Customer Energy Efficiency Program
Measurement and Evaluation Program

IMPACT EVALUATION OF PACIFIC GAS & ELECTRIC COMPANY'S 1996 COMMERCIAL ENERGY EFFICIENCY INCENTIVES PROGRAM: HVAC TECHNOLOGIES

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1. EXECUTIVE SUMMARY

This section presents a summary of the impact results for Heating, Ventilating, and Air-Conditioning (HVAC) technologies offered under the Pacific Gas & Electric Company's (PG&E's) 1996 Commercial Energy Efficiency Incentive (CEEI) Programs, referred to in this report as the HVAC Program. This evaluation covers HVAC technology retrofits that were performed at PG&E customer facilities, for all rebates paid in 1996. These retrofits were performed under five different PG&E programs: the Retrofit Express (RE), the Retrofit Efficiency Options (REO), the Customized Incentives (CI), the Advanced Performance Options (APO) and Thermal Energy Storage (TES) 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, demand and therm savings results (ex post and ex ante), together with each applicable gross realization rate. The net-to-gross ratio is comprised of free ridership, and participant and nonparticipant spillover effects.

Exhibit 1-1
Summary of Gross Evaluation Results
for Commercial HVAC Applications

	Gross Savings	Gross Realization Rate	Net-To-Gross 1-FR	Net-To-Gross Spillover	Net-To-Gross NTG Ratio	Net Savings	Net Realization Rate
EX ANTE							
kW	5,736	-	0.59	0.10	0.69	3,954	-
kWh	26,608,318	-	0.60	0.10	0.70	18,666,929	-
Therms	1,334,684	-	0.65	0.10	0.75	999,248	-
EX POST							
kW	6,593	1.15	0.45	0.17	0.62	4,059	1.03
kWh	35,479,520	1.33	0.37	0.17	0.54	19,149,445	1.03
Therms	1,136,403	0.85	0.75	0.17	0.92	1,040,531	1.04

Overall, the ex post net impacts are relatively consistent with the predicted ex ante impact estimates, differing by only a few percent. Although the ex post gross impacts exceed ex ante by 33 percent for energy and 15 percent for demand, the lower ex post NTG ratios have brought the overall ex post net impacts in line with ex ante.

The ex ante numbers presented above in Exhibit 1-1 were obtained from PG&E's Marketing Decision Support System (MDSS), PG&E's program 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.

These ex post results illustrate the following key points about the gross and net commercial HVAC impacts:

Program Accomplishments: More than half of program energy savings are from HVAC technologies installed through the Retrofit Express program. All of the program therm savings are from HVAC technologies installed through the Customized Incentives program, which historically has also contributed significant impacts to the overall HVAC Program energy savings. This shift in program composition is the direct result of the removal of the CI program from PG&E's portfolio of DSM programs.

Gross Impacts: Overall ex post gross impacts were 33 percent larger than the ex ante estimates for energy, and 15 percent larger for demand. Higher-than-predicted impacts were observed in several key technologies, including Adjustable Speed Drive (ASD) HVAC fan motors. These findings are based on a calibrated engineering model for ASD measures. No Statistically Adjusted Engineering (SAE) coefficient is applied to this technology group, as the results from the billing regression model indicated significantly higher ASD estimates, and the evaluation team chose the more conservative result. Consequently, the protocol compliant calibrated engineering results are accepted as the final ex post value.

Evaluation of therm impacts was limited to the Customized Incentives program. The ex post gross therm impacts were 15 percent lower than the ex ante estimates.

Net Impacts: The net ex post impacts exceed the net ex ante estimates by 3 percent for energy and demand, and 4 percent for therms. To a certain extent, these results reflect the higher gross realization rates for energy and demand, but they are also driven by the ex ante and ex post net-to-gross (NTG) ratios. The ex ante NTG ratio was 0.67 for both demand and energy, while the ex post NTG ratio applied was lower: 54 percent for energy and 62 percent for demand. These lower estimates significantly reduce the net program effects. The NTG ratio for therms was significantly higher (85 percent, as opposed to the ex ante estimate of 75 percent), and increased the net program effects accordingly.

1.2 MAJOR FINDINGS

The key findings are summarized as follows:

- Overall, PG&E's ex ante estimates for the commercial HVAC technologies paid under the 1996 programs were conservative, resulting in net realization rates exceeding one.

- Gross ex post demand and energy impacts where significantly higher than the ex ante estimates. The high participation technologies of Adjustable Speed Drives, Reflective Window Film, and Water Chillers yielded large realized savings and drove the higher realization rate.

- Lower NTG ratios, combined with higher gross ex post values, adjusted the net realized savings to within 3 percent of their ex ante estimates.

1.3 MAJOR RECOMMENDATIONS

Application Engineering Review is a necessary component of the submittal process, and can be used to effectively screen applications that have significant analysis errors. In some instances, large errors were observed in the Customized Incentives applications submitted, resulting in inaccurate reporting of project impacts. Since applications submitted for the Customized Incentives program (or other current programs like Advanced Performance Options) can result in relatively large incentives, it is recommended that a more intensive application review be used to capture these anomalies.

Demand Impact information for ASD Measures suggests that the ex ante estimates are too low. Future evaluation activities should include the collection of additional End-Use Metering (EUM) data for these technologies, provided they continue to be a major component of the HVAC Program.

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) Commercial Energy Efficiency Incentive (CEEI) Program for HVAC technologies (the HVAC Evaluation). These technologies are covered by five separate program options, the Retrofit Express (RE) Program, the Retrofit Efficiency Options (REO) Program, the Customized Incentives (CI) Program, the Advanced Performance Options (APO) Program, and the Thermal Energy Storage (TES) Program. The latter two programs each comprised only one paid application each. The three programs (RE, REO, and CI) that contribute most to total program impacts, 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, and food service. Customers were required to submit proof of purchase with these applications in order to receive rebates. The program was marketed to small- and medium-sized commercial, industrial, and agricultural (CIA) customers. The maximum rebate amount, including all measure types, was $300,000 per account. No minimum amount was required to qualify for a rebate.

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

Technology
High-efficiency central air-conditioning units in various capacity ranges
Variable speed drive HVAC fans
High-efficiency package terminal air-conditioning units
Programmable thermostats, bypass timers, and electronic timeclocks
Reflective window film
Water chillers of various capacity ranges
Direct evaporative cooler units, evaporative condensers, and evaporative cooler towers

2.2 THE RETROFIT EFFICIENCY OPTIONS PROGRAM

The REO program included nine HVAC technologies, that can be summarized into four general technology groups, described below:

Technology
Variable frequency drive supply fans
Installation of high efficiency water chillers
Variable air volume supply systems, which replace constant air volume supply systems
Evaporative cooling towers

The REO program targeted commercial, industrial, agricultural, and multi-family market segments most likely to benefit from these selected measures. Customers were required to submit calculations for the projected first-year energy savings along with their application prior to installation of the high efficiency equipment. PG&E representatives worked with customers to identify cost-effective improvements, with special emphasis on operational and maintenance measures at the customers' facilities. Marketing efforts were coordinated amongst PG&E's divisions, emphasizing local planning areas with high marginal electric costs to maximum the program's benefits.

2.3 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 Customized Incentives program in 1995 or 1996. Due to the significant documentation and analysis involved in Customized Incentives program measures, however, rebates for a number of 1992, 1993, and 1994 measures were delayed for payment until 1996. All equipment applied for under the program must have been installed and in operation by November 30, 1995. This evaluation covers those measures where rebates were paid in 1996. A total of 94 Customized Incentives HVAC Program participants were paid rebates in 1996.

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. The following technologies were analyzed as part of the evaluation:

Technology
HVAC variable speed drive
High efficiency chiller
Energy Management Systems (EMS)
Other miscellaneous Customized Incentives HVAC measures, which included:

- Installation of various energy efficient motors
- Installation of various HVAC controls
- Various technologies (i.e., precoolers and economizers) added to increase overall system efficiency

2.4 EVALUATION OVERVIEW

The impact evaluation described in this report covers all HVAC technologies installed at commercial accounts, as determined by the Marketing Decision Support System (MDSS) sector code, that were included under the RE, REO, Customized Incentives, APO, and TES programs and for which rebates were *paid* during calendar year 1996.

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

2.4.1 Objectives

The research objectives are as follows:

- Determine first-year gross energy, demand, and therm impacts by business type and technology group for RE, REO, Customized Incentives, APO, and TES HVAC technologies paid in 1996, 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, REO, Customized Incentives, APO, and TES HVAC technologies paid in 1996, and overall impacts for the commercial sector as required by the CPUC Protocols.

- Compare evaluation results (ex post) 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 ex post and ex ante estimates.

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

- Complete tables 6 and 7 of the Protocols.

Results are segmented by technology and building type. Technologies are defined by measures offered by the RE, REO, Customized Incentives, APO, and TES programs. Building types for the commercial market sector, as defined by PG&E, are:

Office	Health Care
Retail	Hotel/Motel
College and University	Warehouse
Schools	Personal Service
Grocery	Community Service
Restaurant	Miscellaneous

While gross impacts account for program participant actions, net impacts account for customer participation choices and the effect that the HVAC Programs' infrastructure has had on the HVAC retrofit market. For example, adjustments were made to the gross savings estimates to account for customers that would have installed energy-efficient measures in the absence of the program (**free-riders**). The adjustment also included participant and nonparticipant **spillover** rates, defined as energy-efficient measures installed outside the program (and as a result of the presence of the program).

The evaluation investigated and, where possible, explains differences between ex ante estimates and ex post results.

2.4.2 Timing

The 1996 HVAC Evaluation began in June 1997, completed the planning stage in July 1997, executed data collection between mid-July and early November 1997, and completed the analysis and reporting phase in February 1998.

2.4.3 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.

2.5 EVALUATION APPROACH – AN OVERVIEW

This overview of the integrated evaluation approach begins by presenting the data sources used for the HVAC 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.

2.5.1 Data Sources

The HVAC Evaluation used data supplied by PG&E to develop a 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 HVAC Program. Of particular importance were PG&E's historical billing data, program participant data from the Marketing Decision Support System (MDSS), paper copies of RE, REO, Customized Incentives, APO, and TES applications, and other program-related data. 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.

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[1] California Public Utilities Commission Decision 93-05-063, Revised January 1997 Pursuant to Decisions 94-05-063, 94-10-059, 94-12-021, 95-12-054, and 96-12-079.

PG&E 1996 Customer Energy Efficiency Programs Advice Filing[2] **-** 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, operating factors, baseline SEER and EER estimates, and other program related calculations. This document supplies the best information available on ex ante estimates and assumptions, thus facilitating knowledge-based comparisons to ex post estimates derived in this study.

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. For all applicable measures, Title 24 standards were used to define baseline efficiencies.

Copies of RE, REO, Customized Incentives, APO, and TES Paper Application Files **-** QC requested and received complete copies of application files for a random 50 RE participants and all REO, Customized Incentives, APO, and TES 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 REO applications provided additional information not found in the MDSS, predominantly on attachment equipment invoices (such as horsepower, and SEER ratings). The Customized Incentives (CI) files provided detailed information on how the application estimate was computed. For premises recruited for on-site audits, these applications provided the QC engineer with enough information to determine what additional information was needed to be collected. The remaining (not visited) CI files had enough information in the documentation to support an engineering review of the impact calculations. A thorough assessment of each CI application was conducted, and unadjusted engineering estimates of impact and savings were calculated for each CI participant.

1994-1995 Commercial HVAC Results. Equivalent full load hours from the 1995 Commercial HVAC Evaluation were applied to the participant population during the course of the engineering analysis.

Primary Data Collected

Based on an assessment of existing data, program evaluation requirements were established for additional data to be collected. The three primary areas of data collection included End-Use Metering, On-Site Audits, and Telephone Survey data. A brief description of each follows:

End-Use Metering. Any HVAC retrofit that included an Adjustable Speed Drive (ASD) was targeted for end-use metering. Within that population, specific business types (offices and groceries) were identified as segments that could significantly contribute to a calibrated engineering model. A total of 15 sites were recruited and meters installed for a period of 3 months. This data was used in the engineering analysis for the ASD technology segment ex post energy and demand impact and savings calculations.

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[2] "1996 Air Conditioning Retrofit Express Program; Advice Filing 1921-G/1540-E, October 1995.

On-Site Audits. A total of 228 customer sites were visited by a QC engineer to gather site-specific data used in support of the engineering and survival analyses, as well as to create the retention panels to be used in subsequent evaluations. The on-site visit included a customer interview and an equipment/facilities audit. Only data required for this PG&E study was collected. This sample contributes equipment details that are site-specific, and better estimates of operating hours, operating factors, equipment efficiency, 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

Telephone Survey Data. A significantly larger telephone survey sample was collected. A total of 350 participant, 462 nonparticipant, and 3,796 canvass surveys were completed to gather customer profiles used in all of the analyses. Due to the limited size of the HVAC population, a census was attempted, and 350 sample points collected, gathering information on the rebated installations, other changes at the facilities (during the analysis period), and factors that influenced program participation. The nonparticipant survey was similar to the participant survey, and served as a control group in the SAE analysis. The canvass survey was used in support of the net-to-gross analysis.

2.5.2 Analysis Elements

This sub-section describes the general approach used to estimate both the gross and net demand and energy impacts for the Commercial HVAC Evaluation. The application and program design data are used to create a data collection plan, which in turn guides the evaluation data collection efforts. The sample design, engineering analysis, billing analysis, and net-to-gross analysis are all described in greater detail in *Section 3, Methodology*.

The analysis approach illustrated in Exhibit 2-1 consists of three primary analysis components: the **engineering analysis**, the **billing analysis**, and the **net-to-gross analysis**. This integrated approach reduces a complicated problem into manageable components, while incorporating the comparative advantages of each method. This approach describes per-unit net impacts as:

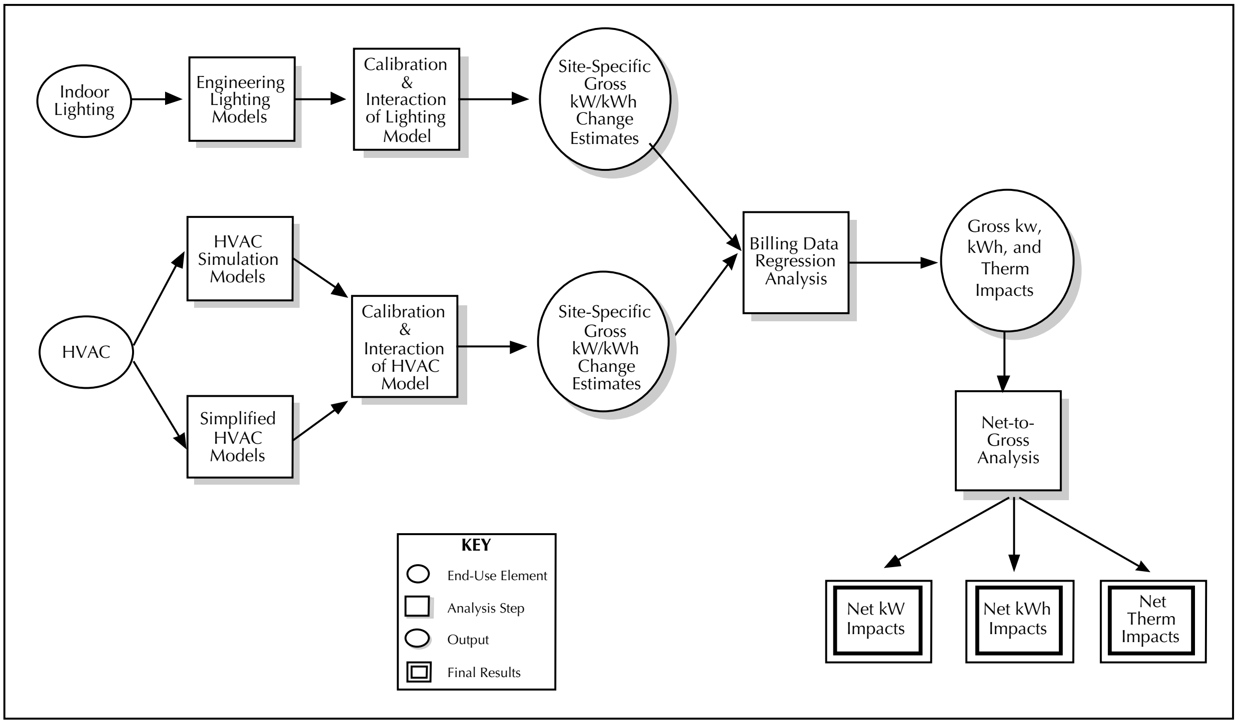
Net Impact = (Operating Impact) * (Operating Factor) * (SAE Coefficient) * (Net-to-Gross)

Where,

Operating impact is defined as the load impact coincident with a specific hour, given that the equipment is operating. The engineering analysis will simulate equipment performance independent of premise size and customer behavioral factors to obtain operating impacts.

Operating factor is defined as the fraction of premises with equipment operating during the analysis period. This term reflects the equipment's operating schedule, and will be estimated at a high level of precision using metered data in conjunction with on-site audit and telephone survey results.

Exhibit 2-1
Overall Impact Analysis Approach



The Statistically Adjusted Engineering (SAE) Coefficient will be estimated for those cases in which an engineering model estimate is not used as the final result. This term is defined as the percentage of savings estimate that is detected, or realized, in the statistical analysis of actual changes in energy usage. The SAE coefficient is applied to an impact estimate based upon the program baseline, equipment purchased under the program, and typical weather.

The Net-to-Gross (NTG) Ratio adjusts the program baseline derived from estimates of free ridership and spillover associated with the program.

Engineering Analysis

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. Gross impacts were developed for CAC technologies using calibrated DOE-2.1E simulations. These simulations were carried out for Office, Grocery, and Retail business types; and then leveraged to additional business types using telephone survey data and MDSS information. A similar methodology was developed for Adjustable Speed Drive (ASD) technologies using End-Use Metered (EUM) data. Ideally, estimates for all business types and measures would be generated based on calibrated models (either DOE-2.1E or EUM), given sufficient resources (and sample sizes). In this evaluation, the optimal solution was to leverage the models for business types with sufficient participation to all other business types, and then adjust the results with the SAE analysis. The engineering methods used are described in greater detail in *Section 3.2*.

Site specific engineering impact estimates were generated for 102 selected premises. The results of these analyses are provided in *Attachment 1, Custom HVAC Analysis*. Included in the attachments are, for each facility visited, an on-site summary and resulting impact estimate. The detailed engineering calculations to determine impact and savings are also provided.

For all other measures, such as Reflective Window Film and Evaporative Coolers, the algorithms used to generate the ex ante estimates were extensively reviewed and modified to include new and more accurate information. A complete evaluation of these algorithms and the associated adjusted algorithms are included in *Attachment 2, HVAC Algorithm Review*. These modified algorithms were then applied to the MDSS participants to produce site-specific estimates of impact and savings.

Gross demand estimates are based solely upon unadjusted hourly engineering estimates. Whenever possible, engineering demand estimates were developed using EUM or site survey data in conjunction with the methods used for the gross energy 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.

Billing Analysis

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 output of the analysis are SAE-adjusted estimates of gross and net program energy savings.

Net-to-Gross Analysis

The NTG analysis is designed to adjust gross program impacts for free ridership and the actions taken by PG&E customers outside the HVAC 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. In addition, self-reported data are used to calculate the percent of participant and nonparticipant spillover attributed to the program.

A more sophisticated estimate of NTG for selected high-participation measures was developed through the application of discrete choice analysis. The discrete choice model estimates the probability that a customer will purchase a particular energy efficient HVAC measure, both with and without the incentive program in place. The results of the discrete choice model are also estimates of free-ridership and spillover, independent of those found through the self report method. Because the discrete choice model requires a sufficient sample size of nonparticipant adopted, only CAC and evaporative cooler technologies yielded significant results. The remaining estimates of net were based on the self-report model.

Application of the final NTG adjustments, by technology, yields total net program impacts. *Section 3, Methodology* describes in explicit detail, each step taken to achieve the final net results, beginning with the sample design, followed by the engineering and SAE analyses, and ending with the Net-to-Gross findings.

2.6 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. *Section 4* presents the detailed results and a discussion of important findings. This section also includes the impacts by Time-of-Use costing periods. *Section 5* presents recommendations for improving the evaluation, the program measures, the program tracking system, and the CPUC Protocols. *Attachment 1* are a collection custom site write-ups on each site reviewed and/or audited by QC engineers. *Attachment 2* are the results of the engineering algorithm review of standard (RE/REO) HVAC measures. *Attachment 3* are the results tables for the gross ex ante, net ex ante, and unadjusted engineering impacts, as well as the SAE coefficients, gross ex post, NTG adjustments, net ex post, and gross and net realization rates. The attachment also contains gross demand and energy savings by costing period for commercial indoor HVAC measures. *Attachment 4* contains the Protocol Tables 6 and 7 for the HVAC end use. The *Survey Appendices* provide the survey and on-site data collection instruments, and the survey call dispositions, frequencies, and refusal comments.

3. METHODOLOGY

This section provides the specifics surrounding the methods used to conduct the 1996 Pacific Gas & Electric Company (PG&E) Commercial Energy Efficiency Incentives (CEEI) Program Evaluation for HVAC Technologies (the HVAC Evaluation). This section begins with a detailed discussion on the sampling plan for the HVAC Evaluation. From there, details regarding the Engineering Analysis (*Section 3.2*), the Billing Analysis (*Section 3.3*), and the Net-to-Gross Analysis (*Section3.4)* are discussed.

3.1 SAMPLE DESIGN

This section presents the sample design for the HVAC Evaluation. An integrated sample design was implemented for the Lighting and HVAC end uses, due to the high number of participant crossover amongst the various end uses. First, the overall sample design approach is discussed, followed by the resulting sample allocation. The section concludes with a discussion of the California Public Utilities Commission (CPUC) Evaluation and Measurement Protocols (the Protocols) requirements.

3.1.1 Existing Data Sources

The participant tracking system for the Retrofit Express (RE), Retrofit Efficiency Options (REO), Customized Incentives (CI), Advanced Performance Options (APO), and Thermal Energy Storage (TES), Programs are maintained as part of PG&E's Marketing Decision Support System (MDSS). Henceforth, the RE program components (excluding Chillers) are referred to as simply Retrofit, with the remaining program components referred to as Custom. The MDSS contains program application, rebate, and technical information regarding installed measures, including measure description, quantities, rebate amount, and ex ante demand, energy, and therm savings estimates. The MDSS extract used in this evaluation is consistent with data used in the PG&E Annual Earning Assessment Proceedings (AEAP) Report.

For the Retrofit and Custom programs, participation was tracked at both an application and measure level. They are linked by application code and program year. Each application can cover multiple measures and accounts, and each measure is linked to a PG&E electrical or gas service location where the measures are supposed to be installed. The account location is designated by its account number, or a unique seven-digit identification number (PG&E's control number). Unlike customer accounts, control numbers are used to identify service locations and serve as stable identifiers for linking datasets.

The billing series requested in support of the HVAC Evaluation cover a period from January 1993 to September 1997. PG&E's billing data contain monthly energy-consumption as well as other customer information, such as customer name, service location, rate schedule, and Standard Industrial Classification (SIC) code.

3.1.2 Sample Design Overview

The objectives of the sample design were to:

- Determine the optimal sample allocation for first-year gross impact analysis, based upon sample size and evaluation accuracy requirements of the Protocols and available project resources.

- Allocate sufficient sample points to meet net-to-gross (NTG) objectives.

- Reallocate available resources, wherever feasible, to focus on measures and/or program features deemed most important by PG&E staff, while not compromising the overall accuracy of the evaluation.

3.1.3 Sample Segmentation

Evaluation of the HVAC Program at the participant segment level allows more precise, and insightful, analyses than those undertaken at the aggregate PG&E system level. The sample segmentation consists of two primary components: participant segmentation and technology segmentation. As will become apparent, a key feature of the sample design is that the sampling unit is a unique customer site. Significant effort was undertaken to aggregate billing and participation records to this level.

The first step in the participant segmentation process grouped firms by business type, as recorded in the MDSS. There are a total of 12 business types used to segment a customer. A total of 29 technology groups were defined (see definition following Exhibit 3-1) to classify measures. Exhibit 3-1 presents the distribution of unique customer sites across the business type and technology group segmentation.

Exhibit 3-1
1996 Commercial HVAC Segmentation and Distribution of Unique Sites

Business Type / Technology		Commercial												
		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Serv.	Comm. Serv.	Misc.	Total
HVAC	Central A/C	192	77	13	62	9	52	61	7	17	42	77	25	633
	Adjustable Speed Drives	25	7	2	0	11	0	2	2	3	1	6	0	59
	Package Terminal A/C	2	1	0	0	1	4	1	45	2	1	0	0	57
	Set-Back Thermostat	83	31	5	29	1	26	20	5	8	22	27	9	265
	Reflective Window Film	100	31	2	4	9	14	22	5	16	14	19	5	241
	Water Chillers	10	3	1	1	0	0	1	0	0	0	4	1	21
	Customized EMS	2	0	1	38	8	0	0	0	0	0	1	1	50
	Customized Controls	0	0	0	0	0	0	1	0	0	0	0	0	1
	Convert to VAV	3	0	0	0	0	0	1	0	0	0	0	0	4
	Other Customized Equipment	0	0	0	0	1	0	1	0	1	0	0	4	7
	Cooling Towers	4	1	0	0	0	0	0	0	0	0	0	0	5
	High Efficiency Gas Boilers	0	0	2	0	0	0	0	0	0	0	0	0	2
	Other HVAC Technologies	2	4	1	0	15	2	0	1	0	0	1	0	26
	VFD Chillers	0	0	0	0	0	0	0	0	0	0	1	0	1
HVAC End Use Total		336	123	18	116	52	73	91	61	40	58	109	37	1,112

Annual energy consumption values were used to group customers into five usage/size strata based upon a Dalenius-Hodges[3] stratification procedure. The comparison group customers are then selected to mirror the underlying distribution of the participant target population by size and business type.

3.1.4 Technology Segmentation

Program measures are classified into technology groups through combining measures with similar energy reduction characteristics. This grouping strengthens the analysis by creating homogenous analysis segments in terms of electricity use. The three elements of the technology segmentation are as follows:

Technology Groups consist of those measures that comprise, in the case of the HVAC end use, those specific measures that are expected to have similar energy saving characteristics. For example, all Central Air Conditioning (CAC) retrofit measures are grouped together under a single CAC Technology Group. The projected energy savings differences will be accounted for in the engineering estimates, yielding similar per-unit estimates.

Measure Group, the second level of segmentation, groups measures by the PG&E program measure description.

Measure, the finest level of segmentation, is the actual measure offered by the PG&E program.

The technology segmentation presented in Exhibit 3-1 above shows the level of segmentation that was performed for this evaluation. While the engineering analysis was conducted at the finest level of segmentation (the measure level), the statistical billing analysis was conducted at a much coarser level (the technology group), or in some cases, at an even higher level of aggregation; such as with the Custom HVAC analysis, that was conducted across program technologies.

3.1.5 Sample Allocation

For the HVAC Evaluation, there were three types of primary data collected: telephone survey data, on-site audit data, and end-use metered data. These data sources formed the basis for the various analyses conducted as part of this evaluation (e.g., billing analysis, free-rider analysis, and spillover analysis). The sample design for each of these primary data sources was developed to meet each of analysis objectives. The following sections describe these objectives and sampling strategies for each of the primary data sources collected.

Participant Telephone Sample

The telephone sample was designed to be used for the engineering, billing and net-to-gross analyses. For each of these analyses, it was necessary for a representative sample of participants to be collected. To allow for more accurate results, a total of 425 HVAC participants was planned, which far exceeded the Protocol requirement of 350. Ultimately, due

[3] Cochran, W.G *Sampling Techniques*, Third Edition, John Wiley & Sons, 1997. pp. 127-134.

to the low numbers of participation with the HVAC end use, a census was conducted and 350 sample points were collected.

Participant On-Site Sample

Because 150 on-sites were planned (50 custom and 100 retrofit), HVAC segmentation was possible for on-site recruitment. Participants were segmented by Technology and Business Type where participation was concentrated. These groups were then further stratified by the analysis class ("**standard**" or "**custom**") based on the technology installed.

Participant EUM Sample

EUM data were collected for premises that were categorized as either an Office or a Grocery building type. These segments were selected because there was sufficient enough participation to contribute to a calibrated engineering model. This sample is not intended to be a random sample, nor strictly proportional to the program-avoided cost. Exhibit 3-2 illustrates the final HVAC segmentation.

Comparison (nonparticipant) Sample

The primary objective of the nonparticipant telephone sample was to provide a control group for the net and gross billing analyses. The final comparison group sample frame consists of 82,400 commercial customers drawn from an eligible population of over 400,000 commercial controls. Since comparison group surveys were conducted only for customers in the commercial sector, the first step in creating the sample frame is to limit eligibility to only those accounts having SIC codes representing commercial business activities. In addition to the aforementioned criteria, the following screening rules were also used:

Presence of a billing rate for the customer: Customers are required to have a rate schedule code for all years spanned by the billing data.

Quality of usage readings: Customers are required to have non-missing, non-zero usage values for at least 7 month of every billing year spanned by the billing data. Customers with mean zero, or missing billing data, were removed from the sample.

Reasonable usage and miscellaneous data across years: Accounts are screened to ensure that the mean usage on the account for 1995 and 1996 is no more than twice (or less than half) the mean usage on the account for 1994 and 1995, respectively. Accounts are also screened to ensure that they have reasonable phone numbers, meter numbers, and division codes. Any accounts with invalid data are rejected from the sample frame.

