covered by two separate program options, the Retrofit Express (RE) Program and the Customized Incentives Program. The evaluation effort includes customers who were paid rebates in 1995. These programs are summarized below.

2.1 THE RETROFIT EXPRESS PROGRAM

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

Lighting end-use rebates were offered in the program for the following technologies:

- Halogen lamps, which replace existing lamps
- Compact fluorescent lamps, which replace incandescent lamps
- T-12 and T-8 fluorescent lamps, which replace incandescent lamps
- Compact fluorescent lamps and LEDs, which replace incandescent lamps in exit signs
- Removal of lamps, ballasts, and lamp holders in overlit areas
- Electronic ballasts, which replace electromagnetic ballasts
- T-8 and T-10 lamps and electronic ballasts, which replace T-12 lamps and electromagnetic ballasts in various lengths and configurations
- High-intensity discharge (HID) fixtures, which replace incandescent or mercury vapor fixtures
- Installation of occupancy sensors, bypass or delay timers, photocells, and time clock controls for lighting applications

2.2 THE CUSTOMIZED INCENTIVES PROGRAM

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

There was no 1995 Customized Incentives Program. Due to the significant documentation and analysis involved in Customized Incentives Program measures, however, rebates for a number of 1993 and 1994 measures were delayed until 1995. All equipment applied for under the program must have been installed and in operation by November 30, 1995. This evaluation covers those measures that were rebated in 1995. A total of 64 Customized Incentives Lighting Program participants were paid rebates in 1995.

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

2.3 *EVALUATION OVERVIEW*

The impact evaluation described in this report covers all lighting measures installed at commercial accounts, as determined by the Management Decision Support System (MDSS) sector code, that were included under the RE and Customized Incentives programs and for which rebates were *paid* during calendar year 1995. Although all customers were paid in 1995, only about 2/3 of the applications submitted were applied for in 1995. The remaining 1/3 applied under a previous program year, spanning 1992-1994.

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

2.3.1 Objectives

The objectives of the evaluation were originally stated in the Request for Proposals (RFP), refined during the project initiation meeting, and documented in the evaluation research plan. These research objectives are as follows:

- Determine first-year gross energy, demand, and therm impacts by business type and technology group for RE and Customized Incentives lighting technologies paid in 1995, and overall impacts for the commercial sector as required by the California Public Utilities Commission (CPUC) protocols.

- Determine first-year net energy, demand, and therm impacts by business type and technology group for RE and Customized Incentives lighting technologies paid in 1995, and overall impacts for the commercial sector as required by the CPUC protocols.

- Compare evaluation results with PG&E's (ex ante) estimates, and investigate and explain any discrepancies between the two.

- Assess free-ridership and spillover rates, and investigate and explain differences between evaluation and program design estimates.

- Create an impact sample subset of participants for future retention monitoring as required by the CPUC protocols.

- Complete tables 6, 7, and 11 of the Protocols.

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

While gross impacts account for program participant actions (and the fuel use benefits and secondary costs associated with those retrofit decisions), net impacts account for customer participation choices and the effect that the lighting programs' infrastructure has had on the lighting retrofit market. For example, adjustments were made to the gross savings estimates to account for customers that would have installed energy-efficient measures anyway, despite the program (free-riders). Spillover rates, defined as energy-efficient measures installed outside the program (as a result of the presence of the program), were also estimated and used to adjust the program impacts.

The evaluation investigated and, where possible, explains differences between program design estimates and evaluation results.

2.3.2 Timing

The 1995 Commercial Lighting Impact Evaluation began in December 1995, completed the planning stage in December 1996, executed data collection between mid-March and early November 1996, and completed the analysis and reporting phase in January 1997.

2.3.3 Role of Protocols

This evaluation was conducted under the rules specified in the "Protocols and Procedures for the Verification of Cost, Benefits, and Shareholder Earnings from Demand Side Management Programs" (the Protocols).[1] The Protocols control most aspects of the evaluation. They specify the minimum sample sizes, the required precision, data collection techniques, certain minimum analysis approaches, and formats for documenting and reporting results to the CPUC. This evaluation has endeavored to meet all Protocol requirements.

2.4 REPORT LAYOUT

This report presents the results of the above evaluation. It is divided into five sections, plus appendices. *Sections 1 and 2* are the *Executive Summary* and the *Introduction*. *Section 3* presents the *Methodology* of the evaluation. It is supported in detail by *Appendices A, B, C,* and *D*. *Section 4* presents detailed results and discussion and is supported by *Appendix E*. *Section 5* presents recommendations for improving the evaluation, the program measures, the program tracking system, and the CPUC Protocols. *Appendix F* provides impacts by Time-of-Use costing periods. The survey appendices provide the survey and on-site data collection instruments, and the survey call dispositions, frequencies, and refusal comments.

[1] California Public Utilities Commission Decision 93-05-063, Revised January 1996 Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, and 95-12-054.

3. METHODOLOGY

In this section, the methods used to conduct the 1995 Pacific Gas & Electric Company (PG&E) Commercial Lighting Technologies Evaluation (the Lighting Evaluation) are presented. This section begins with an overview of the evaluation approach. This is followed by more detailed discussions of the specific engineering, billing regression, and net-to-gross (NTG) analysis approaches used in the evaluation. Additional detail on these three approaches is supplied in *Appendices B, C* and D, respectively.

3.1 INTEGRATED EVALUATION APPROACH

This overview of the integrated evaluation approach begins by presenting the data sources and the sample design approach used for the Lighting evaluation. An overview of how the engineering and statistically adjusted engineering (SAE) estimates are used together to derive gross energy, demand and therm impacts follows. The final section discusses how the net-to-gross estimates are used to derive net program impacts.

3.1.1 Data Sources

The Lighting Evaluation used data supplied by PG&E to develop a nested sample design plan. This plan was used to specify sample points from which additional evaluation data were collected.

Existing Data

All available data supplied by PG&E were used in the analysis of the Lighting program. Of particular importance were PG&E's historical billing data, program participant data (Management Decision Support System [MDSS]), paper copies of Retrofit Express (RE) and Customized Incentives applications, other program-related data, and industry standards information. Each of the existing data sources is described briefly below.

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

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

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

PG&E 1995 Customer Energy Efficiency Programs Advice Filing[1] - This report documents the ex ante earnings claims, including specific information on the derivation of per-unit ex ante savings estimates and the assumptions that go into those estimates. This documentation often includes assumptions such as operating hours and operating factors, by fixture type. This document supplies the best information available on ex ante estimates and assumptions, thus facilitating knowledge-based comparisons to ex post estimates.

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

Copies of RE and Customized Incentives Paper Application Files - QC requested and received complete copies of application files for a random 50 RE participants and all Customized Incentives participants. The RE files were used to verify the entries in the MDSS electronic files and to identify additional information that could be extracted from the file to improve the analysis. The Customized Incentives files were used to classify these participants into categories similar to the RE program, where possible, thus allowing maximum use of the statistical billing regression analysis.

Nested Sample Plan Design

The impact analysis plan is based upon a nested sample design approach. The integrated evaluation methods make use of a core lighting logger sample that is leveraged to a larger audit sample, which in turn, is leveraged to a less expensive telephone survey sample. The smaller samples provide greater detail surrounding each analysis component, and allow results from these more desirable data sources to be transferred (or leveraged) to the larger samples. Eventually, the MDSS database program application information is used to leverage results to the entire participant population. This approach, as shown in Exhibit 3-1, results in the efficient use of information contributing to the final impact results.[2]

Lighting loggers (represented by the innermost circle in Exhibit 3-1) supply the most accurate source of data used to calibrate the engineering estimates. For a monitored fixture, lighting loggers register the time and date the fixture is turned on or off, for periods up to two months in length. This information allows calibration of self-reported operating schedules, and supplies facility closed-period operating information which cannot be collected during on-site audits.

The on-site audit sample (represented by the band around the innermost circle in Exhibit 3-1) is designed to support the telephone sample for the largest participation segments. This sample contributes equipment details that are site-specific, and better estimates of operating hours, operating factors, equipment efficiency, lamp burn-out rates, missed opportunities, and other technical factors that are difficult to collect over the telephone. The on-site sample itself is not designed to be statistically representative, but rather to support the estimate of detailed engineering parameters collected within the segments with the highest projected impact.

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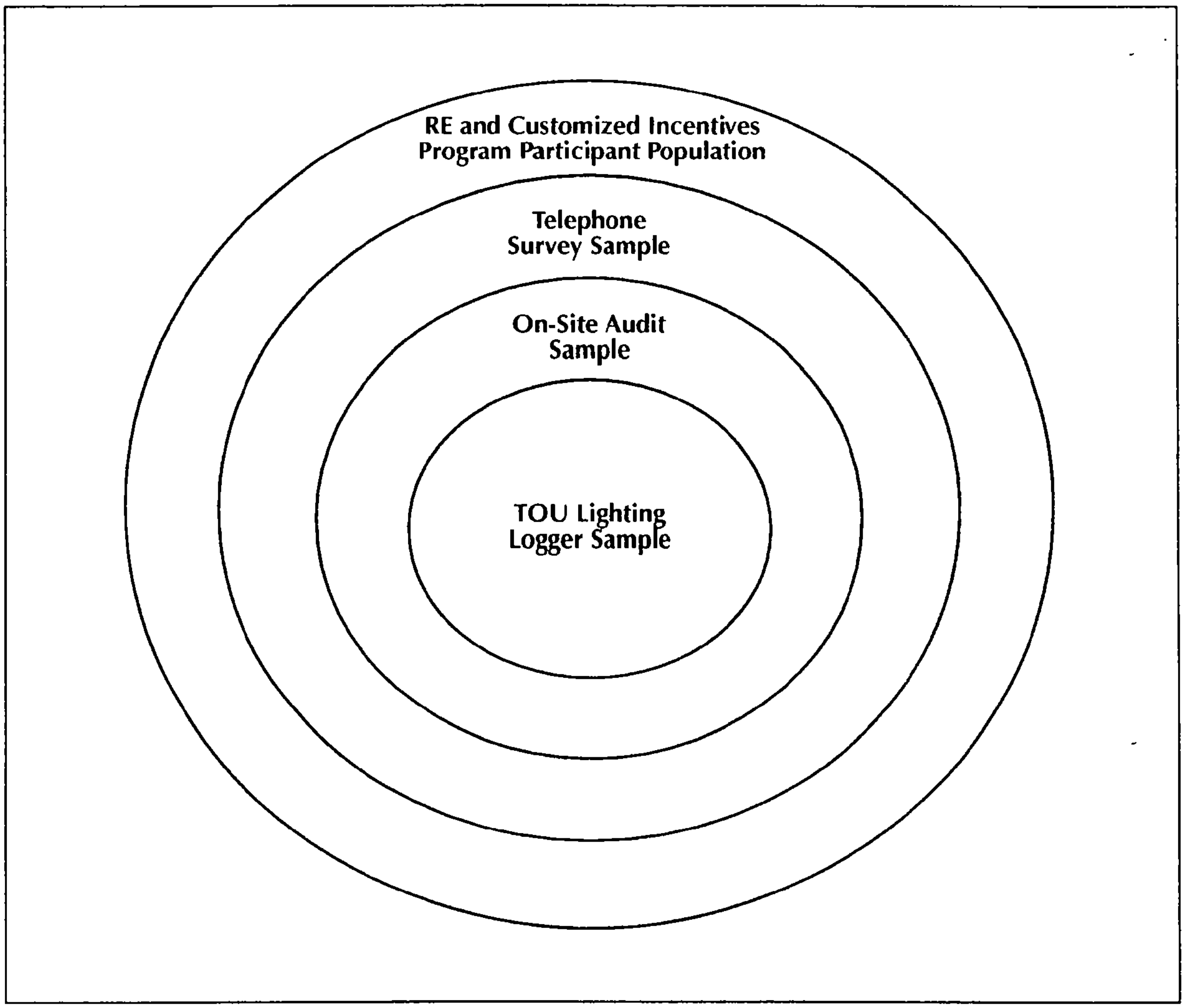
[1] "1995 Lighting Retrofit Express Program" submitted by Darrell Hall and Sam Cohen; Advice Filing 1867-G/1481E, October 1994.

[2] For a detailed description of the allocation of each of these sample types by technology and building type refer to Appendix A.

Exhibit 3-1
Nested Sample Design



A significantly larger telephone survey sample (represented in Exhibit 3-1 by the second band from the core circle), is designed to be representative of the participant population by technology and business type. The telephone survey supplies information on participant decision-making, energy-related changes at each site for the billing period covered by the billing analysis, and data for estimating the NTG adjustments.

The participant population (represented by the outermost circle in Exhibit 3-1), is based upon MDSS data that provide the information needed to generalize estimated per-unit impact estimates for the telephone-surveyed sample (to the entire population of program participants). Using the population to leverage impact estimates corrects for potential bias in the sample selection process, especially in terms of the actual distribution of installed measures.

Primary Collected Data

Data were collected from both participant and nonparticipant samples in order to support the integrated evaluation approach. The sample design developed for the data collection plan complies with the Protocols and meets the program evaluation objectives. In this evaluation, the sampling unit is a customer site, which is defined by a unique service address. The final sample sizes for used to evaluate all of PG&E's nonresidential commercial sector programs are summarized in Exhibit 3-2 by end-use element.

Exhibit 3-2
Commercial Sector Data Collection
For the Indoor Lighting End Use

Program	End Use	Commercial: Telephone Surveys	On-Site Audits	End-Use Metering	Time-of-Use (TOU) Loggers	Combination
Custom	Lighting	18	1	0	0	0
	HVAC	58	32	0	0	0
	Refrigeration	7	16	0	1	1
Retrofit	Lighting	600	227	5	108	112
	HVAC	434	107	20	13	31
	Refrigeration	235	16	0	1	1
Total	Lighting	614	228	5	108	112
	HVAC	487	137	20	13	31
	Refrigeration	241	18	0	2	2
Total Participants (Unique Sites)		1,217	380	20	108	126
Total Nonparticipants (Unique Sites)		808	36	0	0	0
Total (Unique Sites)		2,025	416	20	108	126

Telephone Survey Sample - For each segment, the retrofit program sample design allocated the sample in proportion to the program-avoided cost by segment. This sample design yields analysis data that are concentrated with the segments within the highest impact, in order to obtain the best estimate of impact for the largest portion of the population.

In addition, a census was attempted for the largest customers. This sample allocation, combined with the random sampling techniques used in other segments, produces a stratified random telephone survey sample representing the program-participant population (paid in 1995). Annual energy consumption values were used to group customers into five usage/size strata based upon a Dalenius-Hodges procedure. The comparison group customers were then selected to mirror the underlying distribution of the participant target population by size and business type. (For the customers in the largest size strata, a census was attempted among both participants and nonparticipants.) A nonparticipant sample was developed based upon the business type and usage strata distribution that resulted from the participant sample allocation.

For all of the end-use evaluations, telephone surveys were collected from a total of 2,025 customers, 1,217 of which were participants. 614 of these were lighting participants. The remaining 808 were in the comparison group, including 451 in the original lighting and HVAC comparison group, and 156 outside the program retrofitters found through the canvass survey (as well as 201 in the supplemental refrigeration comparison group).

On-Site Audit Sample - For the lighting end-use, audits were conducted at 228 participant sites (providing critical engineering data surrounding lighting system operation), and 36 additional audits were conducted at nonparticipant sites (providing an opportunity to measure the accuracy of customer self-reports regarding fixture retrofits outside the program).

Lighting Logger Sample - A total of 108 lighting participant sites were loggered. This sample is not intended to be a random sample, nor strictly proportional to the program-avoided cost -- rather the purpose is to provide an adequate sample that is used to calibrate the engineering models.

3.1.2 Gross Impact Estimates

Per participant gross energy, demand, and therm impacts were developed for specified time-of-use (TOU) costing periods, using engineering and statistically adjusted engineering (SAE) estimates. Steps detailed in this section are displayed in Exhibit 3-3.

Gross Energy Estimates

Gross energy estimates were developed using two distinct analysis steps. Engineering estimates were first developed for each participant. These estimates were then adjusted using billing data-derived SAE coefficients.

Gross, unadjusted engineering impacts were developed for each retrofit measure. First, hourly direct impacts were developed using the net change in fixture connected load in conjunction with operating schedules and fixture operating factors. Then, hourly impacts were estimated for the HVAC interaction contribution, resulting from reduced heat gain due to the replacement of standard-efficiency fixtures with high-efficiency fixtures. Lastly, gross engineering energy impacts were derived by aggregating hourly impacts for specified time-of-use (TOU) costing periods. The engineering methods used are described in greater detail in *Section 3.2*.

Statistical analysis was then used to determine the fraction of the unadjusted engineering estimates actually observed or "realized" in customer billing data. The per-unit engineering energy impacts, combined with the units installed, form the input to the billing regression analysis, or SAE analysis. In the SAE analysis, the engineering estimates are compared to billing data using regression analyses, in order to adjust for behavioral factors of occupants and other unaccounted for effects. The outputs of the analysis are SAE-adjusted estimates of program energy savings.

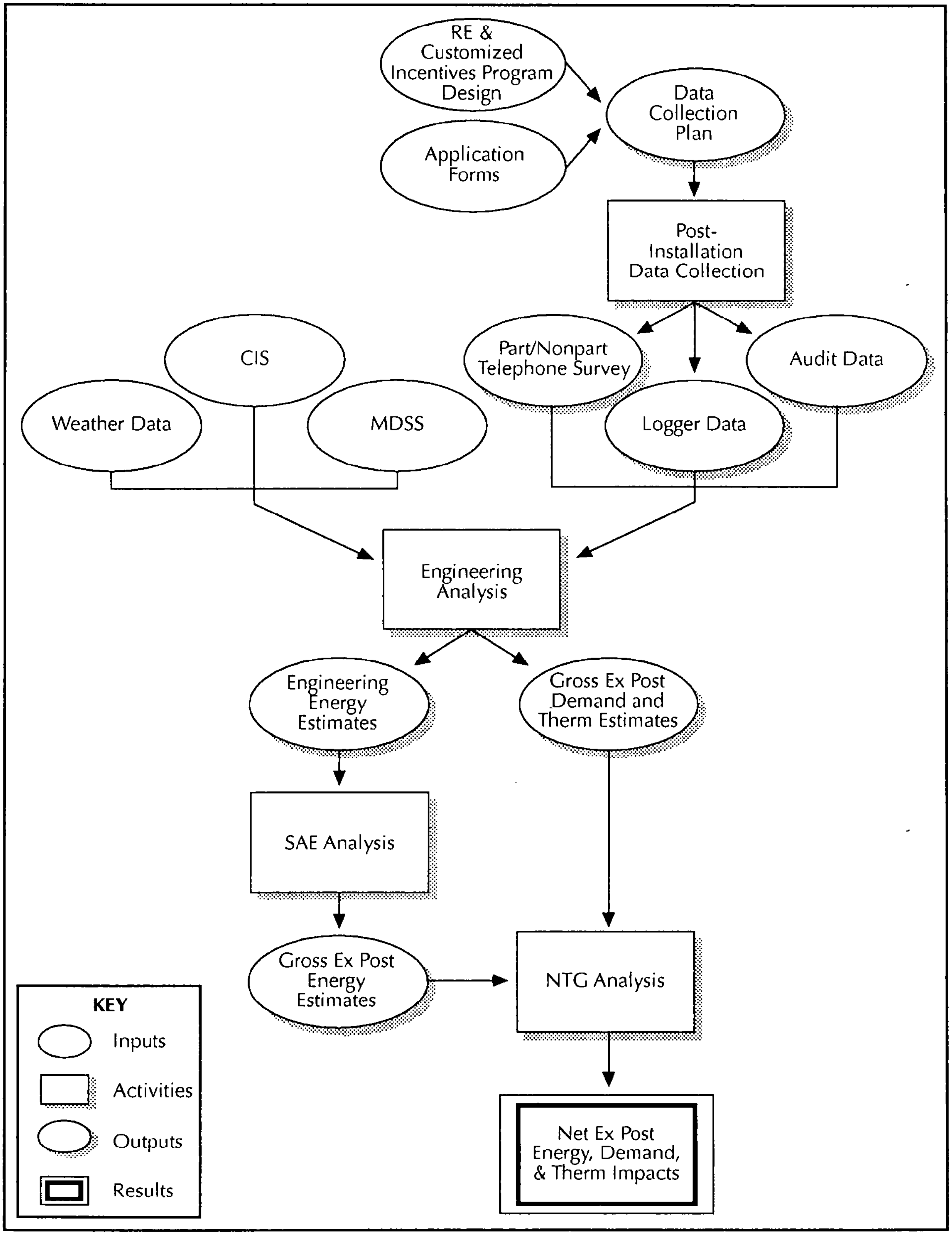
Gross Demand Estimates

Gross demand estimates are based solely upon unadjusted hourly engineering estimates. Engineering demand estimates were developed using the same hourly impacts developed for the gross engineering energy estimates. However, instead of aggregating the hourly impacts, demand impacts were determined by averaging all impacts for a selected hour in a particular TOU costing period.

Gross Therm Estimates

Like gross demand estimates, therm estimates are not adjusted using SAE coefficients For each TOU costing period, therm estimates were aggregated using methods similar to energy estimates.

Exhibit 3-3
Method for Estimating Impacts



3.1.3 Net-to-Gross Estimates

The NTG analysis is designed to adjust gross program impacts for free ridership and the actions taken by PG&E customers outside the Lighting program. Self-reported data were initially used to estimate the percentage of free-riders in the program; that is, the number of participants who would have undertaken the energy efficiency action promoted by the program in the absence of the program. This self-reported estimate of program NTG was not adjusted for the effects of program spillover, where energy efficiency actions taken outside the program are claimed

A more sophisticated estimate of NTG for selected high-participation measures was developed through the application of discrete choice analysis. The discrete choice probit model estimates the probability that a customer will purchase a particular energy efficient lighting measure, both with and without the incentive program in place.

Application of the final NTG adjustments, by technology, yields net program impacts. Each step taken to achieve final net results is explained in the remainder of this section, starting with the engineering analysis.

3.2 ENGINEERING ANALYSIS

The engineering analysis combines information from telephone surveys with detailed on-site audit data to develop unadjusted engineering impacts (UEIs). The general lighting model used to estimate most of the impacts under the RE and Customized Incentives programs was founded on the decomposition of lighting impacts into manageable engineering parameters (referred to as the "impact decomposition approach"). This approach was used to develop hourly impacts for each of three daytypes, Weekday, Saturday, and Sunday. The impact decomposition equation that was used to estimate UEIs is displayed below.

$$UEI_t = [(\Delta UOL \times U \times OF_t) \times T] \times [1+HVAC]$$

Where

ΔUOL = the technology level change in connected kW associated with a particular measure.

U = the number of measure units installed for a particular application.

OF_t = the operating factor which describes the percentage of full load used by a group of fixtures during a prescribed period of time, t

T = the time interval for which an impact is estimated; for most measures, the OF term is the engineering parameter that changes significantly over time. Time intervals for lighting estimates were single hours, segmented by hours "on" (open operating factor) and hours "off" (closed operating factor) schedules.[3]

[3] Although there are periods of time when lights are generally considered off, many lights are either accidentally or purposely left on during these periods. The effective hours of lighting operation captured during these off periods were applied using the operating factor term (the probability that lights operate during a particular time interval).

HVAC = the component of impact associated with both the net savings due to cooling (demand or energy) and the net increase due to heating (energy or therm).

Each of the parameters listed above are developed as follows:

ΔUOL - The change in Unit Operating Load (ΔUOL) is derived by adjusting the change in connected load (taken from the MDSS) with burned out lamp rates developed using on-site audit data.

U - The number of units (U) of each measure type installed is verified during the post-installation on-site audit.

OF_t - The operating factor (OF_t) consists of two parameters; the probability that a given facility is open for that hour (operating schedule), and the percentage of lights operating during the period (open-period and closed-period operating factors). Operating schedules were developed for each business type using logger, on-site audit and telephone survey data. Open-period and closed-period operating factors (OOFs and COFs) were developed, by business type, using logger and on-site audit data.

HVAC - HVAC interactive effects (HVAC) were developed using weather and telephone survey data. An increase in heating loads and a decrease in cooling loads are caused by a reduction in internal heat gains when retrofit technologies are installed.

Demand estimates were developed for every hour of the year using this equation. Hourly impacts were then aggregated, yielding energy and therm impacts by costing period. Additionally, peak demand impacts were averaged for selected hours across all weekdays in a particular costing period.

Exhibit 3-4 presents a flowchart of the method used to develop hourly impacts using the decomposition approach. *Section 3.2.1* describes the methods used to develop inputs for this equation, while *Section 3.2.2* and *Section 3.2.3* describe how hourly impacts were derived, and used to develop demand and energy impacts.

Additional detail surrounding the engineering steps are described in *Appendix B.*

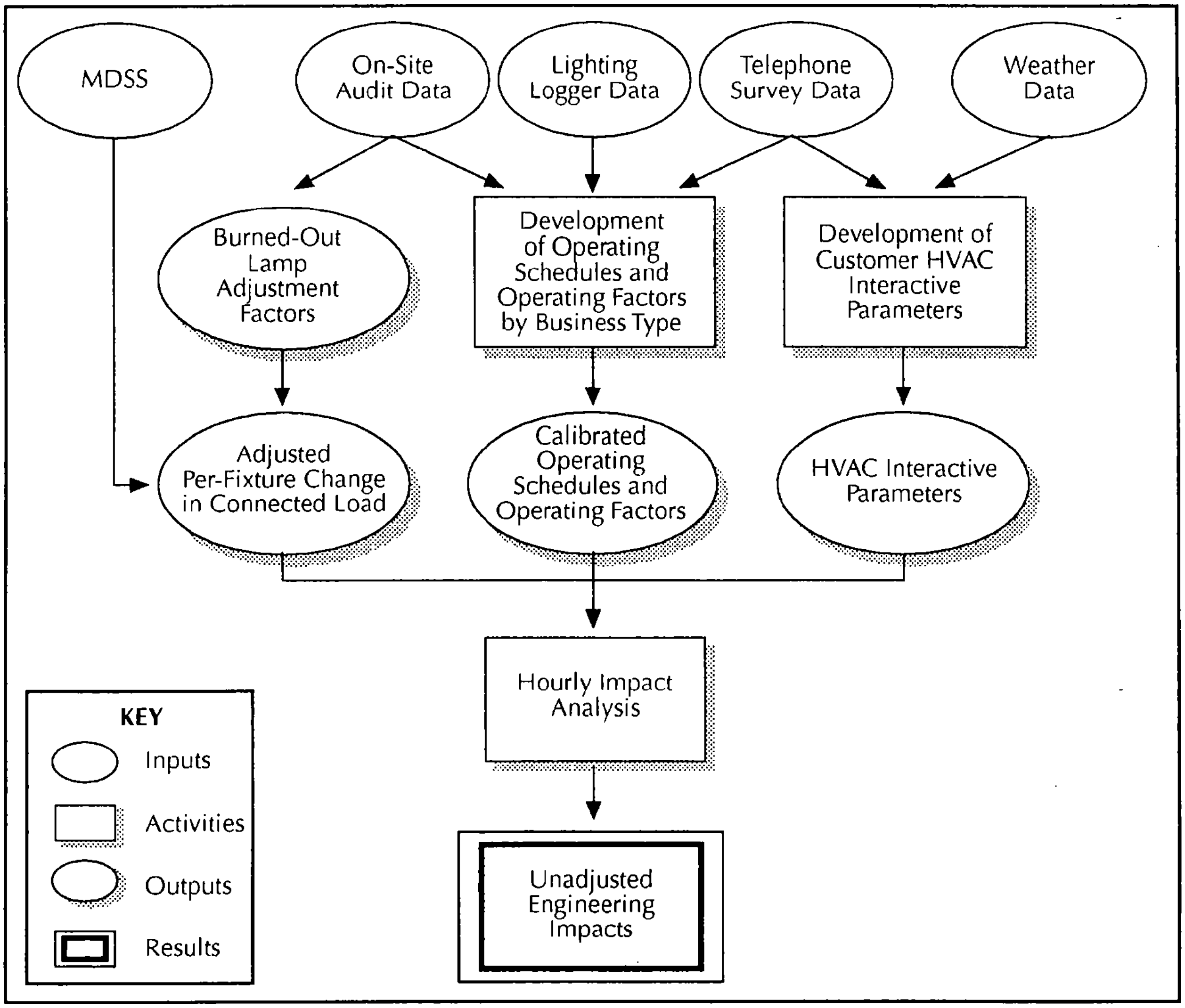
3.2.1 Derivation of Engineering Parameters

This section provides an overview of the methods used to develop each of the parameters used in the impact decomposition approach.

Engineering Connected Load Estimates

The change in connected load (ΔUOL) was determined for each fixture using pre- and post-retrofit information. As PG&E retains few records (hard copy application records for the Customized Incentives Program only) of the removed fixtures, an assumed pre-retrofit (existing) fixture was developed for each RE measure. The difference in connected load is based upon both the measure definition specified under the lighting RE program (and typical installations for each measure), and an assumed existing system that represents a typical customer configuration prior to retrofit.

Exhibit 3-4
Method Used to Develop Hourly Engineering Estimates



These connected load values were further refined using burned-out lamp rates to adjust for potential discrepancies between ex ante estimates and observed participation. When retrofit lighting programs are implemented, often the replaced lamps are burned out, which results in an increase in energy use for the first year impacts. In addition, new fixtures sometimes fail a short time after installation, resulting in a decrease in energy use for first year energy use. For this reason, typical lamp burn-out rates were determined for specific technology groups (both for new fixtures and existing fixtures), based upon data gathered during on-site audit activities.

Final ΔUOL values were developed by applying burned-out lamp rates (where applicable) to the assumed change in connected load.

Engineering Operating Schedule and Operating Factor Estimates

For each business type and technology group, operating factors (the OF_t parameter in the impact decomposition equation) were developed for each of the three daytypes. This operating factor variable consists of two parameters; the probability that a given facility is open for that hour (operating schedule), and the percentage of lights operating during a particular period (open-period and closed-period operating factors). The following sections discuss the development of these two parameters.

Engineering Operating Schedules - Calibrated hourly operating schedules (or profiles) for each daytype were developed, by business type, using data gathered from lighting loggers, on-site audits, and participant and non-participant telephone surveys. The method used is described below and depicted in Exhibit 3-5.

Operating schedules were first developed for each "schedule group" (a group of similar fixtures that operate together) at a particular premise, and then aggregated to the premise level. Once operating schedules were developed for each premise, business type-specific schedules were developed using weighted average premise-specific schedules. The business type schedules were calibrated using the nested sample design, according to the following steps:

First, logger data were used to calibrate customer self-reported operating hours gathered during the on-site audits.

Then, once calibrated, the on-site self-reported schedules were used to adjust operating schedules derived using telephone survey data.

Finally, the adjusted telephone survey schedules were used to develop final business type-specific operating schedules. These schedules were used to generate final evaluation impacts for the entire MDSS sample.

By adjusting these operating profiles with two distinct calibration steps, bias adjustment for on-site self-reported schedules, and bias adjustment for telephone survey self-reported schedules; the final operating profiles are grounded in the most accurate information gathered in this research effort: lighting logger data. The final derived schedules represent, at a business type level, the probability that a particular customer will operate their lighting system for a given hour and daytype.

Engineering Open-Period and Closed-Period Operating Factors - Operating factors, the percentage of lights operating during a specified time interval, were generated by business type, technology group, and daytype for facility open and closed periods. The data sources contributing to these estimates were taken primarily from two sources: lamp counts performed at the time of each audit, and lighting logger data used in conjunction with the calibrated schedule group profiles. The methods used to generate open-period operating factors (OOFs) or closed-period operating factors (COFs), for each daytype varied slightly in response to available data.

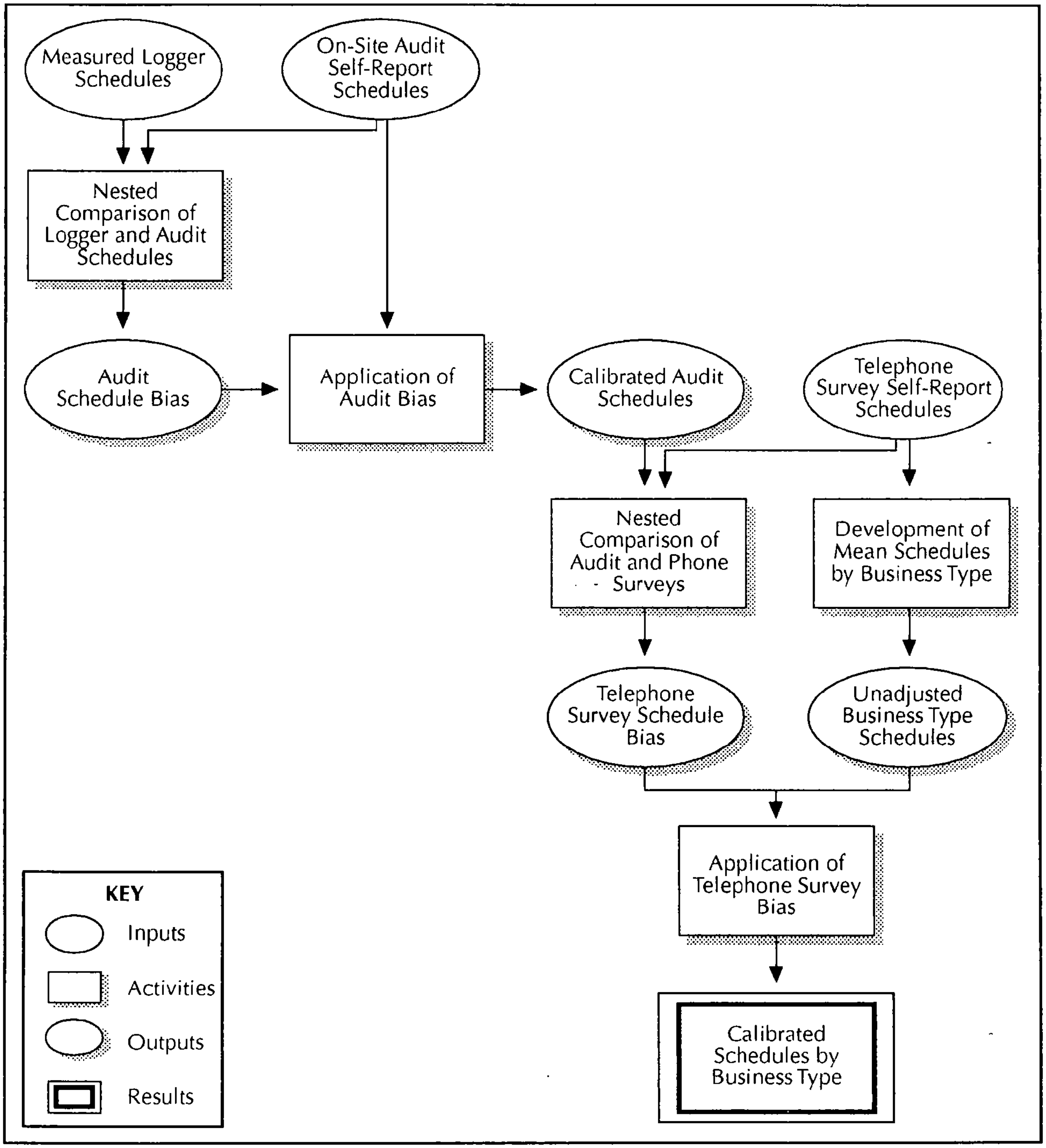
Weekday OOFs were developed using lamp counts (a visual count of lamps that were "on" and lamps that were "off") that were recorded during each on-site audit. On-site audits were conducted during normal weekday facility business hours, and so lamp counts represent highly accurate business type- and technology-specific instantaneous weekday open-period operating factors.