Exhibit 3-2
Final Participant HVAC Segmentation

	Business Type	# of Avail. Points	Standard On-Site	Custom On-Site	EUM Recruit
Strata 1 (ASDs Without Custom Measure)	Office	21	15	-	15
SEGMENT: EUM & "Standard" on-sites	Retail	7	3	-	-
Goal: 25 On-Site Points, 15 EUM Points	Schools	-	-	-	-
	Other	16	7	-	-
	Total	44	25	-	15
Strata 2 (Chillers)	Office	10	-	5	-
SEGMENT: "Custom" On-Sites	Retail	3	-	1	-
GOAL: 10 "Custom" Points	Schools	1	-	1	-
	Other	7	-	3	-
	Total	21	-	10	-
Strata 3 (Other 'Custom' Sites)	Office	6	-	3	-
SEGMENT: "Custom" On-Sites	Retail	-	-	-	-
GOAL: Census, At least 30 "Custom" Points	Schools	-	-	-	-
	Other	36	-	27	-
	Total	42	-	30	-
Strata 4 (EMS Only Sites)	Office	2	-	1	-
SEGMENT: "Custom" On-Sites	Retail	-	-	-	-
GOAL: 4 Schools, 4 Groceries, 2 Other	Schools	38	-	4	-
NOTE: May be covered by Strata 2 & 3	Other	10	-	5	-
	Total	50	-	10	-
Strata 5 (Remaining HVAC Population)	Office	296	30	-	-
SEGMENT: "Standard" On-Sites	Retail	113	25	-	-
GOAL: At least 100 "Standard" Points	Schools	78	15	-	-
	Other	468	55	-	-
	Total	955	125	-	-
TOTALS		**1,112**	**150**	**50**	**15**

In drawing the sample frame, targets are established for each business type and usage segment, so that the nonparticipant distribution, by business type and usage segment, is the same as that of the program participant population. The drawing is conducted in this manner to ensure sufficient representation of each business type/usage segment combination in the sample frame and allows for survey data collection in accordance with the sample design. Exhibit 3-3 below illustrates the business type/usage segments, the available nonparticipant sample, the calculated quota (based on the participant population), and the desired sample size to draw. Gray cells indicate nonparticipant segments where the available population to quota ratio is low. The final sample allocation was randomly selected within each customer segment.

Exhibit 3-3
Nonparticipant Survey Quotas
Telephone Survey Sample

SAMPLE DESIGN															
Small				Medium				Large				Very Large			
Business Type	Avail.	Quota	N	Business Type	Avail.	Quota	N	Business Type	Avail.	Quota	N	Business Type	Avail.	Quota	N
Office	12,644	52	1,031	Office	1,383	54	1,079	Office	61	7	146	Office	33	8	158
Retail	13,402	42	849	Retail	1,684	26	522	Retail	52	1	24	Retail	12	1	12
Col/Univ	211	2	49	Col/Univ	42	0	0	Col/Univ	5	0	0	Col/Univ	10	3	61
School	619	10	194	School	545	26	522	School	23	2	36	School	5	0	0
Grocery	3,004	7	133	Grocery	1,370	12	230	Grocery	90	3	61	Grocery	1	0	0
Restaurant	5,906	12	230	Restaurant	1,273	13	255	Restaurant	5	0	0	Restaurant	0	0	0
Health Care/Hosp	5,537	13	267	Health Care/Hosp	287	8	158	Health Care/Hosp	22	2	36	Health Care/Hosp	21	7	133
Hotel/Motel	1,001	7	146	Hotel/Motel	158	9	182	Hotel/Motel	15	5	109	Hotel/Motel	6	1	24
Warehouse	4,139	15	303	Warehouse	505	18	364	Warehouse	28	1	24	Warehouse	9	1	12
Personal Service	9,405	21	412	Personal Service	258	7	146	Personal Service	10	1	12	Personal Service	4	0	0
Community Servic	9,306	38	764	Community Servic	791	18	352	Community Servic	61	2	49	Community Servic	24	2	49
Misc. Commercial	7,629	18	364	Misc. Commercial	658	8	158	Misc. Commercial	95	4	73	Misc. Commercial	51	4	73
	SUB-TOTAL:	237	4,742		SUB-TOTAL:	198	3,966		SUB-TOTAL:	29	570		SUB-TOTAL:	26	522
	GRAND TOTAL:	490	9,800												

Due to the lack of "very large" commercial customers available in the nonparticipant population, a final quota of 490 sample points was set, with the expectation that only 450 surveys would be completed. Ultimately, 462 points were collected from a draw of 9,214 customers.

Finally, the canvass survey sample draw of 50,000 customers was randomly drawn from a frame of 147,762 customers who met the criteria outlined above. Although this number is well in excess of the number needed for 4,000 completes, it ensured that additional sample draws would not be necessary for the canvass telephone survey. A total of 3,796 canvass surveys were conducted to support the net-to-gross analysis.

3.1.6 Final Sample Distribution

The sample design outlined above complies with the Protocols and meets the program evaluation objectives. In this evaluation, the sampling unit is a customer site, which defines a unique service address. Applications in the MDSS database may cover more than one control number.

The final sample distribution for the telephone, on-site, and end-use metering are summarized in Exhibit 3-4 by end-use element.

Telephone Survey Sample – For each segment, the retrofit program sample design allocated the sample in proportion to the program-avoided cost by the segments in Exhibit 3-2. This sample design concentrates sample points to segments that represent the highest impact, in order to obtain the best estimate of impact for the largest portion of the population. This sample allocation, combined with the random sampling techniques within each segment, produces a stratified random telephone survey sample representing the program participants population paid in 1996. As discussed previously, the nonparticipant telephone sample is developed based upon the business type and usage strata distribution resulting from the participant sample allocation.

Telephone surveys were collected for a total of 1,270 customers, 350 of which were HVAC participants.

Exhibit 3-4
Data Collected by Program and End Use

Program	End Use	Available Population	Data Collected			Data Used in HVAC Analysis		
			Telephone Surveys	On-Site Audits	End-Use Metering	Telephone Surveys	On-Site Audits	End-Use Metering
Custom	Lighting	36	1	-	-	1	-	-
	HVAC	90	21	50	-	21	50	-
Retrofit	Lighting	3,359	495	162	-	495	0	-
	HVAC	1,025	329	178	15	329	178	15
Total	Lighting	3,383	496	162	-	496	0	-
	HVAC	1,112	350	228	15	350	228	15
Total Participants		4,367	808	351	15	808	228	15
Total Nonparticipants		408,668	462	-	-	462	-	-
Total Sites		413,035	1,270	351	15	1,270	228	15

On-site Audit Sample – Similar to the telephone survey sample, this sample was also structured to be approximately proportional to program-avoided costs, with a finer level of segmentation by technology. Within the Custom program, a census of HVAC participants were attempted for recruitment, with a total of 50 on-site audits completed. An additional 178 RE and REO standard measure on-sites were completed amongst sites that installed HVAC technologies. In all, a total of 228 HVAC on-site surveys were conducted.

End-Use Metering – This sample was not intended to be a random sample, nor strictly proportional to the program-avoided cost. Rather, the sample allocations were manipulated in order to assure adequate sample sizes for calibration of engineering models. A total of 15 participant sites were end-use metered. This data provided the ASD calibrated engineering results.

3.1.7 Relative Precision

Given a sample design, the relative precision, based upon total annual energy use, reflects the uncertainty regarding the extent to which the allocated sample sizes are large enough to control for the population variance in terms of annual energy usage. Precision for the telephone sample is calculated using the following procedure. First, the 1994 annual energy consumption is computed for all participants in the analysis dataset.

Next, five strata are constructed based on a customers' annual usage using the Delanius-Hodges procedure. Then, the program level mean and standard error are calculated using classic stratified sample techniques[4]. Finally, the relative precision at a 90 percent confidence level is calculated as a two-tailed test. The very large customers (with annual energy usage greater than 3,000,000 kWh) were excluded from these calculations.

By survey, the following relative precision was achieved:

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[4] Ibid. pp. 91-95

- For nonparticipants, the relative precision is 6.3 percent based upon a survey sample of 451.

- For HVAC, the relative precision is 8.1 percent based upon a survey sample of 334.

Exhibit 3-5 presents the stratum-level sample size, sample weight, sample mean, and estimated standard errors for each end use evaluated.

Exhibit 3-5
Telephone Sample Relative Precision Levels

Nonparticipants

Weight	Sample	Mean	STD	Standard Error	Relative Precision
96.1%	385	53,784	52,739	2,681	8.2%
3.0%	42	318,960	166,942	25,513	13.2%
0.8%	18	1,169,320	404,165	93,876	13.2%
0.1%	6	2,237,123	434,312	171,228	12.6%
TOTAL	451	73,630		2,805	6.3%
Large Customers					
Population = 281	11	6,072,193	5,247,728	1,519,643	41.2%

HVAC Participants

Weight	Sample	Mean	STD	Standard Error	Relative Precision
70.1%	252	70,289	83,178	3,470	8.1%
16.6%	56	382,449	164,797	15,055	6.5%
10.6%	22	1,272,086	785,314	134,833	17.4%
2.6%	4	2,945,090	558,387	239,309	13.4%
TOTAL	334	325,505		16,028	8.1%
Large Customers					
Population = 46	16	17,979,274	38,620,243	6,296,779	57.6%

3.1.8 Demonstration of Protocol Compliance

Sampling Procedures Adopted

The sample design follows the rules established by the CPUC in the January 1996 revisions to the "Protocols and Procedures for the Verification of Costs, Benefits, and Shareholder Earnings from Demand Side Management Programs."

Sample Definitions

The following definitions are provided to introduce the primary segments targeted—both a participant sample and a comparison group — to ensure experiment control:

Participants - According to Table 5, part C, paragraph 1 of the Protocols, participants are defined as "those who received utility financial assistance to install a measure or group of measures during the program year."

Comparison Group - A control group is defined as a group of customers that represents what would have happened in the absence of the program. According to Table 5, part D, paragraphs 3 & 4, the comparison groups include both "customers who installed applicable measures" and "customers who did not install applicable measures," with no preference for either group (i.e., random or stratified random sample). This sample is therefore representative of the population, excluding only program participants during the evaluation year.

Overall Sampling Procedures

The commercial customer samples are driven by a primary data collection activity; in this case, the telephone surveys serve as the primary site-specific data collection elements that contribute to the analysis dataset. The commercial telephone sample was drawn to achieve a stratified random sample and optimally distribute the allocated sample points.

Detailed Protocol Sample Requirement

The commercial participant and comparison group samples are designed to meet the Protocol requirements in terms of analysis dataset sample size, precision of the results, availability of pre- and post-billing data contributing to the analysis dataset, and in ensuring cost-effective use of measured data.

Analysis Dataset Sample for Commercial Participants: The Protocols require that a program with more than 450 participants has a randomly drawn sample sufficiently large to achieve minimum energy use precision of ±10 percent at the 90 percent confidence level, and at least 350 contributing points in the analysis dataset. This requirement was either met or exceeded.

As illustrated in Exhibit 3-5, the sample collected for the HVAC end use achieved a relative precision of at least 8 percent at a 90 percent confidence level. This is below the 10 percent required by the Protocols, Table 5, part C, paragraph 4. Each participant chosen for the telephone sample is required to have at least nine months of post-installation billing data, and 12 months of pre-installation data, as per the Protocols, Table 5, part D, paragraphs 2 and 1, respectively. This requirement is met, with a pre- and post-installation period of 1 year used in the statistical billing analysis.

Analysis Dataset Sample for Commercial Comparison Group - The Protocols require that the comparison group sample "be drawn using the same criteria for participants," as per Table 5, part C, paragraph 6. The nonparticipant sample frame was drawn using the participant population by business type and usage segment.

The analysis dataset meets the sample size requirement in Table 5, part C, paragraph 3. The calculated relative precision meets the precision requirement in Table 5, part C, paragraph 4. Exhibit 3-5 illustrates a relative precision of 6.3 percent at a 90 percent confidence interval, well below the 10 percent allowable.

To ensure compliance with comparison group protocols, the telephone survey sample frame is drawn to meet the billing data requirements of Table 5, part D, paragraphs 3 and 4 of the Protocols. All customers in the analysis dataset have billing data from January 1993 to September 1997, which ensures an adequate pre- and post-installation billing period for customers who installed applicable measures between 1994 and 1997.

3.2 ENGINEERING ANALYSIS

The technical approach and engineering results that support realized gross impacts in the 1996 Evaluation of Pacific Gas and Electric Company (PG&E) Commercial HVAC Technologies (HVAC Evaluation) are presented in this section. This section will provide detailed intermediate results that either verify or contradict the methods used to generate program design demand and energy impact estimates in the Marketing Decision Support System (MDSS). Results are presented to ensure that future program design and evaluation activities will benefit from the engineering parameters generated during the 1996 evaluation.

Additional documentation for the custom on-site analyses are found in *Attachment 1*. The bin weather analyses and supporting ASHRAE documentation that contributed to the RE and REO "standard" measure algorithm review can be found in *Attachment 2*.

This section is structured as follows:

- First, an overview of the engineering approach is presented.
- Then, details surrounding the development of impacts for central air conditioners and adjustable speed drives for fans are discussed.
- The methods used and the engineering estimates developed for CI program participants or participants who installed "custom[5]" measures is then presented.
- Finally, an overview of the methods used and the engineering estimates developed for other RE and REO measures are summarized.

3.2.1 Overview of the Engineering Approach

The HVAC Evaluation consisted of the analysis of five separate PG&E programs, Retrofit Express (RE), Retrofit Efficiency Options (REO), Customized Incentives (CI), Advanced Performance Options (APO), and Thermal Energy Storage (TES). The latter two programs consisted of one application each; and were analyzed in a similar manner as the CI program.

[5] Refer to *Section 3.1, Sample Design* for a discussion of "custom" vs. "standard" measures.

Where measures offered in different programs are similar (such as water chillers and adjustable speed drives), identical analysis methods were applied across all programs.

Listed below are various RE and REO measures and an overview of the evaluation done for each:

Central Air-Conditioners - Estimates of energy use were derived using the DOE-2.1E building energy simulation model, calibrated to billing data (see *Section 3.2.2*).

Adjustable Speed Drives (ASDs) for HVAC Fans - This measure was offered in all three of PG&E's primary programs. For extremely large ASD sites, a custom (site-specific) analysis was conducted. For the remaining RE and REO installations, a single method was used to develop estimates, using End-Use Metering (EUM) data (see *Section 3.2.3*).

"Custom" Measures - The analysis method used data gathered from on-site audits, along with ex ante calculations, to develop engineering estimates (see *Section 3.2.4*). Measures that were included in this category included the following: Water Chillers (RE, REO, CI, and APO), Convert to VAV (REO and CI), Cooling Towers (REO), High Efficiency Gas Boilers (REO), Customized EMS (CI), and other Customized Incentives technologies.

Other Measures - A detailed review of the algorithms used to develop ex ante impacts was performed for the remaining RE measures (see *Section 3.2.5*), with the exception of two technologies: cooling towers and chillers. Due to the low level of participation within these technology groups, and the often unique nature of their implementation; these measures were treated as a "Custom" measure, with premise-specific impacts calculated.

As a result of program design, some of the measures installed in the Customized Incentives program were similar to or the same as those for the RE and REO programs, but were installed in larger and more complex projects. For this reason, some of the analysis methods used are similar to those employed in the RE and REO program evaluations.

It is noteworthy to mention that on-site audits and/or a detailed application review was performed for every applicant who installed a "custom" measure.

3.2.2 Central Air-Conditioners (CAC)

Demand and energy estimates of savings and impact for the program measures associated with Central Air Conditioning (CAC) were determined on a per unit basis using the DOE-2 building energy simulation program.

The engineering analysis combines detailed on-site audit data with information from telephone surveys to supply reliable engineering estimates of both *savings* and *impact*. There is an important distinction between these two values. Estimates of *savings* are used as inputs to a statistically-adjusted engineering (SAE) regression model, and use the pre-existing unit's efficiency. This estimate will be larger than the *impact* estimate, whose calculation is based on current Title 24 efficiencies. The *impact* estimate is used for calculating ex post energy and demand.

The engineering estimates for CAC were developed as follows:

- Develop DOE-2 models
- Calibrate DOE-2 models
- Create undiversified and diversified energy models
- Calculate CAC energy savings
- Compute energy and demand impacts

On-site audit data were used to develop DOE-2 models of office, grocery, and retail facilities that participated in the program. These models were then calibrated using EUM data from the 1995 HVAC Evaluation and current evaluation year billing data in conjunction with California Energy Commission (CEC) weather data adjusted for local temperatures[6]. The resulting hourly estimates were then diversified and leveraged to additional building types using telephone survey data cooling system operating schedules. Finally, the DOE-2.1E model estimates were regenerated using long term weather (TMY) data and CEC baseline equipment efficiencies to compute program impacts.

Develop DOE-2 Models

Audit and billing data were analyzed to determine the number of DOE-2.1E prototypes needed to represent typical participating office, grocery, and retail facilities. The primary variables reviewed were conditioned square footage and the ratio of summer usage[7] to conditioned square footage

For CAC Measures it was determined that Office participants could be represented by one prototype, since the relationship between energy use and building size appears to be relatively linear. Similar analysis suggested that Grocery and Retail participants could be similarly grouped.

For all prototypes, lighting density was entered using equipment holdings and lighting schedules collected during each on-site. Lighting schedules were based on segment average operating profiles using on-site audit data that were collected in support of both the Lighting and HVAC Evaluations.

Key characteristics for the three prototypes are detailed in Exhibit 3-6.

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[6] This approach is consistent with the approach used for the 1995 HVAC Program year evaluation. Observed dry bulb temperatures from PG&E local office weather stations were integrated along with addition weather parameters from WYEC climate zone data.

[7] Total premise kWh for the months of June, July and August, 1996.

Exhibit 3-6
Key Characteristics for DOE-2.1E Prototypes

Variable	Office CAC	Retail CAC	Grocery CAC
Conditioned Area (Sq Ft)	38,583	80,745	36,909
Slab Floor Area (Sq Ft)	22,970	65,693	36,909
Gross Wall Area (Sq Ft)	22,684	20,532	14,450
Frame Wall Area	34%	0%	0%
Block Wall Area	66%	100%	100%
Frame Insulation	R-11	R-13	-
Block Insulation	R-7	R-0	R-0
Roof Area (Sq Ft)	22,970	65,693	9,045
Roof Insulation	R-11	R-11	R-19
Ceiling Height (Ft)	9	16	18
Window Type	Single Clear	Single Clear	Single Clear
Cooling Capacity (Btuh)	1,246,605	2,595,841	1,107,270
Number of Occupants	87	906	315
Thermostat Setpoint (°F)	72	72	77

Calibrate DOE-2 Models

To ensure that the modeled results were accurate and reasonable, models were calibrated to 1995 HVAC Evaluation EUM data for CAC technologies and current billing data. Calibration was performed by comparing DOE-2 simulations run under weather data from different climate zones with the respective EUM data.

Audit data for CAC sites indicated that both Office and Retail HVAC systems were designed with an average sizing of approximately 400 square feet per ton of cooling. This sizing was used for all CAC sites across climate zones. Minimum ventilation, miscellaneous equipment watts per square foot, and economizer control strategies were used in calibrating the model.

Billing data were then used to verify the accuracy of the calibration across climate zones. This was accomplished by comparing the annual estimates of HVAC and lighting usage to annual billing data for the sites that contributed to each prototype.

Create Undiversified and Diversified Energy Estimates

Using the calibrated DOE-2.1E prototypes discussed above, undiversified energy usage estimates were created by setting the HVAC system to operate 24 hours a day. Other operational aspects of the building, such as lighting and miscellaneous equipment schedules, were based on audit data and information calculated in the Lighting Evaluation. The calibrated DOE-2 models were run using the adjusted CEC weather data in each climate zone. The weather data covered October 1, 1996, through September 30, 1997, the post-retrofit period used in the SAE model.

Undiversified CAC savings estimates (used in the SAE model) were generated using the installed efficiencies of the retrofit equipment taken from the MDSS and estimated existing efficiencies based on the size of the retrofit unit. The existing efficiencies used were based on 1988 Title 24 standards, down graded to reflect a 15 year old CAC system, the assumed equipment life for these types of systems. Impact estimates used in the calculation of ex post gross impacts were based on Title 24 efficiencies, providing relatively smaller impact than the savings estimates.

For CAC, the DOE-2.1E prototypes provide simulated annual energy usage, at an hourly level for Office, Grocery, and Retail business types in all climate zones where there was program participation. All other business types are mapped to the Office, or Retail prototypes as shown in Exhibit 3-7.

Exhibit 3-7
Business Type Mapping

OFFICE	RETAIL	GROCERY
Office	Retail	Grocery
Community Service	Personal Service	-
Health Care Hospital	Restaurant	-
Hotel/Motel	Warehouse	-
College/University	Miscellaneous Commercial	-
School	-	-

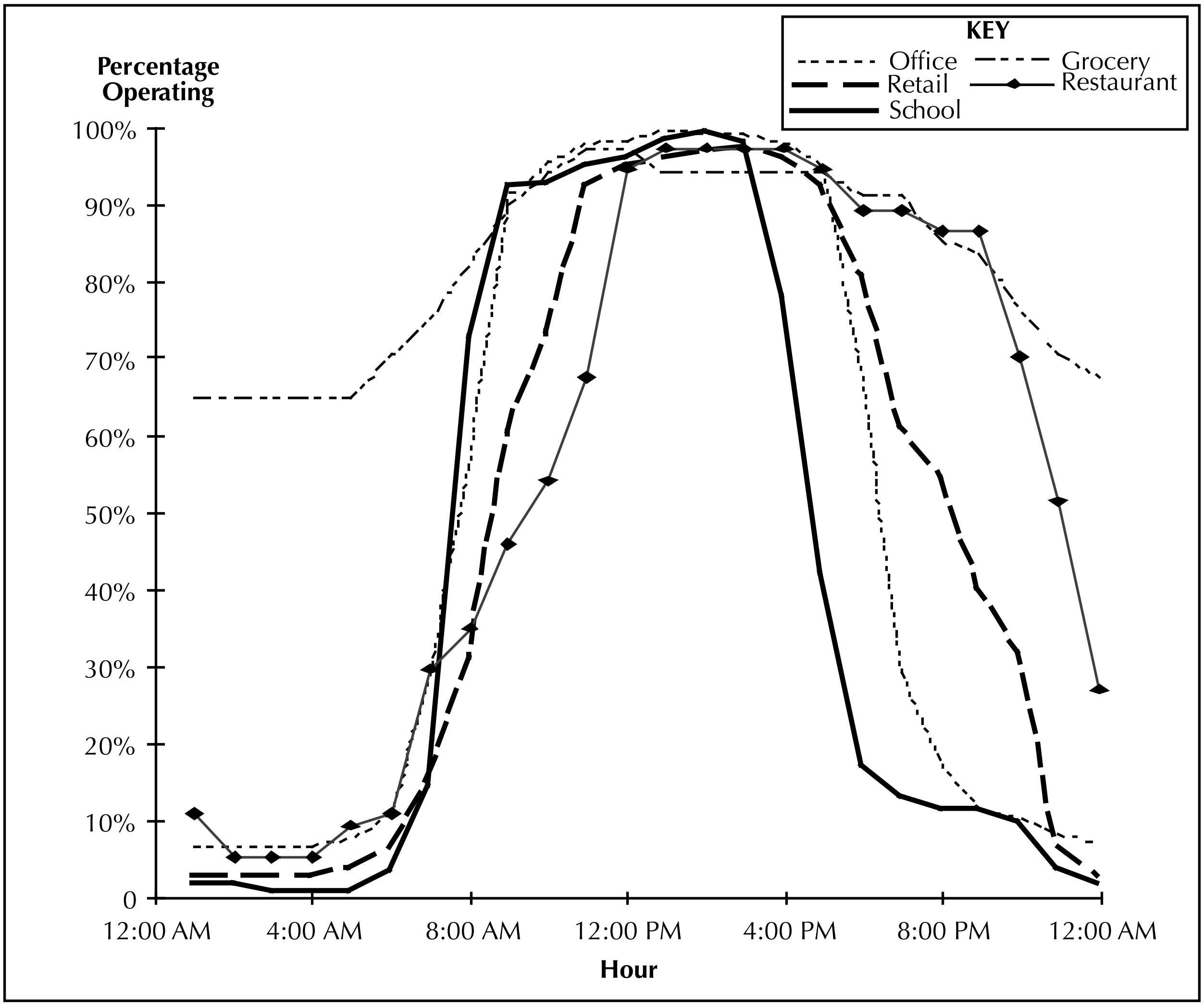
The simulated, hourly cooling and fan energy use was diversified for each business type by hourly self reported operating factors gathered through telephone surveys. The operating factor is defined as the percentage of facilities reporting the availability of space conditioning for a given hour and season. Business type specific hourly operating factors for key business types are illustrated in Exhibit 3-8. Note that these are average, annual profiles. The School business type underwent an additional adjustment for the summer months of June, July, and August. For those months, the diversified load was multiplied by 27 percent, which is the telephone survey reported peak operating factor. This additional factor reflects the large reduction in occupancy within schools during the summer months.

The result of this step are a series of hourly loads for CACs adjusted for the occupancy and operational patterns of participants.

CAC Energy Savings

For all CAC energy usage and savings estimates, a method of calculation incorporating Equivalent Full Load Hours (EFLH) was developed. The EFLH is defined as the total annual cooling energy usage, divided by the connected load for the CAC unit. The diversified CAC energy model produced an annual equivalent full load hour (EFLH) estimate for each business type and climate zone.

Exhibit 3-8
Annual Average HVAC Operating for Key Business Types



Energy savings estimates for each site in the SAE sample were calculated using estimated EFLH, total tons retrofit, post retrofit EER, and an assumed existing EER as discussed previously. Energy savings were computed for each participant in the SAE sample using the equation in Exhibit 3-9.

Compute Energy and Demand Impacts

The final step in the analysis of CAC measures was the calculation of energy and demand impacts for each participant for use in the ex-post gross impacts. The energy savings estimates described above were based on actual adjusted weather data for dates between October 1, 1996, through September 30, 1997; that were then used as inputs to the SAE analysis. The following steps were taken to convert the energy *savings* estimates to *impact* estimates:

Exhibit 3-9
Equation for Estimating CAC Energy Savings

$$kWh_{sav,i} = U * \left[EFLH_j * T * 12 * \left(\frac{1}{EER_1} - \frac{1}{EER_{MDSS}} \right) \right]$$

Where,

$kWh_{sav,i}$ = Annual energy savings for participant "j" (kWh/yr.);

U = Number of units installed;

$EFLH_j$ = Diversified Equivalent Full Load Hours for business type j;

T = Number of tons installed;

12 = Conversion of tons to kBtuh;

EER_1 = Existing System EER; and,

EER_{MDSS} = Post-retrofit EER.

Current CEC - CEC weather data[8] were used to generate the calibrated DOE-2.1E energy estimates, instead of actual adjusted CEC weather data.

Baseline - CAC savings estimates were adjusted to reflect the difference between post-retrofit conditions and minimum efficiencies defined by Title 24, rather than the pre-retrofit equipment.

CAC peak demand impacts were based on an undiversified peak duty cycle calculated from EUM data in the 1995 HVAC Evaluation. For each metered CAC unit, the five highest weekday duty cycles occurring between 3 and 4 PM were selected as representing peak duty cycles. The average of these duty cycles across all metered CAC units was 88.7 percent.

Except for Schools, Coincident Diversity Factors (CDF) were computed as the product of the peak duty cycle and the weekday 3 to 4 PM operating factor used in the energy analysis. For schools, the telephone survey reported peak operating factor of 27 percent was used to compute the CDF.

[8] Approved for use with the 1992 and 1995 Energy Efficiency Standards for Residential and Nonresidential Buildings. Referred to on magnetic media as CZxxRV2.WY2, where xx indicates the climate zone.

Exhibit 3-10
Equation for Estimating CAC Demand Savings

$$kW_{sav,i} = U * \left[CDF_j * T * 12 * \left(\frac{1}{EER_1} - \frac{1}{EER_{MDSS}} \right) \right]$$

Where,

$kW_{sav,i}$ = Peak demand impact for participant I ;

U = Number of units installed;

CDF_j = Coincident Diversity Factor, computed as 0.887 times the hour 3-4 PM operating Factor;

T = Number of tons per installed unit;

EER_1 = Baseline EER; and,

EER_{MDSS} = Post-retrofit EER.

3.2.3 Adjustable Speed Drives (ASDs) for Ventilation Fans

Demand and energy impacts for the Adjustable Speed Drive measures of both the RE and REO programs were computed using empirical relationships drawn from observed metered data and weather data. These estimates were normalized by motor horsepower and then leveraged to the entire participant population.

The engineering analysis combines detailed on-site audit data with information from telephone surveys to supply reliable engineering estimates of both *savings* and *impact*. There is an important distinction between these two values. Estimates of *savings* are used as inputs to a statistically-adjusted engineering (SAE) regression model, and use actual adjusted CEC weather data. This estimate will be different from the *impact* estimate, whose calculation is based on long term weather data. The *impact* estimate is used for calculating ex post energy and demand.

The engineering estimates for ASD measures were developed as follows:

- Clean metered frequency and demand data
- Compute fully loaded demand for each fan
- Calculate fan savings normalized by motor HP

- Correlate frequency data with outdoor temperature or time
- Compute annual undiversified savings and impact
- Diversify savings and impact estimates with operating factors
- Compute energy and demand impacts for all participants

EUM data were used to develop an ASD model of hourly savings broken out by peak and off-peak usage and binned by weather temperature. These models were then calibrated using CEC weather data adjusted for local temperatures. The resulting hourly estimates were then diversified (to get an annual kWh estimate of savings) and leveraged to additional building types using telephone survey data of operating factors (gathered in the 1995 HVAC Evaluation). Finally, ASD model estimates were regenerated using long term weather to compute program impacts.

Clean Metered Frequency and Demand Data

EUM data were collected for Office and Grocery building types. At each site, data were collected for both interval kWh and output frequency of the ASD. After the data had been successfully downloaded, a cleaning process was carried out to screen for unreasonable data. Based on field logs and observations within the data, small amounts of data were censored and omitted from the analysis. Typically, missing data were the result of meter read errors that resulted in unrecognizable character output.

Exhibit 3-11
Baseline Interval Demand Estimate

$kW_{100,i} = \frac{kW_i}{PER_{kW,i}}$ and

$$PER_{kW,i} = 0.2198 - \left[0.8748 * \left(\frac{Hz_i}{60}\right)\right] + \left[1.6526 * \left(\frac{Hz_i}{60}\right)^2\right]$$

Where,

$kW_{100,i}$ = Fully loaded draw of the fan during interval i;

kW_i = Observed frequency during interval i;

$PER_{kW,i}$ = The percent of ASD load in operation during interval i; and

Hz_i = The recorded Hz during interval i;

Compute Fully Loaded Demand For Each Fan

In order to compute impacts and savings associated with the ASD installations, the demand for each fan running at constant volume had to be estimated. Based on the well established ASD operating curve, the fully loaded or 100 percent flow case, was computed for each observation of operating fan data. A fan was defined as "operating" if the observed frequency at interval i was greater than 15 Hertz (Hz). The following quadratic equation was then applied to estimate the percentage of power drawn by the ASD during that interval:

The fully loaded draw of the fan is the observed energy use for that interval divided by the percent power in operation. The percent of frequency is computed as the observed frequency divided by a base of 60 Hz. The final step is to take the mean of the fully loaded fan estimates for each observation, and use this value as the constant volume case.