Since there were no supporting lamp count data for periods other than the weekday open period, Saturday and Sunday open-period operating factors were developed by using logger data in conjunction with the (lamp count-based) weekday OOFs. Logger-based open-period operating factors were developed for Saturday and Sunday, in conjunction with weekday logger derived open-period operating factors, based on the same sample points. The ratio of these two terms (weekend logger to weekday logger) was then used to adjust lamp count based weekday open-period operating factors to produce weekend operating factors.

Business type-specific closed-period operating factors were developed for the three daytypes using logger data exclusively, since there were no lamp count data available.

Operating factors were applied in the hourly impact calculation; open-period operating factors were applied to the probability that a facility is open, while closed-period operating factors were applied to one minus the probability that a given facility is open.

Exhibit 3-5
Derivation of Operating Schedules for Use in Engineering Estimates



Engineering HVAC Interactive Estimates

In addition to the direct effects of lighting retrofits on premise energy and demand, the contribution of impact caused by cooling and heating system use is significant. Internal gains affect both the air-conditioning and heating loads in buildings, and thus HVAC equipment run-time and consumption. Lighting retrofits modify the heat gain in buildings, and thus heating system and air-conditioner usage. When high-efficiency lighting systems replace standard-efficiency systems, cooling loads are decreased while heating loads increase. This section presents the method used to quantify those impacts.

Telephone survey responses served as the primary evaluation data source used to estimate HVAC interactive impacts. Weather data were used to determine the appropriate periods to which HVAC interactive impacts were applied.

Engineering Cooling Interactive Estimates - Engineering cooling interactive estimates were developed, using an ASHRAE method, for premises served by electric-powered cooling systems. Interactive cooling impacts were achieved by multiplying the heat gain fraction removed mechanically and the marginal coefficient of performance with annual fixture-level energy impacts for indoor lighting systems, on a per-premise basis. Additionally, the percentage of each facility that is conditioned is applied to each interactive cooling impact, serving as a proxy for the percent of each retrofit installed within conditioned space. The resulting cooling energy savings are used as inputs to the SAE analyses, along with both technology-level impacts and heating penalty estimates (as described below).

Engineering Heating Interactive Estimates - As described earlier, the efficient lighting technologies installed under the lighting program caused a reduction in internal heat gains in buildings, and a related increase in the energy required to heat internal spaces. A similar ASHRAE method was used to develop energy and therm impacts associated with the effects of fixture change-out on heating system use. Interactive heating penalties were achieved by multiplying the heat gain fraction and the marginal coefficient of performance with annual fixture-level energy impacts for indoor lighting systems, on a per-premise basis. Additionally, the percentage of each facility that is heated is applied to each interactive heating impact, serving as a proxy for the percent of each retrofit installed within conditioned space. To apply the ASHRAE method, the heating system fuel must be known and, if electric, whether or not the system is a heat pump.

3.2.2 Development of Engineering Hourly Energy Estimates

Using the engineering parameters discussed above, hourly engineering impact estimates were developed to satisfy the PG&E requirements for impacts by TOU costing period. To estimate hourly energy impacts, fixture noncoincident demand connected loads are used along with the applicable schedule and operating factors, according to the following equation:

$$UEI_{ijzdh} = \Delta UOL_i \times U_{ij} \times \left[\left(PO_{jdh} \times OOF_{izd} \right) + \left(\left(1 - PO_{jdh} \right) \times COF_{izd} \right) \right] \times \left[1 + HVAC_{ij} \right]$$

Where

UEI_{ijzdh} is the unadjusted engineering impact for measure i, customer j, business type z, daytype d, and hour h.

ΔUOL_i is the change in connected load for technology measure i.

U_{ij} is the number of units of technology type i installed by customer j.

PO_{jdh} is the schedule defined probability that customer j will be open on daytype d during the hour h.

OOF_{izd} is the open-period operating factor which describes the percentage of full load (during normal business hours) used by a group of fixtures of type i, in business type z, during daytype d.

COF_{izd} is the closed-period operating factor which describes the percentage of full load (during non-business hours) used by a group of fixtures of type i, in business type z, during daytype d.

$HVAC_{ij}$ is the contribution of impact caused by both heating and cooling interaction for technology measure i, installed by customer j.

Energy impacts for each measure/daytype/hour were derived and applied to the 1995 calendar year, yielding demand profiles which encompassed all 8,760 hours in a year. In addition, hourly HVAC interactive therm impacts were calculated for premises with gas heating systems.

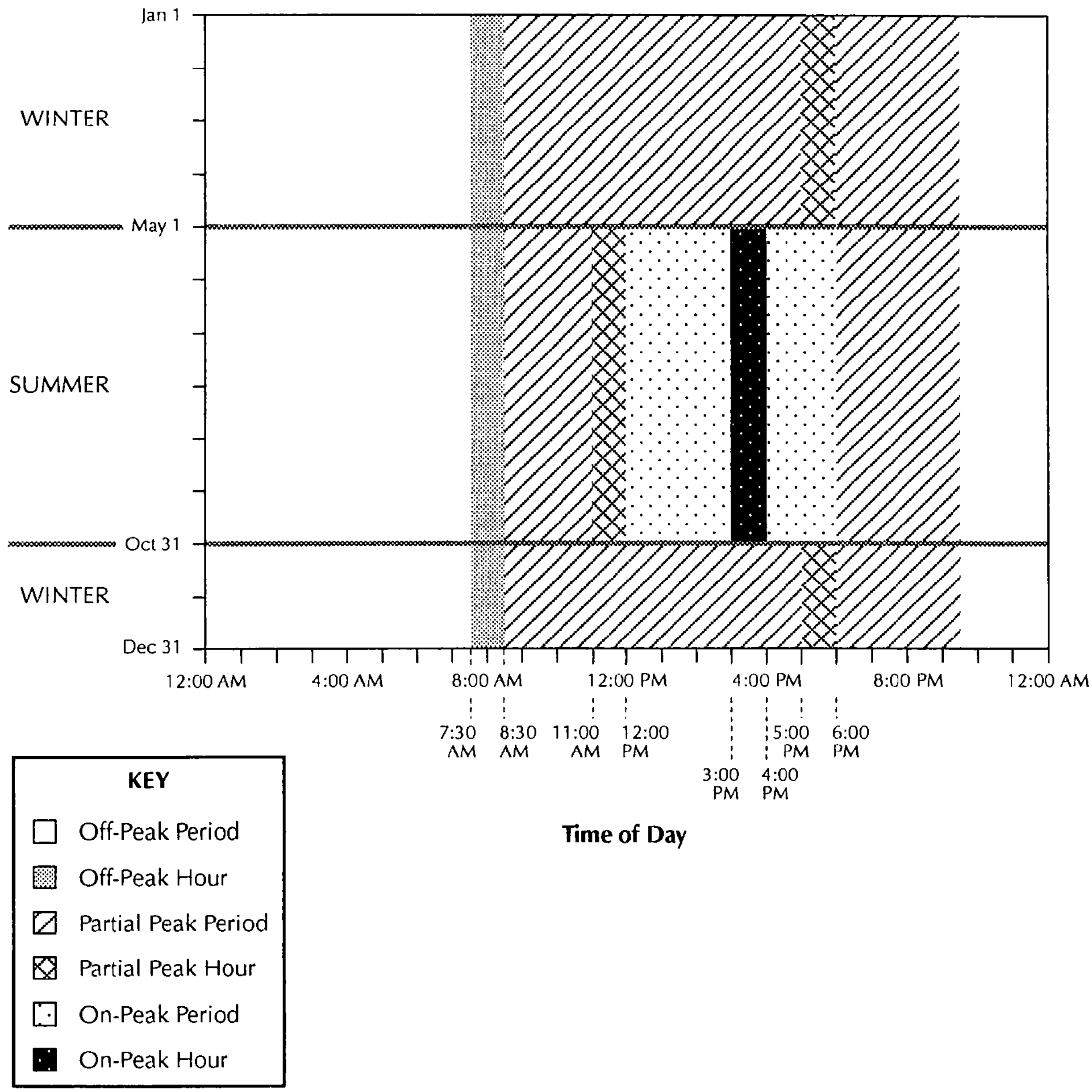
3.2.3 Aggregated Engineering Estimates by Time-of-Use Costing Period

Exhibit 3-6 illustrates the time-of-use costing periods used to derive final energy, therm and demand engineering (unadjusted) impacts.

Annual energy and therm impacts were derived by aggregating hourly impacts by TOU costing period, while demand impacts were derived by averaging all impacts for a selected hour in a particular TOU costing period.

The engineering demand and therm estimates are used as the final gross ex post impacts. Engineering energy impacts serve as inputs to the statistical billing analysis, described in detail in *Section 3.3* below.

Exhibit 3-6
Weekday Time-of-Use Costing Periods*



* All weekend hours are considered part of the off-peak period.

3.3 *BILLING REGRESSION ANALYSIS*

The key objective of the billing analysis is to determine the first-year program energy impacts. A statistical analysis is employed to model the differences in customers' energy usage between pre- and post-installation periods. The model is specified using actual customer billing data and independent variables that explain changes in customers' energy usage including engineering estimates of program participation. This statistically adjusted engineering (SAE) analysis is consistent with the requirements of the Load Impact Regression Model (LIRM) defined in the

California Public Utilities Commission's (CPUC's) Measurement and Evaluation Protocols (the Protocols).

The results of the billing regression analysis are estimated as ratios, termed "SAE coefficients," of realized impacts to engineering impact estimates. Realized impacts represent the fractions of the engineering estimates actually "observed" or "detected" in the statistical analysis of actual billing data. The SAE coefficients estimated in the billing analysis regression models are relative to the results of the evaluation-based engineering estimates, not the PG&E Program ex ante estimates. The SAE coefficients are then used to estimate program impacts and realization rates relative to the ex ante estimates.

As discussed below, the billing regression analysis was conducted on a sample of telephone surveyed participants and nonparticipants. Because many Commercial Program participants installed measures under multiple end uses, one integrated billing analysis approach was used to model the Lighting, HVAC and Refrigeration end uses. *Appendix C* discusses the billing regression analysis in more detail.

3.3.1 Data Sources for Billing Regression Analysis

The billing regression analysis for the 1995 Commercial Program Evaluation used data from five primary data sources: the PG&E Management Decision Support System (MDSS) tracking database, the billing database, the telephone survey data, the engineering estimates of changes of usage between the pre- and post-installation periods, and the weather data tapes from PG&E's load research weather sites. A summary of the data elements used in the regression analysis are presented below.

Program Participant Tracking System

The participant tracking system for the Retrofit Express (RE) and Customized Incentives programs was maintained as part of the MDSS. It contains program applications, rebate and technical information about installed measures, including measure description, quantity, rebate amount, and ex ante demand, and energy and therm savings estimates. The MDSS database is linked to the billing database and other program databases through PG&E's customers control numbers.

PG&E Billing Data

For this evaluation, the PG&E billing data were obtained from two different data sources within PG&E. The original nonresidential billing dataset contains monthly energy usage for all nonresidential accounts in PG&E's service territory, and was used in the sample design as described in *Appendix A*. The billing histories contained in this data base only run through September 1995.

The second billing dataset, which consists only of customer accounts in the surveyed dataset, was later obtained from PG&E Load Data Services. This billing dataset contains bill readings that run through September 1996. In addition, the billing series from this database is the PG&E pro-rated monthly usage data, a series calculated by PG&E for each calendar month, from January 1992 to September 1996.

Weather Data

The hourly dry bulb temperature collected for 25 PG&E load research weather sites was used in the billing regression analysis to calculate total monthly cooling and heating degree days for each month in the analysis period. For each customer in the analysis dataset, the appropriate weather site was linked to that customer by using the PG&E-defined weather site to PG&E local office mapping.

Telephone Survey Data

All available telephone surveys collected as part of the evaluation for the Commercial Sector Program were used in the billing regression(except for the Canvass surveys, which do not collect detailed information regarding changes that have occurred at the premise). Four telephone survey samples totaling 1,217 participants and 652 nonparticipants were collected for the Commercial Sector Evaluation. The 1,217 participant surveys included 614 Lighting participants, 487 HVAC participants, and 241 Refrigeration participants. Because of the significant levels of cross-over among participants across the Commercial Program end uses, one integrated billing regression model was developed to evaluate all three Commercial Program end uses.

The data collected in the telephone survey supplies information on energy-related changes at each site for the billing period covered by the billing regression analysis. For a detailed discussion of the telephone survey sample design and the final sample distribution, see *Appendix A*.

Engineering Estimates

Engineering estimates of savings were estimated for each of the 614 Lighting participants. Separate estimates were calculated for every measure installed under the Commercial Sector Program. The engineering estimates were calculated based on expected savings from the pre-installation technology to the post-installation technology. *Appendix B* discusses in greater detail the calculation of the savings estimates used in the billing analysis.

3.3.2 Data Aggregation and Analysis Dataset Development

Because many measures installed under the Commercial Program affected multiple customer accounts within a unique site, the billing analysis had to be performed at the site level. Therefore, all account level data had to be aggregated up to the site level. A unique Site ID was created based on a combination of the PG&E service address, premise number and corporation number in the billing system to serve as the key variable for aggregating and linking data.

The telephone surveys were sampled at the Site ID level, and all questions were phrased to ask about all of the control numbers associated with the Site ID.

The engineering estimates of change were also aggregated to the Site ID level. However, prior to aggregating to the Site ID level, the installation dates for each individual measure were analyzed to ensure that only the impacts occurring within the billing analysis periods were being aggregated. The selection of analysis periods is discussed in the next section.

All data elements mentioned above were linked to the final analysis database by Site ID.

3.3.3 Analysis Periods

When the billing regression analysis is used to model the change of consumption attributable to the program measures, the first step is to isolate the pre- and post-installation periods for each customer in the analysis database so that the impact of these measures can be verified.

In accordance with the Protocols, participants are defined by the "paid date" instead of "installation date." Therefore, almost all customers actually installed measures in 1993, 1994 or 1995, with 1995 installations accounting for approximately two-thirds of total installations. *Appendix C* discusses in detail how the selection of an installation date was estimated, since the installation date is not always provided in the MDSS. In summary, the application received date was used as a proxy for the installation date, unless a valid self-reported installation date was provided by the customer through the telephone survey, in which case the self-report date was used.

Billing data were available from January 1992 through September 1996. To maximize the number of post installation months, a post period of October 1995 through September 1996 was used. Because the majority of installations occurred during 1995, the only feasible pre-periods were October 1992 through September 1993 and October 1993 through September 1994. Survey data gathered change information dating back from the beginning of 1993. Therefore, both pre-installation periods could be used. However, the further back the pre-installation period is chosen, the more likely there are to be changes that have occurred at the site. To minimize the number of changes that have occurred outside the program between the pre- and post-installation periods (and to minimize the errors associated with self-reported changes and dates the changes occurred), the October 1993 through September 1994 pre-installation period was selected.

3.3.4 Data Censoring

Prior to implementing the billing analysis models, the customer sample was screened for invalid data and potential outliers. The data screening was applied to the entire participant and nonparticipant billing analysis sample frame. Three primary screening criteria were applied to remove customers that a) had invalid billing data, b) may not have had their bill properly aggregated to the Site ID level, or c) were extremely large users which could not be adequately controlled for in the billing analysis model. *Appendix C* describes in detail the criteria that were used to remove customers from the billing regression analysis.

Exhibits 3-7 and 3-8 present the final sample sizes used in the billing analysis by business type and technology for participants and by business type for nonparticipants.

3.3.5 Model Specification

The billing regression analysis for the Commercial Program Evaluation used two different multivariate regression models under an integrated framework, to provide unbiased and robust model estimates in the commercial sector. The key feature of the approach is that it employs a simultaneous equation approach to account for both the year-to-year and cross-sectional variation in a manner that consistently and efficiently isolates program impacts.

A baseline model is initially estimated using only the comparison group sample. This model estimates a relationship that is then used to forecast the post-installation-year energy consumption for participants as a function of pre-installation year usage. In this way, baseline energy usage is forecasted for participants by assuming that their usage will change, on average, in the same way that usage did for the comparison group.

The resulting SAE coefficients are used to adjust the engineering estimates of expected annual energy impacts for the entire participant population. These impacts are presented in *Section 4* and are used to compute program realization rates.

Exhibit 3-7
Billing Analysis Sample Used
Post-Censoring
Indoor Lighting End-Use Technologies

Program and Technology Group	Business Type												
	Office	Retail	College/ University	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Service	Community Service	Misc.	Total
Retrofit Express Program													
Compact Fluorescent	46	20	2	47	8	10	15	13	5	3	12	2	183
Incandescent to Fluorescent	5	0	0	3	0	1	0	1	0	0	1	0	11
Efficient Ballast	5	7	1	4	4	0	1	0	1	0	1	0	24
T8 Lamps and Electronic Ballasts	109	53	2	95	29	13	25	6	16	8	22	6	384
Optical Reflectors w/ Fluor. Delamp	60	24	2	26	12	10	8	1	5	5	4	2	159
High Intensity Discharge	3	5	1	10	0	0	0	1	10	4	2	5	41
Halogen	8	3	1	7	1	2	1	1	1	0	5	1	31
Exit Signs	29	10	1	22	2	5	4	0	2	1	5	1	82
Controls	14	1	0	25	0	1	3	2	2	1	4	4	57
Retrofit Express Total	123	61	3	99	40	22	27	16	20	13	30	10	464
Customized Incentives Program													
Compact Fluorescent													
Standard Fluorescent													
High Intensity Discharge													
Halogen													
Exit Signs													
Controls													
Other													
Customized Incentives Total	5	0	0	0	9	0	0	0	1	0	0	0	15
Total	123	61	3	99	40	22	27	16	20	13	30	10	464

Exhibit 3-8
Billing Analysis Sample Used
Post-Censoring
Nonparticipants

Program and Technology Group	Business Type												
	Office	Retail	College/ University	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Service	Community Service	Misc.	Total
Total	74	124	1	26	185	34	27	15	53	6	31	44	620

Baseline Model

The baseline model explains post-installation energy usage as a function of the pre-installation energy usage, weather changes, and customer self-reports of factors that could affect energy usage. In order to isolate the program impact from the energy usage changes, only the comparison group is used to fit this model. The baseline model has the following functional form:

$$kWh_{post,i} = \sum_j (\alpha_j + \beta_j kWh_{pre,i}) + \gamma(\Delta CDD_i) * kWh_{pre,i} + \phi(\Delta HDD_i) * Elec_i * kWh_{pre,i} + \sum_k \eta_k Chg_{i,k} + \varepsilon$$

Where

$kWh_{post,i}$ and $kWh_{pre,i}$ are customer i's annualized energy usage for the post- and pre-installation periods, respectively;

ΔCDD_i and ΔHDD_i are the annual change of cooling and heating degree days (base 65°F) between the post-installation year and pre-installation year;

$Elec_i$ is an indicator variable (0/1) for the ith customer, which equals 1 if the customer has electric heating;

$Chg_{i,k}$ are the customer self-reported change variables from the survey data, including adding, replacing, or removing equipment associated with major end uses, changes in number of employees and square footage;

α_j is the indicator variable (0/1) for the jth business type, which equals 1 if the customer is in that business type and 0 otherwise;

β, γ and ϕ are the estimated slopes on their respective independent variables. Separate slopes on pre-usage are estimated by business type; and,

ε is the random error term of the model.

For each customer in the analysis dataset, a post-installation predicted usage value is calculated using the parameters of the baseline models estimated for the 1994 to 1996 analysis period. They both take the same functional form with different segment-level intercept series (α_j) and slopes (β, γ and ϕ):

$$k\hat{W}h_{post,i} = F_{pre}(kWh_{pre}, \Delta CDD, \Delta HDD) = \sum_j (\alpha_j + \beta_j kWh_{pre,i}) + \gamma(\Delta CDD_i) * kWh_{pre,i} + \phi(\Delta HDD_i) * Elec_i * kWh_{pre,i}$$

The final functional relation, based on all 620 nonparticipants used in the baseline model, is estimated as follows:

Baseline Model (1994 to 1996):

$$\begin{aligned} k\hat{W}h_{96,i} = & -40834 * OFF\_LG + 1349 * OFF\_SM - 19849 * RET\_LG - 120 * RET\_SM \\ & +942 * SCHOOLS + 5378 * GROCERY + 8461 * SUPERMKT + 4756 * REST \\ & +10964 * HEALTH + 2403 * HOTEL + 4167 * WAREHOUS + 675 * PERSONAL \\ & +4795 * COMMUN + 37895 * MISCBT \\ & +1.13 * OFF\_LG4 + 0.91 * OFF\_SM4 + 0.99 * RET\_LG4 + 1.00 * RET\_SM4 \\ & +1.00 * SCHOOLS4 + 0.98 * GROCERY4 + 0.98 * SUPERMKT4 + 0.99 * REST4 \\ & +0.99 * COLLEGE4 + 0.94 * HEALTH4 + 1.02 * HOTEL4 + 1.04 * WAREHOUS4 \\ & +0.94 * PERSONAL4 + 0.95 * COMMUN4 + 0.95 * MISCBT4 \\ & +0.0000456 * CDD_{96-94,i} * kWh_{94,i} + 0.0000324 * HDD_{96-94,i} * kWh_{94,i} \end{aligned}$$

SAE Model

Using the predicted post-installation usage values estimated in the baseline model, a simultaneous equation model is specified to estimate the SAE coefficients on energy impact. The SAE simultaneous system can be described as follows:

$$kWh_{96,i} - F_{94}(kWh_{94}, \Delta CDD, \Delta HDD) = \sum_{m} \beta'_{m} Eng_{m} + \sum_{k} \eta'_{k} Chg_{i,k} + \mu_{i}$$

The difference between predicted and actual usage in 1996 was used as the dependent variable in a SAE model. Based upon the estimated participation month, the pro-rated engineering estimates and change variables were used to explain the deviation in actual usage from the predicted usage. As discussed above, the predicted usage is estimated using only the comparison group to forecast the 1996 usage as a function of 1994 usage and change of cooling and heating degree days from 1994 to 1996. This usage prediction presents what would have happened in the absence of the program.

3.3.6 Billing Regression Analysis Results

The coefficients of the engineering impact, termed the SAE coefficients, are used to calculate the ex post gross energy impacts. Independent realization rates are estimated to provide PG&E with business type and technology group level results. Exhibit 3-9 below summarizes the final SAE model results that were estimated using 935 participants (464 Lighting participants), as discussed in the Data Censoring section. Also, summarized below are the independent variables used in the SAE model, together with the t-statistics and the sample sizes available for each parameter estimate.

Exhibit 3-9
Billing Regression Final Model Outputs

Parameter Descriptions	Units	Parameter Estimate	t-Statistic	Sample Size
SAE Coefficients				
Lighting End Use				
Office Flourescents	kWh	-1.00	14.67	116
Other Flourescents	kWh	-0.68	7.41	261
Controls	kWh	-1.38	2.09	57
Warehouse HIDs	kWh	0.02	0.07	10
School HIDS	kWh	0.11	0.30	10
Other RE Lighting	kWh	-1.26	2.15	119
Custom Lighting	kWh	-0.51	3.07	15
HVAC End Use				
Central A/Cs	kWh	-2.07	3.67	184
ASDs	kWh	-1.90	6.75	27
Chillers	kWh	-1.58	2.39	5
EMS	kWh	-1.03	8.38	20
Other Custom HVAC	kWh	-0.65	4.76	5
Office Thermostats	kWh	0.05	1.06	36
Other RE/REO HVAC	kWh	-0.90	2.89	153
Refrigeration				
Custom Refrigeration	kWh	-0.75	2.00	3
RE/REO Refrigeration	kWh	-0.53	1.98	181
Other End Uses	kWh			
Other	kWh	-1.71	2.90	62
Change Variables	kWh			
Cooling System Replacement	(0,1)*kWh	-0.03	0.70	10
Lighting System Replacement	(0,1)*kWh	-0.08	4.17	48
Change in Employees	(±1,0)*kWh	0.01	0.64	57
Square Foot Change	± sqft	4.42	2.37	27
Heating System Replacement	(0,1)*kWh	-0.07	0.04	4
Other Equipment Change	(0,1)*kWh	0.03	1.17	42
Remove Equipment	(0,1)*kWh	0.08	0.64	2
Refrigeration Replacement	(0,1)*kWh	0.00	0.01	3
Add Equipement	(0,1)*kWh	0.11	0.49	11
Other Additions	(0,1)*kWh	0.14	12.41	375

The dependent variable is the difference between the actual and predicted 1996 usage using the 1994 baseline model.

SAE coefficients are calculated for sixteen different combinations of business type and measure. Primarily those measures that have broad participation and relatively high expected impacts were supported by separate SAE coefficients. In addition, a separate SAE coefficient was calculated for other Commercial Program measures.

All but three of the SAE coefficients are significant at the 95 percent confidence level (t-statistics greater than 1.96). In addition, all of the statistically significant SAE coefficients were the correct sign, and therefore used in the calculation of the final ex post energy calculations. The three SAE coefficients that were not significant at the 95 percent confidence interval (HIDs in warehouses and schools, and thermostats in offices) were not used in the final ex post energy calculations. Because each of the insignificant SAE coefficients were also the wrong sign, they were set to zero. Therefore, no energy impacts are being claimed for these three segments.

The SAE coefficients are multiplied by the evaluation estimates of gross energy impact to calculate the gross ex post energy impacts.

3.3.7 Self-Selection

In addition to conducting a billing analysis to estimate gross energy impacts as described above, a net billing analysis was performed, with the objective of estimating SAE coefficients that could be applied to gross engineering estimates to calculate net energy impact. The net billing analysis model specification differs from the gross billing analysis model, which used two different multivariate regression models (a baseline model using a control group and an SAE model using participants). Instead, the net billing analysis model runs one integrated model combining both the participants and nonparticipants.

A disadvantage of combining both participants and nonparticipants into one model of net energy savings is that the resulting sample is not random. In particular, participants self-select into the program and therefore may not be randomly distributed. As a result, there are certain unobserved characteristics that influence the decision to participate. If these characteristics are not accounted for in the model, the net savings model could produce biased coefficient estimates.

One solution to this problem is to include an Inverse Mills Ratio in the model to correct for self-selection. This method was developed by Heckman[4] (1976, 1979) and is used by others (Goldberg and Train[5], 1996) to address the problem of self-selection into energy retrofit programs. The Mills Ratio technique assumes that the unobserved factors that are influencing participation are distributed normally. The influence of these unobserved factors on participation can be approximated by a Mills Ratio which itself is distributed normally. Using the Mills Ratio corrects for the self-selection bias in the net savings regression as the unobserved factors affecting participation are now controlled for in the model. As a result, standard regression techniques should produce unbiased coefficient estimates.

Goldberg and Train (1996) develops the technique of using an additional Mills Ratio in the savings regression to account for the possibility that participation is correlated with the size of energy savings. The second Mills Ratio is interacted with a measure of energy savings, which allows the amount of net savings to vary with participation. The rationale for the second term is that those customers who have potentially large savings are more likely to participate in the program. Consequently, the unobserved factors that are influencing participation are also affecting the amount of savings. The additional Mills Ratio accounts for the fact that amount of savings will be correlated with participation.

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[4] Heckman, J. 'The Common Structure of Statistical Models of Truncation, Sample Selection and Limited Dependent Variables and a Simple Estimator for Such Models.", Annals of Economic and Social Measurement, Vol. 5, pp. 475-492, 1976.

Heckman, J. "Sample Selection Bias as a Specification Error." Econometrica, Vol. 47, pp. 153-161, 1979.

[5] Goldberg, Miriam and Kenneth Train. 'Net Savings Estimation: An analysis of Regression and Discrete Choice Approaches', prepared for the CADMAC Subcommittee on Base Efficiency by Xenergy, Inc. Madison, WI, March 1996.

To correct for self-selection, a probit model of program participation is estimated. Upon estimation, the parameters of the participation model are then used to calculate an Inverse Mills Ratio for both participants and nonparticipants. This Mills Ratio is then included in the net savings regression that combines both participants and nonparticipants. If the Mills Ratio controls for those unobserved factors that determine participation, and the other model assumptions are met, then the net savings model can then be estimated as if participation in the program is randomly determined.

Using the Inverse Mills Ratio to correct for selection relies on several assumptions. First, the net savings due to the program, whether expressed as naturally occurring savings or a net-to-gross ratio, must be normally distributed. In addition, the Mills Ratio must not be highly correlated with the other independent variables used in the net billing regression. In this application, both of these assumptions are found to be violated. Net savings due to the program is biased upward toward large customers and is not distributed normally. The Mills Ratio term used in the net savings regression is also found to be highly correlated with other independent variables, which introduces multi-collinearity into the model. As a result of these violations, the regression analysis using the Mills Ratio technique does not yield reliable estimates in this application. A description of the methods used for this application are provided in *Appendix C*.

Therefore, self-selection is not treated explicitly in the billing regression analysis. However, because the objective of the billing regression analysis is to estimate the program gross energy impacts, the self-selection bias, if it even exists, has very limited impacts on the outputs of such estimation when both cross-sectional and time series data are used. In addition, the effects of free ridership are explicitly modeled in the net to gross analysis, described in *Section 3.4*.

3.3.8 Relative Precision Calculation

Relative precision at 90 percent and 80 percent confidence levels for the adjusted gross energy impact estimates are calculated for each of the SAE analysis segments. As mentioned above, there are a total of sixteen analysis segments that were explicitly modeled and the relative precision estimates based upon the model output are presented in Exhibit 3-10 below. In order to calculate the total program level adjusted gross impact and relative precision, the segment level results were weighted by their unadjusted engineering energy impact estimates in the following equations.

$$\text{Total Adjusted Energy Impact} = \sum_i \beta_i \text{Eng}_i$$

Where β_i and Eng_i are the SAE coefficients and unadjusted engineering impact estimates for segment i, respectively. The program level standard error can be estimated as:[6]

$$\text{StdErr} = \sqrt{\sum_i (CV_i * \beta_i * \text{Eng}_i)^2}$$

Where CVi = (std(βi)/βi) is the coefficient of variation in segment i, estimated in the billing regression model. Finally, the relative precision at 90 percent and 80 percent confidence levels were calculated as

$$RP = \frac{t * \text{StdErr}}{\text{Total Adj. Energy Impact}}$$

[6] This procedure assumes that the samples in different segments are independent and can be treated as strata in a stratified sampling.

where t equals 1.645 and 1.282 for the 90% and 80% confidence levels, respectively.

Exhibit 3-10
Relative Precision Calculation

SAE Analysis Level	Engineering Gross Energy Impact Estimate (MWh)	SAE Coefficient	t-Statistic	Relative Precision at 80%	Relative Precision at 90%
Lighting End Use					
Office Flourescents	51,455	1.00	14.67	9%	11%
Other Flourescents	76,591	0.68	7.41	17%	22%
Controls	5,318	1.38	2.09	61%	79%
Warehouse HIDs	4,306	0.00	-	-	-
School HIDS	815	0.00	-	-	-
Other RE Lighting	17,534	1.26	2.15	60%	77%
Customized Incentives Lighting	10,242	0.51	3.07	42%	54%
Total	166,261	0.83		13%	16%

3.4 NET-TO-GROSS METHOD

The methods used to derive net-to-gross (NTG) results for the Lighting evaluation are presented in this section. The NTG ratios derived using these methods are applied to the gross ex ante energy, demand, and therm impacts to derive net program impacts after customer actions outside the program are accounted for. After a brief discussion of data sources, estimates of free-ridership and spillover from participant self-reports are discussed, followed by more sophisticated statistical modeling techniques that were used to estimate program net effects

3.4.1 Data Sources

Data used in the net-to-gross analysis include 597 telephone surveys from lighting end use participants surveyed from April through August 1996, and 451 telephone surveys from lighting end use nonparticipants surveyed from June through August 1996. Other data used in this analysis include 156 telephone surveys from canvass nonparticipants and 634 canvass nonparticipants who were "thanked and terminated" because they had not made an equipment retrofit or installation. The canvass nonparticipants were surveyed from June through July 1996.

3.4.2 Self-Report-Based Estimates Of Free-Ridership

The RE and Customized Incentives participants surveyed installed or adopted the following technology groups. (Participants who installed multiple technologies may be included in more than one technology group.)

Technology Group	N
T-8: New and Replacements	491
Compact Fluorescents	232
Delamp Fluorescent Fixtures	202
Exit Signs	104
Controls	91
HID Fixtures	62
Halogen	36
Electronic Ballasts	32
Incandescent-to-fluorescent Conversion	16
Reduced Wattage Lighting	2
Custom	17

Because free-ridership often varies by technology, results were calculated for each technology group. However, caution should be employed in interpreting the analysis results, given the small sample sizes for some technology groups.

Methods for Scoring Free-Ridership

The method used to score free-ridership uses participant responses to survey questions regarding the timing of and reasons for equipment replacement actions. The complete text of the participant surveys may be found in *Survey Appendix S-1*. Questions used for the self-report analysis are summarized in *Appendix D*.

As described in the workplan, a series of questions was posed to program participants. If the customer indicated that he had not been shopping for new lighting before becoming aware of the program, he was scored initially as a net participant. A customer was then classified as a free-rider if he (1) stated that he would have installed high-efficiency lighting within the year and had already selected the lighting equipment; and (2) stated that he would have purchased high-efficiency lighting equipment if the program had not existed.

Free-Ridership Results

NTG results weighted by avoided cost and calculated by subtracting the free-ridership rates (obtained through the method described above) are presented in Exhibit 3-11. Results are presented overall and by segment.

Exhibit 3-11
NTG Weighted by Avoided Cost

	RE Measures					
	T-8: New and Replacements	Delamp Fluorescent Fixtures	HID Fixtures	Compact Fluorescents	Controls	Exit Signs
N	491	202	62	232	91	104
% Avoided Cost	67.65%	15.28%	7.30%	2.88%	1.33%	1.05%
1 - FR	0.911	0.903	0.732	0.876	0.962	0.925

	RE Measures (Cont.)					
	Incandescent-to-Fluorescent Conversion	Electronic Ballasts	Halogen	Reduced Wattage Lighting	Custom	Overall
N	16	32	36	2	17	1285
% Avoided Cost	0.57%	0.42%	0.04%	0.02%	3.46%	100%
1-FR	1.00	0.994	0.649	1.00	0.783	0.890

Overall, weighted NTG results range from a low of 0.65 for halogen fixtures to a high of 1.00 for incandescent-to-fluorescent conversions and reduced wattage lighting. The program-wide NTG ratio, weighted by avoided cost, was 0.89. This result was used as the basis for subsequent spillover adjustment.

3.4.3 Self-Report-Based Estimates of Spillover

Lighting spillover can be defined as lighting efficiency improvements implemented outside the program but influenced by the program. Preliminary estimates of lighting spillover rates were generated by analyzing responses to a combination of questions asked of 597 participants and 1,241 nonparticipants.

Methods for Scoring Spillover

The integrated approach used to estimate lighting spillover is summarized below.

All surveyed respondents were asked if they had installed lighting equipment outside the program since January 1993. Participants who answered "yes" to the first question were asked if these changes were made after participating in the program. Nonparticipants, and participants who said the changes were made after participation, were asked if they made the equipment changes through a PG&E program.

Participants who passed the first two screening questions and had not changed out lighting equipment through a PG&E program, and nonparticipants who passed the first two screening questions and were aware of the program at the time of equipment purchase, were asked how influential the program was in their decision. Those who said that the program had influenced their decision[7] were included in the estimate of program spillover.