Calculate Fan Savings Normalized by Motor HP

After the mean, fully loaded demand for each fan is calculated, savings estimates are generated by subtracting the observed demand for each hour from the computed fully loaded demand. This difference, for each observation, is the gross savings associated with the given fan. Exhibit 3-12 below illustrates the mean weekday fully loaded demand profile for all fans in the EUM sample, compared to the observed demand.

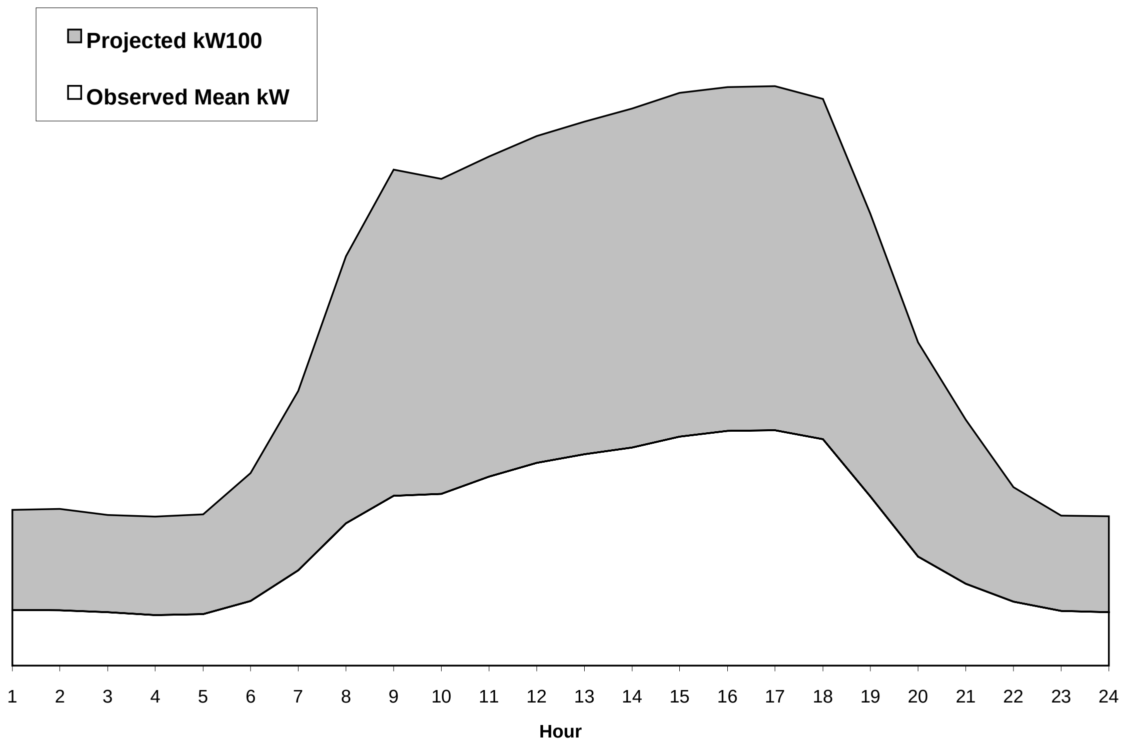
This process of calculating gross savings was carried out for all of the observed data for each of the fans. Since few of the fans were of the same motor horsepower, the data had to be normalized in order to average the results. This was accomplished by simply dividing the savings estimate for each fan by the fans' motor horsepower. The resulting hourly dataset of savings estimates was then represented as kW savings per motor horsepower.

Correlate Average Fan Savings with Outdoor Temperature or Time

In order to compute annual savings and typical year impacts, the monitored data needed to be correlated with another parameter to project savings for the unmonitored period, and for a typical weather year. The first step in correlating the observed fan usage with another parameter was to assess the data for usage patterns. An initial investigation revealed that the metered data could be divided into two categories, those that varied with time, and those that varied with temperature. The division of these sites clearly indicated that the grocery stores operated fans on fixed schedules, while the office sites allowed the fans to adjust throughout the course of the day. Based on these observations, the sample was divided into two categories, fixed operation for the grocery stores and variable operation for the office facilities. For the grocery stores, projecting savings and impacts for other time periods was very simple, since the assumption was made that the per-horsepower savings were consistent over time. For the variable case, the following process was used to project impacts.

For each of the metered sites, real-time weather data collected from various sites throughout PG&E's service territory was merged onto the calculated normalized hourly savings estimates by date and time. Similar to the calculation of full load, the data was then flagged as either operating or not operating based on the observed frequency. In addition, the data were also subdivided based on the hour of day, with daytime being defined as 8:00 AM to 7:00 PM, and nighttime as the remaining hours.

Exhibit 3-12
Average Weekday Comparison of
kW vs. kW_{100}



The data were then sorted by temperature and average, per-horsepower savings estimates were generated in 5 degree temperature bins. That is, for all observations of savings, within a given temperature bin and time of day, the average per-horsepower savings was calculated. The result was two curves, one for daytime and one for nighttime, of per-horsepower savings as a function of temperature.

Compute Annual Undiversified Savings and Impact

The next step in the process was to use the savings relationships identified above, to estimate annual savings and impacts. At this point it should be noted that the only difference between savings estimates and impact estimates is in the weather data used in the computation. Savings estimates, to be consistent with the billing data used in the SAE analysis, were computed using actual weather data from October 1, 1996 through September 30, 1997. Impact estimates were computed using the current California Energy Commission (CEC) approved long-term average weather data. In both cases, estimates were generated by climate zone for representative weather stations.

Using the temperature dependent savings curves developed above and both sets of weather data, full year savings estimates were generated with the actual weather data and impact estimates were generated using the CEC weather data. This was accomplished by simply selecting the appropriate temperature dependent savings estimate for the given temperature associated with the particular hour of weather data. Note that no restrictions were placed on the savings calculations for operating conditions, meaning that the equipment is assumed to always be available. The resulting datasets were hourly savings estimates on a per-horsepower basis.

Diversified Savings and Impact Estimates with Operating Factors

The last step in the process, prior to computing participant specific impacts, was to diversify the fully loaded operating savings estimates to reflect the best information available in terms of operating hours. This was accomplished by first collapsing the full year savings estimates into representative daytypes and then applying the survey-derived operating factor. For this study, average daytypes were developed for weekdays, Saturdays, and Sundays/Holidays. To do this, the savings estimates for each contributing day for a given month and daytype were simply averaged by hour of day. After the averaging had been accomplished, the daytype specific operating factor for each business type was applied to the average daytype savings estimate.

These diversified savings estimates were then summed to produce daily, total, per-horsepower savings estimates for each month, daytype, and business type. The final step in this process was to multiply the daily totals for each daytype by the number of days in each month/daytype to generate monthly totals. These totals were in turn summed, to produce monthly, per-horsepower savings estimates by business type and climate zone.

Compute Savings and Impact Estimates for All Participants

The final step in the process was to produce annual savings and impact estimates for each participant in the MDSS. Using the savings and impact estimates generated above, final participant-specific estimates were generated by selecting the appropriate annual savings value by business type and climate zone, and then multiplying by the installed number of horsepower. Savings estimates, generated with 1996-1997 weather data were used as input for the SAE analysis, while impact estimates provided the gross engineering estimate of impact that supported the ex post analysis.

The final step in the analysis of ASD measures is the calculation of energy and demand impacts. The energy savings estimates described above were based on weather data for dates between October 1, 1996, through September 30, 1997; and were used as inputs to the SAE analysis. To convert the energy *savings* estimates to *impact* estimates, long term weather data was used in lieu of adjusted CEC weather data. Separate estimates of kWh and kWh_{100} were calculated, and energy impacts calculated using the same equation applied in Exhibit 3-13.

To calculate ASD peak demand, the ten hottest weekday temperatures (observed any time between the hours of 12PM to 6PM) for each climate zone were averaged together. This average represents the hottest temperature at peak time (where, presumably the fan would be operating at its maximum capacity). The savings estimate from the correct temperature bin (which the hottest mean temperature fell into) was selected as an estimate of peak demand. This was done for each climate zone, with the resulting estimate adjusted by the mean operating factor of the premise's business type.

Exhibit 3-13
Equation for Estimating ASD Energy Savings

$$kWh_{sav,i} = U_i * \left[kWh_{100,jz} - kWh_{jz}\right]$$

Where,

$kWh_{sav,i}$ = Annual energy impact for customer i (kWh/yr.);

U_i = Total retrofit Horsepower for customer i;

$kWh_{100,jz}$ = Annual diversified energy use per horsepower for business type j (kWh/yr.) and climate zone z for fans without adjustable speed drives;

kWh_{jz} = Annual diversified energy use per horsepower for business type j (kWh/yr.) and climate zone z for fans with adjustable speed drives;

Exhibit 3-14
Equation for Estimating ASD Demand Impacts

$$kW_{imp,i} = OF_j * \left[kW_{100} - kW\right]$$

Where,

$kW_{imp,i}$ = Peak demand impact for participant i;

OF_j = Mean weekday operating factor between the hours of 12PM to 6PM for business type j;

kW_{100} = Estimated mean peak demand of the fan without an ASD; and,

kW = Observed mean peak demand of the fan with an ASD.

3.2.4 Custom Measures

The following RE, REO, CI, APO, and TES technologies were considered part of the "custom" measure segment:

- Water Chillers;
- Convert to VAV;
- Cooling Towers;
- High Efficiency Gas Boilers;
- VFD Chillers;
- Customized EMS;
- Customized Controls; and,
- Other Customized Equipment and HVAC Technologies.

Every application that installed a "custom" measure was requested for thorough engineering review. On-site recruitment focused on premises that claimed the highest avoided cost under the programs. Applicants were ranked according to the total claimed avoided cost for the facility. Specific sites (within the Customized EMS action code) were also targeted for on-site recruitment due to their relatively high level of participation amongst CI participants. Based on this sampling strategy, on-site audits were performed for 50 of the 96 participant sites.

When on-site data were available, a comparison was made between on-site data and data found in the MDSS and on the application forms. If a discrepancy was found between the audit data and the ex ante impacts, then one or all of the following were developed on a premise-specific basis:

- Temperature bin models
- Spreadsheet-based algorithms

If a participant site did not receive an on-site audit, the application form was thoroughly reviewed for errors in calculations. Generally, the custom applications were well documented, and an independent estimate of both savings and impacts could be derived. In some instances (such as Custom EMS), results from on-site surveys conducted at one of several schools within a district would be leveraged against the remaining sites that did not undergo an on-site audit.

Attachment 1 contains a summary of information regarding the development of impacts for each Customized Incentives participant who had an on-site visit. Details surrounding the site-specific calculations (including the spreadsheets used to generate the QC unadjusted engineering impacts) can also be found in *Attachment 1*.

3.2.5 Other RE Measures

For RE measures other than CAC, ASDs, and Water Chillers, the evaluation approach was based on a review of the algorithms and input assumptions used to develop the ex ante impacts. Since many of the same measures were offered in both the RE and REO programs, methods developed for evaluating a measure in one program were, for consistency, applied to other programs. The aim of the evaluation was to either confirm or correct the methods and inputs used in the ex ante estimates.

When applicable, the engineering algorithms used by PG&E to develop ex ante impacts for RE measures were reviewed thoroughly (algorithms were taken from the 1995 Advice Filing[9]). For each measure, the following analysis steps were performed in an algorithm review:

- Ex ante impacts were re-calculated using methods and inputs listed in the Advice Filing.
- Evaluation impacts are developed using revised methods and inputs when applicable. When possible, inputs and methods were verified using either sources referenced in the Advice Filing or alternate sources such as ASHRAE, the CEC or ARI.

The following pages contain

a written one page summary of information regarding the development of impacts for each algorithm-based RE and REO measure. The summary provides an overview of the algorithm review used to develop QC per unit impacts which were in turn applied to the contents of the MDSS to determine unadjusted engineering estimates of impact and savings. Detailed information surrounding the development of the algorithms used in the unadjusted engineering estimates (including bin analysis and per-unit comparisons of advice filing recommendations on program evaluation) results can be found in *Attachment 2*.

[9] PG&E 1995 Customer Energy Efficiency Programs Advice Letter No. 1867-G/1481-E, filed October 1994.

Setback Programmable Thermostats

Measure Description:	Installation of setback programmable thermostats in spaces with regular occupied and unoccupied periods.
Summary of Advice Filing Calculations:	A bin analysis method was employed to create per thermostat energy and therm impacts. Demand impacts were not calculated, as setback thermostats do not affect peak demand.
Comments on Advice Filing Calculations:	Program review has shown that the per-unit impacts were applied to each participant with the assumption that each thermostat controlled the conditioning of 5,000 sq ft of office space, regardless of building size or type. These impacts were not adjusted to account for different climate zones.
Comments on Advice Filing Inputs:	Incorrect return air values were used to determine the heating and cooling loads during setback hours. Weather data was for San Jose, and thus only represented one climate zone.
Evaluation Process:	Energy and therm impacts were developed using modified return air values during setback hours and binned weather data from all 16 California climate zones. A conditioned square footage value was developed for each participant using MDSS, survey, and audit data. Climate zone-specific impacts (leveraged by square footage) were then applied.
Additional Notes:	If the ex ante assumptions for a given premise indicated only energy impacts, then no therm impact was developed.

Package Terminal AC Units

Measure Description:	Installation of high efficiency packaged terminal air-conditioners and heat-pumps. This measure provides an incentive to install PTAC and PTHP units that exceed Title20 standards.
Summary of Advice Filing Calculations:	Demand and energy impacts were developed using equivalent full load hours (ELFHs), coincident demand factors (CDFs), and system efficiency.
Comments on Advice Filing Calculations:	Calculation methods cited in the Advice Filing do not accurately model participant specific retrofits. This is due to a generalized assumption regarding typical efficiency and capacity upgrades.
Comments on Advice Filing Inputs:	Sufficient data are not available to verify either the CDF or the EFLH values used in the calculation. ELFHs do not take climate zone variation into account.
Evaluation Process:	Using the change in EER for each site (based upon the MDSS), a revised equation was used in conjunction with Advice Filing EFLH and CDF values, to estimate per participant impacts.
Additional Notes:	

Reflective Window Film

Measure Description:	Provides an incentive for the installation of reflective window film on clear non-North facing glazing.
Summary of Advice Filing Calculations:	Cooling loads attributable to solar heat gain were calculated using equation 27.41 of the ASHRAE Fundamentals Handbook (p.27.24). Per square foot energy and demand impacts were estimated for applied reflective film.
Comments on Advice Filing Calculations:	Methods used to determine energy and demand impacts are valid.
Comments on Advice Filing Inputs:	A review of the inputs from ASHRAE revealed a discrepancy between the annual solar heat gains listed in ASHRAE and those used in Advice Filing calculations.
Evaluation Process:	Energy and demand estimates were developed using the correctly applied ASHRAE method.
Additional Notes:	

Direct Evaporative Coolers

Measure Description:	Provides an incentive for the replacement of an existing AC unit with an equally sized direct evaporative cooler system. Measure participation is restricted to certain climate zones.
Summary of Advice Filing Calculations:	Used HVAC manufactures' software to develop demand and energy impacts.
Comments on Advice Filing Calculations:	No documentation is provided for the method used. Additionally, final impacts are greater than baseline demand and energy usage, which is theoretically impossible. (See Additional Notes)
Comments on Advice Filing Inputs:	The inputs used in the calculations are not substantiated.
Evaluation Process:	Demand and energy savings were determined using climate zone-specific cooling degree hours, fan motor horsepower and the efficiency of the existing AC unit (see Additional Notes). Impacts were developed using motor efficiency values listed in the baseline assumptions for the RE Motors program.
Additional Notes:	In the interim between the 1994 Advice Filing and the current evaluation, PG&E revised substantially the methods used to determine impacts. The evaluation effort concentrated on the revised algorithms, and used (with slight modifications) the current methods developed by PG&E for the 1996 Advice Filing.

Bypass Timer

Measure Description:	Installation of a bypass timer to control the fans of a space which is intermittently occupied after hours when the space conditioning system is off.
Summary of Advice Filing Calculations:	Using fan motor horsepower, assumed hours of operation and a fan load/efficiency value, energy savings were developed. No demand savings are estimated since bypass timers do not affect the peak demand.
Comments on Advice Filing Calculations:	The percent a fan is loaded is generally independent from efficiency.
Comments on Advice Filing Inputs:	The fan load/efficiency value is not substantiated with documentation. Assumed hours of operation are poorly documented.
Evaluation Process:	Energy impacts were developed using fan load and motor efficiency values listed in the baseline assumptions for RE HVAC measures and the RE Motors program, respectively.
Additional Notes:	

Timeclocks

Measure Description:	Installation of timeclocks, which regulate HVAC usage in spaces with regular occupied and unoccupied periods.
Summary of Advice Filing Calculations:	A bin analysis method was employed to create per timeclock energy impacts. Demand impacts were not calculated, as timeclocks do not affect peak demand.
Comments on Advice Filing Calculations:	Program review has shown that the per-unit impacts were applied to each participant with the assumption that each timeclock controlled the conditioning of 5,000 sq ft of office space, regardless of building size or type. These impacts were not adjusted to account for different climate zones.
Comments on Advice Filing Inputs:	Weather data was for San Jose, and thus only represented one climate zone.
Evaluation Process:	Energy and therm impacts were developed using modified return air values during setback hours and binned weather data from all 16 California climate zones. A conditioned square footage value was developed for each participant using MDSS data. Climate zone-specific impacts (leveraged by square footage) were then applied.
Additional Notes:	If the ex ante assumptions for a given premise indicated only energy impacts, then no therm impact was developed.

Water and Evaporative Cooled Single Package AC Unit

(• 135,000 Btu/hr)

Remote Condensing Unit (RCU); Air-Cooled

(• 135,000 Btu/hr)

Remote Condensing Unit (RCU); Water- and Evaporative- Cooled (• 135,000 Btu/hr)

Measure Description:	All three measures involve the replacement of an existing standard-efficiency AC unit with a high-efficiency unit that exceeds Title20 specifications.
Summary of Advice Filing Calculations:	Demand and energy impacts were developed using equivalent full load hours (ELFHs), coincident demand factors (CDFs), and system efficiency.
Comments on Advice Filing Calculations:	Calculation methods cited in the Advice Filing do not accurately model participant specific retrofits. This is due to a generalized assumption regarding typical efficiency and capacity upgrades.
Comments on Advice Filing Inputs:	Baseline efficiencies are consistent with Title 20 standards. Sufficient data are not available to verify either the CDF or the EFLH values used in the calculation. ELFHs do not take climate zone variation into account.
Evaluation Process:	Using the change in EER for each site (based upon the MDSS), a revised equation was used in conjunction with EFLHs (developed as part of the evaluation of the RE Central AC measures), to estimate per participant impacts.

3.3 BILLING REGRESSION ANALYSIS

This section documents the detailed analytical steps undertaken in the billing regression analysis of Pacific Gas and Electric Company's (PG&E's) 1996 CEEI Programs. The section begins with a discussion of the analysis periods and data sources used in the billing regression model. Then, the results of the data censoring that was applied to the analysis sample are provided. Next, the gross billing analysis regression model specification and SAE coefficients are presented, along with the relative precision calculations. Finally, the net billing analysis regression model specification and results are presented.

3.3.1 Overview

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 of customers' energy usage between pre- and post-installation periods using actual customer billing data. The model is specified using the billing data and independent variables gathered in the telephone survey that explain changes in customers' energy usage, including the engineering estimates of energy impact due to 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 the engineering impact estimates. These realized impacts represent the fraction of engineering estimates actually "observed" or "detected" in the statistical analysis of the billing data. The SAE coefficients estimated in the billing analysis are relative to the results of the evaluation-based engineering estimates, not the PG&E Program ex ante estimates. This distinction is important, as the SAE coefficients are then used to estimate gross ex post program impacts, which in turn are used to calculate realization rates relative to the ex ante estimates.

As discussed in detail 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 both the Lighting and HVAC end uses. This section of the report presents the analysis findings for both end uses – as each was an essential input to the overall model used.

3.3.2 Data Sources for Billing Regression Analysis

The billing regression analysis for the 1996 HVAC Evaluation uses data from five primary data sources: PG&E's Marketing Decision Support System (MDSS) tracking database, the billing database, the telephone survey data, the engineering estimates of changes in usage between the pre- and post-installation periods, and weather data 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), Retrofit Efficiency Options (REO), Customized Incentives (CI), Advanced Performance Options (APO), and Thermal Energy Storage (TES) Programs are maintained as part of the MDSS. It contains program applications, rebate and technical information about installed measures; including measure descriptions, quantities installed, rebated amounts, and ex ante demand, energy, and therm savings estimates. The MDSS database is linked to the billing database and other program databases through PG&E's customer specific control number.

PG&E Billing Data

The PG&E billing data used in this year's evaluation study were obtained from two different data requests to PG&E's Load Data Services department. The original nonresidential billing dataset contained prorated monthly energy usage for all nonresidential accounts in PG&E's service territory, and was used in the sample design described in *Section 3.1*. The billing histories contained in this database run from January 1995 through April 1997.

A second billing dataset was later obtained from PG&E Load Data Services for use in the SAE analysis. This billing dataset contains bill readings that run from January 1993 through December 1994, and then from January 1997 to September 1997. The resulting combined dataset represents the billing series of PG&E pro-rated monthly usage data for each calendar month from January 1993 to September 1997.

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 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 (embedded in the account code for each customer).

Telephone Survey Data

All available telephone surveys (except for the Canvass surveys, which do not collect detailed information regarding changes that have occurred at the premise) collected as part of the evaluation for the HVAC Program were used as inputs to the billing regression analysis. Two telephone survey samples totaling 1,270 sample points (350 of which were HVAC participants and 462 nonparticipants) were collected for the HVAC Evaluation. Because of cross-over among participants across Commercial Program end uses, one integrated billing regression model was developed to evaluate both the Lighting and HVAC 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 and the final sample disposition, see *Survey Appendices*. A discussion of the sample design can be found in *Section 3.1.*

Engineering Estimates

Engineering estimates of savings were estimated for each of the 350 HVAC participants. Separate estimates of energy savings were calculated for every measure installed under a Commercial Program. The engineering estimates were calculated based on expected savings from the pre-installation technology to the post-installation technology. For some technologies, such as Central A/C's installed in the HVAC Program, these savings estimates will differ from the impact estimates. This is due to the impacts being calculated relative to a baseline efficiency, compared to the savings estimates, which are based on a pre-existing unit's efficiency. In the example above, many CAC's existing efficiency had a SEER rating much lower than the program baseline estimate. Consequently, the savings estimate for energy would be much higher. The engineering analysis (*Section 3.2*) discusses the calculation of the savings estimates used in the billing analysis in greater detail.

3.3.3 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 (including billing usage) had to be aggregated up to the QC defined site identifier. In PG&E's billing data, an array of variables are defined to track a customer. These include the following:

- Control number, which is the finest level of aggregation, and is usually unique to a customer's meter.
- Premise number, which is used to define a unique site, but can sometimes contain multiple buildings. The premise number may map to many control numbers, but a control number will always map to a unique premise number.
- Corporation number, which is used to define a unique corporation, which can map to many premise numbers. A premise number maps to a unique corporation number.

Of the three, the premise number serves as the best indicator of a unique site. However, there are some premise numbers that contain multiple sites. To address this issue, the customer's service address was also used to help identify a unique site. If there was more than one service address for a premise number, it was broken out into multiple sites. Therefore, a unique site was defined as all of the control numbers within a unique combination of service address,[10] premise number, and corporation number. A unique Site ID was created based on this combination of address, premise, and corporation to serve as the key variable for linking data.

The billing data was provided at the control number level. To meet the needs of the analysis team, the monthly billing data had to be aggregated to the Site ID level. One concern with aggregating to the Site ID level is that there may be control numbers associated with a different premise number, service address, or corporation number that are in the same physical site and are being affected by the installed measures. If this is the case, the billing analysis will have the effect of underestimating the impacts. This a topic that will be discussed further in the *Data Censoring* section below.

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

[10] Because of potential data entry errors in the billing system, or inconsistencies in tracking service addresses in the billing system, only the first eight characters of the service address were used. Generally, this would contain the numeric portion of the address and the first few characters of the street name. For the large majority of records in the billing system, premise number and service address were unique.

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. Exhibits 3-15 and 3-16 below provide the sample frame that was available for the billing analysis for HVAC participants and nonparticipants. The sample sizes are provided by business type and technology (for participants) and by business type only for nonparticipants. The values presented are the unique number of the Site IDs within a given segment.

Exhibit 3-15
Billing Analysis Sample Frame
Pre-Censoring
HVAC End-Use Technologies

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	60	25	4	20	3	21	16		9	14	40	11	223
	Adjustable Speed Drives	5	1						1	1				8
	Package Terminal A/C					1		1	12	1				15
	Set-Back Thermostat	26	10	2	9	1	7	4	1	4	9	12	2	87
	Reflective Window Film	31	10	1	1	1	4	5		7	6	6	2	74
	Water Chillers				1								1	2
	Other HVAC Technologies	1	1			1	1							4
Retrofit Express Program Total		96	37	5	25	6	26	22	14	19	20	46	14	330
Retrofit Efficiency Options	Adjustable Speed Drives	1										1		2
	Water Chillers	1	2									1		4
	Convert To VAV													
	Cooling Towers	2												2
	High Efficiency Gas Boilers													
	VFD Chillers													
Retrofit Efficiency Options Program Total		3	2									2		7
Customized Incentives	Adjustable Speed Drives	1												1
	Water Chillers	1										1		2
	Customized EMS	1		1	6									8
	Customized Controls													
	Convert To VAV	1												1
	Other Customized Equip												2	2
	Other HVAC Technologies	1		1										2
Customized Incentives Program Total		3		2	6							1	2	14
Thermal Energy Storage	Other Customized Equip													
Advanced Perf. Options	Water Chillers													
Total		102	39	7	30	6	26	22	14	19	20	49	16	**350**

Exhibit 3-16
Billing Analysis Sample Frame
Pre-Censoring
Nonparticipants

Program and Technology Group	Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Nonparticipant Total	117	69	2	30	22	25	24	17	35	28	59	34	**462**

3.3.4 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, all customers paid in 1996 actually installed measures in 1992, 1993, 1994, 1995, or 1996. HVAC installations prior to 1995 accounted for less than 2 percent of the total program.

Selection of Installation Date

While 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. For customers who installed these energy saving measures during the pre- or post-installation period, their energy savings must be prorated to account for energy consumption using the older technologies.

Although installation date is a field in the MDSS, it is rarely populated (only 2 percent of the time). And because the "paid date" (another field in the MDSS) can vary from the installation date by as much as 4 years, another approach had to be developed to estimate an installation date. For 66 percent of the MDSS records, a pre- and post-installation inspection date was collected. In every case where the installation date was populated, it's value fell between the pre- and post-installation inspection dates. Therefore, we can derive from these two variables a time interval containing the installation date. Another date field in the MDSS that is populated 100 percent of the time is the date the application was received by PG&E. This date always occurs after the pre-installation inspection date (when populated) and rarely exceeds the post-installation inspection date (when populated) by more than a month (only 9 percent of the time). Consequently, the application received date served as an excellent proxy to the installation date, when the installation date was not populated.

In addition to the dates recorded in the MDSS, the telephone survey asked every participant to estimate the installation date. If their self-reported installation date fell between the pre- and post-installation inspection dates (as recorded in the MDSS), the customer reported date was used over the application received date.

Selection of Analysis Periods

The selection of the primary analysis period has to be defined in such a way that allows for the inclusion of the majority of the sample with high-quality data.

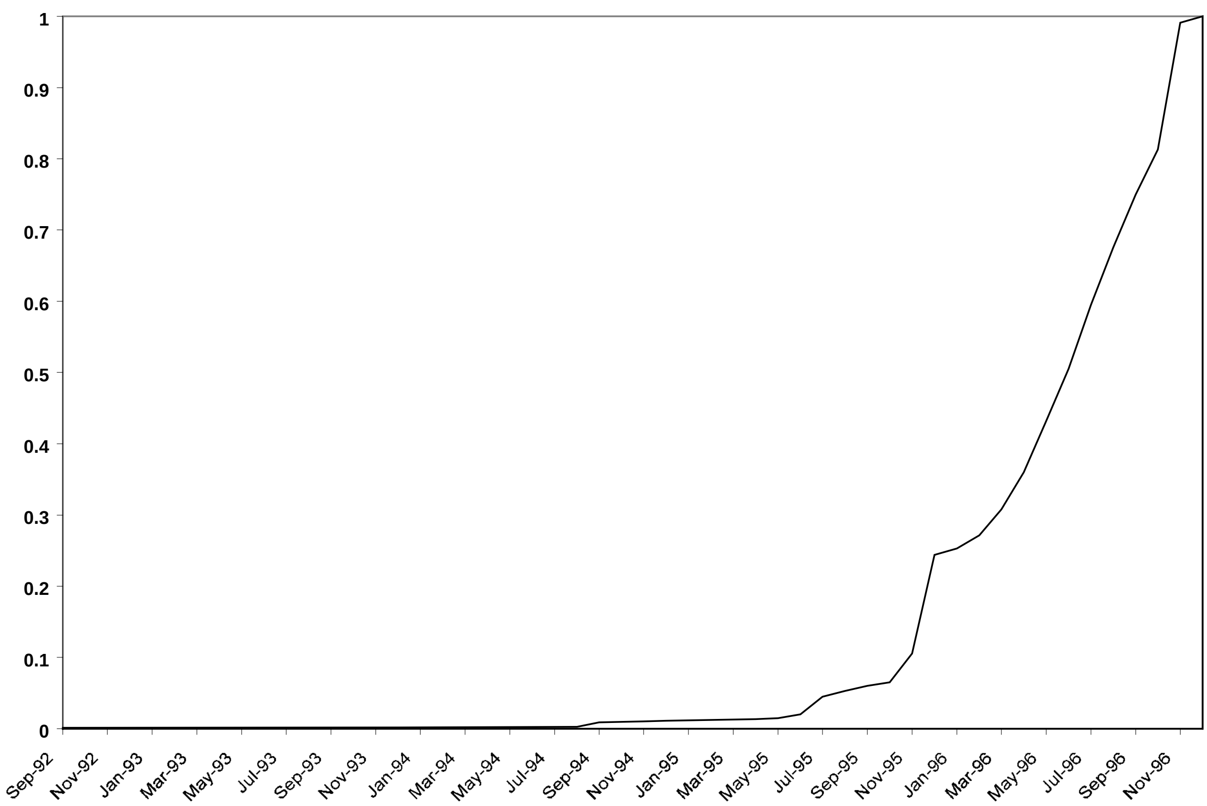
Billing data were available from January 1993 through September 1997. To maximize the number of post installation months in the regression model, a post period of October 1996 through September 1997 was used. As illustrated in Exhibit 3-17, this post period occurs after 85 percent of the installation dates.