Survey-based estimates were applied to the lighting participant population and the lighting nonparticipant population along with estimates of impact per site, resulting in a final spillover impact.

It should be noted that this analysis provides a preliminary indication of spillover rates and more in-depth analysis is required to quantify spillover impacts.

Spillover Results - Participants

Forty-eight surveyed participants (8 percent of the total participant sample) reported that since January 1993 they had added lighting equipment. Fifty percent of those participants who added equipment (4 percent of the total participant sample) added the equipment after participating in the program. Thirty-five percent (2.85 percent of the total participant sample) did not install the equipment through the program. Ten of these respondents (1.68 percent of the total participant sample) reported that the program influenced their additional lighting equipment installations. Of these 10, 4 installed additional lighting equipment in 1995. Four of 597 participants yields an initial unweighted spillover rate of 0.67 percent for 1995.

Spillover Results - Nonparticipants

One hundred seventy-nine of 1,241 program nonparticipants reported making lighting changes outside the program, of which 126 respondents confirmed their installations were not done through the program. Seventeen respondents (1 percent of the total nonparticipant sample) reported they were aware of the program before they purchased the equipment. Of these 17, 6 respondents reported that their knowledge of the program influenced their equipment selection. One of these 6 respondents installed lighting equipment in 1995. One of 1,241 nonparticipants yields an unweighted spillover estimate of 0.08 percent for 1995.

Because the levels of self-reported spillover are so low and based on such a small number of responses, it was decided not to apply a correction for either participant or nonparticipant spillover. One minus the self-reported rate of free-ridership (1 - 0.11 = 0.89) was therefore used as the self-reported NTG ratio for the Lighting program.

3.5 OVERVIEW OF DISCRETE CHOICE METHOD

A discrete choice logit model is used to estimate both a net-to-gross ratio and the free ridership rate associated with PG&E's Commercial Lighting Energy Efficiency Incentive (EEI) Program (the Lighting program). The decision to purchase high-efficiency equipment is explained in the logit model by the cost and savings of the equipment, any rebate offered by the Lighting program, awareness of the Lighting program, and other customer characteristics. In this application, the high-efficiency equipment examined is fluorescent lighting.[8] Once estimated, the model can be used to determine the probability of purchasing high-efficiency equipment in the absence of the

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[7] "To what extent did participating in the program influence your additional equipment selection?" Values of 2, 3, 4, and 5 (slightly influential to very influential) were considered to demonstrate program influence on the purchase.

[8] Other lighting technologies such as compact fluorescents and HIDs did not have enough data to estimate additional logit purchase models. However, the fluorescent lighting measures account for the majority of the lighting retrofits, over 70 percent of the energy impacts from the Lighting program.

Lighting program. This is simulated by setting both the rebate and program awareness variables to zero in the logit purchase model.

The net-to-gross ratio is calculated using the probability of purchasing high-efficiency equipment both with and without the existence of the retrofit program. The expected impact with the program is the probability of choosing high-efficiency equipment multiplied by the energy impact of the equipment. Similarly, the expected energy impact in absence of the Lighting program is the probability of purchasing high-efficiency equipment without the program multiplied by the energy impact of the equipment. The net-to-gross ratio is the net savings due to the program divided by the expected energy that results from having the program. As discussed below, this method is also used to determine free ridership rates and nonparticipant spillover.

3.5.1 Data Sources for the Net-to-Gross Analysis

The data used for the net-to-gross analysis are a combination of telephone survey information and the program information contained in the MDSS dataset. The sample is divided into both a high-efficiency equipment purchase group and a group of customers that maintain the current lighting system. Those that bought high-efficiency fluorescent lighting equipment either in or outside of the retrofit program are considered purchasers. Those that maintain their current lighting equipment or that purchased standard efficiency lighting equipment comprise the nonpurchase group.

The sample used to estimate the logit model contains information on 1,369 customers. Of these, 819 did not make any lighting equipment purchases. For high-efficiency equipment purchases, 504 customers purchased 1,455 separate lighting measures within the retrofit program while 23 customers purchased 56 separate measures outside the program. For standard equipment, 23 customers purchased 29 different measures. This results in a sample of 848 observations for those who did not purchase high-efficiency equipment and a sample of 1,511 observations where high-efficiency equipment was purchased.

3.5.2 Estimating Lighting Equipment Economic Variables

For those customers that installed high-efficiency equipment within the Lighting program, the reported cost, savings, and rebate data is used in the model. For those customers who installed high-efficiency equipment outside of the Lighting program, the costs are determined from vendor prices of equipment multiplied by the number of reported fixtures installed. Energy savings is calculated by multiplying the noncoincident demand savings for a given technology by the electricity rate, number of fixtures installed, and the operating hours for that customer.

3.5.3 Logit Purchase Model Specification

The logit model is a discrete choice model with a dependent variable of either zero or one. In this application, customers are given a value of one if they purchased high-efficiency fluorescent lighting either in or outside the program and a zero if they purchased standard equipment or did not make any fluorescent lighting purchase. The logit model specification is defined as:

$$PURCHASE = \alpha + \beta'X + \gamma'Y + \vartheta'Z + \varepsilon$$

Exhibit 3-12
Definitions for Variables Used in the Logit High-Efficiency Equipment Purchase Model

Variable Name	Variable Units	Description
INTERCPT	1.00	
PAYBACK	years	Years for installation payback given by (cost - rebate) / savings
AWARE	0,1	Aware of the Lighting Program
ADDCOOL	0,1	Added cooling equipment since 1/93
ADDHEAT	0,1	Added heating equipment since 1/93
ARCOOL	0,1	Added and removed cooling equipment since 1/93
ARHEAT	0,1	Added and removed heating equipment since 1/93
COLLEGE	0,1	College
COMMSERV	0,1	Community service building
SIZE	Square feet	Size of facility
AVGUSE	Kwh	Average monthly electric use over 1992-1994
ELECHEAT	0,1	Customer has electric heat
GASHEAT	0,1	Customer has gas heat
GROCERY	0,1	Grocery
HEALTH	0,1	Health
HEAT95	0,1	Heating equipment change occured in 1995 or later
HOTEL	0,1	Hotel
LARGCUST	0,1	Large sized customer based on electricity use
OFFICE	0,1	Office Building
OTHER95	0,1	Other change in energy use occured in 1995 or later
WAREHSE	0,1	Warehouse
SMALCUST	0,1	Small sized customer based on electricity use
RETAIL	0,1	Retail
RESTRNT	0,1	Restaurant

The variables AWARE and PAYBACK are specified to capture the effect of the lighting program on high-efficiency equipment purchases. For AWARE, all program participants are coded as being aware and have a value of one. For those outside the program, customers are coded as being aware if they participated in the lighting program with a different technology, or if they indicated in the telephone survey that they were aware of the program. For those maintaining the current lighting system, 28 percent reported being aware of the program. For high-efficiency measures done outside the Lighting program, 46 percent were performed by customers aware of the Lighting program.

The rebate amount is contained in the variable PAYBACK, which is the cost of the measure minus the rebate divided by the yearly dollar savings due to the technology. The payback value reflects the number or years of savings required to equal the initial net cost of the equipment. Since the majority of the technologies have an expected life of around 16 years, the PAYBACK variable was capped at a maximum value of 16. This avoids the problem of using a payback measure that is longer than the estimated life of the equipment.

3.5.4 Logit Model Estimation Results

The coefficient estimates are given in Exhibit 3-13. As expected, program awareness has a strong positive effect on whether to purchase high-efficiency equipment. The coefficient estimate for PAYBACK is also positive, which suggests that program participants may have higher payback periods than nonparticipants. This is not surprising since those that choose not to participate may have more stringent payback criteria. Office, retail, college, community service, and warehouses are the business types most likely to purchase high-efficiency lighting.

Exhibit 3-13
Logit Estimation Results

Variable Name	Coefficient Estimate	Standard Error	Significance Level
INTERCPT	-3.60	0.35	1%
PAYBACK	0.22	0.04	1%
AWARE	4.93	0.22	1%
ADDCOOL	0.45	0.32	16%
ADDHEAT	-0.06	0.43	90%
ARCOOL	0.18	0.29	53%
ARHEAT	-0.21	0.34	54%
COLLEGE	1.11	0.59	6%
COMMSERV	0.62	0.27	2%
SIZE	0.00	0.00	3%
AVGUSE	0.00	0.00	3%
ELECHEAT	-0.48	0.24	4%
GASHEAT	0.00	0.20	100%
GROCERY	-0.27	0.30	37%
HEALTH	0.44	0.30	13%
HEAT95	1.00	0.61	10%
HOTEL	-1.18	0.43	1%
LARGCUST	-0.17	0.20	39%
OFFICE	0.49	0.22	2%
OTHER95	-0.51	0.51	32%
WAREHSE	0.96	0.36	1%
SMALCUST	-0.84	0.17	1%
RETAIL	0.46	0.25	6%
RESTRNT	-0.16	0.35	64%

The estimated model parameter are used to calculate the probability of purchasing high-efficiency fluorescent lighting. With the logit model, the probability of purchasing is given by:

PURCHASE = exp (Q) / 1 + exp (Q)

where $Q = \alpha + \beta'X + \gamma'Y + \vartheta'Z + \varepsilon$

The estimated probabilities for each group are given in Exhibit 3-14.

Exhibit 3-14
Estimated Probabilities of Purchasing High-Efficiency Fluorescent Lighting

Group	Estimated Probability With Program	Estimated Probability In Absence of Program
Maintain Current System	0.25	0.05
Install Standard Efficiency	0.41	0.05
High Efficiency Outside the Program	0.46	0.08
High Efficiency in the Program	0.87	0.14

As expected, Lighting program participants have a high probability of purchasing high-efficiency equipment with an estimated purchase probability of 87 percent. Conversely, those that are maintaining their current lighting system have a relatively low estimated probability of purchasing high-efficiency equipment at 27 percent.

The probability of a high-efficiency equipment purchase is estimated by removing the effect of the Lighting program from the model. This is done by setting AWARE equal to zero and setting the rebate equal to zero in the PAYBACK variable and then recalculating the purchase probability using the logistic density function given above. All other variable values remain the same as they are not expected to change in absence of the program.

The new probabilities of a high-efficiency purchase in the absence of the Lighting program are also given in Exhibit 3-14. In the absence of the Lighting program, the probability of purchasing high-efficiency equipment drops from 87 percent to 14 percent. This suggests that most of those who purchased high-efficiency equipment would not have done so without the Lighting program. The Lighting program also decreases the probability that those outside the program will purchase high-efficiency equipment. For those purchasing high-efficiency outside the program, removing the program decreases the probability of a high-efficiency purchase from 46 percent to 8 percent.

3.5.5 Net-to-Gross Ratio Calculations

Given the estimated probabilities of purchasing high-efficiency equipment with and without the retrofit program, the model can be used to determine net energy savings resulting from the program. For those that participated in the Lighting program, the expected energy savings is:

$$\text{EXPECTED IMPACT}_W^{HEIN} = P_W^{HEIN} * \text{IMPACT}$$

where P_W^{HEIN} = Probability of a high-efficiency purchase made by a program participant with the existence of the Lighting program

IMPACT = Energy impact of the high-efficiency equipment adopted

For those who purchase high-efficiency equipment outside the Lighting program, the expected savings is calculated in the same manner:

$$\text{EXPECTED IMPACT}_W^{HEOUT} = P_W^{HEOUT} * \text{IMPACT}$$

where P_W^{HEOUT} = Probability of a high-efficiency purchase for a customer outside of the program with the existence of the Lighting program

The calculations for expected energy impacts in the absence of the program follow the same format. For program participants and those purchasing high-efficiency equipment outside the program, the expected energy savings without the program is given by:

$$\text{EXPECTED IMPACT}_{WO}^{HEIN} = P_{WO}^{HEIN} * \text{IMPACT}$$

$$\text{EXPECTED IMPACT}_{WO}^{HEOUT} = P_{WO}^{HEOUT} * \text{IMPACT}$$

where P_{WO}^{HEIN} = Probability of a high-efficiency purchase made by a program participant without the Lighting program

P_{WO}^{HEOUT} = Probability of a high-efficiency purchase for a customer outside of the program without the Lighting program

3.5.6 Net -to-Gross Ratio

The expected savings for both groups of high-efficiency purchasers with and without the Lighting program is used to calculate the net energy savings due to the Lighting program as well as a net-to-gross ratio. The expected energy savings are given for each group in Exhibit 3-15. To calculate the net-to-gross ratio, the net energy savings for each group is weighted up to the population. For program participants, the weight reflects the total energy impact from fluorescent lighting due to the retrofit program represented in the sample. For those that did high-efficiency outside the program but also participated in the Lighting program in some other fashion, the weight assigned is the same assigned to the program participants. If the customer purchased high-efficiency equipment outside the program and did not participate in the lighting program in any way, the weight assigned reflects the number of similar customers in the non-participant population.

Exhibit 3-15
Estimated Energy Impacts and Net-to-Gross Ratios

	Annual GWh		
Group	**With Program**	**In Absence of Program**	**Net Impact**
Maintain Current System	777.49	141.71	635.78
Install Standard Efficiency	55.12	6.03	49.09
High Efficiency in the Program	85.17	8.27	76.9
High Efficiency Outside the Program	15.26	3.05	12.21

Estimated Net-To-Gross Ratio	
Program Participants Only	0.9
With Nonparticipation Spillover	1.05

To calculate the net-to-gross ratio, the net savings is divided by the expected energy savings with the program. For program participants the net-to-gross ratio (NTG) is:

$$NTG^{HEIN} = (EXPECTED\ IMPACT_{W}^{HEIN} - EXPECTED\ IMPACT_{WO}^{HEIN}) / EXPECTED\ IMPACT_{W}^{HEIN}$$

$$= (85.17 - 8.27) / 85.17$$

$$= 0.90$$

The level of free ridership among program participants is one minus the net-to-gross ratio, or 0.10. This means that 10 percent of the estimated program impact among participants would have been achieved without the Lighting program.

This method is also used to incorporate the spillover effect that the program has on those installing high-efficiency equipment outside the Lighting program. The above formula is modified to take into account the net savings for those installing high-efficiency outside the Lighting program both with and in absence of the program. The net-to-gross ratio including spillover is the sum of the net savings from those installing high-efficiency equipment both inside and outside the Lighting program, divided by the total expected savings due to the program.

$$NTG^{HEIN+HEOUT} = (NET\ IMPACT^{HEIN} + NET\ IMPACT^{HEOUT}) / EXPECTED\ IMPACT_{W}^{HEIN}$$

$$= (76.91 + 12.13) / 85.17$$

$$= 1.05$$

where $NET\ IMPACT^{HEIN} = EXPECTED\ IMPACT_{W}^{HEIN} - EXPECTED\ IMPACT_{WO}^{HEIN}$

$NET\ IMPACT^{HEOUT} = EXPECTED\ IMPACT_{W}^{HEOUT} - EXPECTED\ IMPACT_{WO}^{HEOUT}$

The net-to-gross ratio estimate of 1.05 can be decomposed to the 90 percent of the Lighting program impact that is expected from the program participants as well as an additional 15 percent expected from spillover from those customers installing outside the Lighting program.

3.6 Summary of Final Net -to-Gross Adjustments

The final net-to-gross ratios applied to the ex post gross impacts are derived from a combination of both methods described above. For the fluorescent technologies (efficient ballasts, T8 lamps and electronic ballasts, and optical reflectors with fluorescent delamping) the results of the logit model are applied. This includes an adjustment for free ridership and spillover. It is important to also note that the adjustment for free ridership is almost identical for both the logit model results and the self report results.

For the remaining technologies, since no logit model was estimated, the self report results are applied. This should be considered a very conservative approach because no spillover is included in the net-to-gross adjustment for these segments.

Exhibit 3-16 below summarizes the final net-to-gross adjustments that were applied to the ex post gross impacts as described in *Section 4*. Because the net-to-gross adjustments are estimated at the technology level, the totals presented in Exhibit 3-16 are weighted by the ex post gross energy impacts. The totals will differ slightly when weighted by demand and therm, which are presented in the executive summary in Exhibits 1-3 and 1-4.

Exhibit 3-16
Summary of Final Net-to-Gross Adjustments

Business Type / Program and Technology Group	NTG Adjustment		
	Free Ridership (1-FR)	Spillover	NTG Ratio
Retrofit Express Program			
Compact Fluorescent	0.88	0.00	0.88
Incandescent to Fluorescent	1.00	0.00	1.00
Efficient Ballast	0.90	0.14	1.05
T8 Lamps and Electronic Ballasts	0.90	0.14	1.05
Optical Reflectors w/ Fluor. Delamp	0.90	0.14	1.05
High Intensity Discharge	0.73	0.00	0.73
Halogen	0.65	0.00	0.65
Exit Signs	0.93	0.00	0.93
Controls	0.96	0.00	0.96
Retrofit Express Total*	0.88	0.10	0.98
Customized Incentives Program			
Compact Fluorescent	0.78	0.00	0.78
Standard Fluorescent	0.78	0.00	0.78
High Intensity Discharge	0.78	0.00	0.78
Halogen	0.78	0.00	0.78
Exit Signs	0.78	0.00	0.78
Controls	0.78	0.00	0.78
Other	0.78	0.00	0.78
Customized Incentives Total*	0.78	0.00	0.78
Total*	0.88	0.09	0.97

*** Weighted by ex post gross kWh.**

4. EVALUATION RESULTS

This section contains the results of this evaluation, beginning with ex post gross impacts, then presenting the net-to-gross (NTG) adjustments, and concluding with the program realization rates (ratio of ex post evaluation findings to the ex ante program design estimates), for both gross and net impacts. Explanations for the differences between the ex ante and ex post estimates are discussed in the presentation of program realization rates.

Where segment analysis could be supported, results are presented by technology group and business type. All results are segmented by program, Retrofit Express (RE), and Customized Incentives. All results are aggregated to the entire commercial sector by program.