Based on the selection of post period, there are only two feasible pre-periods that could have been used: October 1993 through September 1994 (a 1994 pre-period), and October 1994 through September 1995 (a 1995 pre-period). (Exhibit 3-17) suggests that over 95 percent of the installations occurred between January 1995 and December 1996. In order to minimize the number of installation periods for which the engineering estimate would have to be pro-rated, it was decided to use the 1994 pre-period.

For installations that occurred prior to the pre-installation period, the engineering impact is set to zero. For installations that occurred during either the pre- or post-installation period, the engineering impact is only aggregated over the months for which there is an impact that should be realized.

Exhibit 3-17 provide the cumulative participation by month for the participants that are part of the billing analysis sample frame.

Exhibit 3-17
Commercial HVAC Rebated Technologies
By Estimated Installation Date



3.3.5 Data Censoring

Three types of data censoring screens were applied to the billing analysis sample frame to remove customers: those that had invalid billing data, or that may not have had their bill properly aggregated to the Site ID level, or that were extremely large users.

Invalid Usage

For customers to be included in the final billing analysis, customers had to have billing data that met the following two criteria:

The pre- and post-installation annual bills had to have been comprised of at least six non-zero monthly bills. If there were seven or more monthly bills with zero energy, the customer was removed from the analysis. If there were between one and six monthly bills with zero energy, the remaining months were prorated to an annual estimate.

The pre-installation annual bill could not be more than twice or less than one half the post-installation bill. If this occurred, the customer was removed from the analysis.

Exhibit 3-18 presents the number of participants and nonparticipants that were deleted for each of the above criteria. Note that only 24 nonparticipants were deleted, whereas 123 participants were deleted. This is due to the fact that the nonparticipants were pre-screened to have relatively valid billing data prior to being selected into the nonparticipant survey sample frame. The participants, however, were often a census and no pre-screening was done on their billing data prior to being selected into the participant survey sample frame. Of the 123 participants, 59 were deleted due to the zero bill criteria.

Large Customers

Customers whose annual pre-installation energy consumption that exceeded three million kWh were excluded from the billing analysis. A total of 41 participants and 10 nonparticipants were dropped for this reason. This decision was made *a priori* to collecting the survey data, as is documented in the Evaluation Research Plan; and is based upon the results of the last year's HVAC Evaluation, which was unsuccessful in obtaining reliable results when including customers with usage above this level. This is also consistent with the recommendations made by the Verification Report of PG&E's 1995 Commercial HVAC Evaluation, which states "program effects can be difficult to detect for large customers," and recommended censoring large customers from the final billing analyses.

Although the decision to censor these customers was made *a priori*, large participants and nonparticipants were still surveyed (as discussed above in the *Section 3.1, Sample Design*) in order to meet other evaluation objectives. Because data were available, and *after* the billing analysis models were finalized, the large customers were included back into the model to test the hypothesis that reliable results could not be obtained. When included, seven of the nine SAE Coefficients became insignificant, with six of the coefficients having t-statistics of less than 0.5. Furthermore, the most significant result was lighting offices with a parameter estimate with the wrong sign of 7.39 (indicating that this would cause an *increase* of usage of over 700% of the expected impact) and a t-statistic of 9.8. Clearly, the censoring of the large customers was valid.

Exhibit 3-18
Distribution of Customers Removed from Billing Analysis
By Data Censoring Criteria
Customers with Invalid Billing Data

Participant or Nonparticipant	Zero Monthly Bills > 6	Usage Doubled or Cut In Half	Usage Tripled	Number Removed From Analysis
NP	No	No	Yes	5
NP	No	Yes	No	4
NP	Yes	No	No	4
NP	Yes	No	Yes	8
NP	Yes	Yes	No	3
TOTAL				24
P	No	No	Yes	29
P	No	Yes	No	35
P	Yes	No	No	6
P	Yes	No	Yes	51
P	Yes	Yes	No	2
TOTAL				123

Aggregation to Site ID Level

As mentioned above, one concern with aggregating to the Site ID level is that there may be control numbers associated with a different premise number, service address, or corporation number that are in the same physical site and are being affected by the installed measures. Therefore, a comparison was made between the engineering energy impact and the aggregated pre- and post-installation bills to identify any customers where this problem of bill aggregation may exist. In addition, both a ratio of energy to square feet (from the MDSS and the survey), and energy to employee was calculated for each participant to further aid in the identification of poorly aggregated sites.

There were 278 HVAC and/or lighting participants that were identified as having total Commercial Sector Program energy impacts that were either more than 50 percent of their pre-installation usage or whose energy to square foot or energy to employee ratio was in the bottom 10^{th} percentile of the participant population. These 278 participants were further analyzed to determine whether the impact was large relative to usage because of a problem in aggregating the bill, or if the engineering estimates were just over-estimated. In the latter case, the customer would **not** be removed from the billing analysis.

Three criteria were used to determine if there was a problem with aggregating the bill for these 278 participants. If a participant failed any of these criteria, the customer was removed from the analysis on the basis that their billing data were not properly aggregated to the Site ID level, and the entire impact would not be detected in an analysis of the customer's billing data.

- If the customer's energy impacts were greater than 100 percent of their pre-installation usage and any one of their annual kWh per square foot or annual kWh per employee was in the bottom tenth percentile of all participants, the customer was removed.

- If the customer's energy impacts were greater than 50 percent of their pre-installation usage and either their annual kWh per square foot or annual kWh per employee was in the bottom tenth percentile of all participants, the customer was removed.

- If all three of the annual kWh per square foot and annual kWh per employee ratios were in the bottom tenth percentile of all participants, the customer was removed.

As a result of these three criteria, 94 of the 278 premises were removed. Of the 94 removed customers, 39 also failed the invalid usage data screening checks. Therefore, only an additional 55 premises were removed based solely upon the data screening criteria described above.

Exhibit 3-19 presents the number of participants that were removed from the analysis for each of the above criteria,

Exhibit 3-19
Distribution of Customers Removed from Billing Analysis
By Data Censoring Criteria
Customers with Billing Aggregation Problems

Low Usage per Sqft (MDSS)	Low Usage per Sqft (Survey)	Low Usage Per Employee	Estimated Savings Greater Than Usage	Low Usage Relative to Estimated Savings	Number of Participants Removed
No	No	No	Yes	No	3
No	No	Yes	No	Yes	5
No	No	Yes	Yes	No	1
No	Yes	No	No	Yes	5
No	Yes	Yes	No	Yes	2
No	Yes	Yes	Yes	No	4
Yes	No	No	No	Yes	5
Yes	No	No	Yes	No	2
Yes	No	Yes	No	Yes	2
Yes	No	Yes	Yes	No	7
Yes	Yes	No	No	Yes	13
Yes	Yes	No	Yes	No	7
Yes	Yes	Yes	No	No	9
Yes	Yes	Yes	No	Yes	6
Yes	Yes	Yes	Yes	No	23
Total					94

In summary, out of the original sample frame of 462 nonparticipants, 34 were removed for bad billing data or for being an extremely large customer. This low attrition rate can be attributed to the fact that the nonparticipant sample was pre-screened for invalid billing data (though not for large usage, as they may have served as a control group for the participants). Of the original sample of 808 HVAC and lighting participants, 217 were removed because of bad billing, improper site aggregation, or because they were large customers. Of these 217 customers, 91 were HVAC participants.

Exhibit 3-20 summarizes the total number of participants and nonparticipants that were removed from the billing analysis. Exhibits 3-21 and 3-22 present the final sample sizes used in the billing analysis by business type and technology for HVAC participants and by business type for nonparticipants.

Exhibit 3-20
Distribution of Customers Removed from Billing Analysis
By Data Censoring Criteria

Participant or Nonparticipant	Zero Monthly Bills > 6	Usage Doubled or Cut in Half?	Usage Tripled or Cut in Third?	Large Customer?	Bill Not Aggregated Properly?	Number of Sites Removed
NP	No	No	No	Yes	No	10
NP	No	No	Yes	No	No	5
NP	No	Yes	No	No	No	4
NP	Yes	No	No	No	No	4
NP	Yes	No	Yes	No	No	8
NP	Yes	Yes	No	No	No	3
TOTAL						34
P	No	No	No	No	Yes	55
P	No	No	No	Yes	No	39
P	No	No	Yes	No	No	18
P	No	No	Yes	No	Yes	11
P	No	Yes	No	No	No	22
P	No	Yes	No	No	Yes	11
P	No	Yes	No	Yes	No	2
P	Yes	No	No	No	No	3
P	Yes	No	No	No	Yes	3
P	Yes	No	Yes	No	No	39
P	Yes	No	Yes	No	Yes	12
P	Yes	Yes	No	No	Yes	2
TOTAL						217

Exhibit 3-21
Billing Analysis Sample Used
Post-Censoring
HVAC End-Use Technologies

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	55	18	3	19	2	18	13		9	11	35	7	190
	Adjustable Speed Drives	3								1				4
	Package Terminal A/C							1	10					11
	Set-Back Thermostat	24	7	1	8	1	6	3	1	3	7	8	2	71
	Reflective Window Film	18	5		1	1	3	2		5	3	5		43
	Water Chillers				1									1
	Other HVAC Technologies	1				1	1							3
Retrofit Express Program Total		76	23	3	24	4	22	16	11	15	14	38	7	253
Retrofit Efficiency Options	Adjustable Speed Drives													
	Water Chillers		2											2
	Convert To VAV													
	Cooling Towers													
	High Efficiency Gas Boilers													
	VFD Chillers													
Retrofit Efficiency Options Program Total			2											2
Customized Incentives	Adjustable Speed Drives													
	Water Chillers													
	Customized EMS	1			4									5
	Customized Controls													
	Convert To VAV													
	Other Customized Equip													
	Other HVAC Technologies													
Customized Incentives Program Total		1			4									5
Thermal Energy Storage	Other Customized Equip													
Advanced Perf. Options	Water Chillers													
Total		77	25	3	27	4	22	16	11	15	14	38	7	**259**

Exhibit 3-22
Billing Analysis Sample Used
Post-Censoring
Nonparticipants

Program and Technology Group	Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Nonparticipant Total	105	68	2	28	21	23	23	15	34	25	54	30	**428**

3.3.6 Model Specification

The billing regression analysis for the HVAC Evaluation used two different multivariate regression models under an integrated framework of providing 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 (nonparticipant) group sample. This model estimates a relationship that is then used to forecast what the post-installation-year energy consumption for participants (as a function of pre-installation year usage) would have been in the absence of the program. 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 from the first baseline model 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.

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:

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

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 are the annual change of cooling degree days (base 62°F) between the post-installation year and pre-installation year;

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

β, γ and η 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 1997 analysis period.

They both take the same functional form with different segment-level intercept series and slopes (β and γ):

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

It should be noted that the post-installation predicted usage is not a function of changes that occurred at the premise. As was discussed in *Section 3.1, Sample Design*, the control group was chosen to represent the participant sample with respect to business type and usage. It is very unlikely that the control group could be considered a representative control group for the types of changes that have occurred at the premise, simply because the participants are all installing some type of equipment and only a fraction of the nonparticipants are making changes. Furthermore, participants are installing rebated high efficiency equipment (HVAC, Lighting, and other) through the program, so it is unlikely that the other HVAC and Lighting equipment changes made outside the program are similar to those made by nonparticipants. Finally, it is likely that changes made by participants outside the program will have interaction effects with the measures rebated. Therefore, the incremental effects of participant changes made outside the program on energy usage will be different than those of the nonparticipants. For these reasons, the customer self-reported change variables from the survey data ($Chg_{i,k}$), were not included in the estimate post-installation predicted usage. The SAE model discussed below, did include the customer self-reported change variables to control for the differences between actual and predicted post-installation usage.

Exhibit 3-23 summarizes the final baseline model results that were estimated using 428 nonparticipant customers, as discussed in the *Data Censoring* section. Exhibit 3-23 summarizes the independent variables used in the baseline model, together with the t-statistics and the sample sizes available for each parameter estimate used to predict the post-period usage. The final functional relation is estimated as follows:

Baseline Model (1994 to 1997):

$$\begin{aligned} k\hat{W}h_{97,i} = {} & 1.04 * SM\_OFF4 + 1.06 * OTH\_OFF4 + 1.11 * SM\_RET4 + 1.00 * OTH\_RET4 \\ & + 1.23 * SCHOOL4 + 1.18 * SM\_GRC4 + 1.17 * OTH\_GRC4 + 0.98 * RESTRNT4 \\ & + 1.18 * HOSP4 + 1.13 * HOTMOT4 + 1.28 * WHRSE4 + 1.30 * PERSVC4 \\ & + 1.10 * SM\_COM4 + 1.13 * OTH\_COM4 + 1.36 * MISC4 \\ & - 0.002535 * CDD1_{97-94,i} * kWh_{94,i} - 0.000150 * CDD2_{97-94,i} * kWh_{94,i} \\ & - 0.000006165 * CDD3_{97-94,i} * kWh_{94,i} - 0.000307 * CDD4_{97-94,i} * kWh_{94,i} \\ & - 0.000389 * CDD5_{97-94,i} * kWh_{94,i} - 0.000298 * CDD11_{97-94,i} * kWh_{94,i} \\ & - 0.000041334 * CDD12_{97-94,i} * kWh_{94,i} + 0.000494 * CDD13_{97-94,i} * kWh_{94,i} \\ & - 0.000363 * CDD16_{97-94,i} * kWh_{94,i} \end{aligned}$$

Exhibit 3-23
Billing Regression Analysis Final Baseline Model Outputs

Parameter Descriptions	Analysis Variable Name	Units	Parameter Estimate	t-Statistic	Sample Size
Pre-Usage					
Small Office	SM_OFF4	kWh	1.044147	3.535	49
Large Office	OTH_OFF4	kWh	1.060393	69.987	56
Small Retail	SM_RET4	kWh	1.107020	2.543	41
Large Retail	OTH_RET4	kWh	1.001194	20.511	27
Schools	SCHOOL4	kWh	1.235795	17.186	30
Small Grocery	SM_GRC4	kWh	1.176976	3.098	6
Large Grocery	OTH_GRC4	kWh	1.172005	35.380	15
Restaurant	RESTRNT4	kWh	0.979361	11.391	23
Hospital	HOSP4	kWh	1.175914	41.709	23
Hotel/Motel	HOTMOT4	kWh	1.126563	13.675	25
Warehouse	WHRSE4	kWh	1.278263	24.786	34
Personal Service	PERSVC4	kWh	1.302686	22.802	25
Small Comm. Service	SM_COM4	kWh	1.104953	2.529	34
Large Comm. Servcie	OTH_COM4	kWh	1.133564	25.238	20
Miscellaneous	MISC4	kWh	1.364311	53.663	20
Weather Changes					
Change in CDD CliZone 1	CDD1_74	CDD*kWh	-0.002535	-1.335	9
Change in CDD CliZone 2	CDD2_74	CDD*kWh	-0.000150	-2.388	51
Change in CDD CliZone 3	CDD3_74	CDD*kWh	-0.000006165	-0.063	116
Change in CDD CliZone 4	CDD4_74	CDD*kWh	-0.000307	-5.314	38
Change in CDD CliZone 5	CDD5_74	CDD*kWh	-0.000389	-4.079	26
Change in CDD CliZone 11	CDD11_74	CDD*kWh	-0.000298	-0.644	51
Change in CDD CliZone 12	CDD12_74	CDD*kWh	-0.000041334	-0.469	74
Change in CDD CliZone 13	CDD13_74	CDD*kWh	0.000494	1.927	59
Change in CDD CliZone 16	CDD16_74	CDD*kWh	-0.000363	-0.066	4
Other Site Changes					
Lighting Changes	LIT_CHG4	kWh	0.073123	2.357	41
HVAC Changes	HVC_CHG4	kWh	-0.237771	-10.514	53
Other Equipment Changes	OTHR4	kWh	0.128064	1.326	19
Employee Changes	EMP_CHG4	# Emp*kWh	346.394623	3.473	70

Participant 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:

$$kWh_{97,i} - k\hat{W}h_{97,i} = kWh_{97,i} - F_{94}(kWh_{94}, \Delta CDD) = \sum_m \beta_m^{'} Eng_m + \sum_k \eta_k^{'} Chg_{i,k} + \mu_i$$

The difference between predicted and actual usage in 1997 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 of the actual usage from the predicted usage. As discussed above, the predicted usage is estimated using only the comparison group to forecast the 1997 usage as a function of 1994 usage and change of cooling degree days from 1994 to 1997. This usage prediction presents what would have happened in the absence of any changes made at the facility, either rebated or done outside of the program.

3.3.7 Billing Regression Analysis Results

The coefficients of the engineering impact, termed the SAE coefficients, are then 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 3-24 summarizes the final SAE model results that were estimated using 591 participants, as discussed in the *Data Censoring* section. The exhibit illustrates the independent variables used in the SAE model, together with the t-statistics and the sample sizes available for each parameter estimate.

Exhibit 3-24
Gross Billing Regression Analysis Final Model Outputs

Parameter Descriptions	Analysis Variable Name	Units	Parameter Estimate	t-Statistic	Sample Size
SAE Coefficients					
Lighting End Use					
Lighting Offices	LGTOFF4	kWh	-0.796704	-5.494	154
Lighting Schools	LGTSCH4	kWh	-0.886600	-2.339	32
Lighting Hotel/Motel	LGTHOT4	kWh	-0.694864	-5.458	23
Lighting Warehouse	LGTWAR4	kWh	-1.284596	-1.745	18
Lighting Miscellaneous	LGTMSC4	kWh	-1.461133	-3.928	113
HIDs	HID4	kWh	-0.484505	-6.131	28
HVAC End Use					
Retrofit Express Measures	RETX4	kWh	-1.553054	-2.993	248
ASDs	ASD4	kWh	-3.240228	-5.452	4
Custom HVAC	CSTHVC4	kWh	-2.237938	-1.927	8
Other End Uses					
Other Impacts	OTHMEAS4	kWh	-1.693618	-0.937	47
Change Variables					
Lighting Changes	LIT_CHG4	kWh	0.132770	5.463	78
HVAC Changes	HVC_CHG4	kWh	-0.035071	-1.524	87
Other Equipment Changes	OTHR4	kWh	0.073020	0.786	28
Employee Changes	EMP_CHG4	# Emp*kWh	589.214738	2.791	90

The dependent variable is the difference between the actual and predicted 1997 usage using the 1994 baseline model.

SAE coefficients are calculated for 10 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 outside the Lighting and HVAC end uses.

Attempts were made to estimate the SAE coefficients at a finer level of segmentation, but generally either one of two problems were encountered. First, available sample sizes were too small to support a finer level of segmentation. Or second, certain parameters were correlated with each other and needed to be combined into a single parameter (a standard econometric solution to solving the problem of collinearity). For example, it was determined that there was a high incidence of central air conditioners and setback thermostat installations at the same site in office buildings. Therefore, there was enough correlation between the central air conditioners and setback thermostat engineering estimates to warrant combining the two estimates into a single office estimate in the model.

Because of the high incidence of many types of standard HVAC measures being installed at the same premise and some of the low sample sizes, the HVAC analysis was conducted for three distinct technology groupings: ASDs, other RE measures, and other Custom measures. ASDs were modeled separately because the model indicated a highly significant result for ASDs and detected large impacts for the technology. So as not to confound the effects of ASDs with other measures, the ASDs were modeled separately. Other RE measures were modeled separately from Custom measures because the application of the technologies is very different, and there is a lower rate of incidence of RE measures being installed with Custom measures.

All of the HVAC SAE coefficients are significant at the 95 percent confidence level, and all were of the correct sign. As mentioned above, however, the ASD parameter estimate was found to be large, 3.24, indicating that the actual impact was three times as large as the engineering estimate. Because the sample for ASDs consisted of only 4 sites, and because the engineering estimates were based on engineering models (calibrated to the ASD end-use metered data) the SAE results for ASDs were not used. Instead, the calibrated engineering estimates were used as the ex-post energy estimates (which is equivalent to setting the SAE coefficient to one). It should be noted that this approach is Protocol compliant, as the Protocols accept calibrated engineering estimates in lieu of a statistically adjusted engineering impact.

The Custom HVAC segment consists only of Custom EMS and Chiller measures. Because the resulting parameter estimate is considered to be reliable and accurate for these two measures, the SAE coefficient for Custom HVAC was applied to EMS and Chiller measures. However, a conservative approach was taken for the remaining Custom measures that were not represented in the SAE analysis. For those Custom measures not represented in the SAE analysis, the calibrated engineering estimate was used (which is equivalent to setting the SAE coefficient to one, instead of using the 2.24 parameter estimate). As discussed in *Section 3.2*, *Engineering Analysis*, detailed on-site audits and engineering analyses were conducted for all of the custom measures. Therefore, using the calibrated engineering estimates for these measures is protocol compliant, and should be considered a conservative approach.

Impact estimates from the MDSS for other end uses were included in the model for customers that installed measures outside the Lighting and HVAC end uses. It is not recommended that this value be used because the sample may not be representative of the population of participants installing these measures.

In addition to the SAE Coefficients, independent variables were included to capture changes in lighting, HVAC and other equipment, made outside of the program. Of these, only the lighting parameter estimate is significant at the 90 percent confidence level. Another independent variable was included to capture the effects of the number of employees changing at the facility, which was statistically significant.

The final SAE coefficients for the HVAC end use is provided in Exhibit 3-25. The SAE coefficient is multiplied by the evaluation estimates of gross energy impact to calculate the gross ex post energy impacts.

Exhibit 3-25
Commercial HVAC Gross Energy Impact SAE Coefficients
By Business Type and Technology Group

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.
Retrofit Express	Central A/C	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
	Adjustable Speed Drives	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Package Terminal A/C	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
	Set-Back Thermostat	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
	Reflective Window Film	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
	Water Chillers	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24
	Other HVAC Technologies	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
Retrofit Express Program Total													
Retrofit Efficiency Options	Adjustable Speed Drives	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Water Chillers	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24
	Convert To VAV	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Cooling Towers	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	High Efficiency Gas Boilers	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	VFD Chillers	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Retrofit Efficiency Options Program Total													
Customized Incentives	Adjustable Speed Drives	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Water Chillers	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24
	Customized EMS	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24
	Customized Controls	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Convert To VAV	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Other Customized Equip	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Other HVAC Technologies	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Customized Incentives Program Total													
Thermal Energy Storage	Other Customized Equip	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Advanced Perf. Options	Water Chillers	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24	2.24
Total													

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 3-26 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.

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

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:[11]

$$\text{StdErr} = \sqrt{\sum_i \left(CV_i * \beta_i * Eng_i\right)^2}$$

Where,

$CV_i = \frac{std(\beta_i)}{\beta_i}$ 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:

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

Where,

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

Exhibit 3-26 presents the relative precision calculations.

Exhibit 3-26
Relative Precision Calculation

SAE Analysis Level	Gross Engineering Energy Impact (MWh)	SAE Coefficient	t-Statistic	Relative Precision at 80%	Relative Precision at 90%
HVAC End Use					
Retrofit Express Measures	7,996	-1.55	-2.99	-43%	-55%
ASDs	7,767	-3.24	-5.45	-24%	-30%
Custom HVAC	9,045	-2.24	-1.93	-67%	-85%
HVAC Total	24,808	-1.69	-3.44	-37%	-48%

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

3.3.8 Net Billing Analysis

In addition to conducting a billing analysis to estimate gross energy impacts, 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, in that the SAE Model incorporates both participants and nonparticipants into one model.

A disadvantage of combining both participants and nonparticipants into one model of net energy savings is that the resulting sample is not randomly determined. In particular, participants self-select into the program and therefore are unlikely to 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 bias. This method was developed by Heckman (1976, 1979[12]) and is used by others (Goldberg and Train, 1996[13]) to address the problem of self-selection into energy retrofit programs. This assumes that the unobserved factors that are influencing participation are distributed normally. The influence of these unobserved factors on participation can be approximated by including an Inverse Mills Ratio in the model as an explanatory variable. This 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) develop the technique of including a second Inverse 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.

To calculate the Inverse Mills Ratios, a probit model of program participation is estimated separately for the Lighting and HVAC retrofit programs. Once the probit model is estimated, the parameters of the participation model are used to calculate an Inverse Mills Ratio for both participants and nonparticipants. This Mills Ratio is included in a net savings regression that combines both participants and nonparticipants into one model. If the Mills Ratio controls for those unobserved

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[12] 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.

[13] 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.

factors that determine participation (i.e. the self-selection bias), and the other model assumptions are met, then the net savings model will produce unbiased estimates of net savings.

A description of the methods used for this application are given in the following sections. The following sections describe the data and variables used for the probit participation model and give the estimation results. Finally, a description of how the Inverse Mills Ratio is used in the Net Billing Model is discussed, concluding with the estimation results from the Net Billing Model.

Probit Model of Participation

The first stage of calculating the Mills Ratio is to develop a probit model of HVAC Program participation. The probit model is a discrete choice model with a dependent variable of either zero or one indicating whether or not an event occurred. In this application, individuals receive a value of one if they participated in the HVAC Program and a zero otherwise. The sample includes 350 HVAC Program participants and 920 nonparticipants (which includes Lighting participants that did not have HVAC measures rebated), and includes information obtained from the telephone surveys, as well as billing data. All of the 1,270 survey respondents were used to estimate the participation probit for the HVAC Program. For those customers with missing information for any of the explanatory variables, an average value is assigned based on both building type and program participation.

Using the probit specification, the decision to participate in the HVAC Program is given by:

$$\text{PARTICIPATION} = \alpha + \beta' X + \gamma' Y + \varepsilon$$

A description of the explanatory variables is given in Exhibit 3-27. The dependent variable PARTICIPATION has a value of one if the customer participated in the 1996 HVAC Program and a zero if they did not participate. The independent variables used are those characteristics that are likely to influence program participation. The first set of variables (X) used in the participation probit describe the customer's business activity. These consist of indicator variables for various building types. The second group of variables (Y) reflect the building characteristics. These include customer size and energy use as well as recent changes in high energy equipment. Finally, the error term (ε) is assumed to be normally distributed for the probit specification.

Probit Estimation Results

The estimation results for the HVAC probit are given in Exhibit 3-28. For the HVAC probit, customer size as reflected by energy use has a positive impact on program participation, although this estimate is not statistically significant. The variables for building type are all negative and statistically significant, which indicates that there is not a particular building type that make a customer more likely to participate in the HVAC Program. Those that recently purchased cooling equipment (PURCHASE) or had an employment change (EMPCHG) are also less likely to participate. In contrast, those that own their building (OWN) or recently added or removed lighting (ARLIGHT) are most likely to participate. Finally, those facilities where the main cooling equipment is central A/C (CENTAC), individual A/C (INDIVAC), or a combined of central and individual A/C equipment (MIXAC) are all more likely to participate in the HVAC Program.

Exhibit 3-27
Variables Used in HVAC Probit Model

Variable Name	Units	Variable Type	Description
AVGUSE	Kwh	Y	Average monthly electricity use over 1993-1995
ARLIGHT	0,1	Y	Lighting equipment was added and removed since 1/95
COMMSERV	0,1	X	Community service building
EMPCHG	0,1	Y	Employee change by 10 % since 1/95
HEALTH	0,1	X	Health Care Building
HOTEL	0,1	X	Hotel
HVAC95	0,1	Y	HVAC change done in 1995 or later
INDIVAC	0,1	Y	Individual AC units used as main cooling
MIXAC	0,1	Y	Central AC and smaller AC units at facility
MISCCOM	0,1	X	Miscellanious commercial building
OFFICE	0,1	X	Office building
OWN	0,1	Y	Own building
PERSONAL	0,1	X	Personal services building
CENTAC	0,1	Y	Central AC main cooling equipment at facility
RESTRNT	0,1	X	Restaurant
RETAIL	0,1	X	Retail Building
SCHOOL	0,1	X	School
WAREHSE	0,1	X	Warehouse

Once the probit model is estimated, the coefficient estimates are used to calculate the Inverse Mills Ratio for use in the net savings regression. The product of all of the independent variables and respective coefficient estimates are used in the following calculation:

$$\text{Mills Ratio} = \phi(Q) / \Phi(Q) \text{ (for participants)}$$

$$= -\phi(Q) / \Phi(Q) \text{ (for nonparticipants)}$$

Where,

$$Q = \alpha + \beta' X + \gamma' Y$$

The function ϕ is the standard normal probability density function and Φ is the standard normal cumulative density function. Again, this Inverse Mills Ratio is used to control for unobserved factors that may influence both program participation and the amount of energy savings achieved for measures done within the program. In the following sections, the Inverse Mills Ratio is included in the net billing regression as an additional explanatory variable to correct for the problem of self-selection into the HVAC Program.

Exhibit 3-28
HVAC Probit Estimation Results

Variable Name	Units	Variable Type	Coefficient Estimate	Standard Error	Significance Level
AVGUSE	Kwh	Y	0.00	0.00	29%
ARLIGHT	0,1	Y	0.74	0.14	1%
COMMSERV	0,1	X	-1.10	0.18	1%
EMPCHG	0,1	Y	-0.23	0.10	2%
HEALTH	0,1	X	-1.10	0.19	1%
HOTEL	0,1	X	-1.35	0.22	1%
HVAC95	0,1	Y	-0.30	0.11	1%
INDIVAC	0,1	Y	0.59	0.11	1%
MIXAC	0,1	Y	0.57	0.16	1%
MISCCOM	0,1	X	-1.45	0.19	1%
OFFICE	0,1	X	-1.05	0.13	1%
OWN	0,1	Y	0.22	0.09	1%
PERSONAL	0,1	X	-1.16	0.19	1%
CENTAC	0,1	Y	0.41	0.12	1%
RESTRNT	0,1	X	-0.75	0.18	1%
RETAIL	0,1	X	-1.32	0.14	1%
SCHOOL	0,1	X	-1.18	0.15	1%
WAREHSE	0,1	X	-1.36	0.18	1%

Net Billing Model Specification

The net billing regression analysis for the Commercial Program Evaluation uses the same two-stage approach as the gross billing analysis, with three significant differences. In fact, the net billing model uses the exact same model specification as the baseline model (for the first stage). Refer to the previous section for baseline model results. The SAE models differ between the net and gross billing analyses in the following ways:

- Both participants and nonparticipants are used in the net SAE model.
- The Mills Ratios, corresponding to each end use, are included as two separate independent variables.
- The Mills Ratios are also interacted with the engineering impact estimates for each corresponding technology. The engineering impacts alone are not used in the second stage model.

The resulting SAE coefficients on the energy impacts (that have been interacted with the Mills ratios) are then used to adjust the engineering estimates of expected annual energy impacts (the original SAE coefficients) for the entire participant population. This is one estimate of net ex post energy impacts. The net billing analysis model has the following functional form:

$$kWh_{97,i} - k\hat{W}h_{97,i} = kWh_{97,i} - F_{94}(kWh_{94,i}, \Delta CDD_i)$$
$$= \vartheta_1 Mills_{Light,i} + \vartheta_2 Mills_{HVAC,i} + \sum_m \delta_m Mills_{Light,i} * Eng_{Light,m,i}$$
$$+ \sum_m \delta_m Mills_{HVAC,i} * Eng_{HVAC,m,i} + \sum_k \eta_k' Chg_{i,k} + \varepsilon$$

Where,

$kWh_{97,i}$ and $kWh_{94,i}$ are customer i's annualized energy usage for the post- and pre-installation periods, respectively;

ΔCDD_i are the annual change of cooling degree days (base 62°F) between the post-installation year and pre-installation year;

$Chg_{i,k}$ 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;

$Mills_{Light,i}$ is the Mills Ratio for the Lighting end use for customer i;

$Mills_{HVAC,i}$ is the Mills Ratio for the HVAC end use for customer i;

$Eng_{Light,m,i}$ are the engineering impact estimates for Lighting technology m, customer i;

$Eng_{HVAC,m,i}$ are the engineering impact estimates for HVAC technology m, customer i;

ϑ and δ are the coefficients on the individual Mills ratios, and on the Mills ratios interacted with the engineering energy impacts, respectively;

ε is the random error term of the model.

This net SAE model was run with the same set of 428 nonparticipants and 591 participants that were used in the gross billing analysis model. The results of the model are presented below. The parameter estimates, t-statistics and sample sizes are presented for all of the net SAE coefficients and Mills ratios.

It was found that the net billing model results were significant at the 95 percent level for all HVAC measures. The parameter coefficients from the net billing model represent net participation within that technology (having accounted for self-selection). From these estimates, we can now "back out" an estimate of free-ridership, by taking the product of these coefficients with their Mills ratio and dividing by the regression coefficients from the gross model. This equation has the following functional form:

Exhibit 3-29
Net Billing Regression Analysis Final Model Outputs

Parameter Descriptions	Analysis Variable Name	Units	Parameter Estimate	t-Statistic	Sample Size
Mills Ratios					
Lighting	LRMILLS	Unitless	-6852.243796	-0.774	154
HVAC	HRMILLS	Unitless	613.304572	0.079	32
SAE Coefficients					
Lighting End Use					
Lighting Offices	LGTOFFM	Mills * kWh	-0.729372	-4.289	154
Lighting Schools	LGTSCHM	Mills * kWh	-0.955361	-3.154	32
Lighting Hotel/Motel	LGTHOTM	Mills * kWh	-1.501011	-6.006	23
Lighting Warehouse	LGTWARM	Mills * kWh	-1.516367	-1.563	18
Lighting Miscellaneous	LGTMSCM	Mills * kWh	-1.757547	-3.083	113
HIDs	HIDM	Mills * kWh	-1.048963	-6.227	28
HVAC End Use					
Retrofit Express Measures	RETXM	Mills * kWh	-1.121011	-1.989	248
ASDs	ASDM	Mills * kWh	-2.543545	-5.289	4
Custom HVAC	CSTHVCM	Mills * kWh	-1.817877	-1.926	47
Change Variables					
Lighting Changes / Additions	LIT_CHG4	kWh	0.131659	5.470	78
HVAC Changes / Additions	HVC_CHG4	kWh	-0.043436	-1.896	87
Other Equipment Changes	OTHR4	kWh	0.076376	0.816	28
Employee Changes	EMP_CHG4	# Emp*kWh	574.591239	2.700	90

$$(1 - FR)_m = \frac{Mills_m * \delta_m}{\beta_m}$$

Where,

$Mills_m$ is the mean Mills coefficient for all customers with technology m;

β_m is the SAE coefficient from the Gross Billing model for technology m; and,

δ_m is the regression coefficient from the Mills Model 1 regression for technology m.

Exhibit 3-30 illustrates the resulting estimate of net, or one minus free-ridership.

Exhibit 3-30
Net Billing Regression Analysis Estimates of (1-FR)

Parameter Descriptions	Mills Model 1		Gross Model		From Probit	Resulting (1-FR)
	Variable Name	Parameter Estimate	Variable Name	Parameter Estimate	Mean Mills	
HVAC End Use						
Retrofit Express Measures	RETXM	-1.121011	RETX4	-1.553054	1.05816	0.76379
ASDs	ASDM	-2.543545	ASD4	-3.240228	1.18892	0.93329
Custom HVAC	CSTHVCM	-1.817877	CSTHVC4	-2.237938	1.26834	1.03027

Because the net billing model produced statistically significant coefficients at the 95 percent confidence level for all HVAC measures, the estimates of (1-FR) were incorporated into the final net ex post energy impact estimates. Although the values from the net billing model were not actually applied in the net-to-gross adjustments; they were used to verify similar results found in the self-report and nested logit analyses discussed next, in *Section 3-4.*

3.4 NET-TO-GROSS ANALYSIS

An important step in estimating total impacts from the HVAC Program is the calculation of net to gross ratios. Estimated net to gross ratios represent the proportion of net participants in the program. A net participant is defined to be a customer who engaged in retrofit activities as a direct result of the program. In order to calculate a net to gross ratio, estimates of both free ridership and spillover resulting from the program must be made.

The methods used to derive net-to-gross (NTG) results for the HVAC 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. A third approach for estimating free ridership using a net billing model was discussed in the previous section. Finally, a comparison of the three sets of results is presented along with the final selection of NTG ratios.

3.4.1 Data Sources

The primary data sources used in the net-to-gross analysis include the 808 HVAC and lighting participant, 462 nonparticipant and 3,796 canvass telephone surveys collected in 1997. Other data used in this analysis include the MDSS, CIS, and information from the Advice Filings.

3.4.2 Self-report Methods

Self-report Method for Scoring Free Ridership

The following discussion explains the methods employed to calculate "self-report" estimates of free ridership amongst program participants (as opposed to "modeled" free ridership estimates based on the discrete choice model). Definitions used for free ridership and net participation among the participant population are presented. Specific scoring algorithms and questions used to identify free riders in the participant survey are also discussed.

<u>Overview of Methodology</u>

Participants involved in the CEEI retrofit program can be classified into four basic categories depending on the actions they would have taken in the absence of the CEEI program:

1. In the absence of the CEEI program, the participant would not have installed any new equipment

2. In the absence of the CEEI program, the participant would have installed standard efficiency equipment

3. In the absence of the CEEI program, the participant would have installed high efficiency equipment, but not as soon (more than one year later)

4. In the absence of the CEEI program, the participant would have installed high efficiency equipment at the same time (within the year)

Customers who fall into the first three categories can be considered net program participants. Customers who fall into the fourth category should be considered free riders. The self-report estimates of free ridership were based on these four categories. Data used to calculate the self-report free ridership estimates was collected as part of a telephone survey of CEEI program participants. The survey collected information on the participants' likely HVAC retrofit behavior, with regards to the CEEI program. Responses consistent with category 4 were counted towards free ridership. Responses consistent with categories one through three were counted towards net participation.

The questions used to classify responses directly reflect the definitions of net participation and free ridership presented above. Respondents were asked what they would have done in the absence of the program. They were asked whether or not they would have adopted high efficiency equipment, and when they would have installed that equipment. Generally, the answers to both of these questions allowed the responses to be classified based on the categories described above. Specific scoring algorithms and the exact text of the corresponding questions are presented below.

Raw results from the self-report free ridership estimates were weighted by the avoided cost associated with a given respondent. Results of the weighted self-report free ridership estimates were then calculated for each technology group. Results are presented at the technology group level, allowing differences in free ridership rates by technology to be examined.

Scoring Method and Scoring Algorithms

Responses were initially scored based on the following questions:

pd310	*Which of the following statements best describes actions your firm would have undertaken had the HVAC Program NOT existed...* 1 = We would not have changed our HVAC system 2 = We would have bought high-efficiency HVAC equipment 3 = We would have bought standard efficiency HVAC 8 = (Refused) 9 = (Don't Know)
pd315	*Which of the following statements best describes your firm's plans to install HIGH EFFICIENCY HVAC had the program NOT existed...* 1 = We would have installed high efficiency HVAC at the same time we did it through the program 2 = We would have installed high efficiency HVAC within the year 3 = We would have installed high efficiency HVAC, but not within the year 4 = We wouldn't have installed high efficiency HVAC at all 8 = (Refused) 9 = (Don't Know)

A response counted towards **net participation** (consistent with categories 1 through 3) if:

pd310 = 1 or 3

pd310 = 2 AND pd315 = 4

pd310 = 2 AND pd315 = 3

Under the first condition, the respondent indicated that, in the absence of the program, they would have made no equipment changes, or would have installed standard efficiency equipment.

Under the second and third conditions, the respondents first indicated that, had the program not existed, they would have bought high efficiency equipment. Under the third condition, they subsequently indicated that they would not have installed high efficiency equipment had the program not existed. Under the fourth condition, they subsequently indicated that, had the program not existed, they would have installed high efficiency equipment, but not within the year.

A response counted towards **free ridership** if:

pd310 = 2 AND pd315 = 1 or 2

Under this condition the respondent indicated that, in the absence of the program, they would have bought high efficiency equipment, and would have installed it at the same time, or within the year.

If the participant answered "don't know" or refused to give a response to question pd310, their responses were reclassified according to a second set of questions:

pd300	*Before you knew about the HVAC Program, which of the following statements best describes your company's plans to install HVAC fixtures? (READ RESPONSES).* 1 = You hadn't even considered purchasing new HVAC equipment. 2 = You were interested in installing HVAC equipment, but hadn't yet decided on energy efficient lighting. (i.e. you were considering all your options.) 3 = You had already decided to install HIGH efficiency HVAC, but probably not within the year. 4 = You had already decided to install HIGH efficiency HVAC within the year. 8 = (Refused) 9 = (Don't Know)

A response counted toward **net participation** if:

pd300 = 1 or 3

Under this condition, the respondent indicated that, before they knew about the program, they hadn't even considered purchasing high efficiency equipment, or were planning on purchasing high efficiency equipment, but not within the year.

A response counted toward **free ridership** if:

pd300 = 4

Under this condition, the respondent indicated that, before he knew about the program, he had already decided to install high efficiency equipment within the year.

If the answer to pd300 was also a "don't know" or "refused," a third set of questions was used:

pd250	*If you had not replaced this equipment under the program how long would you have waited to replace it?* 1 = You would have replaced the equipment at the same time 2 = You would have replaced the equipment at a year or within a year

	3 = You would have replaced the equipment more than a year later 4 = You would not have replaced the equipment at all

The response counted towards **net participation** if:

pd250 = 3 or 4

In other words, the respondent indicated that, if they had not replaced their equipment under the program, they would have replaced it at least a year later, or not at all.

The response was not used if :

pd250 = 1 or 2

In this case, the respondent indicated that, had they not replaced the equipment under the program, they would have made the replacement at the same time, or within the year. However, it is unclear whether this question applies to new high efficiency equipment or new standard efficiency equipment. For this reason, the additional condition will not be used.

The scoring routine described above classified responses in accordance with the four categories described at the beginning of this section. Respondents who indicated that, in the absence of the program, they 1) would not have done a retrofit; 2) would have bought standard efficiency equipment instead; or 3) would have installed high efficiency equipment, but at a later time; were counted as net participants. Customers who fit the fourth classification; those who, in the absence of the program, would have installed high efficiency equipment at the same time, were counted as free riders.

If the initial combination of questions (pd310 and pd315), could not classify a response because of a "don't know" or a "refusal" response, then the responses to the additional questions were used. The pd300 questions made almost the same distinctions as the previous questions. The only difference is that the respondent was asked what they intended to do "before they knew about the retrofit program," as opposed to what they would have done "in the absence of the program." The pd250 questions determined when those responding to the additional classification questions would have made the retrofit.

In the absence of a clear response to the first set of questions, the additional classification questions served as an appropriate way to assign responses to one of the four categories described at the beginning of this section. The form of the additional questions was very similar to that of the initial questions.

Data Sources

Data used in deriving the self-report estimates of free ridership included responses from 808 completed telephone surveys of CEEI program participants. The responses included 350 HVAC end use adopters. The surveys were conducted between July and September of 1997 as part of a comprehensive telephone survey of CEEI program participants.

HVAC Results

Self-reported estimates of free ridership are presented below by technology group. The technology group with the lowest rate of free ridership was the Other Custom Measures category, comprised of Customized Incentives actions implemented by the respondents. The rate for this group was estimated to be 7.8%. The highest rate of free ridership was observed in the Energy Management System group, with a rate of 91.4%. These free ridership rates were developed within technology group by weighting by each site's avoided cost associated with the technology retrofit.

Exhibit 3-31
Weighted Self-report Estimates of Free Ridership
for HVAC Technology Groups
in the 1996 CEEI Program

Technology Group	Sample	Free Ridership
Adjustable Speed Drives	11	86.8%
Central Air Conditioning	223	56.0%
Energy Management System	8	91.4%
Other Custom Measures	6	7.8%
Other HVAC	4	47.0%
Package Air Conditioners	15	52.2%
Set Back Thermostats	87	62.3%
Water Chiller	8	79.8%
Reflective Window Film	74	30.2%

Self-report Method for Scoring Spillover

In determining the total net-to-gross ratio for the CEEI program, spillover impacts resulting from the program must be estimated for both program participants and nonparticipants. The overall impact of spillover represents an additional social benefit from the CEEI program, contributing towards total market transformation. The following discussion explains the methods employed to calculate "self-report" estimates of spillover amongst program participants and nonparticipants (as opposed to "modeled" spillover estimates based on the discrete choice model). Definitions used for spillover and net participation among the participant and nonparticipant population are presented. Specific scoring algorithms, and questions used to identify spillover in the participant and nonparticipant surveys are also discussed. The final calculation of these impacts is also described.

Overview of Methodology

The self-report methodology is composed of three steps:

- Identification of the spillover rate
- Calculation of the impact per unit of spillover

- Estimation of the spillover contribution to the net-to-gross ratio

The spillover rate is simply the percentage of the participant or nonparticipant population that is identified as being influenced by the CEEI program to install non-rebated high-efficiency equipment. The spillover rate is estimated using self-reported survey results, as described below. Multiplying the participant or nonparticipant population by the respective spillover rate provides an estimate of the total number of participants or nonparticipants influenced by the CEEI program to install non-rebated high-efficiency equipment.

To estimate the contribution towards the net-to-gross ratio represented by these participants and nonparticipants, a per participant or nonparticipant estimate of impact is required. The per unit impact estimate is based on the equipment installed as reported in the surveys, as described below. The contribution of spillover to the net-to-gross ratio can then be estimated as:

Participant Spillover:

NTGpart_spill = SP_RATEpart * POPpart*IMPACTpart_spill/IMPACTpop

Where,

NTGpart_spill = the participant contribution of spillover to the net-to-gross ratio

SP_RATEpart = the participant spillover rate

POPpart = the participant population, in number of sites

IMPACTpart_spill = the per participant site impact associated with spillover

IMPACTpop = the total CEEI Program impact

Nonparticipant Spillover:

NTGnp_spill = SP_RATEnp * POPnp*IMPACTnp_spill/IMPACTpop

Where,

NTGnp_spill = the nonparticipant contribution of spillover to the net-to-gross ratio

SP_RATEnp = the nonparticipant spillover rate

POPnp = the nonparticipant population, in number of sites

IMPACTnp_spill = the per nonparticipant site impact associated with spillover

IMPACTpop = the total CEEI program impact

Identification of the Spillover Rate

The participant and nonparticipant spillover rates were estimated as the percentage of participants or nonparticipants surveyed that indicated that they were influenced by the CEEI program to install non-rebated high-efficiency equipment.

In general, a spillover action was defined as any action taken outside of the program which increases energy efficiency, and occurred as a direct result of the program' s influence. In counting the total number of surveyed participants and nonparticipants contributing towards spillover, the following three conditions, which reflect this definition of spillover, were used:

1. the action involved the installation of **high efficiency equipment**, as recognized by the CEEI program

2. the action was **not rebated** as part of the program

3. the respondent stated that this action was taken as a result of the **CEEI program's influence**

In other words, the respondent's knowledge of, awareness of, or participation in the CEEI program encouraged them to install high efficiency equipment outside the program.

After identifying all the equipment adoptions which meet the spillover criteria, the spillover rate was calculated by dividing the total number of spillover adoptions for each end use against the total population surveyed. This was done for both participants and nonparticipants.

Identifying Participant Spillover Actions

The three spillover conditions were evaluated in the participant survey by using the following questions:

For Condition 1:

Questions cr020 and cr099 were used to determine whether or not additional, program qualifying, high efficiency HVAC equipment was installed. If an HVAC response qualified as a spillover, it was checked against a series of questions to ensure that it was a high efficiency installation. The text for these questions were as follows:

cr020	*Since January 1995, did you add to, replace, or remove any cooling equipment?*
cr099	*What type of units were added?*
Vseries	*Just to confirm, the additional HVAC "EQUIPMENT TYPE" was high efficiency?*

For Condition 2:

Question cr060 was used to determine whether or not additional participant HVAC installations were rebated. The question text for cr060 was as follows:

cr060	*Was your firm paid a rebate by PG&E for these changes in your HVAC equipment ?*

For Condition 3:

The third condition, whether or not the program influenced the respondents equipment selection, was tested with question sp110. Only those respondents who met the first two criteria were asked the final spillover question.[14] Because of this design, spillover could be calculated based solely on the response to question sp110 for HVAC adoptions. The question text for sp110 was as follows:

sp110	*Did your participation in the Retrofit Express and Customized Incentives program at all influence your additional HVAC equipment selection?*

Participant Spillover Scoring Algorithm

The final scoring algorithm for participant spillover was based on question sp110. This question was used because, as explained above, it was only asked of respondents who had already met the first two spillover criteria. The scoring algorithm is as follows:

If sp110 = 1 then spillover = 1

else spillover = 0

If a respondent scores a 1 for spillover, they have met all three spillover conditions set forth above. As described above, the total number of spillovers counted using this algorithm was divided by the total number of participant's surveyed to obtain the participant spillover rate.

14 Respondents who answered this question, but installed standard efficiency equipment types were not counted as spillover. Again, no one who was rebated was allowed to respond to this question.

Participant Self-report Spillover Results

Of the 808 HVAC and lighting participants surveyed, a total of 23 participants were identified as contributing to HVAC spillover. This results in a participant spillover rate of 2.8%. Because there were a total of 5,230 participants, this is equivalent to a total of 149 participant spillover HVAC actions.

Identifying Nonparticipant Spillover Actions

For Condition 1:

As with the participant spillover, questions cr020 and cr099 were used to determine whether or not additional HVAC equipment was installed. In addition, a series of questions were asked to determine if the HVAC equipment was high efficiency. The text for these questions and their response values were identical to the ones used in calculating the participant spillover. The text can be found in the explanation of the participant spillover methodology given in the preceding section.

For Condition 2:

Question cr060 was used to determine whether or not additional nonparticipant HVAC installations were rebated. The text for this question was identical to the one used in calculating the participant spillover. The text can be found in the explanation of the participant spillover methodology given in the preceding section.

For Condition 3:

The third condition, whether or not the program influenced the respondents equipment selection, was tested with question sp180. Only those respondents who met the first two criteria were asked the final spillover question. Because of this design, spillover could be calculated based solely on the response to question sp180. This question was used to evaluate the third spillover criterion, as follows:

sp180	*Did your knowledge of the Retrofit program at all influence your additional HVAC equipment selection?*

Nonparticipant Spillover Scoring Algorithm

The final scoring algorithm for nonparticipant spillover was based on question sp180. This question was used because, as explained above, it was only asked of respondents who had already met the first two spillover criteria. The scoring algorithm is as follows:

If sp180 = 1 then spillover = 1

else spillover = 0

If a respondent scores a 1 for spillover, they have met all three spillover conditions set forth above.

As described above, the total number of spillovers counted using this algorithm was divided by the total number of nonparticipant's surveyed to obtain the nonparticipant spillover rate.

Nonparticipant Self-report Spillover Results

Of the 4,258 nonparticipants surveyed, a total of 4 nonparticipants were identified as contributing to HVAC spillover. Because nonparticipants reported installations that spanned approximately a 3 year period (since 1995), the spillover rate was divided by 3 to correspond only to 1996. This results in a nonparticipant spillover rate of 0.03%.

From PG&E's 1996 CIS, there were 413,898 unique sites identified, resulting in a total of 408,668 nonparticipant sites less the 5,230 participants. Therefore, because there were a total of 408,668 nonparticipants, the spillover rate is equivalent to a total of 128 nonparticipant spillover HVAC actions.

Calculation of Impacts Associated With Spillover

In order to calculate the impacts associated with spillover, self-reported installation information was used. The reported equipment type and number of units installed from the telephone surveys were used to estimate an impact for each installation occurring outside of the program. From these estimates, the average impact associated with spillover could be calculated.

Participant Spillover Impact Calculation

A total of 23 participants were identified as contributing to spillover. Of these 23, 22 provided valid equipment type information and the number of units installed. To calculate the impacts associated with spillover, avoided cost was used as a proxy for impact. The MDSS was used to determine what the average avoided cost per unit installed was, by equipment type. By multiplying the average avoided cost per unit by the number of units installed, an estimate of avoided cost could be calculated for each of the 22 participant installations.

Exhibit 3-32 below, presents the 23 participant installations identified as contributing to spillover, along with the estimate of avoided cost for the 22 installations that provided valid information. As discussed above, the average avoided cost per unit was estimated using the MDSS. Based on these 22 participant installations, the average avoided cost per participant was estimated at $8,138.

Exhibit 3-32
Participant Spillover Adoptions

Equipment Type	# units	Per Unit Av Cost	Total Av Cost
Adjustable Speed Drives	1	$12,088	$12,088
Controls: Set Back	1	$851	$851
Evaporative Cooler	1	$1,931	$1,931
Other	10		$0
Package Terminal	5	$122	$609
Package Terminal	3	$122	$365
Package Terminal	1	$122	$122
Single Package A/C	6	$570	$3,421
Single Package A/C	4	$570	$2,281
Single Package A/C	5	$570	$2,851
Single Package A/C	5	$570	$2,851
Single Package A/C	2	$570	$1,140
Single Package A/C	6	$570	$3,421
Single Package A/C	12	$570	$6,842
Single Package A/C	6	$570	$3,421
Single Package A/C	6	$570	$3,421
Single Package A/C	6	$570	$3,421
Split System A/C	6	$579	$3,472
Split System A/C	15	$579	$8,681
Split System A/C	2	$579	$1,157
Water Chiller	2	$20,646	$41,293
Water Chiller	3	$20,646	$61,939
Window Film	5000	$3	$13,448

<u>Nonparticipant Spillover Impact Calculation</u>

Only a total of four nonparticipants were identified as contributing to spillover. Of these four, only three provided valid equipment type information and the number of units installed. Instead of using only the three responses, it was assumed that a high-efficiency installation that was influenced by the program was the same as one that was not influenced by the program. There were a total of 155 high-efficiency installations, for which valid responses were obtained for equipment type and number of units installed. Therefore, these 155 installations were used to estimate the average nonparticipant impact associated with spillover.

To calculate the impacts associated with spillover, avoided cost was used as a proxy for impact. The MDSS was used to determine what the average avoided cost per unit installed was, by equipment type. The 155 nonparticipant installations were used to determine the average number of units installed by equipment type. Multiplying the number of units by the average avoided cost per unit from the MDSS gives an estimate of the average avoided cost per nonparticipant installation by equipment type. The 155 nonparticipant installations were then used to determine the distribution of installations across equipment type. Using this distribution, the overall average avoided cost per nonparticipant installation could be estimated.

Exhibit 3-33 below, presents the average avoided cost per nonparticipant install by equipment type, along with the distribution of installations across equipment type. As discussed above, the average avoided cost by equipment type is based on the average number of units installed from the 155 nonparticipant adopters and the average avoided cost per unit from the MDSS. Based on distribution of the 155 nonparticipant installations, the average avoided cost per nonparticipant was estimated at $5,904. It should be noted that the average avoided cost associated with a nonparticipant installation contributing towards spillover was just 73% of the average avoided cost associated with a participant installation contributing towards spillover.

Exhibit 3-33
Nonparticipant Adoption Distribution

Equipment Type	*Ave # Units Per NP Install*	*Per Unit Av Cost*	*Ave Av Cost Per Install*	*Distribution of Installs*
Split System A/C	4	$579	$2,213	11%
Single Package A/C	2	$570	$1,064	39%
Package Terminal	4	$122	$460	12%
Condensing units	1	$8,809	$8,809	2%
Evaporative Coolers	1	$1,931	$2,840	22%
Water Chillers	2	$20,646	$41,293	7%
Evaporative Condensers	6	$8,809	$48,451	1%
Window Film	125	$3	$336	1%
Cooling Towers	3	$36,082	$108,245	1%
EMS	1	$17,727	$17,727	1%
Set Back	2	$851	$1,702	4%

<u>Calculating the Contribution of Spillover to the Total Net to Gross Ratio</u>

As discussed above, the contribution of spillover to the total net-to-gross ratio can be estimated as follows:

Participant Spillover:

NTGpart_spill = SP_RATEpart * POPpart*AV_COSTpart_spill/AV_COSTpop

Where,

NTGpart_spill = the participant contribution of spillover to the net-to-gross ratio

SP_RATEpart = the participant spillover rate

POPpart = the participant population, in number of sites

AV_COSTpart = the per participant site avoided cost associated with spillover

AV_COSTpop = the total avoided cost for the CEEI program

Nonparticipant Spillover:

NTGnp_spill = SP_RATEnp * POPnp*AV_COSTnp_spill/ AV_COSTpop

Where,

NTGnp_spill = the nonparticipant contribution of spillover to the net-to-gross ratio

SP_RATEnp = the nonparticipant spillover rate

POPnp = the nonparticipant population, in number of sites

AV_COSTnp = the per nonparticipant site avoided cost associated with spillover

AV_COSTpop = the total avoided cost for the CEEI program

These equations are identical to those presented earlier, with the exception of using avoided cost as a proxy for impact. Each of the components to calculating the contribution to participant and nonparticipant spillover have been identified and are discussed above, except for the total avoided cost. The total avoided cost as reported in the MDSS is $11,865,829 for HVAC.

<u>Participant Spillover NTG Calculation</u>

Exhibit 3-34 presents the participant spillover contribution to the net-to-gross ratio applying the equation above and using all of the previously described results. The total resulting contribution to the net-to-gross ratio made by participants is 10.21%.

Exhibit 3-34
Participant Spillover Estimate

Avoided Cost Per Participant	$8,138
Spillover Rate	3%
Number of Participants	5,230
Number Contributing to Spillover	149
Spillover Avoided Cost	$1,211,468
HVAC Avoided Cost	$11,865,829
NTG Contribution from Participant Spillover	**10.21%**

Nonparticipant Spillover NTG Calculation

Exhibit 3-35 presents the nonparticipant spillover contribution to the net-to-gross ratio applying the equation above and using all of the previously described results. The total resulting contribution to the net-to-gross ratio made by nonparticipants is 6.41%.

Exhibit 3-35
Nonparticipant Spillover Estimate

Avoided Cost Per Nonparticipant	$5,940
Spillover Rate	0.03%
Number of Nonparticipants	408,668
Number Contributing to Spillover	128
Spillover Avoided Cost	$760,142
HVAC Avoided Cost	$11,865,829
NTG Contribution from NonparticipantSpillover	**6.41%**

3.4.3 Discrete Choice Model

A two-stage discrete choice model is used to simulate the decision to purchase commercial HVAC equipment. The results of this model are used to estimate a net-to-gross ratio as well as spillover and free ridership rates associated with the HVAC Program. This section contains a detailed description of the two stage model used in the discrete choice analysis.

The probability of purchasing any given equipment option A can be expressed as the product of two separate probabilities: the probability that a purchase is made multiplied by the probability that equipment option A is chosen given that a purchase has been made. This can be written as:

*Prob (Purchase & Equipment A) = Prob(Purchase) * Prob(Equipment A | Purchase)*

The two stage model adopted for this analysis estimates both of the right hand side probabilities separately. The first stage of the model estimates the probability that a customer makes an HVAC equipment purchase and is referred to as the **purchase probability**. The second stage of the model estimates the type of HVAC equipment chosen given that the decision to purchase has already been made and is referred to as the **equipment choice probability**. The product of the purchase probability and the equipment choice probability is the **total probability** and reflects the probability that any one HVAC equipment option is purchased. Once estimated, the model is used to determine the probability of purchasing high-efficiency equipment in the absence of the HVAC Program. This is simulated by setting both the rebate and program awareness variables to zero in both stages of the model.

The net-to-gross ratio is calculated using the total probability of purchasing high-efficiency HVAC equipment both with and without the existence of the retrofit program. The expected impact with the program is the total probability of choosing high-efficiency equipment multiplied by the energy impact of the equipment. Similarly, the expected energy impact in the absence of the HVAC Program is the total 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 spillover.

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 a purchase and nonpurchase group. Those that purchased HVAC equipment either in or outside the program are in the purchase group, while those that made no purchases are in the nonpurchase group.