4.1 EX POST GROSS IMPACT RESULTS

Ex post gross energy and demand impacts for the RE and Customized Incentives programs (for indoor lighting applications), are presented in Exhibits 4-1 and 4-2, respectively. The ex post gross energy and demand impacts by PG&E costing period are provided in *Appendix F.*

Exhibit 4-1
Ex Post Gross Energy Impacts
By Business Type and Technology Group
For Commercial Indoor Lighting Applications

Business Type / Program and Technology Group	First Year Gross Energy Impacts (kWh)												
	Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Service	Community Service	Misc	Total
Retrofit Express Program													
Compact Fluorescent	1,939,701	466,620	379,826	549,961	170,390	339,063	638,566	5,048,981	81,305	49,699	434,158	189,953	10,288,224
Incandescent to Fluorescent	142,576	4,208	15,081	122,315	—	23,779	26,016	350,442	17,790	—	88,493	261,877	1,052,576
Efficient Ballast	151,093	251,004	10,146	58,809	98,869	4,729	10,318	650	39,648	2,134	39,216	6,733	673,349
T8 Lamps and Electronic Ballasts	27,917,758	8,412,346	1,724,318	6,054,271	3,324,058	654,010	2,595,244	931,592	1,266,286	1,160,649	2,540,175	1,142,209	57,722,919
Optical Reflectors w/ Fluor. Delamp	21,243,516	3,321,022	701,364	2,309,771	889,205	635,787	1,511,284	355,641	789,078	494,203	904,714	367,710	33,523,294
High Intensity Discharge	4,287,990	3,532,683	448,612	0	340,936	71,000	3,832	16,211	0	750,871	1,914,122	4,705,616	16,071,876
Halogen	352,373	728,344	199,293	54,860	15,523	255,846	42,468	513,326	78,634	41,502	233,272	108,684	2,624,127
Exit Signs	1,581,007	93,366	201,480	509,190	31,329	100,786	311,622	59,896	70,636	35,574	432,615	49,713	3,477,212
Controls	3,235,982	156,384	194,711	1,564,399	17,374	22,085	808,560	211,425	246,960	123,959	666,804	78,490	7,327,131
Retrofit Express Total	60,851,995	16,965,978	3,874,832	11,223,576	4,887,683	2,107,085	5,947,909	7,488,163	2,590,338	2,658,592	7,253,569	6,910,988	132,760,708
Customized Incentives Program													
Compact Fluorescent	37,452	—	—	—	6,053	—	—	—	—	—	—	—	43,505
Standard Fluorescent	385,988	—	—	—	1,081,282	—	—	—	239,433	—	—	—	1,706,703
High Intensity Discharge	—	10,980	46,342	—	181,358	—	—	—	275,204	—	33,190	—	547,074
Halogen	1,379	—	—	—	—	—	—	—	—	—	—	—	1,379
Exit Signs	4,471	—	—	—	—	—	—	—	—	—	—	—	4,471
Controls	272,445	—	—	—	1,996,505	—	—	—	28,841	—	83,051	—	2,380,843
Other	—	—	—	—	215,993	—	—	—	114,306	—	225,621	5,893	561,813
Customized Incentives Total	701,735	10,980	46,342	0	3,481,192		0	0	657,785	0	341,862	5,893	5,245,788
Total	61,553,729	16,976,958	3,921,174	11,223,576	8,368,875	2,107,085	5,947,909	7,488,163	3,248,123	2,658,592	7,595,432	6,916,880	138,006,496

Exhibit 4-2
Ex Post Gross Demand Impacts
By Business Type and Technology Group
For Commercial Indoor Lighting Applications

Business Type / Program and Technology Group	First Year Gross Demand Impacts (kW)												
	Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Service	Community Service	Misc.	Total
Retrofit Express Program													
Compact Fluorescent	437	138	106	142	41	79	172	996	27	14	113	54	2,320
Incandescent to Fluorescent	32	1	4	32	----	6	8	69	6	----	26	88	271
Efficient Ballast	34	73	3	15	24	1	3	0	13	1	11	2	179
T8 Lamps and Electronic Ballasts	6,334	2,436	490	1,560	796	160	752	202	427	343	714	339	14,552
Optical Reflectors w/ Fluor. Delamp	4,820	968	201	595	212	156	444	70	270	141	259	109	8,244
High Intensity Discharge	781	554	69	142	44	9	1	2	999	116	298	718	3,732
Halogen	63	115	31	8	2	34	7	54	14	6	38	17	388
Exit Signs	156	9	19	49	3	10	31	6	7	3	43	5	339
Controls	292	14	17	138	2	2	73	19	21	11	61	7	655
Retrofit Express Total	12,948	4,308	938	2,679	1,124	457	1,490	1,418	1,784	635	1,563	1,338	30,682
Customized Incentives Program													
Compact Fluorescent	17	----	----	----	2	----	----	----	----	----	----	----	18
Standard Fluorescent	171	----	----	----	348	----	----	----	108	----	----	----	627
High Intensity Discharge	----	4	17	----	58	----	----	----	125	----	13	----	217
Halogen	1	----	----	----	----	----	----	----	----	----	----	----	1
Exit Signs	1	----	----	----	----	----	----	----	----	----	----	----	1
Controls	66	----	----	----	491	----	----	----	7	----	20	----	584
Other	----	----	----	----	53	----	----	----	26	----	55	1	136
Customized Incentives Total	255	4	17	0	952	0	0	0	266	0	88	1	1,585
Total	13,204	4,312	956	2,679	2,076	457	1,490	1,418	2,050	635	1,651	1,339	32,267

The results in Exhibits 4-1 and 4-2 illustrate the following gross impact findings:

RE Program -- Overall, the vast majority of the savings are from lighting technologies installed through the RE program, where RE retrofits represent more than 95 percent of the energy and demand impacts. Historically, participation has been significantly larger within the RE program. This is especially true with respect to recent participation, because the Customized Incentives Program was dropped from PG&E's DSM portfolio in 1995.

Customized Incentives Program - The Customized Incentives Program plays a small role in the overall impact, with less than 5 percent of the energy and demand savings being attributable to this program. The largest Customized Incentives participation was found within the grocery business type, which contributed more than 40 percent of that programs impacts.

High Participation Business Types - Office and retail business types represent about 55 percent of the impacts, with office being the largest single segment, accounting for about 41 percent of demand and 45 percent of energy impacts. These business types have historically contributed a large share of lighting program impacts, which in-turn is driven by the large number of lighting retrofits performed within those particular business types.

High Participation Technologies - The four technologies that made the largest contributions to impacts were the replacement of standard-efficiency fluorescent lamps and ballasts with T-8 lamps and electronic ballasts; the installation of optical reflectors in combination with delamping of fluorescent fixtures; the installation of high-intensity discharge (HID) lamps and ballasts in place of less efficient technologies; and the installation of compact fluorescent fixtures to replace incandescent lighting. These four technologies represent 86 percent of the program energy savings and 92 percent of demand savings, and T-8 lamps and electronic ballasts alone account for 47 percent of gross demand impacts and 43 percent of energy savings. The large impacts attributable to these technologies are driven by the equally large participation within those particular measure categories.

Low Participation Business Types - The lowest energy impacts were contributed by the restaurant business type, because of low participation in that segment. Lighting quality requirements within this segment help to explain the predominance of incandescent installations, which are preferred because they have the dimming capability that is lacking in energy-efficient technologies.

Statistically Insignificant SAE Results - Ex post energy impacts were set to zero for HIDs in schools and warehouses. As explained in more detail in *Appendix C*, the SAE coefficients were statistically insignificant and the wrong sign within those particular segments. Therefore, a conservative estimate of zero impact was assigned to these segments.

Because of the heating penalty (associated with reduced gas heating usage) during the heating season, the Lighting program also has therm impacts. These impacts, which are by definition negative, are presented in Exhibit 4-3.

As a function of the program energy impacts, gross therm impacts are concentrated in the same segments that dominate the kWh impacts. For example, T-8 lamps and electronic ballasts account for almost 50 percent of therm impacts, followed by optical reflectors and delamping of fluorescent fixtures. Together these technologies are responsible for over 75 percent of therm impacts (and 66 percent of gross energy impacts).

The above measures are concentrated in the office segment, which accounts for over half of total therm impacts. Schools, which account for only 8 percent of annual kWh impacts, are responsible for 15 percent of therm impacts, since their usage is concentrated in the heating rather than the cooling season.

Exhibit 4-3
Ex Post Gross Therm Impacts
By Business Type and Technology Group
For Commercial Indoor Lighting Applications

Business Type / Program and Technology Group	First Year Gross Impacts (Therm)												
	Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Service	Community Service	Misc.	Total
Retrofit Express Program													
Compact Fluorescent	-640	-158	-54	-300	-21	-199	-146	-345	-7	-5	-180	-21	-2,075
Incandescent to Fluorescent	-47	-1	-2	-67	---	-14	-6	-24	-2	---	-37	-29	-230
Efficient Ballast	-50	-85	-1	-32	-12	-3	-2	0	-4	0	-16	-1	-207
T8 Lamps and Electronic Ballasts	-9,232	-2,849	-244	-3,301	-411	-383	-598	-65	-115	-114	-1,064	-127	-18,502
Optical Reflectors w/ Fluor. Delamp	-7,023	-1,126	-99	1,260	-110	-373	-349	-24	-71	-48	-382	-41	10,906
High Intensity Discharge	-1,130	-642	-39	-301	-23	-22	0	-1	-264	-39	-429	-279	-3,168
Halogen	-92	-132	-15	-16	-1	-80	-5	-19	-4	-2	-53	-6	-426
Exit Signs	-361	-17	-13	-127	-2	-32	-36	-2	-3	-2	-97	-3	-695
Controls	-679	-26	-12	-358	-1	-6	-85	-7	-11	-6	-137	-4	-1,331
Retrofit Express Total	-19,253	-5,037	-480	-5,761	-581	-1,112	-1,227	-486	-481	-216	-2,396	-511	-37,540
Customized Incentives Program													
Compact Fluorescent	-24	---	---	---	-1	---	---	---	---	---	---	---	-25
Standard Fluorescent	-249	---	---	---	-177	---	---	---	-29	---	---	---	-454
High Intensity Discharge	---	-5	-9	---	-30	---	---	---	-33	---	-18	---	-94
Halogen	-1	---	---	---	---	---	---	---	---	---	---	---	-1
Exit Signs	-3	---	---	---	---	---	---	---	---	---	---	---	-3
Controls	-154	---	---	---	-317	---	---	---	-3	---	-46	---	-520
Other	---	---	---	---	-34	---	---	---	-14	---	-125	-1	-174
Customized Incentives Total	-430	-5	-9	0	-559	0	0	0	-79	0	-189	-1	-1,272
Total	-19,683	-5,042	-489	-5,761	-1,140	-1,112	-1,227	-486	-559	-216	-2,586	-512	-38,812

4.2 NET-TO-GROSS ADJUSTMENTS

The NTG results are designed to account for all of the market spillover effects (free-ridership, participant spillover, and nonparticipant spillover) by measure.

Exhibit 4-4 presents the NTG values by technology. Where supported by measure-specific data, discrete choice analysis was used. For other measures, the NTG results are based on self-reported data. Discrete choice analysis was used only for the efficient ballast, T8 lamps and electronic ballasts, and optical reflectors with fluorescent delamping measures. Both methods are described in detail in *Appendix D, Net-to-Gross Analysis*.

In the case of self-reported data, results are presented without participant and nonparticipant spillover. Nonparticipant spillover accounts for the percentage of customers who installed high-efficiency measures outside of the program, but were influenced by the presence of the program. This effect is determined by assessing the percentage of the nonparticipant population who installed high-efficiency measures (because of the presence of the program), which is, in turn, multiplied by the nonparticipant population. Since the nonparticipant population is large, a small percentage of nonparticipant action can create a large spillover effect relative to the program impact. To avoid having a very small number of nonparticipants exert disproportionate influence over the evaluation results, nonparticipant spillover was not incorporated within the NTG calculations (that were based on self-reported data).

The ex ante NTG ratio was just 0.77 for the RE program and 0.75 for the Customized Incentives Program, while the ex post NTG ratio for all indoor lighting measures averaged 0.97. When compared to the ex ante NTG assumption, this results in an average 20 percent increase in realized savings.

Exhibit 4-4
NTG Adjustments by Technology Group

Business Type / **Program and Technology Group**	NTG Adjustment		
	Free Ridership (1-FR)	Spillover	NTG Ratio
Retrofit Express Program			
Compact Fluorescent	0.88	0.00	0.88
Incandescent to Fluorescent	1.00	0.00	1.00
Efficient Ballast	0.90	0.14	1.05
T8 Lamps and Electronic Ballasts	0.90	0.14	1.05
Optical Reflectors w/ Fluor. Delamp	0.90	0.14	1.05
High Intensity Discharge	0.73	0.00	0.73
Halogen	0.65	0.00	0.65
Exit Signs	0.93	0.00	0.93
Controls	0.96	0.00	0.96
Retrofit Express Total*	0.88	0.10	0.98
Customized Incentives Program			
Compact Fluorescent	0.78	0.00	0.78
Standard Fluorescent	0.78	0.00	0.78
High Intensity Discharge	0.78	0.00	0.78
Halogen	0.78	0.00	0.78
Exit Signs	0.78	0.00	0.78
Controls	0.78	0.00	0.78
Other	0.78	0.00	0.78
Customized Incentives Total*	0.78	0.00	0.78
Total*	0.88	0.09	0.97

*** Weighted by ex post gross kWh.**

Several of the technology-specific NTG estimates deserve individual discussion.

Compact Fluorescents - The self-reported rate of free-ridership yielded a NTG estimate of 0.88. This is slightly higher than the MDSS-assumed NTG of 0.77 for this technology (which includes a 1-FR component of 0.67 in conjunction with an 0.10 spillover component). Therefore the ex post NTG, even in the absence of the spillover component, significantly exceeds the conservative ex ante value.

Other Fluorescents - A discrete choice model was estimated for measures in the three most widely installed fluorescent technology groups: efficient ballasts; T-8 lamps and electronic ballasts; and optical reflectors with fluorescent delamping. For these measures, the NTG ratio is 1.05, reflecting the significant level of qualifying installations outside the program (both participants and nonparticipants). In addition to this 0.14 contribution from spillover (that was only measured within this particular set of technologies using the discrete choice model), free-ridership rates were also relatively low within this important (high participation) segment. Where 1-FR alone contributes the additional 0.90 to the overall NTG applied, 1.05.

Halogen, HID - The self-reported rate of free-ridership for these technologies was higher than for other measures, with little other than program-induced installation activity.

Customized Incentives - Participants in the Customized Incentives Program had self-reported free-ridership rates of 0.22. No adjustments were made to these rates for outside-the-program spillover activity, yielding a NTG ratio of 0.78—somewhat higher than the ex ante assumed NTG of 0.75 for Customized Incentives measures.

4.3 EX POST NET IMPACTS

Exhibits 4-5 and 4-6 present the ex post net energy and demand indoor lighting impacts, respectively, for the RE and Customized Incentives programs.

Overall, Exhibits 4-5 and 4-6 show reductions of 3 percent in ex post program energy impacts and 2 percent in demand impacts (when compared to Exhibits 4-1 and 4-2, gross impacts), as a result of the application of the NTG adjustments presented in Exhibit 4-4. T-8/electronic ballast, optical reflectors with delamp, compact fluorescents, and HID replacements still dominate the savings representing more than two thirds of the energy and demand impacts. Among the various business segments, office and retail still dominate impacts, yielding more than 55 percent of the total program savings.