The sample used to estimate the purchase model contains information on 2,777 customers. Of these, 2,387 are nonparticipants that did not make any HVAC equipment purchases either in or outside the program. Of those that did make HVAC equipment purchases, 222 customers did so within the HVAC Program. An additional 77 customers purchased high-efficiency HVAC equipment outside the program. Finally, 91 customers reported purchasing standard HVAC equipment.

Stage 1 -- Purchase Model Specification

The purchase decision is specified as a logit model with a dependent variable having a value of either zero or one. In this application, customers are given a value of one if they made an HVAC equipment purchase either in or outside the program and a zero if they did not purchase any HVAC equipment. The purchase decision model specification is defined as:

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

Variable definitions are given in Exhibit 3-36. The explanatory variables X contain information on building type. Building characteristics such as square footage, AC equipment type, and changes to the facility are contained in Y. Variable group Z contains information on rebate and program awareness that capture the effect of the HVAC Program. The error term ε is assumed to be distributed logistic, consistent with the logit model specification.

Exhibit 3-36
Purchase Model Variable Definitions

Variable Name	Units	Variable Type	Description
AWARE	0,1	Z	Aware of program before selecting equipment
ARHEAT	0,1	Y	Lighting equipment was replaced since 1/95
ARLIGHT	0,1	Y	Cooling equipment was replaced since 1/95
CINDEX	ratio	Z	(Incremental Cost - Rebate) / Incremental Cost
COMMSERV	0,1	X	Community service building
EMPCHG	0,1	Y	Employee change by 10 % since 1/95
HEALTH	0,1	X	Health Care Building
HOTEL	0,1	X	Hotel
MISCCOM	0,1	X	Miscellanious commercial building
NOAC	0,1	Y	No AC equipment at facility
OFFICE	0,1	X	Office building
OWN	0,1	Y	Own building
PERSONAL	0,1	X	Personal services building
RESTRNT	0,1	X	Restaurant
RETAIL	0,1	X	Retail Building
SCHOOL	0,1	X	School
SFADD	0,1	Y	Square footage added to facility since 1/95
SQFEET	Square ft.	Y	Square footage of facility
TENACT	0,1	Y	Tenants active in equipment decisions
WAREHOUSE	0,1	X	Warehouse

The variables AWARE and CINDEX are specified to capture the effect of the HVAC Program on the decision to make a purchase. Nonpurchasers are coded as aware (AWARE = 1) if they indicated in the survey that they had heard of PG&E's Retrofit Express Program and were aware that the program covered high-efficiency HVAC equipment. Purchasers are coded as being aware if they indicated that they were aware of the retrofit program before they selected their HVAC equipment. If they became aware of the program after or at the same time they selected the equipment, they are given a value of zero for AWARE. Program awareness is defined in this manner to take into account that the process of shopping for HVAC equipment will result in some customers becoming aware of the HVAC Program. When awareness is set to zero to simulate the absence of the program, only those who started shopping after they became aware of the program will be affected since it is assumed that the program had some influence on their decision to shop for new HVAC equipment. This definition avoids attributing to much importance to program awareness for those customers who were already looking for HVAC equipment when they became aware of the program.

Using this restricted definition of awareness, 51 percent of program participants were aware of the HVAC Program at the time that they selected their HVAC equipment. For those that did not make any HVAC purchases, 13 percent were aware of the program. For the entire sample, 20 percent of the customers were coded as being aware of the HVAC Program.

The variable CINDEX gives the fraction of the incremental cost of the HVAC equipment that is paid by the customer and is defined by the incremental cost of the equipment minus any rebate divided by the incremental cost:

CINDEX = (Incremental Cost – Rebate) / Incremental Cost

For those that did not purchase HVAC equipment or were unaware of the program when the HVAC equipment was selected, the expected rebate is zero. This results in a CINDEX value of one since the entire cost of the measure is paid by the customer. Similarly, for those that made a purchase and are aware of the program, the expected rebate is nonzero and CINDEX takes on a value less than one.

Purchase Model Estimation Results

The estimation results from the purchase model are given in Exhibit 3-37. A likelihood ratio test yields a test statistic of over 2242 with 20 degrees of freedom, which is well above the critical value at any of the conventional levels of significance. In addition, Exhibit 3-37 shows that the estimated probability of making a purchase is high for those customers who made purchases both in and outside the program, which conforms to *a priori* expectations. These factors suggest that the purchase model does have significant explanatory power.

The coefficient estimates from the purchase model are shown in Exhibit 3-37. As expected, the program variables have a positive effect on making an HVAC purchase. The estimate for AWARE is positive and significant, but is relatively low in magnitude. The coefficient estimate for CINDEX is negative. This suggests that the greater the percentage of incremental costs that are paid by the customer, the less attractive it is to make a purchase. Based on the building type coefficient estimates, offices and schools are the only building types that were likely to make an HVAC purchase. Buildings categorized as health, personal, miscellaneous commercial are all less likely to make HVAC purchases. The facility size variable (SQFEET) is negative and small in magnitude, indicating that larger facilities are less likely to make a purchase. The variables reflecting building ownership (OWN) and the role tenants play in equipment decisions (TENACT) also have a positive and significant effect on the likelihood of an HVAC purchase. Not surprisingly, changes to the facility (ARLIGHT, ARHEAT, SFADD, EMPCHG) are also likely to lead to an HVAC equipment purchase.

The estimated model parameters are used to calculate the probability of making an HVAC equipment purchase. With the logit model, the probability of purchasing is given by:

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

$$\text{where } Q = \alpha + \beta' X + \gamma' Y + \vartheta' Z$$

Exhibit 3-37
Purchase Model Estimation Results

Variable Name	Coefficient Estimate	Standard Error	Significance Level
AWARE	0.77	0.15	1%
ARHEAT	1.82	0.34	1%
ARLIGHT	1.20	0.24	1%
CINDEX	-4.97	0.42	1%
COMMSERV	2.27	0.52	1%
EMPCHG	0.38	0.16	2%
HEALTH	1.99	0.47	1%
HOTEL	1.99	0.64	1%
MISCCOM	1.35	0.48	1%
NOAC	-2.82	0.35	1%
OFFICE	1.90	0.44	1%
OWN	1.55	0.22	1%
PERSONAL	1.18	0.49	2%
RESTRNT	1.81	0.49	1%
RETAIL	1.55	0.45	1%
SCHOOL	1.98	0.45	1%
SFADD	0.60	0.25	2%
SQFEET	-0.00	0.00	1%
TENACT	1.03	0.24	1%
WAREHOUSE	1.50	0.50	1%

The estimated probabilities for different customer groups are given in Exhibit 3-38. As expected, HVAC Program participants have a high probability of making an equipment purchase with an estimated purchase probability of 0.65. Conversely, those that did not make any purchases have a low estimated probability of purchasing high-efficiency equipment at 0.09.

The probability of making an HVAC equipment purchase in absence of the program is calculated by removing the effect of the HVAC Program from the purchased decision model. This is done by setting AWARE equal to zero and setting CINDEX equal to one to reflect the absence of a rebate. The probability of making an HVAC purchase is then recalculated 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 absence of the HVAC Program are also given in Exhibit 3-38. In the absence of the HVAC Program, the probability of purchasing HVAC equipment drops from 0.65 to 0.60. This small decrease suggests that customers are purchasing HVAC equipment for reasons other than the existence of the HVAC Program, such as to replace broken cooling equipment. This mirrors the result found in the self report analysis, where 90 percent of those that made an HVAC purchase stated that they would have made the purchase even if the HVAC Program had not existed. A similar effect is found with the estimated purchase probabilities for those that purchase high-efficiency HVAC equipment outside the program. For those purchasing high-efficiency outside the program, removing the program decreases the purchase probability from 0.28 to 0.20.

Exhibit 3-38
Estimated Purchase Probabilities

Customer Group	With Program	Without Program
No Purchase	0.09	0.08
Participants	0.65	0.60
Purchase HE Outside Program	0.28	0.20
Purchase Std Efficiency	0.25	0.21

Stage 2 -- Equipment Choice Model Specification

The second stage of the model is devoted to estimating the probability that a specific HVAC equipment option is chosen given that the decision to purchase HVAC equipment has already been made. This second stage of the model is specified as a conditional logit and is described below.

A conditional logit specification is used to model the equipment choice decision given that the decision has already been made to purchase HVAC equipment. The choice set for the equipment choice model contains three different options: high-efficiency single and split AC units, evaporative coolers, and standard efficiency single and split AC units. These equipment options were selected for the model as they comprised a large portion of the purchases made in and outside the program and were judged to be reasonable substitute technologies. In the logit model, customers are given a value of one for the dependent variable for the option they actually chose and a zero for the remaining two nonchosen alternatives.

A conditional logit model is used to estimate the equipment choice decision. The equipment choice model specification is:

$$\text{EQUIPMENT CHOICE} = \beta'\text{AWARE} + \beta'\text{PREDISP} + \beta'\text{SQFEET} + \beta'\text{CINDEX} + \beta'\text{SAVINGS} + \Sigma\, \beta'\text{BLDTYPE} + \varepsilon$$

Where AWARE = Awareness of the retrofit program

PREDISP = Predisposition towards high-efficiency equipment

SQFEET = Square footage of the facility

CINDEX = (Incremental Cost – Rebate) / Incremental Cost

SAVINGS = Annual dollar amount of electricity savings expected from equipment

BLDTYPE = Vector of dummy variables indicating building type

ε = Random error term assumed logistically distributed.

The explanatory variables used in the equipment choice model are described in Exhibit 3-39. In this stage of the model, a customer is considered aware of the program (AWARE = 1) if he became aware of the program before or at the same time they selected the HVAC equipment. This is slightly different from the definition of awareness used in the purchase model, where a customer is coded as aware only if they became aware before they start shopping for HVAC equipment. Awareness is redefined in the equipment choice model since, although program awareness does not encourage all customers to make a purchase, it will tend to influence more people to purchase high-efficiency if they are aware of the program at the time they make the purchase.

Exhibit 3-39
Equipment Choice Model Variable Definitions

Variable Name	Units	Description
AWARE	0,1	Aware of program at time of purchase
CINDEX	ratio	(Incremental Cost - Rebate) / Incremental Cost
COMMSERV	0,1	Community services building
GROCERY	0,1	Grocery
HEALTH	0,1	Health Care Building
MISCCOM	0,1	Miscellanious commercial building
OFFICE	0,1	Office building
PERSONAL	0,1	Personal services building
PREDISP	0,1	Predispostion to buying high efficiency
RETAIL	0,1	Retail building
RESTRNT	0,1	Restaurant
SAVINGS	0,1	Expected dollar amount of electricity savings
SCHOOL	0,1	School
SQFEET	0,1	Square footage of facility

A characteristic of the conditional logit specification is that variables that do not vary over choices will drop out of the model.[15] For instance, firmographic variables such as size do not vary across the equipment options and therefore cannot be included in the model. One way to avoid this problem is to interact firmographic variables with choice specific dummy variables.

[15] For a fuller explanation of the conditional logit model and its properties, see Greene (1990) pp. 699-703.

This method is used in this application to allow for firm specific variables such as size, building type, and program awareness to influence equipment choice. The variables AWARE, PREDISP, SQFEET, and all of the building type variables are interacted with a dummy variable for the high-efficiency equipment options. As a result, these variables have positive values for two of the three choices and values of zero for the standard efficiency option.

For those that purchased high-efficiency HVAC within the retrofit program, survey information was available that helped identify those customers that might be predisposed to purchasing high-efficiency equipment even if the program did not exist. For those program participants that indicated that they would have installed high-efficiency HVAC even if the program had not existed, the variable PREDISP has a value of one, otherwise PREDISP has a value of zero.

As in the purchase model, cost and rebate information is combined into one variable called CINDEX. As before, CINDEX is determined by calculating the fraction of the cost that the customer must pay for equipment installation after any rebate has been paid. For those that are unaware of the retrofit program and for standard equipment options not covered by the program, CINDEX has a value of one.

Estimation of Cost, Savings, and Rebates

A requirement of the conditional logit specification is that information must be included in the model for all of the choices in the choice set and not just for the option that is actually selected. As a result, data on equipment characteristics is needed for the nonchosen equipment alternatives as well as for the equipment option actually chosen. How this information is calculated for nonchosen equipment alternatives is described below.

For those customers that installed high-efficiency equipment within the HVAC Program, the incremental cost is calculated for the equipment purchased. This is referred to as the **calculated incremental cost** in the discussion below. Along with the calculated incremental cost, savings are calculated using the impact estimate from the MDSS. Rebate amount is also taken from the MDSS.

Incremental costs and savings are also calculated for high-efficiency equipment purchased outside the HVAC Program. Incremental costs and savings are determined using survey information and per unit cost and savings information from the Advice Filings. The per unit incremental cost is multiplied by the number of reported units installed to determine the total incremental cost of the HVAC retrofit. Energy savings are calculated by multiplying the annual energy savings for that technology as given in the Advice Filings by the electricity rate and the number of units installed as reported in the survey.

For those outside the program that reported installing high-efficiency equipment, the equipment is assigned an efficiency rating based on the minimum EER rating required for the program for that technology. Equipment capacity is estimated based on the square footage of the facility. If a customer did not specifically indicate in the survey that the equipment installed outside the program was high-efficiency, then the equipment is assumed to be standard efficiency. This results in a more conservative estimate of nonparticipant spillover. For those that installed standard efficiency equipment, the incremental cost, savings, and rebate values are all set to zero.

For the nonchosen equipment options, cost, savings, and rebate information is assigned based on available data in the MDSS and customer surveys. For each of the HVAC equipment options, the cost per square foot is determined from those who reported installing the technology. Based on these customers, the median incremental cost per square foot is calculated for each technology. Finally, an incremental cost for each nonadopted technology is estimated by multiplying the square footage of the site by the median cost per square foot for that technology. The estimated savings for nonadopted technologies are estimated in a similar manner using the median savings per square foot based on those who reported installing the technology.

To calibrate these estimates, the incremental cost for the equipment actually chosen by the customer is estimated using the method described above. The estimated incremental cost is then compared with the calculated incremental cost for participants. The ratio of the estimated incremental costs to the calculated costs is used as an adjustment factor for the estimated costs and savings for all nonchosen equipment alternatives for that customer. In the event that the calculated incremental cost is greater than the total installation cost reported in the MDSS, the calculated incremental cost is multiplied by the average ratio of the incremental cost to reported installation cost for that technology based on installations found in the MDSS.

Expected rebate amounts are determined using a similar method. The average ratio of rebate to the calculated incremental cost is calculated for program participants for each technology. To get an estimated rebate for those that did not choose the technology, the rebate-to-cost ratio for the technology is multiplied by the estimated incremental cost to get the expected rebate associated with the installation of that equipment option. If a person was unaware of the program, the expected rebate amount is automatically set to zero for all equipment options. The costs, savings, and rebate calculations are summarized below.

Actual Equipment Option Chosen – In Program: Incremental costs and savings are calculated using the reported capacity, efficiency, and number of units installed as reported in the MDSS. Rebate amount is also taken from the MDSS.

Actual Equipment Option Chosen – Outside Program: Incremental costs and savings are calculated using estimated capacity based on square footage and per unit costs and savings information from the Advice Filings.

Non Chosen Equipment Alternatives: Incremental costs are estimated by multiplying the square footage of the facility by the median cost per square foot from the MDSS associated with that technology. Savings are assigned using the same method. Rebate amount is determined by multiplying the expected cost of the technology by the rebate-to-cost ratio for that technology. For those unaware of the retrofit program, rebate is set to zero for all program qualifying equipment options.

Equipment Choice Model Estimation Results

The estimation results for the equipment choice model are given in Exhibit 3-40. The coefficient estimate on CINDEX is negative, indicating that the greater portion of the incremental cost a customer must pay himself, the less attractive the equipment option. However, the estimate is small in magnitude and significant only at the 11 percent level. The estimate for SAVINGS is negative, but small in magnitude.

Exhibit 3-40
Equipment Choice Model Estimation Results

Variable Name	Coefficient Estimate	Standard Error	Significance Level
AWARE	2.98	0.43	1%
CINDEX	-0.70	0.43	11%
COMMSERV	-1.30	0.56	2%
GROCERY	-1.36	0.67	4%
HEALTH	-1.97	0.52	1%
MISCCOM	-0.25	0.56	66%
OFFICE	-1.31	0.38	1%
PERSONAL	-0.12	0.71	87%
PREDISP	0.90	0.57	12%
RETAIL	-0.47	0.42	26%
RESTRNT	0.10	0.70	89%
SAVINGS	-0.00	0.00	1%
SCHOOL	-1.18	0.41	1%
SQFEET	-0.00	0.00	86%

The remaining variables are all interacted with a dummy variable indicating a high-efficiency equipment option. The coefficient estimate on AWARE is positive and significant, indicating that those that are aware of the retrofit program are more likely to purchase high-efficiency equipment. Similarly, the coefficient estimate on PREDISP is positive, indicating that those identified as predisposed to purchasing high-efficiency do in fact tend to choose high-efficiency equipment. The coefficient on PREDISP, however, is lower in magnitude than the estimate for AWARE and is significant at the 12 percent level. SQFEET is the square footage of the facility interacted with a dummy variable for the high-efficiency equipment options. The coefficient estimate on SQFEET is negative and small in magnitude and not statistically significant, indicating that facility size does not significantly effect the choice of high-efficiency equipment. The remaining variables indicate business type. Of these, COMMSERV, GROCERY, HEALTH, and OFFICE have negative coefficient estimates that are statistically significant.

Using the coefficient estimates from the purchase model, the probability of choosing any particular equipment option is calculated. Using the conditional logit density function, the probability of selecting equipment option j is given by:

$$P_j = exp(\beta' X_j) / \Sigma exp(\beta' X)$$

where $\beta' X_j$ is the product of the variables and coefficient estimates used in the equipment choice model for equipment option j and the denominator is the sum of $\beta' X$ across all three equipment options in the choice set.

As is done with the purchase probability, the equipment choice probability is calculated both with and in absence of the program. To simulate the absence of the program, AWARE is set to zero and CINDEX is set to one for all of the HVAC equipment options. For program participants, the probability of choosing high-efficiency equipment is the sum of the individual probabilities for the two high-efficiency options. The probability of choosing a standard equipment is the probability of choosing the remaining standard efficiency option. For participants, the probability of purchasing high-efficiency equipment is 0.62 with the program and falls 60 percent to 0.25 without the program. This suggests that the HVAC Program is having a significant effect on high-efficiency HVAC equipment purchases.

Net-to-Gross Calculation

Once both the purchase probability and the equipment choice probability are estimated, the two probabilities are multiplied together to determine the total probability that a purchase is made and that an individual equipment option is selected. This total probability is calculated twice. First, the total probability is calculated using the original values for the program variables AWARE and CINDEX. This gives the total probability with the existence of the program. Next, the total probability is calculated in absence of the program. This is done by setting AWARE equal to zero and CINDEX equal to one to reflect the absence of rebates. While AWARE is set to zero, PREDISP retains its original value since this variable captures the effect of those that are predisposed to high-efficiency equipment who would likely purchase the equipment even if the HVAC Program did not exist.

The estimated impacts are weighted up to the population based on participation. Participants are weighted to reflect the HVAC Program participation population in the MDSS. Nonparticipants are assigned weights based on the nonparticipant population represented in the sample. For those that reported in the survey of making an HVAC purchase within the last three years, the weight is divided by three to adjust for the fact that only a third of these actions were likely to have been done during the 1996 program year. Finally, those that reported purchasing HVAC outside the program since 1995 and receiving a rebate from PG&E were given a weight of zero since these impacts were already counted toward a program other than the 1996 HVAC Program.

To calculate expected impacts, the total probability of making a purchase with the program is multiplied by the gross impact associated with the technology. The expected impact is then summed across the eight high-efficiency equipment options to get a total expected impact for each customer. The calculation is given by:

$$\text{EXPECTED IMPACT}^{W} = \Sigma\, P^{W}_{j} * \text{IMPACT}_{j}$$

Where P^{W}_{j} = Total probability of choosing equipment option j with the program

IMPACT_{j} = One year impact associate with equipment option j.

The expected impact without the program is calculated in the same manner using the total probability in absence of the program:

$$\text{EXPECTED IMPACT}^{WO} = \Sigma\, P^{WO}_{j} * \text{IMPACT}_{j}$$

Where P^{WO}_{j} = Total probability of choosing equipment option j without the program.

The net impact associated with program is simply the difference in expected impacts with and without the program:

$$\text{NET IMPACT} = \text{EXPECTED IMPACT}^{W} - \text{EXPECTED IMPACT}^{WO}_{j}$$

The net-to-gross ratio is then the net impact divided by the expected impact with the program:

$$\text{NTG} = \text{NET IMPACT} / \text{EXPECTED IMPACT}$$

Both participant and nonparticipant spillover are also calculated using the two stage model. For actions done outside the program, net impacts are calculated using the same method shown above:

$$\text{NET IMPACT}_{P\_SP} = \text{EXPECTED IMPACT}^{W}_{P\_SP} - \text{EXPECTED IMPACT}^{WO}_{P\_SP}$$

$$\text{NET IMPACT}_{NP\_SP} = \text{EXPECTED IMPACT}^{W}_{NP\_SP} - \text{EXPECTED IMPACT}^{WO}_{NP\_SP}$$

Spillover is broken out into participant spillover (P_SP), which reflects actions done by current program participants outside the program, and nonparticipant spillover (NP_SP). The net impact for actions done outside the program is then incorporated into the net-to-gross calculations:

$$\text{NTG} = (\text{NET IMPACT}_{P} + \text{NET IMPACT}_{P\_SP} + \text{NET IMPACT}_{NP\_SP}) / \text{EXPECTED IMPACT}^{W}_{P}$$

Using the above formulas, net-to-gross ratios are calculated for both single and split package air conditioners as well as for evaporative coolers. The combined net-to-gross ratios for both technologies are shown by building type in Exhibit 3-41. The net-to-gross ratios range from 0.37 for warehouses to 1.02 for personal services buildings. For split and single package units, the overall estimated net-to-gross ratio is 0.78 while for evaporative coolers the net-to-gross ratio is 0.67.

Exhibit 3-41
Estimated NTG Ratios by Building Type

Building Type	NTG
Office	0.81
Retail	0.56
College	0.53
Community Serv.	1.00
Grocery	0.77
Restaurant	0.66
Health	0.92
Warehouse	0.37
Personal	1.02
School	0.72
Misc. Comm.	0.54

3.4.4 Final Net-to-Gross Ratios

As mentioned previously, three separate models were implemented to estimate the components of the net-to-gross ratio (free ridership and spillover). The first methodology relied on self-reported estimates of free ridership, participant spillover, and nonparticipant spillover to estimate the net-to-gross ratios. The second approach relied on a net billing regression analysis model and applied the double inverse Mills ratio methodology, which resulted in estimates of free ridership only. The final approach relied on a two-stage discrete choice model to estimate free ridership, participant spillover, and nonparticipant spillover.

The most sophisticated, and preferred, of the three approaches is the two-stage discrete choice model. The Mills ratios lack the estimate of spillover, and are also run on a reduced set of the data due to the censoring of customer billing data. The self-report values rely on customers to provide an unbiased response to their hypothetical actions in the absence of the program. Recall that the discrete choice model was only estimated for the CAC and Other RE (evaporative coolers) technology segments.

Exhibit 3-42 presents the results of each model, by business type, and for the total program. Results (both within business type and overall) are weighted by the ex-post gross energy impacts. The exhibit illustrates the total net-to-gross ratio, as well as the two primary components, free ridership and spillover. For the Mills ratio methodology, only free ridership is presented, as discussed above.

Upon comparison of the three models, it is clear that the discrete choice approach (where the model can be applied) is supported by both the self-report and Mills results. For Other RE Measures (i.e., evaporative coolers) the NTG ratio is within 4 percent of the self-reported results and 30 percent of the Mills results. Finally, spillover for both Evaporative Coolers and CACs is aligned very well with self-reported values.

The free ridership estimates using the Mills approach appears to provide significantly higher estimates of net participation. This in part due to the large net estimates for Water Chillers and Adjustable Speed Drives[16]. However, the Mills results for Custom EMS and Water Chillers should be excluded from estimates of (1-FR) because we believe free ridership is biased towards large customers. Because large customers are not included in the SAE model, free ridership will be underestimated in the Mills results for these segments.

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[16] It should be noted that values greater than one for the (1-FR) term from the Mills approach should be considered invalid (i.e., negative free ridership). Recall that these values are estimated as a ratio of the Mills SAE Coefficients and the Gross SAE Coefficients. Therefore, there is a considerable amount of error surrounding these estimates, since the variance incorporates the error from both the Mills and the Gross SAE Coefficients.

Exhibit 3-42
Comparison of Net-to-Gross Ratios

Program and Technology Group		Self Report NTG	Self Report 1-FR	Self Report Spill	Discrete Choice Model* NTG	Discrete Choice Model* 1-FR	Discrete Choice Model* Spill	Mills* 1-FR
Retrofit Express	Central A/C	0.61	0.44	0.17	0.78	0.62	0.16	0.76
	Adjustable Speed Drives	0.30	0.13	0.17	-	-	-	0.93
	Package Terminal A/C	0.64	0.48	0.17	-	-	-	0.76
	Set-Back Thermostat	0.54	0.38	0.17	-	-	-	0.76
	Reflective Window Film	0.86	0.70	0.17	-	-	-	0.76
	Water Chillers	0.37	0.20	0.17	-	-	-	1.03
	Other HVAC Technologies	0.70	0.53	0.17	0.67	0.53	0.14	0.76
Retrofit Express Program Total		0.58	0.42	0.17	0.60	0.44	0.17	0.82
Retrofit Efficiency Options	Adjustable Speed Drives	0.30	0.13	0.17	-	-	-	0.93
	Water Chillers	0.37	0.20	0.17	-	-	-	1.03
	Convert To VAV	1.09	0.92	0.17	-	-	-	-
	Cooling Towers	1.09	0.92	0.17	-	-	-	-
	High Efficiency Gas Boilers	-	-	-	-	-	-	-
	VFD Chillers	1.09	0.92	0.17	-	-	-	-
Retrofit Efficiency Options Program Total		0.46	0.30	0.17	-	-	-	0.99
Customized Incentives	Adjustable Speed Drives	0.30	0.13	0.17	-	-	-	0.93
	Water Chillers	0.37	0.20	0.17	-	-	-	1.03
	Customized EMS	0.25	0.09	0.17	-	-	-	1.03
	Customized Controls	1.09	0.92	0.17	-	-	-	-
	Convert To VAV	1.09	0.92	0.17	-	-	-	-
	Other Customized Equip	1.09	0.92	0.17	-	-	-	-
	Other HVAC Technologies	1.09	0.92	0.17	-	-	-	-
Customized Incentives Program Total		0.51	0.35	0.17	-	-	-	0.98
Thermal Energy Storage		-	-	-	-	-	-	-
Advanced Performance Options		0.30	0.13	0.17	-	-	-	1.03
TOTAL		0.53	0.37	0.17	0.54	0.37	0.17	0.90

* Totals calculated by applying self-reported values for segments not estimated for Mills or Discrete Choice Approach.

For example, there is one particularly large customer in the Customized EMS segment that was excluded from the SAE model. This customer was the only EMS participant to report being a free rider, yet significantly contributed to the much lower observed self-report value because of that customer's overall contribution to total avoided costs. Comparing the two Customized EMS results, the self-report estimate of 0.09 is significantly lower than the Mills estimate of 1.03. One can see how much influence this customer has.

For the same reasons that the gross billing model SAE coefficients weren't used, the ASD results should also be excluded from estimates of (1-FR).

Final NTG

The resulting net-to-gross ratios that were applied to the gross ex-post impacts are based on two models: the discrete choice model and the self report model.

The discrete choice estimates for CAC technologies and RE Other HVAC technologies were considered to be the most accurate, and were substantiated by the other two methods. To be both conservative and consistent, the self-report estimates of NTG were applied to the remaining HVAC technology segments.

Based on the discussions above, the only technologies for which we could apply the Mills estimates of (1-FR) are the RE segments set-back programmable thermostats, window film, and PTAC. In all but the case of window film, the Mills results are significantly larger than the estimates of (1-FR) derived in the self-report model. Additionally, the self-report method was conducted at a finer level of segmentation, and was thus selected over the Mills results. This is consistent with the most conservative approach.

Overall program net-to-gross ratio are presented, weighted across business type by ex-post gross energy, demand and therm savings, respectively, in Exhibit 3-43.

Exhibit 3-43
Final Net-to-Gross Ratios

Program and Technology Group		***NTG***	***1-FR***	***Spill***
Retrofit Express	Central A/C	0.78	0.62	0.16
	Adjustable Speed Drives	0.30	0.13	0.17
	Package Terminal A/C	0.64	0.48	0.17
	Set-Back Thermostat	0.54	0.38	0.17
	Reflective Window Film	0.86	0.70	0.17
	Water Chillers	0.37	0.20	0.17
	Other HVAC Technologies	0.67	0.53	0.14
Retrofit Express Program Total		0.60	0.44	0.17
Retrofit Efficiency Options	Adjustable Speed Drives	0.30	0.13	0.17
	Water Chillers	0.37	0.20	0.17
	Convert To VAV	1.09	0.92	0.17
	Cooling Towers	1.09	0.92	0.17
	High Efficiency Gas Boilers	-	-	-
	VFD Chillers	1.09	0.92	0.17
Retrofit Efficiency Options Program Total		0.46	0.30	0.17
Customized Incentives	Adjustable Speed Drives	0.30	0.13	0.17
	Water Chillers	0.37	0.20	0.17
	Customized EMS	0.25	0.09	0.17
	Customized Controls	1.09	0.92	0.17
	Convert To VAV	1.09	0.92	0.17
	Other Customized Equip	1.09	0.92	0.17
	Other HVAC Technologies	1.09	0.92	0.17
Customized Incentives Program Total		0.51	0.35	0.17
Thermal Energy Storage		-	-	-
Advanced Performance Options		0.30	0.13	0.17
Totals Weighted By				
	Energy	**0.54**	**0.37**	**0.17**
	Demand	**0.62**	**0.45**	**0.17**
	Therm	**0.92**	**0.75**	**0.17**

4. EVALUATION RESULTS

This section contains the results of the HVAC 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. Explanation 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, the Retrofit Express (RE), Retrofit Efficiency Options (REO), Customized Incentives, and the single Advanced Performance Options (APO) and Thermal Energy Storage (TES) applications. All results are aggregated to the total commercial sector.

4.1 EX POST GROSS IMPACT RESULTS

Ex post gross energy and demand impacts for the RE, REO, Customized Incentives, APO, and TES programs for HVAC 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 *Attachment 3*. *Attachment 3* also provides all of the results tables in this section (as well as the ex ante impacts, not included in the main body of this report), in a larger, more readable format.

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

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	588,795	210,200	58,194	153,807	16,113	185,885	137,750	20,936	41,777	101,406	230,942	54,437	1,800,242
	Adjustable Speed Drives	1,607,098	1,533,700	185,759	-	108,979	-	122,523	224,354	258,806	93,170	737,752	-	4,872,141
	Package Terminal A/C	8,805	452	-	-	495	19,616	56,707	222,755	2,705	699	-	-	312,234
	Set-Back Thermostat	1,411,318	453,693	153,157	956,385	10,374	266,071	301,179	139,884	94,047	228,157	406,134	93,460	4,513,860
	Reflective Window Film	4,556,999	206,841	112,858	22,212	108,735	60,657	174,758	89,940	119,141	83,389	105,413	30,041	5,670,984
	Water Chillers	40,217	-	72,730	34,770	-	-	22,592	-	-	-	18,002	185,006	373,317
	Other HVAC Technologies	5,827	70,740	-	-	1,727	17,695	-	2,447	-	-	22,300	-	120,736
Retrofit Express Program Total		8,219,060	2,475,625	582,698	1,167,174	246,423	549,924	815,509	700,317	516,476	506,820	1,520,543	362,945	17,663,514
Retrofit Efficiency Options	Adjustable Speed Drives	480,936	-	105,090	-	-	-	-	-	-	-	484,224	-	1,070,250
	Water Chillers	2,635,641	344,716	-	-	-	-	-	-	-	-	428,574	-	3,408,932
	Convert To VAV	73,678	-	-	-	-	-	-	-	-	-	-	-	73,678
	Cooling Towers	272,591	23,097	-	-	-	-	-	-	-	-	-	-	295,688
	High Efficiency Gas Boilers	-	-	-	-	-	-	-	-	-	-	-	-	0
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	427,029	-	427,029
Retrofit Efficiency Options Program Total		3,462,846	367,813	105,090	0	0	0	0	0	0	0	1,339,827	0	5,275,577
Customized Incentives	Adjustable Speed Drives	1,338,761	-	-	-	259,873	-	-	-	-	-	226,169	-	1,824,803
	Water Chillers	681,179	-	-	-	-	-	-	-	-	-	103,675	-	784,854
	Customized EMS	258,576	-	1,867,839	1,147,755	1,737,633	-	-	-	-	-	23,112	7,720	5,042,635
	Customized Controls	-	-	-	-	-	-	142,655	-	-	-	-	-	142,655
	Convert To VAV	25,447	-	-	-	-	-	223,029	-	-	-	-	-	248,476
	Other Customized Equip	-	-	-	-	229,095	-	901,764	-	-	-	-	396,931	1,527,790
	Other HVAC Technologies	397,093	-	-	-	884,546	-	-	-	-	-	-	-	1,281,639
Customized Incentives Program Total		2,701,056	0	1,867,839	1,147,755	3,111,146	0	1,267,448	0	0	0	352,956	404,651	10,852,851
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	-	-	-	-	0
Advanced Perf. Options	Water Chillers	1,687,578	-	-	-	-	-	-	-	-	-	-	-	1,687,578
Total		16,070,540	2,843,438	2,555,626	2,314,929	3,357,570	549,924	2,082,957	700,317	516,476	506,820	3,213,326	767,596	**35,479,520**

As shown in Exhibit 4-1, the RE program technologies represent half of the energy impacts. The Customized Incentives program (which last year comprised 55 percent of the total impact) contributed only 35 percent this year.

By business segment, offices and community service represent over half of the overall energy impacts, with office being the largest single segment, accounting for just over 45 percent of energy impacts.

Adjustable Speed Drives (ASDs), which were offered through all three programs, contributed more to energy impacts than any other technology, with approximately 7,700 MWh, or about 22 percent of the total. Programmable thermostats (including timeclocks, bypass timers, and setback programmable thermostats) and CACs, were the second largest contributor, having a total program impact of 6,300 MWh, or 18 percent of the total. These technology groups were combined, because typically retrofits included the installation of both technologies. Another technology with a relatively large share of the impact was Reflective Window Film, accounting for 16 percent of the program total. High efficiency chillers contributed just under 13 percent of HVAC energy impacts, with the REO and Customized Incentives programs representing more than 90 percent of that impact.

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

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	614.9	124.3	42.1	85.9	10.0	94.2	107.6	10.4	27.9	67.5	165.2	37.3	1,387.2
	Adjustable Speed Drives	396.9	346.1	44.2	-	31.4	-	17.5	14.1	54.5	21.5	156.2	-	1,082.5
	Package Terminal A/C	4.9	0.3	-	-	0.4	8.4	17.0	157.0	4.6	0.5	-	-	193.2
	Set-Back Thermostat	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	Reflective Window Film	553.8	24.6	11.5	0.7	12.7	7.3	21.7	9.6	13.3	10.0	10.7	3.3	679.2
	Water Chillers	16.0	-	24.1	27.7	-	-	4.7	-	-	-	6.0	76.6	155.0
	Other HVAC Technologies	3.1	17.7	-	-	1.8	8.0	-	0.8	-	-	12.3	-	43.7
Retrofit Express Program Total		1,589.7	513.0	121.8	114.3	56.4	117.9	168.5	191.9	100.3	99.4	350.2	117.2	3,540.8
Retrofit Efficiency Options	Adjustable Speed Drives	103.5	-	25.2	-	-	-	-	-	-	-	52.2	-	180.9
	Water Chillers	671.5	134.5	-	-	-	-	-	-	-	-	106.2	-	912.2
	Convert To VAV	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	Cooling Towers	208.5	19.0	-	-	-	-	-	-	-	-	-	-	227.5
	High Efficiency Gas Boilers	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	116.1	-	116.1
Retrofit Efficiency Options Program Total		983.5	153.5	25.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	274.5	0.0	1,436.7
Customized Incentives	Adjustable Speed Drives	188.3	-	-	-	56.2	-	-	-	-	-	76.5	-	321.0
	Water Chillers	294.6	-	-	-	-	-	-	-	-	-	85.6	-	380.2
	Customized EMS	1.7	-	-	-	45.5	-	-	-	-	-	-	-	47.2
	Customized Controls	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	Convert To VAV	21.2	-	-	-	-	-	-	-	-	-	-	-	21.2
	Other Customized Equip	-	-	-	-	41.7	-	151.0	-	-	-	-	196.5	389.2
	Other HVAC Technologies	-	-	-	-	101.0	-	-	-	-	-	-	-	101.0
Customized Incentives Program Total		505.8	0.0	0.0	0.0	244.4	0.0	151.0	0.0	0.0	0.0	162.1	196.5	1,259.8
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	211.6	-	-	-	211.6
Advanced Perf. Options	Water Chillers	144.4	-	-	-	-	-	-	-	-	-	-	-	144.4
Total		3,223.4	666.5	147.1	114.3	300.8	117.9	319.5	191.9	311.9	99.4	786.8	313.7	**6,593.3**

The REO program plays a small role in the overall impact, with just under 15 percent of the energy savings being attributable to this program.

The office segment represented just under 50 percent of total HVAC Program demand impacts. The Community Service segment, which was often found during the course of the analysis to be offices, contributed 12 percent. Amongst other segments, only retail accounted for more than 10 percent. The sharply lower demand impact (relative to energy) for the retail, grocery, and personal service segments results from their large participation in Adjustable Speed Drive (ASD) fans, which have significant energy impacts but limited demand impact.

Therm impacts associated with the installation of HVAC technologies paid in 1996 are presented next in Exhibit 4-3.

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

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	-	-	-	-	-	-	-	-	-	-	-	-	0
	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	0
	Package Terminal A/C	-	-	-	-	-	-	-	-	-	-	-	-	0
	Set-Back Thermostat	-	-	-	-	-	-	-	-	-	-	-	-	0
	Reflective Window Film	-	-	-	-	-	-	-	-	-	-	-	-	0
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	0
	Other HVAC Technologies	-	-	-	-	-	-	-	-	-	-	-	-	0
Retrofit Express Program Total		0	0	0	0	0	0	0	0	0	0	0	0	0
Retrofit Efficiency Options	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	0
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	0
	Convert To VAV	-	-	-	-	-	-	-	-	-	-	-	-	0
	Cooling Towers	-	-	-	-	-	-	-	-	-	-	-	-	0
	High Efficiency Gas Boilers	-	-	23,203	-	-	-	-	-	-	-	-	-	23,203
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	-	-	0
Retrofit Efficiency Options Program Total		0	0	23,203	0	0	0	0	0	0	0	0	0	23,203
Customized Incentives	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	0
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	0
	Customized EMS	4,609	-	181,648	42,622	-	-	-	-	-	-	3,543	2,007	234,428
	Customized Controls	-	-	-	-	-	-	-	-	-	-	-	-	0
	Convert To VAV	45,491	-	-	-	-	-	-	-	-	-	-	-	45,491
	Other Customized Equip	-	-	-	-	-	-	535,543	-	-	-	-	-	535,543
	Other HVAC Technologies	-	-	297,738	-	-	-	-	-	-	-	-	-	297,738
Customized Incentives Program Total		50,100	0	479,386	42,622	0	0	535,543	0	0	0	3,543	2,007	1,113,200
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	-	-	-	-	0
Advanced Perf. Options	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	0
Total		50,100	0	502,589	42,622	0	0	535,543	0	0	0	3,543	2,007	**1,136,403**

Gross therm impacts are associated only with program participants who have gas heating. Since accurate fuel type/heating equipment saturation data were not available for program participants in such RE measures as programmable thermostats and reflective window film (which would presumably have negative therm impacts), ex post therm impacts were calculated only for those segments for which ex ante therm impacts were estimated.

Other Customized Equipment and Other HVAC Technologies (under the Customized Incentives program) accounted for over half of the ex post therm impacts, all of which were within the Health Care segment.

Therm impacts from energy management systems were concentrated in the schools segment.

Exhibit 4-4
NTG Adjustments by Program and Technology Group

Program and Technology Group		***NTG***	***1-FR***	***Spill***
Retrofit Express	Central A/C	0.78	0.62	0.16
	Adjustable Speed Drives	0.30	0.13	0.17
	Package Terminal A/C	0.64	0.48	0.17
	Set-Back Thermostat	0.54	0.38	0.17
	Reflective Window Film	0.86	0.70	0.17
	Water Chillers	0.37	0.20	0.17
	Other HVAC Technologies	0.67	0.53	0.14
Retrofit Express Program Total		0.60	0.44	0.17
Retrofit Efficiency Options	Adjustable Speed Drives	0.30	0.13	0.17
	Water Chillers	0.37	0.20	0.17
	Convert To VAV	1.09	0.92	0.17
	Cooling Towers	1.09	0.92	0.17
	High Efficiency Gas Boilers	-	-	-
	VFD Chillers	1.09	0.92	0.17
Retrofit Efficiency Options Program Total		0.46	0.30	0.17
Customized Incentives	Adjustable Speed Drives	0.30	0.13	0.17
	Water Chillers	0.37	0.20	0.17
	Customized EMS	0.25	0.09	0.17
	Customized Controls	1.09	0.92	0.17
	Convert To VAV	1.09	0.92	0.17
	Other Customized Equip	1.09	0.92	0.17
	Other HVAC Technologies	1.09	0.92	0.17
Customized Incentives Program Total		0.51	0.35	0.17
Thermal Energy Storage		-	-	-
Advanced Performance Options		0.30	0.13	0.17
Totals Weighted By				
	Energy	**0.54**	**0.37**	**0.17**
	Demand	**0.62**	**0.45**	**0.17**
	Therm	**0.92**	**0.75**	**0.17**

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 business type, separating out the effects of free ridership and spillover (note that due to rounding, values may not sum properly). Also shown are the overall program level NTG results, weighted across business type by the ex-post gross energy, demand and therm savings.

For this HVAC Evaluation, the results from the discrete choice analysis were used for the CAC and Other RE HVAC technology groups (which were the only two technologies modeled in the discrete choice analysis). The remaining technology groups applied the results from the self-report analysis. Refer to *Section 3.4, Net-to-Gross Analysis* for additional information surrounding the decision-making process.

The overall NTG ratio ranged from 0.54 based on energy savings, to 0.92 based on therm savings. On average, spillover was approximately 17 percent, overall. Free-ridership ranged from 63 percent for energy savings to only 25 percent for therm savings. This variation is due to the distribution of ex-post energy, demand and therm savings across technologies. Because the majority of free-ridership occurs in ASDs and Water Chillers and a smaller proportion of therm and demand savings occurs within these technology groups, overall free-ridership for therm and demand savings is smaller than for energy savings.

4.3 EX POST NET IMPACTS

Exhibits 4-5, 4-6, and 4-7 present the ex post net energy, demand, and therm HVAC impacts for the RE, REO, Customized Incentives, APO, and TES programs.

These exhibits show reductions of 46 percent in ex post program energy impacts and 38 percent in ex post program demand impacts (when compared to Exhibits 4-1 and 4-2), as a result of the application of the NTG adjustments presented in Exhibit 4-4.

On a net basis, Adjustable Speed Drives for HVACs share of energy impact fell dramatically to only 12 percent of the program total. Another technology group that experienced a similar reduction was Custom EMS, which fell from 14 percent to 7 percent. Due to its relatively larger NTG adjustment, Reflective Window Film became the dominant technology, accounting for just over 25 percent of program impact. Offices remained the dominant business segment, claiming just under 50 percent of the net energy impacts.

The net demand picture remained the same as gross. The office segment's share of net impact fell only slightly to 45 percent, while the only other segment contributing more than ten percent to the program total was community service.

Net therm impacts, summarized above in Exhibit 4-7, differ from the gross therm impacts by 8.43 percent, reflecting the 0.92 NTG ratio applied to all Customized Incentives measures.

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

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	477,775	118,024	31,070	110,744	12,339	122,517	127,127	16,235	15,440	103,667	231,825	29,208	1,395,972
	Adjustable Speed Drives	479,687	457,779	55,445	-	32,528	-	36,571	66,965	77,248	27,809	220,204	-	1,454,237
	Package Terminal A/C	5,675	291	-	-	319	12,644	36,552	143,583	1,744	451	-	-	201,260
	Set-Back Thermostat	766,106	246,278	83,138	519,154	5,631	144,431	163,489	75,933	51,051	123,850	220,462	50,733	2,450,259
	Reflective Window Film	3,937,521	178,723	97,516	19,193	93,953	52,411	151,001	77,714	102,945	72,053	91,083	25,957	4,900,071
	Water Chillers	14,789	-	26,744	12,786	-	-	8,308	-	-	-	6,620	68,030	137,276
	Other HVAC Technologies	4,728	39,719	-	-	1,322	11,663	-	1,651	-	-	22,386	-	81,470
Retrofit Express Program Total		5,686,281	1,040,815	293,914	661,877	146,093	343,667	523,047	382,082	248,429	327,831	792,580	173,929	10,620,543
Retrofit Efficiency Options	Adjustable Speed Drives	143,550	-	31,367	-	-	-	-	-	-	-	144,531	-	319,448
	Water Chillers	969,178	126,759	-	-	-	-	-	-	-	-	157,595	-	1,253,532
	Convert To VAV	80,175	-	-	-	-	-	-	-	-	-	-	-	80,175
	Cooling Towers	296,628	25,134	-	-	-	-	-	-	-	-	-	-	321,762
	High Efficiency Gas Boilers	-	-	-	-	-	-	-	-	-	-	-	-	0
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	464,684	-	464,684
Retrofit Efficiency Options Program Total		1,489,531	151,893	31,367	0	0	0	0	0	0	0	766,811	0	2,439,602
Customized Incentives	Adjustable Speed Drives	399,593	-	-	-	77,567	-	-	-	-	-	67,507	-	544,667
	Water Chillers	250,483	-	-	-	-	-	-	-	-	-	38,123	-	288,606
	Customized EMS	65,099	-	470,247	288,959	437,466	-	-	-	-	-	5,819	1,944	1,269,534
	Customized Controls	-	-	-	-	-	-	155,234	-	-	-	-	-	155,234
	Convert To VAV	27,691	-	-	-	-	-	242,696	-	-	-	-	-	270,387
	Other Customized Equip	-	-	-	-	249,297	-	981,282	-	-	-	-	431,932	1,662,511
	Other HVAC Technologies	432,109	-	-	-	962,545	-	-	-	-	-	-	-	1,394,654
Customized Incentives Program Total		1,174,975	0	470,247	288,959	1,726,875	0	1,379,212	0	0	0	111,449	433,876	5,585,593
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	-	-	-	-	0
Advanced Perf. Options	Water Chillers	503,708	-	-	-	-	-	-	-	-	-	-	-	503,708
Total		8,854,495	1,192,707	795,528	950,835	1,872,968	343,667	1,902,259	382,082	248,429	327,831	1,670,839	607,805	**19,149,445**

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

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	498.9	69.8	22.5	61.9	7.7	62.1	99.3	8.1	10.3	69.0	165.8	20.0	1,095.2
	Adjustable Speed Drives	118.5	103.3	13.2	-	9.4	-	5.2	4.2	16.3	6.4	46.6	-	323.1
	Package Terminal A/C	3.2	0.2	-	-	0.3	5.4	11.0	101.2	3.0	0.3	-	-	124.5
	Set-Back Thermostat	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	Reflective Window Film	478.5	21.3	10.0	0.6	11.0	6.3	18.7	8.3	11.5	8.6	9.2	2.8	586.8
	Water Chillers	5.9	-	8.9	10.2	-	-	1.7	-	-	-	2.2	28.2	57.0
	Other HVAC Technologies	2.6	9.9	-	-	1.4	5.3	-	0.6	-	-	12.3	-	32.0
Retrofit Express Program Total		1,107.5	204.5	54.4	72.7	29.7	79.1	135.9	122.3	41.1	84.3	236.1	51.0	2,218.7
Retrofit Efficiency Options	Adjustable Speed Drives	30.9	-	7.5	-	-	-	-	-	-	-	15.6	-	54.0
	Water Chillers	246.9	49.5	-	-	-	-	-	-	-	-	39.1	-	335.4
	Convert To VAV	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	Cooling Towers	226.9	20.7	-	-	-	-	-	-	-	-	-	-	247.6
	High Efficiency Gas Boilers	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	126.3	-	126.3
Retrofit Efficiency Options Program Total		504.7	70.1	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	181.0	0.0	763.3
Customized Incentives	Adjustable Speed Drives	56.2	-	-	-	16.8	-	-	-	-	-	22.8	-	95.8
	Water Chillers	108.3	-	-	-	-	-	-	-	-	-	31.5	-	139.8
	Customized EMS	0.4	-	-	-	11.5	-	-	-	-	-	-	-	11.9
	Customized Controls	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	Convert To VAV	23.1	-	-	-	-	-	-	-	-	-	-	-	23.1
	Other Customized Equip	-	-	-	-	45.4	-	164.3	-	-	-	-	213.8	423.5
	Other HVAC Technologies	-	-	-	-	109.9	-	-	-	-	-	-	-	109.9
Customized Incentives Program Total		188.0	0.0	0.0	0.0	183.5	0.0	164.3	0.0	0.0	0.0	54.3	213.8	804.0
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	230.3	-	-	-	230.3
Advanced Perf. Options	Water Chillers	43.1	-	-	-	-	-	-	-	-	-	-	-	43.1
Total		1,843.4	274.6	62.0	72.7	213.2	79.1	300.3	122.3	271.3	84.3	471.4	264.8	**4,059.4**

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

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	-	-	-	-	-	-	-	-	-	-	-	-	0
	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	0
	Package Terminal A/C	-	-	-	-	-	-	-	-	-	-	-	-	0
	Set-Back Thermostat	-	-	-	-	-	-	-	-	-	-	-	-	0
	Reflective Window Film	-	-	-	-	-	-	-	-	-	-	-	-	0
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	0
	Other HVAC Technologies	-	-	-	-	-	-	-	-	-	-	-	-	0
Retrofit Express Program Total		0	0	0	0	0	0	0	0	0	0	0	0	0
Retrofit Efficiency Options	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	0
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	0
	Convert To VAV	-	-	-	-	-	-	-	-	-	-	-	-	0
	Cooling Towers	-	-	-	-	-	-	-	-	-	-	-	-	0
	High Efficiency Gas Boilers	-	-	25,249	-	-	-	-	-	-	-	-	-	25,249
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	-	-	0
Retrofit Efficiency Options Program Total		0	0	25,249	0	0	0	0	0	0	0	0	0	25,249
Customized Incentives	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	0
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	0
	Customized EMS	1,160	-	45,732	10,730	-	-	-	-	-	-	892	505	59,020
	Customized Controls	-	-	-	-	-	-	-	-	-	-	-	-	0
	Convert To VAV	49,502	-	-	-	-	-	-	-	-	-	-	-	49,502
	Other Customized Equip	-	-	-	-	-	-	582,767	-	-	-	-	-	582,767
	Other HVAC Technologies	-	-	323,993	-	-	-	-	-	-	-	-	-	323,993
Customized Incentives Program Total		50,663	0	369,724	10,730	0	0	582,767	0	0	0	892	505	1,015,282
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	-	-	-	-	0
Advanced Perf. Options	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	0
Total		50,663	0	394,973	10,730	0	0	582,767	0	0	0	892	505	**1,040,531**

4.4 REALIZATION RATES

Exhibits 4-8 through 4-13 present the gross and net realization rates for energy, demand, and therm impacts for the RE, REO, Customized Incentives, APO, and TES HVAC applications. Exhibit 4-14, at the end of this section, summarizes the gross and net ex ante impacts, ex post impacts, and realization rates for the entire HVAC Program.

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 findings to the gross ex ante estimates. These realization rates illustrate how well the ex ante estimates predicted energy savings, before taking into account customer behavior effects, both inside and outside the rebate programs.

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

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	0.83	1.88	0.82	0.89	2.41	1.31	0.63	2.31	4.10	1.12	0.86	1.00	0.96
	Adjustable Speed Drives	1.81	2.07	2.36	-	2.24	-	3.27	5.21	2.08	2.07	2.42	-	2.11
	Package Terminal A/C	2.12	0.90	-	-	1.51	1.35	1.39	1.39	1.57	0.98	-	-	1.40
	Set-Back Thermostat	1.12	2.23	2.34	0.81	2.55	1.33	2.24	2.12	1.21	1.40	1.33	1.52	1.21
	Reflective Window Film	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
	Water Chillers	1.73	-	1.73	1.73	-	-	1.73	-	-	-	1.73	0.60	0.90
	Other HVAC Technologies	0.65	0.74	-	-	0.55	0.69	-	0.70	-	-	1.76	-	0.81
Retrofit Express Program Total		1.45	1.94	1.79	0.84	1.91	1.31	1.48	2.08	1.80	1.45	1.57	0.82	1.46
Retrofit Efficiency Options	Adjustable Speed Drives	0.43	-	0.98	-	-	-	-	-	-	-	0.87	-	0.60
	Water Chillers	2.96	0.62	-	-	-	-	-	-	-	-	1.02	-	1.83
	Convert To VAV	0.47	-	-	-	-	-	-	-	-	-	-	-	0.47
	Cooling Towers	0.72	0.40	-	-	-	-	-	-	-	-	-	-	0.68
	High Efficiency Gas Boilers	-	-	-	-	-	-	-	-	-	-	-	-	-
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	0.45	-	0.45
Retrofit Efficiency Options Program Total		1.36	0.60	0.98	-	-	-	-	-	-	-	0.70	-	1.02
Customized Incentives	Adjustable Speed Drives	1.13	-	-	-	0.36	-	-	-	-	-	1.00	-	0.86
	Water Chillers	1.91	-	-	-	-	-	-	-	-	-	0.99	-	1.70
	Customized EMS	1.25	-	2.01	2.55	2.01	-	-	-	-	-	1.95	2.07	2.04
	Customized Controls	-	-	-	-	-	-	0.34	-	-	-	-	-	0.34
	Convert To VAV	0.16	-	-	-	-	-	1.01	-	-	-	-	-	0.66
	Other Customized Equip	-	-	-	-	1.23	-	1.01	-	-	-	-	1.36	1.11
	Other HVAC Technologies	1.01	-	-	-	0.89	-	-	-	-	-	-	-	0.93
Customized Incentives Program Total		1.17	-	2.01	2.55	1.13	-	0.83	-	-	-	1.03	1.37	1.26
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	-	-	-	-	-
Advanced Perf. Options	Water Chillers	2.55	-	-	-	-	-	-	-	-	-	-	-	2.55
Total		1.44	1.51	1.88	1.26	1.16	1.31	1.00	2.08	1.80	1.45	0.99	1.04	**1.33**

Exhibit 4-8 illustrates that the ex post impacts are larger than the ex ante estimates within each program, but that the realization rates by business type and technology group vary dramatically, ranging from 0.16 to 5.21. This variation cannot be explained by a general, sweeping statement, as the individual results are due to a complex integration of individual ex post simplified and calibrated engineering models, ex ante forecasts applied in the MDSS, and the results of the SAE billing model. Explanations are provided below for specific technology and/or business type segments that have ex post impacts that vary significantly from the ex ante values.

Warehouse, Grocery, Hotel/Motel and Retail CACs: The high realization rates achieved for these business type/technology segments are primarily attributed to the differences in Equivalent Full Load Hour (EFLHs) between ex ante estimates and ex post estimates. For example, the ex ante EFLH estimates for the warehouse segment are just 300 hours per year, the lowest of any business segment. All four of these business types have ex ante EFLH estimates that fall below 1,000 hours per year; while the evaluation found all four of these business types reporting estimates well above 1,000 hours per year. The evaluation team agreed with the schools ex ante EFLH estimate (of 500 hours per year). An SAE coefficient of 1.55 for the entire central air conditioner segment also contributed to the relatively high realization rates achieved in those segments.

Adjustable Speed Drives: The end-use metered data for ASDs, and the calibrated engineering models developed using the EUM results, indicate that the gross engineering estimates of savings are two times higher than the RE program design estimates. It should be noted that the SAE coefficient for ASD measures (from the billing regression model) indicated that the evaluation's engineering estimates were furthermore three times too small. The evaluation team, however, selected the more conservative estimate, by setting the SAE coefficient to 1 and relying on the calibrated engineering result.

In contrast, the ex post adjustable speed drive results are only 60 percent as large as the ex ante REO estimates. The REO ex ante estimates were developed using a different program design method. While the RE program design and evaluation methods rely upon the fan motor horse power (hp), the REO program design estimates rely upon the building conditioned area served.

The evaluation applied a consistent method for determining both RE and REO engineering estimates of savings (by applying an annual energy per horsepower estimate to the fan's total hp). It is recommended that the program design methods be applied for ASD measures using a consistent strategy, rather than separate methods for each. For further details surrounding the ASD estimates, refer to *Section 3.2, Engineering Analysis*.

Miscellaneous RE HVACMeasures: The realized ex post engineering impacts observed in the SAE analysis were 35 percent too low for the group of RE measures that consist of package terminal A/C, set-back thermostat, reflective window film, evaporative coolers, and condenser measures. An SAE coefficient of 1.55 was applied to adjust those ex post engineering estimates, resulting in technology-level realization rates that range in value between 0.81 and 1.64.

Water Chillers: The water chiller realization rates for all programs were typically greater than 1.5 at the business type level. This is due to the large SAE coefficient that was estimated and applied to these technologies.

Interestingly, there were several instances where the realized savings fell below 0.70 within the retail and miscellaneous business types. In both cases, the ex post estimates are based upon calibrated engineering results that included a careful review of the original application calculations, an on-site audit to supplement the application information, and revisions using a temperature bin model. In one instance (the RE miscellaneous building type segment; where the realization rate equals 0.60), the retrofit chillers are used to cool and dehumidify rockets on a launch pad prior to lift-off. This is a rare occurrence, and so the impacts for the chiller upgrade are smaller than most. In the other instance (the REO retail segment; where the realization rate equals 0.62), the revised bin models suggest a large reduction in savings.

Convert to VAV: This REO or Customized Incentives measure was installed at only a few sites. Because of this, and the highly complex nature of the technology, they were treated as a "custom" measure, and site-specific calibrated engineering estimates calculated for each participant. The engineering-based results indicate a significant reduction in the application-based energy savings, yielding realization rates as low as 0.16. In this one particular case, the equipment installed was an EMS system, not VAV, and on-site records indicated that the EMS system had not been programmed with the appropriate equipment schedules (as suggested in the application).

Customized Incentives EMS: The total program/technology group realization rate of 2.04 for Custom EMS was the direct result of the application of a 2.24 realization rate from the SAE analysis.

Other REO and Customized Incentives Measures: In general, the differences observed between ex post impacts and ex ante estimates for other REO and Customized Incentives measures are due to improved information contributing to the ex post estimates or updated calculation methods. Each REO and Customized Incentives site underwent a thorough engineering review of the application, generally supplemented with an on-site audit to improve the application records. This yielded a calibrated engineering estimate for each site. The interested reader can refer to the individual application-level analyses in the attachments to this report, for any additional explanations surrounding the realization rates reported here.