Exhibit 4-5
Ex Post Net Energy Impacts
By Business Type and Technology Group
For Commercial Indoor Lighting Applications

Business Type / Program and Technology Group	First Year Net Energy Impacts (kWh)												
	Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Service	Community Service	Misc.	Total
Retrofit Express Program													
Compact Fluorescent	1,699,178	408,760	332,728	481,766	149,262	297,020	559,384	4,422,908	71,224	43,536	380,322	166,398	9,012,484
Incandescent to Fluorescent	142,576	4,208	15,081	122,315	—	23,779	26,016	350,442	17,790	—	88,493	261,877	1,052,576
Efficient Ballast	157,953	262,402	10,607	61,479	103,359	4,944	10,786	679	41,448	2,231	40,997	7,039	03,924
T8 Lamps and Electronic Ballasts	29,185,433	8,794,329	1,802,615	6,329,181	3,474,995	683,707	2,713,088	973,893	1,323,785	1,213,352	2,655,518	1,194,074	60,343,971
Optical Reflectors w/ Fluor. Delamp	22,208,130	3,471,821	733,212	2,414,652	929,581	664,656	1,579,907	371,790	824,908	516,644	945,794	384,407	35,045,503
High Intensity Discharge	3,138,809	2,585,924	328,384	0	249,565	51,972	2,805	11,866	0	549,638	1,401,137	3,444,513	11,764,613
Halogen	228,690	472,695	129,341	35,604	10,074	166,044	27,562	333,149	51,034	26,935	151,394	70,536	1,703,058
Exit Signs	1,462,431	86,364	186,369	471,001	28,979	93,227	288,250	55,403	65,339	32,906	400,169	45,984	3,216,421
Controls	3,113,014	150,441	187,312	1,504,952	16,714	21,246	777,834	203,391	237,576	119,248	641,465	75,507	7,048,700
Retrofit Express Total	61,336,215	16,236,945	3,725,648	11,420,949	4,962,529	2,006,594	5,985,632	6,723,521	2,633,103	2,504,489	6,705,290	5,650,336	129,891,251
Customized Incentives Program													
Compact Fluorescent	29,325	—	—	—	4,740	—	—	—	—	—	—	—	- 34,065
Standard Fluorescent	302,228	—	—	—	846,644	—	—	—	187,476	—	—	—	1,336,349
High Intensity Discharge	—	8,597	36,286	—	142,004	—	—	—	215,485	—	25,988	—	428,359
Halogen	1,080	—	—	—	—	—	—	—	—	—	—	—	1,080
Exit Signs	3,501	—	—	—	—	—	—	—	—	—	—	—	3,501
Controls	213,324	—	—	—	1,563,264	—	—	—	22,583	—	65,029	—	1,864,200
Other	—	—	—	—	169,122	—	—	—	89,502	—	176,661	4,614	39,900
Customized Incentives Total	549,458	8,597	36,286	0	2,725,773	0	0	0	515,046	0	267,678	4,614	4,107,452
Total	61,885,674	16,245,541	3,761,934	11,420,949	7,688,302	2,006,594	5,985,632	6,723,521	3,148,148	2,504,489	6,972,969	5,654,950	133,998,703

Exhibit 4-6
Ex Post Net Demand Impacts
By Business Type and Technology Group
For Commercial Indoor Lighting Applications

Business Type / Program and Technology Group	First Year Demand Impacts (kW)												
	Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Service	Community Service	Misc.	Total
Retrofit Express Program													
Compact Fluorescent	383	121	93	124	36	69	151	873	24	12	99	47	2,032
Incandescent to Fluorescent	32	1	4	32	----	6	8	69	6	----	26	88	271
Efficient Ballast	36	76	3	16	25	1	3	0	14	1	11	2	187
T8 Lamps and Electronic Ballasts	6,621	2,547	512	1,630	832	168	786	212	447	359	747	354	15,213
Optical Reflectors w/ Fluor. Delamp	5,039	1,012	210	622	222	163	464	73	282	147	270	114	8,618
High Intensity Discharge	571	406	50	104	32	7	0	1	732	85	218	526	2,732
Halogen	41	75	20	5	1	22	4	35	9	4	25	11	.252
Exit Signs	144	8	17	45	3	9	28	5	6	3	40	4	314
Controls	281	13	16	132	2	2	70	18	20	10	58	6	630
Retrofit Express Total	13,148	4,259	926	2,710	1,153	447	1,515	1,286	1,539	621	1,495	1,153	30,251
Customized Incentives Program													
Compact Fluorescent	13	----	----	----	2	----	----	----	----	----	----	----	14
Standard Fluorescent	134	----	----	----	273	----	----	----	85	----	----	----	491
High Intensity Discharge	----	3	14	----	45	----	----	----	98	----	10	----	170
Halogen	0	----	----	----	----	----	----	----	----	----	----	----	0
Exit Signs	1	----	----	----	----	----	----	----	----	----	----	----	1
Controls	52	----	----	----	385	----	----	----	5	----	16	----	458
Other	----	----	----	----	42	----	----	----	20	----	43	1	106
Customized Incentives Total	200	3	14	0	746	0	0	0	208	0	69	1	1,241
Total	13,348	4,262	939	2,710	1,898	447	1,515	1,286	1,747	621	1,564	1,154	31,492

Close examination of these results has contributed to the following findings:

Fluorescent Technologies - The impact for fluorescent technologies increased by 5 percent, as predicted by the NTG adjustment. Office buildings and retail stores, where these technologies are often installed, also showed a net increase over the gross impacts, following the application of NTG adjustments.

Compact Fluorescents - With a NTG ratio of 0.88, CFLs accounted for a somewhat smaller share of net impacts than gross impacts. Similarly, business segments such as hotels/motels (that installed large numbers of CFLs) showed the largest reductions in impacts following the application of the NTG adjustments.

HIDs, Halogens - Business segments with a large proportion of HIDs and halogen lighting also have net impacts that contribute relatively small impacts when compared with their relatively large contribution to gross impacts.

Customized Incentives Program - Impacts within the Customized Incentives Program were reduced significantly following the application of a very conservative 0.78 NTG within that particular segment. However, because the Customized Incentives Program contributed less than 5 percent of gross energy and demand impacts, the effect of this NTG adjustment did not reduce the overall net lighting end-use impacts significantly.

Exhibit 4-7
Ex Post Net Therm Impacts
By Business Type and Technology Group
For Commercial Indoor Lighting Applications

Business Type / Program and Technology Group	First Year Net Impacts (Therm)												
	Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Service	Community Service	Misc.	Total
Retrofit Express Program													
Compact Fluorescent	-560	-139	-47	-263	-19	-174	-128	-302	-6	-4	-158	-18	-1,818
Incandescent to Fluorescent	-47	-1	-2	-67	—	-14	-6	-24	-2	—	-37	-29	-230
Efficient Ballast	-52	-89	-2	-34	-13	-3	-2	0	-4	0	-17	-1	-216
T8 Lamps and Electronic Ballasts	-9,651	-2,979	-255	-3,451	-430	-401	-625	-68	-120	-119	-1,112	-133	-19,343
Optical Reflectors w/ Fluor. Delamp	-7,342	-1,178	-104	-1,317	-115	-390	-364	-25	-75	-50	-399	-43	11,401
High Intensity Discharge	-827	-470	-28	-220	-17	-16	0	0	-193	-29	-314	-204	-2,319
Halogen	-60	-86	-10	-10	-1	-52	-3	-12	-2	-1	-34	-4	-276
Exit Signs	-334	-15	-12	-117	-2	-30	-33	-2	-3	-2	-90	-3	-643
Controls	-653	-25	-11	-344	-1	-6	-82	-6	-10	-6	-132	-4	-1,281
Retrofit Express Total	-19,526	-4,981	-472	-5,823	-596	-1,085	-1,244	-440	-416	-211	-2,294	-439	-37,526
Customized Incentives Program													
Compact Fluorescent	-19	—	—	—	-1	—	—	—	—	—	—	—	-20
Standard Fluorescent	-195	—	—	—	-139	—	—	—	-22	—	—	—	-356
High Intensity Discharge	—	-4	-7	—	-23	—	—	—	-26	—	-14	—	-74
Halogen	-1	—	—	—	—	—	—	—	—	—	—	—	-1
Exit Signs	-2	—	—	—	—	—	—	—	—	—	—	—	-2
Controls	-120	—	—	—	-248	—	—	—	-3	—	-36	—	-407
Other	—	—	—	—	-27	—	—	—	-11	—	-98	-1	-136
Customized Incentives Total	-337	-4	-7	0	-438	0	0	0	-62	0	-148	-1	-996
Total	-19,863	-4,985	-479	-5,823	-1,034	-1,085	-1,244	-440	-477	-211	-2,443	-440	-38,522

Net therm impacts, summarized in Exhibit 4-7, differ from the gross therm impacts presented in Exhibit 4-3 by less than 1 percent. NTG ratios of greater than one in the high-participation fluorescent technologies almost completely offset the reduction (due to the application of NTG adjustments) observed within the other segments.

4.4 *REALIZATION RATES*

Exhibits 4-8 through 4-11 present the gross and net realization rates for energy and demand impacts for the RE and Customized Incentives indoor lighting applications. Exhibit 4-12, at the end of this section, presents ex ante and ex post gross and net impacts and realization rates. Because there were no ex ante estimates for therm impacts, no therm realization rates could be calculated.

4.4.1 Gross Realization Rates for Energy Impacts

The gross energy realization rates are presented in Exhibit 4-8. These values represent, by segment, the ratio of the ex post gross impact evaluation findings to the gross ex ante program design estimates. These realization rates illustrate how well the ex ante estimates predicted energy savings, before taking into account customer behavioral effects, both inside and outside the program.

Exhibit 4-8
Gross Energy Impact Realization Rates
By Business Type and Technology Group
For Commercial Indoor Lighting Applications

Business Type / Program and Technology Group	Gross Energy Impact Realization Rates												
	Office	**Retail**	**College/Univ**	**School**	**Grocery**	**Restaurant**	**Health Care**	**Hotel/Motel**	**Warehouse**	**Personal Service**	**Community Service**	**Misc.**	**Total**
Retrofit Express Program													
Compact Fluorescent	1.29	0.82	0.75	0.77	0.61	0.53	0.59	0.98	0.56	0.62	0.36	0.68	0.84
Incandescent to Fluorescent	1.31	0.75	0.85	0.78	—	0.74	0.73	1.12	0.65	—	0.55	0.67	0.84
Efficient Ballast	1.11	0.77	0.73	0.61	0.49	0.70	0.70	1.07	0.64	0.56	0.46	0.71	0.70
T8 Lamps and Electronic Ballasts	1.29	0.73	0.83	0.77	0.50	0.70	0.73	0.98	0.61	0.69	0.50	0.71	0.88
Optical Reflectors w/ Fluor. Delamp	1.31	0.75	0.85	0.78	0.51	0.71	0.74	1.13	0.66	0.71	0.52	0.73	1.00
High Intensity Discharge	1.64	1.44	1.02	0.00	1.10	1.63	1.55	2.13	0.00	1.32	1.08	1.41	0.98
Halogen	2.34	4.43	2.61	1.10	6.81	4.89	2.96	4.32	2.27	2.51	2.20	2.53	3.16
Exit Signs	1.40	1.40	1.27	1.35	1.42	1.41	1.38	1.36	1.29	1.28	1.42	1.31	1.38
Controls	1.54	1.55	1.42	1.49	1.56	1.55	1.52	1.50	1.42	1.41	1.54	1.44	1.51
Retrofit Express Total	1.34	0.86	0.91	0.80	0.53	0.78	0.79	1.06	0.33	0.84	0.67	1.11	0.96
Customized Incentives Program													
Compact Fluorescent													
Standard Fluorescent													
High Intensity Discharge													
Halogen													
Exit Signs													
Controls													
Other													
Customized Incentives Total													0.49
Total													0.93

Overall, Exhibit 4-8 shows that the ex ante estimates are close to the ex post gross impact estimates for RE measures and for the program overall, but very low for the Customized Incentives measures. The average realization rate for RE measures is 0.96, while Customized Incentives is 0.49. This low realization rate for Customized Incentives can be attributed almost exclusively to the 0.51 SAE coefficient estimated for this program. Because participation for the Customized Incentives program is very small, the overall energy realization rate is still relatively high at 0.93.

The SAE coefficients ranged in magnitude from zero to 1.38, resulting overall in a 17 percent reduction to the engineering-based gross energy impact results. The SAE adjustment made to the Customized Incentives estimates was significant, resulting in a 49 percent reduction to the engineering-based gross energy impact results. Refer to Appendix E for additional details surrounding both the engineering-based gross impact results and the SAE coefficients that were applied to those results.

Segment-level realization rates could not be developed for Customized Incentives impacts because the MDSS does not adequately track ex ante estimates by technology group.

The technology group results presented in Exhibit 4-8 are explained below (using information from the review of the ex ante estimates in conjunction with the impact analysis results).

Compact Fluorescents - The below-average energy realization rates for compact fluorescent technologies are a product of the billing regression analysis yielding a 0.68 coefficient on the engineering estimates for all business types other than offices. Several segments (notably health care and community services) also had engineering estimates of energy impacts that were significantly lower than those in the MDSS, contributing to the overall realization rate of 0.84.

Halogen - The high realization rates for halogen technologies are due to ex ante lamp life assumptions for this technology, where the lamp is replaced with a conventional light at the end of the original lamp life. Ex ante estimates were incorrectly calculated due to analysis procedures surrounding lamp life. Lamp life was incorrectly incorporated into the impact twice, resulting in artificially low estimates. Moreover, no evidence of this short measure life was uncovered during field inspection, nor detected in the billing regression analysis. In addition, a 1.26 SAE coefficient was applied to all halogen observations, driving the ex post numerator in each realization rate even higher. The high realization rates for halogen lamps, however, have only a small effect on the overall lighting end-use realization rate because the energy impact of this technology accounts for only 2 percent of the total.

Office Business Type - The Office business type contributed over 40 percent of the ex post energy and demand impacts that were achieved within the lighting end-use programs, and scored a 1.34 realization rate when compared with ex ante values. This is due in part to the SAE result within this segment, which influenced the overall lighting end-use result significantly. The SAE coefficient result (from the billing regression, for the Office business type) yielded a value greater than or equal to 1.0 for all RE program technologies. This significant result (based on t-statistics that range in value from 2.15 to 14.67) within the Office business type alone, had a large influence over the ex post result.

Fluorescent Technologies, Low Billing Regression Coefficients - In contrast, the high participation lighting technologies (i.e., fluorescent fixtures) in all other business types show realization rates far below 1.0. This is due almost entirely to the low SAE coefficient of 0.68 found in the billing regression analysis for these technologies. In addition, the low realization rates for the grocery and community service business types are a direct result of both this SAE coefficient and intermediate engineering impact results (which indicate that the annual hours of lighting operation, for fixtures in these particular facilities, are lower than that predicted using ex ante impact calculation methods).

High Intensity Discharge, Exit Signs and Controls - In all but two of the business types (see comments below under "High Intensity Discharge in Schools and Warehouses"), SAE coefficients in excess of 1.26 were found in the billing regression analysis and then applied to the ex post gross impact results. The application of these adjustments explains the relatively high realization rates observed in those segments.

High Intensity Discharge in Schools and Warehouses - The zero realization rates reported for the HID technology resulted from a failure of the SAE analysis to detect any HID impact in the school and warehouse business segments. Since the SAE coefficients for these two technology/business segment combinations were a) the wrong sign and b) not statistically significant, it was decided that no energy impact should be claimed. The counterintuitive SAE results may reflect changes in lighting levels, operating characteristics, or other factors not disclosed by the analysis.

4.4.2 *Gross Realization Rates for Demand Impacts*

Gross demand realization rates are presented in Exhibit 4-9. These values represent, by segment, the ratio of the ex post gross impact evaluation findings to the gross ex ante program design estimate. These realization rates illustrate how well the ex ante estimates predicted demand savings, before taking into account customers' actions within the lighting market. Refer to Exhibit 4-12 for an individual presentation of both the ex ante and ex post impacts.

Exhibit 4-9
Gross Demand Impact Realization Rates
By Business Type and Technology Group
For Commercial Indoor Lighting Applications

Business Type / Program and Technology Group	Gross Demand Impact Realization Rates												
	Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Service	Community Service	Misc.	Total
Retrofit Express Program													
Compact Fluorescent	1.48	1.70	1.10	0.63	1.54	0.88	0.96	1.16	1.11	1.04	0.56	1.14	1.08
Incandescent to Fluorescent	1.50	1.51	1.26	0.63	----	1.28	1.26	1.31	1.33	----	0.96	1.34	1.15
Efficient Ballast	1.28	1.54	1.07	0.49	1.18	1.22	1.20	1.22	1.25	0.98	0.75	1.18	1.13
T8 Lamps and Electronic Ballasts	1.48	1.48	1.23	0.62	1.25	1.23	1.26	1.27	1.23	1.21	0.84	1.26	1.20
Optical Reflectors w/ Fluor. Delamp	1.50	1.52	1.28	0.63	1.28	1.24	1.29	1.32	1.34	1.21	0.88	1.29	1.30
High Intensity Discharge	1.51	1.58	0.82	0.65	1.49	1.49	1.47	1.34	1.47	1.22	1.00	1.29	1.31
Halogen	1.77	2.98	1.67	0.64	3.92	2.76	2.04	1.91	1.77	1.69	1.54	1.71	1.99
Exit Signs	1.20	1.20	1.04	1.13	1.24	1.22	1.20	1.17	1.05	1.04	1.23	1.07	1.18
Controls	0.56	0.61	0.50	0.52	0.98	0.86	0.56	0.59	0.54	0.48	0.60	0.60	0.56
Retrofit Express Total	1.43	1.52	1.15	0.62	1.27	1.20	1.16	1.19	1.35	1.18	0.85	1.27	1.20
Customized Incentives Program													
Compact Fluorescent													
Standard Fluorescent													
High Intensity Discharge													
Halogen													
Exit Signs													
Controls													
Other													
Customized Incentives Total													1.36
Total													1.21

Overall, the gross demand estimates are 20 percent higher than the ex ante values, as presented in Exhibit 4-9. This is primarily the result of the ex post components of each applicable summer on-peak operating factor, the lighting system operating schedule and the open-period operating factors (as determined by field inspections). Evaluation estimates for operating factor are generally higher than the typical ex ante CDF of 0.67). In addition, the evaluation estimates include an HVAC interaction component, which was not accounted for in the ex ante values. For additional detail surrounding these engineering components of impact, refer to Appendix B.

Some of the results presented in Exhibit 4-9 can be explained using information from review of the ex ante estimates and the evaluation engineering analyses. Specific comments and justifications for the results are as follows:

Compact Fluorescents - The slightly lower-than-average realization rates are due to lower operating factors observed for this technology during field inspections. These operating factors partly offset the added impact attributed to the ex post HVAC interactive impact effects.

Halogen - As previously discussed, the high realization rate for halogen technologies results from ex ante estimates for this technology, which are based on an assumed average lamp life of less than one year (depending on business type full load operating hours). Ex ante estimates assume the replacement of each lamp with a standard technology at the end of the original lamp life. Because this assumption was not observed during on-site evaluation activities, the ex post estimates are substantially larger than the ex ante values.

Retail, Office - The high realization rate for the retail and office business types is due to high open-period operating factors (as observed during on-site inspections), and high diversity factors (high percentage of facilities open during the peak hour). In addition, the HVAC interactive effect represents an additional 20 percent or so in net impact.

Schools - The low realization rate is a result of low diversity factor for schools (a high percentage of schools are closed during the summer peak hour).

Community Service - Like schools, these organizations have relatively low open-period operating factors during the summer peak hour (particularly for compact fluorescent technologies) and are also more likely than other business types to be closed during the summer weekday peak hour.

Controls - The estimated impacts for controls are low because the ex ante assumptions regarding the relationship between energy and coincident demand impacts were not confirmed. As a result, energy impacts were evenly distributed throughout the year, leading to a relatively lower peak demand impact than that contained in the MDSS. Interestingly, the opposite was found to be true within the Customized Incentives program, where ex ante values for controls related technologies were found to contribute less impact during the peak hour than ex post estimates (using the same "even" distribution of ex post energy impacts).

4.4.3 Net Realization Rates

The difference between the gross and net realization rates is substantial. This is because of the differences between the ex ante and the ex post NTG adjustments. The ex ante estimate was 0.77 for RE measures and 0.75 for Customized Incentives measures. As can be seen from Exhibit 4-4 above, the NTG estimates vary between 0.65 and 1.05, depending on the technology, resulting in an overall NTG of 0.97 for energy and 0.98 for demand.

The net energy realization rates by segment are presented in Exhibit 4-10 and the net demand realization rates in Exhibit 4-11. These values represent, by segment, the ratio of net impact evaluation findings to the net ex ante program design estimates. The realization rates illustrate how well the ex ante estimates predict savings, after taking into account customers' actions within the lighting market.

Overall, given the difference between the ex ante and ex post NTG adjustment factors discussed above, and the high gross realization rates for the dominant office segment discussed earlier, it is not surprising that the net realization rate for the program as a whole is greater than 1.0. Additionally, even though the NTG ratio for the Customized Incentives program was 0.78, this was somewhat higher than the ex ante estimate, resulting in a minor increase from the gross to the net realization rate for the Customized Incentives program.

Many of the results presented in Exhibit 4-10 and 4-11 can be explained using information from the review of the ex ante estimates and the evaluation engineering and billing regression analyses, as discussed under the review of the gross realization rates. Most of the comments discussed in relation to the gross realization rate estimates apply to the net realization rates. Since the same NTG ratio was applied to the energy and demand impacts, the comments and justifications for the net realization rates discussed below apply to both Exhibit 4-10 and 4-11.

Exhibit 4-10
Net Energy Impact Realization Rates
By Business Type and Technology Group
For Commercial Indoor Lighting Applications

Business Type / Program and Technology Group	Net Energy Impact Realization Rates												
	Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Service	Community Service	Misc.	Total
Retrofit Express Program													
Compact Fluorescent	1.47	0.93	0.85	0.88	0.69	0.60	0.68	1.11	0.63	0.70	0.41	0.77	0.96
Incandescent to Fluorescent	1.69	0.97	1.11	1.01	----	0.96	0.95	1.46	0.84	----	0.71	0.88	1.10
Efficient Ballast	1.51	1.04	0.99	0.83	0.66	0.95	0.95	1.45	0.87	0.76	0.63	0.96	0.95
T8 Lamps and Electronic Ballasts	1.75	1.00	1.13	1.04	0.67	0.95	0.99	1.33	0.83	0.93	0.68	0.97	1.19
Optical Reflectors w/ Fluor. Delamp	1.78	1.01	1.16	1.06	0.70	0.96	1.00	1.53	0.89	0.97	0.70	0.99	1.36
High Intensity Discharge	1.55	1.37	0.97	0.00	1.05	1.55	1.47	2.02	0.00	1.25	1.03	1.34	0.94
Halogen	1.97	3.73	2.20	0.93	5.74	4.12	2.49	3.64	1.91	2.11	1.86	2.14	2.67
Exit Signs	1.68	1.69	1.52	1.62	1.71	1.69	1.66	1.64	1.55	1.53	1.70	1.57	1.66
Controls	1.92	1.93	1.78	1.86	1.95	1.94	1.90	1.87	1.78	1.76	1.92	1.80	1.89
Retrofit Express Total	1.75	1.07	1.14	1.06	0.70	0.97	1.03	1.24	0.44	1.02	0.80	1.17	1.22
Customized Incentives Program													
Compact Fluorescent													
Standard Fluorescent													
High Intensity Discharge													
Halogen													
Exit Signs													
Controls													
Other													
Customized Incentives Total													0.51
Total													1.17

T-8 Fluorescents, Electronic Ballasts, and Delamping - The NTG ratio of more than 1.0 for these technologies helps account for the relatively high overall net impact realization rate for the program. Particularly for demand, the positive NTG combines with the HVAC interactive effect and the higher operating factor to create net demand impact realization rates of more than 1.5 for these technologies.

Halogen - The high realization rates for halogen technologies are driven by the gross impact results—notably the correction for the ex ante assumption of a very short measure life.

Controls - Although the ex post NTG ratio for controls is greater than the ex ante assumption, the net demand impact realization rate is less than one for this measure. The higher ex post NTG does not offset the low gross demand impact realization rate for this measure. As a result, only controls have a net demand realization rate of less than 1.0.

Exhibit 4-11
Net Demand Impact Realization Rates
By Business Type and Technology Group
For Commercial Indoor Lighting Applications

Business Type / Program and Technology Group	Commercial Sector Net RR												
	Office	**Retail**	**College/Univ**	**School**	**Grocery**	**Restaurant**	**Health Care**	**Hotel/Motel**	**Warehouse**	**Personal Service**	**Community Service**	**Misc.**	**Total**
Retrofit Express Program													
Compact Fluorescent	1.68	1.93	1.25	0.72	1.75	1.00	1.09	1.32	1.26	1.19	0.64	1.30	1.23
Incandescent to Fluorescent	1.95	1.97	1.64	0.82	----	1.66	1.64	1.71	1.72	---	1.25	1.75	1.50
Efficient Ballast	1.73	2.09	1.45	0.67	1.61	1.66	1.63	1.66	1.70	1.33	1.02	1.60	1.54
T8 Lamps and Electronic Ballasts	2.01	2.01	1.66	0.84	1.69	1.66	1.71	1.72	1.67	1.64	1.15	1.72	1.63
Optical Reflectors w/ Fluor. Delamp	2.04	2.07	1.73	0.86	1.74	1.69	1.75	1.79	1.82	1.64	1.20	1.76	1.77
High Intensity Discharge	1.44	1.50	0.78	0.61	1.42	1.41	1.39	1.27	1.40	1.16	0.95	1.22	1.25
Halogen	1.49	2.51	1.41	0.54	3.30	2.33	1.72	1.61	1.49	1.43	1.30	1.44	1.68
Exit Signs	1.45	1.44	1.24	1.36	1.49	1.46	1.44	1.40	1.26	1.25	1.48	1.29	1.42
Controls	0.70	0.76	0.63	0.65	1.23	1.08	0.71	0.74	0.68	0.60	0.74	0.75	0.69
Retrofit Express Total	1.89	1.96	1.48	0.81	1.69	1.53	1.53	1.40	1.51	1.50	1.05	1.43	1.54
Customized Incentives Program													
Compact Fluorescent													
Standard Fluorescent													
High Intensity Discharge													
Halogen													
Exit Signs													
Controls													
Other													
Customized Incentives Total													1.42
Total													1.54

4.5 OVERVIEW OF REALIZATION RATES

Overall, the net energy and demand impacts are higher than predicted by the ex ante impact estimates. The net ex post impacts exceed the net ex ante design estimates by 17 percent for energy and 55 percent for demand. To a certain extent, these results reflect the high gross realization rates, but they are really driven by the ex ante and ex post net-to-gross (NTG) ratios. The NTG adjustments apply equally to energy and demand impacts, since they represent behavioral effects regarding the decision to purchase energy-efficient equipment. However, these high realization rates are well documented and supportable based on the information developed during the evaluation. The ex post estimates are higher than the ex ante values for the following reasons:

Ex Post vs. Ex Ante NTG Adjustments -- The ex ante NTG ratio was just 0.77 for the RE program and 0.75 for the Customized Incentives Program, while the ex post NTG ratio for all indoor lighting measures averaged 0.97. When compared to the ex ante NTG assumption, this results in an average 20 percent increase in realized savings, and therefore net realization rates that are consistently higher than gross realization rates.

Discrete Choice NTG Adjustments -- High NTG rates detected in the discrete choice NTG analysis for high-participation measures help account for the generally high net realization rates.

For example, the combined NTG adjustment (free-ridership and spillover) of 1.05 was applied to the RE Programs' primary fluorescent retrofits. These retrofits alone make up 67 percent of the gross indoor lighting end-use energy impacts and 71 percent of demand.

Conservative Ex Ante Estimates -- The high overall savings estimates reflect not only the high NTG ratios, but the conservative ex ante design estimates. The high operating factors that the evaluation identified in the commercial sector, and the inclusion of HVAC savings in the ex post evaluation impacts, also contributed to the high net demand savings. The evaluation field data collection established generally higher operating factors and longer operating hours than were assumed in the ex ante estimates.

Billing Regression Results -- The billing regression analysis established solid (0.68 to 1.00) SAE coefficients (billing regression estimate divided by the evaluation engineering estimates) for the highest participation segments.

Ex Post Spillover -- The NTG adjustment resulted in a mean estimate 21 percent higher than the conservative estimates used in the ex ante values. And yet the ex post NTG can be considered conservative since the majority of the technology segments did not have spillover applied (only the standard fluorescent measures had spillover applied).

In summary, PG&E's ex ante estimate of energy savings was 15 percent below the ex post estimate of net energy savings, and the ex ante estimate of demand savings was 35 percent below the ex post estimate of net demand.

Exhibit 4-12 summarizes all of the gross and net energy, demand and therm impacts discussed above. Results are also presented for the net to gross adjustments and the realization rates.

Exhibit 4-12
Commercial Indoor Lighting Impact Summary
By Technology Group

Business Type / Program and Technology Group	Gross Program Impact			NTG Adjustment		Net Program Impact		
	kWh	kW	Therm(1	FR)	Spillover	kWh	kW	Therm
EX ANTE								
Retrofit Express Program								
Compact Fluorescent	12,179,480	2,142	-	0.67	0.10	9,378,199	1,650	-
Incandescent to Fluorescent	1,246,825	235	-	0.67	0.10	960,055	181	-
Efficient Ballast	959,932	158	-	0.67	0.10	739,148	122	-
T8 Lamps and Electronic Ballasts	65,641,070	12,119	-	0.67	0.10	50,543,623	9,331	-
Optical Reflectors w/ Fluor. Delamp	33,529,753	6,329	-	0.67	0.10	25,817,909	4,874	-
High Intensity Discharge	16,318,498	2,840	-	0.67	0.10	12,565,243	2,187	-
Halogen	829,302	195	-	0.67	0.10	638,563	150	-
Exit Signs	2,522,894	288	-	0.67	0.10	1,942,628	222	-
Controls	4,842,039	1,179	-	0.67	0.10	3,728,370	908	-
Retrofit Express Total	138,069,793	25,486	-	0.67	0.10	106,313,738	19,624	-
Customized Incentives Program								
Compact Fluorescent	-	-	-	-	-	-	-	-
Standard Fluorescent	-	-	-	-	-	-	-	-
High Intensity Discharge	-	-	-	-	-	-	-	-
Halogen	-	-	-	-	-	-	-	-
Exit Signs	-	-	-	-	-	-	-	-
Controls	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-
Customized Incentives Total	10,772,306	1,168	-	0.65	0.10	8,079,230	876	-
Total	148,842,099	26,654	-	0.67	0.10	114,392,967	20,501	-
EX POST								
Retrofit Express Program								
Compact Fluorescent	10,288,224	2,320	-2,075	0.88	0.00	9,012,484	2,032	-1,818
Incandescent to Fluorescent	1,052,576	271	-230	1.00	0.00	1,052,576	271	-230
Efficient Ballast	673,349	179	-207	0.90	0.14	703,924	187	-216
T8 Lamps and Electronic Ballasts	57,722,919	14,552	-18,502	0.90	0.14	60,343,971	15,213	-19,343
Optical Reflectors w/ Fluor. Delamp	33,523,294	8,244	-10,906	0.90	0.14	35,045,503	8,618	-11,401
High Intensity Discharge	16,071,876	3,732	-3,168	0.73	0.00	11,764,613	2,732	-2,319
Halogen	2,624,127	388	-426	0.65	0.00	1,703,058	252	-276
Exit Signs	3,477,212	339	-695	0.93	0.00	3,216,421	314	-643
Controls	7,327,131	655	-1,331	0.96	0.00	7,048,700	630	-1,281
Retrofit Express Total	132,760,708	30,682	-37,540	0.88	0.10	129,891,251	30,251	-37,526
Customized Incentives Program								
Compact Fluorescent	43,505	18	-25	0.78	0.00	34,065	14	-20
Standard Fluorescent	1,706,703	627	-454	0.78	0.00	1,336,349	491	-356
High Intensity Discharge	547,074	217	-94	0.78	0.00	428,359	170	-74
Halogen	1,379	1	-1	0.78	0.00	1,080	0	-1
Exit Signs	4,471	1	-3	0 78	0.00	3,501	1	-2
Controls	2,380,843	584	-520	0.78	0.00	1,864,200	458	-407
Other	561,813	136	-174	0.78	0.00	439,900	106	-136
Customized Incentives Total	5,245,788	1,585	-1,272	0.78	0.00	4,107,452	1,241	-996
Total	138,006,496	32,267	-38,812	0.88	0.09	133,998,703	31,492	-38,522
REALIZATION RATES								
Retrofit Express Program								
Compact Fluorescent	0.84	1.08	-	-	-	0.96	1.23	-
Incandescent to Fluorescent	0.84	1.15	-	-	-	1.10	1.50	-
Efficient Ballast	0.70	1.13	-	-	-	0.95	1.54	-
T8 Lamps and Electronic Ballasts	0.88	1.20	-	-	-	1.19	1.63	-
Optical Reflectors w/ Fluor. Delamp	1.00	1 30	-	-	-	1.36	1.77	-
High Intensity Discharge0.98		1.31	-	-	-	0.94	1.25	-
Halogen	3.16	1.99	-	-	-	2 67	1.68	-
Exit Signs	1.38	1.18	-	-	-	1.66	1.42	-
Controls	1.51	0.56	-	-	-	1.89	0.69	-
Retrofit Express Total	0.96	1.20	-	-	-	1.22	1.54	-
Customized Incentives Program								
Compact Fluorescent	-	-	-	-	-	-	-	-
Standard Fluorescent	-	-	-	-	-	-	-	-
High Intensity Discharge	-	-	-	-	-	-	-	-
Halogen	-	-	-	-	-	-	-	-
Exit Signs	-	-	-	-	-	-	-	-
Controls	-	-	-	-	-	-	-	-
Other	-	-	-	-	-	-	-	-
Customized Incentives Total	0.49	1.36	-	-	-	0.51	1.42	-
Total	0.93	1.21	-	-	-	1.17	1.54	-

5. RECOMMENDATIONS

Recommendations that would enhance future program performance and evaluation are presented in this section. Recommendations regarding evaluation methods are followed by those affecting the program's design.

5.1 EVALUATION METHODS

The evaluation team offers the following comments and recommendations regarding methods used in the 1995 evaluation:

Calculation of Ex Ante Impacts - As part of the 1995 Lighting Evaluation, an attempt was made to reproduce the Retrofit Express Program impacts found in the MDSS. This resulted in several observations where ex ante impact methods were misapplied. Such errors could probably be avoided in the future with a regular and thorough review of the MDSS contents by the program manager or a qualified analyst. MDSS staff who currently review the MDSS records may not be trained in the technology-specific details that are essential to conducting meaningful quality checks.

Recording of Removed Lighting System Data - Ex ante impact estimates are calculated based on the assumption that a single type of removed fixture replaces each measure installed. We recommend that PG&E record the type of fixture removed for each program installation. This would enable a far more accurate assessment of program impacts, in particular enhancing future billing analysis results.

Application of Heating Penalty for HVAC Interactive Effects - Although PG&E has integrated the 1994 Lighting Evaluation results into the Advice Filing (ex ante) methods for the 1997 RE program, some modifications are recommended based upon the evaluation results presented in this report. Specifically, the 1997 RE program methods use evaluation results for annual fixture operating hours, peak hour coincident diversity factors, and HVAC interactive energy effects. For the latter, the 1997 program applies an additional nine percent energy savings due to the combined effect of the cooling benefits and heating penalties (for both electric and gas heat). Based on the results in this report, PG&E now has the ability to account for the gas heating penalty separately from the electric cooling benefits and electric heating penalty. It is therefore recommended that the full electric benefits be accounted for exclusive of gas heating, and that the gas penalty be applied separately, thereby affecting the appropriate gas fuel.

Trade on Established Information in Future Evaluations - This evaluation developed extensive observed and measured operating factor and operating hours information on the highest participation segments, in order to obtain the best estimates of savings for the largest contributors to savings. Less robust information was developed on medium- and low- participation segments. There is no reason to believe that the operating factor and operating hours information developed in this evaluation will change from year to year. It is recommended that PG&E develop an understanding with the CPUC on the validity and use of this information in subsequent evaluations. This would allow the resources used in subsequent evaluations to be dedicated to the medium- and low- participation segments.

Alternatively, resources could be used to assess other parameters; for example, a baseline market transformation study could be conducted both within the PG&E service territory and within a control group service territory. By comparing the baseline fixture retrofit in PG&E service territory against the baseline given no demand side management (DSM) infrastructure, market transformation due to PG&E programs could be measured.

5.2 *MEASURES OFFERED*

The exhibits in *Section 4* allow identification of technologies or building types that should be reassessed in terms of their viability. This does not imply that these technologies are not valuable, but rather that the original estimate of design savings was higher than that actually achieved. The following segments should be reviewed for viability as part of the overall assessment.

Schools showed relatively low realization rates on both a gross and net basis for most technologies, and were the only business segment with a net demand realization rate below 1.0. The evaluation demand impacts were low because the operating factors for the school business type were substantially below those anticipated (when compared with ex ante impact methods). That is, many schools do not operate during several summer months (months coincident with the summer peak period), and are less likely to be air conditioned than other commercial buildings. However, excluding schools from participation in PG&E's programs is probably not a viable proposal.

Warehouses and community service organizations all had net energy impact realization rates well below the average. As with schools, the operating factors for these building types were generally low, especially for T-8s and electronic ballasts, which accounted for the majority of fixtures installed in these business types.

Controls had a low net demand impact realization rate due to the evaluation assumption that connected load impacts for this measure could not be predicted with any certainty for a specific time. Energy impacts were therefore evenly distributed across the year. Future evaluations efforts should be used to assess both a measured impact level and the allocation of impacts by time period.

Additional explanations are offered for other technologies or building segments with low realization rates in *Section 4.*