4.4.2 Gross Realization Rates for Demand Impacts

Gross demand realization rates are presented next 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 estimates. These realization rates illustrate how well the ex ante estimates predicted demand savings, before taking into account customers' actions within the HVAC market. Refer to Exhibit 4-14 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 HVAC Applications

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	1.15	1.18	0.94	0.33	1.19	1.15	1.24	1.06	1.09	1.18	0.98	1.09	0.98
	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	-
	Package Terminal A/C	1.58	0.66	-	-	1.08	1.00	1.06	0.91	1.07	1.08	-	-	0.94
	Set-Back Thermostat	-	-	-	-	-	-	-	-	-	-	-	-	-
	Reflective Window Film	0.56	0.55	0.47	0.15	0.54	0.56	0.57	0.49	0.51	0.55	0.47	0.50	0.55
	Water Chillers	0.92	-	0.92	0.92	-	-	0.91	-	-	-	0.92	0.40	0.56
	Other HVAC Technologies	0.83	0.50	-	-	1.01	0.70	-	0.55	-	-	0.89	-	0.64
Retrofit Express Program Total		1.03	2.76	1.28	0.39	1.65	1.02	1.15	0.95	1.80	1.32	1.65	0.50	1.11
Retrofit Efficiency Options	Adjustable Speed Drives	7.25	-	28.30	-	-	-	-	-	-	-	6.98	-	7.99
	Water Chillers	1.28	0.44	-	-	-	-	-	-	-	-	0.95	-	0.97
	Convert To VAV	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cooling Towers	1.35	0.41	-	-	-	-	-	-	-	-	-	-	1.13
	High Efficiency Gas Boilers	-	-	-	-	-	-	-	-	-	-	-	-	-
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	0.42	-	0.42
Retrofit Efficiency Options Program Total		1.41	0.44	28.30	-	-	-	-	-	-	-	0.70	-	1.00
Customized Incentives	Adjustable Speed Drives	52.62	-	-	-	-	-	-	-	-	-	1.00	-	4.01
	Water Chillers	1.22	-	-	-	-	-	-	-	-	-	0.98	-	1.16
	Customized EMS	1.01	-	-	-	4.16	-	-	-	-	-	-	-	3.74
	Customized Controls	-	-	-	-	-	-	-	-	-	-	-	-	-
	Convert To VAV	-	-	-	-	-	-	-	-	-	-	-	-	-
	Other Customized Equip	-	-	-	-	2.87	-	-	-	-	-	-	1.25	2.27
	Other HVAC Technologies	-	-	-	-	0.90	-	-	-	-	-	-	-	0.59
Customized Incentives Program Total		1.66	-	-	-	1.77	-	-	-	-	-	0.99	1.25	1.65
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	1.11	-	-	-	1.11
Advanced Perf. Options	Water Chillers	1.04	-	-	-	-	-	-	-	-	-	-	-	1.04
Total		1.20	1.25	1.53	0.39	1.74	1.02	2.19	0.95	1.27	1.32	1.02	0.81	**1.15**

Overall, the gross demand estimates are 15 percent higher than the ex ante values, as illustrated above.

Some of the results can be explained using information from review of the ex ante estimates and the evaluation engineering analysis. Specific comments and justifications are as follows:

Central Air Conditioners - For central air conditioners, as well as for package terminal air conditioning units, the evaluation calculated demand impacts based upon the observed peak period duty cycle; that is, the percentage of the time that an operating system was running during the peak hour, as gathered from EUM data. This was multiplied by the self-reported peak hour operating factor for each premise to create a customer-specific CDF that could be multiplied by the connected load. Because this process led to a dramatically lower CDF in the school business type segment (than the 0.75 value assumed in the ex ante estimates), the gross realization rates are less than 1.0 overall.

Reflective Window Film: A review of the inputs from ASHRAE revealed a discrepancy between the annual solar heat gains listed in ASHRAE and those used in Advice Filing calculations. For details, refer to *Attachment 2, Standard HVAC Algorithm Review*.

Water Chillers - In the engineering analysis for chillers, data collected during on-site visits were used to determine peak loading factors, which were utilized in each applications' ex post temperature bin model. The resulting ex post estimates generally agreed with the ex ante estimates for each program with chiller measures.

Adjustable Speed Drives (ASDs): Very large impacts were observed for ASD measures installed under the RE, REO, and Custom Incentives programs. The ex ante estimates assumed that, for the majority of measures, at peak loads there is zero demand impact since the ASD is operating at 100 percent. If the existing fans are oversized, there will be a demand impact since the ASD will only operate the fan at the level required to meet space conditioning needs. This trend was observed in the EUM data collected, and verified following the application of the calibrated engineering ASD model. In Exhibit 4-9, some very large realization rates are presented, which reflects the fact that many ASD installations had no ex ante demand impact.

Retrofit Express Total: The total RE gross demand impact realization rate presented in Exhibit 4-9 is greater than one, even though all technology group totals are less than one. This is due to the fact that there were no ex ante demand impacts associated with ASDs. Therefore, no realization rate is shown for RE ASDs. The total realization rate for the RE program, however, is incorporating the effects of the ASD demand impacts.

Grocery Business Type EMS Measures: Gross demand impacts for EMS measures were often found to control refrigeration display anti-sweat heaters in conjunction with HVAC and lighting systems. The ex ante estimates did not accept any peak demand savings for anti-sweat heaters, while the evaluation found the cycling of the anti-sweat heater to reduce the peak load. Because participation was concentrated in the grocery segment, ex post demand increased significantly for this business type.

Exhibit 4-10
Gross Therm Impact Realization Rates
By Business Type and Technology Group
For Commercial HVAC Measures Paid in 1996

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	-	-	-	-	-	-	-	-	-	-	-	-	-
	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	-
	Package Terminal A/C	-	-	-	-	-	-	-	-	-	-	-	-	-
	Set-Back Thermostat	-	-	-	-	-	-	-	-	-	-	-	-	-
	Reflective Window Film	-	-	-	-	-	-	-	-	-	-	-	-	-
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	-
	Other HVAC Technologies	-	-	-	-	-	-	-	-	-	-	-	-	-
Retrofit Express Program Total		-	-	-	-	-	-	-	-	-	-	-	-	-
Retrofit Efficiency Options	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	-
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	-
	Convert To VAV	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cooling Towers	-	-	-	-	-	-	-	-	-	-	-	-	-
	High Efficiency Gas Boilers	-	-	1.17	-	-	-	-	-	-	-	-	-	1.17
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	-	-	-
Retrofit Efficiency Options Program Total		-	-	1.17	-	-	-	-	-	-	-	-	-	1.17
Customized Incentives	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	-
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	-
	Customized EMS	0.88	-	1.00	0.91	-	-	-	-	-	-	0.78	0.90	0.97
	Customized Controls	-	-	-	-	-	-	-	-	-	-	-	-	-
	Convert To VAV	0.19	-	-	-	-	-	-	-	-	-	-	-	0.19
	Other Customized Equip	-	-	-	-	-	-	1.00	-	-	-	-	-	1.00
	Other HVAC Technologies	-	-	1.00	-	-	-	-	-	-	-	-	-	1.00
Customized Incentives Program Total		0.20	-	1.00	0.91	-	-	1.00	-	-	-	0.78	0.90	0.85
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	-	-	-	-	-
Advanced Perf. Options	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		0.20	-	1.01	0.91	-	-	1.00	-	-	-	0.78	0.90	**0.85**

Of importance to note in regards to Exhibit 4-10 is the significantly lower estimate of ex post therms in the Office/Convert to VAV segment. Only one application contributed to this business/technology segment. Similar to the comments in the gross energy realization rate section, the premise-specific review of this application found significant errors in the calculation of therm impacts. They were adjusted accordingly.

4.4.3 Net Realization Rates

The difference between the gross and net realization rates is due to the differences between the ex ante and the ex post NTG adjustments, in combination with the differences already exhibited between the ex ante gross impacts and their corresponding ex post values.

The net energy realization rates by segment are presented in Exhibit 4-11, with the net demand realization rates illustrated in Exhibit 4-12. Net therm realization rates are presented in Exhibit 4-13. 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 HVAC market.

To the extent that they build upon the gross evaluation results, many of the results presented in Exhibits 4-11, 4-12, and 4-13 can be explained using information from the review of the ex ante estimates and the evaluation engineering and billing analyses, as discussed under the review of the gross realization rates. Most of the comments mentioned previously are applicable to the calculation of 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 all three exhibits.

The differences between the net realization rates and the gross realization rates discussed earlier are, by definition, determined by differences between the ex ante and the ex post estimates of the NTG adjustment. For the HVAC Program, these differences reflect the low ex post NTG ratio applied to several key analysis segments. Specifically, the 0.25 Customized EMS, 0.37 water chiller, and 0.30 adjustable speed drive NTG ratios caused a significant reduction in the net realization rates (when compared with the gross impact realization rates across all programs). For example, the gross energy impact realization rate fell from 1.33 to a net realization rate of just 1.03. Specific comments and justifications for the results are as follows:

Overall Comparison of Ex Post and Ex Ante Realization Rates – Even if one considers the significant level of spillover measured as part of this ex post evaluation (0.17), the overall ratio of ex post to ex ante NTG ranges from 0.77 to 0.88, for energy and demand, respectively. This has caused a dramatic reduction in the ex post net savings achieved.

Exhibit 4-11
Net Energy Impact Realization Rates
By Business Type and Technology Group
For Commercial HVAC Measures Paid in 1996

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	0.99	1.56	0.65	0.95	2.74	1.28	0.86	2.66	2.25	1.70	1.28	0.80	1.11
	Adjustable Speed Drives	0.80	0.92	1.05	-	0.99	-	1.45	2.31	0.92	0.92	1.07	-	0.93
	Package Terminal A/C	2.03	0.86	-	-	1.45	1.29	1.33	1.33	1.50	0.94	-	-	1.34
	Set-Back Thermostat	0.91	1.80	1.89	0.65	2.05	1.07	1.80	1.71	0.98	1.13	1.07	1.22	0.98
	Reflective Window Film	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11
	Water Chillers	0.95	-	0.95	0.95	-	-	0.95	-	-	-	0.95	0.33	0.49
	Other HVAC Technologies	0.78	0.62	-	-	0.62	0.67	-	0.71	-	-	2.62	-	0.81
Retrofit Express Program Total		1.49	1.21	1.34	0.71	1.68	1.22	1.41	1.69	1.29	1.39	1.22	0.59	1.30
Retrofit Efficiency Options	Adjustable Speed Drives	0.19	-	0.43	-	-	-	-	-	-	-	0.38	-	0.26
	Water Chillers	1.61	0.34	-	-	-	-	-	-	-	-	0.56	-	1.00
	Convert To VAV	0.76	-	-	-	-	-	-	-	-	-	-	-	0.76
	Cooling Towers	1.17	0.65	-	-	-	-	-	-	-	-	-	-	1.10
	High Efficiency Gas Boilers	-	-	-	-	-	-	-	-	-	-	-	-	-
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	0.73	-	0.73
Retrofit Efficiency Options Program Total		0.87	0.37	0.43	-	-	-	-	-	-	-	0.59	-	0.70
Customized Incentives	Adjustable Speed Drives	0.45	-	-	-	0.14	-	-	-	-	-	0.40	-	0.34
	Water Chillers	0.93	-	-	-	-	-	-	-	-	-	0.48	-	0.83
	Customized EMS	0.42	-	0.67	0.85	0.67	-	-	-	-	-	0.65	0.69	0.68
	Customized Controls	-	-	-	-	-	-	0.49	-	-	-	-	-	0.49
	Convert To VAV	0.24	-	-	-	-	-	1.45	-	-	-	-	-	0.95
	Other Customized Equip	-	-	-	-	1.78	-	1.45	-	-	-	-	1.96	1.60
	Other HVAC Technologies	1.45	-	-	-	1.29	-	-	-	-	-	-	-	1.34
Customized Incentives Program Total		0.68	-	0.67	0.85	0.83	-	1.19	-	-	-	0.43	1.94	0.86
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	-	-	-	-	-
Advanced Perf. Options	Water Chillers	1.01	-	-	-	-	-	-	-	-	-	-	-	1.01
Total		1.14	0.94	0.80	0.75	0.86	1.22	1.24	1.69	1.29	1.39	0.76	1.17	**1.03**

Exhibit 4-12
Net Demand Impact Realization Rates
By Business Type and Technology Group
For Commercial HVAC Measures Paid in 1996

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	1.38	0.99	0.75	0.35	1.35	1.12	1.69	1.22	0.60	1.80	1.45	0.87	1.14
	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	-
	Package Terminal A/C	1.51	0.63	-	-	1.03	0.95	1.01	0.87	1.02	1.03	-	-	0.90
	Set-Back Thermostat	-	-	-	-	-	-	-	-	-	-	-	-	-
	Reflective Window Film	0.72	0.70	0.60	0.20	0.69	0.71	0.73	0.63	0.66	0.70	0.60	0.64	0.71
	Water Chillers	0.50	-	0.50	0.50	-	-	0.50	-	-	-	0.50	0.22	0.31
	Other HVAC Technologies	0.99	0.41	-	-	1.15	0.69	-	0.55	-	-	1.32	-	0.70
Retrofit Express Program Total		1.06	1.63	0.85	0.36	1.29	1.02	1.38	0.90	1.09	1.66	1.65	0.33	1.03
Retrofit Efficiency Options	Adjustable Speed Drives	3.21	-	12.53	-	-	-	-	-	-	-	3.09	-	3.54
	Water Chillers	0.70	0.24	-	-	-	-	-	-	-	-	0.52	-	0.53
	Convert To VAV	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cooling Towers	2.18	0.67	-	-	-	-	-	-	-	-	-	-	1.83
	High Efficiency Gas Boilers	-	-	-	-	-	-	-	-	-	-	-	-	-
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	0.68	-	0.68
Retrofit Efficiency Options Program Total		1.08	0.30	12.53	-	-	-	-	-	-	-	0.68	-	0.79
Customized Incentives	Adjustable Speed Drives	20.82	-	-	-	-	-	-	-	-	-	0.40	-	1.59
	Water Chillers	0.60	-	-	-	-	-	-	-	-	-	0.48	-	0.56
	Customized EMS	0.34	-	-	-	1.39	-	-	-	-	-	-	-	1.25
	Customized Controls	-	-	-	-	-	-	-	-	-	-	-	-	-
	Convert To VAV	-	-	-	-	-	-	-	-	-	-	-	-	-
	Other Customized Equip	-	-	-	-	4.14	-	-	-	-	-	-	1.81	3.28
	Other HVAC Technologies	-	-	-	-	1.29	-	-	-	-	-	-	-	0.85
Customized Incentives Program Total		0.82	-	-	-	1.76	-	-	-	-	-	0.44	1.81	1.39
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	1.60	-	-	-	1.60
Advanced Perf. Options	Water Chillers	0.41	-	-	-	-	-	-	-	-	-	-	-	0.41
Total		1.00	0.76	0.96	0.36	1.67	1.02	3.05	0.90	1.49	1.66	0.88	0.96	**1.03**

Exhibit 4-13
Net Therm Impact Realization Rates
By Business Type and Technology Group
For Commercial HVAC Applications

Program and Technology Group		Office	Retail	College/Univ	School	Grocery	Restaurant	Health Care	Hotel/Motel	Warehouse	Personal Svcs.	Comm. Svcs.	Misc.	Total
Retrofit Express	Central A/C	-	-	-	-	-	-	-	-	-	-	-	-	-
	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	-
	Package Terminal A/C	-	-	-	-	-	-	-	-	-	-	-	-	-
	Set-Back Thermostat	-	-	-	-	-	-	-	-	-	-	-	-	-
	Reflective Window Film	-	-	-	-	-	-	-	-	-	-	-	-	-
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	-
	Other HVAC Technologies	-	-	-	-	-	-	-	-	-	-	-	-	-
Retrofit Express Program Total		-	-	-	-	-	-	-	-	-	-	-	-	-
Retrofit Efficiency Options	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	-
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	-
	Convert To VAV	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cooling Towers	-	-	-	-	-	-	-	-	-	-	-	-	-
	High Efficiency Gas Boilers	-	-	1.89	-	-	-	-	-	-	-	-	-	1.89
	VFD Chillers	-	-	-	-	-	-	-	-	-	-	-	-	-
Retrofit Efficiency Options Program Total		-	-	1.89	-	-	-	-	-	-	-	-	-	1.89
Customized Incentives	Adjustable Speed Drives	-	-	-	-	-	-	-	-	-	-	-	-	-
	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	-
	Customized EMS	0.30	-	0.34	0.31	-	-	-	-	-	-	0.26	0.30	0.33
	Customized Controls	-	-	-	-	-	-	-	-	-	-	-	-	-
	Convert To VAV	0.27	-	-	-	-	-	-	-	-	-	-	-	0.27
	Other Customized Equip	-	-	-	-	-	-	1.45	-	-	-	-	-	1.45
	Other HVAC Technologies	-	-	1.45	-	-	-	-	-	-	-	-	-	1.45
Customized Incentives Program Total		0.27	-	1.03	0.31	-	-	1.45	-	-	-	0.26	0.30	1.03
Thermal Energy Storage	Other Customized Equip	-	-	-	-	-	-	-	-	-	-	-	-	-
Advanced Perf. Options	Water Chillers	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		0.27	-	1.06	0.31	-	-	1.45	-	-	-	0.26	0.30	**1.04**

4.5 OVERVIEW OF REALIZATION RATES

The ex post net impacts are relatively consistent with the predicted ex ante impact estimates, differing by only a few percent. Although the ex post gross impacts exceed ex ante by 33 percent for energy and 15 percent for demand, the lower ex post NTG ratios have brought the overall ex post net impacts in line with ex ante.

Exhibit 4-14 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 4-14
Commercial HVAC Impact Summary
By Technology Group

Program and Technology Group		Gross Program Impact kWh	kW	Therm	NTG Adjustment* (1-FR)	Spillover	Net Program Impact kWh	kW	Therm
				EX ANTE					
Retrofit Express	Central A/C	1,872,161	1,421	0	0.57	0.10	1,260,894	958	0
	Adjustable Speed Drives	2,312,069	0	0	0.57	0.10	1,557,170	0	0
	Package Terminal A/C	223,138	205	0	0.57	0.10	150,283	138	0
	Set-Back Thermostat	3,716,083	0	0	0.57	0.10	2,502,769	0	0
	Reflective Window Film	3,450,179	1,231	0	0.57	0.10	2,323,684	830	0
	Water Chillers	414,936	277	0	0.57	0.10	279,458	186	0
	Other HVAC Technologies	149,127	68	0	0.57	0.10	100,436	46	0
Retrofit Express Program Total		12,137,693	3,202	0	0.57	0.10	8,174,693	2,158	0
Retrofit Efficiency Options	Adjustable Speed Drives	1,792,047	23	0	0.57	0.10	1,206,937	15	0
	Water Chillers	1,866,049	937	0	0.57	0.10	1,256,778	631	0
	Convert To VAV	155,688	5	0	0.57	0.10	104,855	3	0
	Cooling Towers	435,100	201	0	0.57	0.10	293,038	135	0
	High Efficiency Gas Boilers	0	0	19,916	-	-	0	0	13,341
	VFD Chillers	941,168	276	0	0.57	0.10	633,874	186	0
Retrofit Efficiency Options Program Total		5,190,052	1,441	19,916	0.57	0.10	3,495,482	971	13,341
Customized Incentives	Adjustable Speed Drives	2,131,885	80	0	0.65	0.10	1,607,258	60	0
	Water Chillers	461,296	328	0	0.65	0.10	347,777	248	0
	Customized EMS	2,469,970	13	240,502	0.65	0.10	1,862,145	10	180,346
	Customized Controls	416,529	0	0	0.65	0.10	314,027	0	0
	Convert To VAV	378,130	0	240,841	0.65	0.10	285,077	0	180,600
	Other Customized Equip	1,375,750	171	535,635	0.65	0.10	1,037,198	129	401,657
	Other HVAC Technologies	1,384,042	172	297,789	0.65	0.10	1,043,449	130	223,304
Customized Incentives Program Total		8,617,603	765	1,314,768	0.65	0.10	6,496,931	577	985,907
Thermal Energy Storage	Other Customized Equip	0	191	0	-	-	0	144	0
Advanced Perf. Options	Water Chillers	662,970	138	0	0.65	0.10	499,823	104	0
Total		26,608,318	5,736	1,334,684	0.60	0.10	18,666,929	3,954	999,248
				EX POST					
Retrofit Express	Central A/C	1,800,242	1,387	0	0.62	0.16	1,395,972	1,095	0
	Adjustable Speed Drives	4,872,141	1,083	0	0.13	0.17	1,454,237	323	0
	Package Terminal A/C	312,234	193	0	0.48	0.17	201,260	125	0
	Set-Back Thermostat	4,513,860	0	0	0.38	0.17	2,450,259	0	0
	Reflective Window Film	5,670,984	679	0	0.70	0.17	4,900,071	587	0
	Water Chillers	373,317	155	0	0.20	0.17	137,276	57	0
	Other HVAC Technologies	120,736	44	0	0.53	0.14	81,470	32	0
Retrofit Express Program Total		17,663,514	3,541	0	0.44	0.17	10,620,543	2,219	0
Retrofit Efficiency Options	Adjustable Speed Drives	1,070,250	181	0	0.13	0.17	319,448	54	0
	Water Chillers	3,408,932	912	0	0.20	0.17	1,253,532	335	0
	Convert To VAV	73,678	0	0	0.92	0.17	80,175	0	0
	Cooling Towers	295,688	228	0	0.92	0.17	321,762	248	0
	High Efficiency Gas Boilers	0	0	23,203	-	-	0	0	25,249
	VFD Chillers	427,029	116	0	0.92	0.17	464,684	126	0
Retrofit Efficiency Options Program Total		5,275,577	1,437	23,203	0.30	0.17	2,439,602	763	25,249
Customized Incentives	Adjustable Speed Drives	1,824,803	321	0	0.13	0.17	544,667	96	0
	Water Chillers	784,854	380	0	0.20	0.17	288,606	140	0
	Customized EMS	5,042,635	47	234,428	0.09	0.17	1,269,534	12	59,020
	Customized Controls	142,655	0	0	0.92	0.17	155,234	0	0
	Convert To VAV	248,476	21	45,491	0.92	0.17	270,387	23	49,502
	Other Customized Equip	1,527,790	389	535,543	0.92	0.17	1,662,511	424	582,767
	Other HVAC Technologies	1,281,639	101	297,738	0.92	0.17	1,394,654	110	323,993
Customized Incentives Program Total		10,852,851	1,260	1,113,200	0.35	0.17	5,585,593	804	1,015,282
Thermal Energy Storage	Other Customized Equip	0	212	0	-	-	0	230	0
Advanced Perf. Options	Water Chillers	1,687,578	144	0	0.13	0.17	503,708	43	0
Total		35,479,520	6,593	1,136,403	0.37	0.17	19,149,445	4,059	1,040,531

*The NTG adjustment presented here is weighted by gross kWh.

Exhibit 4-14 cont'd
Commercial HVAC Impact Summary
By Technology Group

Program and Technology Group		Gross Program Impact			NTG Adjustment*		Net Program Impact		
		kWh	kW	Therm	(1-FR)	Spillover	kWh	kW	Therm
		REALIZATION RATES							
Retrofit	Central A/C	0.96	0.98	-	-	-	1.11	1.14	-
Express	Adjustable Speed Drives	2.11	-	-	-	-	0.93	-	-
	Package Terminal A/C	1.40	0.94	-	-	-	1.34	0.90	-
	Set-Back Thermostat	1.21	-	-	-	-	0.98	-	-
	Reflective Window Film	1.64	0.55	-	-	-	2.11	0.71	-
	Water Chillers	0.90	0.56	-	-	-	0.49	0.31	-
	Other HVAC Technologies	0.81	0.64	-	-	-	0.81	0.70	-
Retrofit Express Program Total		1.46	1.11	-	-	-	1.30	1.03	-
Retrofit	Adjustable Speed Drives	0.60	7.99	-	-	-	0.26	3.54	-
Customized	Adjustable Speed Drives	0.86	4.01	-	-	-	0.34	1.59	-
Incentives	Water Chillers	1.70	1.16	-	-	-	0.83	0.56	-
	Customized EMS	2.04	3.74	0.97	-	-	0.68	1.25	0.33
	Customized Controls	0.34	-	-	-	-	0.49	-	-
	Convert To VAV	0.66	-	0.19	-	-	0.95	-	0.27
	Other Customized Equip	1.11	2.27	1.00	-	-	1.60	3.28	1.45
	Other HVAC Technologies	0.93	0.59	1.00	-	-	1.34	0.85	1.45
Customized Incentives Program Total		1.26	1.65	0.85	-	-	0.86	1.39	1.03
Thermal Energy Storage	Other Customized Equip	-	1.11	-	-	-	-	1.60	-
Advanced Perf. Options	Water Chillers	2.55	1.04	-	-	-	1.01	0.41	-
Total		1.33	1.15	0.85	-	-	1.03	1.03	1.04

*The NTG adjustment presented here is weighted by gross kWh.

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 1996 HVAC Evaluation:

Revisions to the Ex Ante Impact Methods - All ex ante algorithms for RE "standard" HVAC measures paid in 1996 were thoroughly reviewed. Where necessary, these methods were updated using alternate methods or assumptions, as described in detail in *Attachment 2*. It is recommended that PG&E carefully review the updates to these algorithms, and apply those updates to future Advice Filings.

Multiple Account Records - Application records are currently stored in the MDSS based on the PG&E control number, which is in turn linked to a particular account. Premises (an entire building or even multiple buildings with a single address) are often retrofit, but records are not available that adequately link each retrofit to the total sample of accounts affected. Billing regression analyses and other calibrated engineering models which incorporate this information may be adversely affected, since the observed usage is inconsistent with the measure and number of units retrofit. PG&E may be able to more thoroughly reconcile each retrofit in the MDSS with all customer accounts.

Demand Impact Information for ASD Measures – Larger ex post demand impacts were observed for the Adjustable Speed Drive measures installed under the program. For the ex ante estimates, the assumption is made that at peak loads there is zero demand impact for RE measures and very small impacts for REO measures, since the ASD is operating at nearly 100 percent load. However, in the evaluation EUM data, sample fans were observed to be oversized, yielding demand impacts for fans with an ASD. Those fans only operate at the level required to meet space conditioning needs at the time of system peak. It is recommended that PG&E update their forecasting methods to account for the additional peak demand impacts realized through an ASD retrofit.

Impact Estimates Based on Conditioned Square Feet – Some ex ante algorithms make use of the facility conditioned square feet to represent the installed system capacity instead of a more reliable engineering figure. This is especially true within the REO program, where chiller retrofits, cooling tower retrofits, air handler variable frequency drive retrofits, and boiler retrofits are all based in part upon the facility square footage. Quality checks using engineering and industry rules, such as tons per square foot, should be implemented to ensure realistic impacts, or a more reliable method of computing impact estimates should be developed. In some instances, square foot estimates were incorrectly entered, or missing, from the MDSS, resulting in inaccurate ex ante impact estimates.

End-Use Classification - Ex ante HVAC impact estimates in the Customized Incentives program were often mis-classified by end-use. In those instances, measures were lumped together prior to MDSS data entry. These entry errors are due in part to the design of the Customized Incentives application, because the application form "cover sheet" only has space to enter a single measure. While measure-specific results are available in other portions of the application (for example, Attachment 7 includes impacts by measure, which are normally classified by end use as well) this information is not consistently entered into the MDSS. This misclassification of measures typically occurred within the supermarket segment.

It is recommended that application forms for programs similar to the Customized Incentives program (such as the Advanced Performance Options program) be modified to allow data entry for multiple measures on the application "cover sheet."

Anti-Sweat Heater Demand Impacts - Energy Management System (EMS) retrofits that are installed within the grocery business type generally control store overhead lights, refrigerated case display lights, refrigerant setpoints (for example, the condensing temperature), the HVAC system, and anti-sweat heater runtime. Anti-sweat heaters prevent condensation from forming on the surfaces of refrigerated case displays. These heaters are often oversized and can readily evaporate condensate from the case surfaces with only fifty percent duty cycle. EMS controls will normally cycle the anti-sweat heaters (where the entire anti-sweat load is split across two circuits) using a fifty percent duty cycle, or will cycle these circuits based on real-time dew point and temperature measurements. Using either strategy, anti-sweat loads are significantly reduced.

During PG&E application review, anti-sweat heater demand impacts were rejected, while energy impacts were accepted. However, anti-sweat controls provide significant demand reduction during all hours of the year, including the system peak hour. Evaluation demand impacts are based upon an assumed 50 percent duty cycle of the anti-sweat heaters. PG&E should consider accepting this control strategy as a valid peak period demand reduction measure.

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.

Energy Management Systems are an effective means of reducing energy consumption, but require a knowledgeable operator to achieve those savings. EMSs used to monitor and control complicated HVAC plants require significant operator input, ideas, and operational decisions to achieve savings. EMSs cannot be expected to save energy without adequate system commissioning. PG&E should require commissioning for these systems (or other complicated measures) and offer incentives based on a performance contract. On-site investigations conducted as part of this evaluation effort have shown that performance contracts are an effective means of ensuring savings from installation of a particular system. Oftentimes EMSs were incorrectly programmed, or manually overridden, thus eliminating the effectiveness of this energy-saving technology.

On-Site Findings – Some noteworthy observations that were recorded during the on-site audits include the following:

- Impacts where Reflective Window Film was installed were being claimed for facilities that were either unconditioned, or where the film was installed in non-cooled areas. PG&E's Policies and Procedures should be updated to ensure that future window film installations are restricted to mechanically conditioned spaces.

- Many of the on-site reviews of Water Chiller retrofits uncovered the inappropriate application of chiller technologies. At specific sites, the following were recorded:
  - Redundant chillers were installed at sites that required just one chiller to meet the cooling requirements. This resulted in an overestimation of the ex ante chiller impacts at those particular sites.
  - At a large California Air Force base one chiller was used to cool/dehumidify rockets on a launch pad. The program design estimates assumed a standard office operating schedule, and significantly overstated the energy impacts.

- Several of the ASD sites where audits were conducted found the technology in a decommissioned state. At one such site, the ASD was in override mode, forcing the fan to operate at 100 percent capacity throughout the day.

Thermal Energy Storage (TES) application review has shown that the off-peak ice making served an agricultural process rather than the HVAC end-use. This particular application would have been more accurately identified as a measure affecting the refrigeration end use.

Application Engineering Review is a necessary component of the submittal process, and can be used to effectively screen applications that have significant analysis errors. In some instances, large errors were observed in the Customized Incentives applications submitted, resulting in inaccurate reporting of project impacts. Since applications submitted for the Customized Incentives program (or other current programs like Nonresidential New Construction and Advanced Performance Options) can result in relatively large incentives (often based on impact achieved), it is recommended that a more intensive application review be used to capture these anomalies.

Analysis of Reasonableness of Savings should be another method used to assess errors in the application savings estimates. For example, the Customized Incentives application includes this type of comparison information within Attachment 7, where measure savings are compared against both the baseline quantity used and also against total billing records for the site. However, in some instances, these valuable data do not appear to be used in an effort to reject claimed savings.

Rebates Offered for Infrequently Operated Systems - Measures are sometimes installed that are either redundant systems (in case the primary system fails or requires repair), or are strictly peaking systems (coming on-line only on rare occasions). Due to the potentially low impacts for such retrofits, PG&E should consider rejecting rebates for equipment that meet these criteria.

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